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## **An Empirical Study of the Desirability and Usability of Model-Based Scenarios for Informing Energy and Low-Carbon Transitions**

THÈSE

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Based Scenarios for Informing Energy and Low-Carbon  
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**Le Doyen**

*The future: time's excuse  
to frighten us; too vast  
a project, too large a morsel  
for the heart's mouth.*

Rainer Maria Rilke, The Future

*I stepped from plank to plank  
So slow and cautiously;  
The stars about my head I felt,  
About my feet the sea.*

*I knew not but the next  
Would be my final inch,--  
This gave me that precarious gait  
Some call experience.*

Emily Dickinson, I Stepped from Plank to Plank

*The days to come stand before us  
Like a row of lighted candles —  
Golden, warm, and lively.*

Constantine P. Cavafy, Candles





## Abstract

Many energy and low-carbon transitions are underway around the World today, guided by strategies such as the Swiss Energy Strategy 2050, the European Green Deal, and the Paris Agreement. A key method to inform transition strategies is scenario analysis. Scenarios can highlight uncertainties, explore alternatives, or show how to reach specific targets. For energy and climate change mitigation topics, the story-and-simulation approach is usually followed, where scenario developers define storylines which are then quantified using modeling. Research has so far focused on improving models themselves, as well as the diversity and consistency of the analyzed scenarios. Nevertheless, significant challenges remain such as enhancing the inclusivity of transition stakeholders in scenario generation and ensuring the usability of scenario results.

Energy and low-carbon transitions involve diverse stakeholders, including policymakers, industries, NGOs, and the wider public. However, it has been shown that even large scenario ensembles from multiple models and modeling organizations may focus on a relatively narrow range of views about the future. As citizen perspectives have been rarely used in scenario generation, it remains unclear whether energy technologies and other alternatives that are frequently included in scenarios are also desirable by the citizens. Nevertheless, incorporating citizen perspectives in scenario generation carries its own challenges, since these perspectives can be influenced by knowledge gaps, prior beliefs, or even demographics. Similarly, user characteristics such as numeracy can affect the usability of scenario information, especially in the case of more complex visualizations of large scenario ensembles. While interactive visualizations have been seen as a solution to show large scenario ensembles, it is unclear whether interactive visualizations outperform their static counterparts to merit the extra investment.

In response to these research gaps, this thesis aimed to empirically evaluate large scenario ensembles that inform energy and low-carbon transitions in terms of desirability and usability. On desirability, the thesis assessed the representation of citizen perspectives in scenario ensembles that inform energy transitions. On usability, the thesis assessed the performance of various interactive and static formats for visualizing large scenario ensembles in terms of supporting the understanding and engagement of transition stakeholders. Methodologically, all evaluations were structured in five research studies (journal articles). The studies were based on data collected from large population surveys and workshops and almost all of the studies used a newly developed interactive scenario tool Riskmeter, both for collecting data and for evaluating its performance in terms of scenario communication. In terms of case studies, the thesis focused on the electricity supply transition until 2035 in Switzerland, the European Union, and the World, as the electricity sector is especially crucial for decarbonizing the energy system and it is prioritized in most transition strategies.

The thesis showed that existing multi-organization, multi-model scenario ensembles for the electricity supply in 2035 in France, Germany, Poland, Switzerland, and the European Union

are only narrowly representative of citizen perspectives. Compared to most model-based scenarios, most citizens preferred deeper decarbonization and/or denuclearization by 2035, increased efficiency and electricity savings, and an electricity supply based on domestic hydropower, solar photovoltaic, wind power, and biomass. Scenario preference patterns were affected by the knowledge level and the national context of the citizens but remained mostly similar among groups of citizens with different demographics, political orientation, and attitudes on the transition and its governance. In contrast, scenario usability was affected by the prior beliefs, age, education, and relevant abilities of the scenario users such as numeracy. In fact, user understanding and engagement with scenario visualizations was more strongly influenced by user characteristics than by different visualization formats. Among the five static visualization formats that were tested, none was consistently outperforming the rest, while no evidence was found that an interactive format was superior to a static alternative. Nevertheless, customizing formats to user characteristics was shown to allow to control adverse effects from these user characteristics.

The outcomes of the thesis underline the need to explicitly consider informed and diverse citizen perspectives in scenario generation in order to improve the desirability of scenarios that inform transitions. For the examined countries and the European Union, findings indicate that more scenarios are needed with an early and ambitious deployment of renewable electricity. In terms of scenario communication, results suggest that no visualization format is perfect and that formats should be customized according to the needs and characteristics of different audiences. In all cases, empirical evaluation is key to ensure that methods for scenario generation and communication perform as intended. Future research should focus on integrating iterative empirical evaluations in all design phases of scenario visualizations and on investigating how to achieve a better trade-off between eliciting scenario preferences at scale and assuring that stakeholders are properly informed beforehand.

## Résumé

De nombreuses transitions énergétiques et bas carbone sont en cours dans le monde aujourd'hui, guidées par des stratégies telles que la Stratégie énergétique suisse 2050, le Green Deal européen et l'Accord de Paris. L'analyse de scénarios est une méthode essentielle pour explorer diverses stratégies de transition. Les scénarios ont le potentiel de mettre en évidence des incertitudes, d'explorer des alternatives ou de montrer comment atteindre des objectifs spécifiques. Pour les sujets liés à l'énergie et à l'atténuation du changement climatique, l'approche *story-and-simulation* est généralement employée, les développeurs de scénarios définissant des scénarios qui sont ensuite quantifiés à l'aide de méthodes de modélisation. La recherche s'est jusqu'à présent concentrée sur l'amélioration des modèles eux-mêmes, ainsi que sur la diversité et la cohérence des scénarios analysés. Néanmoins, des défis importants restent à relever, comme améliorer l'inclusion des parties prenantes de la transition lors de la phase de génération de scénarios, ainsi que de garantir l'utilisabilité des résultats issus des scénarios.

Les transitions énergétiques et à bas carbone impliquent diverses parties prenantes, notamment les décideurs politiques, les industries, les ONG et le grand public. Cependant, il a été démontré que même les grands ensembles de scénarios provenant de plusieurs modèles et organisations de modélisation se sont concentrés sur un spectre relativement étroit de possibles futurs. Comme les perspectives des citoyens ont rarement été utilisées dans la génération de scénarios, il est incertain si les technologies énergétiques et autres alternatives qui sont fréquemment inclus dans les scénarios sont également souhaités par les citoyens. Toutefois, l'intégration des perspectives des citoyens dans la génération de scénarios comporte ses propres défis, car les perspectives des citoyens peuvent être influencées par des lacunes dans les connaissances, des croyances antérieures ou des caractéristiques démographiques. De même, des caractéristiques telles que la numératie peuvent affecter l'utilisabilité des informations du scénario, en particulier dans le cas de visualisations plus complexes de grands ensembles de scénarios. Tandis que les visualisations interactives ont été considérées comme une solution pour montrer de grands ensembles de scénarios, il demeure incertain si les visualisations interactives surpassent leurs équivalents statiques.

En réponse à ces lacunes dans la recherche, cette thèse vise à évaluer empiriquement les grands ensembles de scénarios qui informent les transitions énergétiques et bas carbone en termes de désirabilité et d'utilisabilité (facilité d'utilisation). En ce qui concerne la désirabilité, cette thèse a évalué la représentation des perspectives citoyennes dans les ensembles de scénarios qui informent sur les transitions énergétiques. En ce qui concerne l'utilisabilité, cette thèse a évalué la performance de divers formats interactifs et statiques pour la visualisation de grands ensembles de scénarios en termes de soutien à la compréhension et à l'engagement des parties prenantes de la transition. Sur le plan méthodologique, toutes les évaluations ont été structurées en cinq études (articles de journaux scientifiques). Les études étaient basées sur des données collectées à partir d'enquêtes et d'ateliers auprès d'une large population et presque toutes les études ont utilisé un outil de scénario interactif, nommé Riskmeter, à la fois pour la

collecte de données et pour l'évaluation de ses performances. En termes d'études de cas, la thèse s'est concentrée sur la transition en termes d'approvisionnement en électricité jusqu'en 2035 en Suisse, dans l'Union européenne et dans le monde, car le secteur de l'électricité est particulièrement crucial pour la décarbonisation du système énergétique, et il est devenu un secteur prioritaire dans la plupart des stratégies de transition.

La thèse a montré que les ensembles de scénarios multi-organisations et multi-modèles existants pour l'approvisionnement en électricité en 2035 en France, en Allemagne, en Pologne, en Suisse et dans l'Union européenne ne représentent que faiblement les perspectives des citoyens. Par rapport à la plupart des scénarios basés sur des modèles, la plupart des citoyens préfèrent une décarbonisation et/ou une dénucléarisation plus rapide d'ici 2035, une efficacité accrue et des économies d'électricité, ainsi qu'un approvisionnement en électricité basé sur l'hydroélectricité, l'énergie solaire, l'énergie éolienne et la biomasse. Les préférences en matière de scénarios ont été influencées par le niveau de connaissances et le contexte national des citoyens, mais sont restées similaires entre les groupes de citoyens ayant des caractéristiques démographiques, des orientations politiques et des attitudes différentes vis-à-vis de la transition et de sa gouvernance. En revanche, l'utilisabilité des scénarios dépendait des croyances antérieures, de l'âge, de l'éducation et des capacités pertinentes des utilisateurs de scénarios, telles que la capacité de calcul. Dans les faits, la compréhension et l'engagement des utilisateurs vis-à-vis des visualisations de scénarios étaient plus fortement influencés par les caractéristiques des utilisateurs que par les différents formats de visualisation. Parmi les cinq formats de visualisation statiques testés, aucun n'était systématiquement plus performant que les autres, et rien n'indiquait qu'un format interactif était supérieur à une alternative statique. Néanmoins, il a été démontré que l'adaptation des formats aux caractéristiques de l'utilisateur permettait de contrôler les effets négatifs de ces caractéristiques.

Les résultats de la thèse soulignent la nécessité de considérer explicitement les perspectives à la fois informées et diverses des citoyens dans la génération de scénarios afin d'améliorer la désirabilité des scénarios qui informent les processus de transitions. Pour les pays examinés et l'Union européenne, les résultats indiquent que davantage de scénarios qui incluent un déploiement rapide et ambitieux d'une électricité renouvelable sont nécessaires. En termes de communication des scénarios, les résultats suggèrent qu'aucun format de visualisation n'est parfait et que les formats doivent être personnalisés en fonction des besoins et des caractéristiques des différents publics. Dans tous les cas, une évaluation empirique est essentielle pour garantir que les méthodes de génération et de communication de scénarios fonctionnent comme prévu. Les recherches futures devraient se concentrer sur l'intégration d'évaluations empiriques dans toutes les phases de conception de visualisations de scénarios à travers des processus itératifs, ainsi que sur la recherche d'un meilleur compromis entre l'obtention de préférences de scénarios à grande échelle et l'assurance que les parties prenantes sont correctement informées au préalable.

## Σύνοψη

Πολλές ενεργειακές και πράσινες μεταβάσεις εξελίσσονται σήμερα σε όλο τον κόσμο, με γνώμονα στρατηγικές όπως η ελβετική Ενεργειακή Στρατηγική 2050, η Ευρωπαϊκή Πράσινη Συμφωνία και η Συμφωνία του Παρισιού. Μια βασική μέθοδος χάραξης στρατηγικής είναι η ανάλυση σεναρίων. Τα σενάρια μπορούν να αναδείξουν αβεβαιότητες, να βοηθήσουν στη διερεύνηση εναλλακτικών λύσεων ή να οδηγήσουν στην επίτευξη συγκεκριμένων στόχων. Στα θέματα ενέργειας και αντιμετώπισης της κλιματικής αλλαγής, συνήθως ακολουθείται η προσέγγιση «story-and-simulation», όπου οι αρμόδιοι για την ανάπτυξη σεναρίων καθορίζουν ιστορίες οι οποίες στη συνέχεια ποσοτικοποιούνται με τη χρήση μοντέλων. Η έρευνα έχει επικεντρωθεί μέχρι στιγμής στη βελτίωση των ίδιων των μοντέλων, καθώς και στην ποικιλομορφία και τη συνοχή των σεναρίων που αναλύονται. Παρόλα αυτά, παραμένουν σημαντικές προκλήσεις, όπως η ενίσχυση της συμμετοχικότητας στην παραγωγή σεναρίων και η διασφάλιση της χρηστικότητας των αποτελεσμάτων των σεναρίων.

Οι ενεργειακές και πράσινες μεταβάσεις έχουν αρκετά ευρύ κοινό, συμπεριλαμβανομένων των κυβερνητικών φορέων, των βιομηχανιών, των ΜΚΟ, και των πολιτών. Ωστόσο, έχει αποδειχθεί ότι ακόμη και σύνολα σεναρίων προερχόμενα από πολλαπλά μοντέλα και οργανισμούς μπορεί να εστιάζουν σε ένα στενό φάσμα απόψεων για το μέλλον. Καθώς οι απόψεις των πολιτών σπανίως χρησιμοποιούνται στη δημιουργία σεναρίων, παραμένει ασαφές το κατά πόσο οι ενεργειακές τεχνολογίες που περιλαμβάνονται στα σενάρια είναι επιθυμητές από τους πολίτες. Ωστόσο, η ενσωμάτωση των απόψεων των πολιτών στη δημιουργία σεναρίων ενέχει τις δικές της προκλήσεις. Οι απόψεις των πολιτών μπορεί να επηρεάζονται από κενά γνώσεων, προηγούμενες πεποιθήσεις ή ακόμη και από τα δημογραφικά χαρακτηριστικά τους. Παρομοίως, τα χαρακτηριστικά των πολιτών μπορούν να επηρεάσουν τη χρηστικότητα των σεναρίων, ιδίως στην περίπτωση σύνθετων οπτικοποιήσεων με πολλαπλά σενάρια. Παρόλο που οι διαδραστικές οπτικοποιήσεις έχουν θεωρηθεί ως πιθανή λύση για την παρουσίαση πολλαπλών σεναρίων, δεν είναι σαφές κατά πόσο υπερτερούν έναντι των αντίστοιχων στατικών οπτικοποιήσεων ώστε να αξίζουν την επιπλέον επένδυση χρόνου και κόστους.

Ως απάντηση σε αυτά τα ερευνητικά κενά, η παρούσα διατριβή σκοπεύει στην εμπειρική αξιολόγηση σεναρίων για ενεργειακές και πράσινες μεταβάσεις ώστε να γίνουν αυτά τα σενάρια επιθυμητά και χρηστικά. Όσον αφορά την επιθυμητότητα, η διατριβή αξιολόγησε το κατά πόσο οι απόψεις των πολιτών αντιπροσωπεύονται στα υπάρχοντα σενάρια για ενεργειακές μεταβάσεις. Όσον αφορά τη χρηστικότητα, η διατριβή αξιολόγησε τις επιδόσεις διαδραστικών και στατικών μέσων οπτικοποίησης σεναρίων στο κατά πόσο κάνουν κατανοητά και ενδιαφέροντα τα σενάρια. Μεθοδολογικά, όλες οι αξιολογήσεις διαρθρώθηκαν σε πέντε ερευνητικές μελέτες (άρθρα σε επιστημονικά περιοδικά). Οι μελέτες βασίστηκαν σε εμπειρικά δεδομένα που συλλέχθηκαν με ερωτηματολόγια και εργαστήρια πολιτών, ενώ σχεδόν όλες οι μελέτες χρησιμοποίησαν ένα διαδραστικό εργαλείο σεναρίων με το όνομα Riskmeter, τόσο για τη συλλογή δεδομένων όσο και για την αξιολόγηση των επιδόσεων του εργαλείου στην

επικοινωνία σεναρίων. Όσον αφορά τις περιπτώσιακές μελέτες, η διατριβή επικεντρώθηκε στη μετάβαση του συστήματος παροχής ηλεκτρικής ενέργειας έως το 2035 στην Ελβετία, την Ευρωπαϊκή Ένωση και παγκοσμίως, καθώς ο τομέας της ηλεκτρικής ενέργειας είναι ιδιαίτερα κρίσιμος για τις περισσότερες πράσινες μεταβάσεις και τις στρατηγικές τους.

Η διατριβή έδειξε ότι τα υφιστάμενα σενάρια για την παροχή ηλεκτρικής ενέργειας το 2035 στη Γαλλία, τη Γερμανία, την Πολωνία, την Ελβετία και την Ευρωπαϊκή Ένωση δεν είναι ιδιαίτερα αντιπροσωπευτικά των απόψεων των πολιτών, παρόλο που αυτά τα σενάρια δημιουργήθηκαν από ποικίλους οργανισμούς και μοντέλα. Σε σύγκριση με τα περισσότερα σενάρια, οι περισσότεροι πολίτες προτίμησαν ταχύτερη απεξάρτηση από τον άνθρακα και/ή αποπυρηνικοποίηση έως το 2035, αυξημένη εξοικονόμηση ηλεκτρικής ενέργειας, καθώς και ένα μίγμα ηλεκτρικής ενέργειας βασισμένο στην εγχώρια υδροηλεκτρική ενέργεια, τα φωτοβολταϊκά, την αιολική ενέργεια και τη βιομάζα. Η προτίμηση των πολιτών επηρεάστηκε περισσότερο από το επίπεδο γνώσεων και την εθνικότητά τους και λιγότερο από τα δημογραφικά χαρακτηριστικά, τον πολιτικό προσανατολισμό και τις στάσεις τους σχετικά με τη μετάβαση και τη διακυβέρνησή της. Αντίθετα, η χρηστικότητα των σεναρίων επηρεάστηκε από τις πεποιθήσεις των χρηστών, την ηλικία, την εκπαίδευση και άλλες σχετικές ικανότητες, όπως η αριθμητική ικανότητα. Συνολικά, η κατανόηση και το ενδιαφέρον των χρηστών για τις οπτικοποιήσεις σεναρίων επηρεάστηκε περισσότερο από τα προαναφερθέντα χαρακτηριστικά των χρηστών παρά από τις διαφορετικές μορφές οπτικοποίησης. Μεταξύ των πέντε στατικών μέσων οπτικοποίησης που δοκιμάστηκαν, καμία δεν υπερείχε σταθερά έναντι των υπολοίπων, ενώ δεν βρέθηκε καμία ένδειξη ότι ένα διαδραστικό μέσο οπτικοποίησης ήταν ανώτερο από ένα αντίστοιχο στατικό. Παρ' όλα αυτά, η προσαρμογή των οπτικοποιήσεων στα χαρακτηριστικά του χρήστη βοήθησε στον περιορισμό δυσμενών επιδράσεων από αυτά τα χαρακτηριστικά.

Τα αποτελέσματα της διατριβής υπογραμμίζουν την ανάγκη συμπερίληψης απόψεων πολιτών στη δημιουργία σεναρίων, προκειμένου να βελτιωθεί η επιθυμητότητα των σεναρίων για ενεργειακές και πράσινες μεταβάσεις. Για τις εξεταζόμενες χώρες και την Ευρωπαϊκή Ένωση, τα ευρήματα δείχνουν ότι χρειάζονται περισσότερα σενάρια με έγκαιρη και φιλόδοξη ανάπτυξη της ηλεκτρικής ενέργειας από ανανεώσιμες πηγές. Όσον αφορά την επικοινωνία των σεναρίων, τα αποτελέσματα υποδεικνύουν ότι καμία μορφή οπτικοποίησης σεναρίων δεν είναι τέλεια και ότι η οπτικοποίηση θα πρέπει να προσαρμόζεται ανάλογα με τις ανάγκες και τα χαρακτηριστικά του ακροατηρίου. Σε κάθε περίπτωση, η εμπειρική αξιολόγηση είναι το κλειδί για να διασφαλιστεί ότι οι μέθοδοι δημιουργίας και επικοινωνίας σεναρίων αποδίδουν. Η μελλοντική έρευνα θα πρέπει να επικεντρωθεί στη χρήση επαναληπτικών αξιολογήσεων σε όλες τις φάσεις σχεδιασμού οπτικοποιήσεων σεναρίων και σε μεθόδους ενσωμάτωσης πολλών και καλά ενημερωμένων απόψεων πολιτών στην ανάπτυξη σεναρίων.



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# Chapter 1 Introduction

## 1.1 Context

Many energy and low-carbon transitions are underway around the World today (Markard, 2018). Examples of such transitions can be found across several spatial levels. At a global level, the Paris agreement set almost every country in the World towards a low-carbon transition, with the target to keep global warming to well below 2°C, compared to pre-industrial levels (UN, 2015). At a regional level, the European Union (EU) aspires through its European Green Deal to become climate-neutral by 2050 while ensuring a fair transition that leaves no one behind (European Commission, 2020a). At a country level, Switzerland, for example, plans to phase-out its nuclear fleet by 2035 (SFOE, 2017), while also aiming to substantially increase its electricity supply from renewable sources (SFOE, 2021) and to reach net zero greenhouse gas emissions by 2050 (Federal Council, 2021). Such transitions can be conceptualized as multi-level and multi-actor movements towards a desirable future (Geels and Schot, 2007; Markard et al., 2012; Sarrica et al., 2016), guided by diverse and multiple drivers. Examples of such drivers include climate change mitigation efforts (Li et al., 2015; Markard, 2018), energy security (Gracceva and Zeniewski, 2014; Markard et al., 2012), and social acceptance (Demski et al., 2015; Pidgeon et al., 2014). However, transitions can also lead to significant impacts such as rising electricity prices, unequal access to energy, and increased resource extraction and waste (Luderer et al., 2019; Sasse and Trutnevyte, 2020; Sovacool et al., 2019), requiring thus careful design as well as a well-monitored implementation (Fankhauser et al., 2021).

Long-term planning for energy and low-carbon transitions is considered a highly complex problem (DeCarolís et al., 2017). First, there are diverse uncertainties related to future socioeconomic conditions, technological innovation, and policy environment (Moss et al., 2010). Other relevant uncertainties stem from disruptive events and shocks due to economic crises and pandemics (Le Quéré et al., 2020) or climate change impacts and extreme weather events (Stern, 2016). Second, there are many individual measures to achieve transitions, such as technological solutions, financial instruments, or behavioral interventions (Davis et al., 2018; European Commission, 2018a). However, none of these measures is a silver bullet and efficient combinations of all measures are usually required to achieve a transition (Hamilton et al., 2015; Markard, 2018; UNEP, 2019). Third, there are multiple actors with different interests that can affect the transition, such as energy companies (Sovacool and Brisbois, 2019) or the wider public (Wüstenhagen et al., 2007). The aforementioned issues are further accentuated by the long-term planning horizons (Morgan, 2011) and the challenge of defining and implementing intermediate goals and strategies (Geels et al., 2017; Rockström et al., 2017).

One of the key methods to inform strategies and policies for energy and low-carbon transitions is scenario analysis (Keppo et al., 2021; van Vuuren et al., 2012). Scenarios can be viewed as “pictures of plausible future realities” (Trutnevyte et al., 2016a, p. 373) and are usually constructed to highlight uncertainties, explore different alternatives, or understand how a strategic target can be reached. Scenario methods have a long history of application in diverse fields (Bradfield et al., 2005), ranging from military research (Kahn and Wiener, 1967) and corporate decision-making (Wack, 1985a, 1985b) to energy planning (Braunreiter and Blumer, 2018) and global assessments of climate change (Rogelj et al., 2018b; van Vuuren et al., 2012), material use (Pauliuk et al., 2021), sustainable development (Soergel et al., 2021), and even the COVID-19 pandemic (Kissler et al., 2020). In the context of energy and climate change topics, scenario development usually follows the story-and-simulation approach, where scenario builders define qualitative storylines which are then quantified using modeling (Alcamo, 2008). These models range from simple energy models to fully integrated assessment models (IAMs) that simulate the impacts of these scenarios in the broad nexus of climate-energy-economy (Nikas et al., 2019). Apart from producing knowledge that promotes scientific understanding in these fields, the outcomes of these model-based scenarios are often used to inform policies (Duan et al., 2019; Rogelj et al., 2018b; Weber et al., 2018). Usually, researchers create ensembles of scenarios from different studies, organizations, and models, perform meta-analyses on them (e.g., Huppmann et al., 2018b), and prescribe policy advice based on these analyses (e.g., Sognaes et al., 2021). One famous policy-informing application was the assessment of all available scenarios that keep global warming to 1.5°C by the Intergovernmental Panel for Climate Change (IPCC, 2018a) which informed the targets of carbon neutrality in 2050 in more than 130 countries (Höhne et al., 2021).

Despite the broad use of scenario analysis, its theoretical foundation is not well defined (Derbyshire, 2017), leading to numerous and sometimes conflicting methodologies (DeCarolís et al., 2017; Spaniol and Rowland, 2017), and impeding the formulation of consistent evaluation benchmarks for scenarios (Bradfield et al., 2005). Evaluations are important for ensuring the continuous improvement of scenario methods and the quality of resulting policy advice (Elsawah et al., 2020). This is especially crucial for scenarios and models that underpin energy and climate transitions, as potential shortcomings can mislead policies and endanger the success of the transitions (Stern, 2016). While there have been multiple suggestions for benchmarks to evaluate scenarios (Bradfield et al., 2005; Hulme and Dessai, 2008a; Schmidt-Scheele, 2020), some of the most widely adopted criteria are salience, legitimacy, and credibility (Auer et al., 2021; Cash et al., 2003; Girod et al., 2009; Rounsevell and Metzger, 2010; van Voorn et al., 2016). Salience reflects the need for understandable and useful scenario information, legitimacy reflects the fairness and inclusivity of different stakeholder views in information production, and credibility reflects the scientific adequacy of information (Girod et al., 2009). Many credibility-related issues have been addressed in the last decade for scenarios for energy and low-carbon transitions, with some studies focusing on improving the diversity and consistency of scenarios (Berntsen and

Trutnevyte, 2017; Haasnoot and Middelkoop, 2012; Schweizer and Kriegler, 2012; Trutnevyte et al., 2016b) and others focusing on improving the models that simulate these scenarios as well as their input data (Giarola et al., 2021; Keppo et al., 2021; Trutnevyte et al., 2019a; van Beek et al., 2020). Modeling evaluations have started as early as in the 1980s and diverse evaluation methods have been developed since then, such as hind-casting and model inter-comparison (Wilson et al., 2021). Nevertheless, significant challenges remain for the salience and legitimacy criteria, notably, the need to enhance the inclusivity of transition stakeholders in scenario generation (Braunreiter et al., 2021) and the usability of scenario results (Auer et al., 2021).

The following two sections present in more detail these challenges, which form the main motivation of this thesis, and identify pertinent research gaps (Sections 1.2 and 1.3). Based on these gaps, Section 1.4 formulates the research questions of this thesis and divides the work into five research studies. Finally, Section 1.5 defines the expected outcomes of the thesis in terms of conceptual, methodological, and case-specific contributions.

## **1.2 Representation of stakeholder views in energy and low-carbon scenarios**

### **1.2.1 Current practices and challenges**

Existing literature asserts that the inclusion of diverse stakeholder views in scenarios can increase the transparency of scenario processes (Elsawah et al., 2020; Hulme and Dessai, 2008a) and support the validity of its outputs (EEA, 2009; O'Neill et al., 2020; Parson, 2008). Since energy and low-carbon transitions are essentially value-laden (Markard, 2018; Shaw, 2014), scenario development forms a negotiation among stakeholders (Hulme and Dessai, 2008b). However, even local-scale transitions may include numerous and diverse stakeholders that should be represented in scenario development, including policymakers, energy and emissions-intensive industries, civil society organizations, Non-Governmental Organizations (NGOs), and the wider public (Andersen and Jæger, 1999; Pidgeon et al., 2014; Renn, 2015; Trutnevyte et al., 2019a; van Asselt and Rotmans, 1996; Volken et al., 2018). This plurality of perspectives can be instrumental for the socio-political feasibility, fairness, and effective implementation of policies informed by scenario analysis (Braunreiter et al., 2021; Markard, 2018).

While policy institutions, NGOs, and industrial associations can explore alternatives or uncertainties that they find important by performing or outsourcing scenario studies (Elsawah et al., 2020), other stakeholders may not have the same capacity, most notably, the citizens. Nevertheless, citizens play a critical role in transition policies: they can vote for political parties with different transition strategies (Dryzek and Niemeyer, 2019), support or block infrastructures and policies (Rand and Hoen, 2017), and can even directly influence decision making through referenda (Stadelmann-Steffen, 2011) and participatory processes, such as citizen panels (Eymard, 2020). While policymakers and civil society organizations can potentially represent

citizen perspectives, large divergences can still occur. A characteristic example has been seen in 2019 in Germany, where a commission of policymakers, industry representatives, labor unions, and NGOs advised the government to phase out coal by 2038, while the majority of German citizens preferred a much earlier date (Rinscheid and Wüstenhagen, 2019). Additionally, there have been several calls for scenario developers and modelers to explore futures that are more socially inclusive and desirable from a societal view (Bai et al., 2016; Braunreiter et al., 2021; Fratini et al., 2019; Nikas et al., 2020), apart from the cost-optimal solutions that scenarios are usually focused on (Trutnevyte, 2016).

While there are various methods to engage stakeholders and citizens with policy questions (Renn, 2015; Voinov et al., 2016), scenario literature suggests that participatory methods need to be better adapted to the existing practices of scenario development (Elsawah et al., 2020; Rounsevell and Metzger, 2010). Participatory methods are mostly based on workshops that bring together a small number of stakeholders or members of the public to exchange views and information on the issue at hand (Eker et al., 2017; L. A. Mayer et al., 2014; Schmid and Knopf, 2012; Trutnevyte et al., 2011; Volken et al., 2018). However, the diversity of these views can be limited due to the potentially small number of participants, organizational or time restrictions, and group dynamics (Andersen and Jæger, 1999; Rounsevell and Metzger, 2010). Another option is to use large-scale data collection methods such as surveys to increase the diversity and number of perspectives. Large-scale surveys have been widely used to collect preferences for individual technologies or policies for low-carbon and energy transitions (e.g., European Commission, 2019a; Poortinga et al., 2018). In contrast, surveys have been more infrequent for eliciting preferences for transition strategies (Fleishman et al., 2010; Pidgeon et al., 2014; Scheer et al., 2013; Volken et al., 2018). Preferences on overall strategies could be more easily used to inform scenario development than preferences on individual technologies or policies, as they could also capture relative preferences among the alternatives included in the strategies. Despite their potential, studies that translated preferences into scenarios have been limited so far (Schmid and Knopf, 2012).

### 1.2.2 Research gaps

Despite calls for making scenarios for energy and low-carbon transition more inclusive of the views of all transition stakeholders (Elsawah et al., 2020; van Vliet et al., 2020), the perspectives of citizens have been rarely considered to directly inform scenario generation (Braunreiter et al., 2021; Saujot et al., 2021). Public views may have been considered indirectly, as scenario developers are often creating scenarios that respond to contemporary debates (Trutnevyte, 2016) and policymakers may request scenarios that correspond to popular transition alternatives. However, it has been shown that even multi-model, multi-organizational scenario ensembles can be focusing on a relatively narrow range of futures (Trutnevyte, 2016). While researchers frequently assess the diversity of existing scenarios using meta-analyses, they

mostly focus on finding similarities and differences among the scenarios (Centre d'Analyse Stratégique, 2012; Densing et al., 2016; Tsiropoulos et al., 2020). Only two studies have evaluated the inclusivity of perspectives in scenario development. Girod et al. (2009) evaluated the legitimacy of IPCC assessments before 2001 and found an imbalance in the participation of policymakers from different countries. Rounsevell and Metzger (2010) evaluated prominent scenario methods and suggested that most of them have been excessively depending on the beliefs and visions of the scenario analysts. Therefore, it may not be clear whether alternatives that are frequently included in scenarios—and are thus more likely to be translated into policies—are also desirable by the citizens. For example, carbon capture and storage (CCS) was included in considerable quantities in many scenarios of the latest IPCC assessments (Grant et al., 2021; Holz et al., 2018), despite being a largely unknown technology for the public (L'Orange Seigo et al., 2014; Wenger et al., 2021).

Even if citizen perspectives were more often used to inform scenario development, there would be still considerable challenges with using these perspectives meaningfully. While there have been extensive large-scale surveys and empirical studies that collected and analyzed citizen perspectives on the transition (e.g., European Commission, 2019a), their outcomes may not be easily transferred in scenarios. First, many of these outcomes are based on methods such as Likert scales to assess support for specific alternatives or policies, hindering their use in scenario analysis. For instance, if a responder answers that they strongly support solar PV, how many megawatts of installed capacity they would be willing to accept? While some studies have matched Likert scales with specific quantities (e.g., Allen and Chatterton, 2013), the combination of choices for each individual alternative or policy may not form a technically feasible or internally consistent scenario. Second, survey responses can be distorted due to knowledge gaps or misconceptions of the respondents about the subject (Fleishman et al., 2010; Van Rijnsoever and Farla, 2014; Volken et al., 2017; Wong-Parodi et al., 2016). Providing information about the topic of the elicitation has been shown to reduce knowledge gaps in workshops (L. A. Mayer et al., 2014; Volken et al., 2018). However, it is not easy to provide such information in online, large-scale surveys, which could be an ideal method for eliciting more diverse and numerous perspectives. Third, apart from the knowledge level, other factors may affect preference elicitation for transition strategies such as the demographics, prior beliefs, and the country of the participants. The country context has been shown to affect energy security concerns on citizens (Demski et al., 2018) and preferences for individual alternatives for energy transition (e.g., Poortinga et al., 2018). However, it is relatively less known whether and how it can control preferences for overall transition strategies that include trade-offs among individual alternatives. Additionally, factors such as age, education level, and political beliefs have been extensively studied in terms of interactions with beliefs on climate change (e.g., Chan and Faria, 2022; Fairbrother et al., 2019; Lee et al., 2015; Swim et al., 2022). In contrast, the effects of such factors on detailed transition strategies were usually addressed in short side analyses (e.g., Bessette and Arvai, 2018; Braunreiter et al., 2020; Jobin et al., 2019). Thus, there is no comprehensive

picture yet on how these demographics and prior beliefs would affect the elicitation of preferred scenarios for energy transitions from citizens and stakeholders.

### 1.3 Communication of scenario results

#### 1.3.1 Current practices and challenges

Traditionally, scenarios for energy and low-carbon transitions have been communicated through reports, scientific publications and large-scale assessments of the scenario literature (e.g., Rogelj et al., 2018b). In terms of communication formats, assumptions and results of the scenarios and other uncertainty methods are often reported in verbal, numerical, visual presentation formats, or a combination of the above (Kause et al., 2021). As model-based scenarios usually result in a wealth of numerical information, visualizations can be especially useful to reveal patterns in a succinct way (McInerny et al., 2014). Visualizations are typically used to show the main outcomes of scenario studies (Harold et al., 2016) and form an integral part of the communications strategy of IPCC (Corner et al., 2018; IPCC, 2016).

Unfortunately, comprehensibility has been a persistent problem in scenario visualization (Fischer et al., 2020; Harold et al., 2016). Scenario visualizations are often considered too complex to understand (Harold et al., 2019), especially among users without expertise in energy or climate sciences (Kause et al., 2021). Even among expert users, there have been significant misconceptions about the underlying uncertainties shown in the scenarios (Braunreiter and Blumer, 2018; Fischer et al., 2020; McMahon et al., 2015) or biases that affected the adoption of scenario information (Bosetti et al., 2017). These issues are further accentuated by the dramatic increase in the number of scenarios for energy and low-carbon transitions, especially during the last decade (Trutnevyte et al., 2016a). The evolution of scenario and modeling techniques, the increasing number of scenario developing organizations, as well as the need to assess diverse alternatives and uncertainties led to the use of large scenario ensembles, including hundreds or thousands of scenarios (Riahi et al., 2017; Trutnevyte et al., 2016a). Therefore, the pertinent challenge for scenario communication is to ensure that scenario users can correctly comprehend the ever-increasing scenarios in order to meaningfully inform their decisions (E. Ho et al., 2019; Huppmann et al., 2018b).

Apart from the growing number of scenarios, another challenge comes from the increased diversity of scenario users. Stakeholders from business and finance have been increasingly using ensembles of scenarios to measure the ambition of corporate strategies for climate change mitigation or to stress-test climate-related financial risks (Weber et al., 2018). Additionally, due to the growing public attention to the emergency of climate change, outcomes of scenario studies are communicated through the media (O'Neill et al., 2015). As these new users have different abilities and needs, scenario communication needs to adapt accordingly to ensure continuous usefulness and relevance (Auer et al., 2021). For instance, the communication formats that are used for scientists or policymakers may be too technical or complex for media use.



Additionally, new users may not have the training nor the knowledge to understand the technical details or the wider implications of alternatives shown in the scenarios. Apart from knowledge gaps, the interpretation of visualizations can be affected by other characteristics of the users, such as prior beliefs or numeracy (Dieckmann et al., 2017; Spiegelhalter et al., 2011). Knowing the audience and designing the communication accordingly is an important guideline in risk communication in general (Bostrom and Löfstedt, 2003) and in visualizations in particular (Harold et al., 2017). This becomes even more important for scenarios for energy and low-carbon transitions as such scenarios often require significant infrastructure, policy, or behavioral changes that can interact with the values, preferences, and feelings of the audiences, affecting the interpretation of scenarios.

One promising method to adapt scenario information to user abilities and support comprehension is using online interactive tools (Bostrom et al., 2008; Spiegelhalter et al., 2011; Trutnevyte et al., 2016a). Such tools are often used for outreach and education (Grainger et al., 2016), as interfaces for two-way engagement and research (Bessette et al., 2016; Gong et al., 2017), or as decision aids (Aye et al., 2015). There have been multiple claims in the literature that interactivity can increase user understanding and engagement by promoting active learning and exploration of the results (McInerney et al., 2014; Spiegelhalter et al., 2011). Such tools have been already used as interfaces to explore large databases of scenario information (Huppmann et al., 2018a) or to allow stakeholders to build their own preferred scenarios (DECC, 2011; EPFL, 2015). For scenario communication, the advantage of using such interactive scenario tools is that they can show large amount of data and allow the users to customize the data shown and its format to their own needs. Online scenario builders can be also useful for opening up deliberation in scenario and policy development as they can be easily accessible online (Pidgeon et al., 2014). However, interactive scenario tools usually come with higher costs and time requirements than traditional methods for communicating scenarios. They also need to be carefully designed, as design choices in their interface or operation may inadvertently affect their use (Demski et al., 2017).

### **1.3.2 Research gaps**

While scenario visualizations are often used to substantiate the most important outcomes of scenario studies, studies that prove their effectiveness and show their limitations are relatively limited. McMahon et al. (2015) evaluated a visualization of IPCC mitigation scenarios using a sample of its intended audience and found that, apart from climate scientists, most readers misunderstood the main message of the visualization. Bosetti et al. (2017) assessed the uptake of findings from a visualization of global warming by policymakers and reported effects of biases due to prior beliefs. Dieckmann et al. (2017) tested a similar visualization with a sample of the US public and reported that the more detailed the visualization was, the more it could reduce motivated reasoning due to diverse beliefs on climate change. However, it is uncertain whether

existing findings would be transferrable for the communication of large scenario ensembles that represent dozens or hundreds of alternative solutions. Apart from the proportional rise of complexity, a large number of scenarios would increase the uncertainty shown, which could interfere with the clarity of the communication (Hullman, 2020; Knoblauch et al., 2017) or with decision-making processes (Bostrom et al., 2008). Since the choice of visualization format can have significant implications on the interpretation of uncertainty (Correll and Gleicher, 2014; Harold et al., 2019; Kale et al., 2019), it would be important to test multiple formats in order to understand their effectiveness in visualizing complex scenario information.

As suggested in Section 1.3.1, a promising format to communicate complex scenario information is interactive scenario tools. While Wong-Parodi et al. (2014) have suggested methods for evaluating interactive scenario tools, evidence of benefits of these tools in comparison with existing methods remained limited (Moss, 2016; Stellamanns et al., 2016). Evaluations have shown that interactive scenario tools can have benefits when used in decision support (Blasch et al., 2017) or preference elicitation (Jeanneret et al., 2014). However, there was no benefit in evaluations of understanding and engagement, where interactive scenario tools had similar or worse performance compared to static equivalents such as reports or graphics without interactivity (Ancker et al., 2011; Volken et al., 2018; Zikmund-Fisher et al., 2011). Based on existing evaluations, it is unclear whether interactive scenario tools would perform much better than static counterparts in order to merit the increased time and cost investment to create them. Especially for the case of communicating scenarios, a lack of clarity due to a wrong format can have impacts on the confidence of the users in the scenario results (Elsawah et al., 2020).

Apart from interactivity, characteristics of the users such as demographics and prior beliefs can affect the interpretation of scenario results. Previous evaluations showed that different beliefs could lead to varying interpretations of visualizations of climate change impacts (Bosetti et al., 2017; Dieckmann et al., 2017; Guilbeault et al., 2018; Luo and Zhao, 2019). High numeracy has been shown to support the interpretation of visualizations that show climate uncertainty (Dieckmann et al., 2015), while effects from other characteristics such as demographics have been rarely evaluated (Hullman et al., 2019). However, no empirical study has examined the effects of audience characteristics on scenario visualizations for low-carbon or energy transitions. Since such scenarios represent collective actions, interpretations can be affected by other beliefs, for instance, beliefs in the ability and will of stakeholders to achieve the transition (Doherty and Webler, 2016). Interpretations can be also affected by interactions between the information presented in the visualizations and the underlying values of the audience, for instance, on environmental issues or security of supply (Demski et al., 2015). However, more empirical research is needed to establish the relationship of different characteristics with the interpretation of scenario visualizations and possible interactions with visualization formats. This need becomes even more pressing with the expansion of the audience of scenario information (Weber et al., 2018), which will bring more user profiles that visualizations need to adapt to (Harold et al., 2017).

## 1.4 Aim and outline of the thesis

Section 1.2 substantiated the need for including citizen perspectives in scenario development, outlined challenges of doing so, and argued that there might be a lack of these perspectives in existing, policy-guiding scenario ensembles. Section 1.3 questioned the effectiveness of prominent visualization methods for scenario communication in light of the constantly growing number of scenarios and the diverse needs of new scenario users. In response to the identified research gaps, this thesis aims:

*To empirically evaluate large scenario ensembles that inform energy and low-carbon transitions in terms of desirability and to test prominent visualization methods to make these ensembles usable.*

In order to operationalize the aim of the thesis, a research framework is created based on the properties of desirability and usability in large ensembles of energy or low-carbon scenarios. In this thesis, desirability refers to scenario results describing states of the future that largely agree with popular public views and values, following similar definitions in the literature (Bai et al., 2016; Braunreiter et al., 2021; Nikas et al., 2020). Going further from previous definitions, it is also assumed that these desirable views need to be at least technically feasible in order to facilitate their integration in scenario modelling and contribute to viable and sustainable transitions (Wright, 2009). Usability refers to successfully understanding and engaging with large scenario ensembles in the case of stakeholders with or without expertise in energy and climate analysis, which could be policymakers, industry representatives, civil society organizations, NGOs, or the wider public (Pidgeon et al., 2014; Weber et al., 2018). Since scenario visualization is a widely used method to summarize the outcomes of scenario ensembles (Harold et al., 2016), it forms a focal point in this thesis for studying the usability of scenarios. Additionally, the thesis focuses on interactive scenario tools as a promising but not well evaluated method for scenario communication. Both usability and desirability are important properties of scenarios as they are closely related to salience and legitimacy, two widely-used criteria for measuring scenario success (van Voorn et al., 2016).

Within this framework, this thesis is divided in five research studies that are presented in Chapters 3 – 7 and answer the following research questions:

1. How broad is the representation of popular public perspectives in the ensembles of scenarios that inform energy and low-carbon transitions? (Chapters 3 and 5)
  - a. Do these perspectives differ among citizens with different knowledge levels on energy transition topics? How do citizen perspectives compare with the perspectives of energy experts? (Chapter 3)

- b. How do different demographics, prior beliefs, and the national context of the citizens affect their perspectives? (Chapter 4)
- 2. What is the performance of prominent formats for visualizing large ensembles of scenarios for energy and low-carbon transitions in terms of supporting the understanding and engagement of transition stakeholders? (Chapters 6 and 7)
  - a. What is the difference between interactive and static formats for visualizing scenario information, and between different static visualizations? (Chapter 6)
  - b. Does understanding of and engagement with scenario information change given different demographics, opinions, and knowledge levels on the topics of the transition? (Chapters 6 and 7)

From the methodological perspective, all studies were based on data collected from large population surveys and workshops in order to provide empirical insights and recommendations. Additionally, almost all studies used an interactive scenario tool Riskmeter that was developed specifically for this PhD project, both for collecting data and for evaluating its performance in terms of scenario communication (see Section 1.5 and Chapter 2 for more details). The Riskmeter was also used in two related studies that the author contributed to during this thesis (Dubois et al., 2019; Volken et al., 2018), featuring citizen panels for exploring preferences on future Swiss electricity supply.

In terms of case studies, the thesis focused on the electricity supply transition in Switzerland, the EU, and the World (Table 1.1). The electricity sector forms an integral part of the overall energy system and it is especially crucial for achieving the targets of the Paris Agreement: the global electricity system will need to decarbonize rapidly while other energy sectors will need to be increasingly electrified (IPCC, 2018a). In terms of countries, Switzerland is a scientifically relevant case because of its strong tradition of direct democracy, offering the opportunity to every Swiss citizen to vote in crucial policy topics, including on its ongoing energy and low-carbon transition (FSO, 2021; SFOE, 2017). Similarly, a fair and just energy transition is considered to be a pillar of the European Green Deal to achieve a climate neutral economy in the EU (European Commission, 2020a), while more than 90% of the EU citizens want to increase their participation in major policy decisions (EU, 2022). For both the EU and Swiss contexts, scenarios are often used to communicate alternative energy strategies and pertinent perspectives are often informing energy modelling (e.g., European Commission, 2018b; PSI, 2012). In the context of the global electricity transition, Chapter 7 has tested different visualization formats using scenarios that were sourced from the scenario database of the IPCC Special Report on Global Warming of 1.5°C (Huppmann et al., 2018a). One of the major outcomes of analyzing these scenarios, i.e., that global CO<sub>2</sub> emissions should be reduced to net zero around 2050, played a major role in the current plans of most countries to achieve decarbonization within the second half of the 21<sup>st</sup> century (Hale et al., 2021).

Table 1.1. Research framework, research questions, and case studies

| Evaluation dimensions | Research questions                                                                                                                                                                                                     | Studies                                                                                                                             |                                                                                                                                                                                                                   |
|-----------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Desirability          | 1. How broad is the representation of popular public perspectives in the ensembles of scenarios that inform energy and low-carbon transitions?                                                                         | <u>Chapter 3</u><br>Evaluation of the representation of citizen preferences in an ensemble of national electricity supply scenarios | <u>Chapters 4 and 5</u><br>Evaluation of the representation of citizen preferences in an ensemble of national and EU electricity supply scenarios across multiple EU Member States                                |
|                       | 1a. Do these perspectives differ among citizens with different knowledge levels on energy transition topics? How do citizen perspectives compare with the perspectives of energy experts?                              | Case study: electricity supply transition in Switzerland                                                                            | Case study: electricity supply transition in France, Germany, Poland, and the EU as a whole                                                                                                                       |
|                       | 1b. How do different demographics, prior beliefs, and the national context of the citizens affect their perspectives?                                                                                                  | Published as Xexakis et al. (2020) in <i>Renewable and Sustainable Energy Reviews</i>                                               | Chapter 4 was published as Xexakis and Trutnevyte (2021a) in <i>Energy Strategy Reviews</i><br><br>Chapter 5 was published as Xexakis and Trutnevyte (2022) in <i>Renewable and Sustainable Energy Transition</i> |
| Usability             | 2. What is the performance of prominent formats for visualizing large ensembles of scenarios for energy and low-carbon transitions in terms of supporting the understanding and engagement of transition stakeholders? | <u>Chapter 6</u><br>Evaluation of interactive and static formats for visualizing scenario ensembles                                 | <u>Chapter 7</u><br>Evaluation of prominent static formats for visualizing scenario ensembles                                                                                                                     |
|                       | 2a. What is the difference between interactive and static formats for visualizing scenario information, and between different static visualizations?                                                                   | Case study: electricity supply transition in Switzerland                                                                            | Case study: low-carbon transition at a global level                                                                                                                                                               |
|                       | 2b. Does understanding of and engagement with scenario information change given different demographics, opinions, and knowledge levels on the topics of the transition?                                                | Published as Xexakis and Trutnevyte (2019a) in <i>Environmental Modelling &amp; Software</i>                                        | Published as Xexakis and Trutnevyte (2021b) in <i>Global Environmental Change</i>                                                                                                                                 |

Note: In the context of this thesis, the author additionally contributed to Volken et al. (2018) and Dubois et al. (2019) which were related to the case study of Swiss electricity supply presented in Chapter 3.

## 1.5 Contributions and novelty of the thesis

The key methodological contribution of the thesis is the interactive scenario tool Riskmeter. The tool was developed by the author as a user-friendly method to map scenarios of the future electricity supply mix of different countries and elicit stakeholder perspectives to inform modelling. Interactive scenario tools have been developed for well over a decade for energy topics (e.g., DECC, 2011; EPFL, 2015) and have been also used to collect preferred scenarios (e.g., Allen and Chatterton, 2013; Bessette and Arvai, 2018; Jobin et al., 2019; Mayer et al., 2014; Rooney-Varga et al., 2018; Scheer et al., 2013). The Riskmeter shares many

characteristics with previous interactive scenario tools for energy but was specifically designed to strike a balance between a user-friendly design, fast interaction, and technical realism in the topic of electricity supply. Equally importantly, the Riskmeter was developed as a highly customizable tool that could be easily adapted to support almost all studies of this thesis (Chapters 3 – 6). Since the Riskmeter is representative of the design of other major interactive scenario tools, insights from these studies are relevant for these other tools as well. Due to its high customizability, the Riskmeter could be also integrated in workshops (Dubois et al., 2019; Volken et al., 2018) and surveys (Chapters 3 – 6). For extensive details on the Riskmeter, its design, and its underlying calculation model, see Chapter 2.

In terms of other methodological and conceptual contributions, this thesis introduced two novel frameworks to evaluate the desirability of scenario ensembles and the usability of scenario visualizations. The first framework was designed to assess large scenario ensembles in terms of how well they represent citizen views on topics reflected in the scenarios. This evaluation of desirability was conceptualized as a comparison between an ensemble of model-based scenarios and an ensemble of technically-feasible scenarios elicited by the citizens. The comparison was operationalized as a set of statistical measures, contrasting the scenario ensembles in terms of centrality and dispersion as well as revealing the role of minority preferences in this contrast (see Sections 4.2.4 and 5.2.4 for more details). This approach was much more comprehensive than previous methods of comparing scenarios with stakeholder perspectives that were based on single statistics e.g., from van Sluisveld et al. (2018). The second framework focuses on evaluating the usability of scenario visualizations, both in the context of interactive scenario tools and traditional formats such as reports. The framework consists of a consistent and structured collection of evaluation measures from diverse scientific disciplines, ranging from cognitive psychology to operations research and decision sciences. This framework includes both self-reported and tested measurements, as well as pertinent variables that have not been used before in similar evaluations (e.g., Bessette et al., 2016; Wong-Parodi et al., 2014), such as measures of trust and website navigation skills. In addition to measuring desirability and usability, all studies evaluated their interactions with demographics, prior beliefs, and characteristics of scenario stakeholders and users.

Since empirical evaluation is at the core of this thesis, all studies include case-specific contributions in the form of empirical data-based recommendations. First, Chapters 3 and 5 assessed five multi-model, multi-organization ensembles of electricity supply scenarios for 2035 in Switzerland, France, Germany, Poland, and the EU with the perspectives of respective citizen groups. While previous studies have compared a limited number of model-based scenarios with stakeholder preferences (Allen and Chatterton, 2013; Fleishman et al., 2010; Scheer et al., 2013), this thesis used large and systematically collected ensembles that included dozens or hundreds of scenarios. Insights from these assessments can inform on the desirability of existing scenario ensembles in the examined countries and the EU and on missing scenarios that need to be modelled. Second, Chapter 4 provided information on the consensus among citizens of France,

Germany, and Poland in terms of the electricity supply transition in their countries and the EU as a whole. Consensus was also assessed among citizens with different demographics, political orientations, and attitudes towards the transition and its governance, measuring thus the consistency of preferences within as well as between the examined countries. Third, Chapters 6 and 7 offered valuable insights for improving the effectiveness of scenario visualizations, especially for large ensembles such as the ones used by the IPCC. The study in Chapter 7 used the ensemble of climate change mitigation scenarios from the IPCC Special Report on Global Warming of 1.5°C as a case study to evaluate different visualization formats. While there have been previous evaluations of visualizations showing the impacts of climate change (Bosetti et al., 2017; McMahon et al., 2015), this thesis provided the first evaluation of visualizations for climate change mitigation. The focus on mitigation is increasingly relevant, as global attention has shifted from the question of whether climate change should be addressed to how to address it. Finally, both studies in Chapter 6 and 7 examined the role of demographics and prior beliefs of the citizens in understanding of and engaging with scenario results, while Chapter 7 also provided an example of customizing visualizations to citizens of different characteristics.

## Chapter 2 Interactive scenario tool Riskmeter

### 2.1 Concept and use

The Riskmeter is an interactive scenario tool developed by the author for exploring scenarios of future electricity supply in various European countries and for eliciting preferences for these scenarios (Figure 2.1). Through a user-friendly interface, the Riskmeter helps users understand the technical potential of different alternatives for electricity supply, along with their impacts on pertinent environmental, economic, and societal indicators. Additionally, the Riskmeter allows users to combine electricity supply alternatives to build the scenario they prefer. In comparison with public opinion surveys that commonly elicit preferences for individual electricity supply technologies (e.g., European Commission, 2019a; Poortinga et al., 2018), the Riskmeter frames electricity supply as a mix of supply alternatives. In that way, users are prompted to think holistically and make tradeoffs among the different alternatives. In addition, the Riskmeter is highly customizable and can be easily adapted to different spatial regions, target years, and any number of electricity supply alternatives and impacts, using simple, spreadsheet-like inputs. The tool has been programmed by the author in Python and JavaScript and can be found online in <https://riskmeter.ch> (Xexakis and Trutnevte, 2020a).

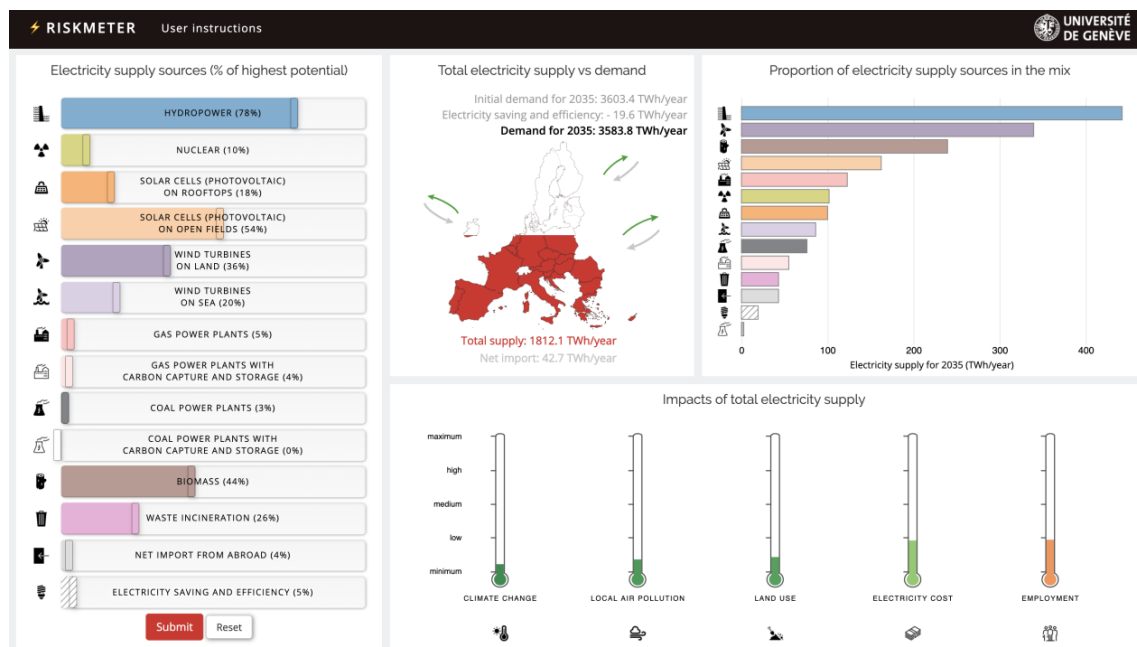


Figure 2.1. The interactive scenario tool Riskmeter for the EU27 (Xexakis and Trutnevte, 2020a)



In total, seven different versions have been developed: five versions for the electricity supply in 2035 for France, Germany, Poland, Switzerland, and the EU as a whole, one simpler version for the Swiss electricity supply without interactive impact information, and one version intended for school pupils in Switzerland. All Riskmeter versions are offered in English, French, and German, while the versions for France, Germany, Poland, and the EU have been additionally translated in Polish. The Riskmeter has been used in four out of the five studies of this thesis (described in Chapters 3 – 6) and in two additional studies that the author participated in, i.e., Volken et al. (2018) and Dubois et al. (2019). Before its initial release, the Riskmeter has been pretested by energy experts and non-experts and has been empirically evaluated for usability numerous times (Dubois et al., 2019; Volken et al., 2018; Xexakis et al., 2020; Xexakis and Trutnevyte, 2021a). These evaluations have been overall positive, especially when the Riskmeter was used for preference elicitation (Chapters 3 – 5) or integrated into a workshop (Dubois et al., 2019; Volken et al., 2018). Details on these evaluations are provided in Sections 3.3.1 and 4.3.1 and in Chapter 6.

## **2.2 Interactive interface and underlying calculation model**

When visiting the Riskmeter, users are shown a full-screen webpage with a simple interface (Figure 2.1). The left side of Figure 2.1 shows a set of sliders that form the main interaction elements for the users. These sliders represent the yearly electricity supply from alternatives that are already used or could be used in the future in a country of interest (see Table 2.1 for a detailed list of the alternatives). Users can choose to generate electricity domestically using sources such as solar PV, nuclear power, or natural gas or import electricity from neighboring countries. Users can also decrease electricity demand by increasing electricity savings and efficiency. Each slider extends from zero supply (0%) to the alternative's highest technical potential for the future (100%) and can be moved in positions of 1%. For some sliders, the minimum position is fixed to the current supply, representing power plants that are expected to stay operational in the foreseeable future. The right side of Figure 2.1 shows a set of visualizations that change interactively with each move of the sliders. These visualizations inform the users about: 1) the relation between total supply and demand, 2) the relative contributions of each alternative, and 3) the impacts of the selected scenario. The latter include impacts on climate change, cost of electricity, employment and other environmental, economic, and societal aspects that are frequently used to evaluate electricity supply scenarios (Ortega et al., 2020; Volkart et al., 2017). See Table 2.1 for a detailed list of the impacts for each Riskmeter version and Sections 4.2.3 and 6.3.2 for more details on their implementation in the Riskmeter.

Table 2.1. Riskmeter versions and features

| Riskmeter versions                         | Used in study                                                    | Electricity supply alternatives                                                                                                                                                                                                                                                                                                                             | Impacts                                                                                                                                                                                                                                                                                                                                                                                                                      |
|--------------------------------------------|------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| EU                                         |                                                                  | <ol style="list-style-type: none"> <li>1. hydropower</li> <li>2. nuclear</li> <li>3. rooftop solar</li> <li>4. open field solar</li> <li>5. onshore wind</li> <li>6. offshore wind</li> </ol>                                                                                                                                                               | <ol style="list-style-type: none"> <li>1. climate change (CO<sub>2</sub>-eq) (Bauer et al., 2019, 2017; JRC, 2014)</li> </ol>                                                                                                                                                                                                                                                                                                |
| France                                     |                                                                  | <ol style="list-style-type: none"> <li>7. gas power plants</li> <li>8. gas power plants with CCS</li> </ol>                                                                                                                                                                                                                                                 | <ol style="list-style-type: none"> <li>2. local air pollution (PM<sub>10eq</sub>) (Luderer et al., 2019)</li> </ol>                                                                                                                                                                                                                                                                                                          |
| Germany                                    | (Xexakis and Trutnevyte, 2022, 2021a)                            | <ol style="list-style-type: none"> <li>9. coal power plants</li> <li>10. coal power plants with CCS</li> <li>11. biomass</li> <li>12. waste incineration</li> <li>13. net import from abroad</li> <li>14. electricity savings and efficiency</li> </ol>                                                                                                     | <ol style="list-style-type: none"> <li>3. land use (m<sup>2</sup>) (Masanet et al., 2013; Maxim, 2014)</li> <li>4. levelized cost of electricity (EUR/kWh) (Bauer et al., 2019, 2017; De Vita et al., 2018; JRC, 2014)</li> </ol>                                                                                                                                                                                            |
| Poland                                     |                                                                  | <p>Supply data sources: (Sasse and Trutnevyte, 2020; Xexakis and Trutnevyte, 2022, 2021a)</p> <p>See Section 4.2.3 for more details</p>                                                                                                                                                                                                                     | <ol style="list-style-type: none"> <li>5. employment (jobs/kWh) (Kis et al., 2018)</li> </ol>                                                                                                                                                                                                                                                                                                                                |
| Switzerland                                |                                                                  | <ol style="list-style-type: none"> <li>1. large hydropower dams</li> <li>2. large run-of-river hydropower</li> <li>3. small hydropower</li> <li>4. solar cells (photovoltaic)</li> <li>5. wind</li> <li>6. deep geothermal</li> <li>7. woody biomass</li> </ol>                                                                                             | <ol style="list-style-type: none"> <li>1. climate change (CO<sub>2</sub>-eq) (Bauer et al., 2017, 2012; Volkart et al., 2016)</li> <li>2. local air pollution (PM<sub>10eq</sub>, SO<sub>x</sub>, NO<sub>x</sub>) (Bauer et al., 2012; Masanet et al., 2013)</li> <li>3. water withdrawal and consumption (m<sup>3</sup>) (Fthenakis and Kim, 2010; Wernet et al., 2016)</li> </ol>                                          |
| (including interactive impact information) | (Xexakis and Trutnevyte, 2019a)                                  | <ol style="list-style-type: none"> <li>8. biogas</li> <li>9. nuclear power</li> <li>10. waste incineration</li> <li>11. large natural gas power plants</li> <li>12. net import from abroad</li> <li>13. electricity savings and efficiency</li> </ol> <p>Supply data sources: (Berntsen and Trutnevyte, 2017)</p> <p>See Section 6.3.2 for more details</p> | <ol style="list-style-type: none"> <li>4. landscape and land use (m<sup>2</sup>) (Masanet et al., 2013; Maxim, 2014)</li> <li>5. accidental impacts (expected mortality and maximum fatalities in an accident) (Volkart et al., 2016)</li> <li>6. levelized cost of electricity (Rp/kWh) (SFOE, 2016)</li> <li>7. electricity supply reliability (autonomy, dispatchability, availability) (Volkart et al., 2016)</li> </ol> |
| Switzerland                                | (Dubois et al., 2019; Volken et al., 2018; Xexakis et al., 2020) | Same as the version for Switzerland with interactive impacts                                                                                                                                                                                                                                                                                                | Interactive impacts were not included                                                                                                                                                                                                                                                                                                                                                                                        |
| Switzerland                                |                                                                  | <p>Simplifications for the school version:</p> <ul style="list-style-type: none"> <li>• all hydropower alternatives were merged into one category</li> <li>• woody biomass and biogas were merged into one category</li> <li>• deep geothermal was removed</li> </ul>                                                                                       | Interactive impacts were not included                                                                                                                                                                                                                                                                                                                                                                                        |
| (school version)                           | -                                                                |                                                                                                                                                                                                                                                                                                                                                             |                                                                                                                                                                                                                                                                                                                                                                                                                              |

The underlying model of the Riskmeter is simple: the position of each slider is translated to TWh/year and then added to the total electricity supply. While this method does not consider design aspects of electricity supply system, such as temporal dispatch, it produces a simplified approximation of the yearly electricity supply mix. This leads to a fast interaction with the Riskmeter and allows the users to create their preferred scenarios without restrictions, for instance, due to cost optimization. Nevertheless, the electricity supply potentials for all alternatives in the Riskmeter were informed by extensive reviews of the scenario literature in the examined countries and the EU (see Sections 3.3 and 5.3.2). In that sense, the Riskmeter can be assumed to be a meta-model of literature-derived, multi-organization scenario ensembles, allowing users to reproduce most of the scenarios included in these ensembles. This reinforces the realism of Riskmeter as it covers a wide range of technically possible scenarios that have been simulated by different models that are based on diverse paradigms (including cost optimization). Additionally, several design aspects of electricity supply are included in Riskmeter parameters indirectly. First, estimations of build rates were considered in the definition of the technical potential for each alternative. Second, expert-derived assessments on the dispatchability of different electricity supply technologies were used to quantify their impacts on the overall electricity supply reliability. Third, the cost of electricity storage for renewable alternatives was included in their impacts on electricity cost.

Impacts are calculated in real-time by multiplying the electricity supply from each alternative in TWh/year with relevant indicators, such as the CO<sub>2</sub> equivalent emissions per TWh (see Table 2.1 for all indicators). Each impact value is then normalized between the maximum and minimum value that could be achieved by any scenario in the Riskmeter. Data for electricity supply potentials, electricity demands, and impact indicators were collected from the literature (see Table 2.1 for detailed sources).

Overall, the aforementioned design choices lead to a highly responsive and straightforward interaction with the Riskmeter. The Riskmeter also includes a tutorial that guides users through all elements of its interface. Finally, when the Riskmeter is used for preference elicitation, a pop-up window is included, stating that the goal of the users is to create a scenario that covers the electricity demand.

## **Chapter 3 Alignment between model-based and preferred electricity scenarios for Switzerland**

This chapter is based on Xexakis et al. (2020).

### **3.1 Introduction**

Many countries around the World have set long-term targets to transform their electricity systems (Markard, 2018). Common targets concern specific technologies, such as phasing out nuclear power and increasing renewable electricity in Switzerland (SFOE, 2017) and Germany (BMW, 2010), or refer to a system-wide change, such as 100% decarbonization envisioned by the EU (European Commission, 2018c) and the UK (UK government, 2019). Model-based scenarios, e.g. using models like MARKAL/TIMES (Giannakidis et al., 2015; Kannan, 2018) or other energy optimization models (DeCarolis et al., 2017), are commonly used in strategic decision making for electricity system planning and policy in order to explore uncertainties and assess the consequences of different alternatives (Berntsen and Trutnevyte, 2017; Lempert, 2013; Maier et al., 2016; O'Neill et al., 2017; Trutnevyte et al., 2016a, 2016b). Although multiple uncertainties can lead to infinite scenarios, scenario developers usually focus on three to four scenarios to analyze in detail and to communicate the results efficiently (Trutnevyte et al., 2016b, 2016a). While there are many structured techniques to choose small sets of scenarios, such as the most internally consistent or maximally diverse sets of scenarios (Carlsen et al., 2016b; Trutnevyte et al., 2016a), modelers often select scenarios subjectively based on their perspectives of the most influential uncertainties or the most plausible alternative (Alcamo, 2008; Trutnevyte et al., 2016b; van 't Klooster and van Asselt, 2006). Yet, due to the multi-dimensional uncertainties that surround electricity system transition, subjectively-derived scenarios might miss important developments of the future (Trutnevyte et al., 2016a, 2016b).

A solution to increase the diversity of scenario sets is to combine scenarios from multiple studies and models, as commonly done in comprehensive scientific assessments like the reports of the Intergovernmental Panel on Climate Change (IPCC) (Trutnevyte et al., 2016b; van Vuuren et al., 2012). In many countries, energy and electricity supply scenarios have been developed by multiple organizations in public administration, academia, non-governmental institutions, and

industry (Berntsen and Trutnevyte, 2017; Laugs and Moll, 2017; Schmid and Knopf, 2012). Combining these studies in multi-model, multi-organization scenario ensembles could increase the diversity of uncertainties and alternatives considered (Trutnevyte et al., 2016b). However, it has been argued that even such scenario ensembles may exhibit shortcomings. Retrospective scenario studies showed that even diverse scenario sets may be affected by common contemporary debates and worldviews and explore in the end similar uncertainties, avoiding seemingly extreme scenarios and perspectives (Craig et al., 2002; Laugs and Moll, 2017; Trutnevyte et al., 2016b). There is also a concern that the underlying techno-economic focus of common methods to quantify scenarios, such as cost optimization models, might limit the diversity of examined perspectives for a large-scale transition (Blok et al., 2018; Shaw, 2014).

All targets and transition alternatives for the future of the national electricity system are essentially value-laden, i.e. based on perspectives, wishes and concerns of the transition's stakeholders (Markard, 2018; Shaw, 2014; Volken et al., 2018). Since large-scale transitions have significant and wide environmental, social, and economic consequences (Markard, 2018), transition-related decisions should be a subject of democratic deliberation among the transition's stakeholders, including the public (Cherp et al., 2018; Lund, 2007; Shaw, 2014; Stirling, 2008). Consequently, an important part of this deliberation is the consideration of the perspectives of the diverse stakeholder groups in the scenarios that inform these decisions (Pidgeon et al., 2014; Trutnevyte et al., 2019a; Volken et al., 2018). Including diverse stakeholders in scenario development can augment the legitimacy of scenarios (Börjeson et al., 2006; Kunseler et al., 2015; Trutnevyte et al., 2011), allowing scenarios to become more "socially robust" (Eker et al., 2017). Stakeholder participation can also lead a more transparent weighting of decision alternatives (Renn, 1999; Schmid and Knopf, 2012), especially for decisions where social acceptance can be a potential barrier (Dermont et al., 2017; Wüstenhagen et al., 2007). Despite these benefits, involving diverse stakeholder groups directly in scenario development is a difficult and not a widespread practice. While stakeholder engagement methods have been developed for many years now (Eker et al., 2017; Pidgeon et al., 2014; Schmid and Knopf, 2012; Trutnevyte et al., 2011; van Asselt and Rotmans, 1996), many require specialized expertise and cost- and time-intensive stakeholder workshops. Even for studies that use opinion polls and online web-tools to elicit scenario preferences (Allen and Chatterton, 2013; Bessette et al., 2016), these preferences may not reflect the true values if the participants have knowledge gaps and misconceptions about the subject (Fleishman et al., 2010; Van Rijnsoever and Farla, 2014; Volken et al., 2017). Previous studies showed that non-experts in energy topics may radically change their opinions based on the framing of information on new technologies (Stadelmann-Steffen, 2019), significantly underestimate the energy dependency of their country (Cousse and Wüstenhagen, 2018a), or even believe that wind turbines can "deplete" wind and disrupt pollination (Volken et al., 2017). Therefore, without explicit stakeholder engagement and without ensuring that elicited preferences are not biased by knowledge gaps, it is unclear whether stakeholder perspectives can be adequately represented in model-based scenarios.

Only few studies compared the alignment of existing scenarios for energy transitions with stakeholder preferences; all of them found discrepancies for some scenarios. Allen and Chatterton (2013) compared three energy scenarios for the UK developed by the government with preferred scenarios collected from more than 10,000 citizens in a web tool and found low preference of the public for a scenario with growing nuclear power. Other studies used informed citizen panels, where non-expert participants received balanced information about the subject prior to providing preferences (Fleishman et al., 2010; L. A. Mayer et al., 2014; Scheer et al., 2013, 2017). Fleishman et al. (2010) and Scheer et al. (2013) collected informed public preferences for a few scenarios inspired by existing energy scenarios in the USA and Germany and found low support in both countries for traditional coal power plants in scenarios. Model-based scenarios were also compared with expert opinions (Eker et al., 2017; van Sluisveld et al., 2018). Van Sluisveld et al. (2018) compared expert projections with two model-based global energy scenarios and found that while experts agreed with models in a business-as-usual scenario, there was a disagreement in a scenario with stringent climate policy. Eker et al. (2017) incorporated stakeholder perspectives for the future of the Dutch gas sector in a large ensemble of scenarios produced by a single model and identified the incompatible elements between the model and the stakeholder perspectives. Yet, no study evaluated if a multi-organization, multi-model scenario ensemble could represent diverse stakeholder perspectives in a balanced way that would avoid discrepancies. Additionally, the effect of knowledge gaps of stakeholders on such evaluations have not been yet systematically assessed.

This study compares a multi-organization, multi-model ensemble of existing Swiss electricity supply scenarios for 2035 with scenarios preferred by three samples of participants that differ in their knowledge level about electricity supply: citizens (non-experts), informed citizens, and energy experts. The electricity system transition of Switzerland provides a fitting case study. Due to the Fukushima accident in 2011, the Swiss Federal Council decided to phase-out nuclear power in 2035, raising the question of what could substitute the nuclear power plants that currently provide around 30% of Swiss electricity supply (SFOE, 2018). Multiple organizations contributed to these policy discussions by developing model-based electricity supply scenarios. The resulting scenario ensemble were found to be diverse enough to cover the range of plausible future options (Berntsen and Trutnevyte, 2017; Densing et al., 2016). Yet, past public opinion polls and studies indicated possible disagreements between model-based scenarios and public preferences for the electricity system future in Switzerland (Cousse and Wüstenhagen, 2018a; Volken et al., 2018). Additionally, no past study has explicitly compared public preferences with a large ensemble of model-based scenarios.

By conducting a review of 19 model-based scenario studies between 2011 and 2018 for the Swiss electricity supply in 2035 and by eliciting preferred scenarios from the three samples of participants, this study aims to answer the following questions:

1. How does an ensemble of multi-organization, multi-model electricity scenarios compare to the preferred scenarios from citizens, informed citizens, and energy experts?

2. What are the key factors of scenario development that may explain the alignment or misalignment between the model-based scenarios and the preferred scenarios?
3. Does the difference in energy knowledge level of the three samples result in differences in preferred scenarios?

In order to answer these questions, this paper is structured as follows: Section 3.2 presents the methods used for the review, for the elicitation of preferred scenarios, and for the comparison; Section 3.3 reports the results; Section 3.4 discusses the findings; and Section 3.5 summarizes and concludes with implications for scenario development in general and for the electricity supply transition in Switzerland.

## 3.2 Methods

### 3.2.1 Overall study design

This study compares a multi-organization, multi-model ensemble of existing Swiss electricity supply scenarios for 2035 with scenarios preferred by the public and energy experts. The scenario ensemble (henceforth referred as “model-based scenarios”) is created by reviewing scenario studies in Switzerland that were published between 2011 and 2018 (Section 3.2.2). The preferred scenarios for the electricity supply in 2035 are elicited from three samples of participants with different levels of knowledge on the electricity supply topic: (1) non-experts (“citizens”,  $N = 61$ ), (2) non-experts that received balanced information and participated in informational workshops about the electricity supply topic prior to giving their preferred scenarios (“informed citizens”,  $N = 46$ ), and (3) participants that were mainly working in or studying about energy topics in Switzerland (“energy experts”,  $N = 60$ ) (Section 3.2.3). The ensemble of model-based scenarios is then compared with the scenarios preferred by the three samples in terms of technology-specific electricity supply and the whole electricity supply system (Section 3.2.4).

### 3.2.2 Review of existing model-based scenarios

The review focused on the studies that provided detailed results of model-based Swiss electricity supply scenarios for 2035, including the electricity mix, the contribution of each electricity technology, and the total electricity demand in TWh/year. Studies published after 2011 were used because the Swiss government’s decision to phase out nuclear power in 2011 made the previous scenarios less relevant. A variety of strategies was used to collect the studies for the review. First, eight studies were included that were published between 2011 and 2013 from a previous review in 2016 by Densing et al. (2016, 2014). Second, the Web of Science platform was searched for more recent peer-reviewed studies based on a combination of keywords: scenarios AND (model OR simulation) AND (electricity OR power) AND (Switzerland OR Swiss). This search resulted in 85 publications from which only five studies that provided the required

electricity mix results were selected. Third, since many past scenario studies were technical reports and published in German, the publication repositories of Swiss organizations that have published scenarios in the past were surveyed, using the aforementioned keywords translated in German. Specifically, the repositories of the Swiss Federal Office of Energy (SFOE), Paul Scherrer Institute (PSI), the Association of Swiss Electricity Producers (VSE) were searched, and four additional studies were collected. Fourth, modeling groups that are active in energy scenario modeling in Switzerland were contacted. Based on these methods, 19 studies have been found in total.

From each study the resulting electricity supply scenarios for 2035 were extracted. Only the main scenarios were included from each study and not any variants used for sensitivity analyses, for which usually no detailed results were given. Five studies did not include scenario results for 2035; estimates for 2035 were calculated using linear interpolation between the results for 2030 and 2040 or 2050 for each electricity technology. An exception to this was nuclear power that is planned to be phased-out until 2035; there it was assumed that the supply from nuclear power in 2035 would be zero and its share was substituted with another technology. For example, if a study assumed that the supply share of nuclear is replaced by fossil fuel-based generation in 2050, then it was assumed that this have happened already from 2035 when the phase-out was completed. Details on the substitutions and their underlying assumptions are given in Table A1 in Appendix A.

The key factors of scenario development were also extracted in order to understand how and why scenarios were chosen and to assess if there were any trends in the scenario choice across all studies. The selection of these key factors was informed by previous scenario evaluation studies (Berntsen and Trutnevyte, 2017; Densing et al., 2016; Eker et al., 2017; Riahi et al., 2017; Trutnevyte et al., 2016b) and included: 1) the category of each scenario based on the typology from Börjesson et al. (2006) of predictive (answering to the question: “what will happen?”), explorative (“what can happen?”) and normative scenarios (“how can a certain target be reached?”); 2) the guiding questions in order to understand the main objectives of each scenario study; 3) the scenario generation techniques in order to see whether there was any public participation, and 4) details on the choice of each scenario in order to find any commonalities in the uncertainties explored in the studies.

### **3.2.3 Elicitation of the preferred scenarios**

#### **3.2.3.1 Materials**

For all samples of participants, preferred scenarios were elicited for the Swiss electricity supply in 2035 using an interactive web-tool Riskmeter (Xexakis et al., 2017). Using methodologies from decision sciences and psychology (Fleishman et al., 2010; L. A. Mayer et al., 2014; Pidgeon et al., 2014; Wong-Parodi et al., 2016), the participants were asked to choose their preferred technologies and scenarios directly instead of eliciting derivative metrics, such as



willingness to pay. The Riskmeter was developed as a method to collect preferred and yet realistic electricity supply scenarios (Figure 3.1). The Swiss electricity demand for 2035 was assumed to be 70 TWh/year, corresponding to the business-as-usual demand scenario of the Swiss Federal Office of Energy (Prognos, 2012). Riskmeter users could choose among 12 supply alternatives that already exist in Switzerland or could be built in the future: large hydropower dams, large run-of-river hydropower, small hydropower, solar cells (photovoltaic), wind, deep geothermal, woody biomass, biogas, nuclear power, waste incineration, large natural gas power plants and net import from abroad. Users could also reduce demand by choosing to expand electricity savings and efficiency measures up to 6.8 TWh/year (equivalent to the moderate demand scenario from Swiss Office of Energy (Prognos, 2012)). This eventually led to some demand variations in the resulting preferred scenarios, but not as much as in some model-based scenarios which assumed stronger demand reductions or even demand increase as compared to the current level.

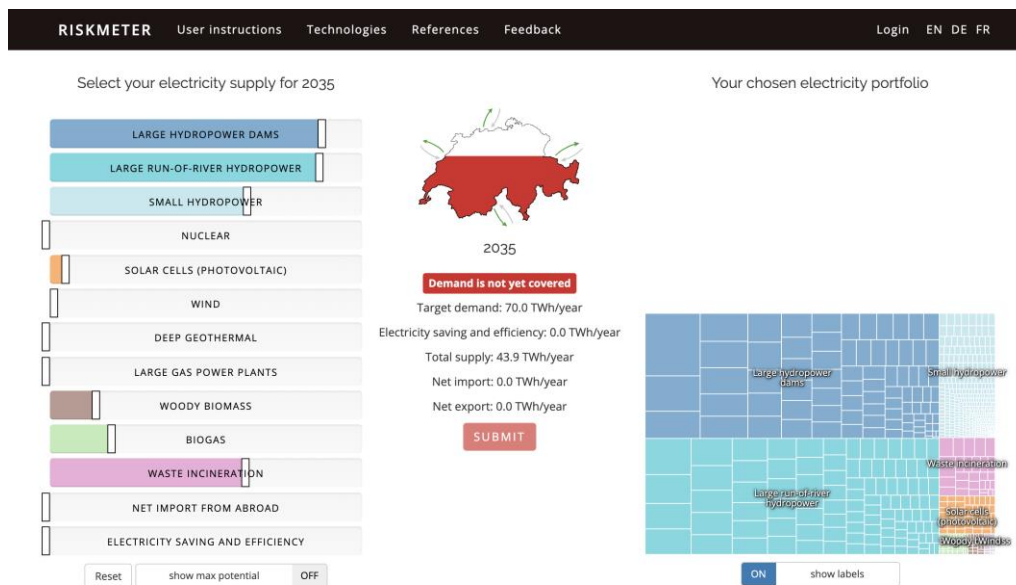


Figure 3.1. The interactive web-tool Riskmeter for building Swiss electricity supply scenarios for 2035 (Xexakis et al., 2017)

Users controlled the yearly electricity supply for 2035 from each alternative through an interface of sliders (left panel of Figure 3.1). The sliders represented the utilization percentage for each alternative, extending from zero supply (0%) to the alternative's highest technical and resource potential for 2035 (100%). The potentials were informed by a previous study (Berntsen and Trutnevyte, 2017) and were in line with the other studies in Switzerland (Bauer et al., 2017; Densing et al., 2016). For existing alternatives that are expected to last until 2035, the minimum value of their slider was constrained to their yearly supply for 2015. The only exception was nuclear power which was set to 0% due to the phase-out envisioned in 2035 (SFOE, 2017). To keep the interaction with the Riskmeter as fast as possible, the contribution from each alternative

in TWh/year was added to the total supply for 2035. If the total supply was higher than the demand, then the difference was calculated as net export. Riskmeter was pretested before its release with energy experts and non-expert users in order to ensure that it was comprehensible and user-friendly.

#### 3.2.3.2 Procedures

Using the Riskmeter, preferred scenarios were elicited from three samples of participants with different levels of knowledge on electricity supply topics: citizens (non-experts), informed citizens, and energy experts. These samples were chosen in order to study the effect of participants' knowledge on their preferred scenarios and, consequently, on the comparison with model-based scenarios. In order to ensure the required knowledge level, a different recruitment and data collection procedure was followed for each sample.

For the citizen sample ( $N = 61$ ), the goal was to elicit preferred scenarios from Swiss non-experts without familiarizing them first with the topic. Participants were given a link to an online survey which started with demographics and questions on their experience with the topic. Participants were then redirected to the Riskmeter and submitted their preferred electricity supply scenario for 2035 without any background information on the electricity supply technologies. Participants were recruited through an access panel in the German-speaking part of Switzerland during April 2018, based on two requirements: 1) to exclude people working or studying in energy-related sectors, and 2) to provide a representative sample of the Swiss population in terms of *gender*, *age*, and *highest education level*.

The informed citizen sample ( $N = 46$ ) was created in a previous study which examined the role of information on the evolution of public preferences for the electricity supply technologies and scenarios in Switzerland (Volken et al., 2018). Participants were first asked to read at home factsheets for 13 electricity supply alternatives and their environmental, health, economic, and supply security impacts (Trutnevyte et al., 2019b). Participants were then invited to workshops and discussed in groups of six to seven participants about individual technologies and scenarios for the electricity supply in 2035 and then submitted their individually preferred scenarios in Riskmeter. Overall, the participants came from the German-speaking part of Switzerland as well and were recruited in May 2017 through advertisements on online platforms and public places. Again, people working or studying in any energy-related sector were excluded and the remaining participants were sampled to achieve a diverse sample in terms of initial *individual technology preferences* and then in terms of *gender*, *age*, and *highest education level*. More details on the procedure and materials are given by Volken et al. (2018).

The energy expert sample ( $N = 60$ ) was recruited between August 2017 and March 2018. The recruitment involved advertisements in Swiss academic and professional networks about energy, inviting all interested individuals to visit the Riskmeter and submit their preferred electricity supply scenario for 2035. After submitting their scenario, participants were redirected to a survey with questions about their demographic information, professional background, and

Riskmeter evaluation. From the total sample, only people that reported working on or studying mainly on energy topics at the time of the survey were selected. Most energy experts came from academia (78.3%) and mainly from the fields of Engineering and Technology (33.3%) and Social Sciences and Management (35%). Many energy experts were also working in industry or businesses (40%), while some were also involved in public administration (13.3%), non-governmental (15%), or political organizations (3.3%). A detailed list of the energy experts' occupations is given in Appendix A.

All samples answered the same questions on demographics (*gender, age, highest education level*) and two scales measuring the participants' *self-rated interest* in the topic of electricity supply (three items with 7-point Likert scale from 1 = completely disagree to 7 = completely agree; available in Appendix A) and their *self-reported Riskmeter evaluation* in terms of knowledge gains and engagement (10 items with 7-point Likert scale; available in Appendix A). Similar items have been also used in past studies (Fleishman et al., 2010; L. A. Mayer et al., 2014; ter Mors et al., 2013). Both scales yielded good internal consistency (*Cronbach's  $\alpha$*  = 0.88, *N* = 3 and *Cronbach's  $\alpha$*  = 0.80, *N* = 10 respectively), thus the scores of individual items were averaged in a total scale score. The two citizen samples were also asked for their initial *individual technology preferences* in order to compare their initial preference level (7-point Likert scale for each alternative; available in Appendix A). The survey scripts for the citizen and energy expert samples can be found in Appendix A.

### 3.2.4 Comparison between existing model-based and preferred scenarios

All samples of participants were compared for technology-specific supply and the whole electricity supply in Switzerland. Technologies were compared in terms of their yearly electricity supply (TWh/year) and their share in the total supply (%). To explore patterns in the electricity supply system, technology combinations that are commonly found in the scenario literature were calculated (Eker et al., 2017; Riahi et al., 2017; van Sluisveld et al., 2020): (1) the share of domestic renewable technologies, including hydropower, solar PV, wind, biomass, waste incineration (its renewable part), and deep geothermal electricity, and (2) the share of net electricity import and the share of non-renewable electricity technologies, including nuclear and fossil fuel-based generation. The electricity demand between preferred and model-based scenarios was also compared as it relates with the objective of the Swiss Energy Strategy 2050 to reduce demand in 2035 (SFOE, 2017).

In order to compare the mean differences between model-based scenarios and preferred scenarios by the three samples, a methodology derived from van Sluisveld et al. (2020) was used, based on the Wilcoxon rank sum test that is a non-parametric statistical test. Since this study involved four groups in total, the Kruskal-Wallis test was used, a non-parametric statistical test for comparing more than two independent groups. Although the size of the samples could allow

parametric tests such as ANOVA, this was avoided due to the high heterogeneity of the ensemble of the model-based scenarios. Since these scenarios are based on different modeling choices and scenario inputs, statistical averaging of their outputs may lead to implausible or unrealistic results (Densing et al., 2016; Huppmann et al., 2018b; Knutti et al., 2010). As the Kruskal-Wallis test is based on comparing rank sums instead of means between the groups, it is more appropriate for this study.

### 3.3 Results

#### 3.3.1 Participants

In terms of demographics (Table 3.1), both citizen samples were close to being representative of the Swiss population in terms of female *gender* ratio (49.2% for citizens, 50.0% for informed citizens, 50.9% for the Swiss population), *highest education level* (e.g. for tertiary level: 41% for citizens, 43.5% for informed citizens, 41.3% for the Swiss population) and average *age* (43.4 years for citizens, 42.1 years for informed citizens, 41.7 years for the Swiss population) (Eurostat, 2020a; SFSO, 2017). While for citizens the representativeness was the primary requirement of their sampling, for the informed citizens representativeness and diversity in initial technology preferences played an equal role. On the contrary, the energy expert sample deviated from the population: it had a low female *gender* ratio (27.6%) and almost all energy experts had attained tertiary level of education (98.3%). The energy expert sample hence included statistically significantly less females than both citizen samples (Chi-square test,  $\chi^2(2) = 7.45$ ,  $p = 0.025$ ) and was statistically significantly more educated (Kruskal-Wallis test,  $H(2) = 63.52$ ,  $p < 0.001$ ). 67.2% of the energy experts belonged in the *age* group between 25 and 44. Experts were younger than the other samples but not statistically significantly so (39.4% for citizens and 30.2% for informed citizens).

Table 3.1. Comparison of the three samples of participants in terms of demographics, *self-rated interest* in the electricity supply topic and *self-reported Riskmeter evaluation*

|                                |                        | percentage within sample / M (SD) |                                  |                          | statistic            | post hoc |
|--------------------------------|------------------------|-----------------------------------|----------------------------------|--------------------------|----------------------|----------|
|                                |                        | (i) energy experts<br>N = 60      | (ii) informed citizens<br>N = 46 | (iii) citizens<br>N = 61 |                      |          |
| <i>gender</i>                  | male                   | 72.4%                             | 50.0%                            | 50.8%                    | $\chi^2(2) = 7.45^*$ | -        |
|                                | female                 | 27.6%                             | 50.0%                            | 49.2%                    |                      |          |
| <i>highest education level</i> | primary                | 1.7%                              | 8.7%                             | 9.8%                     | $H(2) = 63.52^{***}$ | -        |
|                                | secondary              | 0                                 | 47.9%                            | 49.2%                    |                      |          |
|                                | tertiary               | 98.3%                             | 43.5%                            | 41.0%                    |                      |          |
| <i>age</i>                     | 18 - 24                | 3.4%                              | 20.9%                            | 13.1%                    | $H(2) = 3.55$        | -        |
|                                | 25 - 44                | 67.2%                             | 30.2%                            | 39.4%                    |                      |          |
|                                | 45 - 64                | 25.9%                             | 39.6%                            | 36.1%                    |                      |          |
|                                | 65+                    | 3.4%                              | 9.3%                             | 11.5%                    |                      |          |
|                                | average age (in years) | n/a                               | 42.1 (16.6)                      | 43.4 (14.5)              |                      |          |

Table 3.1. (continued)

|                                                                                                       |              |              |              |                          |                                  |
|-------------------------------------------------------------------------------------------------------|--------------|--------------|--------------|--------------------------|----------------------------------|
| <i>time spent in Riskmeter</i><br>(in minutes)                                                        | 6.5 (5.2)    | n/a          | 3.8 (2.8)    | $t(108) = 3.08^{**}$     | -                                |
|                                                                                                       | ( $n = 58$ ) | ( $n = 45$ ) | ( $N = 61$ ) |                          |                                  |
| <i>self-reported interest</i><br>(average of 3 items,<br>7-point Likert scale)                        | 6.3 (0.9)    | 4.7 (1.2)    | 4.6 (1.4)    | $F(2,161) = 34.87^{***}$ | i-ii***<br>i-iii***              |
|                                                                                                       | ( $n = 55$ ) | ( $n = 45$ ) | ( $N = 61$ ) |                          |                                  |
| <i>self-reported Riskmeter</i><br><i>evaluation</i><br>(average of 10 items,<br>7-point Likert scale) | 3.8 (1.2)    | 5.3 (0.7)    | 4.5 (0.8)    | $F(2,158) = 32.65^{***}$ | i-ii***<br>i-iii***<br>ii-iii*** |

Note:  $*p < .05$ ;  $**p < .01$ ,  $***p < .001$ . All survey questions and results for individual scale items for *self-rated interest* and *self-reported Riskmeter evaluation* are available in Appendix A.

The three samples were also statistically significantly different in terms of *self-reported interest* ( $F(2,161) = 34.87$ ,  $p < 0.001$ ) and *self-reported Riskmeter evaluation* ( $F(2,158) = 32.65$ ,  $p < .001$ ). Post hoc tests showed that energy experts had significantly higher *self-reported interest* than both citizen samples ( $M_{\text{experts}} = 6.3$  vs  $M_{\text{citizens}} = 4.6$  and  $M_{\text{inf\_citizens}} = 4.7$ ,  $p < 0.001$  for both pairwise comparisons), which can be expected based on their background. For the *self-reported Riskmeter evaluation*, all samples were statistically significantly different from each other, with energy experts giving the lowest and informed citizens – the highest evaluation ( $M_{\text{experts}} = 3.8$  vs  $M_{\text{citizens}} = 4.5$  vs  $M_{\text{inf\_citizens}} = 5.3$ ,  $p < 0.001$  for all pairwise comparisons). The low evaluation rate from energy experts may indicate that the information given in the Riskmeter was already known to them. For the difference between the citizen samples, the reason could be that informed citizens were introduced to the Riskmeter in a more gradual way than citizens, after reading factsheets and discussing about individual technologies. Nevertheless, the citizen samples started from more or less the same *individual technology preferences* (full results can be found in Appendix A). There were statistically significant differences for only two out of 13 electricity supply alternatives, namely for small hydropower ( $M_{\text{inf\_citizens}} = 4.7$  vs  $M_{\text{citizens}} = 5.5$ ,  $t(98) = -2.46$ ,  $p = 0.015$ ) and for wind ( $M_{\text{inf\_citizens}} = 4.7$  vs  $M_{\text{citizens}} = 5.4$ ,  $t(75) = -2.04$ ,  $p = 0.015$ ). As shown later in the results, these differences do not affect any of the main findings.

### 3.3.2 General patterns in the development of model-based scenarios

In total, 82 scenarios were reviewed from 19 different studies between 2011 and 2018 (Table 3.2 and Table 3.3). Each study had 1 – 16 scenarios, with most of them including 2 – 6 scenarios. The studies were developed by 12 different organizations, including public administration (e.g., Swiss Federal Office of Energy - SFOE), research institutes (e.g., Paul Scherrer Institute - PSI), universities (e.g., ETH Zurich), and non-governmental organizations (e.g., Cleantech). PSI had the highest contribution, authoring eight studies and more than half of the reviewed scenarios (48 out of 82).

### 3. Alignment between model-based and preferred electricity scenarios for Switzerland

Table 3.2. Scenario development details for all studies included in the review (1/2)

| Pub. year | Study name                | Study ref.                     | Number of scenarios reviewed | Modeling approach                       | Scenario category       |
|-----------|---------------------------|--------------------------------|------------------------------|-----------------------------------------|-------------------------|
| 2018      | PSI - Climate mitigation  | Panos and Kannan (2018)        | 2                            | optimization                            | normative               |
| 2018      | LEURE                     | Babonneau et al. (2018)        | 4                            | optimization                            | normative               |
| 2017      | VSE - Energiewelten       | VSE (2017)                     | 4                            | no model / based on results of VSE-Wege | explorative             |
| 2017      | TD                        | Berntsen and Trutnevite (2017) | 3                            | simulation                              | explorative             |
| 2017      | FEN & PSI                 | Fuchs et al. (2017)            | 16                           | optimization                            | explorative/normative   |
| 2017      | CP - Renewable supply     | Díaz et al. (2017)             | 5                            | simulation                              | explorative / normative |
| 2016      | PSI - Biomass potential   | Panos and Kannan (2016)        | 4                            | optimization                            | explorative/normative   |
| 2016      | PSI - EU nuclear phaseout | Pattupara and Kannan (2016)    | 3                            | optimization                            | explorative/normative   |
| 2016      | UNIL - HEC                | Osorio and van Ackere (2016)   | 2                            | simulation                              | explorative             |
| 2015      | Econability & PSI & LEURE | Maire et al. (2015)            | 6                            | optimization                            | explorative/normative   |
| 2015      | CP - Nuclear phaseout     | Redondo and Van Vliet (2015)   | 2                            | simulation                              | explorative             |
| 2014      | PSI - Energy transition   | Kannan and Turton (2014)       | 6                            | optimization                            | explorative/normative   |
| 2013      | Cleantech                 | Bolliger and Zeyer (2012)      | 1                            | simulation                              | normative               |
| 2013      | Greenpeace                | Teske and Heiligtag (2013)     | 1                            | simulation                              | normative               |
| 2013      | PSI - Sys                 | Weidmann (2013)                | 2                            | optimization                            | explorative/normative   |
| 2012      | VSE - Wege                | VSE (2012a)                    | 3                            | optimization                            | explorative/normative   |
| 2012      | PSI - Elc                 | Kannan and Turton (2012)       | 9                            | optimization                            | normative               |
| 2012      | SFOE                      | Prognos (2012)                 | 8                            | simulation                              | normative               |
| 2011      | ESC                       | Andersson et al. (2011)        | 1                            | simulation                              | normative               |

Note: More details about the acronyms used for each study are given in Table A1 in Appendix A.

Table 3.3. Scenario development details for all studies included in the review (2/2)

| Pub. year | Study name                | Key factors for scenario choice |                                                                                                                        |                                                      |
|-----------|---------------------------|---------------------------------|------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------|
|           |                           | Demand levels                   | Supply factors                                                                                                         | Targets for 2050 (normative scenarios)               |
| 2018      | PSI - Climate mitigation  | • medium/low                    |                                                                                                                        | • CO <sub>2</sub> : -42% / -85%                      |
| 2018      | LEURE                     | • high/low                      | • gas with CCS: with/without                                                                                           | • CO <sub>2</sub> : 1 tCO <sub>2</sub> /person       |
| 2017      | VSE - Energiewelten       | • high/medium /low              | • domestic production/reliance on EU imports                                                                           |                                                      |
| 2017      | TD                        |                                 | • decentralized production/centralized production                                                                      |                                                      |
| 2017      | FEN & PSI                 | • high/medium                   | • imports: with/without<br>• nuclear: with/without<br>• grid: no expansion/double most congested line                  | • CO <sub>2</sub> : - 70%                            |
| 2017      | CP - Renewable supply     |                                 | • large gas plants: with/without<br>• renewable supply incentives: continue trend/increase                             | • renewable supply: 100% (domestic and imports)      |
| 2016      | PSI - Biomass potential   | • high/medium /low              | • large gas plants: with/without<br>• renewable supply incentives: continue trends/increase                            | • CO <sub>2</sub> : - 70%                            |
| 2016      | PSI - EU nuclear phaseout |                                 | • nuclear: with/without                                                                                                | • CO <sub>2</sub> : - 95%                            |
| 2016      | UNIL - HEC                | • high/medium /low              | • nuclear: with/without                                                                                                | • renewable supply: 20%                              |
| 2015      | Econability & PSI & LEURE |                                 | • imports: with/without<br>• gas: with/without<br>• CO <sub>2</sub> tax: normal/increased                              | • CO <sub>2</sub> : - 95%                            |
| 2015      | CP - Nuclear phaseout     |                                 | • imports: with/without<br>• renewable supply incentives: continue trend/increase                                      |                                                      |
| 2014      | PSI - Energy transition   | • high/low                      | • gas: with/without                                                                                                    | • CO <sub>2</sub> : - 60%                            |
| 2013      | Cleantech                 |                                 |                                                                                                                        | • fossil fuel imports: - 55% (relative to 2010)      |
| 2013      | Greenpeace                |                                 |                                                                                                                        | • renewable supply: 100% (domestic and imports)      |
| 2013      | PSI - Sys                 |                                 |                                                                                                                        | • CO <sub>2</sub> : - 95%                            |
| 2012      | VSE - Wege                |                                 |                                                                                                                        | • renewable supply: 90%                              |
| 2012      | PSI - Elc                 | • high/medium /low              | • large gas plants: with/without<br>• imports: with/without<br>• nuclear: with/without                                 | • CO <sub>2</sub> : - 50%                            |
| 2012      | SFOE                      | • high/medium /low              | • large gas plants: with/without<br>• imports: with/without<br>• renewable supply incentives: continue trends/increase | • renewable supply: 100% (domestic and imports)      |
| 2011      | ESC                       |                                 |                                                                                                                        | • CO <sub>2</sub> : 1 – 1.5 tCO <sub>2</sub> /person |
|           |                           |                                 |                                                                                                                        | • CO <sub>2</sub> : 1 – 1.5 tCO <sub>2</sub> /person |
|           |                           |                                 |                                                                                                                        | • CO <sub>2</sub> : 1.6 tCO <sub>2</sub> /person     |

Note: More details about the acronyms used for each study are given in Table A1 in Appendix A.

All reviewed studies produced scenarios for the transition of the Swiss electricity supply system but with different objectives. In most studies between 2011 and 2015, the goal was to depict different perspectives on the future of the Swiss electricity supply in response to the policy discussions, such as the decision to gradually phase out nuclear power and to fill the remaining gap in 2035. The main alternatives considered were large gas power plants and gas-fired Combined Heat and Power plants (CHP), new renewable technologies (without existing hydropower), and increased electricity imports. Later studies focused on more specialized subjects, such as how to deal with the large-scale integration of renewable technologies in the Swiss grid (FEN & PSI) or how to use biomass more effectively (PSI-Biomass potential). Most of the studies also developed scenarios addressing the long-term climate targets of Switzerland for 2050. An exception from the above patterns was the study TD, which developed scenarios that were maximally different to scenarios from studies between 2011 and 2013 in order to increase their diversity. Detailed objectives for all studies are given in Table A.1 in Appendix A.

Most studies did not give details about the methods used for generating the scenarios and about any stakeholder interaction in scenario development, indicating that many modeling teams could have developed the scenarios solely. In most cases, the scenario selection seemed to be subjective for each modeling team and closely related to the guiding questions and recurring themes from policy discussions, such as nuclear phase-out, allowing or not allowing gas power plants, climate targets, etc. Only few studies used structured scenario generation methods such as the scenario-axes/intuitive logics technique (VSE-Energiewelten, PSI-Biomass potential) or maximally diverse scenarios (TD).

In 10 out of 19 studies, a cost-optimization model was used for modeling the scenarios (Table 3.2), which was usually a variation of the Swiss TIMES Energy system Model (STEM) from PSI (8 out of 19 studies). All the other scenarios were modeled by different simulation models. The only study that did not use a model to quantify the scenarios was the VSE-Energiewelten study, which instead reused modeled results from the VSE-Wege study.

Based on the scenario categorization shown in Table 3.2, 14 out of 19 studies included at least one normative scenario, which in most cases involved a CO<sub>2</sub> reduction target for Switzerland in 2050. This target varied between 45 and 95% of CO<sub>2</sub> reductions in relation to 1990 levels, although most studies used the Nationally Determined Contribution target for Switzerland aiming for 70 – 85% CO<sub>2</sub> reductions by 2050 in relation to 1990 levels (or equivalently 1 – 1.5tCO<sub>2</sub>/person). Few studies also used targets on the electricity supply technologies in 2050, such as the target of Cleantech for a 100% renewable electricity supply.

Apart from the targets for normative scenarios, scenarios were mostly based on supply assumptions related to technology deployment (Table 3.2). The majority of these assumptions addressed the uncertainty related to policy decisions about the deployment of large gas power plants or gas-fired CHP, about higher reliance on imports, and about a possible delay of the phase-out of nuclear power. Relatively fewer studies (4 out of 19) explored higher incentives on renewable technologies and only one explored different levels of a CO<sub>2</sub> tax. The VSE-



Energiewelten study is unique in exploring scenarios along two governance-related scenario factors: (1) domestic supply versus relying on EU network, and (2) decentralized versus centralized supply. Many scenarios also explored variations in the demand level, but mostly as a secondary factor that accompanied supply factors or normative targets.

### 3.3.3 Assessment of electricity supply from model-based scenarios

For the majority of reviewed scenarios, electricity supply in 2035 was based on hydropower, fossil fuel-based generation, net imports, and, to a lesser extent, on new renewable technologies i.e., solar PV, wind, geothermal, and biomass (Figure 3.2 in page 32). As shown in Figure 3.3 (page 33), the median supply from hydropower was 55% (range: 39 – 68%), from fossil fuel-based generation, net imports, nuclear power or a combination of them—28% (–4 – 54%), and from new renewable technologies—17% (0 – 49%). For electricity demand, the median was 65 TWh/year (54 – 84 TWh/year). Three quarters of model-based scenarios had a demand in 2035 lower than the business-as-usual of 70 TWh/year (Prognos, 2012), indicating a trend that assumes increased electricity savings and end-use efficiency.

Fossil fuel-based generation was the second mostly used technology after hydropower and its supply ranged between 0 and 39 TWh/year (0 – 51% of total supply) with a median of 12 TWh/year (17% of total supply). This is a very large increase from the current supply share of 2% (SFOE, 2018) and illustrates how most scenarios suggested fossil fuel-based generation as a substitute for nuclear in 2035. In the reviewed scenarios, fossil fuel-based generation mainly consists of large natural gas power plants (Combined Cycle Gas Turbine plants - CCGT) and, to a lesser extent, of gas-fired CHP plants. The role of net imports is also more pronounced in scenarios for 2035, unlike the Swiss electricity mix in recent years (2008 – 2018) where net annual imports were low or even negative (i.e. net exports) (SFOE, 2018). A quarter of the scenarios included more than 4 TWh/year (7% of the total share) of net imports and some scenarios reached an imported supply close to 30 TWh/year (42% of the total share). Domestic solar PV had the highest supply share amongst the new renewable technologies in the scenarios, ranging from 0 to 18.2 TWh/year (0 – 24% of total supply) and with a median of 4.2 TWh/year (7% of total supply). This suggests that although there were a few scenarios that used a supply level close to the technical potential of solar PV in Switzerland [19 TWh/year (Bauer et al., 2017)], most of the scenarios used less than a quarter of this potential. All other renewable technologies played a more limited role in the scenarios. Biomass (including waste incineration) provided a much smaller range of supply than solar PV, although their median values were not very dissimilar (3.1 TWh/year). Wind and deep geothermal provided only few to none TWh per year in most of the studies.

### 3. Alignment between model-based and preferred electricity scenarios for Switzerland



Figure 3.2. Swiss electricity supply scenarios for 2035 from all 19 reviewed studies.

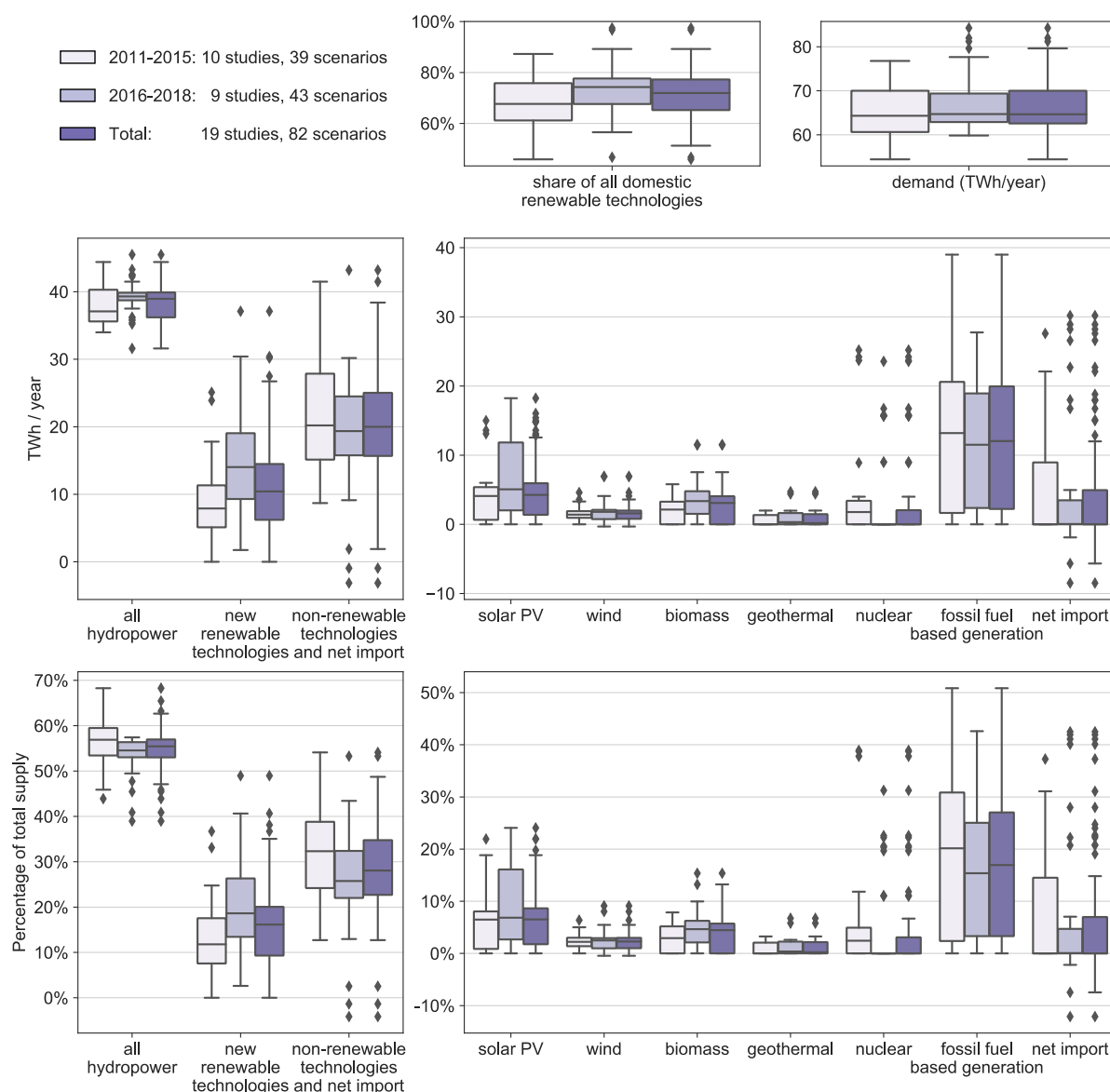


Figure 3.3. Distributions and trends per study publication period (2011 – 2015 and 2016 – 2018) for electricity demand and for different electricity supply sources in 2035. The boxplots depict median, 25th and 75th percentiles, and 1.5 interquartile range. New renewable technologies include solar PV, wind, biomass and geothermal. Non-renewable technologies include nuclear power and fossil fuel-based generation.

The supply levels from some technologies differed between the recent studies from 2016 – 2018 and earlier studies from 2011 – 2015 (Figure 3.3). Recent studies had a higher maximum and median supply from new renewable technologies in comparison with earlier studies (maximum: 37.1 TWh/year versus 25.1 TWh/year, median: 14 TWh/year versus 7.9 TWh/year, respectively). This indicates a trend of using more renewable technologies in recent scenarios and is exemplified in three recent scenarios, where new renewable technologies supplied 30 TWh/year or more. Recent studies had also fewer scenarios with very high supply from fossil fuel-based generation, net import, and nuclear power in comparison with earlier studies (75<sup>th</sup> percentile: 24.5 TWh/year versus 27.9 TWh/year, respectively).

#### 3.3.4 Comparison between model-based and preferred scenarios

##### 3.3.4.1 Comparison of electricity supply scenarios as a whole

As shown in Figure 3.4 (page 35), most energy experts and informed citizens preferred scenarios for 2035 that were close to an almost 100% domestic renewable electricity supply, in contrast to most model-based scenarios and citizens. In model-based scenarios, the median share from all renewable technologies was 72% (range: 46 – 97%), while for energy experts and informed citizens it was 97% (63 – 100% and 61 – 100% respectively) and for citizens 84% (56 – 100%). Kruskal-Wallis test confirmed that there is a statistically significant difference in the share of all renewable technologies between samples ( $H(3) = 79.94, p < 0.001$ ). A follow-up analysis revealed that the share of renewable technologies was significantly lower in model-based scenarios than in the other three samples and significantly lower in the citizen sample than in the informed citizen and energy expert samples. The exactly opposite pattern was found for the combined share from the rest of the technologies, including nuclear, fossil-fuel based generation, and net imports ( $H(3) = 79.94, p < 0.001$ ), where the model-based scenarios had the highest share.

All three samples opted for increased rates of electricity savings and efficiency measures, with most scenarios using an electricity demand for 2035 below the business-as-usual estimations of 70 TWh/year (Prognos, 2012). The median demand was 64.6 TWh/year for the model-based scenarios, 65.8 TWh/year for the energy experts, 66 TWh/year for the informed citizens, and 67.8 TWh/year for the citizens. Model-based scenarios covered a wider range of electricity demand (54.4 – 84.3 TWh/year), while all preferred scenarios were limited to 63.2 – 70 TWh/year. This was due to the design of the Riskmeter that limited participants from choosing more than 6.8 TWh/year of electricity savings. A statistically significant difference was found for electricity demand between the samples ( $H(3) = 16.56, p = 0.001$ ). A follow-up analysis showed that the citizens' preferred demand was statistically significantly higher than the other samples, indicating that the citizens used significantly less electricity savings and efficiency measures than model-based scenarios and the other two participant samples.

##### 3.3.4.2 Technology-by-technology comparison

As in the case of the share of renewable technologies, most preferred scenarios included much more solar PV than most model-based scenarios (Figure 3.4). In model-based scenarios, the median supply from solar PV was only 4.3 TWh/year (range: 0 – 18.2 TWh/year). For energy experts, informed citizens, and citizens, it was 15 TWh/year, 12.7 TWh/year, and 11.6 TWh/year respectively, with the same ranges of 1.1 – 18 TWh/year in all cases. Kruskal-Wallis test and a follow-up analysis confirmed that solar PV supply was significantly lower in model-based scenarios than in all participant samples ( $H(3) = 62.62, p < 0.001$ ).

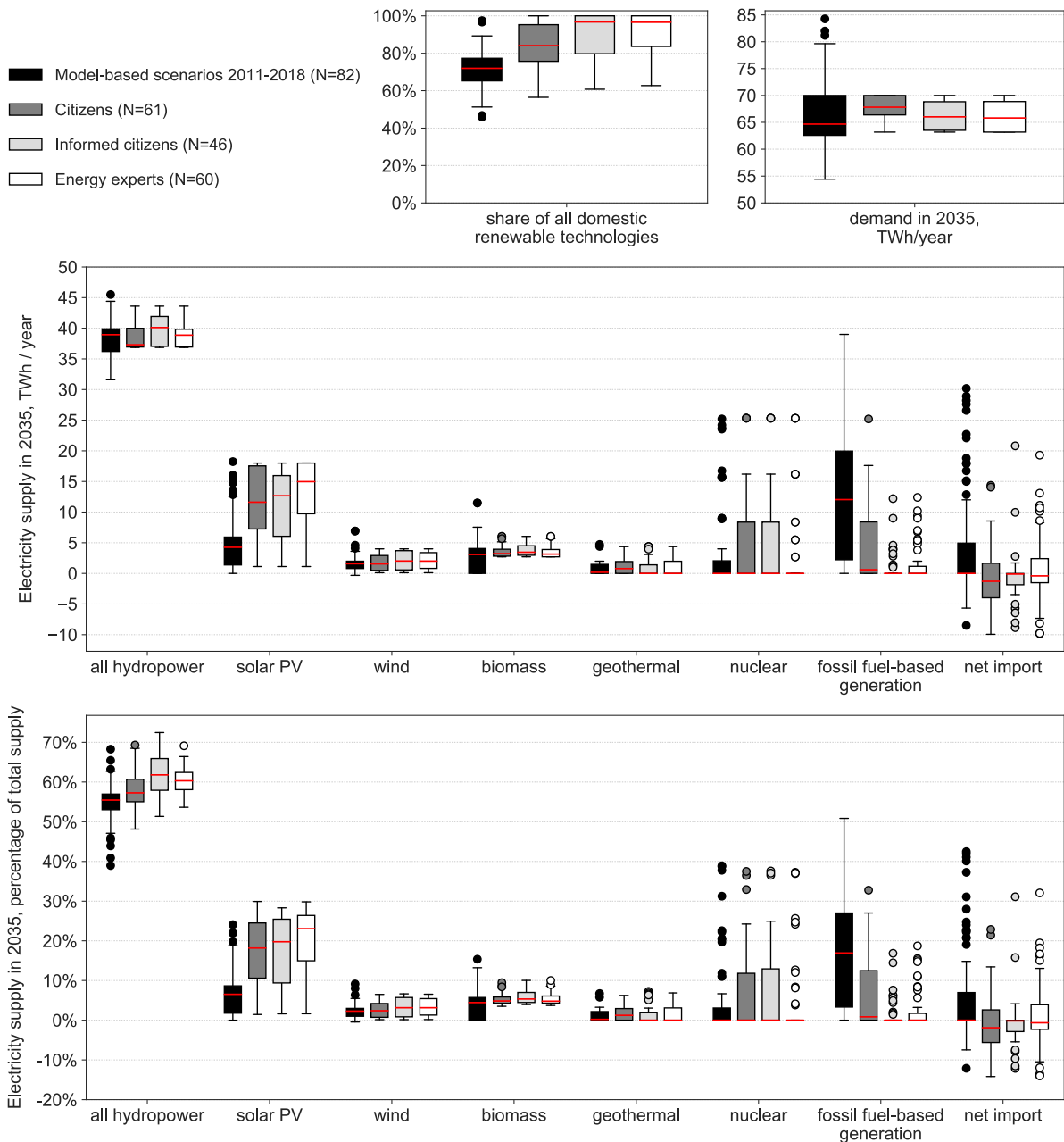


Figure 3.4. Comparison of annual electricity supply for 2035 between model-based and preferred scenarios. The boxplots depict median, 25th and 75th quartiles, and 1.5 interquartile range.

In contrast to solar PV, the median supply from fossil fuel-based generation was almost zero for all three samples (range: 0 – 12.4 TWh/year for energy experts and informed citizens and 0 – 25.20 TWh/year for citizens), while it was 12.1 TWh/year (0 – 39 TWh/year) for model-based scenarios. Kruskal-Wallis showed that differences between samples were statistically significant ( $H(3) = 86.56, p < 0.001$ ): fossil fuel-based generation was statistically significantly higher in model-based scenarios than in all participant samples and statistically significantly higher in the citizen sample than the informed citizen and energy expert sample.

The median of net electricity import was close to zero for all samples: for model-based scenarios it was zero (range: -8.5 – 30.2 TWh/year); for energy experts it was -0.4 TWh/year (-

9.8 – 19.3 TWh/year), for informed citizens it was -0.1 TWh/year (-8.9 – 20.8 TWh/year), and for citizens it was -1.3 TWh/year (-9.9 – 14.4 TWh/year). The negative values of import mean export. Since almost a third of model-based scenarios included some net import, a statistically significant difference between the groups was detected ( $H(3) = 47.49, p < 0.001$ ), as the model-based scenarios included statistically significantly more import than the three participant samples. A similar statistically significant difference was found even when net export was excluded from all samples ( $H(3) = 11.39, p = 0.010$ ), albeit the difference between the model-based scenarios and the three participant samples is then smaller.

For other alternatives, the differences between model-based and preferred scenarios were not as large as for the previous technologies (Figure 3.4). Still, a statistically significant difference was found for biomass ( $H(3) = 11.25, p = 0.010$ ), where the follow-up analysis showed that biomass supply was statistically significantly higher in the informed citizen sample (median: 3.5 TWh/year, range: 2.7 – 6 TWh/year) than in the model-based scenarios (median: 3.1 TWh/year, range: 0 – 11.5 TWh/year). Similarly, another statistically significant difference was found for wind ( $H(3) = 8.17, p = 0.043$ ), but this time with energy experts including statistically significantly more wind power (median: 2 TWh/year, range: 0.1 – 4.1 TWh/year) than the model-based scenarios (median: 1.6 TWh/year, range: 0 – 6.8 TWh/year). Both cases reflect the increased preference of energy experts and informed citizens for domestic renewable electricity sources.

## 3.4 Discussion

The first and main finding is that model-based and preferred scenarios for the Swiss electricity system in 2035 had important differences: most model-based scenarios relied on fossil-fuel based generation and electricity import, while most preferred scenarios suggested a mix of domestic renewable electricity supply. In fact, the majority of preferred scenarios from energy experts and informed citizens supported an almost 100% domestic renewable electricity supply for Switzerland in 2035, while only three out of 82 model-based scenarios explored the share of domestic renewable electricity above 90%. Technology-wise, model-based scenarios included statistically significantly more fossil fuel-based generation and imports and statistically significantly less solar PV than preferred scenarios. For the preferred scenarios, the increased support for renewable technologies and decreased support for fossil fuel-based generation and net import are consistent with the previous public opinion studies in Switzerland (Cousse and Wüstenhagen, 2018a; Jobin and Siegrist, 2018; Trutnevyte et al., 2011; Visschers and Siegrist, 2014). Results thus indicate that, while model-based scenarios were diverse enough to include perspectives found in the preferred scenarios, most of them focused on electricity supply alternatives that were not preferred by the samples. Similar findings were found in past studies. Allen and Chatterton (2013) found that the support for renewable technologies from a sample of UK public was higher than the levels assumed by three model-based energy scenarios from the

UK Government for 2050. Van Sluisveld et al (2018) found that a sample of experts ( $N = 39$ ) projected more renewable technologies and especially solar PV in contrast to seven model-based scenarios, each from a different model and organization. In this study, the thought-provoking finding is that preferred scenarios from the three samples misaligned with a multi-organization, multi-model ensemble of 82 scenarios for Switzerland from 12 organizations, revealing a wider pattern in the scenario development community of the country.

The difference between preferred and model-based scenarios could be attributed to the scenario development methods used in the model-based studies. First, there was no explicit mention of stakeholder or public participation methods for informing the scenario development in the reviewed studies. If such methods were used, more scenarios would have been modeled with high supply from domestic renewable technologies, given the popularity of these technologies in Switzerland (Cousse and Wüstenhagen, 2018a; Jobin and Siegrist, 2018; Visschers and Siegrist, 2014). Second, modeling choices and especially cost-optimization models in the majority of the reviewed studies (10 out of 19) and scenarios (55 out of 82) are known to underrepresent new renewable technologies like solar PV, wind, biomass, geothermal because these technologies are mostly modeled as costlier supply alternatives and with constrained technology build rates (Berntsen and Trutnevyte, 2017; Densing et al., 2016; Trutnevyte, 2016). In contrast, the three scenarios with the highest shares of domestic renewable electricity (above 90%) were developed by studies that did not use cost-optimization models or focused explicitly on scenario diversity beyond cost optimization: the TD study used Modeling to Generate Alternatives to develop technically-feasible scenarios that further diversified existing Swiss scenarios (Berntsen and Trutnevyte, 2017), while the VSE-Energiewelten study combined existing model-based results to create four extremely diverse worlds (VSE, 2017). Some may argue that the informed citizens received too little information on the economics of electricity sector transition. Decision science literature requires informing citizens in a balanced way about all types of aspects that citizens are most interested in and concerned about, but economic performance is consistently shown not to be the priority for the Swiss citizens (Dubois et al., 2019; Tabi and Wüstenhagen, 2017; Volken et al., 2017, 2018). Third, in terms of uncertainties explored by the model-based scenarios, only four studies explored cases of increased renewable supply incentives, while most studies focused on uncertainties related to the deployment of large-scale fossil fuel-based plants, increased net imports, or a phase-out delay of nuclear plants. Fourth, even if many model-based scenarios explored policy targets for CO<sub>2</sub> reduction and renewable supply, most of these targets had a horizon of 2050, allowing fossil fuel-based generation and net imports to be used as a bridging technology after the nuclear phase-out in 2035. Overall, in most of the reviewed studies there was no explicit focus to make scenarios with very high shares of renewable electricity as early as in 2035 and, in combination with the modeling choices, this may have limited the share of domestic renewable technologies. Similar limiting effects of scenario and modeling choices on the deployment of renewable technologies and the diversity of the resulting scenarios have been also accentuated in previous studies for

the UK (Trutnevyte et al., 2016b), the USA (Gilbert and Sovacool, 2016; Mai et al., 2018) and globally (Pietzcker et al., 2017; van Sluisveld et al., 2018).

The second finding is that the preferred scenarios differed between the three samples: in comparison with informed citizens and energy experts, the citizens preferred scenarios with statistically significantly higher supply from fossil fuel-based generation, lower shares of domestic renewable electricity, and less efficiency measures. This indicates that the knowledge level and experience of the participants with electricity supply topics have influenced their preferred scenarios and that this factor should be taken into account in comparisons with model-based scenarios. For the citizen sample, the differences may be explained by potential knowledge gaps on electricity supply technologies and their impacts. For example, the citizen sample might not have realized that large gas power plants (the only fossil fuel-based alternative offered in the Riskmeter) have significant CO<sub>2</sub> emissions and that gas needs to be imported to Switzerland (Jobin and Siegrist, 2018; Volken et al., 2018). For the informed citizens, this was ensured by means of the informational materials and discussions that gave a balanced view of environmental, health, economic, and supply security impacts of the technologies (Volken et al., 2018). That is why informed citizens may have chosen significantly more domestic renewable technologies than uninformed citizens. On the other hand, choosing such a high share of renewable electricity as early as in 2035 might imply that informed citizens did not realize the scale and speed of renewable technology deployment required for this. However, this would not be the case for the energy expert sample, as it is assumed that experts would be more aware of these factors and have incorporated this knowledge in their preferences. For example, energy experts had the highest median solar PV supply from all samples at a level that is close to the technical potential of 19 TWh/year for 2035 (Bauer et al., 2017). This indicates that the energy expert sample found such technology requirements for 2035 at least possible and, in their view, also desirable for Switzerland. The agreement of preferred scenarios between energy experts and informed citizens may thus support the argument that informed public can be used to elicit representative and good-quality value judgements to compare existing scenarios and inform future scenario development (Volken et al., 2018).

This study has a number of limitations. First, while the elicitation of preferred scenarios occurred during 2017 – 2018, model-based scenarios were collected from the wider period of 2011 – 2018, which included many debates, policy decisions, and even a public referendum for the Energy Strategy 2050. Preferred scenarios might have been different if the elicitation occurred during this whole period, but it is assumed that the high support for renewable technologies and decreased support for fossil fuel-based generation would still be apparent (Visschers and Siegrist, 2014). Still, future studies could compare model-based scenarios in tandem with public opinion results from different years, in order to capture the dynamic effects of such energy policy debates. Second, preferred scenarios could have been influenced by simplifications and design choices in the Riskmeter and especially the focus on covering only the yearly electricity demand without considering the temporal dispatch as most model-based



scenarios do. For example, large shares of variable renewable electricity technologies would require storage (Rüdisüli et al., 2019) and large daily imports and exports with neighboring countries would lead to potential tradeoffs with the cost of electricity and the supply reliability. This was not visible in the Riskmeter (only in the factsheets for the informed citizens). Although increased scenario information may not always improve comprehension (Xexakis and Trutnevyte, 2019a), future studies could develop preference elicitation tools that are closer to the models used for electricity scenario modeling. Third, since energy experts volunteered to fill the Riskmeter, the energy expert sample may not have been as diverse as it would be using a formal expert elicitation method (Anadón et al., 2017; Morgan, 2014). But given how central the debates for the Energy Strategy 2050 are to the Swiss energy community, it is assumed that the energy expert sample was more or less familiar with Strategy's targets and policy alternatives.

### 3.5 Conclusions

Model-based scenarios have become the key method to explore uncertainties and decision alternatives for strategic decision about the electricity supply transition (Berntsen and Trutnevyte, 2017; Lempert, 2013; Maier et al., 2016; O'Neill et al., 2017; Trutnevyte et al., 2016a, 2016b). While retrospective energy scenario studies showed that multi-organization, multi-model scenario ensembles may increase the diversity of considered uncertainties (Trutnevyte et al., 2016b), this study shows that such scenario ensembles may not align necessarily with the perspectives and priorities of various stakeholders in the transition, including the wider public. This study compared a multi-organization, multi-model ensemble of 82 Swiss electricity supply scenarios for 2035, collected from 19 studies between 2011 and 2018 (Andersson et al., 2011; Babonneau et al., 2018; Berntsen and Trutnevyte, 2017; Bolliger and Zeyer, 2012; Díaz et al., 2017; Fuchs et al., 2017; Kannan and Turton, 2012, 2014; Maire et al., 2015; Osorio and van Ackere, 2016; Panos and Kannan, 2016, 2018; Pattupara and Kannan, 2016; Prognos, 2012; Redondo and Van Vliet, 2015; Teske and Heiligttag, 2013; VSE, 2012a, 2017; Weidmann, 2013), with preferred scenarios from citizens, informed citizens, and energy experts in Switzerland. To the authors' knowledge, this is the first time that a large scenario ensemble is compared with multiple stakeholder samples. Results showed that most informed citizens and energy experts preferred an almost 100% domestic renewable electricity supply in 2035. On the contrary, most model-based scenarios relied significantly more on fossil fuel-based generation and net electricity imports. Reasons for this misalignment may be the lack of broad stakeholder participation in the generation of model-based scenarios, the model choices such as cost-optimization models that underestimate renewable electricity, and the limited diversity of model-based scenarios due to the focus on specific uncertainties and targets. Additionally, the citizen sample preferred significantly more fossil fuel-based generation than the other more informed participant samples, indicating possible knowledge gaps of the citizens in technology characteristics and impacts. Conversely, informed citizens had similar preferred scenarios to the energy experts, underlining

thus the importance of the knowledge level of participants in the elicitation of preferred scenarios and potentially for informing future scenario development.

The results have implications both for the scenario development practice in general and for the energy transition in Switzerland. For researchers working with meta-analyses of scenario ensembles, e.g. (Trutnevyte et al., 2016b; van Vuuren et al., 2012), this study offers a word of caution that even a wide multi-organization, multi-model scenario ensemble might be focusing too much on unpopular alternatives. Examples can be already found in previous IPCC reports where most scenarios relied on large-scale deployment of Carbon Dioxide Removal measures (Rogelj et al., 2018b), although it is still uncertain how this scale can be established (Geden et al., 2019) and how to overcome local acceptance issues (Budinis et al., 2018; L'Orange Seigo et al., 2014). Increasing the diversity of uncertainties and perspectives should begin with the scenario developers, embracing structured scenario methods (Guivarch et al., 2017), modeling public preferences, e.g. for more renewable electricity (Marchenko, 2007), or by explicitly including diverse perspectives through stakeholder or public engagement (Eker et al., 2017; Schmid and Knopf, 2012). However, as shown by the differences between the three samples, the knowledge level of stakeholders is important and scenario developers may need to provide balanced information on the topic before eliciting preferred scenarios from non-experts.

In terms of implications for the electricity supply transition in Switzerland, the results indicate that a large-scale deployment of renewable electricity before 2035 can be popular for both the wider public and energy experts and thus should be assessed by more model-based scenarios in the future. Large-scale deployment of renewable technologies clearly comes with challenging requirements in terms of storage and electricity trade. While these issues have been partly examined in previous model-based studies already (Fuchs et al., 2017; Pattupara and Kannan, 2016), there could be further evaluations for a fast technology deployment as envisioned by the participants. In that way, Switzerland could avoid building new fossil fuel-based generation power plants that are both unpopular among its citizens and damaging for the global efforts of reducing global warming below 1.5°C (Tong et al., 2019). Future studies could evaluate the alignment of stakeholder and public preferences with model-based scenarios for other countries and for different kinds of scenarios ensembles, such as the global emissions mitigation. Future research should also continue on methods to integrate perspectives from stakeholders and the public in the scenario development in order to ensure that the examined scenarios are socially robust.

# **Chapter 4 Consensus on future EU electricity supply among citizens of France, Germany, and Poland**

This chapter is based on Xexakis & Trutnevyte (2021a).

## **4.1 Introduction**

As part of the European Union's (EU) effort to reach net-zero greenhouse gas emissions by 2050 (European Commission, 2018b), the electricity supply of its Member States must decarbonize and reach 58% of renewable generation in 2030 (Capros et al., 2019) from 34.1% in 2019 (Eurostat, 2020b). Changes in infrastructure are needed throughout the EU electricity system, requiring Member States to coordinate their long-term strategies (European Commission, 2021a). Examples include large-scale deployment of solar PV in Southern Europe and wind turbines in Northern Europe (Schlachtberger et al., 2018, 2017), phasing out coal power plants in Germany and Poland (Kemmler et al., 2020; Ministry of State Assets, 2020), and reinforcing the electricity grid throughout the whole continent (ENTSO-E, 2021; European Commission, 2018b). Additionally, several countries aim to reduce or phase out their nuclear generation (BMW, 2020a; MTES, 2020a). These changes will lead to environmental, social, and economic impacts (Collins et al., 2018b; Jacobson et al., 2019; Markard, 2018; Ortega et al., 2020) that will be unevenly distributed across the EU regions (Sasse and Trutnevyte, 2020). Facing such impacts, public support will be important for successful implementation of the transition (Anderson et al., 2017; Demski et al., 2015; Drews and van den Bergh, 2016; Lund, 2007; Renn, 2015). Citizens can vote for the political parties that implement such transitions (Anderson et al., 2017), they can block the deployment of new power plants (Dermont et al., 2017; Stadelmann-Steffen, 2011; Wüstenhagen et al., 2007), and they can participate in electricity generation as prosumers (GfK Belgium Consortium, 2017; Szulecki, 2018). Public opinion is also crucial for the EU in order to gather support across its Member States for the Energy Union (Tosun and Mišić, 2020), envisioned to increase decarbonization and security of supply through cooperation and solidarity among Member States (European Commission, 2020b; Szulecki et al., 2016). Large divergences of opinions among EU citizens may delay or block the deployment of the required infrastructures, leading to a fragmented implementation of the transition (Battaglini et al., 2012;

Stadelmann-Steffen, 2011; Tosun and Mišić, 2020). The significant role of consensus among EU citizens has been also recognized in the European Green Deal and the recovery plan for the COVID-19 pandemic (European Commission, 2020a).

Representative cross-national surveys in the EU show a growing consensus among EU citizens on positive views on renewable sources, such as solar PV and wind power, and negative views on nuclear and coal power (European Commission, 2019a; NSD, 2020). However, there are still some noticeable differences among Member States. Polish citizens have a relatively higher preference for coal as compared to citizens of other countries (NSD, 2020). While most Western Europeans agree that the highest priority of EU energy policy should be to address climate change, many Southern and Eastern Europeans emphasize affordability instead (European Commission, 2019a). Several studies have shown that national context of a country, such as its current energy mix and policy, can play an important role in the attitudes of its citizens (Demski et al., 2018; Knox-Hayes et al., 2013; Marquart-Pyatt et al., 2019; Stadelmann-Steffen and Eder, 2020; Tosun and Mišić, 2020). For example, Demski et al. (2018) showed that wider energy, social, and economic context was a key determinant of energy security concerns in Europe. Stadelmann-Steffen and Eder (2020) found that existing national energy policy affected policy preferences of EU citizens with strong climate change attitudes and political trust. Marquart-Pyatt et al. (2019) reported differences among former socialist countries and the rest in terms of green energy policy preferences and energy-efficient behavior intentions. However, no study has yet examined whether the national context affects the consensus among EU citizens on key aspects of the ongoing electricity supply transition. While there may be overall consensus among EU citizens on some specific technologies, it is unknown whether there is consensus on the realistic combinations of technologies that will be needed to cover electricity demand in the future in each Member State and the EU as a whole.

Apart from the national context, personal characteristics such as sociodemographic factors can affect consensus among citizens on the transition: literature on public attitudes towards energy and climate policies underline the role of gender, age, education, political orientation, values and norms, knowledge of energy topics, and trust in the government (V. Bertsch et al., 2016; Bertsch et al., 2017; Boudet, 2019; Drews and van den Bergh, 2016; Knox-Hayes et al., 2013; Stadelmann-Steffen and Eder, 2020). Bertch et al. (2016) used a nationally representative survey in Germany and showed that less educated and older respondents tended to reject renewable technologies more often compared to the rest. Tosun and Mišić (2020) analyzed Eurobarometer data on preferences for the Energy Union and reported overall support among Member States, but different priorities depending on the country and political orientation: left-leaning Western Europeans prioritized renewable energy and right-leaning Central-Eastern Europeans prioritized energy security. Batel and Devine-Wright (2018) reported that citizens with stronger European attachment were more likely to support a pan-European grid. The opposite holds for citizens with stronger national attachment (Devine-Wright and Batel, 2017). While existing studies show personal characteristics that can affect preferences on energy policy

topics, it is unclear whether these effects also hold for realistic future scenarios of EU electricity supply transition. Knowing whether there are groups among the EU citizens with significantly different preferences for the transition could inform strategies for engaging with these groups and working towards consensus.

While knowledge on existing consensus and divergence among EU citizens can inform campaigns for public engagement, it is also important to integrate this knowledge into the design of the transition itself (Elsawah et al., 2020; Trutnevyte et al., 2019a). Energy system modeling is a key method for informing relevant policy by exploring various pathways and uncertainties towards transition targets through scenarios (Berntsen and Trutnevyte, 2017; O'Neill et al., 2017; Trutnevyte et al., 2016a). Integrating evidence on citizen preferences in modeling would make the results more realistic from the perspective of socio-political feasibility and hence more relevant for implementation (Cherp et al., 2018; Trutnevyte et al., 2019a; Xexakis et al., 2020). Earlier systematic reviews of electricity supply scenarios in Germany and Switzerland showed that most scenarios neither consider citizen preferences explicitly (Schubert et al., 2015) nor are aligned with citizen preferences (Scheer et al., 2013). This is even the case for large ensembles with hundreds of existing scenarios from multiple organizations and models (Xexakis et al., 2020). Most public opinion surveys collect preferences for individual technologies and high-level policy priorities (European Commission, 2019a, 2019b), leaving a gap for interpretation before the evidence can be integrated into models. Except for a few studies that directly modeled citizen preferences in scenarios (Hirt et al., 2020; Schmid and Knopf, 2012), there are no studies providing citizen preferences on the EU transition that can directly inform modeling.

In order to support the modeling efforts on electricity supply transition in the EU, this study performed a systematic evaluation of consensus among citizens of three different Member States: France, Germany, and Poland. This study aims to answer the following questions: What are the topics and degrees of consensus and divergence among citizens on the electricity supply in 2035 in the three countries and the whole EU in terms of individual technologies, full electricity supply scenarios, and importance of electricity supply impacts? Specifically, what are the topics and degrees of consensus and divergence among citizens of France, Germany, and Poland, and among citizens of different demographics, political orientations, and attitudes towards electricity transition and governance? In order to answer these questions, the study uses representative online surveys coupled with an interactive scenario tool, allowing respondents to create realistic scenarios and allowing modelers to bridge survey data and modeling. The surveyed countries are three large Member States of the EU with very different electricity supply mixes and strategies for the transition. France aims to phase out 50% of its current nuclear generation until 2035 while increasing its share of renewable electricity from 22% to 40% in 2030 (MTES, 2020a). Germany aims to increase its current share of renewable electricity from 40% to 65% by 2030 while phasing out coal until 2038 (BMW, 2020a). Poland aims to replace part of its coal power plants with nuclear generation and increase the share of renewable electricity from 15% to 32% by 2030 (Ministry of State Assets, 2020).

## 4.2 Methodology

### 4.2.1 Overall study design

The study used representative online surveys with citizens in France ("FR",  $N = 202$ ), Germany ("DE",  $N = 199$ ), and Poland ("PL",  $N = 200$ ) coupled with an interactive scenario tool (Section 4.2.2). First, respondents were asked about their individual preferences for all electricity supply technologies and alternatives that could be used in 2035 in their countries and the EU27 (the EU after the UK withdrawal in 2020). Second, respondents were asked to rate, in terms of importance, five impacts of electricity supply, for instance, impacts on climate change. Third, in order to make the survey results comparable with modeling, respondents used the interactive scenario tool to build scenarios combining electricity supply alternatives (Section 4.2.3). The interactive scenario tool calculated and showed in real-time the impacts of the scenarios selected by the respondents, allowing for more informed preferences and tradeoffs among alternatives by the citizens and enabling comparability with model-based electricity supply scenarios. Each respondent submitted two scenarios: one for the electricity supply of their country and one for the EU27. The survey also included questions about the respondents' demographics, political orientations, and attitudes towards electricity transition and governance. The individual technology preferences, preferred scenarios, and impact ratings were then analyzed in terms of consensus among respondents of different countries and among respondents of different demographics, political orientations, and attitudes towards electricity transition and governance (Section 4.2.4).

### 4.2.2 Survey procedure

The representative samples of citizens in France ( $N = 202$ ), Germany ( $N = 199$ ), and Poland ( $N = 200$ ) were recruited during September 2020 using accredited access panels. The sample size was calculated to adequately represent the population variability on variables of interest, such as technology preferences and attitudes towards the EU. The calculation was based on power analyses and on building confidence intervals with a 5% margin of error for the variables of interest using data from the European Social Survey (NSD, 2020).

All respondents received the same online survey which was adapted and translated to their respective languages. For the full survey script in English, see Section B.1 in Appendix B. The survey began with questions on *gender*, *age*, and highest *education level*, and continued with questions related to respondents' attitudes towards governance. Based on (Batel and Devine-Wright, 2018; Hobolt and de Vries, 2016; Lauterbach and De Vries, 2020), the respondents were first asked about their *attitudes towards the EU membership* of their country (3-point scale from 1 = a good thing to 3 = a bad thing) and about their level of *trust in institutions*, including local public authorities, national government, the EU, and the United Nations (11-point

scale for each institution from 0 = no trust at all to 10 = complete trust). Second, respondents were asked which of these institutions should be responsible for decisions related to electricity supply and its impacts on climate change, local air pollution, land use, electricity costs, and employment (*attitudes towards decision-making levels*, 4-point scale based on the four types of institutions). Third, respondents were asked about their *sense of belonging* to their city or region, their country, Europe, and the World (5-point scale for each area from 0 = no sense of belonging to 5 = very strong sense of belonging).

The survey continued with questions related to electricity supply and its impacts. Based on previous studies (Dubois et al., 2019; Volken et al., 2018; Xexakis et al., 2020), the respondents were initially asked a set of questions about their *prior interest in electricity supply topics* (7 items on a 7-point Likert scale from 1 = strongly disagree to 7 = strongly agree; *Cronbach's  $\alpha$*  = 0.83/0.85/0.82 respectively for the French, German, and Polish sample). Next, respondents had to report whether they would agree or disagree to the expansion of 14 electricity supply alternatives to cover the electricity demand of their country and of the EU27 as a whole (*individual technology preferences*, 14 alternatives on two spatial levels each, based on a 7-point Likert scale from 1 = strongly disagree to 7 = strongly agree). Afterward, the respondents had to give their opinion on the importance of the aforementioned impacts (*impact ratings*, 5 items on a 5-point scale each from 1 = not important to 5 = very important). An attention test was integrated too, where the respondents had to correctly choose the colors of their country's flag.

Eventually, the respondents read a short introduction on how to submit their preferred scenarios and were presented with two versions of the interactive scenario tool Riskmeter (Xexakis and Trutnevyte, 2020b) in a row: one for the electricity system of the respondent's country and one for the EU27. The two versions were presented in random order to avoid anchoring effects, and respondents had to submit a scenario in both versions in order to proceed to the end of the survey. For more details on the interactive scenario tool, see Section 4.2.3. Afterward, respondents were given information about the current target for renewable electricity in their country and were asked whether it should be higher or lower (*"attitudes towards targets for renewable electricity"*, 5-point scale from 1 = much lower to 5 = much higher). Finally, the respondents were asked to evaluate their experience with the Riskmeter (*"self-reported Riskmeter evaluation"*, 10 items on a 7-point Likert scale from 1 = strongly disagree to 7 = strongly agree;  $\alpha$  = 0.90/0.88/0.83) and to report their *political orientation* (10-point scale from 1 = left to 10 = right).

### 4.2.3 Interactive scenario tool Riskmeter

To elicit the scenarios preferred by the citizens and to make the results comparable with model-based scenarios, an interactive scenario tool Riskmeter was created (Xexakis and Trutnevyte, 2020b). The Riskmeter is a user-friendly way to elicit preferred and yet realistic scenarios for electricity supply (Figure 4.1). In comparison with usual opinion surveys, the

#### 4. Consensus on future EU electricity supply among citizens of France, Germany, and Poland

Riskmeter allows the respondents to make choices for electricity supply holistically as a realistic mix, applicable to their country, and not expressing separate technology preferences. The Riskmeter has been tested and used for data collection by experts and non-experts for the case of the Swiss electricity supply transition (Dubois et al., 2019; Volken et al., 2018; Xexakis et al., 2020). For the current study, the Riskmeter has been adapted for the electricity supply mixes in 2035 in France, Germany, Poland, and the EU27. For screenshots of all versions, see Section B.2 in Appendix B.

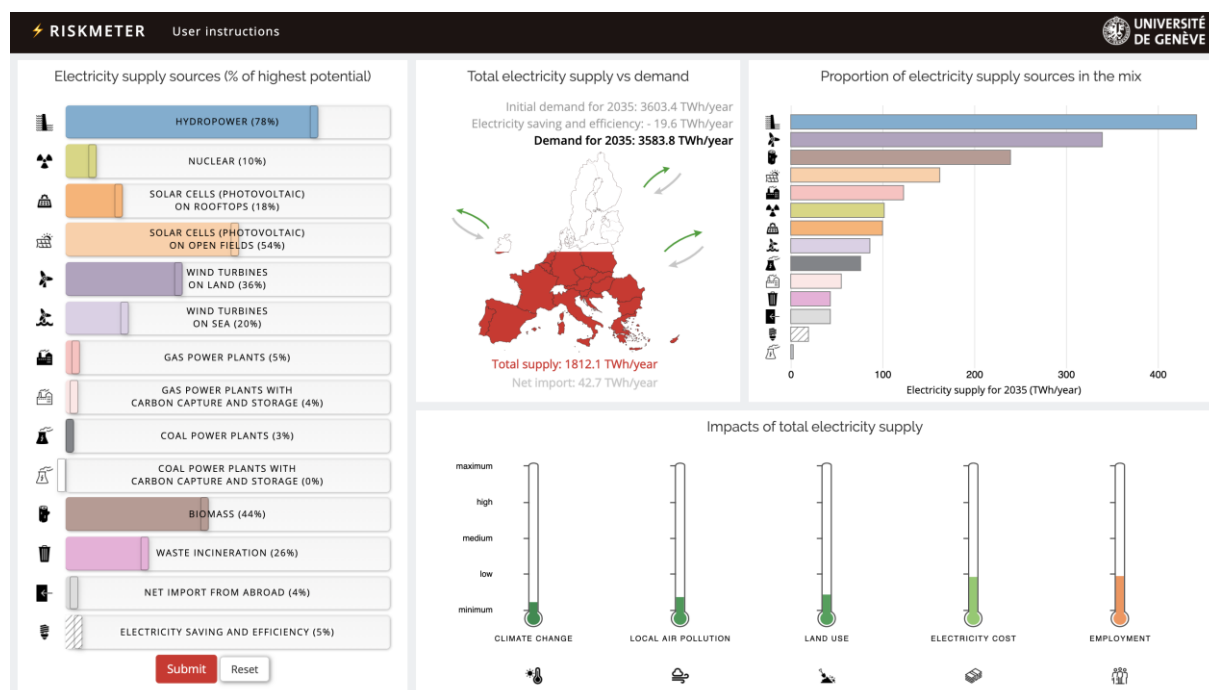


Figure 4.1. Interactive scenario tool Riskmeter used for preference elicitation, illustrated here using the EU27 version (Xexakis and Trutnevyte, 2020b). See Section B.2 in Appendix B for screenshots of all versions.

By moving the sliders on the left of the Riskmeter (Figure 4.1), respondents had to select their preferred electricity supply alternatives with the goal to provide enough annual supply to cover the demand in 2035. The sliders represented alternatives that are already used or could be potentially used in 2035 and included: hydropower; nuclear power; rooftop and open field solar PV; onshore and offshore wind; natural gas power plants with or without carbon capture and storage (CCS); coal power plants with or without CCS; biomass; waste incineration; and net import from abroad. The users could also choose to increase end-use efficiency and electricity savings in order to reduce the demand. The initial positions of the sliders were randomized for each respondent in order to even out any anchoring effects (Demski et al., 2017). While moving the sliders, the respondents also received information on the bottom right about the performance of the selected scenario in terms of five impacts: climate change, local air pollution, land use, electricity costs, and employment (Figure 4.1). The impacts were calculated automatically by multiplying the electricity supply from each alternative in TWh/year with relevant indicators. Specifically, impacts on climate change were measured in CO<sub>2</sub>-eq, local air pollution was measured



in  $PM_{10-eq}$ , land use was measured in  $m^2$ , electricity costs were measured in terms of levelized cost of electricity in EUR/TWh, and employment was measured in jobs per year. The data for the indicators were collected by the literature, preferring, when possible, data that referred to the EU and 2035 (Bauer et al., 2017; De Vita et al., 2018; JRC, 2014; Kis et al., 2018; Sasse and Trutnevyte, 2020). In order to reduce the cognitive load for the respondents, the impacts were normalized between maximum and minimum that could be achieved by any scenario in the Riskmeter.

The levels of electricity demand and supply in the Riskmeter (Xexakis and Trutnevyte, 2020b) were informed by a review of model-based scenarios performed by the authors (Xexakis and Trutnevyte, 2022). Additionally, a study by Sasse and Trutnevyte (2020) was used that modeled 100 maximally different scenarios for the electricity supply in the countries of interest. The demand for each country and the EU27 was set to the 75<sup>th</sup> percentile of the respective model-based scenario ensemble, while the maximum level of savings and end-use efficiency was assumed to be at 10% of the initial demand. For nuclear power and all renewable technologies (rooftop and open field solar PV, onshore and offshore wind, biomass, and waste incineration), the maximum supply was set to the 95<sup>th</sup> percentile of the respective ensemble or the median supply from Sasse and Trutnevyte (2020), whichever was higher. This upper limit ensured that the preferred scenarios of the respondents would be based on realistic technology potentials and build rates for 2035. For coal and gas power plants, it was assumed that, at maximum, they can either cover all demand, or 50% of the demand if they are retrofitted with CCS due to slower build rates of CCS (Crijns-Graus et al., 2011). For net import, it was assumed that it could cover at most 30% of the demand. In terms of minimum supply values, the constraint was set to the level of 2018 for all renewable technologies (Eurostat, 2020c) because it was reasonable to assume that the existing renewable electricity capacity will remain in place until 2035, based on the current energy policy (BMW, 2020a; Ministry of State Assets, 2020; MTES, 2020b). For the remaining alternatives, the minimum values were set to zero so that the respondents could choose to phase out nuclear or fossil fuel plants or not to improve end-use efficiency. Net import could also get negative values up to 10% of the demand, which would be equivalent to net export. For more details on the calculation of the Riskmeter data, see Section B.3 in Appendix B.

#### 4.2.4 Analysis of consensus

Among respondents from France, Germany, and Poland, consensus was analyzed by comparing *individual technology preferences*, preferred scenarios, and *impact ratings* in terms of sample means and shapes of distributions. Means were compared using Analysis of Variance (ANOVA). Since the sample sizes were almost equal at around 200 each ( $N_{FR} = 202$ ,  $N_{DE} = 199$ ,  $N_{PL} = 200$ ), ANOVA was considered robust to violations of the assumption of normality (Field and Wilcox, 2017). In order to address violations of the homoscedasticity assumption in some variables, Welch's  $F$  was used. For comparing the shapes of distributions among respondents of

different countries, overlapping indices were calculated. An overlapping index ( $\eta$ ) measures the percentage of the area shared between two distributions and can be used as an indication of the similarity between them (Pastore and Calcagni, 2019). Overlapping indices were given values from 0 (no overlapping) to 1 (full overlapping). Overlapping indices were also used to evaluate whether *individual technology preferences* and preferred scenarios differed between the national and the EU27 electricity supply, along with correlation coefficients. As an additional measure for comparing distributions, respondents were grouped based on their country and then based on their *individual technology preferences*, preferred scenarios, and *impact ratings*. For example, three groups were created in terms of *individual technology preferences* for each technology and country sample: (1) a group with positive preferences (above 4 on the 7-point Likert scale from 1 = strongly disagree to 7 = strongly agree), (2) a group with negative preferences (below 4 on the scale), and (3) an ambivalent group (equal to 4 on the scale). The size of the groups was then used to evaluate patterns among respondents of different countries, for instance, whether a similar share of respondents from each country had positive preferences on hydropower. Both overlapping indices and the sizes of the three aforementioned groups were used to measure the degree of consensus among samples.

Divergences among samples were assumed based on two conditions: (1) when the samples' means differed statistically significantly, and (2) when the overlapping index was below 0.5 or if the shapes of sample distributions differed among countries beyond a certain criterion. For *individual technology preferences* this criterion checked whether most respondents from one sample had positive preferences and most respondents from another sample had negative preferences. A similar criterion was used for *impact ratings* and whether the impacts were judged as important in one sample and unimportant in another. For preferred scenarios, the criterion was based on categorizing the use of Riskmeter potential as low (below 33%), moderate (above 33% and below 66%), and high (above 66%). A divergence was assumed if most respondents from one sample belonged to a different category of Riskmeter potential they used than most respondents from another sample.

Consensus among respondents of different demographics, political orientations, and attitudes was also analyzed by comparing means and distributions. For comparing means, Multivariate Analysis of Covariance (MANCOVA) was used. MANCOVA was chosen since it can evaluate the effects of multiple covariates over multiple intercorrelated dependent variables, such as the electricity supply sources in the scenarios. Evaluating effects individually for each covariate and each dependent variable was avoided since it would inflate the family-wise error rate. Since the assumptions of normality and homoscedasticity were violated for some of the variables, robust methods were used (Wilcox, 2011). Overall, three MANCOVAs were calculated, one for each set of dependent variables: (1) *individual technology preferences*, (2) preferred Riskmeter scenarios, and (3) *impact ratings*. In order to control for country differences, the country of each respondent was added as a fixed effect. All measured demographics, political orientations, and attitudes were added as control variables, with several exceptions as described

next. First, the MANCOVAs for *individual technology preferences* and preferred scenarios included only the *attitudes towards decision-making level* that were related to electricity supply. Conversely, the MANCOVA for *impact ratings* included only the *attitudes towards decision-making level* that were related to impacts. Using all measured items of *attitudes towards decision-making level* for all MANCOVAs would unnecessarily increase the number of covariates and reduce statistical power. Second, the variable that measured trust in the UN was excluded from all MANCOVAs, due to multicollinearity issues with the variable measuring trust in the EU. The effects of trust in the UN were evaluated by repeating the MANCOVAs with the reverse configuration, i.e., including the variable measuring trust in the UN instead of the one for the EU. The similarity of distributions was also evaluated using overlapping indices and by grouping respondents. For continuous variables, overlapping indices and groups were calculated by splitting respondents into categories of different characteristics seen in Table 4.1. The criteria for consensus and divergences were the same as described for the case of comparing different countries.

Table 4.1. Rules for splitting respondents into categories based on demographics, political orientations, and attitudes

| Variables                                                                                                                                    | Categories                                                      |
|----------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------|
| <i>gender</i>                                                                                                                                | female, male                                                    |
| <i>age</i>                                                                                                                                   | 18 – 35 years, 36 – 55 years, 56 – 69 years                     |
| <i>education level</i>                                                                                                                       | primary and lower secondary, upper secondary, tertiary          |
| <i>political orientation</i><br>(1 = left to 10 = right)                                                                                     | left (1 – 3), center (4 – 6), right (7 – 10)                    |
| <i>prior interest in electricity supply topics</i><br>(sum of 7 items, each item from 1 = strongly disagree to 7 = strongly agree, max = 49) | low (7 – 21), moderate (22 – 35), high (36 – 49)                |
| <i>attitudes towards targets for renewable electricity</i><br>[1 = much lower (than current targets) to 5 = much higher]                     | lower targets (1 – 2), same targets (3), higher targets (4 – 5) |
| <i>attitudes towards decision-making levels</i><br>(local, national, EU, UN)                                                                 | local or national, EU or UN                                     |
| <i>attitudes towards the EU membership</i><br>(1 = a bad thing to 3 = a good thing)                                                          | negative (1), neutral (2), positive (3)                         |
| <i>trust in institutions</i><br>(0 = no trust at all to 10 = complete trust)                                                                 | low (1 – 3), moderate (4 – 6), high (7 – 10)                    |
| <i>sense of belonging</i><br>(1 = no sense of belonging to 5 = very strong sense of belonging)                                               | weak (1 – 2), moderate (3), strong (4 – 5)                      |

## 4.3 Results

### 4.3.1 Survey respondents

Compared to the respective general populations of France, Germany, and Poland, all samples had, on average, similar *gender* ratios and slightly higher *education level* and *age* (Table 4.2). The average *political orientation* was close to the midpoint for all samples and leaned slightly towards the left. In terms of attitudes towards electricity transition, *prior interest in electricity supply topics* was moderate in all samples, with the highest interest found in the Polish and the lowest in the French sample. Average *attitudes towards current targets for renewable electricity* were above the midpoint, suggesting a majority preference for higher than current targets in all countries and particularly in Poland. In terms of *attitudes towards decision-making levels*, most respondents reported that decisions about electricity supply and the management of almost all its impacts should be made by national governments or local authorities. The only exception was for decisions related to climate change, where most German and French respondents reported that these decisions should be made at the UN level, and Polish respondents — at the EU level (see Section B.4 in Appendix B for more details). Most respondents had positive *attitudes towards the EU membership* of their country, with Polish respondents having the most positive and French respondents — the least positive attitudes. Similar patterns have been found for *trust in institutions* and *sense of belonging*, where Polish respondents reported the highest trust in the EU and the UN and the highest *sense of belonging* to Europe and the World. Polish respondents had, on average, the lowest trust in their national government as compared to French and German citizens. Finally, *self-reported Riskmeter evaluation* was well above the midpoint for all samples, indicating that most respondents found the Riskmeter to be helpful and engaging enough.

Table 4.2. Comparison of the three samples in terms of respondents' characteristics.

| Variable names and measurements                                                                                               | <i>M (SD) / percentage in sample</i> |                                  |                                  | Differences among countries   |                                     |
|-------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|----------------------------------|----------------------------------|-------------------------------|-------------------------------------|
|                                                                                                                               | France (FR)<br><i>N</i> = 202        | Germany (DE)<br><i>N</i> = 199   | Poland (PL)<br><i>N</i> = 200    | Statistic<br><i>F</i> (2,598) | Statistically significant contrasts |
| <i>gender</i><br>(% of female respondents; population statistics: FR: 51.0%, DE: 50.7%, PL: 50.1%)                            | 54.3%                                | 49%                              | 49%                              | -                             | -                                   |
| <i>age</i><br>(in years; population statistics: FR: 43.7, DE: 43.9, PL: 41.7)                                                 | 44.7<br>(14.2)<br>(range: 18-69)     | 46.1<br>(13.8)<br>(range: 18-69) | 42.4<br>(13.5)<br>(range: 18-66) | -                             | -                                   |
| <i>education level</i><br>(% of respondents with high school diploma; population statistics: FR: 78.3%, DE: 31.9%, PL: 64.0%) | 86.4%                                | 34.2%                            | 68%                              | -                             | -                                   |
| <i>political orientation</i><br>(1 = left to 10 = right)                                                                      | 4.8 (2.4)                            | 4.8 (2.0)                        | 5.2 (2.8)                        | 1.65                          | -                                   |

Table 4.2. (continued)

|                                                                                                                                    |                             |                |                |                |          |              |
|------------------------------------------------------------------------------------------------------------------------------------|-----------------------------|----------------|----------------|----------------|----------|--------------|
| <i>prior interest in electricity supply topics</i><br>(sum of 7 items, each item from 1 = strongly disagree to 7 = strongly agree) |                             | 25.0 (8.0)     | 28.1 (8.3)     | 32.8 (7.8)     | 48.07*** | PL > DE > FR |
| <i>attitudes towards current targets for renewable electricity</i><br>[1 = much lower (than current targets) to 5 = much higher]   |                             | 3.6 (0.9)      | 3.5 (0.9)      | 4.0 (0.8)      | 16.38*** | PL > DE & FR |
| <i>attitudes towards decision-making levels</i><br>(local, national, EU, UN)                                                       | electricity supply          | national (55%) | national (40%) | national (43%) | -        | -            |
|                                                                                                                                    | climate change              | UN (52%)       | UN (49%)       | EU (52%)       | -        | -            |
|                                                                                                                                    | local air pollution         | national (26%) | local (35%)    | local (42%)    | -        | -            |
|                                                                                                                                    | land use                    | national (40%) | local (43%)    | local (49%)    | -        | -            |
|                                                                                                                                    | electricity costs           | national (58%) | national (51%) | national (51%) | -        | -            |
|                                                                                                                                    | employment                  | national (63%) | national (56%) | national (49%) | -        | -            |
| <i>attitudes towards the EU membership</i><br>(1 = a bad thing to 3 = a good thing)                                                |                             | 2.2 (0.8)      | 2.5 (0.7)      | 2.7 (0.6)      | 23.77*** | PL > DE > FR |
| <i>trust in institutions</i><br>(0 = no trust at all to 10 = complete trust)                                                       | local public authorities    | 6.6 (2.4)      | 6.8 (2.5)      | 6.3 (2.8)      | 2.24     | -            |
|                                                                                                                                    | national government         | 5.1 (2.7)      | 6.3 (3.0)      | 4.3 (3.2)      | 22.54*** | DE > FR > PL |
|                                                                                                                                    | EU                          | 5.3 (2.6)      | 5.7 (2.8)      | 6.7 (3.0)      | 13.38*** | PL > DE & FR |
|                                                                                                                                    | UN                          | 5.3 (2.6)      | 5.5 (2.9)      | 6.6 (2.8)      | 13.2***  | PL > DE & FR |
| <i>sense of belonging</i><br>(1 = no sense of belonging to 5 = very strong sense of belonging)                                     | respondent's city or region | 3.4 (1.2)      | 3.7 (1.1)      | 3.78 (1.1)     | 8.12***  | DE & PL > FR |
|                                                                                                                                    | respondent's country        | 3.7 (1.0)      | 3.6 (1.0)      | 3.8 (1.1)      | 0.56     | -            |
|                                                                                                                                    | Europe                      | 2.9 (1.1)      | 3.1 (1.1)      | 3.5 (1.0)      | 16.36*** | PL > DE > FR |
|                                                                                                                                    | the World                   | 3.0 (1.2)      | 3.0 (1.2)      | 3.3 (1.1)      | 3.82*    | PL > DE & FR |
| <i>self-reported Riskmeter evaluation</i><br>(sum of 10 items, each item from 1 = strongly disagree to 7 = strongly agree)         |                             | 47.0 (9.8)     | 46.4 (10.8)    | 49.0 (9.3)     | 3.86*    | PL > DE & FR |

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Note: Comparison with the general population was based on 2018 values from Destatis (2021) and Eurostat (2020d, 2020a). All survey questions are available in Section B.1 in Appendix B. Detailed results for attitudes towards decision-making levels can be found in Section B.4 in Appendix B. Results for individual scale items for prior interest in electricity supply topics and self-reported Riskmeter evaluation are available in Section B.5 in Appendix B.

### 4.3.2 Consensus among citizens of France, Germany, and Poland

In terms of *individual technology preferences* for national electricity supply, the highest consensus among the citizens of the three countries was found on positive views on electricity savings and efficiency, hydropower, rooftop solar PV, open field solar PV, and offshore wind. Overall, more than 57% of the respondents preferred to include these options in the electricity supply of their countries in 2035 (Figure 4.2). Mean preferences were similar among countries (Figure 4.3), with Polish respondents having statistically significantly higher preferences for all these alternatives than French and German respondents ( $M$  for electricity savings and efficiency in FR: 5.3, DE: 5.2, PL: 5.6; hydropower in FR: 4.9, DE: 5.3, PL: 5.4; rooftop solar PV in FR: 5.1, DE: 5.3, PL: 5.7; open field solar PV in FR: 4.8, DE: 5.1, PL: 5.6; offshore wind in FR: 4.8, DE: 5.2, PL:

5.6). Overlapping indices ( $\eta$ ) that show the overlap of preference distributions among the citizens of the three countries were equal to 0.75 for electricity savings and efficiency, 0.65 for hydropower and rooftop solar PV, and 0.58 for offshore wind (Figure 4.4). The relatively high magnitude of these indices shows that the majority of preferences overlapped among countries, indicating high degree of consensus. Consensus was also found on negative views on alternatives with CCS and net import. Mean values were below the midpoint of 4 for these technologies, with Polish respondents reporting, on average, more positive preferences compared to German and French respondents ( $M$  for natural gas with CCS in FR: 2.5, DE: 2.8, PL: 3.5, overlapping index  $\eta = 0.59$ ; coal with CCS in FR: 2.8, DE: 3.0, PL: 3.9,  $\eta = 0.65$ ; net import in FR: 2.7, DE: 3.3, PL: 3.6,  $\eta = 0.61$ ). The citizen preferences diverged for nuclear power, natural gas plants, coal plants, waste incineration, and onshore wind ( $\eta$ : 0.48, 0.46, 0.61, 0.69, and 0.44 respectively). While half of the Polish respondents agreed with using more nuclear power (50% respondents agreed,  $M = 4.4$ ), most German respondents were strongly against it (61% disagreed,  $M = 2.8$ ), and French respondents were in between (32% agreed and 42% disagreed,  $M = 3.6$ ). Most Polish respondents were also favorable towards natural gas plants (49% agreed,  $M = 4.5$ ), while French respondents were mostly unfavorable (18% agreed,  $M = 3.4$ ), and German respondents were rather ambivalent (35% agreed and 29% disagreed,  $M = 4.0$ ). Similarly, most Polish respondents were favorable towards coal plants (52% agreed,  $M = 4.6$ ), while French and German respondents were ambivalent (FR: 26% agreed and 34% disagreed,  $M = 3.8$ , DE: 35% agreed and 33% disagreed,  $M = 3.9$ ). In terms of waste incineration, most French respondents held positive preferences (47% agreed,  $M = 4.5$ ), while German and Polish respondents were ambivalent (DE: 31% agreed and 29% disagreed,  $M = 3.9$ , PL: 36% agreed and 38% disagreed,  $M = 3.9$ ). Onshore wind plants were rated above the midpoint in all three countries, with Polish respondents having higher mean preferences ( $M = 5.4$ ) than German ( $M = 5.0$ ) and especially French respondents ( $M = 4.5$ ).

| % of respondents per country       |                                   |    |    |                              |    |    |       |    |    |                                                   |    |    |          |    |    |           |    |    |
|------------------------------------|-----------------------------------|----|----|------------------------------|----|----|-------|----|----|---------------------------------------------------|----|----|----------|----|----|-----------|----|----|
|                                    | Individual technology preferences |    |    |                              |    |    |       |    |    | Preferred scenarios<br>(used Riskmeter potential) |    |    |          |    |    |           |    |    |
|                                    | FR                                | DE | PL | FR                           | DE | PL | FR    | DE | PL | FR                                                | DE | PL | FR       | DE | PL |           |    |    |
|                                    | disagree                          |    |    | neither agree<br>or disagree |    |    | agree |    |    | 0 – 33%                                           |    |    | 34 – 67% |    |    | 68 – 100% |    |    |
| hydropower                         | 10                                | 7  | 8  | 27                           | 21 | 17 | 63    | 72 | 76 | 35                                                | 26 | 22 | 21       | 30 | 30 | 45        | 45 | 48 |
| rooftop solar PV                   | 5                                 | 9  | 3  | 26                           | 19 | 18 | 69    | 72 | 79 | 22                                                | 28 | 18 | 25       | 28 | 26 | 53        | 45 | 57 |
| open field solar PV                | 11                                | 11 | 6  | 32                           | 18 | 18 | 57    | 71 | 76 | 34                                                | 33 | 22 | 27       | 34 | 32 | 39        | 34 | 47 |
| onshore wind                       | 19                                | 15 | 4  | 26                           | 17 | 22 | 55    | 68 | 74 | 40                                                | 51 | 33 | 27       | 26 | 28 | 33        | 23 | 40 |
| offshore wind                      | 16                                | 11 | 4  | 26                           | 17 | 22 | 58    | 72 | 74 | 32                                                | 24 | 20 | 28       | 35 | 34 | 40        | 41 | 46 |
| biomass                            | 16                                | 21 | 14 | 47                           | 29 | 36 | 37    | 51 | 50 | 53                                                | 66 | 69 | 26       | 24 | 21 | 21        | 10 | 10 |
| waste incineration                 | 18                                | 29 | 38 | 35                           | 41 | 27 | 47    | 31 | 36 | 44                                                | 56 | 63 | 27       | 33 | 24 | 29        | 11 | 13 |
| nuclear power                      | 42                                | 61 | 26 | 27                           | 18 | 24 | 32    | 21 | 50 | 61                                                | 81 | 58 | 20       | 11 | 21 | 18        | 8  | 21 |
| natural gas                        | 46                                | 29 | 21 | 36                           | 36 | 30 | 18    | 35 | 49 | 94                                                | 86 | 73 | 6        | 12 | 26 | 0         | 2  | 2  |
| coal                               | 34                                | 33 | 19 | 41                           | 32 | 28 | 26    | 35 | 52 | 98                                                | 93 | 92 | 2        | 5  | 5  | 0         | 2  | 2  |
| natural gas with CCS               | 70                                | 63 | 43 | 22                           | 23 | 28 | 7     | 14 | 30 | 85                                                | 84 | 73 | 11       | 13 | 22 | 4         | 3  | 6  |
| coal with CCS                      | 60                                | 59 | 40 | 27                           | 23 | 26 | 13    | 19 | 34 | 89                                                | 95 | 86 | 9        | 3  | 10 | 2         | 2  | 4  |
| net import                         | 61                                | 48 | 36 | 34                           | 31 | 38 | 4     | 22 | 26 | 99                                                | 97 | 93 | 1        | 3  | 6  | 0         | 0  | 2  |
| electricity savings and efficiency | 3                                 | 8  | 6  | 31                           | 25 | 20 | 66    | 68 | 74 | 42                                                | 56 | 43 | 22       | 27 | 27 | 36        | 18 | 30 |

| Impact ratings      | FR            | DE | PL | FR                 | DE | PL | FR                   | DE | PL | FR        | DE | PL | FR             | DE | PL |
|---------------------|---------------|----|----|--------------------|----|----|----------------------|----|----|-----------|----|----|----------------|----|----|
|                     | not important |    |    | slightly important |    |    | moderately important |    |    | important |    |    | very important |    |    |
| climate change      | 2             | 4  | 3  | 2                  | 7  | 6  | 16                   | 11 | 11 | 34        | 37 | 38 | 45             | 41 | 42 |
| local air pollution | 1             | 4  | 0  | 2                  | 7  | 5  | 11                   | 10 | 9  | 42        | 35 | 36 | 43             | 44 | 50 |
| land use            | 1             | 2  | 4  | 4                  | 8  | 6  | 17                   | 20 | 20 | 41        | 47 | 40 | 36             | 24 | 29 |
| electricity costs   | 1             | 1  | 1  | 1                  | 2  | 4  | 21                   | 15 | 10 | 41        | 41 | 38 | 36             | 42 | 46 |
| employment          | 1             | 2  | 2  | 4                  | 6  | 6  | 23                   | 24 | 16 | 43        | 46 | 38 | 29             | 23 | 37 |

Figure 4.2. Grouping of respondents in terms of *individual technology preferences* for national electricity supply, preferred Riskmeter scenarios for national electricity supply, and *impact ratings*. For *individual technology preferences*, all answers relating to agreeing (i.e., strongly agree, agree, and somewhat agree) have been grouped into one category. The same grouping was used for answers relating to disagreeing.

#### 4. Consensus on future EU electricity supply among citizens of France, Germany, and Poland

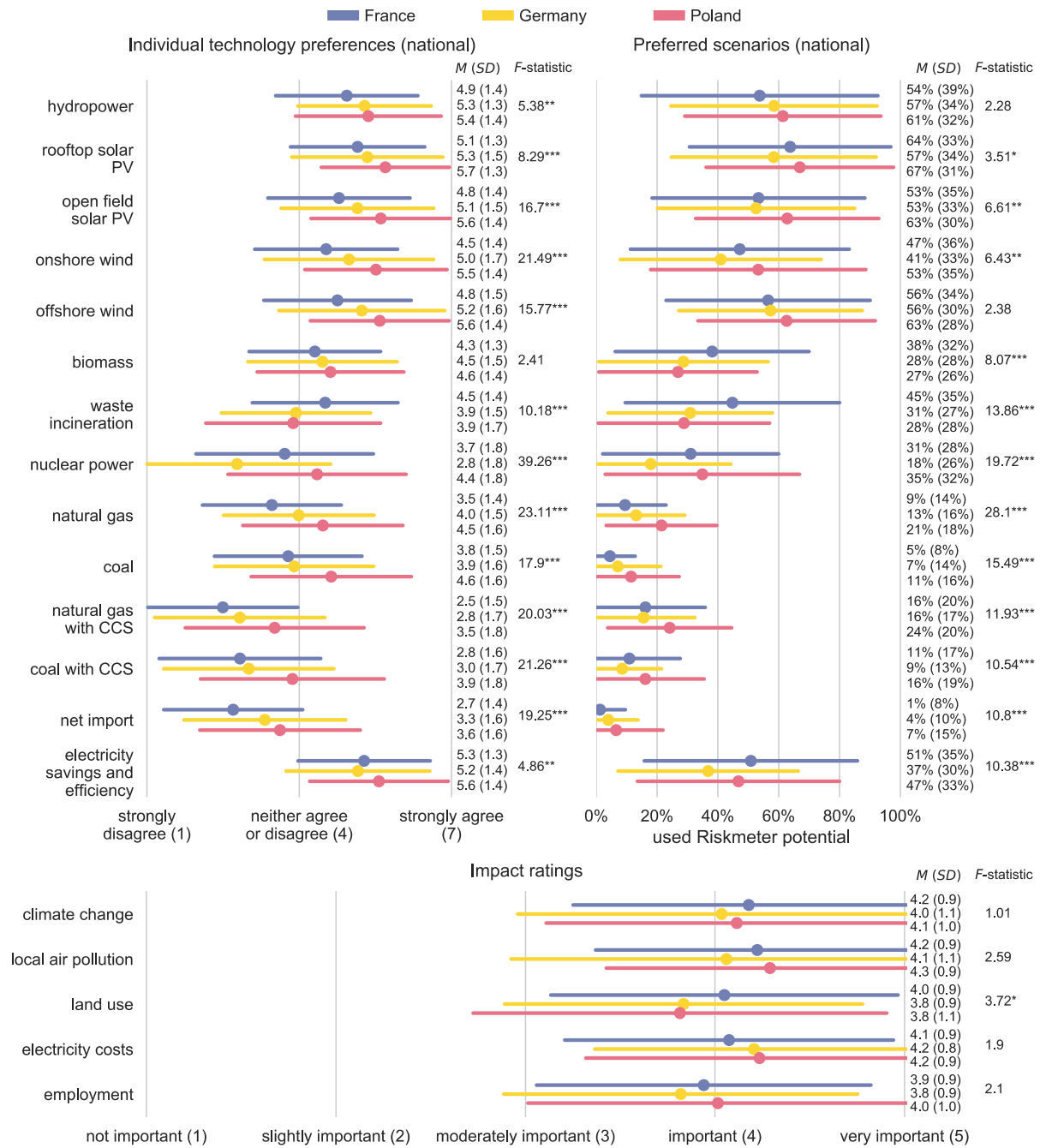


Figure 4.3. Comparison among respondents from France, Germany, and Poland in terms of *individual technology preferences* and preferred Riskmeter scenarios for national electricity supply, and in terms of *impact ratings*. Markers depict means and lines — standard deviations. ANOVA was performed for each comparison (Welch's  $F$  statistic, \* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ ).



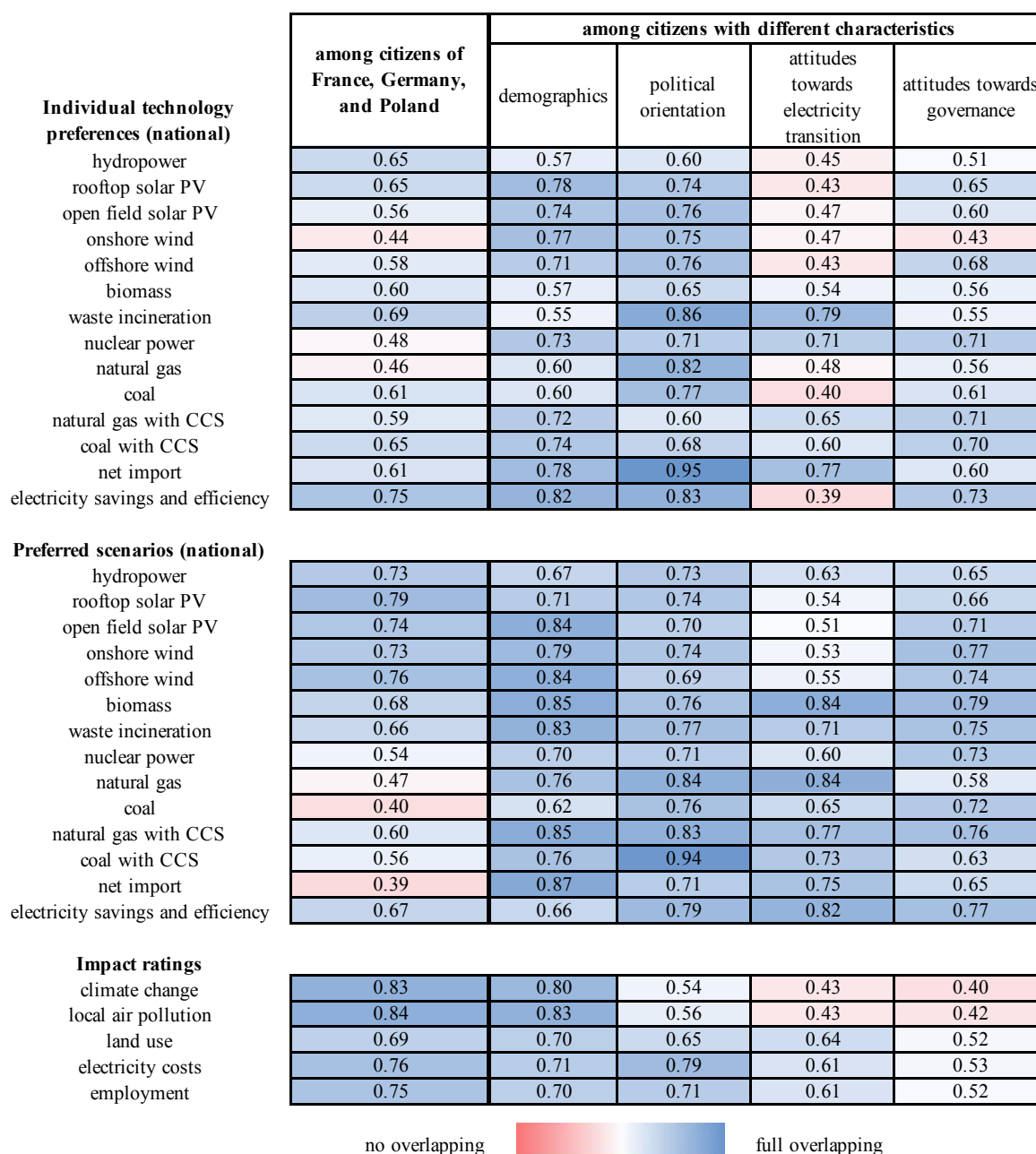


Figure 4.4. Overlapping indices ( $\eta$ ) for *individual technology preferences* and preferred Riskmeter scenarios for national supply, and *impact ratings*. An overlapping index of 1 indicates full overlapping among countries and 0 — no overlapping. In case there are multiple groups compared, the minimum overlapping index is shown. Overlapping indices for all individual comparisons can be found in Section B.6 in Appendix B.

In preferred Riskmeter scenarios with complete combinations of technologies for national electricity supply, high shares of hydropower, rooftop solar PV, and offshore wind power received the highest consensus among the citizens of the countries. On average, respondents used more than half of the maximum potential of these technologies in the Riskmeter (Figure 4.3), with minor differences among countries ( $M$  for hydropower in FR: 54%, DE: 57%, PL: 61%; rooftop solar PV in FR: 64%, DE: 57%, PL: 67%; offshore wind in FR: 56%, DE: 56%, PL: 63%).

Overlapping indices ( $\eta$ ) were 0.73 for hydropower, 0.79 for rooftop solar PV, and 0.76 for offshore wind, indicating consensus because a large majority of preferred Riskmeter scenarios overlapped among countries (Figure 4.4). Some consensus was also found for high shares of open field solar PV and onshore wind among countries, with Polish respondents using, on average, a statistically significantly higher Riskmeter potential ( $M = 63\%$  and  $M = 53\%$ , respectively) than French ( $M = 53\%$  and  $M = 47\%$ ) and German ( $M = 53\%$  and  $M = 41\%$ ). Interestingly, high overlapping indices were still found for both open field solar PV ( $\eta = 0.74$ ) and onshore wind ( $\eta = 0.73$ ), in contrast to the results of *individual technology preferences* where overlapping indices were lower ( $\eta$ : 0.56 and 0.44 respectively). This indicates that the process of building scenarios and making tradeoffs with other technologies narrowed the technology choice among countries for open field solar PV and onshore wind, further highlighting relatively high consensus. Consensus was also found for low shares of alternatives with CCS and moderate shares of biomass and waste incineration. Polish respondents used, on average, slightly higher potential from alternatives with CCS than the rest, and French respondents used the highest potential from biomass and waste incineration ( $M$  for natural gas with CCS in FR: 16%, DE: 16%, PL: 24%,  $\eta = 0.60$ ; coal with CCS in FR: 11%, DE: 9%, PL: 16%,  $\eta = 0.56$ ; biomass in FR: 38%, DE: 28%, PL: 27%,  $\eta = 0.68$ ; waste incineration in FR: 45%, DE: 31%, PL: 28%,  $\eta = 0.66$ ).

Divergences on preferred Riskmeter scenarios were found for net import, coal, natural gas, and nuclear power, but the citizens of all countries still converged to less than a third of the allowed potential for these options in Riskmeter (Figure 4.2). Differences in mean values for these technologies were statistically significant among countries, with Polish respondents using higher Riskmeter potential than the rest ( $M$  for net import in FR: 1%, DE: 4%, PL: 7%,  $\eta = 0.39$ ; coal in FR: 5%, DE: 7%, PL: 11%,  $\eta = 0.40$ ; natural gas in FR: 9%, DE: 13%, PL: 21%,  $\eta = 0.47$ ; nuclear power in FR: 31%, DE: 18%, PL: 35%,  $\eta = 0.54$ ). Most of the differences among countries for net import, nuclear power, natural gas, and coal originated in minority preferences. For instance, 28% of Polish respondents preferred to use more than a third of the potential of natural gas versus 6% and 14% of French and German respondents. For net import, almost all respondents chose to use less than a third of their Riskmeter potential (99% of respondents in FR, 97% in DE, and 93% in PL). In fact, most respondents chose to include net export for their countries (79% of respondents in FR, 53% in DE, 57% in PL), using a large share of the allowed Riskmeter potential for net export ( $M$  for FR: 48%, DE: 53%, PL: 65%). In contrast, the minority that chose to use net import included only a small share of the Riskmeter potential for net import ( $M$  for FR: 1%, DE: 4%, and PL: 7%).

In terms of *impact ratings*, results showed a strong consensus among the citizens of the three countries across all impact types. For all countries, more than 75% of the respondents reported that all impacts were important or very important (Figure 4.2). On average, *impact ratings* were close to 4 for all impact types and countries, indicating small differences among impact types ( $M$  for climate change impacts in FR: 4.2, DE: 4.0, PL: 4.1, local air pollution in FR: 4.2, DE: 4.1, PL: 4.3, electricity costs in FR: 4.1, DE: 4.2, PL: 4.2, and employment in FR: 3.9, DE: 3.8, PL: 4.0). Differences among countries were statistically significant for impacts on land use,

where French respondents reported slightly higher importance of these impacts ( $M = 4.0$ ) than German and Polish respondents ( $M = 3.8$  for both). The overlapping indices ( $\eta$ ) were 0.83 for climate change impacts, 0.84 for local air pollution, 0.69 for land use impacts, 0.76 for electricity costs, and 0.75 for employment impacts, indicating that the majority of respondents from the three countries had high degree of consensus on *impact ratings* (Figure 4.3).

In terms of *individual technology preferences* and scenario preferences in Riskmeter for the EU27 as a whole, results indicate that most respondents in all countries did not differentiate their preferences between national and EU27 electricity supply since they reported very similar preferences at both spatial levels (see Section B.7 in Appendix B). These similarities were further supported by calculating correlations and overlapping indices between the two spatial levels for *individual technology preferences* and preferred scenarios in Riskmeter. For all countries, correlation coefficients on *individual technology preferences* were statistically significant and ranged between 0.54 and 0.90, indicating very similar preferences between the two spatial levels (see Section B.8 in Appendix B for detailed results). Overlapping indices were very high too and ranged between 0.73 and 0.95 for French respondents, 0.70 and 0.95 for German, 0.76 and 0.94 for Polish (see Section B.8 in Appendix B for detailed results). In terms of preferred scenarios in Riskmeter, correlations were weaker but still statistically significant. Almost all correlation coefficients ranged between 0.30 and 0.75, indicating moderate to high correlations between spatial levels. The only exception was coal plants with CCS for German respondents with a correlation coefficient of 0.15. However, this low correlation was not reflected in the German respondents' *individual technology preferences* for coal with CCS ( $r = 0.79$  between spatial levels) or the average values of Riskmeter potentials for this technology ( $M = 9\%$  for both spatial levels). Therefore, this individual instance of low correlation could be a statistical artifact due to the different proportions between the Riskmeter potentials in the national and the EU27 Riskmeter. Overlapping indices ( $\eta$ ) on preferred scenarios were also moderate to high and ranged between 0.72 and 0.94 for French respondents, 0.62 and 0.92 for German, and 0.66 and 0.87 for Polish, indicating that the distributions of national and EU27 scenarios were mostly similar.

For *individual technology preferences* for the EU27, the highest consensus among countries was found for high use of electricity savings and efficiency, hydropower, and rooftop solar PV ( $M$  for electricity savings and efficiency in FR: 5.2, DE: 5.2, PL: 5.5; hydropower in FR: 4.9, DE: 5.3, PL: 5.4; rooftop solar PV in FR: 5.1, DE: 5.3, PL: 5.6). Additionally, consensus was found on negative views on alternatives with CCS and net import ( $M$  for natural gas with CCS in FR: 2.5, DE: 2.9, PL: 3.6; coal with CCS in FR: 2.8, DE: 2.9, PL: 3.9; net import in FR: 2.8, DE: 3.4, PL: 3.7). Divergences were found for nuclear power and natural gas, where most Polish respondents had positive views and most German and French respondents had negative views or were ambivalent ( $M$  for nuclear power in FR: 3.6, DE: 2.8, PL: 4.4; natural gas in FR: 3.4, DE: 4.0, PL: 4.5).

In the case of preferred Riskmeter scenarios for the EU27, consensus was found on high shares of electricity savings and efficiency, hydropower, both types of solar PV, and onshore

wind ( $M$  for electricity savings and efficiency in FR: 51%, DE: 42%, PL: 40%; hydropower in FR: 57%, DE: 57%, PL: 46%; rooftop solar PV in FR: 66%, DE: 65%, PL: 57%; open field solar PV in FR: 57%, DE: 64%, PL: 56%; onshore wind in FR: 49%, DE: 54%, PL: 44%). Consensus was also found on low shares of alternatives with CCS and net import ( $M$  for natural gas with CCS in FR: 18%, DE: 16%, PL: 18%; coal with CCS in FR: 13%, DE: 9%, PL: 15%; net import in FR: 5%, DE: 5%, PL: 3%). Divergences on preferred scenarios for the EU27 were found for nuclear power, net import, and coal, with Polish respondents using, on average, higher Riskmeter potentials than the rest ( $M$  for nuclear power in FR: 28%, DE: 16%, PL: 31%; net import in FR: 5%, DE: 5%, PL: 3%; coal in FR: 6%, DE: 8%, PL: 10%).

### 4.3.3 Consensus among citizens of different demographics and political orientations

Among respondents of different *gender, age, education level, and political orientation*, there were very few divergences on *individual technology preferences*, preferred scenarios, and *impact ratings*. Between female and male respondents of all three samples together, the highest consensus on *individual technology preferences* was found on positive views on electricity savings and efficiency and negative views on net import and alternatives with CCS (Table 4.3,  $M$  for female respondents: 5.2, male: 5.5, overlapping index  $\eta$ : 0.82;  $M$  for net import for female: 3.3, male: 3.2,  $\eta$  = 0.87; natural gas with CCS for female: 3.1, male: 2.8,  $\eta$  = 0.72; coal with CCS for female: 3.3, male: 3.1,  $\eta$  = 0.74). Consensus was also found on positive views on rooftop and open field solar PV, and offshore wind, despite statistically significant differences between respondents of a different gender ( $M$  for rooftop solar PV for female: 5.2, male: 5.6,  $\eta$  = 0.78; open field solar PV for female: 5.0, male: 5.4,  $\eta$  = 0.74; onshore wind for female: 5.0, male: 5.4,  $\eta$  = 0.77). Divergences were identified for nuclear power, where female respondents held mostly negative preferences (48% disagreed,  $M$  = 3.3) and male respondents were ambivalent (38% disagreed and 43% agreed,  $M$  = 3.9). Nevertheless, the overlapping index for nuclear power remained rather high ( $\eta$  = 0.73), indicating a small degree of divergence between male and female respondents.

Table 4.3. Statistically significant effects of demographics and political orientation on *individual technology preferences*, preferred scenarios for national electricity supply, and *impact ratings*. Full MANCOVA results as well as means and standard deviations for all variables can be found in Section B.9 in Appendix B.

|                              | <i>Individual technology preferences</i><br>(from 1 = strongly disagree to 7 = strongly agree) |                        |               |           | Preferred scenarios for national electricity supply<br>(used Riskmeter potential in %) |                                                |               |         | <i>Impact ratings</i><br>(from 1 = not important to 5 = very important) |                        |               |           |
|------------------------------|------------------------------------------------------------------------------------------------|------------------------|---------------|-----------|----------------------------------------------------------------------------------------|------------------------------------------------|---------------|---------|-------------------------------------------------------------------------|------------------------|---------------|-----------|
|                              | <i>V</i>                                                                                       | s.s. effects           | <i>M (SD)</i> |           | <i>V</i>                                                                               | s.s. effects                                   | <i>M (SD)</i> |         | <i>V</i>                                                                | s.s. effects           | <i>M (SD)</i> |           |
| <i>gender</i>                | 0.06**                                                                                         |                        | male          | female    | 0.07**<br>*                                                                            |                                                | male          | female  | 0.03*<br>*                                                              |                        | male          | female    |
|                              |                                                                                                | rooftop solar PV       | 5.6 (1.4)     | 5.2 (1.4) |                                                                                        | waste incineration                             | 32 (30)       | 38 (32) |                                                                         | climate change         | 4.0 (1.1)     | 4.2 (0.9) |
|                              |                                                                                                | open field solar PV    | 5.4 (1.4)     | 5.0 (1.5) |                                                                                        | nuclear power                                  | 34 (32)       | 22 (27) |                                                                         | land use               | 3.8 (1.0)     | 4.0 (0.9) |
|                              |                                                                                                | offshore wind          | 5.4 (1.5)     | 5.0 (1.5) |                                                                                        | coal with CCS                                  | 10 (14)       | 14 (19) |                                                                         |                        |               |           |
|                              |                                                                                                | nuclear power          | 3.9 (2.0)     | 3.3 (1.8) |                                                                                        |                                                |               |         |                                                                         |                        |               |           |
| <i>age</i>                   | 0.09**                                                                                         |                        | younger       | older     | 0.06**                                                                                 |                                                | younger       | older   | 0.01                                                                    | <i>no s.s. effects</i> |               |           |
|                              |                                                                                                | rooftop solar PV       | 5.5 (1.3)     | 5.3 (1.5) |                                                                                        | hydropower                                     | 66 (34)       | 51 (34) |                                                                         |                        |               |           |
|                              |                                                                                                | onshore wind           | 5.1 (1.4)     | 5.0 (1.8) |                                                                                        | rooftop solar PV                               | 59 (33)       | 53 (32) |                                                                         |                        |               |           |
|                              |                                                                                                | waste incineration     | 3.7 (1.6)     | 4.4 (1.5) |                                                                                        | onshore wind                                   | 53 (36)       | 43 (34) |                                                                         |                        |               |           |
|                              |                                                                                                | natural gas            | 3.7 (1.5)     | 4.1 (1.4) |                                                                                        | natural gas electricity savings and efficiency | 13 (15)       | 17 (19) |                                                                         |                        |               |           |
| <i>education level</i>       | 0.05*                                                                                          |                        | low           | high      | 0.03                                                                                   | <i>no s.s. effects</i>                         |               |         | 0.01                                                                    | <i>no s.s. effects</i> |               |           |
|                              |                                                                                                | hydropower             | 5.1 (1.4)     | 5.3 (1.4) |                                                                                        |                                                |               |         |                                                                         |                        |               |           |
|                              |                                                                                                | natural gas            | 4.1 (1.6)     | 3.7 (1.5) |                                                                                        |                                                |               |         |                                                                         |                        |               |           |
|                              |                                                                                                | coal                   | 4.2 (1.6)     | 3.8 (1.6) |                                                                                        |                                                |               |         |                                                                         |                        |               |           |
|                              |                                                                                                | natural gas with CCS   | 3.2 (1.8)     | 2.5 (1.6) |                                                                                        |                                                |               |         |                                                                         |                        |               |           |
|                              |                                                                                                | coal with CCS          | 3.4 (1.8)     | 2.9 (1.7) |                                                                                        |                                                |               |         |                                                                         |                        |               |           |
| <i>political orientation</i> | 0.03                                                                                           | <i>no s.s. effects</i> |               |           | 0.01                                                                                   | <i>no s.s. effects</i>                         |               |         | 0.02                                                                    | <i>no s.s. effects</i> |               |           |
|                              |                                                                                                |                        |               |           |                                                                                        |                                                |               |         |                                                                         |                        |               |           |

Note: \* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ . s.s. = statistically significant.

Statistical significance was calculated with MANCOVA using the respondents' country as a fixed factor and the respondents' demographics, political orientations, and attitudes towards electricity transition and governance as covariates.

In terms of preferred Riskmeter scenarios, the highest consensus between female and male respondents was found on high shares of electricity savings and efficiency and both types of solar PV ( $M$  for electricity savings and efficiency for female: 48%, male: 41%,  $\eta = 0.82$ ; rooftop solar PV for female: 56%, male: 56%,  $\eta = 0.92$ ; open field solar PV for female: 64%, male: 62%,  $\eta = 0.86$ ). Female and male respondents also agreed on including low shares of net import, natural gas, and alternatives with CCS, with female respondents having statistically significantly higher shares of coal with CCS ( $M$  for net import for female: 4%, male: 4%,  $\eta = 0.92$ ; natural gas for female: 14%, male: 15%,  $\eta = 0.89$ ; natural gas with CCS for female: 19%, male: 18%,  $\eta = 0.92$ ; coal with CCS for female: 14%, male: 10%,  $\eta = 0.76$ ). Statistically significant differences were also found for nuclear power, where, on average, female respondents used it at lower shares than male respondents ( $M$  for female: 22%, male: 34%,  $\eta = 0.70$ ). In contrast to *individual technology preferences*, no divergences were observed on preferred scenarios in Riskmeter, as all overlapping indices between respondents with different gender were above 0.5 and the Riskmeter potentials used in their scenarios were similarly distributed (Section B.9 in Appendix B). The lack of a divergence in nuclear power in preferred scenarios can be attributed to potential tradeoffs that respondents made in their scenarios and the already small degree of divergence of *individual technology preferences* for nuclear power. In terms of *impact ratings*, more than 70% of female and male respondents agreed that all impacts are important or very important, with female respondents giving slightly higher importance to climate change and land use impacts than male respondents. For all detailed statistics and overlapping indices, see Sections B.6 and B.9 in Appendix B.

In terms of *individual technology preferences* among respondents of different age groups, there was high consensus on positive views on electricity savings and efficiency, hydropower, and open field solar PV [ $M$  for electricity savings and efficiency for younger respondents (18 – 35 years): 5.2, older (55 – 69 years): 5.4, overlapping index  $\eta = 0.85$ ; hydropower for younger: 5.2, older: 5.3,  $\eta = 0.85$ ; open field solar PV for younger: 5.2, older: 5.1,  $\eta = 0.84$ ]. Consensus was also high for rooftop solar PV, with younger respondents having slightly more positive preferences than older respondents ( $M$  for younger: 5.5, older: 5.3,  $\eta = 0.86$ ). Consensus was also observed on negative views on net import and alternatives with CCS ( $M$  for net import for younger: 3.3, older: 3.1,  $\eta = 0.87$ ; natural gas with CCS for younger: 3.0, older: 2.7,  $\eta = 0.85$ ; coal with CCS for younger: 3.2, older: 3.0,  $\eta = 0.80$ ). Divergences were found on waste incineration and natural gas, with younger respondents having mostly negative views and older respondents having mostly positive views ( $M$  for waste incineration for younger: 3.7, older: 4.4;  $M$  for natural gas for younger: 3.7, older: 4.1). Nevertheless, overlapping indices were still above 0.5 ( $\eta$  for waste incineration: 0.60, for natural gas: 0.55), indicating that the divergences were not large and there were common ranges of preferences among the age groups. In terms of preferred Riskmeter scenarios, the highest consensus among age groups was found on high shares of offshore wind and open field solar PV and low shares of net import and alternatives with CCS ( $M$  offshore wind for younger: 62%, older: 57%,  $\eta = 0.84$ ; open field solar PV for younger:

68%, older: 55%,  $\eta = 0.71$ ; net import for younger: 4%, older: 4%,  $\eta = 0.87$ ; natural gas with CCS for younger: 17%, older: 19%,  $\eta = 0.85$ ; coal with CCS for younger: 12%, older: 12%,  $\eta = 0.84$ ). Consensus was also identified for high shares of hydropower, rooftop solar PV, onshore wind, and electricity savings and efficiency, but with younger respondents using, on average, statistically significantly more Riskmeter potential for these alternatives ( $M$  for hydropower for younger: 66%, older: 51%,  $\eta = 0.67$ ; rooftop solar PV for younger: 59%, older: 53%,  $\eta = 0.84$ ; onshore wind for younger: 53%, older: 43%,  $\eta = 0.79$ ; electricity savings and efficiency for younger: 51%, older: 39%,  $\eta = 0.66$ ). In contrast, older respondents used more potential from natural gas plants ( $M$  for younger: 13%, older: 17%,  $\eta = 0.76$ ). Despite the aforementioned differences for *individual technology preferences*, no divergences were found among age groups on their preferred Riskmeter scenarios because all overlapping indices were well above 0.5 and scenarios from all age groups had similar distributions of Riskmeter potentials (Section B.9 in Appendix B). The small degree of the divergences in *individual technology preferences* and the potential tradeoffs with other technologies is a likely explanation for this lack of divergences in preferred scenarios. Consensus was found for all *impact ratings*, with more than 65% of respondents in every age group reporting that all impacts were important or very important.

Among respondents with different education levels, the highest consensus on *individual technology preferences* was found on positive views on open field solar PV and both types of wind power [ $M$  for open field solar PV for respondents with primary education level: 5.1, tertiary: 5.3, overlapping index  $\eta = 0.93$ ; onshore wind for primary: 5.0, tertiary: 5.2,  $\eta = 0.91$ ; offshore wind for primary: 5.2, tertiary: 5.3,  $\eta = 0.90$ ]. There was also a consensus on negative views on net import and alternatives with CCS, where respondents with a higher education level had, on average, statistically significantly more negative views than respondents with a lower education level ( $M$  for net import for respondents with primary education: 3.4, tertiary: 2.9,  $\eta = 0.78$ ; natural gas with CCS for primary: 3.2, tertiary: 2.5,  $\eta = 0.86$ ; coal with CCS for primary: 3.4, tertiary: 2.9,  $\eta = 0.78$ ). Divergences were observed for natural gas and coal, where less educated respondents had ambivalent opinions and more educated respondents had mostly negative opinions ( $M$  for natural gas for respondents with primary education: 4.1, tertiary: 3.7; coal for primary: 4.2, tertiary: 3.8). However, overlapping indices remained rather high for these two technologies ( $\eta$  for natural gas: 0.87, coal: 0.82), indicating that the majority of respondents shared common views regardless of their education level. In terms of preferred scenarios in Riskmeter, consensus among respondents of different education levels was high for all alternatives and no divergences were found, as all overlapping indices were well above 0.5 and there were no statistically significant differences (Table 4.3 and Section B.6 in Appendix B). The highest consensus was found on high shares of hydropower and both types of solar PV and wind power ( $M$  for hydropower for respondents with primary education: 56%, tertiary: 62%,  $\eta = 0.89$ ; rooftop solar PV for primary: 56%, tertiary: 60%,  $\eta = 0.90$ ; open field solar PV for primary: 60%, tertiary: 69%,  $\eta = 0.85$ ; onshore wind for primary: 46%, tertiary: 51%,  $\eta = 0.92$ ; offshore wind for primary: 57%, tertiary: 63%,  $\eta = 0.87$ ). Additionally, high consensus was found on low shares of net import and

alternatives with CCS ( $M$  for net import for respondents with primary education: 4%, tertiary: 5%,  $\eta = 0.91$ ; natural gas with CCS for primary: 19%, tertiary: 19%,  $\eta = 0.87$ ; coal with CCS for primary: 11%, tertiary: 11%,  $\eta = 0.87$ ). Consensus was also found for all *impact ratings*, with more than 68% of respondents at all education levels reporting that all impact types were important or very important.

Among respondents with different political orientations and in terms of *individual technology preferences*, the highest consensus was observed on positive views on electricity savings and efficiency and negative views on net import ( $M$  for electricity savings and efficiency for left-leaning respondents: 5.5, right-leaning: 5.3, overlapping index  $\eta = 0.83$ ;  $M$  for net import for left-leaning: 3.2, right-leaning: 3.1,  $\eta = 0.95$ ). Consensus was also found on negative views on alternatives with CCS (natural gas with CCS for left-leaning: 2.5, right-leaning: 3.4,  $\eta = 0.60$ ; coal with CCS for left-leaning: 2.8, right-leaning: 3.5,  $\eta = 0.68$ ). In contrast, respondents from all political orientation groups held ambivalent views on natural gas and coal without CCS (natural gas for left-leaning: 3.7, right-leaning: 4.1,  $\eta = 0.82$ ; coal for left-leaning: 3.9, right-leaning: 4.2,  $\eta = 0.77$ ). Surprisingly, no divergences have been found as there were no statistically significant differences among respondents of different political orientations (Table 4.3), while their preferences were also distributed in a similar way ( $\eta > 0.5$  for all technologies, see Section B.6 in Appendix B). The lack of divergences was also the case for preferred Riskmeter scenarios, further reinforcing the finding that respondents with different *political orientations* shared similar views on the examined electricity supply technologies and scenarios. The highest consensus on preferred scenarios was found on moderate shares of electricity savings and efficiency ( $M$  for left-leaning: 51%, right-leaning: 42%, overlapping index  $\eta = 0.79$ ) and low shares of net imports and alternatives with CCS ( $M$  for net imports for left-leaning: 5%, right-leaning: 2%,  $\eta = 0.71$ ; natural gas with CCS for left-leaning: 19%, right-leaning: 21%,  $\eta = 0.83$ ; coal with CCS for left-leaning: 12%, right-leaning: 13%,  $\eta = 0.94$ ). Interestingly, while there were ambivalent views on natural gas and coal as individual technologies, most respondents used a small part of their Riskmeter potential regardless of their political orientations ( $M$  for natural gas for left-leaning: 13%, right-leaning: 17%,  $\eta = 0.84$ ; coal for left-leaning: 6%, right-leaning: 10%,  $\eta = 0.76$ ). This inconsistency can be due to the impacts shown in the Riskmeter, as respondents with initially favorable preferences towards natural gas and coal may have been dissuaded from using a large share of their Riskmeter potential due to their high impacts on climate change. Consensus was also found on *impact ratings*, with more than 61% of respondents in all political orientation groups reporting that all impacts are important or very important.

#### 4.3.4 Consensus among citizens of different attitudes towards electricity transition

Compared to all examined demographics, political orientations, and attitudes, the largest number of divergences was found among respondents with different *prior interest in electricity*



*supply topics* and *attitudes towards current targets for renewable electricity*. In terms of respondents with a different *prior interest in electricity supply topics*, the highest consensus on *individual technology preferences* was found on negative views on net import and natural gas with CCS ( $M$  for net import for respondents with a low interest: 2.9, high: 3.2, overlapping index  $\eta = 0.78$ ; natural gas with CCS for low: 2.9, high: 2.9,  $\eta = 0.70$ ). Additionally, consensus was found on positive views on hydropower, where respondents with a high interest were slightly more favorable towards hydropower than respondents with a low interest (Table 4.4,  $M$  for hydropower for low interest: 5.1, high: 5.8,  $\eta = 0.55$ ). Divergences were found for natural gas and coal plants, where respondents with a high interest had, on average, more positive views and respondents with a low interest had negative views ( $M$  for natural gas for low interest: 3.5, high: 4.5,  $\eta = 0.48$ ; coal for low: 3.5, high: 4.7,  $\eta = 0.40$ ). Divergences were also found on electricity savings and efficiency, offshore wind, and both types of solar PV, where respondents with a high interest had statistically significantly more positive views for these alternatives than respondents with a low interest (Table 4.4,  $M$  for electricity savings and efficiency for low: 4.9, high: 6.2,  $\eta = 0.39$ ; rooftop solar PV for low: 5.2, high: 6.2,  $\eta = 0.43$ ; open field solar PV for low: 5.9, high: 4.8,  $\eta = 0.47$ ; offshore wind for low: 4.9, high: 6.0,  $\eta = 0.43$ ). Still, more than 60% of respondents agreed with using these technologies regardless of their *prior interest in electricity supply topics*. None of the aforementioned divergences and statistically significant differences were found in preferred scenarios in Riskmeter. This inconstancy could be an effect of the impacts and realistic technology potentials shown in the Riskmeter, which have potentially reduced the knowledge gap between respondents with different prior interests. The highest consensus on preferred scenarios was identified for high shares of both types of solar PV and wind power ( $M$  for rooftop solar PV for low interest: 57%, high: 59%,  $\eta = 0.89$ ; open field solar PV for low: 66%, high: 66%,  $\eta = 0.84$ ; onshore wind for low: 48%, high: 49%,  $\eta = 0.87$ ; offshore wind for low: 57%, high: 60%,  $\eta = 0.88$ ). High consensus was also found on moderate shares of nuclear power and low shares of coal and alternatives with CCS ( $M$  for nuclear power for low interest: 26%, high: 26%,  $\eta = 0.90$ ; coal for low: 7%, high: 9%,  $\eta = 0.91$ ; natural gas with CCS for low: 15%, high: 21%,  $\eta = 0.73$ ; coal with CCS for low: 11%, high: 10%,  $\eta = 0.83$ ). In terms of *impact ratings*, there was consensus among respondents with a different *prior interest in electricity supply topics* on the importance of all impacts. Grouping respondents based on their prior interest showed that more than 69% of respondents in every group rated all impacts as important or very important. However, respondents with a high interest gave, on average, a higher importance to all impacts, compared to respondents with a low interest.

Table 4.4. Statistically significant effects of attitudes towards electricity transition on *individual technology preferences*, preferred scenarios for national electricity supply, and *impact ratings*. Full MANCOVA results as well as means and standard deviations for all variables can be found in Section B.9 in Appendix B.

| <i>Individual technology preferences</i><br>(from 1 = strongly disagree to 7 = strongly agree) |         |                                          |                  | Preferred scenarios for national electricity supply<br>(used Riskmeter potential in %) |         |                                          |                  | <i>Impact ratings</i><br>(from 1 = not important to 5 = very important) |                        |                        |                  |                   |
|------------------------------------------------------------------------------------------------|---------|------------------------------------------|------------------|----------------------------------------------------------------------------------------|---------|------------------------------------------|------------------|-------------------------------------------------------------------------|------------------------|------------------------|------------------|-------------------|
| <i>V</i>                                                                                       |         | s.s. effects                             |                  | <i>M (SD)</i>                                                                          |         | <i>V</i>                                 |                  | s.s. effects                                                            |                        | <i>M (SD)</i>          |                  |                   |
|                                                                                                |         |                                          |                  | low                                                                                    | high    |                                          |                  |                                                                         |                        | low                    | high             |                   |
| <i>prior interest<br/>in electricity<br/>supply topics</i>                                     | 0.11*** | hydropower                               | 5.1 (1.3)        | 5.8 (1.4)                                                                              | 0.02    | <i>no s.s. effects</i>                   |                  | 0.03**                                                                  | climate change         | 3.9 (1.2)              | 4.5 (0.9)        |                   |
|                                                                                                |         | rooftop solar PV                         | 5.2 (1.4)        | 6.2 (1.2)                                                                              |         |                                          |                  |                                                                         | local air<br>pollution | 4.0 (1.1)              | 4.6 (0.7)        |                   |
|                                                                                                |         | open field solar<br>PV                   | 4.8 (1.5)        | 5.9 (1.4)                                                                              |         |                                          |                  |                                                                         | land use               | 3.8 (1.1)              | 4.2 (1.0)        |                   |
|                                                                                                |         | offshore wind                            | 4.9 (1.7)        | 6.0 (1.3)                                                                              |         |                                          |                  |                                                                         | electricity<br>costs   | 4.2 (0.8)              | 4.5 (0.7)        |                   |
|                                                                                                |         | natural gas                              | 3.5 (1.4)        | 4.5 (1.8)                                                                              |         |                                          |                  |                                                                         | employment             | 4.0 (0.9)              | 4.3 (0.9)        |                   |
|                                                                                                |         | coal                                     | 3.5 (1.5)        | 4.7 (1.9)                                                                              |         |                                          |                  |                                                                         |                        |                        |                  |                   |
|                                                                                                |         | coal with CCS                            | 2.8 (1.5)        | 3.4 (2.2)                                                                              |         |                                          |                  |                                                                         |                        |                        |                  |                   |
|                                                                                                |         | electricity<br>savings and<br>efficiency | 4.9 (1.5)        | 6.2 (1.1)                                                                              |         |                                          |                  |                                                                         |                        |                        |                  |                   |
| <i>attitudes<br/>towards<br/>current<br/>targets for<br/>renewable<br/>electricity</i>         | 0.17*** |                                          | lower<br>targets | higher<br>targets                                                                      | 0.15*** | hydropower                               | lower<br>targets | higher<br>targets                                                       | 0.07**                 | climate change         | lower<br>targets | higher<br>targets |
|                                                                                                |         | hydropower                               | 4.6 (1.7)        | 5.4 (1.4)                                                                              |         | hydropower                               | 45 (38)          | 63 (34)                                                                 |                        | local air<br>pollution | 3.8 (1.3)        | 4.4 (0.8)         |
|                                                                                                |         | rooftop solar PV                         | 4.6 (1.7)        | 5.7 (1.3)                                                                              |         | rooftop solar PV                         | 40 (32)          | 64 (32)                                                                 |                        |                        | 3.9 (1.1)        | 4.4 (0.7)         |
|                                                                                                |         | open field solar<br>PV                   | 4.3 (1.7)        | 5.5 (1.4)                                                                              |         | open field solar<br>PV                   | 47 (32)          | 71 (31)                                                                 |                        | land use               | 3.8 (1.0)        | 4.0 (1.0)         |
|                                                                                                |         | onshore wind                             | 4.5 (1.8)        | 5.3 (1.5)                                                                              |         | onshore wind                             | 33 (34)          | 56 (35)                                                                 |                        | electricity<br>costs   | 4.0 (1.0)        | 4.3 (0.8)         |
|                                                                                                |         | offshore wind                            | 4.5 (1.7)        | 5.5 (1.5)                                                                              |         | offshore wind                            | 45 (28)          | 65 (30)                                                                 |                        | employment             | 3.6 (1.0)        | 4.0 (0.9)         |
|                                                                                                |         | nuclear power                            | 3.9 (2.1)        | 3.4 (2.0)                                                                              |         | nuclear power                            | 38 (35)          | 25 (28)                                                                 |                        |                        |                  |                   |
|                                                                                                |         | natural gas                              | 3.8 (1.6)        | 4.0 (1.7)                                                                              |         | natural gas                              | 12 (16)          | 13 (16)                                                                 |                        |                        |                  |                   |
|                                                                                                |         | natural gas with<br>CCS                  | 3.4 (1.9)        | 2.7 (1.7)                                                                              |         | coal                                     | 13 (21)          | 6 (11)                                                                  |                        |                        |                  |                   |
|                                                                                                |         | coal with CCS                            | 3.2 (1.6)        | 3.1 (1.8)                                                                              |         | electricity<br>savings and<br>efficiency | 43 (34)          | 49 (34)                                                                 |                        |                        |                  |                   |
|                                                                                                |         | electricity<br>savings and<br>efficiency | 4.7 (1.6)        | 5.6 (1.3)                                                                              |         |                                          |                  |                                                                         |                        |                        |                  |                   |

Note: \* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ . s.s. = statistically significant.

Statistical significance was calculated with MANCOVA using the respondents' country as a fixed factor and the respondents' demographics, political orientations, and attitudes towards electricity transition and governance as covariates.

Among respondents with different *attitudes towards current targets for renewable electricity*, the highest consensus on *individual technology preferences* was still found on negative views on net import, and alternatives with CCS. Respondents that reported that current targets should be higher had, on average, statistically significantly more negative views to alternatives with CCS than respondents that reported that current targets should be lower ( $M$  for natural gas with CCS for respondents preferring lower targets: 3.4, higher: 2.7,  $\eta = 0.65$ ; coal with CCS for lower: 3.2, higher: 3.1,  $\eta = 0.77$ ). In contrast, respondents that wanted higher targets had, on average, statistically significantly more positive views on electricity savings and efficiency, hydropower, and both types of solar PV and wind power ( $M$  for electricity savings and efficiency for lower targets: 4.7, higher: 5.6,  $\eta = 0.58$ ; hydropower for lower: 4.6, higher: 5.4,  $\eta = 0.45$ ; rooftop solar PV for lower: 4.6, higher: 5.7,  $\eta = 0.58$ ; open field solar PV for lower: 4.3, higher: 5.5,  $\eta = 0.54$ ; onshore wind for lower: 4.5, higher: 5.3,  $\eta = 0.47$ ; offshore wind for lower: 4.5, higher: 5.5,  $\eta = 0.59$ ). Surprisingly, respondents that wanted higher targets for renewable electricity had also slightly more positive views on natural gas than the rest (lower targets: 3.8, higher: 4.0,  $\eta = 0.82$ ), potentially perceiving natural gas plants either as technology for renewable electricity integration or as a transition technology. Out of all the aforementioned statistically significant differences, only differences in hydropower and onshore wind could be identified as potential divergences. Although overlapping indices were slightly below 0.5 for hydropower and onshore wind, more than 50% of respondents had positive preferences for these technologies, indicating only marginal divergence (Section B.9 in Appendix B). A small divergence was identified for nuclear power too: respondents that wanted lower renewable targets had ambivalent views to nuclear power while respondents that wanted higher targets had mostly negative views ( $M$  for respondents preferring lower targets: 3.9, higher: 3.4, overlapping index  $\eta = 0.75$ ). Additionally, respondents reporting that targets should stay the same tended to be slightly more ambivalent than the rest of the respondents for all alternatives (see Section B.9 in Appendix B for more details).

In terms of preferred scenarios in Riskmeter, the highest consensus among respondents with different *attitudes towards current targets for renewable electricity* was found for low shares of net import and alternatives with CCS ( $M$  for net import for lower targets: 5%, higher: 5%,  $\eta = 0.74$ ; natural gas with CCS for lower: 20%, higher: 19%,  $\eta = 0.77$ ; coal with CCS for lower: 11%, higher: 12%,  $\eta = 0.73$ ). There was also consensus on moderate shares of electricity savings and efficiency and low shares of coal and nuclear power. However, respondents that wanted higher renewable targets used slightly lower shares of coal and nuclear power and higher shares of electricity savings and efficiency than the rest ( $M$  for coal for lower targets: 13%, higher: 6%,  $\eta = 0.65$ ; nuclear power for lower: 38%, higher: 25%,  $\eta = 0.60$ ; electricity savings and efficiency for lower: 43%, higher: 49%,  $\eta = 0.82$ ). Respondents that wanted higher renewable targets had also slightly higher shares of natural gas (lower targets: 12%, higher: 13%,  $\eta = 0.84$ ), following the same pattern as with *individual technology preferences*. Divergences were found for hydropower, both types of solar PV and wind power, where respondents that preferred higher

targets for renewable electricity used much higher shares of these technologies than respondents that preferred lower targets ( $M$  for hydropower for lower targets: 45%, higher: 63%,  $\eta = 0.63$ ; rooftop solar PV for lower: 40%, higher: 64%,  $\eta = 0.51$ ; open field solar PV for lower: 47%, higher: 71%,  $\eta = 0.54$ ; onshore wind for lower: 33%, higher: 56%,  $\eta = 0.53$ ; offshore wind for lower: 45%, higher: 65%,  $\eta = 0.55$ ). These divergences followed similar patterns as in *individual technology preferences*, where respondents that preferred lower renewable targets had less positive preferences for these technologies. A potential reason for the distinctly higher potentials used in the Riskmeter by respondents that preferred higher targets was that they preferred scenarios based on renewable sources almost exclusively. Since hydropower, solar PV, and wind power were the renewable sources with the largest potentials, these respondents had to add them in large shares in order to cover the electricity demand. In terms of *impact ratings*, there was consensus that impacts on land use, electricity costs, and employment are important, with respondents that wanted higher renewable electricity targets having, on average, slightly higher importance ratings ( $M$  for land use for lower: 3.8, higher: 4.0,  $\eta = 0.64$ ; electricity costs for lower: 4.0, higher: 4.3,  $\eta = 0.64$ ; employment for lower: 3.6, higher: 4.0,  $\eta = 0.61$ ). Potential divergences have been found on impacts on climate change and local air pollution, where most respondents that preferred higher targets reported that these impacts were very important, in contrast to the rest of the respondents ( $M$  for climate change impacts for lower targets: 3.8, higher: 4.4,  $\eta = 0.43$ ; local air pollution for lower: 3.9, higher: 4.4,  $\eta = 0.43$ ). Still, more than 65% of respondents that preferred lower targets reported that these impacts were at least important, indicating that the divergences are only minor.

#### 4.3.5 Consensus among citizens of different attitudes towards governance

Among respondents with different governance *attitudes towards decision-making levels, attitudes towards the EU membership, trust in institutions, and sense of belonging*, there were almost no divergences in terms of *individual technology preferences*, preferred scenarios, and *impact ratings*. For example, there was high consensus among respondents with different *attitudes towards decision-making levels* for electricity supply across all *individual technology preferences* (Table 4.5). Between respondents that wanted electricity decisions to be local or national and respondents that wanted supranational decisions (EU or UN), the highest consensus occurred on negative views on natural gas with CCS ( $M$  for respondents preferring local or national decisions: 3.0, EU or UN decisions: 2.9,  $\eta = 0.90$ ) and coal with CCS ( $M$  for local or national: 3.2, EU or UN: 3.3,  $\eta = 0.87$ ). Strong consensus was also found on positive views on electricity savings and efficiency and offshore wind ( $M$  for electricity savings and efficiency for local or national decisions: 5.2, EU or UN decisions: 5.6,  $\eta = 0.82$ ; offshore wind for local or national: 5.1, EU or UN: 5.5,  $\eta = 0.81$ ). Similar results were obtained by comparing the preferences of respondents with different *attitudes towards decision-making levels* for all impacts of electricity supply (see Section B.9 in Appendix B for more details).

Table 4.5. Statistically significant effects of governance attitudes on *individual technology preferences*, preferred scenarios for national electricity supply, and *impact ratings*. Full MANCOVA results as well as means and standard deviations for all variables can be found in Section B.9 in Appendix B.

|                                              | Individual technology preferences<br>(from 1 = strongly disagree to 7 = strongly agree) |                                       |           |           | Preferred scenarios for national electricity<br>supply<br>(used Riskmeter potential in %) |                                 |  | Impact ratings<br>(from 1 = not important to 5 = very important) |         |                                 |                      |           |
|----------------------------------------------|-----------------------------------------------------------------------------------------|---------------------------------------|-----------|-----------|-------------------------------------------------------------------------------------------|---------------------------------|--|------------------------------------------------------------------|---------|---------------------------------|----------------------|-----------|
|                                              | V                                                                                       | s.s. effects                          |           | M (SD)    | V                                                                                         | s.s. effects                    |  | M (SD)                                                           | V       | s.s. effects                    |                      | M (SD)    |
|                                              |                                                                                         |                                       |           |           |                                                                                           |                                 |  |                                                                  |         |                                 |                      |           |
| attitudes towards decision-<br>making levels |                                                                                         |                                       |           |           |                                                                                           |                                 |  |                                                                  |         |                                 |                      |           |
| electricity supply                           | 0.03                                                                                    | no s.s. effects                       |           |           | 0.02                                                                                      | no s.s. effects                 |  |                                                                  | -       | not included in the calculation |                      |           |
| climate change impacts                       | -                                                                                       |                                       |           |           | -                                                                                         |                                 |  |                                                                  | 0.06*** | climate change                  | local or<br>national | EU or UN  |
|                                              |                                                                                         | not included in the calculation       |           |           |                                                                                           | not included in the calculation |  |                                                                  |         | local air pollution             | 3.5 (1.3)            | 4.3 (0.9) |
| local air pollution impacts                  | -                                                                                       |                                       |           |           | -                                                                                         |                                 |  |                                                                  |         | electricity costs               | 3.7 (1.3)            | 4.3 (0.8) |
| land use impacts                             | -                                                                                       |                                       |           |           | -                                                                                         |                                 |  |                                                                  | 0.02    |                                 | 4.0 (1.1)            | 4.2 (0.8) |
| electricity costs impacts                    | -                                                                                       |                                       |           |           | -                                                                                         |                                 |  |                                                                  | 0.01    | no s.s. effects                 |                      |           |
| employment impacts                           | -                                                                                       |                                       |           |           | -                                                                                         |                                 |  |                                                                  | 0.01    |                                 |                      |           |
|                                              |                                                                                         |                                       |           |           |                                                                                           |                                 |  |                                                                  | 0       |                                 |                      |           |
| attitudes towards the EU<br>membership       | 0.02                                                                                    | no s.s. effects                       |           |           | 0.04                                                                                      | no s.s. effects                 |  |                                                                  | 0.02    | no s.s. effects                 |                      |           |
|                                              |                                                                                         |                                       |           |           |                                                                                           |                                 |  |                                                                  |         |                                 |                      |           |
| trust in institutions                        |                                                                                         |                                       |           |           |                                                                                           |                                 |  |                                                                  |         |                                 |                      |           |
|                                              |                                                                                         |                                       | low       | high      |                                                                                           |                                 |  |                                                                  |         |                                 |                      |           |
| local public authorities                     | 0.05*                                                                                   | rooftop solar PV                      | 5.1 (1.7) | 5.7 (1.2) | 0.02                                                                                      |                                 |  |                                                                  | 0.01    |                                 |                      |           |
|                                              |                                                                                         | natural gas (CCS)                     | 3.3 (1.9) | 2.8 (1.6) |                                                                                           | no s.s. effects                 |  |                                                                  |         | no s.s. effects                 |                      |           |
|                                              |                                                                                         | electricity savings<br>and efficiency | 5.2 (1.5) | 5.6 (1.2) |                                                                                           |                                 |  |                                                                  |         |                                 |                      |           |
| national government                          | 0.04                                                                                    | no s.s. effects                       |           |           | 0.02                                                                                      |                                 |  |                                                                  | 0.02    |                                 |                      |           |
| EU                                           | 0.02                                                                                    |                                       |           |           | 0.04                                                                                      |                                 |  |                                                                  | 0.01    |                                 |                      |           |
|                                              |                                                                                         |                                       |           |           |                                                                                           |                                 |  |                                                                  |         |                                 |                      |           |
| sense of belonging                           |                                                                                         |                                       |           |           |                                                                                           |                                 |  |                                                                  |         |                                 |                      |           |
| city or region                               | 0.02                                                                                    |                                       |           |           | 0.03                                                                                      |                                 |  |                                                                  | 0.01    | no s.s. effects                 |                      |           |
| country                                      | 0.03                                                                                    |                                       |           |           | 0.03                                                                                      |                                 |  |                                                                  | 0.02*   | land use                        | weak                 | strong    |
|                                              |                                                                                         | no s.s. effects                       |           |           |                                                                                           | no s.s. effects                 |  |                                                                  |         | electricity costs               | 3.7 (1.2)            | 4.0 (0.9) |
| Europe                                       | 0.03                                                                                    |                                       |           |           | 0.04                                                                                      |                                 |  |                                                                  | 0.01    | employment                      | 4.1 (1.1)            | 4.2 (0.8) |
| the World                                    | 0.02                                                                                    |                                       |           |           | 0.02                                                                                      |                                 |  |                                                                  | 0.02*   | climate change                  | 3.8 (1.2)            | 4.4 (0.9) |
|                                              |                                                                                         |                                       |           |           |                                                                                           |                                 |  |                                                                  |         | employment                      | 3.8 (1.1)            | 4.1 (0.9) |

Note: \* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ . s.s. = statistically significant.

Statistical significance was calculated with MANCOVA using the respondents' country as a fixed factor and the respondents' demographics, political orientations, and attitudes towards electricity transition and governance as covariates. In terms of *attitudes towards decision-making levels*, only relevant items were added for each dependent variable: (1) attitudes towards decisions related to electricity supply were added for *individual technology preferences* and preferred scenarios and (2) attitudes towards decisions related to impacts were added for *impact ratings*.

#### 4. Consensus on future EU electricity supply among citizens of France, Germany, and Poland

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No divergences have been identified neither for *individual technology preferences* nor preferred scenarios among respondents with different *attitudes towards decision-making levels*, as there were no statistically significant differences among them and all overlapping indices remained above 0.5 (see also Section B.6 in Appendix B).

In terms of preferred Riskmeter scenarios, there was also consensus among respondents with different *attitudes towards decision-making levels* across all alternatives. The highest consensus was found on moderate shares of electricity savings and efficiency and offshore wind as well as on low shares of alternatives with CCS ( $M$  for electricity savings and efficiency for local or national decisions: 44%, EU or UN decisions: 46%,  $\eta = 0.88$ ; offshore wind for local or national: 57%, EU or UN: 61%,  $\eta = 0.86$ ; natural gas with CCS for local or national: 18%, EU or UN: 21%,  $\eta = 0.78$ ; coal with CCS for local or national: 12%, EU or UN: 12%,  $\eta = 0.88$ ). In terms of *impact ratings*, consensus was identified for almost all impact types and *attitudes towards decision-making levels*. The only divergences were found between respondents with different *attitudes towards decision-making levels* for climate change impacts. Specifically, respondents that reported that mitigation of climate change impacts should be managed at an EU or UN level had higher ratings for climate change impacts, local air pollution, and electricity costs than the rest of the respondents ( $M$  for climate change impacts for local or national decisions: 3.5, EU or UN decisions: 4.3,  $\eta = 0.45$ ; local air pollution for local or national: 3.7, EU or UN: 4.3,  $\eta = 0.42$ ; electricity costs for local or national: 4.0, EU or UN: 4.2,  $\eta = 0.53$ ). All other impacts were rated as important or very important by more than 68% of respondents regardless of their *attitudes towards decision-making levels* (see Section B.9 in Appendix B for more details).

Among citizens with different *attitudes towards the EU membership* of their country, the highest consensus on *individual technology preferences* was found on negative views on nuclear power ( $M$  for nuclear power for respondents with negative EU membership attitudes: 3.6, positive: 3.7, overlapping index  $\eta = 0.88$ ). High consensus was also identified on positive views on electricity savings and efficiency, where more than 55% of all respondents had positive views regardless of their *attitudes towards the EU membership* ( $M$  for electricity savings and efficiency for negative EU attitudes: 5.4, positive: 5.6,  $\eta = 0.75$ ). Overall, no divergences were found as preferences were similarly distributed for groups of respondents with different *attitudes towards the EU membership* and there were no statistically significant differences among them (Table 4.5). Marginal consensus was found even on the technologies with the lowest overlapping indices, i.e., onshore wind ( $\eta = 0.43$ ) and hydropower ( $\eta = 0.51$ ), as more than 50% of all respondents had positive views on them. While respondents with negative attitudes towards the EU had, on average, lower preferences for these technologies than the rest of the respondents, differences were not statistically significant ( $M$  for onshore wind for negative EU attitudes: 4.4, positive: 5.4; hydropower for negative: 5.3, positive: 5.4).

As with *individual technology preferences*, no divergences have been found among the preferred Riskmeter scenarios of citizens with different *attitudes towards the EU membership*, as there were no statistically significant differences and overlapping indices were well above 0.5

(see Table 4.5 and Section B.6 in Appendix B). The highest consensus on preferred scenarios was identified for moderate shares of electricity savings and efficiency and low shares of natural gas and coal ( $M$  for electricity savings and efficiency for negative EU attitudes: 39%, positive: 46%,  $\eta = 0.83$ ; natural gas for negative: 15%, positive: 15%,  $\eta = 0.85$ ; coal for negative: 8%, positive: 7%,  $\eta = 0.86$ ). As in the case of *individual technology preferences*, consensus was also found on low to moderate shares of nuclear power ( $M$  for nuclear power for negative EU attitudes: 33%, positive: 26%,  $\eta = 0.73$ ). There was also consensus on the importance of impacts, with more than 58% of all respondents reporting that all impacts are important or very important. On average, respondents with positive *attitudes towards the EU membership* had slightly higher *impact ratings* than the rest, especially for climate change and local air pollution. However, none of these differences were statistically significant (Table 4.5).

Interestingly, no divergences have been identified among respondents with different levels of trust in their local public authorities, their national government, the EU, or the UN. Among respondents with high to low levels of trust in the local public authorities of their city or region, the highest consensus on *individual technology preferences* was found on negative views on net import and alternatives with CCS ( $M$  for net import for respondents with low trust: 3.3, high: 3.0,  $\eta = 0.82$ ; coal with CCS for low: 3.4, high: 3.2,  $\eta = 0.83$ ; natural gas with CCS for low: 3.3, high: 2.8,  $\eta = 0.71$ ). Strong consensus was also identified on positive opinions on electricity savings and efficiency and both types of solar PV and wind power. More than 58% of respondents had positive opinions on the aforementioned technologies, while respondents with higher trust had statistically significantly more positive opinions on electricity savings and efficiency and rooftop solar PV ( $M$  for electricity savings and efficiency for low trust: 5.2, high: 5.6,  $\eta = 0.75$ ; rooftop solar PV for low: 5.1, high: 5.7,  $\eta = 0.71$ ; open field solar PV for low: 5.0, high: 5.4,  $\eta = 0.75$ ; onshore wind for low: 4.7, high: 5.3,  $\eta = 0.74$ ; offshore wind for low: 5.0, high: 5.4,  $\eta = 0.77$ ). Small differences among respondents with different trust levels have been identified on coal and natural gas, where respondents with higher trust had, on average, a slightly positive opinion on these technologies and respondents with lower trust had a slightly negative opinion ( $M$  for coal for low trust: 3.8, high: 4.2,  $\eta = 0.78$ ; natural gas for low: 3.7, high: 4.1,  $\eta = 0.76$ ). However, none of these differences were statistically significant (Table 4.5). Additionally, overlapping indices were much higher than 0.5, suggesting that a large majority of respondents had rather similar opinions regardless of their trust levels. The same patterns have been also found among respondents with different trust in the national government, EU, and UN, where all overlapping indices stayed well above 0.5 (see Section B.6 in Appendix B for more details).

In terms of preferred scenarios in Riskmeter, the highest consensus was found on high shares on hydropower and electricity savings and efficiency and low shares of natural gas with CCS (e.g.,  $M$  for electricity savings and efficiency for respondents with low trust in local public authorities: 47%, high: 44%,  $\eta = 0.88$ ; hydropower for low: 61%, high: 59%,  $\eta = 0.91$ ; natural gas with CCS for low: 18%, high: 18%,  $\eta = 0.87$ ). Consensus was also found on low shares of net import and coal with CCS and moderate to high shares of both types of solar PV and wind power

(*M* for net import for low: 3%, high: 4%,  $\eta = 0.72$ ; coal with CCS for low: 15%, high: 10%,  $\eta = 0.63$ ; rooftop solar PV for low: 61%, high: 57%,  $\eta = 0.78$ ; open field solar PV for low: 66%, high: 64%,  $\eta = 0.86$ ; onshore wind for low: 47%, high: 46%,  $\eta = 0.82$ ; offshore wind for low: 56%, high: 61%,  $\eta = 0.83$ ). Similar to *individual technology preferences*, there were no divergences in preferred scenarios as all overlapping indices were well above 0.6 and there were no statistically significant differences between respondents with different trust levels (see Sections B.6 and B.9 in Appendix B for more details). Consensus was also found on *impact ratings*, where more than 67% of respondents suggested that all impacts are important or very important regardless of their level of trust. Differences in *impact ratings* were mostly limited among respondents with different trust levels, with the largest differences found for climate change impacts.

Among respondents with a different *sense of belonging* to their city or region, country, Europe, and the World, no divergences have been found for all examined variables. In terms of respondents with a different *sense of belonging* to their city or region, there was consensus across all *individual technology preferences*. The highest consensus was identified for positive views on electricity savings and efficiency and both types of wind power (*M* for electricity savings and efficiency for respondents with a weak *sense of belonging*: 5.1, strong: 5.4,  $\eta = 0.79$ ; onshore wind for weak: 4.8, strong: 5.1,  $\eta = 0.80$ ; offshore wind for weak: 5.1, strong: 5.3,  $\eta = 0.79$ ). Additionally, a high consensus was observed on negative opinions on net import and alternatives with CCS (*M* for net import for weak a *sense of belonging*: 3.1, strong: 3.2,  $\eta = 0.83$ ; natural gas with CCS for weak: 2.7, strong: 3.0,  $\eta = 0.80$ ; coal with CCS for weak: 2.7, strong: 3.4,  $\eta = 0.73$ ). The above findings were similar among respondents with a different *sense of belonging* to their country, Europe, and the World (see Section B.9 in Appendix B for more details). Overlapping indices were way above 0.50 for all *individual technology preferences* and all levels of *sense of belonging*, indicating that there were no divergences and that groups of respondents with a different *sense of belonging* shared similar preferences (see Section B.9 in Appendix B for more details).

There was also consensus among respondents with a different *sense of belonging* in terms of all alternatives included in preferred Riskmeter scenarios. The highest consensus on preferred Riskmeter scenarios was found on moderate shares of hydropower and wind power, and low shares of alternatives with CCS (*M* for hydropower for respondents with a weak *sense of belonging* to their city or region: 62%, strong: 59%,  $\eta = 0.89$ ; onshore wind for weak: 49%, strong: 46%,  $\eta = 0.83$ ; offshore wind for weak: 62%, strong: 57%,  $\eta = 0.86$ ; natural gas with CCS for weak: 18%, strong: 20%,  $\eta = 0.78$ ; coal with CCS for weak: 14%, strong: 11%,  $\eta = 0.79$ ). Similar to the findings for *individual technology preferences*, no divergences have been found for preferred scenarios as all overlapping indices were well above 0.5 and there were no statistically significant differences (see Table 4.5 and Section B.6 in Appendix B). In terms of impact ratings, more than 65% of respondents reported that all impacts were at least important regardless of their *sense of belonging*. Nevertheless, statistically significant differences have been found for respondents with a different *sense of belonging* to their country and the World (Table 4.5).



Specifically, respondents that had a strong *sense of belonging* to their country gave higher importance to impacts to land use, electricity costs, and employment than the rest of the respondents (*M* for land use for a weak *sense of belonging*: 3.7, strong: 4.0,  $\eta = 0.52$ ; electricity costs for weak: 4.1, strong: 4.2,  $\eta = 0.53$ ; employment for weak: 3.8, strong: 4.0,  $\eta = 0.52$ ). Similarly, respondents with a strong *sense of belonging* to the World reported higher importance for impacts to climate change and employment (*M* for climate change for a weak sense of belonging: 3.8, strong: 4.4,  $\eta = 0.51$ ; employment for weak: 3.8, strong: 4.1,  $\eta = 0.62$ ).

## 4.4 Discussion

As shown in Figure 4.5 that summarizes the key findings, there is a consensus among the respondents with different demographics, political orientations, and attitudes towards governance on having positive views towards hydropower, rooftop and open field solar PV, onshore and offshore wind power, biomass, and electricity savings and efficiency for their national electricity supply. This consensus in terms of *individual technology preferences* is also reflected in the respondents' preferred scenarios, where most respondents used high or moderate Riskmeter potential from these alternatives, regardless of their demographics or attitudes. A similar consensus on positive views is found among the respondents from France, Germany, and Poland for all aforementioned technologies, except for onshore wind, where Polish respondents used high Riskmeter shares in their scenarios and French and German used moderate shares. A high preference for renewable sources and efficiency is expected from citizens of these three countries, as shown by recent large-scale surveys (European Commission, 2018b; Poortinga et al., 2018). A consistent consensus is also found among most respondents on negative views and low Riskmeter shares on natural gas and coal with CCS and on net electricity imports. Previous studies had also shown that the public in the examined countries was indeed concerned about import dependency (Demski et al., 2018) and about CCS as an unknown or untested technology (L'Orange Seigo et al., 2014; Upham and Roberts, 2011). In terms of electricity supply impacts, most respondents agreed that impacts on climate change, local air pollution, land use, electricity costs, and employment are all important or very important, as also shown in previous studies (European Commission, 2019a; Poortinga et al., 2018). This finding is, to some extent, an artefact of the survey's question that used Likert scales to assess the importance of each impact individually. In a previous study where citizens could prioritize impacts, more differentiation among the impacts could be observed. For instance, energy affordability was more important for Polish citizens than climate change concerns, and vice versa for French and German citizens (Poortinga et al., 2018). While the results of the current study cannot prove whether there is consensus on impact priorities, at least they show that none of these impacts were unimportant for most respondents.

#### 4. Consensus on future EU electricity supply among citizens of France, Germany, and Poland

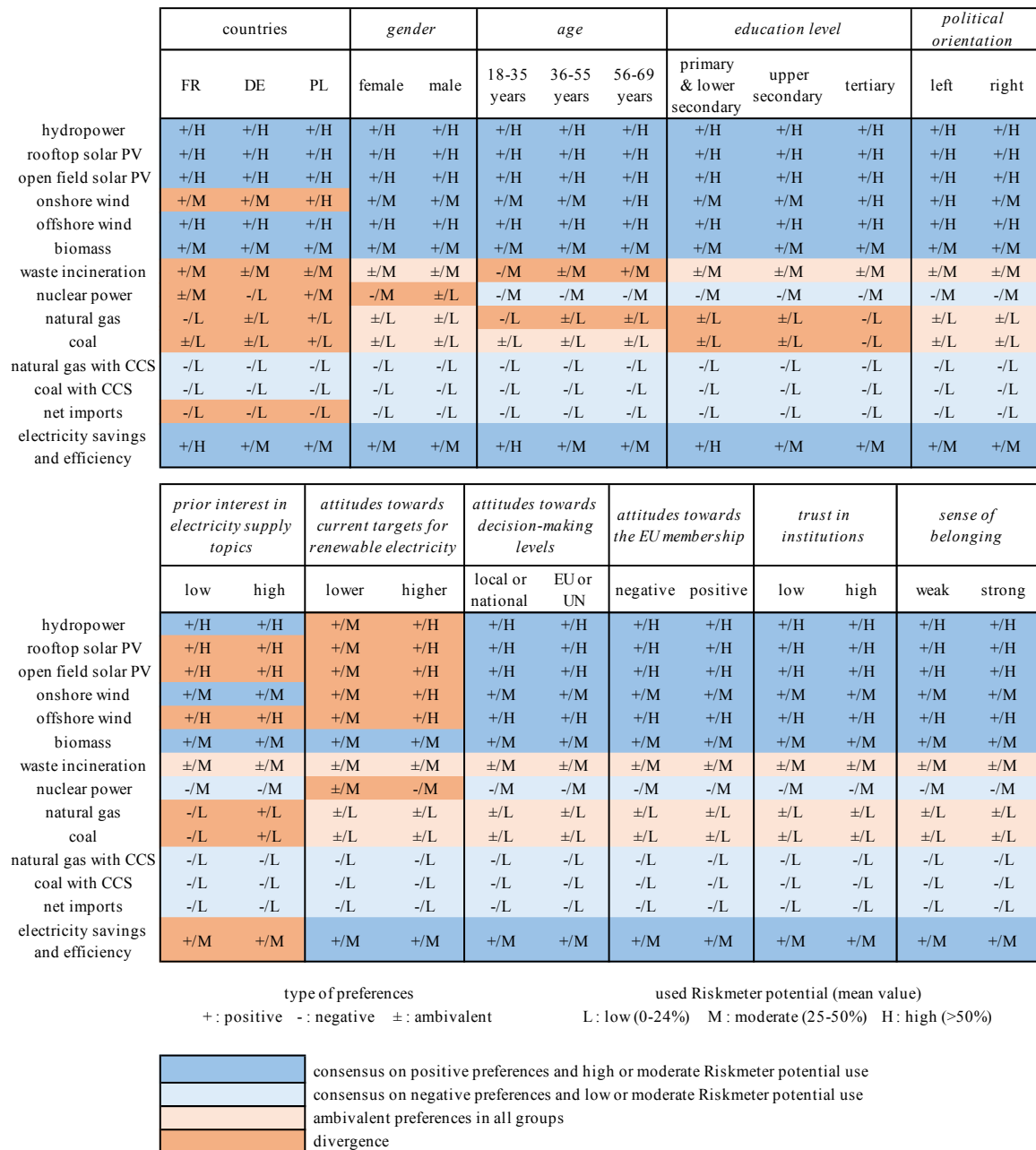


Figure 4.5. Consensus and divergences on *individual technology preferences* and preferred scenarios among citizens of different countries, demographics, *political orientations*, and attitudes. See Table 4.1 for more information on the criteria for splitting variables into categories (e.g., weak and strong *sense of belonging*)

Divergences are found among the respondents from different countries, demographics, and attitudes towards electricity supply for natural gas, coal, waste incineration, and nuclear power (Figure 4.5). Interestingly, despite the diverse political orientations and attitudes towards governance of the respondents (Table 4.2), there are no divergences for these respondents' characteristics. While this does not prove that divergences do not exist, it suggests that attitudes towards political and governance aspects are less divisive than country contexts and other examined characteristics. Indeed, Polish respondents had higher Riskmeter shares and more

positive views towards coal and natural gas than French and German respondents, possibly due to the widely held perceptions among Polish citizens that coal and gas power plants are important for providing jobs and security of supply (Demski et al., 2018; Skjærseth, 2018). Similarly, the different views towards nuclear power—negative for German respondents, ambivalent for French, and positive for Polish—reflect coupling between policy and citizen preferences, where citizen preferences are affected by policy decisions and targets and vice versa (Mettler and Soss, 2004). Tellingly, Germany currently plans to phase-out nuclear plants, France – to reduce them despite their prevalence, and Poland – to build new ones (BMWi, 2020a; Ministry of State Assets, 2020; MTES, 2020a). Identified divergences among respondents with different demographics also fit patterns in the literature (S. S. Ho et al., 2019; Keller et al., 2012; Liebe and Dobers, 2019; Xexakis et al., 2020): younger and more educated respondents had more negative views on natural gas and coal than the rest, while female respondents had more negative views on nuclear power. In terms of attitudes towards electricity supply, respondents that wanted high national targets for renewable sources also used high shares of renewable electricity in their scenarios. Respondents with higher *prior interest in electricity supply topics* had more positive views towards diverse technologies: offshore wind and rooftop and open field solar PV, but also coal and natural gas. While interest in these topics correlates with strong preferences (Boudet, 2019; Jobin et al., 2019), this unlikely mix of preferences suggests that there may be multiple subgroups of respondents with high interest towards different technologies.

Most findings on consensus and divergence among respondents are similar between *individual technology preferences* and preferred scenarios and between national and EU preferences. For the latter, respondents were possibly extrapolating their established national preferences to the EU level. For example, Polish respondents had, on average, positive views on using nuclear power throughout the EU27, German respondents had negative views, and French respondents were more ambivalent, in a striking similarity to their national preferences. Respondents were possibly more familiar with their national electricity context than the EU one, while the EU electricity system was also more psychologically distant and abstract for them (Spence et al., 2012). On the other hand, the similarity between *individual technology preferences* and scenario preferences indicates that most respondents chose Riskmeter scenarios that reflected their preferences. However, respondents chose to create more diversified scenarios than their *individual technology preferences* suggested. For example, while most respondents were favorable towards renewable sources, they did not create fully renewable scenarios. Respondents may have diversified their scenarios due to supply security concerns or because they wanted to keep some of the existing infrastructure to avoid radical change (Demski et al., 2018; Stadelmann-Steffen and Eder, 2020). Another explanation may lie in the interactive information on impacts shown in the Riskmeter (Figure 4.1), as respondents may have attempted to balance them by diversifying their scenarios. Additionally, the information provided by the Riskmeter may have filled knowledge gaps for unfamiliar

technologies, such as CCS (Arning et al., 2020; Boudet, 2019; Harold et al., 2016). While respondents had more negative views towards coal and natural gas with CCS than without it, they used equal or more potential from fossil fuels with CCS, potentially due to the lower impacts on climate change. Another potential benefit of the Riskmeter is that it quantifies technology shares in TWh/year, avoiding the subjective interpretation of Likert scales in the *individual technology preferences*. For instance, all samples had on average ambivalent preferences for coal and natural gas, which could have been interpreted as moderate shares in the scenarios. In reality, respondents used very small shares from these technologies in the Riskmeter, despite being able to cover all demand with them. Overall, results suggest that Riskmeter scenarios approximated patterns of individual preferences, while potentially reducing misinterpretations and knowledge gaps. Still, less divergences are found in preferred scenarios than in *individual technology preferences*, suggesting that the Riskmeter may have slightly homogenized preferences.

Apart from patterns in consensus, this study also provides quantified preferences in terms of Riskmeter scenarios to inform electricity system modeling. Regardless of their demographics or attitudes, most respondents selected an electricity mix that was vastly different from the current one in their countries and the EU, with a drastic increase of solar and wind power and a reduction of traditional sources, such as coal in Poland and Germany and nuclear power in France (see Section B.10 in Appendix B for details). Most preferred scenarios also included a share of fossil fuels with CCS, almost as large as the one without CCS and covering 7-8% of the total supply in France and the EU, 5% in Germany, and 16% in Poland. These findings indicate that the modeling community needs to go well beyond business as usual and systematically assess scenarios with significant decarbonization and denuclearization as early as in 2035, including a limited CCS deployment. Additionally, modeling teams should assess variations of such scenarios with low net electricity imports from neighboring countries, as predominantly preferred by the respondents. The need to quantify more ambitious scenarios is becoming even more pressing, as many recent high-profile scenarios in the examined countries and the EU are lagging behind the preferences of the respondents. For example, most of the long-term scenarios of the French transmission system operator expect more than 46% of electricity to come from nuclear plants in 2035 (RTE, 2017), while most respondents preferred less than 20%. Other influential scenario studies assumed that supply shares from coal and gas in 2035 would be at least 30% for Germany and 37% for Poland (without CCS), while most respondents opted for less than 6% and 21% respectively. As for the modeling study that formed the basis of the current decarbonization strategy in the EU (European Commission, 2018b), most scenarios assume less than 13% of electricity from solar PV, while most respondents preferred more than 18%. Since such discrepancies may also exist between citizen preferences and other model-based scenarios, a systematic assessment is required to uncover wider patterns.

## 4.5 Conclusions

Energy scenarios should ideally account for societal feasibility (Jewell and Cherp, 2020; Trutnevyte et al., 2019a) and hence they could be informed by surveys on citizens' preferences. This study evaluated consensus and divergence among citizens of France ( $N = 202$ ), Germany ( $N = 199$ ), and Poland ( $N = 200$ ) on their national and EU electricity supply for 2035 and its impacts, considering also effects from demographics, political orientations, and attitudes towards the transition and governance. Results showed a broad consensus among citizens of all examined characteristics on positive views towards hydropower, solar PV, wind power, biomass, and electricity savings and efficiency, and on negative views towards alternatives with CCS and net imports. Consensus was also found on the high importance of all electricity supply impacts among most of the surveyed citizens. In contrast, Polish respondents supported coal, natural gas, and nuclear power more than French and German respondents, while female respondents had slightly more negative views on nuclear power, young respondents — on natural gas, and educated respondents — on all fossil fuels. Nevertheless, divergences were mostly small, and they were even non-detectable among respondents with different political orientations and attitudes towards governance, suggesting that these attitudes may be less divisive than country contexts and other examined characteristics. Overall, most citizens preferred a diverse electricity mix for their countries and the EU, with high shares of renewable sources, electricity savings, and efficiency and limited shares of nuclear power and fossil fuels, equally with and without CCS.

Most importantly, these results emphasize that citizens from the three EU countries, regardless of their country or personal characteristics, may prefer a more ambitious transition than the one that is currently planned. While coal should be phased out before 2035 in the view of most respondents in Germany and Poland, the current policy target is only in the year 2038 for Germany (BMW, 2020a) and there is no explicit target for Poland (Ministry of State Assets, 2020). For France, respondents suggested that nuclear power should be limited to around 25% of its current supply by 2035, instead of the policy target of 50% (MTES, 2020a). Such discrepancies indicate that model-based scenarios that inform policy may also misalign with the preferences of the citizens and more ambitious scenarios should be modeled. Apart from modeling scenarios with faster decarbonization or denuclearization rates and fewer net imports, findings suggest that citizens may be more accepting of scenarios with small shares of CCS than previously thought (L'Orange Seigo et al., 2014), at least when CCS is evaluated jointly with other technologies. Interactive tools that reveal trade-offs and collect preferences, such as the Riskmeter, can provide data and insights to modeling efforts. Monitoring the public sentiment towards the transition will become even more important as the planned deployments and phase-outs of power plants will unfold and start affecting a larger share of EU citizens. Modelers could, thus, benefit from using interactive tools for preference elicitation, ensuring that their scenarios align with the perspectives of citizens and stakeholders during the transition.

## **Chapter 5 Alignment between model-based and preferred electricity scenarios for France, Germany, Poland, and the EU27**

This chapter is based on Xexakis & Trutnevyte (2022).

### **5.1 Introduction**

In 2021, the European Climate Law was ratified by the European Union (EU27), establishing legal binding targets for the bloc to reach climate neutrality by 2050 and reduce its greenhouse gas (GHG) emissions to 55% by 2030 as compared to 1990 (European Commission, 2021b). To achieve these targets, the EU27 needs to decarbonize its electricity sector fast, reaching almost net zero GHG emissions in the sector by around 2040 (European Commission, 2018b). Additionally, the EU27 aims to integrate the energy markets of its Member States towards an Energy Union, envisioned to increase energy security and reduce dependency on external energy sources (European Commission, 2020b). Pathways and policies for such energy-related targets in Europe and elsewhere have been traditionally informed through the use of energy models (Capros et al., 2018; Nikas et al., 2021). Models can quantify different scenarios for long-term energy planning, examine various uncertainties, and estimate the costs and impacts of each scenario on a variety of social, economic, and environmental indicators (Collins et al., 2018a; Sasse and Trutnevyte, 2020; Tröndle et al., 2019). In the case of the electricity supply for the EU27 and its Member States, scenario modeling has become very common in the last decade (Lindberg et al., 2019; Tsiropoulos et al., 2020), with diverse perspectives from the European Commission, the Member States, academia, industry associations, and NGOs. Scenarios usually represent pathways and uncertainties that modelers more or less subjectively choose to explore (Braunreiter and Blumer, 2018; Tsiropoulos et al., 2020), and the characteristics or priorities of the organization is known to affect the scenario choice (Jaxa-Rozen and Trutnevyte, 2021).

In addition to the views of other stakeholders, the EU27 and its Member States sought to assess public opinion on the topic of electricity supply transition (European Commission, 2019a, 2019b). Understanding the views of European citizens could help anticipate acceptability issues and evaluate the socio-political feasibility of various policy options in the transition (Boudet, 2019;

Höfer and Madlener, 2020). Subsequently, finding scenarios that are aligned with the views of European citizens would be particularly useful to inform policy decisions that are more defensible by policymakers (Cherp et al., 2018; Knoblauch et al., 2019) and to develop new scenarios that contribute to the debate (Xexakis et al., 2020). However, model-based scenarios are known to rarely represent public perspectives explicitly (Elsawah et al., 2020; Schmid et al., 2017; Trutnevyte et al., 2019a) and large divergences between model-based scenarios and citizen views could be expected, as studies in Switzerland showed (Dubois et al., 2019; Volken et al., 2018; Xexakis et al., 2020). Several methodologies exist to combine model-based scenarios and citizen preferences for the energy transition in Europe (Bertsch and Fichtner, 2016; Hirt et al., 2020; Madlener et al., 2007; Schmid and Knopf, 2012; Stagl, 2006; van Sluisveld et al., 2020), many of them based on workshops and multi-criteria decision analysis (Bertsch and Fichtner, 2016; Madlener et al., 2007; Stagl, 2006). Other studies attempted to create model-based scenarios for energy and climate policy in Europe using insights from socio-technical transition studies (Hirt et al., 2020; van Sluisveld et al., 2020), without collecting empirical data on societal preferences. While many of the aforementioned studies developed new scenarios that are to some extent informed by citizens, a more systematic assessment is missing on whether the numerous existing EU scenarios are aligned with citizen perspectives.

Another challenge for policymakers and modelers is that the electricity supply transition in the EU27 needs to be assessed in tandem with the individual transitions of the Member States. Member States vary widely in the structure of their electricity supply (Eurostat, 2020c) and traditionally had different priorities in their national energy strategies, for instance, climate change mitigation in Germany and energy security in Poland (Szulecki et al., 2016). Additionally, Member States have different social, economic, and political contexts which can influence the concerns and opinions of their citizens on energy issues (Demski et al., 2018). Therefore, in order to understand the socio-political feasibility of transition scenarios for the whole bloc, it is important to first assess how citizens of different Member States view the transition of their national electricity supply. Differences in the speed of the transition among Member States may affect the operation of the whole EU27 electricity system as most Member States are interconnected. Further increase in interconnection can be expected, *inter alia*, due to increased electricity trade for balancing variable renewable generation (Neumann, 2020; Tröndle et al., 2019), increased need for electricity storage (ENTSO-E, 2021; Zsiborács et al., 2019), and the need for low-carbon baseload electricity sources (Zappa et al., 2019). Cross-national surveys in Europe show that the views of citizens from different Member States on their national electricity supply converge on positive views on solar and wind power, but diverge on other alternatives, for instance, nuclear power (European Commission, 2019a; Poortinga et al., 2018). There is no study yet that systematically compares how citizens of different Member States envision the supply of the EU27 and how their views compare to model-based scenarios for the EU27.

In order to contribute to the understanding of socio-political feasibility of electricity supply transition in EU27 and how this feasibility is reflected in model-based scenarios, this study

compares systematically compiled multi-organization, multi-model ensembles of existing electricity supply scenarios for France, Germany, Poland, and the whole EU27 against preferred scenarios elicited in a survey (Xexakis and Trutnevyte, 2021a) with French, German, and Polish citizens. Specifically, the study focuses on the following questions: How does electricity supply for the three countries and the whole EU27 in 2035 differs between: a) scenarios preferred by the citizens and b) ensembles of existing multi-organization, multi-model scenarios? What are the topics and degrees of convergence and divergence between them? The three Member States have been chosen since they together constitute about 42% of the EU27 population (Eurostat, 2020d) and they have to address significant transition challenges: Poland and Germany need to phase-out coal to achieve the decarbonization targets (Gawlik and Mokrzycki, 2019; Osorio et al., 2020), Germany has an ambitious renewable energy agenda (BMWi, 2020a), and France aims to retire several aging nuclear power plants (RTE, 2017). Finally, the year 2035 was chosen as a benchmark for the implementation of the transition in Europe, being midway through the long-term target of climate neutrality in 2050.

## 5.2 Methodology

### 5.2.1 Overall study design

The study combined a systematic literature review of scenario studies for the electricity supply of France, Germany, Poland, and the EU27 with a representative online survey with citizens in the three countries. The literature review (Section 2.2) focused on scenario studies published between 2008 and September 2020, i.e., the month that the review occurred. Studies before 2008 were considered less relevant due to the extensive policy changes brought by the introduction of the 20-20-20 climate and energy targets by the European Union in 2007 (European Commission, 2008). The results of the review were then used to compile multi-organization, multi-model ensembles of electricity supply scenarios for 2035 in France, Germany, Poland, and the EU27. The online survey (Xexakis and Trutnevyte, 2021a) used an interactive scenario tool Riskmeter (Xexakis and Trutnevyte, 2020b) (Section 2.3) to collect electricity supply scenarios that were preferred by citizens in France ("FR",  $N = 202$ ), Germany ("DE",  $N = 199$ ), and Poland ("PL",  $N = 200$ ). Finally, the study analyzed the similarities and differences between these multi-organization, multi-model scenario ensembles (henceforth referred to as "model-based scenarios") and the preferred scenarios for the electricity supply in France, Germany, Poland, and the EU27 (Section 2.4).

### 5.2.2 Systematic review of existing model-based scenarios

The review focused on studies that provided numerical results from model-based scenarios on the future electricity supply in 2035 in France, Germany, Poland, and the EU27. The



process to collect the studies comprised three steps. First, online archives of public institutions were searched, such as those from national ministries in charge of energy (BMWi, 2020b; MTES, 2020c; Republic of Poland, 2020) and the European Commission (European Commission, 2020c). Second, the Web of Science platform was searched for peer-reviewed studies using three layers of keywords: (1) keywords related to scenarios ("scenario" or "pathway" or "projection" or "forecast" or "2030" or "2035" or "2040" or "2045" or "2050"), (2) keywords related to electricity or energy ("power" or "electricity" or "energy"), and (3) keywords related to the countries or the EU (e.g., "EU" or "European Union" or "EU27" or "EU28" or "EU-27" or "EU-28" or "Europe" or "European"). This search resulted in over 6'000 studies which were filtered to select only the studies that provided numerical scenarios for electricity supply. Third, literature reviews found in previous steps (Centre d'Analyse Stratégique, 2012; Domínguez et al., 2020; Grandjean et al., 2014; Hillebrandt et al., 2015; Jägemann et al., 2013; Koppelaar et al., 2016; Lise et al., 2013; Lunz et al., 2016; Osorio et al., 2020; Savvidis et al., 2019; Schmid et al., 2013; Shivakumar et al., 2019; Tsiropoulos et al., 2020) were inspected for additional studies, including grey literature by non-governmental organizations, e.g., Greenpeace (2014), and professional networks, e.g., Eurelectric (2018). The choice of studies was then limited to those published from 2008 to September 2020 as most studies found were published after 2008. For the few exceptions, earlier studies were deemed too outdated to be included in the scenario ensembles due to a significant change in the direction of the European Union's climate and energy policy in 2007 (European Commission, 2008). Additionally, studies were excluded if they did not report results referring to a specific year, for instance, in the case of studies examining effects of renewable penetration levels that could be potentially reached in the future (Drechsler et al., 2017). In total, 180 studies were selected: 23 for France, 40 for Germany, 16 for Poland, 92 for the EU27, and nine studies that provided scenarios for multiple countries (Appendix C provides the full list). These studies resulted in 612 scenarios: 88 for France, 152 for Germany, 71 for Poland, and 301 for the EU27.

From each scenario, the results for electricity demand and supply for 2035 were extracted, including contributions of electricity supply alternatives in TWh/year or as the shares (%) of the total supply. If the results were not given for 2035 but for other years such as 2030, 2040, or 2050, then an approximation for 2035 was calculated using linear interpolation between the closest years available. In the case of EU scenarios, most of the studies provided aggregated results for multiple countries other than the current EU27. Conversion factors were thus used, based on the supply and demand shares of each country in the aggregate EU values. For example, in the case of EU28 (before the withdrawal of the UK), the relative contribution of all countries except the UK was calculated for total electricity demand and supply using Eurostat data from 2018 (Eurostat, 2020c). These relative contributions were subsequently used to downscale scenario results from EU28 to EU27.

### 5.2.3 Survey procedure

Preferred scenarios were elicited from citizens in France ( $N = 202$ ), Germany ( $N = 199$ ), and Poland ( $N = 200$ ) using an online survey that was translated in three languages. All respondents were recruited in September 2020 through access panels provided by certified marketing research companies. The survey script, along with extensive details on all survey items, can be found in Xexakis and Trutnevyte (2021a). Since the present study focuses on the comparison between preferred and model-based scenarios, only selected results of the survey are described in detail.

At the beginning of the survey, respondents were asked about their *gender*, *age*, and highest *education level*. The survey went on with the items related to the respondents' attitudes towards governance, including their *attitudes towards the EU membership* of their country (3-point scale from 1 = a good thing to 3 = a bad thing). Next, the survey measured the respondents' *prior interest in electricity supply topics* (7 items on a 7-point Likert scale from 1 = strongly disagree to 7 = strongly agree; *Cronbach's  $\alpha$*  = 0.83/0.85/0.82 respectively for the French, German, and Polish sample), as well as their preferences for 14 electricity supply technologies (7-point Likert scale from 1 = strongly disagree to 7 = strongly agree) and five environmental, economic, and social impacts of these technologies (5-point scale each from 1 = not important to 5 = very important). The same technologies and impacts were then shown in the interactive scenario tool Riskmeter (Xexakis and Trutnevyte, 2020b). After a short attention test and instructions on how to use the Riskmeter, respondents were redirected to the tool in order to submit their preferred scenarios.

Riskmeter (Figure 5.1) allowed respondents to build own scenarios using electricity supply alternatives that could be used in 2035: hydropower; rooftop and open field solar PV; onshore and offshore wind; biomass; waste incineration; nuclear power; natural gas power plants with or without carbon capture and storage (CCS); coal power plants with or without CCS; and net import from abroad. Respondents could also opt to increase end-use efficiency and electricity savings in order to reduce electricity demand. Each respondent had to build and submit two preferred scenarios: one for her/his national electricity supply and one for the EU27, using two different versions of the Riskmeter. In order to reduce the impact of anchoring effects, the two versions were shown in random order. Compared to traditional opinion surveys that usually ask for individual technology preferences (European Commission, 2019a; Poortinga et al., 2018), Riskmeter allowed respondents to build a scenario that is in principle technically feasible and hence consistent with the types of results of models. More details about the tool and its characteristics can be found in the publication by Xexakis and Trutnevyte (2021a).

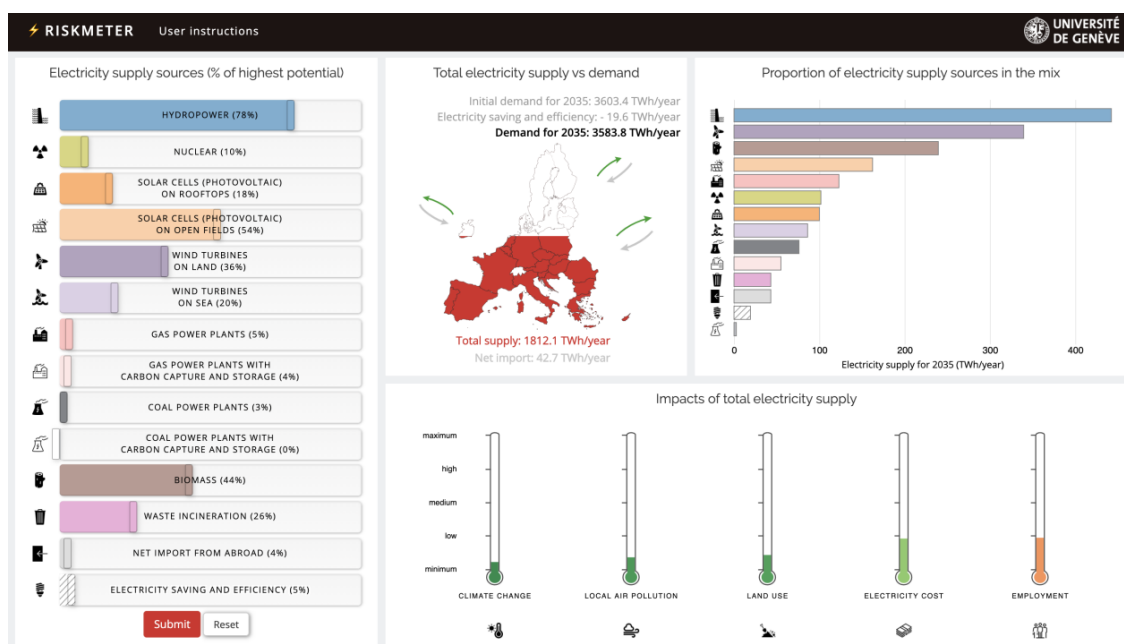


Figure 5.1. Interactive scenario tool Riskmeter (version for the EU27) (Xexakis and Trutnevyte, 2020b).

The colored bars on the left show the amount of supply from each electricity supply source as a percentage of its highest potential. The starting position of the bars was randomized for each user. The users could then move the bars and create their preferred scenario. The visualizations on the right show the total supply and demand, the share of each source in the mix, and the impacts of the total supply.

After returning to the survey, respondents provided their opinion on the current target for renewable electricity in their country ("*attitudes towards targets for renewable electricity*", 5-point scale from 1 = much lower to 5 = much higher). Lastly, respondents evaluated the Riskmeter ("*self-reported Riskmeter evaluation*", 10 items on a 7-point Likert scale from 1 = strongly disagree to 7 = strongly agree;  $\alpha = 0.90/0.88/0.83$ ) and reported their *political orientation* (10-point scale from 1 = left to 10 = right). The survey along with the use of Riskmeter took 12 – 14 minutes on average.

## 5.2.4 Analysis

The degree of convergence or divergence between model-based and citizens' preferred scenarios was analyzed separately for France, Germany, Poland, and the EU27. For all comparisons, scenarios were quantified in terms of shares (%) of electricity supply alternatives in the total supply. Three complementary methods were used. First, between-group statistical comparisons were performed between model-based and preferred scenarios, using non-parametric statistical tests, specifically the Kruskal-Wallis and the Mann-Whitney tests. These tests have been applied in similar studies in the past (van Sluisveld et al., 2018; Xexakis et al., 2020) and were preferred over parametric tests as non-parametric tests can mitigate the influence of outliers and the heterogeneity of the model-based ensembles (Huppmann et al., 2018b). Before each between-group comparison, the respective groups of preferred and model-

based scenarios were checked whether they had the same maximum and minimum values. If they did not, then statistical tests were adjusted to take only the shared range of the two groups into account, thus including scenario data that laid between the lowest maximum and highest minimum of the two groups. Second, in order to compare the shapes of scenario data distributions between model-based and preferred scenarios, overlapping indices were calculated. These overlapping indices measure the similarity between two compared distributions from 0 (no overlapping) to 1 (full overlapping) (Pastore and Calcagni, 2019) and they have been previously used for measuring consensus of opinions between groups in a related study (Xexakis and Trutnevyte, 2021a). Third, the density of scenario data was compared between sets of model-based and preferred scenarios. In order to do this, scenario ensembles were split in six equal groups based on their shares of electricity supply alternatives in the total supply (0–16%, 17%–33%, 34%–50%, 51%–67%, 68%–84%, 85%–100%). For example, model-based scenarios with shares of hydropower ranging between 0 and 16% were grouped together. This grouping helped to illustrate convergences and divergences by comparing the size ( $n$ ) of these six groups between model-based and preferred scenarios. By combining the results of the above methods, a divergence between model-based and citizens' preferred scenarios was concluded if there was a statistically significant difference between model-based and preferred scenarios and their overlapping index was below 0.5. Additionally, a divergence was concluded if there was a statistically significant difference and the plurality of model-based and preferred scenarios belonged to different groups in terms of shares of electricity supply alternatives. In all other cases, model-based scenarios and citizens' scenarios were assumed to converge.

## 5.3 Results

### 5.3.1 Survey respondents

In terms of demographics, all survey samples had similar gender ratios to their respective general populations in 2020 (Eurostat, 2020d) [female in French (FR) sample: 54.3%, FR population: 51.7%; German (DE) sample: 49%, DE population: 50.7%; Polish (PL) sample: 49%, PL population: 51.6%]. The samples had also comparable *age* [Median ( $Md$ ) in years for FR sample: 45, FR population: 41.9; DE sample: 48, DE population: 45.9; PL sample: 43, PL population: 41.3] and *education level* (respondents with academic tertiary education in FR sample: 33.7%, FR population: 36.2%; DE sample: 16.6%, DE population: 18.5%; PL sample: 27%, PL population: 28.6%) with their respective populations (Destatis, 2021; Eurostat, 2020a, 2020e). On average, *political orientation* was on the center and slightly towards the left for all samples [ $Md$  for all: 5; Mean ( $M$ ) for FR: 4.8, DE: 4.8, PL: 5.2;  $F = 1.65$ ,  $p = 0.207$ ; midpoint: 5.5]. *Prior interest in electricity supply topics* was also moderate, with French respondents having the lowest interest and Polish — the highest ( $Md$  for FR: 26.0, DE: 28.0, PL: 33.0;  $M$  for FR: 25.0, DE: 28.1, PL: 32.8;  $F = 48.07$ ,  $p < 0.001$ ; midpoint: 28). In terms of *attitudes towards current targets for renewable electricity*,

most respondents preferred higher targets than the current one, especially for Poland (*Md* for FR: 4.0, DE: 3.0, PL: 4.0; *M* for FR: 3.6, DE: 3.5, PL: 4.0,  $F = 16.38$ ,  $p < 0.001$ , midpoint: 3). Respondents had, on average, favorable *attitudes towards the EU membership* of their country, with French respondents having the least favorable and Polish respondents — the most favorable attitudes (*Md* for FR: 2.0, DE: 3.0, PL: 3.0; *M* for FR: 2.2, DE: 2.5, PL: 2.7,  $F = 23.77$ ,  $p < 0.001$ , midpoint: 2). Finally, most respondents had a positive experience with the Riskmeter, as indicated by the high *self-reported Riskmeter evaluation* for all samples and particularly for the Polish sample (*Md* for FR: 47.0, DE: 46.0, PL: 50.0; *M* for FR: 47.0, DE: 46.4, PL: 49.0,  $F = 3.86$ ,  $p = 0.022$ , midpoint: 38.5).

### 5.3.2 Electricity supply in model-based scenarios

In the 88 model-based scenarios for France (Figure 5.2 in page 84), nuclear power was still dominant in 2035, on average providing almost half of the total electricity supply [Median (*Md*) share of nuclear supply: 47%], in line with the current national energy policy that aims to cover 50% of the French electricity mix in 2035 with nuclear power (MTES, 2020a). Wind power was the second largest source of electricity in most scenarios (*Md*: 21%), almost quadrupling from a share of 6% in 2019 (Eurostat, 2020c). In terms of origin, onshore wind power provided most of this supply (*Md*: 15%). Wind power was followed by other renewable electricity sources, i.e., hydropower (*Md*: 12%), solar PV (*Md*: 6%), and biomass (*Md*: 3%). Hydropower remained mostly constant from 2019, while solar PV and biomass grew from their 2019 shares of 2% and 1%, respectively (Eurostat, 2020c). Natural gas power plants were used only slightly in most scenarios (*Md*: 3%), while waste incineration provided a share of 1% as in 2019 (Eurostat, 2020c). Electricity supply from coal, alternatives with CCS, and net imports from abroad were mostly zero.

In the 152 model-based scenarios for Germany, wind power was prominent, providing more than 41% of the total supply in most scenarios for 2035 (Figure 5.2), which is double than the share of wind power in 2019 (Eurostat, 2020c). In terms of origin, both onshore and offshore wind power were contributing, with the former supplying slightly more than the latter (*Md*: 21% and 16%, respectively). Solar PV had also moderately grown to 12% for most scenarios from a share of around 8% in 2019 (Eurostat, 2020c). Most model-based scenarios also included significant shares from coal (*Md*: 15%) and natural gas (*Md*: 14%) in 2035, despite calls for an earlier coal phase-out in Germany (Rinscheid and Wüstenhagen, 2019; Schmid and Knopf, 2012). The aggregated supply from biomass and waste incineration as well as the supply from hydropower remained at similar levels as in 2019 for most scenarios, with an average share of 8% and 4% respectively. For most scenarios, nuclear power, alternatives with CCS, and net import were zero or close to zero.

Among the 71 model-based scenarios for Poland, most of them were not very far from the current electricity mix (Figure 5.2). Coal power plants provided the bulk of electricity supply

## 5. Alignment between model-based and preferred electricity scenarios for FR, DE, PL, and EU

in most scenarios (*Med*: 50%), albeit at a much lower level than the 73% share in 2019 (Eurostat, 2020c). On average, this gap was mostly filled with wind power (*Med*: 18%), predominantly from onshore turbines (*Med*: 15%). The remaining supply was provided by existing power plants using natural gas (*Med*: 7%) and biomass and waste incineration (*Med*: 7%), as well as newly built nuclear power plants (*Med*: 6%). Hydropower provided a small share of 2% for most scenarios as in 2019, while solar PV, alternatives with CCS, and net imports were almost zero.

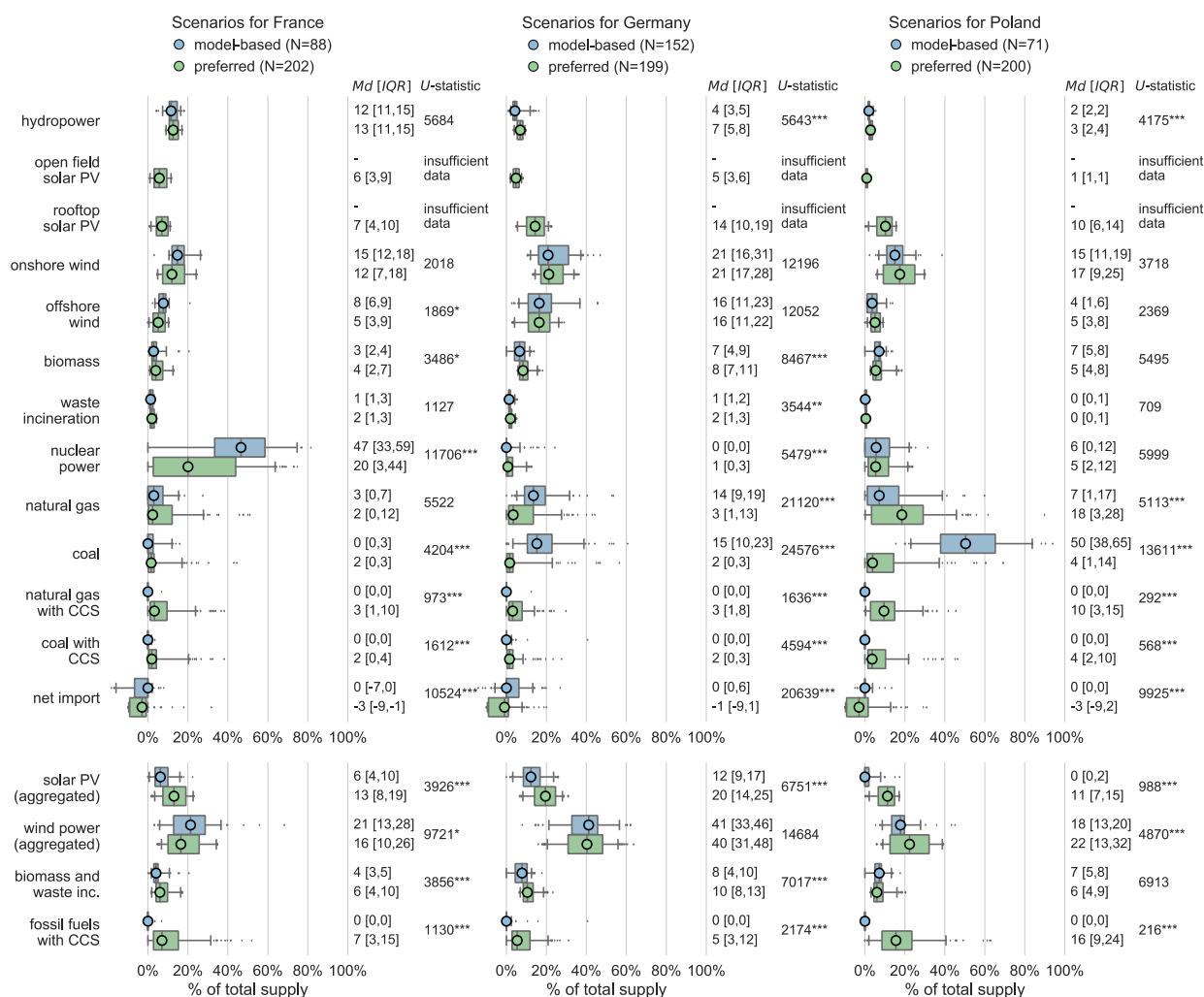


Figure 5.2. Comparison of annual electricity supply for 2035 in France, Germany, and Poland between model-based and citizens' preferred scenarios. Circles depict medians, boxes – the 25th and 75th quartiles, and whiskers – the 5th and 95th quartiles. A Mann-Whitney test (*U*-statistic) is shown for each comparison (\**p* < 0.05, \*\**p* < 0.01, \*\*\**p* < 0.001).

Most of the 301 model-based scenarios for the whole EU27 had a diversified electricity supply mix in 2035 (Figure 5.3). On average, wind power provided almost a quarter of the total supply for the EU27 (*Med*: 23%), doubling the share of 12% in 2019 (Eurostat, 2020c). Onshore wind power (*Med*: 14%) provided more than double the supply of offshore wind power (*Med*: 6%). Nuclear power had the second largest supply for most scenarios with a median share of 18%, which is a moderate reduction from the 2019 share of 26% (Eurostat, 2020c). Hydropower supplied around 12% of the total supply for most scenarios in 2035, a similar share as in 2019

(Eurostat, 2020c), while natural gas was reduced to 12% in most scenarios from a share of 20% in 2019 (Eurostat, 2020c). Coal was also lower than the share of 16% in 2019, but it still provided around 9% in most scenarios. In contrast, the share from solar PV had a moderate increase from 4% in 2019 to 8% in most scenarios, while supply from biomass and waste incineration remained close to 6% as in 2019 (Eurostat, 2020c). Similar to scenarios for the aforementioned Member States, alternatives with CCS and net imports were almost zero in most scenarios for the EU27.

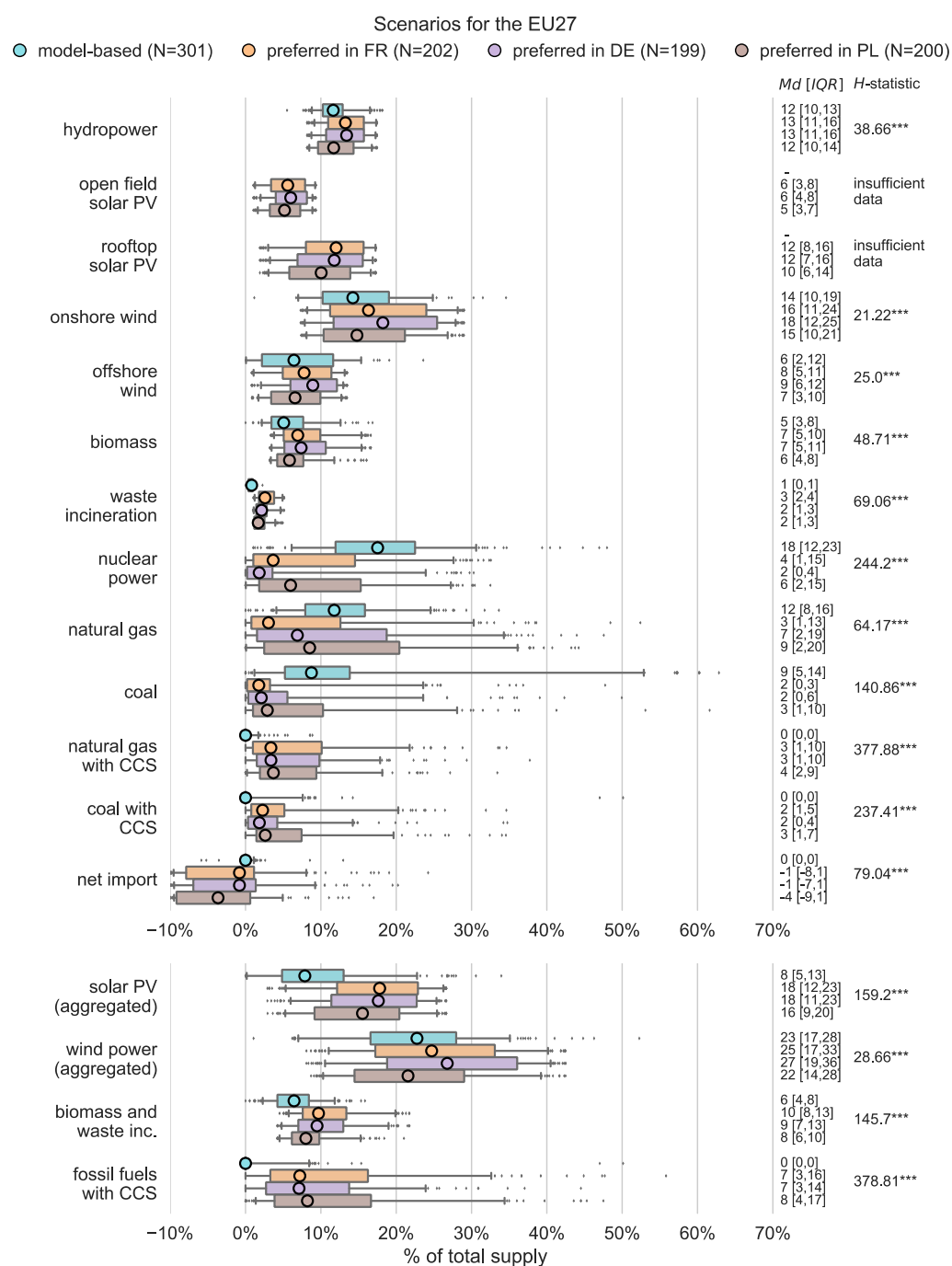


Figure 5.3. Comparison of annual electricity supply for 2035 in the EU27 between model-based and citizens' preferred scenarios. Circles depict medians, boxes – the 25th and 75th quartiles, and whiskers – the 5th and 95th quartiles. A Kruskal-Wallis test ( $H$ -statistic) is shown for each comparison ( $*p < 0.05$ ,  $**p < 0.01$ ,  $***p < 0.001$ ).

### 5.3.3 Preferred electricity supply scenarios of the citizens

In contrast to the model-based scenarios (Figure 5.2) or the French electricity mix in 2019, the 202 preferred scenarios for 2035 by French citizens were substantially more diversified (Figure 5.2). On average, nuclear power was still first in term of supply, albeit it provided only 20% of the total supply in contrast to the 47% median share in model-based scenarios or the almost 75% share in 2019 (Eurostat, 2020c). Wind power contributed 16% of the total supply in most scenarios, with onshore wind power providing most of this share (*Med.* 12%). Solar PV supplied more than 13% of the total supply in most preferred scenarios, with a large increase from the 2019 share of 2% (Eurostat, 2020c). Solar power came almost equally from open field solar PV (*Med.* 6%) and rooftop solar PV (*Med.* 7%). Hydropower provided 13% of the total share in most preferred scenarios like in 2019, while the share from biomass and waste incineration increased to 6% from 2% in 2019 (Eurostat, 2020c). Supply from natural gas and coal was minimal and for most scenarios it was close to 2% for both sources. Interestingly, alternatives with CCS were included in many scenarios from French citizens, providing around 7% of the total supply. Most preferred scenarios for France included more electricity supply than required, leading to a net export of around 3% of the total supply.

The 199 scenarios for Germany in 2035 collected from the citizens had a similar supply structure as model-based scenarios, though the scenarios depended much less on fossil fuels without CCS (Figure 5.2). Wind power dominated electricity supply in most preferred scenarios with a median share of 40% and with onshore wind power providing slightly more supply (*Med.* 21%). Solar PV provided the second largest supply with a share around 20% for most preferred scenarios, which is more than double of the 8% share in 2019 (Eurostat, 2020c). Most of this supply came from rooftop solar PV (*Med.* 14%). The share from biomass and waste incineration slightly increased to 10% in most scenarios from 8% in 2019 (Eurostat, 2020c). A similar increase in the share of hydropower to 7% in most scenarios from 4% in 2019 was observed (Eurostat, 2020c). Most preferred scenarios included minimal shares from natural gas (*Med.* 3%) and coal (*Med.* 2%) which were much lower than the shares in 2019 (15% and 30%, respectively) (Eurostat, 2020c). As with French citizens, German citizens also included a considerable share of alternatives with CCS (*Med.* 5%), split between natural gas with CCS (*Med.* 3%) and coal with CCS (*Med.* 3%). Both shares from nuclear power and net imports were close to zero, while many scenarios included limited net exports at the level of 1% of the total supply.

As with preferred scenarios in other countries, the 200 surveyed citizens in Poland preferred a diversified electricity supply mix for their country (Figure 5.2). In stark contrast to the domination of coal in the Polish supply in 2019 (73% (Eurostat, 2020c)) and in model-based scenarios for 2035 (*Med.* 50%), the share of coal in preferred scenarios was only 4%. The highest share of supply was provided by wind power (*Med.* 22%) and especially from onshore turbines (*Med.* 17%). Natural gas had the second highest supply in most preferred scenarios, providing 18% of the total supply and doubling from the 9% share in 2019 (Eurostat, 2020c). Fossil fuels with



CCS had also a similarly significant share of 16% in most scenarios, mostly coming from natural gas with CCS (*Md*: 10%). Solar PV also supplied an important share of 11% in most preferred scenarios, almost all from rooftop solar PV (*Md*: 10%), in contrast to the almost zero share in 2019 (Eurostat, 2020c). Hydropower remained mostly constant from 2019 in most preferred scenarios (*Md*: 3%), similar to biomass and waste incineration (*Md*: 6%). Most preferred scenarios from Polish citizens included limited net exports in the range of 3% of the total supply.

In all citizen samples (601 in total), most of the preferred scenarios for the whole EU27 in 2035 were diversified (Figure 5.3), as in the case of model-based scenarios for the EU27 (Section 3.3). While the structure of electricity supply was similar among citizen samples, small differences were found, for instance, that the share of nuclear power was, on average, higher in scenarios from Polish respondents than German respondents (Xexakis and Trutnevyte (Xexakis and Trutnevyte, 2021a) provide a detailed comparison among the citizens). Wind power was the electricity source with the highest supply share in all samples [*Md* for the French (FR) sample: 25%; German (DE) sample: 27%; Polish (PL) sample: 22%]. More than half of this supply came from onshore wind power (*Md* for FR: 16%; DE: 18%; PL: 15%), with offshore wind power providing the rest (*Md* for FR: 8%; DE: 9%; PL: 7%). Solar PV had the second largest share in most scenarios (*Md* for FR: 18%; DE: 18%; PL: 16%), in a large increase from 4% in 2019 (Eurostat, 2020c). Rooftop solar PV was the largest contributor of solar power (*Md* for FR: 12%; DE: 12%; PL: 10%). Hydropower also provided a considerable share in most scenarios (*Md* for FR: 13%; DE: 13%; PL: 12%), staying in similar levels as in 2019 and followed by biomass and waste incineration (*Md* for FR: 10%; DE: 9%; PL: 8%). In the latter, the share of biomass was slightly larger in most scenarios than the 5% share in 2019 (*Md* for FR: 7%; DE: 7%; PL: 6%), while waste incineration stayed in similar levels or slightly grew from 2% in 2019 (*Md* for FR: 3%; DE: 2%; PL: 2%). Natural gas had a low but considerable share in most preferred scenarios, especially from Polish and German respondents (*Md* for FR: 3%; DE: 7%; PL: 9%). Nuclear power had also a low but non-trivial share in Polish and French preferred scenarios (*Md* for FR: 4%; DE: 2%; PL: 6%). Fossil fuels with CCS were also present in most scenarios (*Md* for FR: 7%; DE: 7%; PL: 8%), while coal without CCS had a much lower share (*Md* for FR: 2%; DE: 2%; PL: 3%). Finally, most preferred scenarios included net exports of around 1% of the total supply for French and German respondents and 4% for Polish respondents.

### 5.3.4 Convergences and divergences between model-based and preferred scenarios

#### 5.3.4.1 Convergences and divergences for France, Germany, and Poland

Between scenarios preferred by the citizens and model-based scenarios for France, the strongest convergences were found on moderate shares of hydropower and low shares of natural gas. Grouping scenarios based on their shares for each alternative showed that more than 75% of the scenarios had shares of hydropower and natural gas between 0 and 16% (Figure

5.4). Median shares were on similar levels between model-based and preferred scenarios for hydropower [Figure 5.2, *Md* for model-based (MB): 12%, preferred (PR): 13%] and natural gas (*Md* for MB: 3%, PR: 2%). Model-based and preferred scenarios had similar distributions of shares for hydropower and natural gas, as shown by the overlapping index ( $\eta$ ) of 0.74 for both technologies (Figure 5.5). Since overlapping indices were well above 0.5, this implies that model-based and preferred scenarios mostly coincided in terms of shares for these technologies (1 indicates full overlapping and 0 — no overlapping). Convergences were also found on low shares of coal, biomass, and waste incineration, which had overlapping indices of 0.55, 0.56, and 0.66 respectively. Median shares were similar between model-based and preferred scenarios for waste incineration (*Md* for MB: 1%, PR: 2%) and slightly higher in preferred scenarios for coal (*Md* for MB: 0%, PR: 2%) and biomass (*Md* for MB: 3%, PR: 4%). Additionally, both model-based and preferred scenarios included, on average, moderate shares of wind power (aggregated), albeit this share was statistically significantly higher in model-based scenarios (*Md* for MB: 21%, PR: 16%). Despite this small difference in central tendencies, the distributions of model-based and preferred scenarios mostly coincided ( $\eta = 0.71$ ), indicating that the model-based and preferred scenarios converged more than diverged for wind power. Divergences were found on natural gas and coal with CCS, nuclear power, and aggregated solar PV, with small overlapping indices of 0.11, 0.21, 0.44, and 0.46 respectively. Specifically, most preferred scenarios included low shares of natural gas and coal with CCS (*Md*: 3% and 2%), while the vast majority of model-based scenarios did not include any share from these alternatives (*Md*: 0% for both). Additionally, most preferred scenarios covered more than 10% of the total supply from aggregated solar PV (*Md*: 13%), while most model-based scenarios used this technology in a more limited way (*Md*: 6%). In contrast, most model-based scenarios used nuclear power for almost half of the total French supply (*Md*: 47%), while most preferred scenarios used nuclear power for less than a quarter of the total supply (*Md*: 20%). Among 94% of preferred scenarios and 90% of model-based scenarios, there was a convergence of views that France will be a net exporter of electricity in 2035 (on a yearly basis). On average, model-based scenarios included net export on a level closer to the current share of net export in France, while preferred scenarios included a much lower share (*Md* for MB: 8%, PR: 3%, net export in 2019: 10.1% (Eurostat, 2020f)). For the few scenarios that included net import, the average share of net import in total supply was limited (*Md* for MB: 4%, PR: 6%).

|                                          |                                                                      | Scenarios for France |     |        |    |        |    |        |    |        |    |         |    | Scenarios for Germany |     |        |    |        |    |        |    |        |    |         |    |   |
|------------------------------------------|----------------------------------------------------------------------|----------------------|-----|--------|----|--------|----|--------|----|--------|----|---------|----|-----------------------|-----|--------|----|--------|----|--------|----|--------|----|---------|----|---|
| Groups                                   | per scenario type<br>per share of each source<br>in the total supply | MB                   | PR  | MB     | PR | MB     | PR | MB     | PR | MB     | PR | MB      | PR | MB                    | PR  | MB     | PR | MB     | PR | MB     | PR | MB     | PR | MB      | PR |   |
|                                          |                                                                      | 0-16%                |     | 17-33% |    | 34-50% |    | 51-67% |    | 68-84% |    | 85-100% |    | 0-16%                 |     | 17-33% |    | 34-50% |    | 51-67% |    | 68-84% |    | 85-100% |    |   |
|                                          |                                                                      |                      |     |        |    |        |    |        |    |        |    |         |    |                       |     |        |    |        |    |        |    |        |    |         |    |   |
| % of scenarios that belong to each group | hydropower                                                           | 91                   | 83  | 9      | 17 | 0      | 0  | 0      | 0  | 0      | 0  | 0       | 0  | 99                    | 100 | 1      | 0  | 0      | 0  | 0      | 0  | 0      | 0  | 0       | 0  |   |
|                                          | rooftop solar PV                                                     | -                    | 100 | -      | 0  | -      | 0  | -      | 0  | -      | 0  | -       | 0  | -                     | 100 | -      | 0  | -      | 0  | -      | 0  | -      | 0  | -       | 0  |   |
|                                          | open field solar PV                                                  | -                    | 100 | -      | 0  | -      | 0  | -      | 0  | -      | 0  | -       | 0  | -                     | 59  | -      | 41 | -      | 0  | -      | 0  | -      | 0  | -       | 0  |   |
|                                          | onshore wind                                                         | 62                   | 65  | 38     | 35 | 0      | 0  | 0      | 0  | 0      | 0  | 0       | 0  | 25                    | 17  | 58     | 76 | 17     | 7  | 0      | 0  | 0      | 0  | 0       | 0  |   |
|                                          | offshore wind                                                        | 93                   | 100 | 7      | 0  | 0      | 0  | 0      | 0  | 0      | 0  | 0       | 0  | 47                    | 47  | 47     | 53 | 6      | 0  | 0      | 0  | 0      | 0  | 0       | 0  |   |
|                                          | biomass                                                              | 98                   | 100 | 2      | 0  | 0      | 0  | 0      | 0  | 0      | 0  | 0       | 0  | 100                   | 96  | 0      | 4  | 0      | 0  | 0      | 0  | 0      | 0  | 0       | 0  | 0 |
|                                          | waste incineration                                                   | 100                  | 100 | 0      | 0  | 0      | 0  | 0      | 0  | 0      | 0  | 0       | 0  | 100                   | 100 | 0      | 0  | 0      | 0  | 0      | 0  | 0      | 0  | 0       | 0  | 0 |
|                                          | nuclear power                                                        | 11                   | 38  | 8      | 21 | 39     | 17 | 22     | 19 | 20     | 4  | 0       | 0  | 67                    | 100 | 33     | 0  | 0      | 0  | 0      | 0  | 0      | 0  | 0       | 0  | 0 |
|                                          | natural gas                                                          | 95                   | 77  | 5      | 19 | 0      | 3  | 0      | 1  | 0      | 0  | 0       | 0  | 66                    | 76  | 30     | 21 | 3      | 3  | 1      | 0  | 0      | 0  | 0       | 0  | 0 |
|                                          | coal                                                                 | 100                  | 92  | 0      | 7  | 0      | 1  | 0      | 0  | 0      | 0  | 0       | 0  | 53                    | 90  | 36     | 6  | 8      | 3  | 3      | 1  | 0      | 0  | 0       | 0  | 0 |
|                                          | natural gas with CCS                                                 | 100                  | 86  | 0      | 12 | 0      | 2  | 0      | 0  | 0      | 0  | 0       | 0  | 100                   | 96  | 0      | 4  | 0      | 0  | 0      | 0  | 0      | 0  | 0       | 0  | 0 |
|                                          | coal with CCS                                                        | 100                  | 89  | 0      | 11 | 0      | 1  | 0      | 0  | 0      | 0  | 0       | 0  | 94                    | 97  | 0      | 3  | 6      | 0  | 0      | 0  | 0      | 0  | 0       | 0  | 0 |
|                                          | net import                                                           | 100                  | 78  | 0      | 22 | 0      | 0  | 0      | 0  | 0      | 0  | 0       | 0  | 92                    | 95  | 8      | 5  | 0      | 0  | 0      | 0  | 0      | 0  | 0       | 0  | 0 |
|                                          | aggregated sources                                                   |                      |     |        |    |        |    |        |    |        |    |         |    |                       |     |        |    |        |    |        |    |        |    |         |    |   |
|                                          | solar PV                                                             | 92                   | 61  | 8      | 39 | 0      | 0  | 0      | 0  | 0      | 0  | 0       | 0  | 71                    | 32  | 29     | 68 | 0      | 0  | 0      | 0  | 0      | 0  | 0       | 0  | 0 |
|                                          | wind                                                                 | 29                   | 49  | 54     | 41 | 15     | 11 | 1      | 0  | 1      | 0  | 0       | 0  | 3                     | 1   | 24     | 33 | 52     | 48 | 20     | 19 | 0      | 0  | 0       | 0  | 0 |
|                                          | biomass and waste inc.                                               | 98                   | 94  | 2      | 6  | 0      | 0  | 0      | 0  | 0      | 0  | 0       | 0  | 99                    | 87  | 1      | 13 | 0      | 0  | 0      | 0  | 0      | 0  | 0       | 0  | 0 |
|                                          | fossil fuels with CCS                                                | 100                  | 73  | 0      | 21 | 0      | 6  | 0      | 1  | 0      | 0  | 0       | 0  | 94                    | 88  | 0      | 12 | 6      | 0  | 0      | 0  | 0      | 0  | 0       | 0  | 0 |

|                                          |                                                                      | Scenarios for Poland |     |        |    |        |    |        |    |        |    |         |    |
|------------------------------------------|----------------------------------------------------------------------|----------------------|-----|--------|----|--------|----|--------|----|--------|----|---------|----|
| Groups                                   | per scenario type<br>per share of each source<br>in the total supply | MB                   | PR  | MB     | PR | MB     | PR | MB     | PR | MB     | PR | MB      | PR |
|                                          |                                                                      | 0-16%                |     | 17-33% |    | 34-50% |    | 51-67% |    | 68-84% |    | 85-100% |    |
|                                          |                                                                      |                      |     |        |    |        |    |        |    |        |    |         |    |
| % of scenarios that belong to each group | hydropower                                                           | 100                  | 100 | 0      | 0  | 0      | 0  | 0      | 0  | 0      | 0  | 0       | 0  |
|                                          | rooftop solar PV                                                     | -                    | 100 | -      | 0  | -      | 0  | -      | 0  | -      | 0  | -       | 0  |
|                                          | open field solar PV                                                  | -                    | 100 | -      | 0  | -      | 0  | -      | 0  | -      | 0  | -       | 0  |
|                                          | onshore wind                                                         | 57                   | 44  | 41     | 56 | 2      | 0  | 0      | 0  | 0      | 0  | 0       | 0  |
|                                          | offshore wind                                                        | 100                  | 100 | 0      | 0  | 0      | 0  | 0      | 0  | 0      | 0  | 0       | 0  |
|                                          | biomass                                                              | 100                  | 95  | 0      | 5  | 0      | 0  | 0      | 0  | 0      | 0  | 0       | 0  |
|                                          | waste incineration                                                   | 100                  | 100 | 0      | 0  | 0      | 0  | 0      | 0  | 0      | 0  | 0       | 0  |
|                                          | nuclear power                                                        | 72                   | 83  | 28     | 17 | 0      | 0  | 0      | 0  | 0      | 0  | 0       | 0  |
|                                          | natural gas                                                          | 63                   | 44  | 26     | 34 | 10     | 17 | 2      | 4  | 0      | 0  | 0       | 1  |
|                                          | coal                                                                 | 1                    | 73  | 17     | 19 | 31     | 5  | 28     | 2  | 15     | 1  | 7       | 0  |
|                                          | natural gas with CCS                                                 | 100                  | 77  | 0      | 20 | 0      | 3  | 0      | 0  | 0      | 0  | 0       | 0  |
|                                          | coal with CCS                                                        | 100                  | 86  | 0      | 11 | 0      | 3  | 0      | 0  | 0      | 0  | 0       | 0  |
|                                          | net import                                                           | 100                  | 91  | 0      | 9  | 0      | 0  | 0      | 0  | 0      | 0  | 0       | 0  |
|                                          | aggregated sources                                                   |                      |     |        |    |        |    |        |    |        |    |         |    |
|                                          | solar PV                                                             | 97                   | 88  | 3      | 12 | 0      | 0  | 0      | 0  | 0      | 0  | 0       | 0  |
|                                          | wind                                                                 | 27                   | 32  | 69     | 47 | 4      | 22 | 0      | 0  | 0      | 0  | 0       | 0  |
|                                          | biomass and waste inc.                                               | 98                   | 94  | 2      | 6  | 0      | 0  | 0      | 0  | 0      | 0  | 0       | 0  |
|                                          | fossil fuels with CCS                                                | 100                  | 52  | 0      | 38 | 0      | 9  | 0      | 2  | 0      | 0  | 0       | 0  |

Figure 5.4. Grouping of electricity supply scenarios for France, Germany, and Poland per scenario type, i.e., model-based (MB) or preferred (PR), and per share of each electricity supply source in the total supply. For each group, the percentage of the scenarios is shown, e.g., 91% of model-based scenarios for France have a share of hydropower in the total supply between 0 and 16%. The percentages are color coded from dark green (100% of the scenarios belong to the group) to white (0%). Percentages were not calculated for disaggregated solar PV sources due to the scarcity of data in model-based scenarios.

## 5. Alignment between model-based and preferred electricity scenarios for FR, DE, PL, and EU

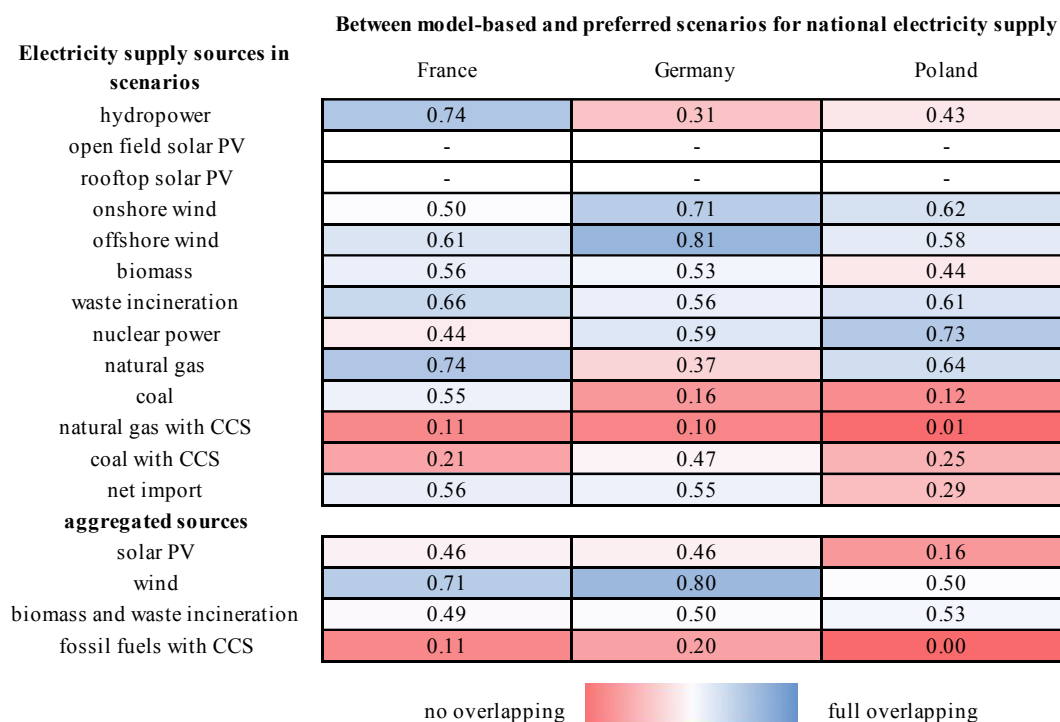


Figure 5.5. Overlapping indices ( $\eta$ ) between model-based and preferred scenarios for France, Germany, and Poland. An overlapping index of 1 indicates full overlap, and 0 — no overlap. Overlapping indices were not calculated for disaggregated solar PV sources due to the scarcity of data in model-based scenarios.

In terms of scenarios for Germany, the strongest convergences between preferred and model-based scenarios were observed for moderate shares of onshore wind power ( $Md$  for MB: 21%, PR: 21%) and offshore wind power ( $Md$  for MB: 16%, PR: 16%). Overlapping indices were 0.71 and 0.81 respectively, indicating a high level of similarity between the distributions of supply shares of model-based and preferred scenarios for these technologies. While the shares of onshore and offshore wind power could range between 10% and 47%, and between 3% and 46% respectively, most preferred and model-based scenarios included shares between 17% and 33% (Figure 5.4). Preferred and model-based scenarios also converged on low shares of nuclear power, biomass, and waste incineration, with the majority of scenarios having shares for these technologies that ranged between 0 and 16% (Figure 5.4). Preferred scenarios had, on average, statistically significantly higher shares than model-based scenarios for nuclear power ( $Md$  for MB: 0%, PR: 1%), biomass ( $Md$  for MB: 7%, PR: 8%), and waste incineration ( $Md$  for MB: 1%, PR: 2%). Overlapping indices were above 0.5 (0.59, 0.56, and 0.59 respectively), indicating an agreement in share distributions, albeit a weak one. Divergences occurred for coal, natural gas, fossil fuels with CCS, hydropower, and aggregated solar PV. Specifically, model-based scenarios had statistically significantly higher shares from coal ( $Md$ : 15%) and natural gas ( $Md$ : 14%) compared to preferred scenarios ( $Md$ : 2% and 3%). In contrast, preferred scenarios had statistically significantly higher shares from hydropower ( $Md$ : 7%), solar PV ( $Md$ : 20%) and fossil fuels with CCS ( $Md$ : 5%) than model-based scenarios ( $Md$ : 4%, 12% and 0%). For all divergent alternatives, overlapping indices were below 0.5, indicating that their distributions mostly

differed between model-based and preferred scenarios ( $\eta$  for coal: 0.16, natural gas: 0.37, fossil fuels with CCS: 0.20, hydropower: 0.31, solar PV: 0.46). In terms of electricity trading, 57% of model-based scenarios and 67% of preferred scenarios included net export. On average, net export in both model-based ( $Med$ : 4%) and preferred scenarios ( $Med$ : 5%) was close to the current share of net export (net export in 2019: 5.4% (Eurostat, 2020f)). For the minority of scenarios that included net import (128 scenarios out of 351 in total), the shares of net import in total supply were much higher in model-based scenarios ( $Med$ : 7%) than in preferred scenarios ( $Med$ : 2%).

For Poland, the strongest convergence between preferred and model-based scenarios was found on low but nonzero shares of nuclear power. The majority of model-based and preferred scenarios included nuclear power in shares that ranged between 0% and 16% of their total supply (Figure 5.4). Median shares were similar ( $Med$  for MB: 6%, PR: 5%), while the overlapping index was 0.73, indicating that most model-based and preferred scenarios coincided in terms of nuclear power shares. Convergences were also found on moderate shares of onshore wind power ( $Med$  for MB: 15%, PR: 17%) and low shares of offshore wind power ( $Med$  for MB: 4%, PR: 5%) and aggregated supply from biomass and waste incineration ( $Med$  for MB: 7%, PR: 6%). As with nuclear power, overlapping indices were above 0.5 for onshore wind (0.62), offshore wind (0.58), and biomass and waste incineration (0.53), showing an agreement between the distributions of model-based and preferred scenarios for these technologies. A similar overlapping index was found for natural gas (0.64). However, preferred scenarios had, on average, statistically significantly higher shares from natural gas ( $Med$ : 18%) than model-based scenarios ( $Med$ : 7%). Divergences were observed for hydropower, alternatives with CCS, aggregated solar PV, and, especially, for coal. Specifically, while most model-based scenarios covered half of the Polish supply with coal ( $Med$ : 50%), most preferred scenarios had a very low share from this technology ( $Med$ : 4%). In contrast, most model-based scenarios had no shares from solar PV, natural gas with CCS, and coal with CCS ( $Med$ : 0%), while most preferred scenarios included these alternatives ( $Med$ : 11%, 10%, and 4% respectively). Additionally, model-based scenarios had, on average, slightly lower shares from hydropower ( $Med$ : 2%) compared to most preferred scenarios ( $Med$ : 3%). Overlapping indices were lower than 0.5 for all these technologies, indicating low convergence between model-based and preferred scenarios in terms of distributions of shares ( $\eta$  for coal: 0.12, fossil fuels with CCS: 0, solar PV: 0.16, hydropower: 0.43). In terms of net import and export, 77% of model-based scenarios and 68% of preferred scenarios included net export or no trade at all, in contrast to the current situation in Poland where there is a net import of electricity (net import in 2019: 6.4% (Eurostat, 2020f)). Net export was much lower in model-based scenarios ( $Med$ : 3%) than in preferred scenarios ( $Med$ : 7%). For the few scenarios that included net import, shares were similar in both model-based scenarios and preferred scenarios ( $Med$ : 3% for both).

### 5.3.4.2 Convergences and divergences for the EU27

In terms of the electricity supply of the EU27 as a whole, the strongest convergence between scenarios preferred by citizens and model-based scenarios was found on low shares of offshore wind, biomass, and hydropower. Grouping the EU27 scenarios in terms of shares of these technologies in the total supply showed that almost all model-based and preferred scenarios had shares that ranged between 0 and 16% (Figure 5.6). In terms of central tendencies (Figure 5.3), preferred scenarios had statistically significantly higher shares than model-based scenarios in terms of offshore wind power [ $Md$  for model-based (MB): 6%, preferred by French respondents (PR-FR): 8%, preferred by German respondents (PR-DE): 9%, preferred by Polish respondents (PR-PL): 7%], biomass ( $Md$  for MB: 5%, PR-FR: 7%, PR-DE: 7%, PR-PL: 6%), and hydropower ( $Md$  for MB: 12%, PR-FR: 13%, PR-DE: 13%, PR-PL: 12%). However, overlapping indices between model-based scenarios and scenarios preferred by citizens of all samples were above 0.5 (Figure 5.7), indicating a convergence between most model-based and preferred scenarios on offshore wind power ( $\eta$  between MB and PR-FR: 0.61, MB and PR-DE: 0.54, MB and PR-PL: 0.61), biomass ( $\eta$  between MB and PR-FR: 0.64, MB and PR-DE: 0.62, MB and PR-PL: 0.69), and hydropower ( $\eta$  between MB and PR-FR: 0.57, MB and PR-DE: 0.55, MB and PR-PL: 0.66). A convergence was also found on moderate shares of onshore wind. As for the aforementioned technologies, preferred scenarios had, on average, slightly higher shares from onshore wind power compared to model-based scenarios ( $Md$  for MB: 14%, PR-FR: 16%, PR-DE: 18%, PR-PL: 15%). Overlapping index was also above 0.5, indicating that most model-based scenarios coincided with preferred scenarios in terms of onshore wind power ( $\eta$  between MB and PR-FR: 0.70, MB and PR-DE: 0.61, MB and PR-PL: 0.75). However, shares for onshore wind power had a large dispersion and ranged between 0% to 33% for all model-based and preferred scenarios (Figure 5.6).

|                                          |                                              | Scenarios for the EU27 |     |     |     |          |    |    |    |          |    |    |    |          |    |    |    |          |    |    |    |           |    |    |    |
|------------------------------------------|----------------------------------------------|------------------------|-----|-----|-----|----------|----|----|----|----------|----|----|----|----------|----|----|----|----------|----|----|----|-----------|----|----|----|
| Groups                                   | per scenario type                            | MB                     |     |     |     | PR       |    |    |    | MB       |    |    |    | PR       |    |    |    | MB       |    |    |    | PR        |    |    |    |
|                                          | per share of each source in the total supply | MB                     | FR  | DE  | PL  | MB       | FR | DE | PL | MB       | FR | DE | PL | MB       | FR | DE | PL | MB       | FR | DE | PL | MB        | FR | DE | PL |
|                                          |                                              | 0 – 16%                |     |     |     | 17 – 33% |    |    |    | 34 – 50% |    |    |    | 51 – 67% |    |    |    | 68 – 83% |    |    |    | 84 – 100% |    |    |    |
| % of scenarios that belong to each group | hydropower                                   | 94                     | 81  | 79  | 88  | 6        | 19 | 21 | 12 | 0        | 0  | 0  | 0  | 0        | 0  | 0  | 0  | 0        | 0  | 0  | 0  | 0         | 0  | 0  | 0  |
|                                          | rooftop solar PV                             | -                      | 100 | 100 | 100 | -        | 0  | 0  | 0  | -        | 0  | 0  | 0  | -        | 0  | 0  | 0  | -        | 0  | 0  | 0  | -         | 0  | 0  | 0  |
|                                          | open field solar PV                          | -                      | 81  | 82  | 90  | -        | 19 | 18 | 10 | -        | 0  | 0  | 0  | -        | 0  | 0  | 0  | -        | 0  | 0  | 0  | -         | 0  | 0  | 0  |
|                                          | onshore wind                                 | 62                     | 48  | 42  | 54  | 37       | 52 | 58 | 46 | 1        | 0  | 0  | 0  | 0        | 0  | 0  | 0  | 0        | 0  | 0  | 0  | 0         | 0  | 0  | 0  |
|                                          | offshore wind                                | 95                     | 100 | 100 | 100 | 5        | 0  | 0  | 0  | 0        | 0  | 0  | 0  | 0        | 0  | 0  | 0  | 0        | 0  | 0  | 0  | 0         | 0  | 0  | 0  |
|                                          | biomass                                      | 98                     | 98  | 98  | 99  | 2        | 2  | 2  | 1  | 0        | 0  | 0  | 0  | 0        | 0  | 0  | 0  | 0        | 0  | 0  | 0  | 0         | 0  | 0  | 0  |
|                                          | waste incineration                           | 100                    | 100 | 100 | 100 | 0        | 0  | 0  | 0  | 0        | 0  | 0  | 0  | 0        | 0  | 0  | 0  | 0        | 0  | 0  | 0  | 0         | 0  | 0  | 0  |
|                                          | nuclear power                                | 43                     | 75  | 87  | 76  | 53       | 25 | 13 | 24 | 4        | 0  | 0  | 0  | 0        | 0  | 0  | 0  | 0        | 0  | 0  | 0  | 0         | 0  | 0  | 0  |
|                                          | natural gas                                  | 75                     | 78  | 65  | 64  | 24       | 17 | 28 | 28 | 0        | 4  | 7  | 8  | 0        | 1  | 0  | 0  | 0        | 0  | 0  | 0  | 0         | 0  | 0  | 0  |
|                                          | coal                                         | 80                     | 87  | 85  | 82  | 14       | 10 | 11 | 14 | 0        | 3  | 4  | 2  | 6        | 0  | 0  | 1  | 0        | 0  | 0  | 0  | 0         | 0  | 0  | 0  |
|                                          | natural gas with CCS                         | 100                    | 86  | 91  | 91  | 0        | 13 | 8  | 9  | 0        | 2  | 1  | 1  | 0        | 0  | 0  | 0  | 0        | 0  | 0  | 0  | 0         | 0  | 0  | 0  |
|                                          | coal with CCS                                | 95                     | 90  | 96  | 90  | 0        | 9  | 2  | 9  | 2        | 1  | 1  | 1  | 2        | 0  | 0  | 0  | 0        | 0  | 0  | 0  | 0         | 0  | 0  | 0  |
|                                          | net import                                   | 100                    | 93  | 96  | 98  | 0        | 7  | 4  | 2  | 0        | 0  | 0  | 0  | 0        | 0  | 0  | 0  | 0        | 0  | 0  | 0  | 0         | 0  | 0  | 0  |
|                                          | aggregated sources                           |                        |     |     |     |          |    |    |    |          |    |    |    |          |    |    |    |          |    |    |    |           |    |    |    |
|                                          | solar PV                                     | 85                     | 42  | 43  | 52  | 15       | 58 | 57 | 48 | 0        | 0  | 0  | 0  | 0        | 0  | 0  | 0  | 0        | 0  | 0  | 0  | 0         | 0  | 0  | 0  |
|                                          | wind                                         | 23                     | 21  | 19  | 30  | 66       | 54 | 48 | 54 | 10       | 25 | 33 | 16 | 0        | 0  | 0  | 0  | 0        | 0  | 0  | 0  | 0         | 0  | 0  | 0  |
|                                          | biomass and waste inc.                       | 100                    | 85  | 85  | 96  | 0        | 15 | 15 | 4  | 0        | 0  | 0  | 0  | 0        | 0  | 0  | 0  | 0        | 0  | 0  | 0  | 0         | 0  | 0  | 0  |
|                                          | fossil fuels with CCS                        | 96                     | 73  | 78  | 72  | 0        | 21 | 21 | 22 | 2        | 5  | 2  | 6  | 2        | 1  | 0  | 0  | 0        | 0  | 0  | 0  | 0         | 0  | 0  | 0  |

Figure 5.6. Grouping of electricity supply scenarios for the EU27 per scenario type, i.e., model-based (MB) or preferred (PR) for France (FR), Germany (DE), and Poland (PL), and per share of each electricity supply

source in the total supply. For each group, the percentage of the scenarios is shown, e.g., 94% of model-based scenarios for the EU27 have a share of hydropower in the total supply between 0 and 16%. The percentages are color coded from dark green (100% of the scenarios belong to the group) to white (0%). Percentages were not calculated for disaggregated solar PV sources due to the scarcity of data in model-based scenarios.

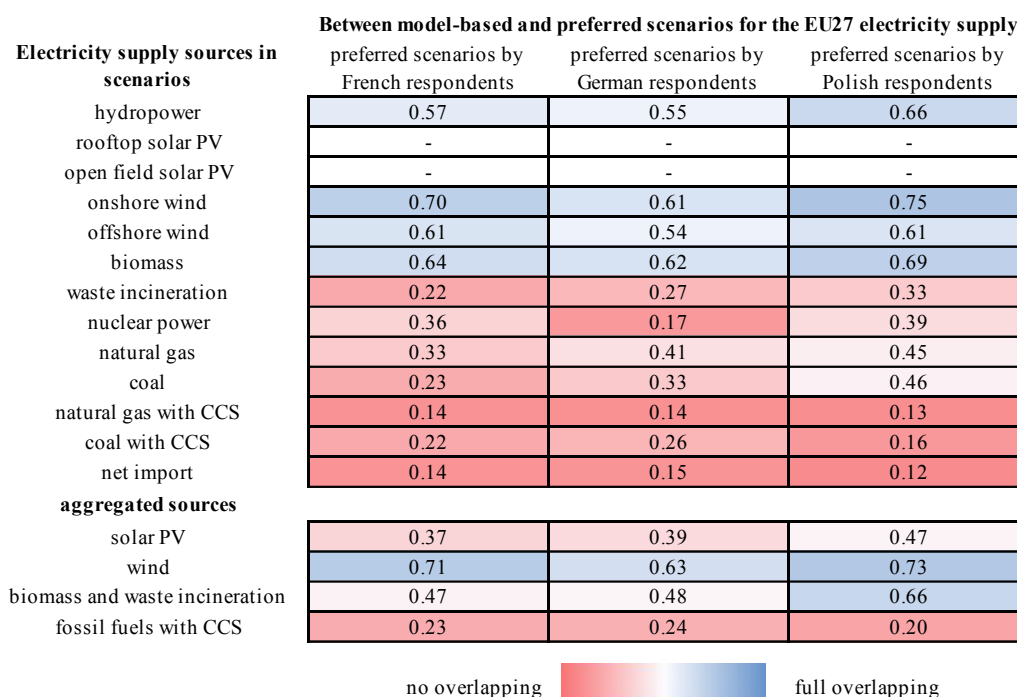


Figure 5.7. Overlapping indices ( $\eta$ ) between model-based and preferred scenarios for the EU27. An overlapping index of 1 indicates full overlap, and 0 — no overlap. Overlapping indices were not calculated for disaggregated solar PV sources due to the scarcity of data in model-based scenarios.

Divergences between model-based and preferred scenarios for the EU27 were found on aggregated solar PV, waste incineration, fossil fuels with CCS, nuclear power, natural gas, and coal power plants. Specifically, the shares of aggregated solar PV in model-based scenarios were, on average, less than half of the shares of preferred scenarios from all three country samples ( $Md$  for MB: 8%, PR-FR: 18%, PR-DE: 18%, PR-PL: 16%). Additionally, while most model-based scenarios had almost zero shares from waste incineration, natural gas with CCS, and coal with CCS, most preferred scenarios included low shares from these alternatives ( $Md$  for waste incineration for MB: 1%, PR-FR: 3%, PR-DE: 2%, PR-PL: 2%; natural gas with CCS for MB: 0%, PR-FR: 2%, PR-DE: 3%, PR-PL: 4%; coal with CCS for MB: 0%, PR-FR: 2%, PR-DE: 2%, PR-PL: 3%). In contrast, most model-based scenarios had more than three times higher shares from nuclear power and coal than citizens' preferred scenarios from all samples ( $Md$  for nuclear power for MB: 18%, PR-FR: 4%, PR-DE: 2%, PR-PL: 6%; coal for MB: 9%, PR-FR: 2%, PR-DE: 2%, PR-PL: 3%). Similarly, model-based scenarios had, on average, higher shares from natural gas than most preferred scenarios and especially than most scenarios by French respondents ( $Md$  for MB: 12%, PR-FR: 3%, PR-DE: 7%, PR-PL: 9%). For all diverging technologies, overlapping indices were

below 0.5, indicating a lack of convergence between model-based scenarios and preferred scenarios of all three countries (Figure 5.7). The lowest indices were found for natural gas with CCS ( $\eta$  between MB and PR-FR: 0.14, MB and PR-DE: 0.14, MB and PR-PL: 0.13) and coal with CCS ( $\eta$  between MB and PR-FR: 0.22, MB and PR-DE: 0.26, MB and PR-PL: 0.16), which signified very low overlapping between model-based scenarios and preferred scenarios from all countries. In terms of solar PV, waste incineration, and coal, overlapping with model-based scenarios was somewhat higher for preferred scenarios by Polish respondents, compared to preferred scenarios by German and, especially, French respondents ( $\eta$  for solar PV between MB and PR-FR: 0.37, MB and PR-DE: 0.39, MB and PR-PL: 0.47;  $\eta$  for waste incineration between MB and PR-FR: 0.22, MB and PR-DE: 0.27, MB and PR-PL: 0.33;  $\eta$  for coal between MB and PR-FR: 0.23, MB and PR-DE: 0.33, MB and PR-PL: 0.46). In terms of nuclear power, the lowest overlapping with model-based scenarios was found for preferred scenarios by German respondents ( $\eta$  between MB and PR-FR: 0.36, MB and PR-DE: 0.17, MB and PR-PL: 0.39). For natural gas, overlapping was the lowest for preferred scenarios by French respondents ( $\eta$  between MB and PR-FR: 0.33, MB and PR-DE: 0.41, MB and PR-PL: 0.45).

Divergences between model-based and preferred scenarios were also found in terms of net import and export for the EU27. Almost all model-based scenarios had near-zero net import or export, reflecting the current electricity supply mix and trade in the EU27 (Eurostat, 2020f). In contrast, the majority of preferred scenarios had some net export (65% of preferred scenarios from France, 63% — from Germany, 73% — from Poland). For the respondents that included net export in their scenarios, most German and French respondents exported more than 4% of the electricity produced in the EU27, while most Polish respondents exported more than 8%. For the minority of respondents that included net import in their scenarios, the share of net import in total supply was limited and ranged between 2 and 3%. Finally, overlapping indices were very low for net import, further emphasizing the divergences between model-based and preferred scenarios ( $\eta$  between MB and PR-FR: 0.14, MB and PR-DE: 0.15, MB and PR-PL: 0.12).

## 5.4 Discussion

For the electricity supply in France, Germany, and Poland in 2035, citizens' preferred scenarios had major differences from the respective electricity supply mixes in 2019. While the French mix in 2019 was dominated by nuclear power, the Polish — by coal, and the German — by a mix of nuclear power, coal, and natural gas, citizens' preferred scenarios were dominated by renewable sources, especially wind power and solar PV. In contrast, model-based scenarios for 2035 with higher shares of nuclear power, coal, and natural gas in all countries were much closer to the current situation than to citizens' preferred scenarios. The most striking divergences between model-based and preferred scenarios for all countries in 2035 were found for solar PV and fossil fuels with CCS. While most preferred scenarios included shares from solar PV at a level of 10% in France and Poland and more than 20% in Germany, most model-based scenarios had



less than half of these shares. Large, representative surveys have shown that citizens of these countries are known to have very high preferences for solar PV (European Commission, 2019a, 2019b; Poortinga et al., 2018). As for model-based scenarios, comparatively low shares of solar PV have been acknowledged as a modeling limitation that needs further improvement of models (Jaxa-Rozen and Trutnevyte, 2021). Model-based scenarios also included very low or zero shares from fossil fuels with CCS, potentially due to high assumed costs of these technologies in models based on a cost-optimization principle (De Vita et al., 2018) and due to limited potential based on acceptance. While European citizens may be indeed concerned by CCS as an unknown technology (L'Orange Seigo et al., 2014; Upham and Roberts, 2011), the Riskmeter results showed that many respondents could possibly accept low shares of these technologies as a tradeoff to keep some of the existing fossil fuel power plants without large impacts on climate change, or as a way to have diversified technology mixes. It is noted that Riskmeter also showed cost impacts for all technologies (Figure 5.1), including CCS.

Model-based and preferred scenarios converged mostly on moderate shares of onshore and offshore wind power and low shares of biomass and waste incineration. Wind power was extensively used in many model-based scenarios that aimed to achieve climate change mitigation targets as it had the highest supply potential among all renewable sources in Europe (Ruiz et al., 2019) as well as one of the lowest costs (Bauer et al., 2019). As for preferred scenarios, most citizens used more than half of the potential of wind power in the Riskmeter. This finding is in line with previous survey results showing that citizens of all examined countries have a high preference for wind power (European Commission, 2019a; Poortinga et al., 2018). Citizen preferences from the same surveys were lower for biomass and waste incineration, explaining potentially the low Riskmeter potential used by most respondents. In model-based scenarios, biomass was also kept constant or slightly grew compared to 2019 due to the higher costs that are usually assumed in models.

For all other examined supply sources (nuclear power, coal, natural gas, hydropower, and net imports), model-based and preferred scenarios converged or diverged differently for each country. In comparison to preferred scenarios, model-based scenarios included more nuclear power in France, more coal in Poland and Germany, and more natural gas in Germany. While most model-based scenarios showed a more decarbonized or denuclearized electricity supply mix for 2035 than the current ones (Eurostat, 2020c), most of these model-based scenarios were still dependent on several existing power plants. In contrast, most preferred scenarios represented a more disruptive break from the current electricity mix and even from the national energy policy targets for 2035 (BMW, 2020a; Ministry of State Assets, 2020; MTES, 2020a). The need for an ambitious transition has been previously articulated in Germany, where citizens preferred a phase-out of coal earlier than 2038 that is currently planned (Rinscheid and Wüstenhagen, 2019), and in France, in the recent citizens' panel for the climate (Cathleen, 2020). One factor behind the divergences is that the vast majority of model-based scenarios did not base their scenarios on broad stakeholder or public consultation, except for a few studies for France (Centre

d'Analyse Stratégique, 2012) and Germany (German Advisory Council on the Environment, 2011; Schmid and Knopf, 2012). Another potential reason behind the divergences where that scenario exercises typically include business-as-usual scenarios for comparison and these scenarios have been included in the review. However, 75% of model-based scenarios had higher coal than 75% of preferred scenarios in Poland, indicating a wider pattern in scenario modeling which is not entirely due to the business-as-usual scenarios. Similar patterns have been found for coal in Germany and nuclear power for France. In terms of hydropower, most preferred scenarios had slightly higher shares from hydropower than most model-based scenarios in Germany and Poland, reflecting higher preferences of citizens for this technology (Poortinga et al., 2018). While a similar result was found for France, the difference was not statistically significant, possibly due to the small range of supply potential that was allowed in the Riskmeter. As for electricity trading, most preferred scenarios in all countries included net exports, potentially reflecting preferences for national autarky or concerns for security of supply (Demski et al., 2018). In model-based scenarios, electricity trading differed depending on the country: net exports were used in France, net imports — in Germany, and almost no net imports or exports — in Poland. For France and Poland, these are the patterns of electricity trading from 2019 (Eurostat, 2020f). Germany is currently a net exporter, but many model-based scenarios suggest that it could become a net importer in 2035 (Lunz et al., 2016).

Interestingly, the comparison between model-based and preferred scenarios for the EU27 electricity supply in 2035 showed patterns of convergences and divergences that were similar to the patterns found for national scenarios. Convergences between model-based and preferred scenarios for the EU27 were found on moderate shares of wind power and low shares of biomass and waste incineration, as in the case of the examined countries. Convergences also occurred on low shares of hydropower, while model-based and preferred scenarios diverged for all other technologies. Specifically, model-based scenarios had more than three times higher shares of nuclear power and coal than preferred scenarios from all citizen samples. Model-based scenarios had also higher shares of natural gas, especially compared to preferred scenarios from the French sample. In contrast, preferred scenarios had more than double shares of solar PV and waste incineration compared to model-based scenarios. As for their national electricity supply, most respondents preferred to use low shares of fossil fuels with CCS (7 – 8% on average) while most model-based scenarios had almost zero supply from these alternatives. Most citizens also preferred to include net exports in their scenarios for the EU27 like for their countries, while most model-based scenarios had almost zero net imports or exports. The similarity between preferred scenarios for national and EU27 electricity supply may be due to the respondents' extrapolation of preferences from their national electricity supply to the one of the EU27, as the respondents were probably more familiar with their national electricity context and discussion than the diversity of the countries in the EU27. To some extent, this finding, however, questions the reliability of online surveys and tools, like Riskmeter, to elicit citizen preferences at national and continental scales that are far from the citizens' everyday lives (Pidgeon et al., 2014). For a more

extensive discussion on this topic, see the discussion by Xexakis and Trutnevyte (2021a). In the case of model-based scenarios, restrictive expectations by modelers about technologies may limit build rates and deployment in both national and EU27 scenarios, as in the case of solar PV and CCS technologies (De Vita et al., 2018; Jaxa-Rozen and Trutnevyte, 2021). Additionally, the energy modeling community has yet to include scenarios with discontinuities or departure from current trends (McCollum et al., 2020), even when modeling for the not-so-distant timeframe of 2035. Many model-based scenarios also simulate policy targets, which have been shown not to always correspond to the ambition of the public (Allen and Chatterton, 2013; Rinscheid and Wüstenhagen, 2019).

## 5.5 Conclusions

With the European Green Deal, the European Union aims to achieve an ambitious decarbonization of its electricity supply, while actively involving its citizens. Scenarios from energy and electricity sector models seek to inform this transition, although it is unclear to what extent these scenarios are aligned with the views of the citizens. We compiled four multi-organization, multi-model ensembles of electricity supply scenarios for 2035 for France, Germany, Poland, and the whole EU27 with 612 scenarios in total, and compared these model-based scenarios with 601 preferred scenarios elicited from French, German, and Polish citizens in an online survey, using an interactive scenario tool Riskmeter. Results for the national electricity supply in three countries show that model-based and citizens' preferred scenarios converged only on moderate shares of onshore and offshore wind and low shares of biomass and waste incineration. In contrast to most model-based scenarios, most Polish and German citizens preferred a deeper decarbonization for their national electricity supply, while French citizens additionally preferred a deeper denuclearization. Citizens used instead comparatively large shares from solar PV and some low shares of fossil fuels with CCS in their national scenarios, diverging from model-based scenarios where the shares of these technologies were minimal. Similar patterns were found for the EU27, where most model-based scenarios included large shares of nuclear power, natural gas, and coal, while citizens of all three countries preferred scenarios dominated by diverse renewable sources and complemented with small shares of fossil fuels with CCS. These divergences are even more significant considering that citizens could use almost exclusively nuclear power, natural gas, and coal (with or without CCS) in their preferred scenarios, while, in reality, they kept these technologies to a minimum. Additionally, Xexakis and Trutnevyte (2021a) showed that these preferred scenarios were mostly independent of the citizens' demographics, political orientations, and attitudes towards governance.

For policymakers and researchers working on the electricity transition of the EU27, this study offers insights that could be used to model new, citizen-informed scenarios for the transition. For all examined Member States and the EU27, future scenarios should consider a faster and deeper transition from the current electricity mix to diverse mixes that rely more on

renewable sources. Additionally, the finding that citizens of different countries preferred a similar electricity supply mix for the EU27 is good news for the implementation of the Energy Union as it highlights an already existing international convergence. However, citizens' views on the energy strategy for the whole bloc are affected by their national context: for instance, German respondents did not want nuclear power neither in their country nor the EU27, whereas Polish citizens saw nuclear power as part of their future electricity mix. For the scenario modeling community in general, the fact that all four multi-organization, multi-model scenario ensembles showed significant divergences from the respective citizens' preferred scenarios suggests a wider pattern of misalignment between models and public opinion. As suggested for addressing a similar issue in Switzerland (Xexakis et al., 2020), modelers could use structured methods for widening scenario generation (Sasse and Trutnevyte, 2020), re-examine modeling assumptions that may constrain alternatives, such as solar PV or CCS, or also engage more in participatory construction of scenarios. The Riskmeter and other similar tools can offer ways for eliciting citizen perspectives that can be directly used by models.

# Chapter 6 Evaluation of an interactive web-tool for scenario communication

This chapter is based on Xexakis and Trutnevyte (2019a).

## 6.1 Introduction

Interaction between scientists and the public, stakeholders and decision makers is often seen as a powerful way to increase the accessibility and impact of scientific results (Lemos et al., 2012; Mach et al., 2017; Voinov et al., 2016). Due to the growing capabilities of web services and the far-reaching connectivity of the Internet, web applications are increasingly appearing in order to allow us to interact with environmental science products, such as databases, models, scenarios and maps (Moss, 2016). Based on the intended interaction between the developers of such interactive web-tools and their users, we observe four types of usage: (1) outreach and education, (2) two-way engagement, (3) scientific research and (4) decision support. First, interactive web-tools have been used to explain complex environmental issues, for instance climate change or energy transition, by providing interfaces for the public to actively explore underlying systems and future scenarios (DECC, 2013; U.S. Federal Government, 2014). Second, some tools have been asking users to submit their views and comments on a subject (Babbar-Sebens et al., 2015; Lai et al., 2011) with the aim to create a two-way dialogue and “reflect useful social intelligence back” (Pidgeon et al., 2014). Third, the results of the interaction with such tools have also been used to inform scientific research, allowing, for example, scientists to analyze submitted answers in order to understand how users formulated them (Bessette et al., 2016; Demski et al., 2017; Volken et al., 2018). Fourth, tools have been developed to support actual decisions by providing interactive interfaces with scientific products in order to assist users, such as policy-makers and stakeholders, in finding a scientific basis for decision-making (Sandink et al., 2016). Apart from the use of these interactive web-tools in the environmental fields, diverse domains have followed the same trend, including medicine (Ancker et al., 2011), life quality (OECD, 2011) and social sciences (Jones et al., 2016).

There have been claims of multiple benefits of interactive web-tools as compared to more traditional scientific outputs, such as technical reports, policy briefs, academic publications, and other written documents. First of all, it has long been assumed that they can promote understanding by allowing the user to actively explore information (McInerney et al., 2014;

Spiegelhalter et al., 2011; Strecher et al., 1999). Whereas traditional scientific outputs show “static” visualizations and explanations of data or model outputs, interactive web-tools offer control over this information. By clicking on interactive elements, like buttons and sliders, the user can change parameters and see the effects, uncovering the data at a custom pace. This is claimed to be particularly helpful in explaining multidimensional problems and can possibly help users in developing robust mental models on a subject (Grainger et al., 2016; McInerny et al., 2014). Other control elements allow the user to change the form of information by zooming, sorting and highlighting (Heer et al., 2012) or even by switching representation format (e.g., from qualitative to quantitative) in order to adapt to the preferences and competences of the users (Spiegelhalter et al., 2011). These adaptation opportunities are also assumed to improve the visibility and accessibility of related uncertainties by directing attention, for example, to low-probability events (Ancker et al., 2011; Spiegelhalter et al., 2011). Furthermore, interactive web-tools are believed to support user engagement even with complex subjects that users have little initial familiarity (Pidgeon et al., 2014). The “learning-by-doing” experience provided by such tools is believed to increase the time and effort spent by users, making them more involved in learning (Strecher et al., 1999, p. 134). Adding gaming mechanisms and appealing graphics to interactive web-tools is also considered to provide further opportunities to engage users through an entertaining and playful environment (I. Mayer et al., 2014; Voinov et al., 2016).

Using interactive web-tools has been also suggested as a solution for effectively customizing information to different audiences, e.g., in the case of communicating scenarios based on long-term climate and energy analysis (DeCarolis et al., 2017; Guivarch et al., 2017; IPCC, 2016; Moss, 2016; Trutnevyte et al., 2016a). As models can generate an infinite number of plausible scenarios to capture future uncertainty, scenario developers reduce them to a small number in order to present them (Berntsen and Trutnevyte, 2017), usually in easily understandable forms such as narratives (Alcamo, 2008; McInerny et al., 2014). This strategy might not match the needs of scenario users who need more customized scenarios or it may lead to a disregard of potentially important uncertainties that exist in other scenarios (Braunreiter and Blumer, 2018; Trutnevyte et al., 2016a). While there are techniques to diversify a set of scenarios and increase the uncertainty considered (Berntsen and Trutnevyte, 2017; Carlsen et al., 2016a; Tietje, 2005), other solutions suggest a more interactive way of iteratively “interrogating” models to explore a larger number of scenarios (DeCarolis et al., 2016; Lempert, 2002). In this case, interactive web-tools could provide access to large databases of scenarios along with transparent methods to extract useful sub-sets tailored to the needs of users, e.g., the most internally consistent or the most policy-relevant scenarios (Trutnevyte et al., 2016a). Such methods are rarely found in existing tools, such as the scenario database viewer from the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IIASA, 2014). Through the process of creating and testing their custom scenarios, users reflect their own values and views on how the policy issue could be solved, leading to a more interesting learning experience (Pidgeon et al., 2014).

Despite calls from many scientific communities, empirical evaluations of interactive web-tools are still relatively limited (Moss, 2016; Stellamanns et al., 2016; Trutnevyte et al., 2016a; Wong-Parodi et al., 2014). Such evaluations may be critical for uncovering potential problems in the real use of these tools, as shown in more common evaluations of other information types, such as written communication or visualizations (Bosetti et al., 2017; Budescu et al., 2014; Canfield et al., 2017; Harold et al., 2016; Knoblauch et al., 2017; McMahon et al., 2015). In the case of interactive web-tools, most evaluations focused on the understanding and engagement of non-expert audiences. Wong-Parodi et al. (2014) suggested a framework for evaluating user comprehension in interactive decision aids and demonstrated it in a tool for coastal flooding. Mayer et al. (2014) and Pidgeon et al. (2014) reported high levels of user understanding and engagement with an interactive scenario-builder for exploring future energy systems. Bessette et al. (2016, 2014) also reported high knowledge gains in users of a similar tool that was embedded in a structured decision-making framework. Gong et al. (2017) reported effects on user exploration strategies, when different types of modelling results were shown in a tool, e.g., scenarios vs. forecasts. Parker et al. (2015) showed that tools that summarized large databases of simulation-derived scenarios resulted in useful and understandable information for the users. Demski et al. (2017) found indications of preference anchoring, when exemplar scenarios were used in interactive scenario-builders. However, none of the above studies asked the very fundamental question whether the interactive web-tools perform better than the equivalent traditional formats, such as a report or a simple website, and hence justify the extra cost and effort to develop such interactive tools.

The few existing comparisons between interactive and static tools are inconclusive. Two studies on medical risk communication, Ancker et al. (2011) and Zikmund-Fischer et al. (2011), compared interactive and static pictographs (i.e., data representations with arrays of icons). While the first study detected no difference between the effects of the two graphics on understanding, the second one found indications of lower understanding and higher cognitive burden in the interactive condition. The last finding has also been identified in a study where users had to make trade-offs for land-use allocation (Arciniegas et al., 2013). On the contrary, a study on the adoption of energy-efficiency appliances showed that users using an interactive web-tool instead of educational slides were more effective in identifying the appliance with the lowest lifetime cost (Blasch et al., 2017). In the case of scenario-related tools, one nation-wide study for the Australian energy system found higher preference consistency using an online interactive scenario-builder than an information table (Jeanneret et al., 2014). Although the aforementioned study clearly commented on the users' understanding and engagement, it did not measure these factors quantitatively. Finally, in a study on Swiss electricity supply scenarios, we found similar satisfaction and self-reported understanding rates between an interactive electricity scenario-builder and static factsheets on paper (Volken et al., 2018).

Empirical evaluations are even scarcer on the role of the users' characteristics, such as demographics, skills or needs. Although it has been suggested many times that audience skills

can enhance or limit the effectivity of interactive web-tools (Cohen and Hegarty, 2007; Harold et al., 2016; Spiegelhalter et al., 2011), only three aforementioned studies evaluated this. Both Ancker et al. (2011) and Zikmund-Fischer et al. (2011) studied numeracy; while the former study found indications that interactive web-graphics could alleviate numeracy problems, their finding was not reproduced in the latter. Blasch et al. (2017) studied a wide range of factors including age, education level and relevant literacy on energy-related investment. They found that higher education and literacy level positively correlated with identifying an appliance with lower lifetime cost, while the opposite was true for age. Nevertheless, they did not find any interaction between these factors and the tool's format. Web-related skills, although assumed important (Harold et al., 2016), have not yet been assessed. Similarly, there is no evaluation of whether users do get better customized information from interactive web-tools and whether this can support their needs in a better way than a non-customizable static output, such as a written document or a conventional static website.

### 6.2 Research questions and case study

In contrast to the growing number of interactive web-tools for outreach and education, two-way engagement, scientific research and decision support, there is little empirical evidence whether they can be more effective in comparison with a static medium. This is especially the case for interactive web-tools that allow users to build scenarios or explore large scenario databases. Although these tools are widely used for engaging non-expert users with complex issues, there have not yet been any empirical evaluation whether they can work better than traditional scenario techniques with a handful of static scenarios with narratives/storylines i.e., the so-called story-and-simulation approach (Alcamo, 2008; Trutnevyte et al., 2016a). This study focuses on these scenario-related tools and aims to address the following questions:

1. How does an interactive web-tool with access to a large scenario database versus four static scenarios with storylines perform in making scenario information understandable, trustworthy and engaging for non-expert users?
2. How do the demographics, prior experience with the topic, numeracy, and website navigation skills of the users, influence this performance for each scenario format type?

As a case study, we chose to adapt an interactive web-tool Riskmeter (available at <https://riskmeter.ch/>) that we have developed in a recent study for understanding the preferences of an informed citizen panel in Switzerland for the Swiss electricity supply scenarios for 2035 and their environmental, health, and economic impacts (Volken et al., 2018). In Riskmeter, the users can explore a database of Swiss electricity scenarios for 2035, while making trade-offs between their environmental, health, and economic impacts and adhering to the technological constraints.



## 6.3 Methodology

### 6.3.1 Overall study design

In order to compare the interactive web-tool with the four static scenarios, an experimental approach was chosen. The format of scenario information was the sole experimental factor, resulting in a between-groups experiment with two experimental conditions: (1) the four scenarios condition and (2) the interactive web-tool condition. The experiment was implemented in the form of an online survey because in this way the personal context of user experience was kept (i.e., when users access such online web-tools by themselves). The survey started with a short introduction in the topic of the Swiss electricity supply and continued with questions related to the control variables of the study (Section 6.3.4). Participants were then randomly assigned to one of the two experimental conditions and received a link to a website that included either the interactive web-tool or four pre-selected scenarios (Section 6.3.2). A tutorial guiding participants in both websites was available but not obligatory. The participants were instructed to spend at least 2-3 minutes studying the information on the website and then to return to the survey to evaluate their experience with the website.

As shown in Table 6.1, we evaluated the two experimental groups in terms of (a) tested understanding, (b) self-reported understanding, (c) self-reported trust of information, (d) self-reported engagement, and (e) time spent on the website and drop-out rates. Our evaluation is based on frameworks used in previous conceptual and empirical evaluation studies of web-tools (Jeanneret et al., 2014; L. A. Mayer et al., 2014; Wong-Parodi et al., 2014; Zikmund-Fisher et al., 2011), although broader literature on user satisfaction exists too, e.g., Violante and Vezzetti (2017). Tested and self-reported understanding as well as tested and self-reported engagement are relatively common evaluation metrics. Trust has been only indirectly used in previous studies, although it can be affected by visualization characteristics (McInerney et al., 2014) and is part of frameworks and methodologies that assess information quality in general (Knight and Burn, 2005; Lee et al., 2002). More details on how dependent variables were measured are given in Section 6.3.3. The whole survey process is given in the form of a flow-chart in Figure 6.1.

Table 6.1. Dependent variables and their measurements

| Dependent variables | Measurement                                              |                                                                   |
|---------------------|----------------------------------------------------------|-------------------------------------------------------------------|
|                     | Self-reported                                            | Tested                                                            |
| Understanding       | Survey construct<br>(6 items, 7-point Likert scale each) | True or False quiz on content<br>(7 items, true/false/don't know) |
| Trust               | Survey construct<br>(7 items, 7-point Likert scale each) | -                                                                 |
| Engagement          | Survey construct<br>(7 items, 7-point Likert scale each) | Time spent on the website<br>Drop-out rates                       |

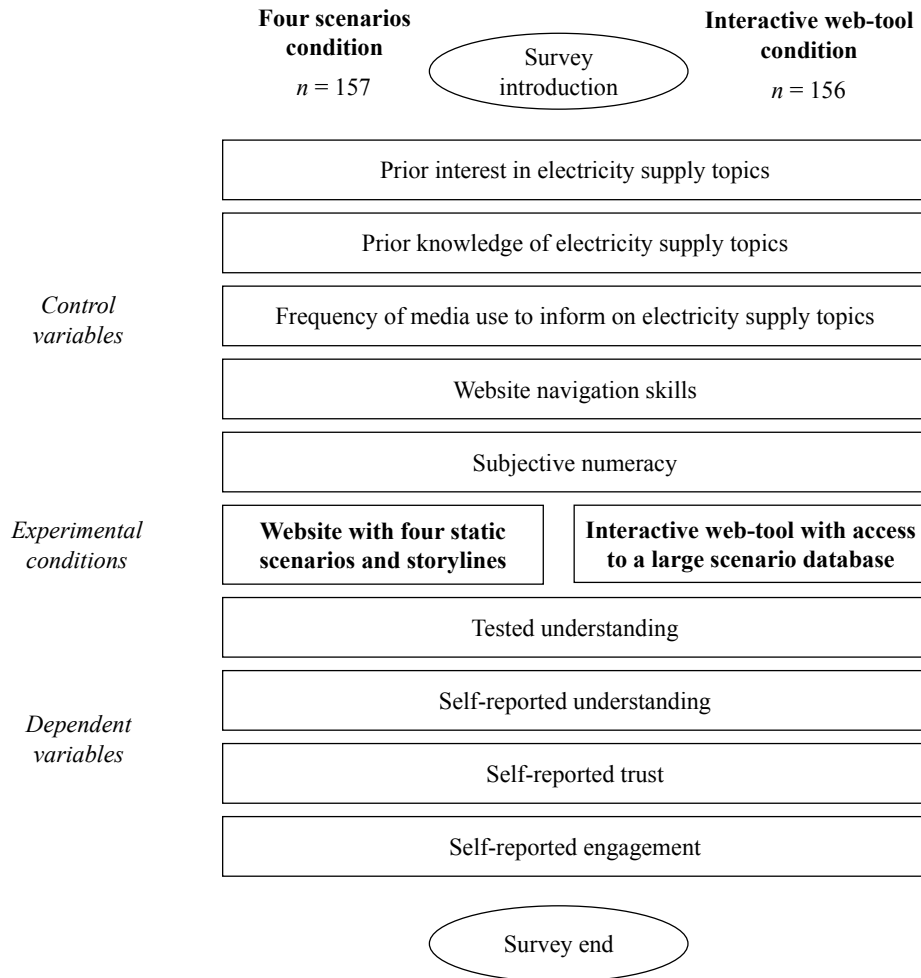


Figure 6.1. The flow-chart of the survey, showing all consecutive steps and the two experimental conditions. The dependent variables also include tested engagement, measured in the time spent on the website and the drop-out rates (see Section 6.3.3).

The survey and both web formats have been pretested with energy experts as well as 60 non-experts. These 60 individuals were only part of the pretesting and did not participate in the actual experiment. Based on the pretest feedback, we made several adjustments before launching the actual experiment. Additionally, as our materials were based on previous research, they have been already evaluated by other non-experts and a communication expert (Volken et al., 2018). The full survey script is available in Appendix D.

### 6.3.2 Experimental conditions

The interactive web-tool illustrated 13 electricity supply alternatives for Switzerland in 2035, their constraints and their environmental, health, and economic impacts. The alternatives included generation technologies that already exist or could be newly developed in Switzerland: large hydropower dams, large run-of-river hydropower, small hydropower, solar cells

(photovoltaic), wind, deep geothermal, woody biomass, biogas, nuclear power, waste incineration, large natural gas power plants and net import from abroad. Electricity savings and efficiency improvements could also be chosen as an alternative to reduce the demand and the need for generation technologies. The choice of supply alternatives and their constraints were based on a previous energy modelling study that resulted in a large database of possible scenarios for the electricity supply in Switzerland 2035 (Berntsen and Trutnevyte, 2017).

The assessment of environmental, health, and economic impacts were informed by two previous studies. Volken et al. (2017) used 12 semi-structured interviews in Switzerland in order to evaluate what non-experts knew and wanted to know about the various impacts of electricity generation. Volken et al. (2018) then used color-coded factsheets with nine environmental, health, and economic impacts to elicit the informed preferences of the Swiss non-experts for electricity scenarios 2035. From these impacts, seven key impacts were chosen for this study and were quantified per TWh of supplied electricity using one or multiple indicators. The indicators' data were found in the literature, prioritizing sources that were closer to the context of the Swiss electricity system and, if possible, to the assessments for 2035. The chosen impacts and indicators included: (1) impacts on climate change, quantified in terms of CO<sub>2-eq</sub> (Bauer et al., 2017, 2012; Volkart et al., 2016); (2) local air pollution, quantified in terms of PM<sub>10eq</sub>, SO<sub>x</sub> and NO<sub>x</sub> (Bauer et al., 2012; Masanet et al., 2013); (3) impacts on water, quantified in terms of water withdrawal and consumption (Fthenakis and Kim, 2010; Wernet et al., 2016); (4) impacts on landscape and land use, quantified in terms of m<sup>2</sup> of land use (Masanet et al., 2013; Maxim, 2014); (5) accidental impacts, quantified in terms of expected mortality and maximum fatalities in an accident (Volkart et al., 2016); (6) electricity costs, quantified in terms of Rp./kWh (SFOE, 2016), and (7) electricity supply reliability, quantified in terms of three expert-derived metrics (Volkart et al., 2016), including autonomy (i.e., the degree to which the electricity supply chain is local), dispatchability (i.e., the degree to which the technology can supply electricity on demand) and equivalent availability factor (i.e., the degree to which a power plant is running at full capacity annually).

Through an interface of sliders (left panel of Figure 6.2), the users of the interactive web-tool controlled the utilization percentage of each alternative in TWh/year with the goal of covering the Swiss electricity demand of 70 TWh/year in 2035 (top center panel of Figure 6.2). The percentage extended from zero supply (0%) to the alternative's highest technical or resource potential for 2035 (100%) and could be moved in positions of 1% interval. For the existing generation technologies that would last until 2035, the slider was constrained to a minimum value equal to the supply that they are providing today. For all other alternatives and nuclear power (the Swiss Energy Strategy 2050 envisages gradual phase-out until 2035), the supply started at zero. For speed of interaction, the underlying model was kept simple: the contribution of each alternative in TWh/year was simply added to the total electricity supply. In this way, the interactive web-tool could create on the spot all possible combinations of supply alternatives given their constraints. The resulting process is equivalent to interactive web-tools querying a

## 6. Evaluation of an interactive web-tool for scenario communication

large database containing all these possible combinations. As in the publicly available Riskmeter version (<https://riskmeter.ch/basic/>), the web-tool showed immediate feedback per slider movement on seven impact categories (bottom right panel of Figure 6.2). Thermometers were used to visualize the impact values, where the rising temperature showed the impact severity that ranged from zero to the maximal value possible from the total set of scenarios in the web-tool.



Figure 6.2. The interactive web-tool for exploring Swiss electricity supply scenarios for 2035 and related environmental, health, and economic impacts. The tool was adapted from the publicly available tool Riskmeter (<https://riskmeter.ch/basic/>)

The four static scenarios were selected following the typical storyline-and-simulation approach (Alcamo, 2008; Trutnevyte et al., 2016a). The user could scroll down on the website and see four electricity supply scenarios with a title and a very short description (Figure 6.3). The scenarios were screenshots of the interactive web-tool, thus presenting exactly the same information and in visualizing this information in the same way. The selection of the scenarios was informed by existing scenarios for Switzerland (Berntsen and Trutnevyte, 2017; SFOE, 2012; VSE, 2012b, 2017) and intended to diversify the technologies and impacts presented by the four scenarios. The storylines along with details of each scenario can be found in Appendix D.



Figure 6.3. The website with four static electricity supply scenarios along with short introductory storylines. The numbering of the scenarios shows the order of the graphics and text on the website. Detailed, readable information about the storylines and the composition of the scenarios can be found in Appendix D.

### 6.3.3 Dependent variables

The dependent variables and their measurements are shown in Table 6.1. Tested understanding was measured through a content-based quiz with seven items, where participants needed to look up scenario information from the web-tool in order to answer "True" / "False" / "Don't know" to statements such as "The impact of electricity supply on local air pollution is low in any scenario". These quiz statements were carefully designed to be answerable by participants in both experimental conditions: participants in the four scenarios condition had to look across the four scenarios to find the answer, while participants in the interactive web-tool condition had to experiment with the sliders or create the test scenario mentioned in the statement in order to see if it was true or false. Self-reported understanding and all other self-reported variables were measured with seven items each on a seven-point Likert scale ranging from 1 = "totally disagree" to 7 = "totally agree". Most of these items were extended from previous studies (Jeanneret et al., 2014; Knight and Burn, 2005; Lee et al., 2002; L. A. Mayer et al., 2014; Wong-Parodi et al., 2014; Zikmund-Fisher et al., 2011). The internal reliabilities of the resulting scales were acceptable for

self-reported understanding (Cronbach's  $\alpha = 0.79$ ,  $N = 6$ , after removing one scale item), good for self-reported trust ( $\alpha = 0.84$ ,  $N = 7$ ), and excellent for self-reported engagement with the web-tool ( $\alpha = 0.92$ ,  $N = 7$ ). The time spent on the website and the drop-out rates were measured only in the survey stages when participants were introduced to the web-tool and when they were using it for answering the quiz. Appendix D includes the full survey.

### 6.3.4 Control variables

The control variables included demographics, questions on prior experience with the electricity supply topic and questions on skills related to the use of interactive web-tools (see Appendix D for the survey). After the introduction, the survey included demographic questions on gender, age, highest education level and employment status. Next, the participants reported on their prior experience with the electricity supply topic, through two sets of seven items each on their interest and knowledge level; similar items were used in previous studies too (Fleishman et al., 2010; L. A. Mayer et al., 2014; ter Mors et al., 2013; Volken et al., 2018). The internal consistency was good for both the prior interest scale ( $\alpha = 0.85$ ,  $N = 7$ ) and the prior knowledge scale ( $\alpha = 0.86$ ,  $N = 7$ ). The participants also had to report how often they used seven media categories (e.g., newspapers, television, internet) for receiving information on the topic, using a seven-point Likert scale coded as 1 = "never" to 7 = "always" ( $\alpha = 0.80$ ,  $N = 7$ ). The last section before the experimental part of the survey included two sets of five self-assessment items each on the participants' website navigation skills and subjective numeracy. The former was adapted from the Internet Skills Scale of Deursen et al. (2016) and reached acceptable internal consistency ( $\alpha = 0.74$ ,  $N = 5$ ). The latter was adapted from the Subjective Numeracy Scale of Fagerlin et al. (2007) and achieved good internal consistency, but only after removing one scale item (final  $\alpha = 0.82$ ,  $N = 4$ ).

### 6.3.5 Survey participants

In May 2018, we recruited 336 participants through an access panel in the German-speaking part of Switzerland. The access panel was designed to ensure that only non-experts can participate by excluding participants working or studying in the electricity or energy sector. From the 336 completed responses to the survey, 23 were assessed as inattentive and were excluded as: (a) they had unrealistically short answering times for the quiz for tested understanding (below one minute) or (b) their answers to a set of five questions pairs, where each pair included a normal and a reversed-phrased version of the same content, were inconsistent. Participants ranged in age from 18 to 69 years ( $M = 43.75$ ,  $SD = 13.99$ ) and  $n = 160$  (51.1%) self-reported as female. In terms of education, at least 42.8% of the participants have attained tertiary level of education (college or university), followed by 48.2% with secondary level (i.e., high school and vocational training) and 8.9% with primary level (obligatory education). The

sample is thus almost representative of the Swiss population: it is slightly older than the Swiss average ( $M = 41.73$  years), with a slightly higher female gender ratio (50.5%) and slightly more educated than the population (41.3% tertiary, 46.0% secondary and 12.7% primary education) (Eurostat, 2018; SFSO, 2016).

## 6.4 Results

### 6.4.1 Experimental check

The two experimental conditions were comparable in terms of all control variables as there were no statistically significant differences observed (Table 6.2). Both experimental groups on average reported moderate experience with electricity supply topics. Their prior interest in electricity supply topics scored slightly higher than the midpoint. Their prior knowledge and frequency of media use scored slightly lower than the midpoint. Website navigation skills and subjective numeracy were moderate-high in both groups with average scores well above the midpoint.

Table 6.2. Control variables by experimental condition

| Control variables                                                                    |                 | Experimental conditions                            |                                          | Statistic        |
|--------------------------------------------------------------------------------------|-----------------|----------------------------------------------------|------------------------------------------|------------------|
|                                                                                      |                 | Four scenarios<br>with storylines<br>( $n = 157$ ) | Interactive<br>web-tool<br>( $n = 156$ ) |                  |
|                                                                                      |                 | Count / $M \pm SD$                                 | Count / $M \pm SD$                       |                  |
| Gender<br>(count)                                                                    | Female          | 83                                                 | 77                                       | $\chi^2 = 0.385$ |
|                                                                                      | Male            | 74                                                 | 79                                       |                  |
| Highest education<br>level<br>(count)                                                | Primary level   | 17                                                 | 11                                       | $\chi^2 = 1.558$ |
|                                                                                      | Secondary level | 76                                                 | 75                                       |                  |
|                                                                                      | Tertiary level  | 64                                                 | 70                                       |                  |
| Age (range: 18-69)                                                                   |                 | 44.10 $\pm$ 14.14                                  | 43.40 $\pm$ 13.87                        | $t = 0.445$      |
| Prior interest in electricity supply topics<br>(score range: 7-49)                   |                 | 29.91 $\pm$ 8.54                                   | 29.44 $\pm$ 7.66                         | $t = 0.511$      |
| Prior knowledge of electricity supply topics<br>(score range: 7-49)                  |                 | 26.99 $\pm$ 7.95                                   | 27.01 $\pm$ 7.87                         | $t = -0.021$     |
| Frequency of media use to inform on<br>electricity supply topics (score range: 7-49) |                 | 26.54 $\pm$ 7.16                                   | 27.42 $\pm$ 6.82                         | $t = -1.107$     |
| Website navigation skills (score range: 5-35)                                        |                 | 24.90 $\pm$ 50.05                                  | 25.01 $\pm$ 4.99                         | $t = -0.202$     |
| Subjective numeracy (score range: 4-28)                                              |                 | 21.38 $\pm$ 3.95                                   | 20.97 $\pm$ 4.50                         | $t = 0.839$      |

Note: No statistically significant differences between experimental conditions at  $p < 0.05$ .  $t$ -tests and  $\chi^2$ -squared tests are used to calculate  $p$ -values. All statistics assume the four scenarios condition as the reference group. All survey items are available in Appendix D.

### 6.4.2 Non-experts using the interactive web-tool scored lower in tested understanding than the ones using four scenarios with storylines

As shown in Table 6.3, we found that non-experts using the interactive web-tool had, on average, less correct answers in the content-based understanding quiz than the ones using the four scenarios with storylines ( $t = 2.318$ ,  $p = 0.021$ ;  $M_{\text{interactive}} = 3.54$  vs.  $M_{\text{four scenarios}} = 40.03$  of

correct answers out of the total 7). The “Don’t know” answers in the quiz were used similarly between the two groups, suggesting that the format did not affect the ability of the participants to answer the quiz questions, but only reduced the accuracy rate. In order to further assess the quality of the participants’ answers to the quiz, the average number of correct and wrong answers was compared to the number that would result from random guessing (i.e., the sum of correct and wrong answers per condition, divided by two). For both conditions, a statistically significant difference was found (four scenarios condition:  $t = 9.148$ ,  $p < 0.001$ ,  $M_{correct} = 40.03$  vs.  $M_{random} = 2.78$ ; interactive web-tool condition:  $t = 4.248$ ,  $p < 0.001$ ,  $M_{correct} = 3.54$  vs.  $M_{random} = 2.82$ ). This finding implies that most of the participants made a genuine effort to answer and performed better with any of the tools than with random guessing. When the effects of demographics, prior interest in electricity supply topics, website navigation skills, and numeracy were controlled in a regression analysis, they did not significantly affect the results. This reinforced the notion that the format was a critical factor in the tested understanding quiz.

Looking at each quiz question separately, participants using the interactive web-tool performed worse in comparison with participants using the four scenarios with storylines in almost all of the quiz questions. These differences were statistically significant in three out of seven questions in total. This suggests that the effects of the interactive web-tool were not uniform across all questions and they may have depended on the complexity of each question. Overall, in our case, the interactive web-tool did not provide any benefit for understanding as compared to the website with four scenarios with storylines. Appendix D introduces the results of the tested understanding per quiz question.

Table 6.3. Dependent variables by experimental condition

| Dependent variables                                           | Experimental conditions                                                              |                                                                            | Statistic         |
|---------------------------------------------------------------|--------------------------------------------------------------------------------------|----------------------------------------------------------------------------|-------------------|
|                                                               | Four scenarios with storylines ( $n = 157$ )<br><i>Count / <math>M \pm SD</math></i> | Interactive web-tool ( $n = 156$ )<br><i>Count / <math>M \pm SD</math></i> |                   |
| Understanding – tested<br>( <i>score range: 0-7</i> )         |                                                                                      |                                                                            |                   |
| Correct answers                                               | 40.03 $\pm$ 1.99                                                                     | 3.54 $\pm$ 1.66                                                            | $t = 2.318^*$     |
| Wrong answers                                                 | 1.57 $\pm$ 1.27                                                                      | 2.10 $\pm$ 1.26                                                            | $t = -3.692^{**}$ |
| Don’t know answers                                            | 1.41 $\pm$ 20.05                                                                     | 1.36 $\pm$ 1.77                                                            | $t = 0.224$       |
| Understanding – self-reported<br>( <i>score range: 6-42</i> ) | 26.64 $\pm$ 5.50                                                                     | 25.88 $\pm$ 5.82                                                           | $t = 1.195$       |
| Trust – self-reported<br>( <i>score range: 7-49</i> )         | 32.56 $\pm$ 5.95                                                                     | 32.62 $\pm$ 60.04                                                          | $t = -0.090$      |
| Engagement – self-reported<br>( <i>score range: 7-49</i> )    | 31.55 $\pm$ 8.36                                                                     | 31.76 $\pm$ 8.60                                                           | $t = -0.218$      |
| Engagement – tested                                           |                                                                                      |                                                                            |                   |
| Time spent on the website ( <i>seconds</i> )                  | 339 $\pm$ 273                                                                        | 366 $\pm$ 334                                                              | $t = -0.806$      |
| Drop-out rates in the website stage<br>( <i>count</i> )       | 7                                                                                    | 10                                                                         | $\chi^2 = 0.504$  |

Note:  $*p < 0.05$ ;  $**p < 0.001$ .  $t$ -tests and chi-squared tests are used to calculate  $p$ -values. All statistics assume the four scenarios condition as the reference group. All survey items are available in the Appendix D.



### 6.4.3 Performance was similar between the two groups in terms of self-reported understanding, trust, engagement, and time spent on the website

In contrast to the tested understanding, all self-reported measures (self-reported understanding, engagement, and trust of the information) did not show any statistically significant difference between the two groups (Table 6.3). Both groups reported a more-than-average usability with all self-reported measures scoring statistically significantly above the midpoint (self-reported understanding:  $t = 4.253$ ,  $p < 0.001$ ,  $M_{four\ scenarios} = 26.64$  vs  $M_{midpoint} = 240.00$  for the four scenarios condition and  $t = 2.853$ ,  $p = 0.005$ ,  $M_{interactive} = 25.88$  vs  $M_{midpoint} = 240.00$  for the interactive web-tool condition; self-reported trust:  $t = 6.790$ ,  $p < 0.001$ ,  $M_{four\ scenarios} = 32.56$  vs  $M_{midpoint} = 280.00$  for the four scenarios condition and  $t = 6.755$ ,  $p < 0.001$ ,  $M_{interactive} = 32.62$  vs  $M_{midpoint} = 280.00$  for the interactive web-tool condition; self-reported engagement:  $t = 3.762$ ,  $p < 0.001$ ,  $M_{four\ scenarios} = 31.55$  vs  $M_{midpoint} = 280.00$  for the four scenarios condition and  $t = 3.861$ ,  $p < 0.001$ ,  $M_{interactive} = 31.76$  vs  $M_{midpoint} = 280.00$  for the interactive web-tool condition).

Similarly, there was some difference, but no statistically significant difference in time spent on the website and drop-out rates between the two experimental conditions. The average duration using the web-tools was around 5 minutes in the four scenarios condition and 6 minutes in the interactive web-tool condition. The average drop-out rates at the stage where participants see the interactive web-tool/four scenarios were 4% and 6%, respectively (the average drop-out rate for the whole survey was 14%). As before, running a regression analysis with the demographics and pre-experimental characteristics as covariates, did not significantly affect these results.

### 6.4.4 Website navigation skills, numeracy and prior experience with the topic had a positive correlation with understanding, trust and engagement

As shown in Table 6.4, there were statistically significant correlations in one or both of the groups between dependent variables and numeracy, website navigation skills and prior experience with the topic. All of these correlations were positive and their effect size ranged from low to moderate, suggesting that numeracy, website navigation skills and prior experience with the topic were beneficial but not critical for usability. Specifically, website navigation skills and numeracy correlated to tested understanding in both conditions, indicating that these skills were more-or-less important for answering the quiz questions (website navigation skills:  $r_{four\ scenarios} = 0.32$ ,  $p < 0.001$ ;  $r_{interactive} = 0.21$ ,  $p = 0.003$  / numeracy:  $r_{four\ scenarios} = 0.22$ ,  $p = 0.007$ ;  $r_{interactive} = 0.16$ ,  $p = 0.046$ ). A similar positive effect was found in the case of self-reported understanding, but only in the four scenarios condition (website navigation skills:  $r_{four\ scenarios} = 0.26$ ,  $p = 0.001$  /

numeracy:  $r_{\text{four scenarios}} = 0.19, p = 0.017$ ). In the interactive web-tool condition, self-reported understanding was significantly related to the prior interest and frequency of media use (prior interest:  $r_{\text{interactive}} = 0.20, p = 0.011$  / frequency of media use:  $r_{\text{interactive}} = 0.21, p = 0.008$ ), suggesting that participants that were feeling informed and interested in the topic felt more confident that they understand the information of the interactive web-tool. This confidence might have also affected self-reported trust as the trust was significantly related to the frequency of media use ( $r_{\text{four scenarios}} = 0.18, p = 0.023$ ;  $r_{\text{interactive}} = 0.21, p = 0.009$ ). Participants that were previously more engaged with the topic reported higher engagement with the tool in both conditions (prior interest:  $r_{\text{four scenarios}} = 0.24, p = 0.002$ ;  $r_{\text{interactive}} = 0.32, p < 0.001$  / prior knowledge:  $r_{\text{interactive}} = 0.17, p = 0.029$  / frequency of media use:  $r_{\text{four scenarios}} = 0.19, p = 0.016$ ;  $r_{\text{interactive}} = 0.30, p < 0.001$ ) and spent more time with it in the interactive condition (prior interest:  $r_{\text{interactive}} = 0.22, p = 0.006$ ). Numeracy also played a role in both conditions for self-reported trust ( $r_{\text{four scenarios}} = 0.21, p = 0.008$ ;  $r_{\text{interactive}} = 0.17, p = 0.033$ ) and engagement ( $r_{\text{four scenarios}} = 0.19, p = 0.017$ ;  $r_{\text{interactive}} = 0.19, p = 0.017$ ), suggesting that it can help in the overall usability of such tools, regardless of the format. On the contrary, website navigation skills affected self-reported trust ( $r_{\text{four scenarios}} = 0.26, p = 0.001$ ) and time spent on the website ( $r_{\text{four scenarios}} = 0.24, p = 0.003$ ) solely for the four scenarios condition, indicating that a possible moderation effect may have diminished the effects of these skills in the interactive web-tool condition. No statistically significant correlations have been observed between the demographics and the dependent variables, showing that even variables such as the age or education level of the participants did not have an effect.

Table 6.4. Correlations between the control and the dependent variables

| Control variables                                                                        | Dependent variables  |                             |                     |                          |                           |
|------------------------------------------------------------------------------------------|----------------------|-----------------------------|---------------------|--------------------------|---------------------------|
|                                                                                          | Understanding tested | Understanding self-reported | Trust self-reported | Engagement self-reported | Time spent on the website |
| Point-biserial correlations — $r_{b, \text{four scenarios}} / r_{b, \text{interactive}}$ |                      |                             |                     |                          |                           |
| Gender                                                                                   | -0.09 / 0.09         | -0.01 / 0.06                | 0.02 / 0.09         | -0.07 / -0.03            | 0.05 / 0.04               |
| Highest education level                                                                  |                      |                             |                     |                          |                           |
| 2 <sup>nd</sup> vs 1 <sup>st</sup>                                                       | -0.10 / -0.02        | -0.02 / 0.04                | 0.01 / -0.05        | 0.06 / -0.04             | -0.10 / -0.02             |
| 2 <sup>nd</sup> vs 3 <sup>rd</sup>                                                       | 0.12 / 0.06          | 0.01 / 0.08                 | -0.01 / 0.07        | -0.06 / 0.04             | 0.06 / -0.02              |
| Pearson's correlations — $r_{\text{four scenarios}} / r_{\text{interactive}}$            |                      |                             |                     |                          |                           |
| Age                                                                                      | 0.03 / -0.04         | -0.14 / -0.05               | -0.08 / 0.02        | -0.07 / -0.01            | 0.01 / 0.09               |
| Prior interest in electricity supply topics                                              | 0.07 / 0.05          | 0.09 / 0.20*                | 0.15 / 0.15         | 0.24** / 0.32***         | 0.04 / 0.22**             |
| Prior knowledge of electricity supply topics                                             | -0.03 / 0.09         | 0.03 / 0.13                 | 0.03 / 0.09         | 0.12 / 0.17**            | 0.01 / 0.05               |
| Frequency of media use to inform on electricity supply topics                            | 0.11 / 0.05          | 0.10 / 0.21**               | 0.18* / 0.21**      | 0.19* / 0.30***          | 0.09 / -0.08              |
| Website navigation skills                                                                | 0.32*** / 0.21**     | 0.26** / 0.02               | 0.26** / 0.10       | 0.15 / 0.04              | 0.24** / 0.02             |
| Subjective numeracy                                                                      | 0.22** / 0.16*       | 0.19* / 0.13                | 0.21** / 0.17*      | 0.19* / 0.19*            | 0.14 / 0.02               |

Note: \* $p < 0.05$ ; \*\* $p < 0.01$ ; \*\*\* $p < 0.001$ . Significance (two-tailed) is based on a 1000 bootstrap samples – BCa

Although most of the correlation coefficients differed between the experimental conditions, these differences were statistically significant only for the case of website navigation skills and their correlation with self-reported understanding ( $r_{\text{four scenarios}} = 0.26$  vs  $r_{\text{interactive}} = 0.02$ ,  $Z_{\text{difference}} = 2.128$ ,  $p = 0.033$ ). A further moderation and simple slope analysis showed that, for the four scenarios condition, there is a significant positive relationship between website navigation skills and self-reported understanding ( $b = 0.28$ , 95% CI  $[-.12, 0.44]$ ,  $t = 3.558$ ,  $p < 0.001$ ). This emphasizes the importance of website navigation skills in understanding and further suggests that another factor might have dampened their effects in the interactive web-tool condition.

In order to assess if the combination of format and the control variables can sufficiently predict the performance in both conditions, regression models were created for each of the dependent variables (tested understanding, self-reported understanding, self-reported trust, self-reported engagement and time spent on the website) using the control variables and the format as predictors (gender, age, highest education level, prior interest, prior knowledge, frequency of media use, website navigation skills, numeracy, format). The resulting standardized regression coefficients revealed similar effects to the correlation coefficients of Table 6.4. For example, the website navigation skills were significant predictors of the tested understanding ( $Beta = 0.24$ ,  $p < 0.001$ ) and the prior interest in electricity supply topics was a significant predictor of the self-reported engagement ( $Beta = 0.36$ ,  $p < 0.001$ ). However, the  $R^2$  was low for all regression models (tested understanding:  $R^2 = 0.11$ ,  $F = 3.88$ ,  $p < 0.001$ ; self-reported understanding:  $R^2 = 0.09$ ,  $F = 2.96$ ,  $p = 0.001$ ; self-reported trust:  $R^2 = 0.10$ ,  $F = 3.58$ ,  $p < 0.001$ ; self-reported engagement:  $R^2 = 0.15$ ,  $F = 5.11$ ,  $p < 0.001$ ; time spend on the website:  $R^2 = 0.05$ ,  $F = 1.60$ ,  $p = 0.107$ ). This suggests that the regression models could not explain a large part of the model variance, but they still supported our previous findings. Due to the low variance explained, detailed regressions results are not reported.

## 6.5 Discussion

Our first, thought-provoking finding is that participants in the four scenarios condition performed better than participants in the interactive web-tool condition in terms of tested understanding. Participants appeared to use the information on electricity supply alternatives and environmental, health, and economic impacts more effectively when having four scenarios with storylines in order to answer the content-based understanding quiz. A reason for this difference may be related to the method of looking for information. In the interactive web-tool condition, the participants had to actively create scenarios to test the validity of the quiz questions, while in the four scenarios condition, participants needed to look up information from only four given scenarios. It is probable that the active way of looking for information in the interactive web-tool have led to higher cognitive effort that in turn reduced the performance in answering understanding quiz. Past evaluation studies also pinpointed the cognitive burden as an issue in tasks involving information comprehension for interactive tools online (Bessette et al.,

2016; Zikmund-Fisher et al., 2011) or in workshops (Arciniegas et al., 2013). Although counter-examples exist in the literature (i.e., where interactive tools supported understanding), two factors could have led to different results than in our study: (a) the participants had studied the information included in the previous interactive web-tools at least for a few hours prior to evaluation (L. A. Mayer et al., 2014; Volken et al., 2018) and (b) a less complex task with one to two objectives was given (Blasch et al., 2017; Jeanneret et al., 2014). In our case, the limited average time spent in learning how to use the interactive web-tool and actually using it (5-6 minutes) along with the complexity of matching 13 technologies with seven impacts, might lead to a disadvantage for the interactive web-tool condition. This argument is supported by the moderate correlations found between time spent and both tested and self-reported understanding (for tested:  $r_{four\ scenarios} = 0.365$ ,  $p < 0.001$ ,  $r_{interactive} = 0.289$ ,  $p < 0.001$ ; for self-reported:  $r_{four\ scenarios} = 0.372$ ,  $p < 0.001$ ,  $r_{interactive} = 0.382$ ,  $p < 0.001$ ). Another factor may be that participant attention became even more fragile by the information “synchronicity” in the interactive web-tool: when the user moves one slider, information about the electricity demand-supply relation and the severity of seven impacts is shown directly. Such simultaneous feedback can help with tradeoff-making but may also lead to an overload of information on diverse and sometimes conflicting objectives. Nonetheless, our findings suggest that scenario-related tools, such as our interactive web-tool, should not be developed with an assumption that they will definitely lead to a better understanding and knowledge of the users.

The second main finding is that the interactive web-tool and the website with four scenarios with storylines had very similar performance in self-reported measures of understanding, trust, and engagement. In terms of self-reported trust, this result was also expected even if, as far as we are aware, it was tested for the first time. People usually perceive the information as reliable if they believe its source is reliable (Knight and Burn, 2005) and if its format is adequately designed (McInerny et al., 2014). Both of our experimental conditions came from the same source and had seemingly similar design. In terms of engagement and understanding, this was also found in our previous workshop study with the same topic, where participants reported similar satisfaction and learning experience for paper factsheets and an interactive web-tool (Volken et al., 2018). For self-reported engagement, other previous studies have suggested that interactive web-tools can have a positive effect (L. A. Mayer et al., 2014; Pidgeon et al., 2014), but these studies did not compare the tools with static equivalents. In our case, it might be again the short use of time and the complex task that did not allow the interactive web-tool condition to outperform the four scenarios condition. The lack of time and task’s complexity could have also increased participant stress, as it was also found in a previous empirical study (Bessette et al., 2016), and that stress may have further reduced engagement (McInerny et al., 2014). Another reason limiting engagement in the interactive web-tool condition might be that participants had to create scenarios to answer the quiz, while participants in the four scenarios condition directly received four scenarios with simple but clear narratives. We designed the quiz questions to serve as motivation for the participants of the interactive web-

tool condition to discover the tool capabilities, but this might not have been enough to overcome the cognitive load and the average prior interest in electricity supply topics. Instead, the statistically significant correlation between prior interest and engagement in the interactive web-tool indicated that participants that were already interested in these topics were also more engaged with the tool. A further moderation analysis showed that the interactive web-tool did not engage low interest participants more than the four scenarios. In conclusion, we do not find evidence for superiority of an interactive web-tool with access to a large scenario database over a website with four scenarios with storylines in terms of self-reported understanding, trust, and engagement.

In the case of understanding, the self-reported measure contradicts the tested one: there was no statistically significant difference between the conditions in terms of self-reported understanding, while in fact the participants of the four scenarios condition performed better in the content-based quiz. Disparities between self-reported and tested measures were also found in previous studies (Arciniegas et al., 2013; Bessette et al., 2016, 2014). In our case, a possible explanation could be found in the topic of the tool: since the debate on the future of the Swiss electricity system goes on for several years now, the participants might have believed that they more or less already understand the electricity topic (Volken et al., 2018). The prior knowledge of electricity supply topics that was reported in our sample as close to the midpoint on average seems to go towards this direction. Nevertheless, awareness gaps in electricity topics have been observed in a past study in Switzerland (Volken et al., 2017). It is thus possible that the participants used the interactive web-tool to look for the answers, but due to the cognitive load and limited time they reverted—possibly without realizing it—to their prior knowledge. Prior attitudes, such as the affect to certain electricity supply technologies, might have also interfered with the scenario building task in the interactive web-tool condition (Jobin and Siegrist, 2018). Cognitive studies in graphic comprehension accentuate the importance of matching the graphic with the viewer's knowledge, goal or visuospatial ability (Harold et al., 2016). The lack of such a matching might also partly explain the disparity in our case.

The third finding is that the website navigation skills, numeracy, and prior experience with electricity supply topics have some—but not decisive—effects on the usability performance. Participants with high website navigation skills and numeracy performed better in the quiz for tested understanding in both experimental conditions. Such a finding is in line with the statements in literature that the appropriate skills are helpful to use interactive and static tools effectively (Harold et al., 2016). At the same time, the low-to-moderate size of the correlation coefficients showed that lower website navigation skills and numeracy are not restrictive for understanding the information in these tools. The same effect of the role of website navigation skills and numeracy was found for self-reported understanding in the four scenarios condition but, surprisingly, not in the interactive web-tool condition. This might correspond to a previous finding where interactive graphics alleviated numeracy differences in risk perception, thus diminishing the effect of these skills in the interactive condition (Ancker et al., 2011). Other factors

for this reduced effect might be the aforementioned cognitive burden and anxiety in the interactive web-tool condition. These factors could also explain why a similar effect was found solely in the four scenarios condition, where website navigation skills correlate with self-reported trust and time spent on the website. On the contrary, high prior interest, knowledge, and frequency of media use to inform on electricity supply topics favored the participants of the interactive web-tool condition and led to higher correlations with self-reported understanding, time spent and self-reported engagement. This finding could indicate that the interactive web-tool was perceived better by “experienced” participants on the topic, although none of the correlation coefficients differed significantly between the conditions. However, there was no effect of prior interest, knowledge and frequency of media use on tested understanding in any condition, unlike the positive correlations found by Blasch et al. (2017). This indicates that our interactive web-tool was not disadvantaging less-experienced participants to answer the quiz of tested understanding. In contrast again to Blasch et al. (2017), we found no statistically significant correlation of gender, age and education level with the performance. This difference in findings could be due to the fact that Blasch et al. (2017) used much higher sample sizes (one sample with  $N = 916$  and another with  $N = 5,015$ ) and a task with lower complexity and number of parameters.

There are some limitations in our study, mainly related with the design of the experiment. First of all, we intentionally did not include a decision or preference task in order to focus on the effectiveness and usability of the tools for education and outreach purposes. This might have negatively affected the engagement and attention of the participants, regardless of our efforts to motivate them to discover the tool by asking them to answer the quiz questions. Similarly, the large number of technologies and impacts may have reduced comprehension regardless of the format. Especially for the interactive web-tool, the simultaneous presentation of so many parameters might have further increased cognitive load. These effects were considered in the experiment’s design phase and could have been studied by developing a version of the tool with less parameters and another one that allowed the users to select and submit a preferred scenario [see, for instance, Volken et al. (2018)]. Another limitation is that we did not record how the participants interact with the tools, e.g., using mouse tracking. This method would not have altered our current findings, but it would have given a more detailed insight in what sliders the participants used in the interactive web-tool etc. Finally, we could have also used gaming features to increase engagement or, as it became apparent by the limited fit in the regression analyses, we could have looked at other factors such as visuospatial skills. All the above limitations should be addressed in the future research and can possibly clarify some of the effects we found.

## 6.6 Conclusions

Interactive web-tools have many claimed benefits of increasing understanding and engagement for the purposes of outreach and education, two-way public engagement, scientific research on eliciting preferences and decision support. In this study, an interactive web-tool for non-experts with access to a large ensemble of Swiss electricity supply scenarios to 2035 was assessed in comparison to a website with four static scenarios with storylines. Our interactive web-tool performed just as well in terms of self-reported understanding, engagement, and trust of the participants as the website with the four scenarios with storylines. Even more, the interactive web-tool did not lead to a measurable advantage over the more traditional website that presented four pre-selected scenarios with short storylines/narratives. In fact, we found that the interactive web-tool could have even reduced comprehension of the information because the participants in the interactive web-tool condition scored statistically significantly worse than the participants in the four scenarios condition in a quiz that required to extract information from the scenarios. A possible explanation for such a reduced performance in the interactive web-tool condition is the higher cognitive load that is required for looking up the information and receiving simultaneous feedback over multiple parameters. In both conditions, we found a low-to-moderate correlation of website navigation skills and numeracy with tested understanding, suggesting that these skills are important but not imperative. Participants with higher prior experience with electricity supply topics were also more engaged in both conditions, while demographics did not have any effect. Although the effects of the control variables varied between the conditions, only one statistically significant difference was found: high website navigation skills increased self-reported understanding in the four scenarios condition but not in the interactive web-tool condition. This suggests that another factor might have moderated the effects of these skills in the interactive web-tool condition, such as a possible overload of information from the interactive web-tool.

As our interactive web-tool was modelled after similar tools found online, the results may provide a word of caution and a call for more frequent empirical evaluations of existing and future tools. The results of our study indicate that interactive web-tools may not automatically bring benefits to any scenario application. Since such tools usually require more time and effort to develop, it is important to assess whether and when such tools really offer a benefit or are necessary. Even with rigorous development of such tools, there might be cases where simpler and more pragmatic approaches, such as conventional websites or written factsheets, would work equally good or even better. For environmental scenario studies that aim to incorporate interactivity to explore scenario databases, it is also worth to investigate the combination of methods, e.g., guiding the users first through diverse example narratives/scenarios and then through scenario-building in an interactive way. In any case, continuous evaluation in all stages of development and deployment of interactive web-tools is necessary in order to assure that they fulfill the goals they are built for.

# Chapter 7 Evaluation of pertinent scenario visualizations for climate change mitigation

This chapter is based on Xexakis and Trutnevyte (2021b).

## 7.1 Introduction

In the past decades, there is an ongoing call for improving communication of climate change research not only to policymakers and experts, but also to society at large (Budescu et al., 2014; Corner et al., 2018; Pidgeon and Fischhoff, 2011; Weber et al., 2018). Current examples of communications range from comprehensive assessments of the Intergovernmental Panel for Climate Change (IPCC, 2018a, 2014), reports and visual aids tailored to specific audiences such as schools (Rumjaun et al., 2018) and investors (CICERO, 2018), to the traditional communication channels of the media. Existing literature on climate change communication is diverse and multidisciplinary: some researchers have studied biases and cognitive effects in communication methods and materials (Hornsey et al., 2015; Hornsey and Fielding, 2016; Jones et al., 2017), while others have evaluated the role of mental models (Marx et al., 2007; Sterman, 2011) and values (Demski et al., 2015). Due to the central role of uncertainty in climate change and its mitigation, many researchers have investigated methods to effectively communicate uncertainty in text or visualizations (Budescu et al., 2014, 2012; Fischhoff and Davis, 2014; Morgan, 2011; Wong-Parodi et al., 2016). As the urgency of mitigating climate change grows, the user base of climate change research is diversifying (Weber et al., 2018) and in particular should now reach citizens in order to enable broad societal consensus on preferred mitigation pathways. While there is an acknowledged need for more user-specific guidelines for climate change communication based on empirical evidence (Elsawah et al., 2020; Pidgeon and Fischhoff, 2011; Trutnevyte et al., 2016a), relatively little has been done for communicating about the options for climate change mitigation to citizens (e.g. Corner et al., 2018). Civil society and media are part of the broader audience of IPCC (IPCC, 2018b) and hence a clear understanding of the available mitigation pathways by the citizens is crucial for their engagement with mitigation options and climate policy (European Commission, 2018d). Communication guidelines also need to be adapted and evaluated for individual countries due to the likely differences in public awareness and opinion about mitigation, where, for example, the role of nuclear power can be perceived differently in countries with relatively positive opinion about nuclear power such as the UK versus the negative one in Germany (Steentjes et al., 2017).



One basic component of communication about climate change mitigation is scenario visualization (Harold et al., 2019, 2016). Visualizations are frequently used to summarize data and show patterns in an engaging way (McInerney et al., 2014) and they are sometimes applied in interactive formats too (Dubois et al., 2019; Volken et al., 2018). Visualizations have been the key element in the communication strategy of IPCC (IPCC, 2016), such as the iconic “burning embers” graph that shows the severity of impacts due to different levels of global warming using a sequential color palette from white to red (Mahony and Hulme, 2012). Visualizations have been also argued to affect how the overall findings of the IPCC reports are covered by the media (O’Neill et al., 2015). However, climate change visualizations have been sometimes observed to be hindered by visual complexity which may confuse even expert readers (Harold et al., 2019; McMahon et al., 2016, 2015). Different formats of visualization are known to affect the framing of communication (Daron et al., 2015; Wardekker and Lorenz, 2019) and they can interact with the prior beliefs of policymakers (Bosetti et al., 2017) or citizens (Dieckmann et al., 2017; Guilbeault et al., 2018). Otherwise, there is little evidence in existing literature on the interactions between visualization formats and readers’ characteristics, such as demographics, but this is a general issue in the overall evaluation literature (Hullman et al., 2019). Despite the existing design guidelines for climate change visualizations stemming from cognitive science (Harold et al., 2016), many authors emphasize the importance of empirically testing such visualizations with the intended readers (Bosetti et al., 2017; Harold et al., 2019; Kause et al., 2020). Yet, such tests remain scarce.

The few existing empirical evaluations of climate change visualizations have mostly focused on comparisons between formats of visualizing climate change impacts. Dieckmann et al. (2015) studied the interpretation by citizens of ranges of future temperature using increasingly detailed formats and showed that a normal density plot of temperature distribution supported the interpretation best, whereas the lower numeracy of some citizens hindered the interpretation. In a subsequent study, Dieckmann et al. (2017) found strong effects of motivated reasoning in the interpretation of temperature ranges and showed that the graph with the exact temperature distribution could mitigate these effects. Bosetti et al. (2017) worked with a sample of policymakers and demonstrated that they relied more on their prior beliefs rather than on a shown visualization of climate model results, whereas novice users (students) took this visualization into account. Other researchers used qualitative methods to evaluate visualizations. McMahon et al. (2015) used interviews with scientists and policymakers to evaluate one widely used IPCC visualization and reported that novice readers confused two types of uncertainties shown there and hence in principle misinterpreted the main message from the visualization. In a further study with a sample of students, McMahon et al. (2016) showed that the current types of IPCC graphs make readers more confident in the content in contrast to an infographic about climate change, although without change in comprehension. Harold et al. (2019) used interviews with IPCC authors to understand the development of IPCC visualizations and found that the need for

scientific accuracy often constrained visualizations in terms of simplifying them for less experienced readers.

Apart from visualization formats and readers' characteristics, contextual and cultural variations between different countries may affect how visualizations are read (Harold et al., 2016). Examples of such effects are related to cultural metaphors, for instance whether the upper side of a visualization is associated with "good" or "bad", and language, where reading direction affects the direction of attention in visuospatial tasks and available color terms affect color perception (Harold et al., 2016). Additionally, as climate change concerns and mitigation implications vary across countries (Lee et al., 2015), country contexts may influence the perception of mitigation visualizations similar to the way that different political orientations (Guilbeault et al., 2018) or cultural worldviews (Dieckmann et al., 2017) led to different interpretations of the same visualization. However, there are no systematic evaluations of visualizations in several countries using representative samples of citizens, as it was done for other aspects of climate change communication (Budescu et al., 2014).

This study aims to fill these research gaps through a cross-country empirical evaluation of visualizations of scenarios for climate change mitigation, using representative online surveys with citizens in Germany, Poland, and France. These three countries were chosen due to the differences in their composition of and plans for electricity supply, and hence the implications for climate change mitigation. Germany supplies a large part of its electricity from renewable sources and fossil fuels, but plans to further increase the share of renewable sources to 65% by 2030 (BMWi, 2020a). France primarily relies on nuclear power, but aims to reduce the nuclear share to 50% by 2035 (MTES, 2020a). Poland has a large fleet of fossil-fuel plants in its electricity supply and aims to increase the share of renewable sources to 32% by 2030 (Ministry of State Assets, 2020). As a case study, visualizations of modelled scenarios to limit global warming to 1.5°C are used, especially the results on required global CO<sub>2</sub> emissions cuts and change in the composition of electricity supply (fossil fuels, nuclear, and renewable sources).

Overall, the study addresses the following research questions:

- (1) What are the effects of readers' characteristics and different visualization formats on the reading accuracy and knowledge gains by citizens of scenario visualizations of CO<sub>2</sub> emissions and composition of electricity supply? The following characteristics are evaluated: country context, demographics, prior beliefs, numeracy, graph literacy, perceived efficacy, and affective responses towards climate change mitigation.
- (2) Which format is perceived as more understandable, trustworthy, concerning, and interesting by citizens?
- (3) How do different visualization formats perform in terms of reducing adverse effects from readers' characteristics on reading accuracy and knowledge gains? How substantial is this reduction in the case of customizing visualization formats for different segments of readers based on their characteristics?

- (4) Do different visualizations lead to different levels of perceived efficacy and affective responses by citizens towards climate change mitigation, and what are the effects of different visualization formats on these changes?

## 7.2 Methodology

### 7.2.1 Overall design

In order to examine the effects of readers' characteristics, country context, and visualization formats on the interpretation of climate change mitigation scenarios, three online surveys were conducted with citizens from three European countries of Germany (N = 379), Poland (N = 223), and France (N = 225). The surveys first measured the demographics and prior beliefs of the respondents and then presented four visualizations of scenarios that limit global warming to 1.5°C and depict the required CO<sub>2</sub> emissions cuts and the share of renewable, nuclear, and fossil fuels-based electricity supply. Next, the survey questions evaluated how well respondents could read numbers off the visualizations, how well they would gain new knowledge from these numbers, and whether there was a change in beliefs after seeing the visualizations. An experimental between-groups design on the visualization format was also included in order to evaluate different formats of graphs that show only uncertainty range or the whole ensemble of scenarios and that show gradual or steep slope. Lastly, the surveys included questions related to the subjective evaluation of the visualizations and the respondents' numeracy and graph literacy.

### 7.2.2 Procedure and measures

The German sample ("DE", N = 379) was recruited between December 2019 and January 2020, while the Polish sample ("PL", N = 223) and French sample ("FR", N = 225) were recruited during March 2020. All samples were recruited from accredited access panels in each country and received the same online survey, translated in their respective language. Each translation was proofread by two native speakers. The full survey script is provided in Section E.1 in Appendix E. The survey started with a short introduction to the topic of global warming, without emphasizing the need or the urgency for climate change mitigation, and continued with questions on *gender*, *age*, and highest *education level*. Next, respondents were asked about their *belief in global warming* (5 items on a 5-point Likert scale from 1 = strongly agree to 5 = strongly disagree; *Cronbach's α* = 0.91/0.93/0.83 respectively for the German, Polish, and French sample), their *perceived efficacy* of humanity/electricity industry to reduce CO<sub>2</sub> emissions (6 items on a 5-point Likert scale from 1 = strongly agree to 5 = strongly disagree; *α* = 0.78/0.85/0.71), and their *affective responses* towards limiting global warming (7 items on a 10-point scale between two diverging *affective responses* e.g. from 1 = hopeless to 10 = hopeful). For the analysis, seven items for *affective responses* were aggregated into two subscales: *feelings of hope* (2 items:

feeling hopeful and empowered,  $\alpha = 0.78/0.89/0.74$ ) and *feelings of urgency* (5 items: feeling engaged, guilty, outraged/angry, alarmed, and very afraid,  $\alpha = 0.84/0.79/0.82$ ). All measures and scales were adapted from previous studies (Budescu et al., 2012; Doherty and Webler, 2016; Rooney-Varga et al., 2018).

In order to examine the prior knowledge of the respondents about the topics of climate change and electricity supply, the next questions asked whether respondents agreed that CO<sub>2</sub> should be cut globally to limit global warming to 1.5°C (*belief about the need to cut CO<sub>2</sub> emissions*, 7-point Likert scale from 1 = strongly disagree to 7 = strongly agree) and what are the global CO<sub>2</sub> emissions cuts required by 2030 and 2050 to limit global warming to 1.5°C as suggested by scientists (*belief about the required percentage of CO<sub>2</sub> emissions cuts*). The respondents could select the percentage of global CO<sub>2</sub> emissions cuts relative to 2020 for 2030 and 2050 or they could select the “Don’t know” option. Similarly, the next question asked about the change in electricity supply from fossil fuels, nuclear power, and renewable sources to limit global warming to 1.5°C as suggested by scientists (*belief about the required electricity supply from fossil fuels/from nuclear/from renewable sources*, 3 items on a 7-point scale from 1 = significantly reduce to 7 = significantly increase). Afterwards, the survey included an attention test where respondents had to select the colours of their national flag.

Then, the topic of mitigation to limit global warming to 1.5°C was briefly introduced and visualizations of four *scenario themes* were presented to each respondent (Figure 7.1): (1) the global CO<sub>2</sub> emissions cuts relative to 2020, (2) the global share of fossil fuels in electricity supply, (3) the global share of nuclear power in electricity supply, and (4) the global share of renewable sources in electricity supply. The four visualizations showed timeseries of percentages of emissions cuts or shares of electricity supply and presented their change between 2020 and 2050. The scenarios were sourced from the scenario database of IPCC Special Report on Global Warming of 1.5°C (IPCC, 2018a; Rogelj et al., 2018a). The scenarios were extracted from the IAMC 1.5°C Scenario Explorer (Huppmann et al., 2018a) and were slightly modified in order to facilitate reading of the graphs: the percentages of the averages, maximum, and minimum values for 2030 and 2050 were rounded to the nearest 5%. Each of the four visualizations was presented in a separate webpage including two *reading accuracy* questions on different *value types*. The first question required respondents to select the average values for 2030 and 2050 as shown in the visualization (i.e., report the percentages given in the y-axis for the blue line in Figure 7.1). The second question asked for the maximum and minimum values for the same years. For the CO<sub>2</sub> emissions cuts, the visualization webpage included two additional questions on the *perceived credibility* and the *perceived uncertainty* of the visualizations [2 items on a 7-point scale from 1 = not at all (credible/uncertain) to 7 = extremely (credible/uncertain); adapted from Bosetti et al. (2017)].

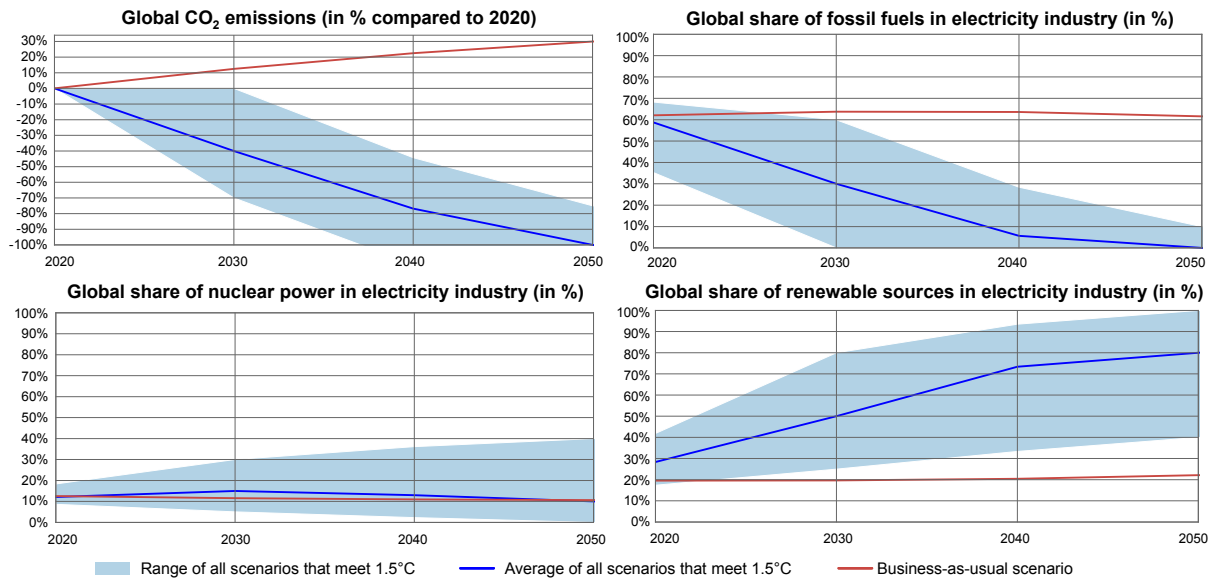


Figure 7.1. Four *scenario themes* shown to the respondents, illustrated using the *gradual range* format of visualization.

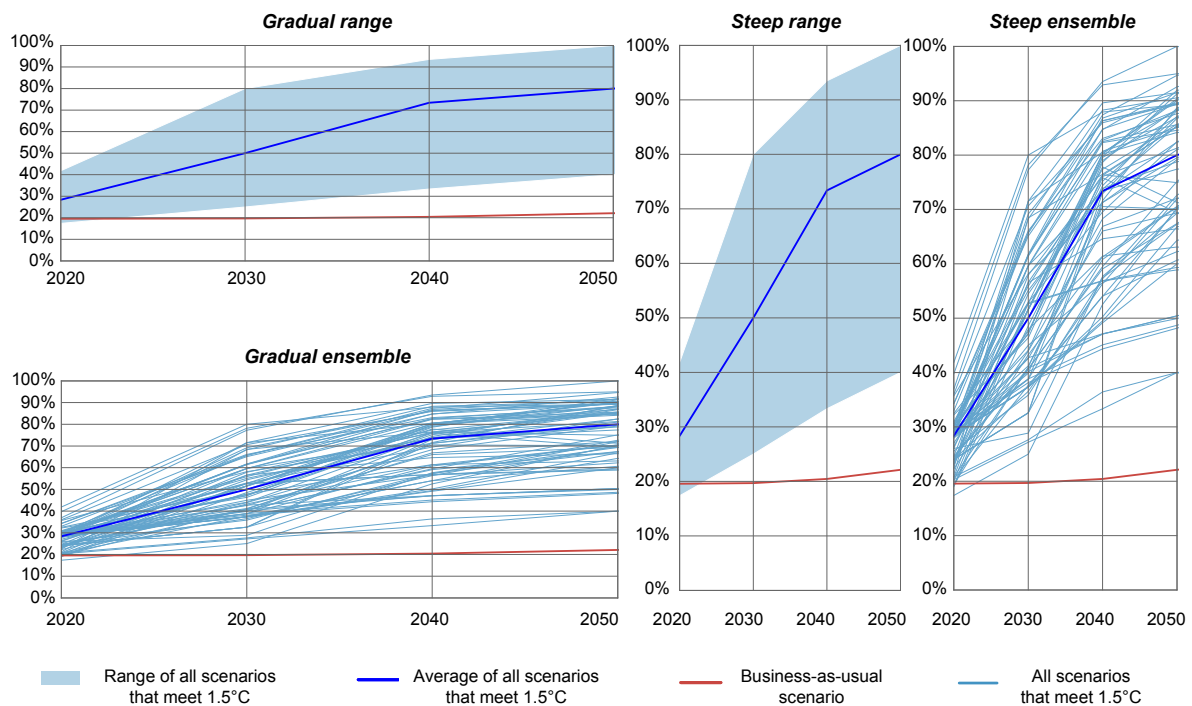
Afterwards, the survey asked the respondents for their *subjective evaluation* of the visualization, whether they found the visualization interesting to read, easy to understand etc. For the German sample, the *subjective evaluation* was related to the visualization that respondents had seen (5 items on a 5-point Likert scale from 1 = strongly disagree to 5 = strongly agree,  $\alpha = 0.67$ ). For the Polish and French samples, similar items were used but respondents were asked to directly compare the visualization format they saw with another format. For example, for the item asking which format was the most interesting to read, respondents could choose among three options: the format they saw, an alternative format, and a statement that there was no difference between formats. Next, the initial questions on *perceived efficacy*, *affective responses*, *belief about the need to cut CO<sub>2</sub> emissions*, *belief about the required percentage of CO<sub>2</sub> emissions cuts*, and *beliefs about the required electricity supply* from various sources were repeated in order to evaluate whether there was any change after seeing the visualization. For the last two variables, this change in answers was used to measure the *knowledge gains* about the required percentage of CO<sub>2</sub> emissions cuts and the *knowledge gains* about the required electricity supply. Finally, the survey measured the subjective *numeracy* (5 items on a 5-point Likert scale from 1 = strongly disagree to 5 = strongly agree; 1 item omitted for scale consistency; final  $\alpha = 0.72/0.71/0.66$ ), subjective *graph literacy* (5 items on a 6-point scale from 1 = not at all good to 6 = extremely good;  $\alpha = 0.96/0.96/0.96$ ), and *political orientation* (10-point scale from 1 = left to 10 = right).

### 7.2.3 Experimental conditions

In order to examine the effects of visualization format on interpretation, the survey included a between-groups experimental design (Figure 7.2). For the German sample, two experimental factors were used: 1) the graph type to either show all scenarios (*ensemble graph*)

## 7. Evaluation of pertinent scenario visualizations for climate change mitigation

or uncertainty ranges from these scenarios (*range* graph), and (2) the slope of the graph to depict *steep* or *gradual* slope. These graph types were chosen since the *range* and *ensemble* graphs are two widely used ways to visualize multiple scenarios (Guivarch et al., 2016; Toet et al., 2019; van Vuuren et al., 2012), including the IPCC reports (IPCC, 2018a). The selection of graph types was informed by a preparatory study (Section E.2 in Appendix E). In this preparatory study, two groups of respondents from the EU (total N = 145; convenience sample with climate experts and stakeholders) received two different formats for visualizing scenarios of greenhouse gas emissions from meeting the target of net zero emissions by 2050 in EU: (1) a range graph; (2) a selection of only three illustrative scenarios with storylines. No statistically significant differences were found between formats in terms of tested understanding and anchoring effects, shifting the focus in the present study to differences between *range* and *ensemble* graphs instead of a depiction of a few illustrative scenarios with storylines.



Table

| Year | Global share of renewable sources in electricity industry (in %) |                                          |                            |
|------|------------------------------------------------------------------|------------------------------------------|----------------------------|
|      | Range of all scenarios that meet 1.5°C                           | Average of all scenarios that meet 1.5°C | Business-as-usual scenario |
| 2020 | 17% to 42%                                                       | 28%                                      | 20%                        |
| 2030 | 25% to 80%                                                       | 50%                                      | 20%                        |
| 2040 | 33% to 93%                                                       | 73%                                      | 20%                        |
| 2050 | 40% to 100%                                                      | 80%                                      | 22%                        |

Figure 7.2. Five experimental conditions on visualization format, illustrated using the scenarios of electricity supply share from renewable sources.

The graph slope was varied since it can be used to emphasize the visualized patterns and can potentially affect their interpretation (Beattie and Jones, 2002). Specifically, it was hypothesized that a steep slope might better convey the urgency for climate change mitigation than a gradual one. The two alternative slopes were implemented by changing the width to height aspect ratio of the graph from 1:2.5 to 2.5:1. Each respondent was shown four scenario themes

(CO<sub>2</sub> emissions cuts and shares of electricity supply) in the same format in sequence in separate webpages. In all experimental conditions, the graph also visualized the average of all scenarios to limit global warming to 1.5°C as well as one business-as-usual scenario. A fifth group received a *table*, as an alternative framing of the same scenario information using numbers. Since respondents could read the answers to *reading accuracy* tests directly off the tables, it was assumed that the *table* condition could act as a baseline and that there would be larger differences in performance between tables and graphs than between the graphs themselves. For the Polish and French samples, only the graph slope was examined due to the limited budget for recruiting respondents. Overall, the experimental conditions were balanced in terms of sample size and included 73–78 respondents each.

### 7.2.4 Survey respondents

In terms of demographics, all samples were close to being representative of their population (Table 7.1). *Numeracy*, *graph literacy*, and *political orientation* were around midpoint and at comparable levels between countries, while *belief in global warming* was high in all three samples. In terms of prior beliefs about climate change mitigation, most respondents agreed that CO<sub>2</sub> emissions cuts are required in the future and that the correct trajectory for electricity from fossil fuels and renewable sources is to significantly decrease and significantly increase respectively (Table 7.2). However, there was a difference between countries for nuclear electricity: while Polish respondents correctly indicated that, on average, it should remain constant, German and French indicated that it should be reduced. *Perceived efficacy*, *feelings of urgency*, and *hope* were around midpoint for all countries. Finally, all above characteristics were similar between experimental conditions (see Section E.3 in Appendix E for a detailed experimental check).

Table 7.1. Descriptives of demographics, *numeracy*, *graph literacy*, *political orientation*, and *belief in global warming* for each sample.

| Characteristics of the respondents | Measurement                | <i>M (SD) / percentage</i>      |                                 |                                 | Demographics in the population  | Qualitative evaluation of the descriptives               |
|------------------------------------|----------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|----------------------------------------------------------|
|                                    |                            | Germany (DE)<br>N = 379         | Poland (PL)<br>N = 223          | France (FR)<br>N = 225          |                                 |                                                          |
| <i>gender</i>                      | % of female respondents    | 52.8%                           | 50.7%                           | 52.0%                           | DE: 50.7%, PL: 50.1%, FR: 51.0% | almost representative of the population in all countries |
| <i>age</i>                         | age in years               | 49.3 (17.0)<br>(range: 18 – 82) | 41.8 (13.4)<br>(range: 18 – 65) | 45.1 (14.5)<br>(range: 18 – 69) | DE: 49.1, PL: 41.7, FR: 43.7    |                                                          |
| <i>education level</i>             | % with high school diploma | 34.8%                           | 65.9%                           | 79.1%                           | DE: 31.9%, PL: 64.0%, FR: 78.3% |                                                          |
| <i>numeracy</i>                    | 4 = low to 20 = high       | 13.3 (3.2)                      | 13.7 (3.2)                      | 13.6 (3.6)                      | -                               | slightly above midpoint of 12 in all countries           |

## 7. Evaluation of pertinent scenario visualizations for climate change mitigation

Table 7.1. (continued)

|                                     |                           |            |               |            |   |                                           |
|-------------------------------------|---------------------------|------------|---------------|------------|---|-------------------------------------------|
| <i>graph literacy</i>               | 5 = low to<br>35 = high   | 20.7 (8.2) | 23.8<br>(8.3) | 18.3 (8.4) | - | around midpoint of<br>20 in all countries |
| <i>political<br/>orientation</i>    | 1 = left to<br>10 = right | 4.6 (1.9)  | 5.4 (2.6)     | 4.9 (2.6)  | - | close to center (5)<br>in all countries   |
| <i>belief in global<br/>warming</i> | 5 = low to<br>25 = high   | 20.8 (4.0) | 20.5 (5.2)    | 21.5 (3.1) | - | high in all countries                     |

Note: Population demographics were based on 2018 values from Destatis (2021) and Eurostat (2020d, 2020a).

Table 7.2. Descriptives of prior beliefs about climate change mitigation, *perceived efficacy*, *feelings of hope* and *urgency*.

| Characteristics of the respondents                                                 | Measurement                                                                | <i>M (SD)</i>           |                         |                         | Qualitative evaluation of the descriptives                                                                            |
|------------------------------------------------------------------------------------|----------------------------------------------------------------------------|-------------------------|-------------------------|-------------------------|-----------------------------------------------------------------------------------------------------------------------|
|                                                                                    |                                                                            | Germany (DE)<br>N = 379 | Poland (PL)<br>N = 223  | France (FR)<br>N = 225  |                                                                                                                       |
| <i>belief about the need to cut CO<sub>2</sub> emissions</i> (prior)               | 1 = strongly disagree to<br>7 = strongly agree                             | 5.6 (1.5)               | 5.6 (1.5)               | 5.9 (1.2)               | high in all countries                                                                                                 |
| <i>belief about the required electricity supply from fossil fuels</i> (prior)      | 1 = significantly reduce to<br>7 = significantly increase<br>(correct = 1) | 2.0 (1.4)<br>(mode = 1) | 2.3 (1.6)<br>(mode = 1) | 2.3 (1.5)<br>(mode = 1) | most respondents in all countries stated that it should be reduced                                                    |
| <i>belief about the required electricity supply from nuclear</i> (prior)           | 1 = significantly reduce to<br>7 = significantly increase<br>(correct = 4) | 2.5 (1.6)<br>(mode = 1) | 3.1 (1.9)<br>(mode = 4) | 2.8 (1.6)<br>(mode = 1) | most German and French respondents stated that it should be reduced, while Polish stated that it should stay constant |
| <i>belief about the required electricity supply from renewable sources</i> (prior) | 1 = significantly reduce to<br>7 = significantly increase<br>(correct = 7) | 6.2 (1.2)<br>(mode = 7) | 6.0 (1.6)<br>(mode = 7) | 5.8 (1.6)<br>(mode = 7) | most respondents in all countries stated that it should be increased                                                  |
| <i>perceived efficacy</i> (prior)                                                  | 6 = low to<br>30 = high                                                    | 19.8 (4.0)              | 21.5 (4.9)              | 20.1 (3.6)              | slightly above midpoint of 18 in all countries                                                                        |
| <i>feelings of urgency</i> (prior)                                                 | 5 = low to<br>50 = high                                                    | 28.3 (9.3)              | 28.8 (7.8)              | 28.3 (8.7)              | around midpoint of 28 in all countries                                                                                |
| <i>feelings of hope</i> (prior)                                                    | 2 = low to<br>20 = high                                                    | 10.1 (3.9)              | 11.9 (3.8)              | 10.1 (4.1)              | around midpoint of 11 in all countries                                                                                |

### 7.2.5 Analysis

Multiple linear regressions coupled with dominance analysis (Azen and Budescu, 2003) were used to analyze the effects of respondents' characteristics and visualization formats on *reading accuracy* and *knowledge gains*. Both variables were measured in terms of the absolute error between respondents' estimations and correct answers. For example, if a respondent estimated the average CO<sub>2</sub> emissions cuts in 2050 as 80%, while the correct value shown in the visualization was 100% (see Figure 7.1), then the absolute error was 20%. For *reading accuracy*,



the total absolute error was used in the regression, summed across three *value types* (average, maximum, and minimum values), two years (2030 and 2050) and four *scenario themes* (i.e., total absolute error:  $\sum_{i=0}^{24} |\text{estimation} - \text{correct}|$ ). By checking the regression assumptions, indications of heteroscedasticity were found. Therefore, robust regression method was used, where significance testing was based on 1000 bootstrap samples (Wilcox, 2011).

*Reading accuracy* was also analyzed separately for each *scenario theme* and *value type* in order to illustrate differences and similarities between *scenario themes* and *value types*. For this purpose, *reading accuracy* was measured in terms of percentage of correct answers, in order to avoid potentially strong effects from outliers in the error in the small subsamples of each *scenario theme* and *value type*. Answering patterns in *reading accuracy* questions indicated that respondents often mixed correct answers between maximum and minimum values (Section E.4 in Appendix E). Since this may be due to a confusion over the meaning of maximum and minimum in the context of CO<sub>2</sub> emissions cuts and shares of electricity supply, answers were considered to be interchangeably correct for maximum and minimum values. Answering patterns also indicated effects of satisficing or epistemic uncertainty (Bruine De Bruin et al., 2002), as shown by the 10% of respondents that selected the 50%-point for many *reading accuracy* questions. However, only 3% of the respondents selected the 50%-point consistently for more than half of *reading accuracy* questions, suggesting that most incidents were unrelated. The respondents that repeatedly selected the 50%-point had, on average, lower *graph literacy* and lower congruence between prior beliefs and visualizations than other respondents. The combination of these factors may have penalized the respondents' ability to find the correct answers from the visualizations, leading them to select an answer that was good enough.

In order to evaluate control effects by visualization formats on respondents' characteristics, two strategies were followed. First, effects were evaluated individually by calculating the interaction between each characteristic and each visualization format, and the effect of the interaction on the performance of the respondents in terms of *reading accuracy* and *knowledge gains*. Second, effects were evaluated collectively by assessing the performance of respondents who had received formats that best matched their characteristics. In order to determine the best matching formats for different respondents, the following process has been used. The total sample was divided into 12 segments based on *country context*, *age*, and *education level*. Although similar segmentations could have been made for other characteristics, such as prior beliefs, the aforementioned variables were chosen as they had substantial effects on *reading accuracy* (see Section 7.3.1) and could be easily targeted in real-world communications (Hine et al., 2014). For each segment, the visualization format with the lowest (*median*) combined error in *reading accuracy* and *knowledge gains* was identified as the best matching format. Respondents who received the best matching format for their segment were then grouped together and their combined error was compared with the error of respondents who received the same format regardless of the segment they belonged to. The combined error was created using a process based on multi-criteria assessment (Belton and Stewart, 2001).

Specifically, the individual errors in *reading accuracy* and *knowledge gains* were first normalized by dividing all values from their respective maximum and were then combined through a weighted sum function with equal weights. Due to the relatively small sample size for segmentation (Hine et al., 2014), comparisons were only made between the *table* format and a grouped graph format that included all graph conditions.

Differences between visualization formats for *perceived efficacy* and *affective responses* were analyzed using Analysis of Variance (ANOVA), while differences for *subjective evaluation* were analyzed in a varied way for each country. In the German sample, the respondents had to evaluate only their assigned format condition on a Likert scale and their answers were analyzed using ANOVA. In the Polish and French samples, the respondents had to compare two formats and select which format was most informative, clear, etc. The Polish and French respondents could also select a third option to indicate that the formats were perceived as equal. In order to take into account all three options, a paired comparison test with an equal option was used (Lawless and Heymann, 2010).

## 7.3 Results

### 7.3.1 Effects of respondents' characteristics and visualization formats

#### 7.3.1.1 Effects on reading accuracy

The characteristics of the respondents had a large effect on *reading accuracy* across all samples in Germany, Poland, and France. As shown in Table 7.3, a multiple regression model using all examined characteristics, country contexts, and visualization formats as predictors explained 35% of the variance of the total error across all *reading accuracy* questions. Standardized *beta* coefficients ( $\beta$ ) showed that younger respondents and respondents with higher *education level* and *numeracy* had lower error and thus, higher *reading accuracy* than their counterparts ( $\beta$  for *age*: 0.17,  $p < 0.001$ ; *education level*: -0.22,  $p < 0.001$ ; *numeracy*: -0.12,  $p = 0.003$ ). Additionally, *reading accuracy* was higher for respondents with higher *belief about the need to cut CO<sub>2</sub> emissions* (-0.14,  $p < 0.001$ ) and for respondents that stated that electricity from fossil fuels has to decrease (0.19,  $p < 0.001$ ) and for renewable sources – to increase (-0.18,  $p < 0.001$ ). All these effects are likely related to knowledge about the required climate change mitigation, suggesting that the respondents that already knew the correct patterns had higher *reading accuracy* too. Interestingly, respondents with higher *perceived efficacy* of humanity or electricity industry to reduce CO<sub>2</sub> emissions (0.17,  $p < 0.001$ ) had lower *reading accuracy*, suggesting a possible interaction between how respondents believe the situation should be and what they read from the visualizations. The country context played also an important role with French and Polish respondents having higher error in *reading accuracy* than German respondents (DE vs. PL: 0.20; DE vs. FR: 0.13;  $p < 0.001$  for both). In contrast, the visualization format had only a minor effect on *reading accuracy* with respondents in the *steep range* condition having lower *reading accuracy* than respondents in the *table* condition (0.08,  $p = 0.021$ ).

Table 7.3. Results of multiple linear regression and dominance analysis on the error in *reading accuracy* and the error in *knowledge gains* in the required percentage of CO<sub>2</sub> emissions cuts

| Error in <i>reading accuracy</i>                                           |          |                    | Error in <i>knowledge gains</i> (% CO <sub>2</sub> ) |          |                    |          |
|----------------------------------------------------------------------------|----------|--------------------|------------------------------------------------------|----------|--------------------|----------|
| <i>F</i> -statistic                                                        | 20.13*** |                    |                                                      | 10.03*** |                    |          |
| <i>R</i> <sup>2</sup>                                                      | 0.35     |                    |                                                      | 0.30     |                    |          |
| <i>R</i> <sup>2</sup> adjusted                                             | 0.33     |                    |                                                      | 0.27     |                    |          |
| Predictors                                                                 | $\beta$  | Dominance analysis |                                                      | $\beta$  | Dominance analysis |          |
|                                                                            |          | rank               | $\rho^2$                                             |          | rank               | $\rho^2$ |
| prior error                                                                | -        | -                  | -                                                    | 0.33***  | 1 <sup>CD</sup>    | 0.12     |
| country contexts                                                           |          |                    |                                                      |          |                    |          |
| <i>Polish sample (vs. German sample)</i>                                   | 0.20***  | 6                  | 0.02                                                 | 0.07     | >15                | 0.00     |
| <i>French sample (vs. German sample)</i>                                   | 0.13***  | >15                | 0.00                                                 | 0.11*    | 9                  | 0.01     |
| visualization formats                                                      |          |                    |                                                      |          |                    |          |
| <i>gradual range (vs. table)</i>                                           | 0.05     | >15                | 0.00                                                 | 0.01     | >15                | 0.00     |
| <i>steep range (vs. table)</i>                                             | 0.08*    | 13 <sup>CD</sup>   | 0.01                                                 | -0.02    | >15                | 0.00     |
| <i>gradual ensemble (vs. table)</i>                                        | 0.04     | >15                | 0.00                                                 | 0.01     | 15                 | 0.00     |
| <i>steep ensemble (vs. table)</i>                                          | 0.03     | >15                | 0.00                                                 | 0.11*    | 10                 | 0.01     |
| demographics                                                               |          |                    |                                                      |          |                    |          |
| <i>gender</i>                                                              | -0.0     | 14 <sup>CD</sup>   | 0.00                                                 | 0.01     | 14                 | 0.00     |
| <i>age</i>                                                                 | 0.17***  | 7                  | 0.02                                                 | 0.07     | >15                | 0.00     |
| <i>education level</i>                                                     | -0.22*** | 3 <sup>CD</sup>    | 0.05                                                 | -0.07    | 7                  | 0.01     |
| abilities                                                                  |          |                    |                                                      |          |                    |          |
| <i>numeracy</i>                                                            | -0.12**  | 5                  | 0.02                                                 | -0.07    | 6                  | 0.02     |
| <i>graph literacy</i>                                                      | -0.04    | 4                  | 0.03                                                 | -0.08    | 4                  | 0.03     |
| prior beliefs                                                              |          |                    |                                                      |          |                    |          |
| <i>political orientation</i>                                               | -0.0     | 15                 | 0.00                                                 | 0.03     | 13                 | 0.00     |
| <i>belief in global warming</i>                                            | -0.08    | 10                 | 0.01                                                 | -0.01    | 8                  | 0.01     |
| <i>belief about the need to cut CO<sub>2</sub> emissions</i>               | -0.14*** | 8                  | 0.02                                                 | -0.17*** | 3                  | 0.03     |
| <i>belief about the required electricity supply from fossil fuels</i>      | 0.19***  | 1 <sup>CD</sup>    | 0.06                                                 | 0.1*     | 5                  | 0.02     |
| <i>belief about the required electricity supply from nuclear</i>           | 0.06     | 12                 | 0.01                                                 | 0.04     | >15                | 0.00     |
| <i>belief about the required electricity supply from renewable sources</i> | -0.18*** | 2 <sup>CD</sup>    | 0.05                                                 | -0.16*** | 2 <sup>CD</sup>    | 0.04     |
| prior <i>perceived efficacy</i> and affective responses                    |          |                    |                                                      |          |                    |          |
| <i>perceived efficacy</i>                                                  | 0.17***  | 9                  | 0.02                                                 | 0.05     | >15                | 0.00     |
| <i>feelings of urgency</i>                                                 | 0.07     | >15                | 0.00                                                 | 0.04     | 12                 | 0.00     |
| <i>feelings of hope</i>                                                    | -0.01    | 11                 | 0.01                                                 | -0.0     | 11                 | 0.00     |

Note: \* $p < 0.05$ ; \*\* $p < 0.01$ , \*\*\* $p < 0.001$ ;  $\beta$  = standardized *beta* coefficients. The statistical significance of  $\beta$  is based on 1000 bootstrap samples. Predictors with the symbol "CD" above their rank are *completely dominating* predictors with lower rank. All other predictors are assumed to be *generally dominating* predictors with lower rank.

A dominance analysis showed that the respondents' *belief about the required electricity supply from fossil fuels* and *renewable sources* as well as their *education level* were the top three

predictors in terms of explanatory power, contributing 48% of the total  $R^2$  and *completely dominating* the rest (Table 7.3). The next most important predictors were abilities related to reading visualizations: *graph literacy* and *numeracy*. Interestingly, *graph literacy* had a non-statistically significant *beta*, indicating that other factors may have dampened its effects in the main regression. The next five predictors were *country context* (PL vs. DE), *age*, *belief about the need to cut CO<sub>2</sub> emissions*, *perceived efficacy*, and *belief in global warming*, which together with the aforementioned predictors contributed more than 90% of the total  $R^2$ . Results for *reading accuracy* were similar for regressions separately for each country (Section E.5 in Appendix E).

The results for the aforementioned characteristics of the respondents were consistent across *scenario themes* and *value types* read from visualizations, including averages, maximum, and minimum values. Logistic regressions on the percentage of correct answers using each characteristic as a single predictor (without *median* split) indicated statistically significant effects across all *scenario themes* and *value types* ( $\chi^2$  ranged between 47.73 and 777.65 for all variables and countries,  $p < 0.001$  for all; see Section E.6 in Appendix E). A *median* split for each characteristic revealed that correct answers to *reading accuracy* dropped on average between younger and older respondents (DE: from 55% to 40%, PL: from 39% to 27%, FR: from 49% to 36%). In contrast, it increased between respondents with lower to higher *education level* (38% to 61%, 17% to 43%, 30% to 45%), *numeracy* (39% to 54%, 26% to 43%, 37% to 48%), and *graph literacy* (32% to 60%, 19% to 43%, 34% to 57%). Correct answers also increased between respondents with lower to higher *belief in global warming* (DE: 36% to 57%, PL: 30% to 39%, FR: 35% to 50%), *belief about the need to cut CO<sub>2</sub> emissions* (38% to 55%; 30% to 40%; 33% to 50%), and for respondents that stated that *fossil fuels* need to decrease (30% to 60%; 26% to 43%; 34% to 52%) and that *renewable sources* need to increase (35% to 56%; 30% to 40%; 36% to 49%). All interaction effects between characteristics of respondents and *value types* and *scenario themes* on *reading accuracy* were weak and inconsistent across countries (Section E.7 in Appendix E provides more details).

Visualization formats ranked low in the dominance analysis and contributed to less than 3% of the total  $R^2$ . A dominance analysis comparing between graph conditions, that is, whether the graph was *range* or *ensemble* and *gradual* or *steep*, led to similarly low ranking (Section E.8 in Appendix E). Separate format comparisons for each *value type* revealed statistically significant differences between *table* and graph conditions on the *reading accuracy* for maximum and minimum values across all countries (DE:  $\chi^2 = 86.31$ ; PL:  $\chi^2 = 15.55$ ; FR:  $\chi^2 = 34.81$ , all  $p < 0.001$ ). Respondents in the *table* condition had statistically significantly higher percentage of correct answers in *reading accuracy* than respondents in the *steep range* condition for all countries (DE: 58% for *table* versus 44% for *steep range*; PL: 37% versus 29%; FR: 44% versus 34%;  $p < 0.001$ ) and respondents in the *gradual range* and *ensemble* conditions for Germany (58% for *table* versus 46% for *gradual range*, 41% for *gradual ensemble*, and 43% for *steep ensemble*;  $p < 0.001$ ). Additionally, respondents in the *gradual range* condition had statistically significantly more correct answers than respondents in the *steep range* condition for Poland and France (PL:

34% versus 29%,  $\chi^2 = 5.08$ ,  $p = 0.024$ ; FR = 44% versus 34%,  $\chi^2 = 26.34$ ,  $p < 0.001$ ). Each *scenario theme* showed similar patterns of differences between the *table* and graph conditions for maximum and minimum values, while there were no consistent statistically significant differences for averages between formats (see Section E.9 in Appendix E for more details).

### 7.3.1.2 Effects on knowledge gains in the required percentage of CO<sub>2</sub> emissions cuts

Similar to *reading accuracy*, the respondents' prior beliefs about climate change mitigation had an important effect on *knowledge gains*, defined as the difference between prior and posterior *belief about the required percentage of CO<sub>2</sub> emissions cuts* in 2030 and 2050 (Figure 7.3). A multiple regression model, including the prior error in these percentages as well as the respondents' characteristics, country contexts, and visualization formats, explained 30% of the posterior error in percentages (Table 7.3). The resulting *betas* showed that the posterior error was strongly correlated with the prior error ( $\beta = 0.33$ ,  $p < 0.001$ ), whereas the dominance analysis showed that the prior error *completely dominated* the rest of the predictors. This effect may be related to the considerable percentage of respondents (14 – 26%) that gave the same answer after seeing the visualizations (Figure 7.3). Some of these answers could be due to satisficing or uncertainty about the correct answer, as shown by the concentration of datapoints in the line of 0% and 50% in Figure 7.3. Similar to *reading accuracy*, the respondents that repeatedly selected the 0% or 50% point were less than 6% of the sample and tended to have lower *graph literacy*, *education level*, and congruence between prior beliefs and visualizations than the rest of the respondents. However, most of the respondents (44 – 60%) improved their answers after seeing the visualizations, while the mean error between prior and posterior answers was statistically significantly reduced in almost all countries, particularly for the 2050 percentage (see Figure 7.3 for the exact *t*- and *p*-values).

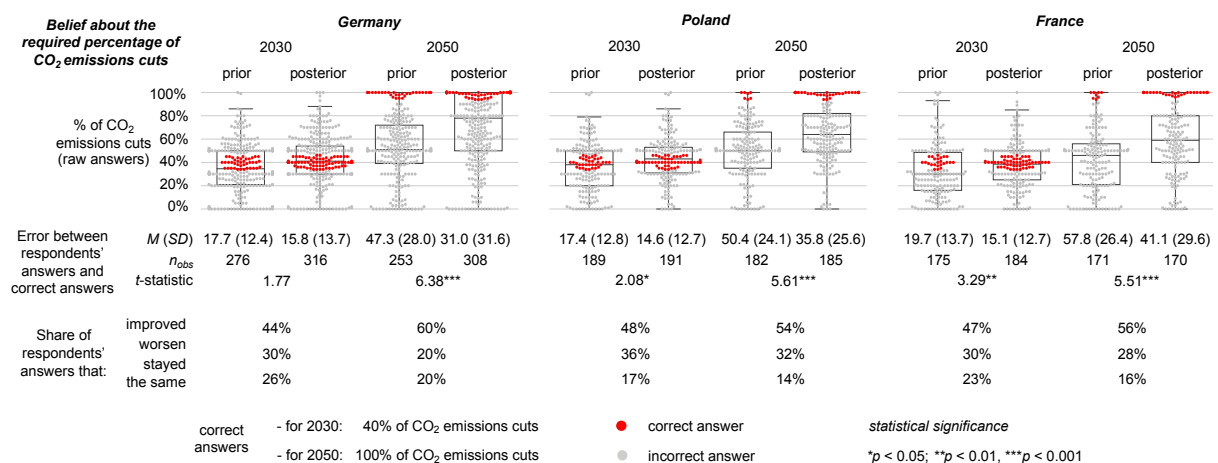


Figure 7.3. Measured *knowledge gains* in the required percentage of CO<sub>2</sub> emissions cuts shown as the change between prior and posterior *belief about the required percentage of CO<sub>2</sub> emissions cuts* in 2030 and 2050. Boxplots and scatterplots show the distribution of answers, indicating with red color the correct answers. A respondent's answer is considered correct if it falls within a margin of  $\pm 5$  from the correct answer to the test.

*Knowledge gains* in the required percentage of CO<sub>2</sub> emissions cuts were mostly correlated with the *belief about the need to cut CO<sub>2</sub> emissions* ( $\beta = -0.17, p < 0.001$ ) and the *belief about the required electricity supply from renewable sources* ( $\beta = -0.16, p < 0.001$ ) and *fossil fuels* ( $\beta = 0.10, p < 0.001$ , Table 7.3). These predictors were also within the top five predictors in the ranking of dominance analysis. *Graph literacy*, *numeracy*, and *education level* followed up in the ranking (even if their *betas* were not statistically significant), and together with the aforementioned predictors contributed to around 90% of the total  $R^2$ . *Country context* was a less significant predictor with only German respondents having a lower error than French ( $\beta = 0.11, p = 0.035$ ). Effects from visualization formats were again low in the ranking with only one statistically significant effect: respondents in the *steep ensemble* condition had lower *knowledge gains* than respondents in the *table* condition ( $\beta = 0.11, p = 0.018$ ). The same lack of differences between visualization formats was found by comparing prior and posterior answers within each condition (Section E.10 in Appendix E).

### 7.3.2 Effects on knowledge gains in the required electricity supply

Respondents' characteristics played a more limited role for the *knowledge gains* in the required electricity supply, calculated as the difference between prior and posterior *beliefs about the required electricity supply from fossil fuels, nuclear, and renewable sources*. In part, this was due to most respondents keeping the same answer across all countries: 59 – 64% of the respondents kept their prior answer for nuclear electricity, 71 – 75% for fossil fuels, and 70 – 82% for renewable sources (see Section E.11 in Appendix E). For fossil fuels and renewable sources, this was normal as most of the prior answers already matched the patterns shown in the visualizations (i.e. significantly decrease and increase respectively) and thus respondents did not need to change them. However, this was not the case for nuclear electricity in the German and French samples: while the pattern shown in the visualization indicated that nuclear electricity should remain constant (corresponding to number 4 in the scale), most respondents kept their posterior answer close to their prior believing that it should be moderately reduced [ $M (SD)$  for DE prior: 2.5 (1.6), posterior 2.6 (1.7); FR prior: 2.8 (1.6), posterior: 2.9 (1.5)]. This may indicate that prior *beliefs about the required electricity supply* were more resistant to change from the visualizations than the CO<sub>2</sub> percentages or that the respondents would read the pattern in a way that matches their beliefs as an effect of motivated reasoning. A multiple regression showed that prior answers were statistically significant predictors for all technologies ( $\beta = 0.58 - 0.63, p < 0.001$ , Section E.12 in Appendix E). Subsequently, a dominance analysis showed that prior beliefs *completely dominated* all other predictors and contributed 74–89% of the total  $R^2$ . Other influential predictors included the *education level*, *perceived efficacy*, *belief about the need to cut CO<sub>2</sub> emissions*, *graph literacy*, and *country context*. However, their effects were much weaker in comparison to the prior beliefs (see Section E.12 in Appendix E for more details).

### 7.3.3 Reducing adverse effects of respondents' characteristics

#### 7.3.3.1 Customizing visualization formats to respondents with different characteristics

While results from Section 7.3.1 showed that there is no optimal visualization format to increase *reading accuracy* and *knowledge gains* in all countries and for all respondents, customizing formats to specific segments of respondents was conducted by to control effects from *country context*, *age*, and *education level*. Across all segments, using the best matching format for each segment led to 19% lower *median* combined error than using a *table* for all segments and 16% lower *median* error than using any of the graph formats for all segments (see the "all segments" row in Table 7.4). These improvements could not be statistically established as, depending on the segment, respondents could belong both to the group of best matching formats and to one of the single-format groups. However, an indication of statistical significance could be found by comparing segments where groups were independent. Specifically, in segments where *table* format was not the best matching format, using graph formats instead led to statistically significantly lower combined error in *reading accuracy* and *knowledge gains* (*median* error: 0.28 versus 0.40,  $U = 3383$ ,  $p = 0.005$ ). Similar results were found by using *table* in segments where graphs were not the best matching formats (0.38 versus 0.41,  $U = 17283$ ,  $p = 0.041$ ).

Table 7.4. Combined error in *reading accuracy* and *knowledge gains* per segment of groups, differing in *country context*, *education level*, and *age*

| country<br>context                                               | Segments                                      |            | Combined error |          |                |          | Best matching format per segment<br>(format with minimum <i>median</i> error) |                |          |
|------------------------------------------------------------------|-----------------------------------------------|------------|----------------|----------|----------------|----------|-------------------------------------------------------------------------------|----------------|----------|
|                                                                  | <i>education level</i> (high school diploma?) | <i>age</i> | <i>table</i>   | <i>n</i> | <i>media n</i> | <i>n</i> | best matching format                                                          | <i>media n</i> | <i>n</i> |
| Germany                                                          | no                                            | low        | 0.27           | 12       | 0.47           | 53       | <i>table</i>                                                                  | 0.27           | 12       |
|                                                                  |                                               | high       | 0.34           | 30       | 0.37           | 98       | <i>table</i>                                                                  | 0.34           | 30       |
|                                                                  | yes                                           | low        | 0.20           | 16       | 0.15           | 70       | graph                                                                         | 0.15           | 70       |
|                                                                  |                                               | high       | 0.54           | 4        | 0.24           | 23       | graph                                                                         | 0.24           | 23       |
| Poland                                                           | no                                            | low        | 0.47           | 9        | 0.48           | 16       | <i>table</i>                                                                  | 0.47           | 9        |
|                                                                  |                                               | high       | 0.46           | 14       | 0.49           | 24       | <i>table</i>                                                                  | 0.46           | 14       |
|                                                                  | yes                                           | low        | 0.26           | 26       | 0.35           | 41       | <i>table</i>                                                                  | 0.26           | 26       |
|                                                                  |                                               | high       | 0.46           | 12       | 0.37           | 43       | graph                                                                         | 0.37           | 43       |
| France                                                           | no                                            | low        | 0.34           | 5        | 0.48           | 10       | <i>table</i>                                                                  | 0.34           | 5        |
|                                                                  |                                               | high       | 0.45           | 5        | 0.49           | 15       | <i>table</i>                                                                  | 0.45           | 5        |
|                                                                  | yes                                           | low        | 0.30           | 30       | 0.37           | 38       | <i>table</i>                                                                  | 0.30           | 30       |
|                                                                  |                                               | high       | 0.49           | 16       | 0.35           | 50       | graph                                                                         | 0.35           | 50       |
| Across all segments                                              |                                               |            | 0.38           | 179      | 0.37           | 481      | -                                                                             | 0.32           | 317      |
| Across segments where:<br>- graphs are the best matching formats |                                               |            | 0.40           | 48       | -              | -        | -                                                                             | 0.28           | 186      |
| - <i>table</i> is the best matching format                       |                                               |            | -              | -        | 0.41           | 295      | -                                                                             | 0.38           | 131      |

Note: Numbers in bold indicate the minimum *median* error per segment. The combined error was normalized from 0 = zero error to 1 = highest error. In order to avoid oversegmentation, *education level* was measured in terms of attaining a high school diploma or an equivalent degree. The segmentation for *age* was based on the *median* for each country.

### 7.3.3.2 Individual interactions between visualization formats and respondents' characteristics

Many individual interactions between formats and respondents' characteristics on *reading accuracy* were statistically significant, indicating that the background of respondents facilitated or hindered *reading accuracy* in a different way for different formats. Among all samples, the most consistent interaction was between slope type and *numeracy*, where respondents with low *numeracy* had lower *reading accuracy* in the *steep* conditions than in the *gradual* conditions (DE: 33% of correct answers for *steep* versus 42% for *gradual*,  $\chi^2 = 45.94$ ; PL: 20% versus 30%,  $\chi^2 = 19.38$ ; FR: 25% versus 42%,  $\chi^2 = 19.67$ ;  $p < 0.001$  for all). Among all other statistically significant interactions, none showed a consistent pattern in all countries (Section E.13 in Appendix E). This could indicate that many of these effects are country-specific or potentially could be products of sampling error or chance, even if the respondents were representative of the general population. Interactions between formats and *knowledge gains* were limited and similarly inconsistent between countries (Section E.14 in Appendix E).

### 7.3.4 Subjective evaluation, perceived efficacy, and affective responses of visualization formats

As shown in Table 7.5, the results of the subjective evaluation of formats were interestingly not identical across different samples and evaluation measures, but there were some similarities between Polish and French samples. A statistically significantly higher percentage of the Polish and French respondents perceived the *steep range* condition as more concerning than a *table* (PL: 43% versus 25%,  $d\text{-prime} = 0.37$ ,  $p = 0.013$ ; FR: 38% versus 18%,  $d\text{-prime} = 0.44$ ,  $p = 0.003$ ) and as less trustworthy than the *gradual range* condition (PL: 21% versus 39%,  $d\text{-prime} = 0.36$ ,  $p = 0.015$ ; FR: 11% versus 31%,  $d\text{-prime} = 0.51$ ,  $p < 0.001$ ). A higher percentage of Polish respondents perceived the *steep range* condition as less easy to understand than the *gradual range* condition (21% versus 36%,  $d\text{-prime} = 0.31$ ,  $p = 0.034$ ), while a higher percentage of French respondents perceived the *steep range* condition as less exact and less interesting to read than the *gradual range* condition (12% versus 28% for exact,  $d\text{-prime} = 0.42$ ,  $p = 0.004$ ; 19% versus 34% for interesting to read,  $d\text{-prime} = 0.33$ ,  $p = 0.023$ ). Comparing between a *table* and the *gradual range* conditions, a higher percentage of Polish respondents found the *gradual range* condition as more interesting to read than a *table* (PL: 51% versus 29%,  $d\text{-prime} = 0.4$ ,  $p = 0.006$ ) and a higher percentage of French respondents found the *gradual range* condition as more trustworthy and concerning than a *table* (FR: 34% versus 19% for trustworthy,  $d\text{-prime} = 0.33$ ,  $p = 0.023$ ; 35% versus 20% for concerning,  $d\text{-prime} = 0.33$ ,  $p = 0.025$ ).



Table 7.5. Results of the *subjective evaluation* of formats for the Polish and French samples.

| Subjective evaluation<br>for Polish and French samples            |                       | % of respondents that selected each option |                  |             | d-prime<br>statistic |
|-------------------------------------------------------------------|-----------------------|--------------------------------------------|------------------|-------------|----------------------|
|                                                                   |                       | table                                      | gradual<br>range | steep range |                      |
| Polish sample                                                     |                       |                                            |                  |             |                      |
| table versus<br>gradual range<br>(n <sub>obs</sub> =147)          | trustworthy           | 36                                         | 42               | 22          | 0.11                 |
|                                                                   | concerning            | 31                                         | 37               | 31          | 0.12                 |
|                                                                   | exact                 | 39                                         | 43               | 18          | 0.06                 |
|                                                                   | easy to<br>understand | 33                                         | 46               | 21          | 0.25                 |
|                                                                   | interesting to read   | 29                                         | 51               | 20          | 0.40**               |
| table versus<br>steep range<br>(n <sub>obs</sub> =150)            | trustworthy           | 39                                         |                  | 31          | 0.15                 |
|                                                                   | concerning            | 25                                         |                  | 43          | 0.37*                |
|                                                                   | exact                 | 41                                         |                  | 35          | 0.10                 |
|                                                                   | easy to<br>understand | 42                                         |                  | 29          | 0.26                 |
|                                                                   | interesting to read   | 34                                         |                  | 43          | 0.17                 |
| gradual range<br>versus steep<br>range<br>(n <sub>obs</sub> =149) | trustworthy           |                                            | 39               | 21          | 0.36*                |
|                                                                   | concerning            |                                            | 25               | 30          | 0.10                 |
|                                                                   | exact                 |                                            | 34               | 28          | 0.14                 |
|                                                                   | easy to<br>understand |                                            | 36               | 21          | 0.31*                |
|                                                                   | interesting to read   |                                            | 37               | 23          | 0.27                 |
| French sample                                                     |                       |                                            |                  |             |                      |
| table versus<br>gradual range<br>(n <sub>obs</sub> =152)          | trustworthy           | 19                                         | 34               | 47          | 0.33*                |
|                                                                   | concerning            | 20                                         | 35               | 45          | 0.33*                |
|                                                                   | exact                 | 26                                         | 26               | 48          | 0.01                 |
|                                                                   | easy to<br>understand | 29                                         | 38               | 33          | 0.18                 |
|                                                                   | interesting to read   | 30                                         | 38               | 33          | 0.15                 |
| table versus<br>steep range<br>(n <sub>obs</sub> =147)            | trustworthy           | 26                                         |                  | 31          | 0.10                 |
|                                                                   | concerning            | 18                                         |                  | 38          | 0.44***              |
|                                                                   | exact                 | 26                                         |                  | 29          | 0.06                 |
|                                                                   | easy to<br>understand | 33                                         |                  | 37          | 0.06                 |
|                                                                   | interesting to read   | 32                                         |                  | 39          | 0.13                 |
| gradual range<br>versus steep<br>range<br>(n <sub>obs</sub> =151) | trustworthy           |                                            | 31               | 11          | 0.51***              |
|                                                                   | concerning            |                                            | 20               | 27          | 0.17                 |
|                                                                   | exact                 |                                            | 28               | 12          | 0.42**               |
|                                                                   | easy to<br>understand |                                            | 33               | 22          | 0.24                 |
|                                                                   | interesting to read   |                                            | 34               | 19          | 0.33*                |

Note: \* $p < 0.05$ ; \*\* $p < 0.01$ , \*\*\* $p < 0.001$ . Numbers in bold indicate a format with a statistically significantly higher evaluation than the other formats. Statistical significance is calculated based on the *d-prime* statistic and includes the *no difference* answers in the calculation.

Overall, the *steep range* received more negative evaluations and the *gradual range* more positive evaluations, while both graphs were perceived as more concerning than a *table*. It is noted that the *no difference* answers were included in all statistical comparisons. The percentage of *no difference* answers was used to increase the threshold beyond which the difference between two formats should lie in order to be statistically significant (Lawless and Heymann, 2010). The high percentage of *no difference* answers (especially for the French sample) may indicate that, even if some of the above differences were statistically significant, their effects were rather weak. For the German sample, there was no statistically significant difference between experimental conditions (Section E.15 in Appendix E).

In contrast to the above results, statistically significant differences between formats on the change in *perceived efficacy*, *feelings of hope*, and *urgency* were limited and found only for individual scale items in the German sample. The German respondents in the *steep range* condition had less *perceived efficacy in the ability of humanity to reduce CO<sub>2</sub> emissions* and more *fear* than respondents in the *table* condition [*perceived efficacy*: 3.9 (0.9) versus 4.1 (0.9),  $F = 2.95$ ,  $p = 0.02$ ; *fear*: 5.8 (2.5) versus 4.8 (2.6),  $F = 2.60$ ,  $p = 0.04$ ]. None of these results were found in the French and Polish samples (Section E.16 in Appendix E). Finally, there was no statistically significant difference between conditions in terms of *perceived credibility* and *uncertainty* of the visualizations across all countries.

### 7.4 Discussion

The first main finding of this study is that most of the examined prior beliefs, demographics, *numeracy*, and *graph literacy* consistently had an important effect on *reading accuracy* and *knowledge gains* in the required percentage of CO<sub>2</sub> emissions cuts in all studied countries. For *reading accuracy*, these effects were similar along all visualized themes of scenarios and types of values that had to be looked up from visualizations (averages, maximum, minimum values). Prior beliefs about the topic of the visualizations were among the most influential predictors of *reading accuracy* and *knowledge gains*, showing a significant positive effect for respondents that agreed that CO<sub>2</sub> emissions cuts are needed for limiting global warming to 1.5°C and that electricity from fossil fuels and renewable sources has to decrease and increase respectively. These were also the patterns shown in the visualizations, indicating that when readers had beliefs about climate change mitigation that matched with the visualizations' information, they were more likely to adopt the information. In line with our results, Bosetti et al. (2017) earlier found that prior beliefs in an international sample of policymakers were influential in adopting information from scenario visualizations. Additionally, Dieckmann et al. (2017) found effects of motivated reasoning in the interpretation of both numerical and graphical information about climate change impacts. Another possible explanation is that the respondents that were interested and open to the topic of climate change mitigation were more attentive in studying graphs and answering the survey overall.

*Reading accuracy* was also high for respondents with higher *education level*, *numeracy*, and *graph literacy*. Previous empirical studies also stressed the importance of *numeracy* and *graph literacy* on interpreting scenario information, but none reported similar effects for demographics (e.g. Dieckmann et al., 2015; McMahon et al., 2015). Xexakis and Trutnevyte (2019a) compared an interactive and a static scenario visualization and also found that higher *numeracy* increased understanding in both cases. Interestingly, *reading accuracy* was also high for younger respondents and for respondents with lower *perceived efficacy* of humanity or electricity industry to reduce CO<sub>2</sub> emissions. For younger respondents, this effect may be due to their higher familiarity with reading information in a digital format (Hunsaker and Hargittai, 2018;

Neter and Brainin, 2012). For *perceived efficacy*, effects may indicate that respondents that were less optimistic about climate change mitigation paid more attention to the exact numbers in the visualizations. As compared to previous research, we focused on empirically testing visualizations with a representative and hence most diverse sample of citizens from three different countries rather than with more experienced samples. The results of the present study indicate that also *education level*, *age*, and *perceived efficacy* may be important for how the intended readers interpret scenario visualizations.

The second main finding is that the differences between visualization formats on *reading accuracy* and *knowledge gains* were rather minor in comparison with the effects of the aforementioned characteristics of the respondents. However, customizing formats according to different readers' characteristics could be used to reduce adverse effects from these characteristics. This study demonstrates this principle by dividing the total sample in segments of *country context*, *age*, and *education level* and selecting the best performing format for each segment. Results showed that *reading accuracy* and *knowledge gains* were higher for groups of respondents that saw formats tailored to their *country context*, *age*, and *education level* than groups of respondents where everybody saw the same format. Previous research has also suggested that providing tailored information could be valuable for climate change communication (Bostrom et al., 2013; Hine et al., 2014), but there has been no evaluation yet for tailor-made visualizations. Such customization could be potentially applied to other characteristics, e.g., for controlling differences in *numeracy* or prior beliefs. Online social marketing methods would be ideal for disseminating customized visualizations, as there are already many solutions to customize digital content based on demographics and other characteristics (Hine et al., 2014).

Comparisons among experimental conditions showed that there was no format that outperformed all the rest neither in *reading accuracy* nor in *knowledge gains*. This was especially surprising for the *table*, as it was hypothesized that it would have the highest *reading accuracy* since respondents could just read the answers. This may be due to the technical wording used in the visualizations (e.g., "average of all scenarios that meet 1.5°C"). Such wording may have penalized interpretation by non-expert readers across all formats, despite the fact that a small introduction to the context of scenarios was provided (see Subsection E.1.9 in Appendix E). Even then, *steep* formats were underperforming in some cases. Specifically, the *steep range* format led to a lower *reading accuracy* in comparison with the *table* for all countries and with the *gradual range* format for France and Poland. Similarly, the *steep ensemble* led to lower *knowledge gains* compared to the *table*. These differences may be due to disadvantages related to how information was shown in *steep* formats. Since both *reading accuracy* and *knowledge gains* in the required percentage of CO<sub>2</sub> emissions cuts asked for values in specific years, it could be that the *steep* format had a disadvantage in contrast to the *gradual* because its x-axis that showed the years was shorter and its values were more concentrated. Additionally, respondents in the *steep ensemble* format had to read the correct values along the visual clutter of all the scenarios.

Previous studies have also shown that visual crowding can be disadvantageous to the interpretation of a visualization (Harold et al., 2016; McMahon et al., 2016, 2015). We therefore conclude that the *steep* conditions may be disadvantageous over other conditions, although only to a small extent.

On average, respondents had similar *beliefs about the required electricity supply*, *perceived efficacy*, and *affective responses* before and after seeing the visualizations, indicating that the visualizations had little effect on these aspects. Additionally, differences between formats were limited and inconsistent. This is an unexpected result especially for the *steep* graphs, as it was assumed that, for example, the steep reduction of CO<sub>2</sub> emissions would increase *feelings of urgency*. Overall, results show that *steep* graphs had no advantage in increasing urgency, while they had aforementioned disadvantages in *reading accuracy*. Results may also indicate that the examined visualizations may have weaker effects in increasing concern about climate change topics in comparison with other information formats such as videos or images (Jones et al., 2017). Such repeated measures have not been investigated before for empirically testing visualizations as far as we are aware. In a preparatory survey for this study (Section E.2 in Appendix E), the lack of statistically significant differences between formats in a between-groups experiment was also the case. Results indicated that, while differences between formats were limited in terms of tested understanding and anchoring effects, the prior knowledge of respondents of scenarios and climate change mitigation had a statistically significant effect in most evaluation questions. These results also reinforce the findings of the main study, emphasizing the role of readers' characteristics in the interpretation of visualizations.

In terms of subjective evaluation, while different formats were perceived as rather similar by the German sample, both the French and Polish respondents perceived the *steep range* format as more concerning than a *table* and less trustworthy than a *gradual range* format. Additionally, the *gradual range* graph was associated with more positive evaluations, such as being more exact, while *steep range* was associated with more negative evaluations, such as being less interesting to read. These results could also support the previous hypothesis that the *steep* graphs were penalized in terms of visual clarity or that the *steep* graphs magnified the uncertainty shown, which could potentially affect the clarity of the communication (Knoblauch et al., 2017). However, a considerable number of respondents indicated that there was no difference between formats which suggests that the aforementioned effects may be relatively weak, as it was the case in previous studies (Bosetti et al., 2017). The small effect size of the differences among formats may also explain the lack of statistically significant differences in the German sample, along with the different evaluation method used.

The primary value of this study is that it provides an example and tools for empirical testing of visualizations of climate change mitigation scenarios to support the existing qualitative guidelines (Harold et al., 2016; Spiegelhalter et al., 2011). In future applications, several limitations of this empirical study shall be addressed. First, since the main intention of the study was to evaluate effects of visualization formats and respondents' characteristics, there was no adequate

sample size to go in depth with evaluating more customized visualizations. Future studies with appropriate sample sizes could explore further the benefits of using customized formats for addressing differences between readers. Second, technical wording may have penalized interpretation, as indicated by the high error in *reading accuracy* even for the *table* condition. Future studies could thus evaluate more optimal ways to frame scenarios for public communication without relying in technical jargon. More broadly, non-technical communication formats such as photos or narratives could be used to inform citizens about mitigation options, as they have been successfully used to raise awareness for climate change and its impacts (Corner et al., 2018). However, such formats should be evaluated thoroughly as, compared to technical formats, they may reduce the perceived credibility of the underlying scientific results (McMahon et al., 2016). Combinations of technical and non-technical formats have also shown promising results, such as combining role-playing elements with interactive technical visualizations to increase willingness to act in citizens (Rooney-Varga et al., 2018). Third, the measurement method in the *belief about the required electricity supply* had limited granularity to detect changes due to its qualitative 7-point Likert scale, in contrast to the continuous scale of 0–100% that was used for CO<sub>2</sub> emissions cuts. Fourth, we did not include *ensemble* visualizations in the Polish and French samples due to budget constraints. While differences between graphs were not large in all samples, the comparison between *ranges* and *ensembles* in all countries could have led to more patterns in performance of the different formats. Finally, this empirical test was rather narrow in its scope, comparing visualizations of scenario *ranges* versus scenario *ensembles* and *gradual* versus *steep* slopes. Future research could hence empirically test a wider range of graphs to optimize them for the intended readers.

## 7.5 Conclusions

Scenario visualizations are among the primary tools to communicate findings about climate change mitigation to expert and non-expert audiences, but empirical testing of how these visualizations are perceived is still rare. This study presents the results of a cross-country evaluation of the visualizations of climate change mitigation scenarios, using online surveys with citizens in Germany (N = 379), Poland (N = 223), and France (N = 225). Results showed that higher education level, numeracy, and graph literacy increased reading accuracy in all countries, while age reduced them. Readers that had prior beliefs about climate change mitigation that agreed with the contents of the visualizations had also higher reading accuracy and knowledge gains. In comparison with the aforementioned characteristics, the effects of different visualization formats were rather minor. However, customizing formats according to different respondents' characteristics could be used to reduce some adverse effects from these characteristics and, in this study, this was demonstrated using the country context, education level, and age. While there was no format that outperformed all the rest neither in reading accuracy nor in knowledge gains, steep formats were often found underperforming.

In terms of implication for communicating scenarios of climate change mitigation, the results emphasize that the characteristics of readers affect the interpretation of visualizations and should be taken into account when designing visualizations. Solutions include customizing visualizations for written or electronic dissemination and providing interactive web visualizations that can be flexibly customized to different user profiles and needs (Trutnevyte et al., 2016a; Weber et al., 2018). While portals of interactive visualizations already exist for experts (Huppmann et al., 2018a), such tools for customizing visualizations to a wider range of users, including citizens, are needed along with empirical research to validate them (Harold et al., 2019; Xexakis and Trutnevyte, 2019a). Our results also indicate that supporting inference-making and adjusting data complexity to the specific reader are important parameters for selecting the visualization format. Future research could use combinations of formats to increase inference-making such as combining text, graphs, and tables, or by using animated visualizations (Kale et al., 2019). In all cases, rigorous evaluation of visualizations for all intended readers is necessary.

## Chapter 8 Conclusions

### 8.1 Overall results

The main aim of this thesis was to empirically evaluate large scenario ensembles that inform energy and low-carbon transitions in terms of desirability and to test prominent visualization methods to make these ensembles usable. Specifically, the thesis focused on assessing model-based scenario ensembles for future electricity supply in France, Germany, Poland, Switzerland, and the European Union (EU) in terms of alignment with citizen perspectives. Additionally, the thesis evaluated the usability of widely used formats for scenario visualization. For both desirability and usability evaluations, the thesis examined the effects of demographics, prior beliefs, and other relevant characteristics of the citizens on their perspectives and on their understanding of and engagement with scenario information. The research studies in Chapters 3 – 7 elaborated on all evaluations, and their results are used here to answer the research questions posed in the introduction of the thesis.

*Research question 1. How broad is the representation of popular public perspectives in the ensembles of scenarios that inform energy and low-carbon transitions?*

The studies in Chapters 3 and 5 compared five multi-organization, multi-model scenario ensembles for the electricity supply in 2035 in France (N = 88), Germany (N = 152), Poland (N = 71), Switzerland (N = 82), and the EU (N = 301) with preferred scenarios collected from respective citizen groups. The Swiss ensemble included scenarios published in 2011 – 2018 while all other scenario ensembles were collected from studies published between 2008 and September 2020. All preferred scenarios were elicited in online surveys in France (N = 202), Germany (N = 199), Poland (N = 200), and, at a lesser extent, Switzerland (N = 61). Citizens from the first three countries submitted preferred scenarios for both their countries and the EU. All scenario elicitations used the Riskmeter, an interactive scenario tool that was developed by the author in the context of this thesis. In all five comparisons, most model-based scenarios included fossil fuel-based generation (mostly natural gas and/or coal) and nuclear power at levels that were mostly avoided by citizens. Notably, French, German, and Polish citizens could potentially use only fossil fuel-based generation and nuclear power to cover almost all required electricity demand in the Riskmeter for their countries and the EU. All scenario elicitations used the Riskmeter, an interactive scenario tool that was developed by the author in the context of this thesis. In all five comparisons, most model-based scenarios included fossil fuel-based generation (mostly natural gas and/or coal) and nuclear power at levels that were mostly avoided by citizens. Notably, French, German, and Polish citizens could potentially use only fossil fuel-based generation and nuclear power to cover almost all required electricity demand in the Riskmeter for their countries and the EU. Similarly, Swiss citizens could keep all existing nuclear power plants in their scenarios for Switzerland (instead of phasing them out as it is currently planned for 2035), or, alternatively, they could substitute some or all of them with fossil fuel-based power plants. In contrast, most preferred scenarios were consistently based on

a diverse mix of domestic renewable sources, usually in much higher levels than most model-based scenarios. This was especially the case for solar PV, which was included in citizens' preferred scenarios in such ambitious levels that were found only in few model-based scenarios. In the case of scenarios for France, Germany, Poland, and the EU, citizens could also choose to cover most of the demand using fossil fuels with Carbon Capture and Storage (CCS). Like with alternatives without CCS, citizens used only limited shares of natural gas and coal with CCS in their scenarios. Model-based scenarios included on average even smaller shares from alternatives with CCS than the citizens, with some model-based scenarios completely avoiding CCS in 2035.

Overall, the results indicate that the examined multi-organization, multi-model scenario ensembles were only narrowly representative of the citizens' perspectives. Note that a perfect alignment was not expected either, as good practice suggests that scenarios should examine a variety of uncertainties (Mach and Field, 2017). However, the thought-provoking finding is that most model-based scenarios for the examined countries led to technology mixes that were undesirable by the citizens. Reasons for the lack of model-based scenarios with high shares of renewable technologies, as desired by the citizens, include model choices and an undue focus of model-based scenarios on specific uncertainties and alternatives. For example, while many model-based scenarios assumed large shares of renewable electricity in the examined countries for 2050, very few did so as early as 2035. Since model-based scenarios are used to inform research and decision-making for the energy transition, there is a danger that an excessive focus on scenarios with delayed deployment of renewable generation capacity may lead to the misconception that faster deployment is not technically possible or feasible (Huppmann et al., 2018b). Another reason for the misalignment between model-based and citizens' preferred scenarios may lie in the lack of broad stakeholder participation in the development phase of almost all model-based scenarios. The studies performed in the context of this thesis offer examples of using elicitation methods in surveys and in workshops to generate preferred scenarios that could be then analyzed further in model-based studies. Additionally, the Riskmeter offers an easy and well-evaluated solution to collect preferred scenarios from different stakeholders.

*Research question 1a: Do these perspectives differ among citizens with different knowledge levels on energy transition topics? How do citizen perspectives compare with the perspectives of energy experts?*

In Chapter 3, preferred scenarios were elicited by two groups of Swiss citizens with different knowledge levels on energy transition topics: 1) citizens that filled the Riskmeter in an online survey without receiving any prior information about these topics (N = 61), and 2) citizens that received balanced information, spent at least one hour reading this information, and participated in a 2.5-hours workshop before giving their preferences (hereinafter called "informed citizens", N = 46). This process was shown to increase the knowledge level of informed



citizens on energy transition topics, based on a self-reported assessment and an extensive knowledge quiz [see Volken et al. (2018) for more details]. Preferred scenarios were also elicited from a group of energy experts in Switzerland (N = 60), recruited through advertisements in professional and academic networks about energy. The energy experts were working or studying on energy topics at the time of the survey, suggesting that they had a higher knowledge level on these topics than non-experts.

Results showed that most informed citizens and experts preferred almost fully domestic renewable electricity for Switzerland. In contrast, citizens that did not receive information beforehand preferred statistically significantly less renewable electricity and more fossil fuel-based generation. Since fossil fuel-based generation is not very common in Switzerland, this difference may be due to potential knowledge gaps of the citizens in technology characteristics and impacts. This was shown also to be the case in the process of creating the group of informed citizens, as these citizens had more positive preferences on natural gas before receiving information than afterwards (Volken et al., 2018). These results underline the importance of providing adequate and balanced information in the elicitation of preferred scenarios in order to avoid knowledge gaps that could potentially distort citizen preferences. Additionally, the fact that both informed citizens and energy experts chose scenarios with ambitious deployment of renewable electricity indicated that these scenarios were assumed to be both technically possible and desirable in Switzerland.

Nevertheless, the breadth of information provided to the informed citizens through reading extensive factsheets and participating in workshops came with significant time and cost expenses. The studies in Chapters 4 and 5 attempted a trade-off by providing interactive information on the impacts for each scenario in an effort to fill some of the knowledge gaps of the citizens. Although the impact of interactive information has not been evaluated directly, results suggest that it may have affected preferences for unfamiliar technologies such as CCS. Before receiving the interactive information, respondents had more negative views towards coal and natural gas with CCS than towards the same alternatives without CCS. In contrast, when they used the Riskmeter that provided interactive information, respondents chose equal or more potential from fossil fuels with CCS than without it, potentially due to the information they received on the reduced impact of CCS alternatives on climate change.

*Research question 1b: How do different demographics, prior beliefs, and the national context of the citizens affect their perspectives?*

The study in Chapter 4 compared the perspectives of the surveyed French, German, and Polish citizens on their national and EU electricity supply for 2035 and considered effects from the citizens' demographics, political orientations, attitudes towards the transition, and attitudes towards governance, including trust in different institutions and sense of belonging. Overall, results indicated relatively high consensus among citizens of different countries, demographics, political orientations, and examined attitudes, both in terms of individual technology preferences

and preferred scenarios. Specifically, there was a broad consensus among all citizen groups on positive views towards electricity savings and efficiency and most major renewable sources, i.e., hydropower, solar PV, wind power, and biomass. Additionally, all citizen groups had mostly negative views towards alternatives with CCS and net imports. Only small divergences were found among citizens of different countries, demographics, and attitudes towards the transition. Many of these divergences confirmed results from previous studies measuring individual technology preferences, such as that Polish citizens supported coal more than French and German citizens (Poortinga et al., 2018), German citizens showed the lowest preference for nuclear power (Steentjes et al., 2017), or that more educated respondents had more negative views on natural gas (Liebe and Dobers, 2019). Remarkably, no divergences were detected on average among respondents with different political orientations and attitudes towards governance, indicating that these characteristics do not affect citizen perspectives on the topic of electricity supply, at least for the examined countries.

The study in Chapter 4 additionally showed that there were less divergences among the examined citizen groups in their preferred scenarios than in their individual technology preferences. This may be a product of the constraints that are included in the Riskmeter to increase its technical realism, which may have inadvertently nudged respondents towards specific scenario configurations, homogenizing, thus, their preferences. Still, most of the divergences found in preferred scenarios reflected patterns found in individual technology preferences, such as that Polish citizens had the higher preference for nuclear power and used the highest potential from this technology in their scenarios. Nevertheless, this homogenization effect may bias the results of scenario elicitation tools similar to the Riskmeter and needs to be studied further if these tools are to be used more extensively in the future.

*Research question 2: What is the performance of prominent formats for visualizing large ensembles of scenarios for energy and low-carbon transitions in terms of supporting the understanding and engagement of transition stakeholders?*

Chapters 6 and 7 presented usability evaluations for seven widely used formats for scenario communication. These formats included five scenario visualizations that are frequently used in the reports of the Intergovernmental Panel for Climate Change (IPCC), an interactive scenario tool, and a format showing representative scenarios and storylines based on a typical story-and-simulation approach (Alcamo, 2008). Specifically, the study in Chapter 6 evaluated an interactive scenario tool Riskmeter that allowed to explore a large scenario ensemble for the future electricity supply in Switzerland and a static website that showed four representative scenarios from this ensemble along with relevant storylines. The evaluation was based on an online survey with a representative sample of Swiss citizens, with one group using the Riskmeter (N = 156) and the other — the website with the four scenarios and storylines (N = 157). Similarly, the study in Chapter 7 used online surveys in France (N = 225), Germany (N = 379), and Poland

(N = 223) to evaluate five static scenario visualizations inspired from IPCC reports. These formats included line graphs, uncertainty ranges, and tables, and showed information from a large scenario ensemble on global climate change mitigation.

The results of these evaluations varied per format: while the five scenario visualizations led to relatively poor usability, the interactive scenario tool and the static website showing four scenarios with storylines resulted to higher-than-average comprehension and engagement. In particular, citizens scored slightly above average on a quiz that required them to extract scenario information from the interactive tool and the static website in Chapter 6, indicating that they mostly comprehended the information and used the formats correctly. Citizens also answered above average to questions that gauged their perceived understanding, engagement, and trust of scenario information, suggesting that both the interactive scenario tool and the website performed relatively well. In contrast, citizens that used the five scenario visualizations in Chapter 7 scored poorly in questions that asked them to accurately read the information of the visualizations and use it to answer a knowledge quiz. For all five scenario visualizations and all three examined samples, the percentage of correct answers in the reading accuracy questions ranged between 30 and 50% while the percentage of correct answers in the quiz of knowledge gains ranged between 20 and 40%.

Overall, results suggest that scenario visualizations similar to the ones tested in Chapter 7 may pose challenges to the comprehension of non-expert users, while interactive scenario tools and representative scenarios with storylines like the ones in Chapter 6 may lead to a rather acceptable usability. However, it is noted that it is not possible to directly compare the usability of the formats in Chapter 6 with the ones in Chapter 7 as they visualized different information and they were tested using different evaluation measures. Instead, usability differences among formats were evaluated separately for each study and the results are described in the answer to Research question 2a below.

*Research question 2a. What is the difference between interactive and static formats for visualizing scenario information, and between different static visualizations?*

Chapters 6 and 7 included a between-groups experiment on the examined formats to visualize scenarios. Both experiments resulted in few statistically significant differences between the formats, indicating that changing the format had little effect on the comprehension of scenario results by the respondents. While interactive scenario tools are suggested as powerful methods for science communication (Bostrom et al., 2008; Spiegelhalter et al., 2011), the empirical study described in Chapter 6 found no evidence that an interactive scenario tool for visualizing large scenario ensembles was superior to a static website presenting four scenarios using a typical story-and-simulation approach. In fact, a tested measurement of understanding was reduced with the interactive format for a set of quiz questions that required respondents to use information from the visualization. This reduced understanding may be due to the higher

cognitive load required for looking up information in the interactive scenario tool. However, there was no statistically significant difference in the performance between the formats in terms of self-reported understanding, trust, and engagement. Similarly, the study in Chapter 7 showed that none of the static visualization formats was consistently outperforming the others. Visualizing scenario information in a graph format with a steep slope led to lower reading accuracy compared to the rest of the formats. This difference could be due to the small width of the steep format that disadvantaged respondents in reading information. In contrast, there was no evidence that showing steep slopes would increase urgency, as it was initially hypothesized. Overall, Chapter 6 and 7 did not find evidence to support that there are considerable differences between the examined formats. Chapter 7 even showed that the size of effects due to differences between visualization formats was much smaller than the size of effects due to different characteristics of the non-expert users, such as prior beliefs.

*Research question 2b. Does understanding of and engagement with scenario information change given different demographics, opinions, and knowledge levels on the topics of the transition?*

The results of the online surveys in Chapters 6 and 7 revealed multiple statistically significant effects on the respondents' understanding and engagement with scenario information due to the different prior beliefs, knowledge, and abilities of the respondents. In Chapter 6, higher website navigation skills and numeracy led to higher understanding in both visualization formats of scenarios, while higher prior interest and knowledge about the topic of the scenarios led to higher engagement. Similarly, in Chapter 7, numeracy and graph literacy increased reading accuracy and knowledge gains from static visualizations for respondents in all examined countries (France, Germany, and Poland). Education level and age also led to statistically significant effects in Chapter 7, respectively increasing and decreasing reading accuracy and knowledge gains performance for all visualizations. Additionally, when the prior beliefs of the respondents were congruent with the information in the visualizations, reading accuracy and knowledge gains were higher.

While interactions between prior beliefs and formats were found in both studies, few of these interactions were influential or consistent. However, the study in Chapter 7 indicated that customizing formats according to different readers' characteristics could be used to control adverse effects from the user characteristics. This was demonstrated by segmenting the total sample of the study into different demographic and country groups and assigning the best matching format for each group. Results indicated that groups of respondents that saw the best matching format for their characteristics had higher reading accuracy and knowledge gains than groups that have seen a less matching format. Overall, while user characteristics can affect comprehension and engagement with scenario information, tailor-made visualization formats can be used to mitigate any adverse effects.

## 8.2 Recommendations

By examining the critical aspects of usability and desirability of scenario ensembles that inform energy transitions, this thesis provides recommendations for scenario developers and communicators as well as it makes specific suggestions for the electricity supply transition in the examined European countries.

### 8.2.1 Recommendations to scenario developers

Consider citizen perspectives in scenario generation and increase stakeholder participation overall. This thesis offers a word of caution that even multi-organization, multi-model scenario ensembles may focus on too narrow a range of futures that are not endorsed by the wider population. As such insights were found in scenario ensembles for four European countries and the EU as a whole, this hints to a more general pattern within scenario development. To counter this, scenario developers can actively embrace stakeholder participation methods (Eker et al., 2017; O'Neill et al., 2020; Schmid and Knopf, 2012) in order to explicitly model a wider range of perspectives, including from citizens. Participatory methods can be especially fitting for scenario exercises performed by public institutions that aim for consensus between perspectives (e.g., Centre d'Analyse Stratégique, 2012). Since scenario methods can also function as learning processes (Hulme and Dessai, 2008a), increased participation of stakeholders in scenario development may facilitate the dialogue between these stakeholders and lead to an iterative refinement of scenarios for each phase of the energy transition. While there is a variety of participatory methods (Simoes et al., 2019; Voinov et al., 2018, 2016), this thesis demonstrated a process based on collecting preferred scenarios using an interactive scenario tool Riskmeter. The process was tested with citizens from multiple European countries and translated their perspectives into scenarios in a mostly accurate manner (see Section 5.4 for a discussion on this). Scenario developers can use adapted versions of the Riskmeter or similar tools to collect a wider range of desirable and technically feasible scenarios. Interactive scenario tools can be also integrated in public opinion surveys such as the Eurobarometer to frequently measure attitudes towards energy and low-carbon transitions and feed these results to modelling exercises. A similar process has been used to inform the EU strategy for achieving climate neutrality in 2050 (European Commission, 2018b), where qualitative survey preferences were compared with the model-based scenarios that underpinned this strategy. Interactive scenario tools such as the Riskmeter can further augment this process by eliciting quantitative preferences at a larger scale.

Elicit informed and diverse preferences. While there are many opportunities in enhancing participatory methods in scenario development, there are also dangers due to potential knowledge gaps, misconceptions, and biases of the stakeholders (Elsawah et al., 2020). Scenario developers can address knowledge gaps by providing stakeholders with balanced

information prior to preference elicitation. This thesis showed that interactive scenario tools such as the Riskmeter can be useful interfaces for two-way communication, combining information provision and elicitation. However, Chapter 6 also demonstrated the dangers of overwhelming stakeholders with information and, thus, the necessity of pretesting tools with their intended audience. For biases, scenario developers can strive to collect a sample of perspectives that adequately represent diverse stakeholders. Chapter 4 provides an example for this in the case of scenarios for the whole EU, by showing that collecting diverse societal perspectives from multiple Member States can be used to balance out country-specific biases. Chapter 4 also suggested that stakeholder characteristics such as political orientations may have a limited effect on the perspectives of French, German, and Polish citizens. Nevertheless, this may not be the case in other countries such as the US where political orientation plays a more critical role (Guilbeault et al., 2018). Therefore, scenario developers that aim to use participatory methods need to carefully scope relevant stakeholder groups for critical characteristics or attitudes that may bias their opinion and diversify stakeholder participation according to their findings.

### 8.2.2 Recommendations to scenario communicators

No format for scenario visualization is perfect. The studies performed in the context of this thesis did not find any empirical evidence for the advantage of a specific visualization format for scenarios, neither in the comparison between interactive and static formats nor among prominent static formats. Especially for interactive scenario tools, scenario communicators are advised to assess whether these tools can bring benefits over traditional solutions such as reports and whether these benefits merit the extra cost and time to develop the tools. Even if the use of an interactive scenario tool is justified, its complexity should be adjusted to its audience. While such tools offer ample opportunity to pack many layers of information, they can prove detrimental to the comprehension of non-experts, as shown in the empirical evaluation in Chapter 6. Scenario communicators can first evaluate what their audience needs to know, e.g., through interviews (Volken et al., 2017), and then design the communication format and message accordingly and through multiple cycles of evaluations if possible (Rubin and Chisnell, 2008). Interactive scenario tools can also provide multiple interfaces, showing initially an overview of the information and then providing details on demand, following established principles in the design of information visualizations (Shneiderman, 1996). Additionally, interactive scenario tools can be integrated in online workshops to ensure that users receive adequate guidance and information before using the tool (Dubois et al., 2019; Rooney-Varga et al., 2018; Volken et al., 2018). Such methodologies could be used more widely to communicate prominent scenario results, such as the ones of IPCC, but also to collect feedback on these scenarios, establishing a meaningful, two-way communication.

Customize visualizations to different audiences. Scenario communicators can improve the comprehension of scenario visualizations by adapting them to the characteristics of their

audience(s). This principle was demonstrated in Chapter 7 by adapting visualizations to groups with demographic and country differences, but it can be similarly used for groups with different prior abilities (e.g., numeracy) or beliefs. Scenario communicators can customize formats both for written and electronic dissemination. In the case of written dissemination such as reports, formats can be adapted to the primary audience or specific “user personas” (Harold et al., 2017), for instance, policymakers, businesspeople, or students. Electronic dissemination can provide many more solutions to fine-tune visualizations to different users. Social media have been already pointed out as a solution for tailoring content to specific user groups (Bostrom et al., 2013), which, in combination with tools for customizable online visualizations (e.g., Tableau, 2020), can provide many opportunities for effective scenario communication, especially to non-experts.

### 8.2.3 Recommendations for the electricity supply transition in Europe

Model more scenarios with early and ambitious transitions from the current electricity mix. Only three out of the 82 model-based scenarios that were reviewed for Switzerland had explored levels of renewable electricity, electricity saving, and efficiency in 2035 as ambitious as those found in the majority of scenarios preferred by Swiss citizens and even energy experts (Chapter 3). Similarly, most model-based scenarios for France, Germany, Poland, and the EU assumed much slower decarbonization and denuclearization than preferred by the citizens (Chapter 5). Similar divergences were also found between policy targets and public perspectives in the examined countries. For instance, German citizens preferred almost a full coal phase-out by 2035 while the relevant policy target calls for a phase-out in 2038 (BMW, 2020a). Nevertheless, policymakers of EU Member States already need to consider a faster decarbonization for electricity supply to match the ambitious greenhouse gas emissions cuts in 2030 prescribed in the European Green Deal and the Fit for 55 policy package (European Council, 2021). Additionally, Swiss policymakers also increased the target for renewable electricity supply in 2035 in order to facilitate the Swiss transition to climate neutrality by 2050 (SFOE, 2021). Scenario developers and energy modelers need to catch up and develop scenarios for Europe that are both policy-relevant and desirable by the citizens. Based on the results of this thesis, the most desirable scenarios for 2035 in the examined countries and the EU assume a diverse electricity mix that is dominated by domestic renewable sources, contains limited shares of nuclear power and fossil fuel-based generation (with and without CCS), and assumes extensive electricity savings and efficiency. While nuclear power is still considered as an option for the energy transition in the EU, as evidenced by the EU taxonomy for sustainable activities (European Commission, 2022), the results of this thesis show that citizens in Germany, Poland, and even France may prefer a more limited role for nuclear power than the one explored by most model-based scenarios. Additionally, this thesis shows that small shares from fossil fuels with CCS may be acceptable in the EU as part of a diverse electricity mix or as a way to keep existing fossil fuel

power plants but reduce their emissions. Finally, while the enhancement of electricity grids and interconnections between countries will be a requirement for reaching the high levels of solar PV and wind power preferred by the citizens (ENTSO-E, 2021), high import dependency is not desired in the examined countries and the EU.

Consider country-specific visions in scenarios for the whole EU. Scenario developers that model the EU electricity supply need to take into account the specific context and visions of individual Member States. As shown in Chapter 4, while citizens from France, Germany, and Poland agreed on predominantly renewable electricity in the EU, they disagreed on the non-renewable alternatives to complement it, selecting the ones that they prefer for their own country. For instance, Polish citizens had a rather strong preference towards expanding natural gas both for their country and for the EU, while French citizens were mostly negative and German citizens were ambivalent. Similarly, German citizens were negative towards nuclear power in Germany and the EU, while French citizens were ambivalent and Polish citizens were positive. These divergent priorities may reflect the overall interactions between the energy policy of the Member States and the EU (Szulecki et al., 2016) and may affect the successful implementation of the Energy Union in the long term. Nevertheless, divergences were limited among citizens with different demographics and attitudes towards the transition, and they were even non-detectable among citizens with different political orientations, attitudes towards the EU, trust in institutions, and sense of belonging. This suggests that there may be limited polarization within the examined countries on national and EU electricity supply visions, facilitating consensus. Overall, most citizens preferred an electricity mix for their countries and the EU with significant shares of renewable electricity (especially hydropower, solar PV, and wind power), high electricity savings, and limited shares of nuclear power and fossil fuel-generation, both with and without CCS. EU and national policymakers can build on these findings to develop policy pathways that are inclusive of the views of different citizen groups in order to increase the potential of gaining high support both within and among EU Member States. Additionally, scenario developers in Europe need to continue exploring the relation between scenarios for individual Member States and for the EU, also considering citizen preferences from Member States other than the ones examined in this thesis.

### **8.3 Future research**

#### **8.3.1 Perspectives on scenario generation**

Future studies could evaluate the alignment of stakeholder and citizen preferences with model-based scenarios for more countries and types of scenarios, e.g., on the decarbonization of heat or of the whole energy system. This thesis uncovered misalignments in scenario ensembles for the electricity supply in four European countries and the EU as a whole, suggesting that a wider pattern could be found for other energy sectors. Especially for countries where only



few organizations can develop scenarios, there is a risk that these scenarios may explore a narrow range of solutions that match the perspectives of only a fraction of transition stakeholders. Eliciting preferences could help expose this narrow range and bring forward questions of desirability and inclusivity. Similarly, studying preferences at lower spatial levels such as regions or municipalities may reveal differences between broad socio-political acceptance at a country level and community acceptance (Wüstenhagen et al., 2007). Additionally, the relation between global targets and targets for individual countries is particularly relevant in the effort towards global emissions mitigation. For example, scenario ensembles from the 6<sup>th</sup> Assessment Report of the IPCC could be compared with preferences from different countries or regions in order to find scenarios that are “socially robust” (Eker et al., 2017) across countries.

In order to ensure the quality of preferences, future studies need to investigate how to achieve a better trade-off between eliciting preferences at scale and assuring that stakeholders are properly informed beforehand. The study in Chapter 4 showed that providing interactive feedback could be a solution for filling knowledge gaps while eliciting preferences at the same time. However, the same study showed that the elicited scenarios may be less diverse than the perspectives they were based on, potentially due to the information provided by the Riskmeter and the unavoidable framing effects that came with such information (Corner et al., 2018). Future studies could evaluate more comprehensively the benefits and drawbacks of interactive feedback, examine effects related to the amount of information, and study interactions with prior beliefs and knowledge of the users. Combinations of interventions can be also used, such as providing a small primer on the topic before using the interactive scenario tool. In order to emulate the moderation of a workshop, human experts or even chatbots can be available online so that stakeholders can ask questions related to the topic before elicitation. Eventually, such methods can be used beyond the fields of energy and low-carbon transitions and help with preference elicitation in other value-laden problems, e.g., in political or environmental issues.

### 8.3.2 Perspectives on scenario communication

While this thesis offered a word of warning that interactivity may backfire for scenario communication, future studies can provide more empirical evidence about when and how interactivity can lead to benefits over traditional methods. Since the Riskmeter was modelled after other tools for energy and low-carbon transitions (e.g., DECC, 2013; EPFL, 2015), findings can be relevant for them. However, it is important that future research would connect evaluation with the intended use of such tools, whether it is learning, two-way communication, research, or decision support. This may lead to a wider set of criteria than the ones used for this thesis and may also help with trade-offs in the design of the tool, such as the amount of information that is provided with each interaction. Future studies may also focus on producing and testing methodologies that combine evaluation in all design stages of interactive tools. Most existing

evaluations, including the one performed in this thesis, evaluated tools after they have been more or less finalized (e.g., Mayer et al., 2014; Wong-Parodi et al., 2014). There are many opportunities to increase the quality of tools for scenario communication by early testing, and structured evaluation methodologies can help with that [see, for example, Rubin & Chisnell (2008)].

In terms of visualizations for scenario communication, future studies may further explore methods to customize visualization formats to specific audiences. As demonstrated in Chapter 7, adapting formats to demographic and country differences increased reading accuracy and knowledge gains. Future research can further evaluate these benefits using experiments with larger and more diverse samples and by customizing formats to other audience characteristics, such as prior beliefs. Combinations of formats such as text, graphs, and animations can be evaluated in order to see whether they can complement each other and reduce adverse effects from user differences more effectively. Last but not least, research needs to find ways to communicate scenarios to non-experts without relying on technical jargon. Finding optimal ways to frame messages from scenario exercises to different audiences could also help with controlling differences in prior beliefs (Hardisty et al., 2010).

### 8.3.3 Perspectives on scenario evaluation

One of the most important suggestions for future research is the same that prompted this thesis: more evaluations are needed for scenario methodologies and their results in order to ensure that they perform as intended. This thesis contributed to this call by conducting five evaluative studies related to the representation of stakeholder views in scenarios and the usability of prominent methods for scenario communication. While these topics are important and relevant, they are by no means exhaustive. As suggested by previous perspectives and reviews of scenario literature (EEA, 2009; Elsworth et al., 2020; Trutnevyte et al., 2016a), other aspects of scenario development need to be also investigated such as including more surprises and discontinuities in scenarios (McCollum et al., 2020).

The call to continue evaluating scenarios and scenario methods becomes even more pertinent due to the increasing number of scenarios that need to be analyzed and communicated (Clarke et al., 2014; IPCC, 2018a) and by the increasing diversity of their users (Weber et al., 2018). Scenario evaluations can be relevant beyond energy and climate change research due to the use of scenario ensembles in different fields, e.g., in the studies analyzing the spread of COVID-19 (Kissler et al., 2020). Scenarios are and will continue to be an important tool for research and policy, and future research needs to ensure that they can serve their purpose through inclusivity, transparency, and effective communication. As Parson (p.5, 2008) candidly points out:

*“... scenario-based reasoning is not an alternative to speculation. It is an approach that seeks to make speculation more disciplined, more anchored to scientific knowledge where it is available, and more transparent, which is essential to informing global-change decision-making.”*

## Appendix A Supplementary materials for Chapter 3

### A.1. Review of model-based scenarios: main study objectives and assumptions

Table A1. Main study objectives and assumptions for substituting nuclear power in the reviewed model-based scenarios

| Study name                | Study ref.                     | Main objectives                                                                                                     | Our assumptions for substituting nuclear in 2035                                              |
|---------------------------|--------------------------------|---------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------|
| PSI - Climate mitigation  | Panos and Kannan (2018)        | Assess scenarios of different climate change mitigation effort for Switzerland                                      | Gas replaces nuclear                                                                          |
| LEURE                     | Babonneau et al. (2018)        | Explore simulations of deep decarbonization pathways for Switzerland                                                | -                                                                                             |
| VSE - Energiewelten       | VSE (2017)                     | Explore potential "energy worlds" for 2035 in Switzerland                                                           | -                                                                                             |
| TD                        | Berntsen and Trutnevyte (2017) | Identify scenarios to increase the diversity of Swiss scenarios between 2011-2013                                   | -                                                                                             |
|                           |                                |                                                                                                                     | Scenarios P, W, and IMP: In scenarios that gas turbines are allowed then they replace nuclear |
| FEN & PSI                 | Fuchs et al. (2017)            | Address the integration of large scale stochastic renewable energy sources in the Swiss electricity system          | Scenario CO2: 50% solar and 50% gas CHP replace nuclear                                       |
|                           |                                |                                                                                                                     | Scenario CO2 + IMP: Replace nuclear with 33% solar, 33% gas CHP and 33% imports               |
| CP - Renewable supply     | Díaz et al. (2017)             | Assess whether natural gas is needed to bridge the transition to renewables                                         | -                                                                                             |
| PSI - Biomass potential   | Panos and Kannan (2016)        | Assess the role of domestic biomass in electricity, heat and grid balancing markets in Switzerland                  | Gas replaces nuclear                                                                          |
| PSI - EU nuclear phaseout | Pattupara and Kannan (2016)    | Assess alternatives to nuclear power in Switzerland and its neighboring countries                                   | Gas replaces nuclear                                                                          |
| UNIL - HEC                | Osorio and van Ackere (2016)   | Assess alternatives to nuclear power in Switzerland and the effect of different schedules for the nuclear phase-out | Scenario Nuc45: Imports replace nuclear                                                       |

Table A1. (continued)

|                           |                              |                                                                                                                                                                                |   |
|---------------------------|------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---|
| Econability & PSI & LEURE | Maire et al. (2015)          | Build a coupled modeling framework for electricity markets in Switzerland and its neighboring countries                                                                        | - |
| CP - Nuclear phaseout     | Redondo and Van Vliet (2015) | Assess two scenarios from the SFOE study to analyze the reliability of domestic renewables                                                                                     | - |
| PSI - Energy transition   | Kannan and Turton (2014)     | Explore pathways of energy system development in Switzerland based on policy discussions and priorities                                                                        | - |
| Cleantech                 | Bolliger and Zeyer (2012)    | Develop a scenario balancing efficiency measures, expansion of renewable generation and economic feasibility                                                                   | - |
| Greenpeace                | Teske and Heiligttag (2013)  | Develop a scenario with a strong deployment of renewables in 2050                                                                                                              | - |
| PSI - Sys                 | Weidmann (2013)              | Develop technology scenarios for a sustainable Swiss energy system                                                                                                             | - |
| VSE - Wege                | VSE (2012a)                  | Analyze three scenarios with increasing degrees of policy measures towards efficiency and renewables                                                                           | - |
| PSI - Elc                 | Kannan and Turton (2012)     | Explore scenarios combining three energy demand variants (low, medium, high) and two supply variants (policy support to renewables or to centralized/decentralized gas plants) | - |
| SFOE                      | Prognos (2012)               | Explore alternative technologies for electricity generation after nuclear phase-out                                                                                            | - |
| ESC                       | Andersson et al. (2011)      | Explore energy scenarios with three different demand variants towards a CO <sub>2</sub> reduction target for 2050                                                              | - |

Note: Assumptions are made only in the case of a study that does not report results for 2035 and assumes that nuclear is phased-out in 2035. Organization acronyms used: PSI = Paul Scherrer Institute; LEURE = Laboratory of Environmental and Urban Economics in EPFL; VSE = Verband Schweizerischer Elektrizitätsunternehmen (Association of Swiss Electricity Producers); CP = Climate Policy group in ETH Zurich; FEN = Forschungsstelle Energienetze (Research center for energy networks) in ETH Zurich; TD = Transdisciplinarity Lab in ETH Zurich; SFOE = Swiss Federal Office of Energy; ESC = Energy Science Center in ETH Zurich; UNIL-HEC = Faculty of Business and Economics at the University of Lausanne.

## A.2. Preference elicitation methodology: detailed participant information

Table A2. Self-reported interest in electricity supply topics by sample

| Questions                                                                          | <i>M (SD)</i>                       |                                         |                                 | <i>F</i> (2,161) | <i>post hoc</i>                |
|------------------------------------------------------------------------------------|-------------------------------------|-----------------------------------------|---------------------------------|------------------|--------------------------------|
|                                                                                    | (i) energy experts<br><i>n</i> = 58 | (ii) informed citizens<br><i>n</i> = 45 | (iii) citizens<br><i>N</i> = 61 |                  |                                |
| I think frequently and intensively about electricity supply topics in Switzerland. | 6.43<br>(0.99)                      | 4.6<br>(1.68)                           | 4.59<br>(1.47)                  | 32.86***         | i-ii***<br>i-iii***            |
| I find electricity supply topics in Switzerland exciting.                          | 6.4<br>(0.95)                       | 5.64<br>(1.13)                          | 4.95<br>(1.58)                  | 19.46***         | i-ii**<br>i-iii***<br>ii-iii** |
| I discuss electricity supply topics in my private environment.                     | 6<br>(1.08)                         | 3.87<br>(1.52)                          | 4.38<br>(1.55)                  | 34.53***         | i-ii***<br>i-iii***            |
| Summarized scale                                                                   | 6.28<br>(0.86)                      | 4.7<br>(1.20)                           | 4.64<br>(1.41)                  | 34.87***         | i-ii***<br>i-iii***            |

Note: \**p* < 0.05; \*\**p* < 0.01, \*\*\**p* < 0.001. Values range from 1 = “do not agree at all” to 7 = “completely agree”.

Table A3. Self-reported evaluation of the Riskmeter by participant sample

| Questions                                                                                                                                         | <i>M (SD)</i>                       |                                         |                                 | <i>F (2,158)</i> | <i>post hoc</i>                  |
|---------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------|-----------------------------------------|---------------------------------|------------------|----------------------------------|
|                                                                                                                                                   | (i) energy experts<br><i>n</i> = 55 | (ii) informed citizens<br><i>n</i> = 45 | (iii) citizens<br><i>N</i> = 61 |                  |                                  |
| The Riskmeter filled some of my knowledge gaps about the Swiss electricity production                                                             | 3.45<br>(1.78)                      | 5.53<br>(1.12)                          | 4.49<br>(1.25)                  | 26.49***         | i-ii***<br>i-iii***<br>ii-iii*** |
| The Riskmeter corrected some of my misunderstandings about the Swiss electricity production.                                                      | 3.09<br>(1.77)                      | 5.36<br>(1.13)                          | 4.56<br>(1.19)                  | 34.29***         | i-ii***<br>i-iii***<br>ii-iii**  |
| The Riskmeter did not influence my opinion on the Swiss electricity production.                                                                   | 4.58<br>(1.93)                      | 3.67<br>(1.68)                          | 4.08<br>(1.27)                  | 3.94*            | i-ii**                           |
| The Riskmeter was useful for me to form an opinion about the Swiss electricity production.                                                        | 3.95<br>(1.83)                      | 5.6<br>(1.05)                           | 4.98<br>(1.16)                  | 18.06***         | i-ii***<br>i-iii***<br>ii-iii*   |
| It was fun to create an electricity portfolio with the Riskmeter.                                                                                 | 4.95<br>(1.88)                      | 6.07<br>(1.03)                          | 5.23<br>(1.38)                  | 7.39**           | i-ii***<br>ii-iii**              |
| It was difficult for me to create an electricity portfolio with the Riskmeter.                                                                    | 2.93<br>(1.76)                      | 3.31<br>(1.59)                          | 3.67<br>(1.69)                  | 2.81             | i-iii*                           |
| Creating an electricity portfolio with the Riskmeter was very interesting for me.                                                                 | 3.98<br>(2.04)                      | 5.36<br>(1.81)                          | 3.13<br>(1.59)                  | 19.51***         | i-ii***<br>i-iii*<br>ii-iii***   |
| The Riskmeter showed information that was new to me.                                                                                              | 3.69<br>(2.07)                      | 5.4<br>(1.34)                           | 4.85<br>(1.54)                  | 13.65***         | i-ii***<br>i-iii***              |
| In general, I like the Riskmeter very much.                                                                                                       | 4.85<br>(1.63)                      | 6<br>(0.88)                             | 5.3<br>(1.2)                    | 9.78***          | i-ii***<br>ii-iii**              |
| Due to the Riskmeter, I was able to develop a clear idea about the electricity portfolio in Switzerland and its positive and negative attributes. | 3.75<br>(1.83)                      | 5.76<br>(1.03)                          | 5.05<br>(1.3)                   | 25.57***         | i-ii***<br>i-iii***<br>ii-iii*   |
| Summarized scale                                                                                                                                  | 3.8<br>(1.15)                       | 5.27<br>(0.70)                          | 4.52<br>(0.77)                  | 32.65***         | i-ii***<br>i-iii***<br>ii-iii*** |

Note: \**p* < 0.05; \*\**p* < 0.01, \*\*\**p* < 0.001. Values range from 1 = “do not agree at all” to 7 = “completely agree”.

Table A4. Institution or sector that the energy expert participants worked or studied at the time of the survey

| Institution or sector                                                                         | No. of participants | Percentage within energy expert sample (N = 60) |
|-----------------------------------------------------------------------------------------------|---------------------|-------------------------------------------------|
| University, research institute, or university of applied sciences (Fachhochschule)            | 47                  | 78.3%                                           |
| Arts and Humanities                                                                           | 0                   | 0.0%                                            |
| Engineering and Technology                                                                    | 20                  | 33.3%                                           |
| Life Sciences and Medicine                                                                    | 0                   | 0.0%                                            |
| Natural Sciences                                                                              | 6                   | 10.0%                                           |
| Social Sciences and Management                                                                | 21                  | 35.0%                                           |
| Political organization                                                                        | 2                   | 3.3%                                            |
| Member of the National Council (Nationalrat) or the Council of States (Ständerat)             | 0                   | 0.0%                                            |
| Political representative in a canton                                                          | 0                   | 0.0%                                            |
| Political representative in a municipality                                                    | 2                   | 3.3%                                            |
| Active role in a political party                                                              | 0                   | 0.0%                                            |
| Industry and businesses                                                                       | 24                  | 40.0%                                           |
| Consulting and engineering companies                                                          | 7                   | 11.7%                                           |
| Energy utilities, transmission and distribution system operators, fuel suppliers              | 7                   | 11.7%                                           |
| Equipment manufacturers, retailers or installers                                              | 2                   | 3.3%                                            |
| Financial services and trading                                                                | 1                   | 1.7%                                            |
| Research and innovation companies                                                             | 7                   | 11.7%                                           |
| Public administration and public service                                                      | 8                   | 13.3%                                           |
| Federal department or office                                                                  | 3                   | 5.0%                                            |
| Cantonal department or office                                                                 | 5                   | 8.3%                                            |
| Municipal department or office                                                                | 0                   | 0.0%                                            |
| Nongovernmental organizations, advocacy groups and foundations                                | 9                   | 15.0%                                           |
| Consumer organization                                                                         | 0                   | 0.0%                                            |
| Environmental organization                                                                    | 5                   | 8.3%                                            |
| Foundation                                                                                    | 1                   | 1.7%                                            |
| Industry or business association                                                              | 3                   | 5.0%                                            |
| Other                                                                                         | 0                   | 0.0%                                            |
| Other                                                                                         | 5                   | 8.3%                                            |
| Primary sector, e.g., agriculture, forestry, raw material extraction                          | 0                   | 0.0%                                            |
| Secondary sector, e.g., chemicals, food, metal processing or textile industry                 | 0                   | 0.0%                                            |
| Tertiary sector, e.g., architecture, education, health and social services, hotels, IT, media | 5                   | 8.3%                                            |

Table A5. Initial *individual technology preferences* for the citizen samples (before using the Riskmeter)

|                                   | <i>M (SD)</i>                         |                              | statistic              |
|-----------------------------------|---------------------------------------|------------------------------|------------------------|
|                                   | informed citizens<br>( <i>N</i> = 46) | citizens<br>( <i>N</i> = 61) |                        |
| large hydropower dams             | 5.36 (1.43)                           | 5.29 (1.41)                  | <i>t</i> (97) = 0.25   |
| large run-of-river hydropower     | 4.63 (1.54)                           | 5.16 (1.36)                  | <i>t</i> (97) = -1.82  |
| small hydropower                  | 4.73 (1.69)                           | 5.48 (1.38)                  | <i>t</i> (98) = -2.46* |
| nuclear                           | 2.65 (2.18)                           | 3.13 (2.00)                  | <i>t</i> (100) = -1.14 |
| solar PV                          | 5.98 (1.36)                           | 6.04 (1.26)                  | <i>t</i> (100) = -0.22 |
| wind                              | 4.70 (1.98)                           | 5.43 (1.43)                  | <i>t</i> (75) = -2.04* |
| geothermal                        | 4.90 (1.64)                           | 4.75 (1.59)                  | <i>t</i> (91) = 0.48   |
| large gas power plants            | 3.76 (1.50)                           | 3.78 (1.34)                  | <i>t</i> (94) = -0.06  |
| woody biomass                     | 4.79 (1.63)                           | 4.85 (1.53)                  | <i>t</i> (96) = -0.20  |
| biogas                            | 5.21 (1.39)                           | 5.16 (1.57)                  | <i>t</i> (95) = 0.17   |
| waste incineration                | 4.93 (1.61)                           | 5.32 (1.53)                  | <i>t</i> (100) = -1.24 |
| net import from abroad            | 3.31 (1.56)                           | 3.63 (1.57)                  | <i>t</i> (99) = -1.00  |
| electricity saving and efficiency | 5.64 (1.94)                           | 5.87 (1.56)                  | <i>t</i> (98) = -0.65  |

Note: \**p* < 0.05; Individual technology preferences show the participants' view in expanding specific types of electricity supply in Switzerland to 2035. All preferences are measured in a 7-point Likert scale from 1 = "completely disagree" to 7 = "completely agree".



### A.3. Detailed comparison of the preferred scenarios

On average, participants from all three samples preferred scenarios based on the supply potential of solar PV, wind, hydropower technologies, and electricity savings and efficiency measures (Table S6). Solar PV and wind were the most popular technologies to increase: the average normalized supply in the preferred scenarios was higher than 60% for solar PV and higher than 42% for wind for all samples (the supply in the preferred scenarios was normalized between the minimum and maximum potential allowed in the Riskmeter). Hydropower technologies were also popular among participants in general, leading to a normalized supply between 24-49%. Many participants also opted for reducing demand through electricity savings and efficiency improvements (normalized supply: 35-56%). Increased support for these alternatives was consistent with the previous studies in Switzerland with citizens (Cousse and Wüstenhagen, 2018b; Jobin and Siegrist, 2018; Trutnevyte et al., 2012). On the other hand, most participants avoided scenarios with large gas power plants, net electricity import and nuclear: the normalized supply from these technologies ranged between 4 and 20%. This is also in line with the previous findings in the literature for Switzerland (Visschers and Siegrist, 2014).

Table A6. Preferred scenarios for all participant samples, normalized between the minimum and maximum potential allowed in the Riskmeter (0-100%)

|                               | <i>M (SD)</i>                       |                                         |                                 | <i>F (2, 164)</i> | <i>post hoc</i> |
|-------------------------------|-------------------------------------|-----------------------------------------|---------------------------------|-------------------|-----------------|
|                               | (i) energy experts<br><i>N</i> = 60 | (ii) informed citizens<br><i>N</i> = 46 | (iii) citizens<br><i>N</i> = 61 |                   |                 |
| large hydropower dams         | 38.9 (42.43)                        | 48.6 (44.52)                            | 30.8 (40.72)                    | 2.32              | ii-iii*         |
| large run-of-river hydropower | 31.3 (40.32)                        | 42.9 (42.43)                            | 27.1 (39.76)                    | 2.06              | ii-iii*         |
| small hydropower              | 24.3 (36.61)                        | 42.6 (44.53)                            | 27.8 (37.84)                    | 3.07*             | i-ii*           |
| nuclear                       | 10.4 (25.76)                        | 19.8 (31.63)                            | 17.7 (27.8)                     | 1.70              | n.s.            |
| solar PV                      | 68.6 (34.08)                        | 60.1 (33.69)                            | 59.6 (33.98)                    | 1.31              | n.s.            |
| wind                          | 51.7 (36.75)                        | 49.8 (39.02)                            | 41.8 (32.75)                    | 1.28              | n.s.            |
| deep geothermal               | 23.9 (34.22)                        | 18.5 (29.9)                             | 25.8 (29.27)                    | 0.74              | n.s.            |

Table A6. (continued)

|                                    |              |              |              |          |                       |
|------------------------------------|--------------|--------------|--------------|----------|-----------------------|
| large gas power plants             | 5.4 (10.76)  | 3.6 (8.68)   | 16.4 (20.89) | 12.30*** | i-iii***<br>ii-iii*** |
| woody biomass                      | 21.9 (33.74) | 16.6 (30.67) | 20.9 (30.35) | 0.39     | n.s.                  |
| biogas                             | 21.7 (28.98) | 32.1 (36.78) | 26.8 (32.82) | 1.33     | n.s.                  |
| waste incineration                 | 21.7 (35.55) | 42.4 (40.96) | 27.5 (38.53) | 3.96*    | i-ii**<br>ii-iii*     |
| net import from abroad             | 10.3 (19.42) | 3.9 (15.37)  | 7.6 (15.09)  | 1.90     | n.s.                  |
| electricity savings and efficiency | 56.7 (39.78) | 54.1 (37.11) | 34.9 (32.37) | 6.27**   | i-iii**<br>ii-iii**   |

Note: \* $p < 0.05$ ; \*\* $p < 0.01$ , \*\*\* $p < 0.001$ . The  $F$ -statistic was calculated using a one-way ANOVA between the three samples.

Despite the above commonalities, we found statistically significant differences between the samples in the normalized supply for large gas power plants ( $F(2,164) = 12.30$ ,  $p < 0.001$ ) and electricity savings and efficiency ( $F(2,164) = 6.27$ ,  $p = 0.002$ ). Post hoc tests revealed that energy experts and informed citizens used less large gas power plants in their scenarios than citizens ( $M_{\text{experts}} = 5.4$  vs  $M_{\text{citizens}} = 16.4$ ,  $p < 0.001$ ;  $M_{\text{inf\_citizens}} = 3.6$  vs  $M_{\text{citizens}} = 16.4$ ,  $p < 0.001$ ). Conversely, energy experts and informed citizens developed scenarios with stronger electricity savings and efficiency measures than citizens ( $M_{\text{experts}} = 56.7$  vs  $M_{\text{citizens}} = 34.9$ ,  $p = 0.001$ ;  $M_{\text{inf\_citizens}} = 54.1$  vs  $M_{\text{citizens}} = 34.9$ ,  $p = 0.008$ ). We also found statistically significant difference between the samples in waste incineration ( $F(2,164) = 3.96$ ,  $p = 0.021$ ) and small hydropower ( $F(2,164) = 3.07$ ,  $p = 0.049$ ). For the former, post hoc tests showed that waste incineration was statistically significantly more preferred in the informed citizen sample rather than in the other two samples ( $M_{\text{inf\_citizens}} = 42.4$  vs  $M_{\text{experts}} = 21.7$ ,  $p = 0.006$ ;  $M_{\text{inf\_citizens}} = 42.4$  vs  $M_{\text{citizens}} = 27.5$ ,  $p = 0.048$ ). Similarly, small hydropower was statistically significantly more popular among informed citizens than among energy experts ( $M_{\text{inf\_citizens}} = 42.6$  vs  $M_{\text{experts}} = 24.3$ ,  $p = 0.018$ ).

## A.4. Survey script of citizen sample

*Note: the survey was presented to the participants originally in German and it has been translated below into English.*

### A.4.1. Introduction

Thank you for your participation in this survey. In this survey we aim to find out more about public opinion regarding future electricity production in Switzerland. The survey uses an interactive online tool Riskmeter.

The Riskmeter and this survey are part of the Ambizione Energy Grant project RIGOROuS of the Swiss National Science Foundation (SNSF). The aim of this project is to better understand the preferences of the general public, experts and stakeholders for the future Swiss electricity portfolio.

All your data will be evaluated anonymously and treated in accordance with data protection regulations. Your data will be used exclusively for scientific purposes and cannot be linked to you personally. Your participation is voluntary.

### A.4.2. Demographics

What is your gender?

- Female
- Male

What year were you born?

Please indicate your highest level of education.

- Compulsory education, e.g., primary or lower secondary education
- Basic vocational education
- High school or higher vocational education
- Professional education and training, e.g., professional colleges
- Higher technical college
- Higher education, e.g., universities or universities of applied science

What is the best description of your current employment situation?

- In education
- Employed (up to 50%)
- Employed (50-100%)
- Job seeking
- Self-employed
- Retired

Where do you live?

- Switzerland (Please fill in your postcode)
- Abroad

Which of the following best describes the area that you live in?

- City (more than 100,000 inhabitants)
- Large town (50,000 - 100,000 inhabitants)
- Town (10,000 - 50,000 inhabitants)
- Village (less than 10,000 inhabitants)
- Rural or remote area

#### **A.4.3. Prior interest in energy topics**

To what extent do you agree or disagree to the following statements related to your interest in energy topics in general (including electricity, heating, cooling, transportation and industry). (7-point Likert scale: 1 = Strongly disagree, 2 = Disagree, 3 = Somewhat disagree, 4 = Neither agree or disagree, 5 = Somewhat agree, 6 = Agree, 7 = Strongly agree)

- I find energy topics in Switzerland exciting.
- I think frequently and intensively about energy topics in Switzerland.
- I read articles in the newspaper about energy topics.
- I follow political discussions on energy topics.
- I discuss energy topics in my private environment.
- I am interested in learning more about energy topics in Switzerland.
- In general, I am familiar with energy topics in Switzerland.

#### **A.4.4. Prior interest in electricity supply topics**

To what extent do you agree or disagree to the following statements related to your interest in electricity supply topics. (7-point Likert scale: 1 = Strongly disagree, 2 = Disagree, 3 = Somewhat disagree, 4 = Neither agree or disagree, 5 = Somewhat agree, 6 = Agree, 7 = Strongly agree)

- I find electricity supply topics in Switzerland exciting.
- I think frequently and intensively about electricity supply topics in Switzerland.
- I read articles in the newspaper about electricity supply topics.
- I follow political discussions on electricity supply topics.
- I discuss electricity supply topics in my private environment.
- I am interested in learning more about electricity supply topics in Switzerland.
- In general, I am familiar with electricity supply topics in Switzerland.

#### **A.4.5. Individual technology preferences**

To what extent do you agree or disagree with the development of the following options to meet Switzerland's electricity needs in 2035? (7-point Likert scale: 1 = Strongly disagree, 2 = Disagree, 3 = Somewhat disagree, 4 = Neither agree or disagree, 5 = Somewhat agree, 6 = Agree, 7 = Strongly agree)

- Large hydropower dams
- Large run-of-river hydropower
- Small hydropower
- Nuclear
- Solar PV
- Wind
- Geothermal
- Large gas power plants
- Woody biomass
- Biogas
- Waste incineration
- Net import from abroad
- Electricity saving and efficiency

#### **A.4.6. Impact evaluation**

Based on your general opinion about the Swiss electricity portfolio in 2035, how would you rank these technology attributes from highest importance to you (top) to lower importance (bottom).

- Impact on climate change
- Impact on local air pollution
- Impact on water
- Impact on landscape and land use
- Impact on flora and fauna
- Accidental impacts
- Resource use and waste
- Electricity costs
- Electricity supply reliability

#### **A.4.7. Link to Riskmeter**

On the next page you can visit the Riskmeter and create your preferred electricity portfolio. The Riskmeter works with the browsers Chrome, Firefox, Safari, Edge and Internet Explorer 10+. If you have problems with the display, please try reloading the Riskmeter or updating your browser.

Mobile phones and tablets are not yet compatible with the Riskmeter. For an optimal visual experience, please use a desktop computer or laptop with at least a 13" screen and maximize your browser window.

#### **A.4.8. General assessment of the Riskmeter**

To what extent do you agree or disagree to the following statements? (7-point Likert scale: 1 = Strongly disagree, 2 = Disagree, 3 = Somewhat disagree, 4 = Neither agree or disagree, 5 = Somewhat agree, 6 = Agree, 7 = Strongly agree)

- The Riskmeter has filled some of my knowledge gaps about electricity supply in Switzerland.
- The Riskmeter corrected some of my misconceptions about electricity supply in Switzerland.
- The Riskmeter has not influenced my opinion on electricity supply in Switzerland.
- The Riskmeter was helpful to form an opinion about the electricity supply in Switzerland.
- I enjoyed using the Riskmeter to create the electricity portfolio of Switzerland.
- I found it difficult to create an electricity portfolio with the Riskmeter.
- It was very interesting to use the Riskmeter to create the electricity portfolio of Switzerland.
- I saw information in the Riskmeter that was new to me.
- Overall, I like Riskmeter a lot.
- Through the Riskmeter, I was able to get an accurate picture of the electricity technologies in Switzerland and their positive and negative attributes.

#### **A.4.9. Your submitted electricity portfolio**

To what extent do you agree or disagree to the following statements? (7-point Likert scale: 1 = Strongly disagree, 2 = Disagree, 3 = Somewhat disagree, 4 = Neither agree or disagree, 5 = Somewhat agree, 6 = Agree, 7 = Strongly agree)

- I am satisfied overall with my electricity portfolio.
- I would suggest my electricity portfolio as a target for the Swiss Energy Strategy for 2035.
- The attributes of my electricity portfolio (e.g. electricity costs, impact on climate change) are in line with my personal preferences.
- The electricity technologies that are included in my electricity portfolio are in line with my personal preferences.

## A.5. Survey script of expert sample

*Note: Participants first submitted their preferred electricity supply scenario in the Riskmeter and then received a link to this survey. The survey was available in three languages, English, German and French. Below, the English version is reported.*

### A.5.1. Introduction

Thank you for your participation in the Riskmeter survey! In the next 5-10 minutes, we would like to know who you are and what experience you had with the Riskmeter. At the end of the survey, you will also be able to leave (optionally) written feedback or your email address if you would like to be informed about the results of the survey.

Riskmeter and this survey are part of the Swiss National Science Foundation Ambizione Energy project RIGOROUS. The project aims at understanding preferences of the public, stakeholders, and experts for the Swiss electricity generation portfolio in the future.

Your responses will be analyzed anonymously and according to the provisions of the Data Protection Act. It will be used for scientific purposes only and cannot be associated with you personally or with your organization. Your participation is voluntary.

### A.5.2. Profession

What is the best description of your current employment situation?

- In education
- Employed (up to 50%)
- Employed (50-100%)
- Job seeking
- Self-employed
- Retired

Please indicate your highest level of education.

- Compulsory education, e.g. primary or lower secondary education
- Vocational education and training without matura, e.g. basic vocational education
- Vocational or academic matura and intermediate school
- Professional education and training, e.g. professional colleges
- Higher education, e.g. universities and universities of applied sciences (Fachhochschule)

Please indicate your highest degree.

- Bachelor's degree
- Master's degree
- Doctorate

What is your relation to energy topics at work or in your studies?

- I mainly work on or study energy topics
- I mainly work on or study other topics, but with some application to energy
- No relation to energy topics

In which institution or sector are you currently working or studying? Please select all categories that apply.

- University, research institute, or university of applied sciences (Fachhochschule)
  - Arts and Humanities
  - Engineering and Technology
  - Life Sciences and Medicine
  - Natural Sciences
  - Social Sciences and Management
- Public administration and public service
  - Federal department or office
  - Cantonal department or office
  - Municipal department or office
  - Other
- Political organization
- Member of the National Council (Nationalrat) or the Council of States (Ständerat)
  - Political representative in a canton
  - Political representative in a municipality
  - Active role in a political party
  - Other
- Nongovernmental organizations, advocacy groups and foundations
  - Consumer organization
  - Environmental organization
  - Foundation
  - Industry or business association
  - Other
- Industry and businesses
  - Consulting and engineering companies
  - Energy utilities, transmission and distribution system operators, fuel suppliers
  - Equipment manufacturers, retailers or installers
  - Financial services and trading
  - Research and innovation companies
- Other
  - Primary sector, e.g. agriculture, forestry, raw material extraction
  - Secondary sector, e.g. chemicals, food, metal processing or textile industry



- Tertiary sector, e.g. architecture, education, health and social services, hotels, IT, media

### **A.5.3. Demographics**

What is your gender?

- Female
- Male

What is your age?

- Under 18 years
- 18 to 24 years
- 25 to 34 years
- 35 to 44 years
- 45 to 54 years
- 55 to 64 years
- Age 65 or older

Where do you live?

- Switzerland (Please fill in your postcode)
- Abroad

Which of the following best describes the area that you live in?

- City (more than 100,000 inhabitants)
- Large town (50,000 - 100,000 inhabitants)
- Town (10,000 - 50,000 inhabitants)
- Village (less than 10,000 inhabitants)
- Rural or remote area

### **A.5.4. Prior interest in energy topics**

To what extent do you agree or disagree to the following statements about your interest in energy topics in general (including electricity, heating, cooling, transportation and industry). (7-point Likert scale: 1 = Strongly disagree, 2 = Disagree, 3 = Somewhat disagree, 4 = Neither agree or disagree, 5 = Somewhat agree, 6 = Agree, 7 = Strongly agree)

- I find energy topics in Switzerland exciting.
- I think frequently and intensively about energy topics in Switzerland.
- I read articles in the newspaper about energy topics.
- I follow political discussions on energy topics.
- I discuss energy topics in my private environment.
- I am interested in learning more about energy topics in Switzerland.

- In general, I am familiar with energy topics in Switzerland.

#### **A.5.5. Prior interest in electricity supply topics**

To what extent do you agree or disagree with the following statements about your interest in electricity supply topics in particular? (7-point Likert scale: 1 = Strongly disagree, 2 = Disagree, 3 = Somewhat disagree, 4 = Neither agree or disagree, 5 = Somewhat agree, 6 = Agree, 7 = Strongly agree)

- I find electricity supply topics in Switzerland exciting.
- I think frequently and intensively about electricity supply topics in Switzerland.
- I read articles in the newspaper about electricity supply topics.
- I follow political discussions on electricity supply topics.
- I discuss electricity supply topics in my private environment.
- I am interested in learning more about electricity supply topics in Switzerland.
- In general, I am familiar with electricity supply topics in Switzerland.

#### **A.5.6. General assessment of the Riskmeter**

To what extent do you agree or disagree to the following statements? (7-point Likert scale: 1 = Strongly disagree, 2 = Disagree, 3 = Somewhat disagree, 4 = Neither agree or disagree, 5 = Somewhat agree, 6 = Agree, 7 = Strongly agree)

- The Riskmeter has filled some of my knowledge gaps about electricity supply in Switzerland.
- The Riskmeter corrected some of my misconceptions about electricity supply in Switzerland.
- The Riskmeter has not influenced my opinion on electricity supply in Switzerland.
- The Riskmeter was helpful to form an opinion about the electricity supply in Switzerland.
- I enjoyed using the Riskmeter to create the electricity portfolio of Switzerland.
- I found it difficult to create an electricity portfolio with the Riskmeter.
- It was very interesting to use the Riskmeter to create the electricity portfolio of Switzerland.
- I saw information in the Riskmeter that was new to me.
- Overall, I like Riskmeter a lot.
- Through the Riskmeter, I was able to get an accurate picture of the electricity technologies in Switzerland and their positive and negative attributes.

#### **A.5.7. Your submitted electricity portfolio**

To what extent do you agree or disagree to the following statements? (7-point Likert scale: 1 = Strongly disagree, 2 = Disagree, 3 = Somewhat disagree, 4 = Neither agree or disagree, 5 = Somewhat agree, 6 = Agree, 7 = Strongly agree)

- I am satisfied overall with my electricity portfolio.

- I would suggest my electricity portfolio as a target for the Swiss Energy Strategy for 2035.
- The attributes of my electricity portfolio (e.g. electricity costs, impact on climate change) are in line with my personal preferences.
- The electricity technologies that are included in my electricity portfolio are in line with my personal preferences.

#### **A.5.8. Evaluation of Riskmeter interface**

While creating your electricity portfolio, which type of information in the Riskmeter Portfolio Builder did you look at in detail? Please click on all that apply below.

- Minimum and/or maximum potentials of technologies
- Minimum and/or maximum potentials of net import from abroad
- Minimum and/or maximum potentials of electricity saving and efficiency
- Minimum and/or maximum potentials of net export
- Switzerland map that shows whether electricity demand is supplied or not
- Overview in numbers including target demand, electricity saving and efficiency, total supply, net import and net export
- Diagram with the chosen electricity portfolio and the proportional contribution of each technology
- User instructions
- Technologies
- References

#### **A.5.9. Impact evaluation**

Based on your general opinion about the Swiss electricity portfolio in 2035, how would you rank these technology attributes from highest importance to you (top) to lower importance (bottom).

- Impact on climate change
- Impact on local air pollution
- Impact on water
- Impact on landscape and land use
- Impact on flora and fauna
- Accidental impacts
- Resource use and waste
- Electricity costs
- Electricity supply reliability

#### **A.5.10. Riskmeter advertisement**

Where did you get to know about the Riskmeter? Please select all categories that apply.

- ETH Energy Science Center
- Swiss Competence Centre for Energy Research - Supply of Electricity (SCCER-SoE)

- Personal invitation per email
- Colleague's recommendation
- Other

## Appendix B    Supplementary materials for Chapter 4

### B.1. Survey script

*The following survey script was used for all three samples in France, Germany, and Poland and was translated in the respective language of each country. Each sub-section below signifies a different webpage. The sub-section titles and all text in italics were not shown in the survey. In most questions, the version for Poland is shown except when indicated.*

#### B.1.1. Introduction

Thank you for your participation.

In the following 20 minutes we would like to learn more about your preferences towards the future of electricity supply in Poland and the European Union (EU) as a whole.

This survey is conducted by the University of Geneva, Switzerland. Your participation is voluntary. All your information will be evaluated anonymously, treated in accordance with the European Union's provisions of data protection (GDPR), and it will only be used for scientific purpose. Your details cannot be associated with you as a person and will not be disclosed to third parties.

#### B.1.2. Gender, age, and highest level of education

What is your gender?

- Female
- Male

How old are you? (in years, for example 35)

Please indicate your highest level of education.

- Compulsory education, e.g., primary or lower secondary education
- Basic vocational education
- High school or higher vocational education
- Higher education, e.g., universities or universities of applied science

### B.1.3. Attitudes towards the EU membership and trust in institutions

First, we would like to learn more about your overall views towards the Polish government, the European Union, and the United Nations (global).

|                                                                                     | A bad thing           | Neither good or bad   | A good thing          |
|-------------------------------------------------------------------------------------|-----------------------|-----------------------|-----------------------|
| Generally speaking, do you think that Poland's membership of the European Union is: | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

On a score of 0-10 how much do you personally trust each of the following institutions? 0 means you do not trust an institution at all, and 10 means you have complete trust.

|                                                                          | No trust at all<br>0  | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | Complete trust<br>10  |
|--------------------------------------------------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Trust in the local public authorities of your city or your Polish region | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Trust in the Polish government                                           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Trust in the European Union                                              | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Trust in the United Nations (global)                                     | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

### B.1.4. Attitudes towards decision-making levels

Do you think that the following decisions should be made by the local public authorities, by the Polish government, by the Polish government jointly with the European Union, or by the Polish government jointly with the United Nations?

| Decisions about...     | local public<br>authorities | Polish government | Polish<br>government<br>jointly with the<br>European Union | Polish government<br>jointly with the<br>United Nations |
|------------------------|-----------------------------|-------------------|------------------------------------------------------------|---------------------------------------------------------|
| ...electricity supply  | O                           | O                 | O                                                          | O                                                       |
| ...climate change      | O                           | O                 | O                                                          | O                                                       |
| ...local air pollution | O                           | O                 | O                                                          | O                                                       |
| ...land use            | O                           | O                 | O                                                          | O                                                       |
| ...electricity costs   | O                           | O                 | O                                                          | O                                                       |
| ...employment          | O                           | O                 | O                                                          | O                                                       |

### B.1.5. Sense of belonging

To what extent do you feel a weak or a strong sense of belonging to the following areas?

|                                                | No sense of<br>belonging | Weak sense<br>of belonging | Moderate<br>sense of<br>belonging | Strong<br>sense of<br>belonging | Very strong<br>sense of<br>belonging |
|------------------------------------------------|--------------------------|----------------------------|-----------------------------------|---------------------------------|--------------------------------------|
| the Polish city or<br>region where you<br>live | O                        | O                          | O                                 | O                               | O                                    |
| Poland                                         | O                        | O                          | O                                 | O                               | O                                    |
| Europe                                         | O                        | O                          | O                                 | O                               | O                                    |
| the World                                      | O                        | O                          | O                                 | O                               | O                                    |

### B.1.6. Prior interest in electricity supply topics

Now we would like to focus on electricity supply topics.

To what extent do you agree or disagree with the following statements related to your interest in electricity supply topics?

|                                                                     | Strongly<br>disagree  | Disagree              | Somewhat<br>disagree  | Neither<br>agree or<br>disagree | Somewhat<br>agree     | Agree                 | Strongly<br>agree     |
|---------------------------------------------------------------------|-----------------------|-----------------------|-----------------------|---------------------------------|-----------------------|-----------------------|-----------------------|
| I do not find electricity supply topics exciting.                   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I think frequently and intensively about electricity supply topics. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I read articles in the newspaper about electricity supply topics.   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I do not follow political discussions on electricity supply topics. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I discuss electricity supply topics in my private environment.      | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I am interested in learning more about electricity supply topics.   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| In general, I am familiar with electricity supply topics.           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

### B.1.7. Individual technology preferences for respondent's country

To what extent do you agree or disagree with the development of the following options to meet the electricity needs of Poland in 2035?

\* "carbon capture and storage" is a technology that captures CO<sub>2</sub> emissions from electricity plants and stores these emissions underground in deep rock formations.



|                                                          | Strongly<br>disagree | Disagree | Somewhat<br>disagree | Neither<br>agree or<br>disagree | Somewhat<br>agree | Agree | Strongly<br>agree |
|----------------------------------------------------------|----------------------|----------|----------------------|---------------------------------|-------------------|-------|-------------------|
| Hydropower                                               | 0                    | 0        | 0                    | 0                               | 0                 | 0     | 0                 |
| Nuclear                                                  | 0                    | 0        | 0                    | 0                               | 0                 | 0     | 0                 |
| Solar cells<br>(photovoltaic) on<br>rooftops             | 0                    | 0        | 0                    | 0                               | 0                 | 0     | 0                 |
| Solar cells<br>(photovoltaic) on open<br>fields          | 0                    | 0        | 0                    | 0                               | 0                 | 0     | 0                 |
| Wind turbines on land                                    | 0                    | 0        | 0                    | 0                               | 0                 | 0     | 0                 |
| Wind turbines on sea                                     | 0                    | 0        | 0                    | 0                               | 0                 | 0     | 0                 |
| Gas power plants                                         | 0                    | 0        | 0                    | 0                               | 0                 | 0     | 0                 |
| Gas power plants with<br>carbon capture and<br>storage*  | 0                    | 0        | 0                    | 0                               | 0                 | 0     | 0                 |
| Coal power plants                                        | 0                    | 0        | 0                    | 0                               | 0                 | 0     | 0                 |
| Coal power plants with<br>carbon capture and<br>storage* | 0                    | 0        | 0                    | 0                               | 0                 | 0     | 0                 |
| Biomass                                                  | 0                    | 0        | 0                    | 0                               | 0                 | 0     | 0                 |
| Waste incineration                                       | 0                    | 0        | 0                    | 0                               | 0                 | 0     | 0                 |
| Net import from abroad                                   | 0                    | 0        | 0                    | 0                               | 0                 | 0     | 0                 |
| Electricity saving and<br>efficiency                     | 0                    | 0        | 0                    | 0                               | 0                 | 0     | 0                 |

### B.1.8. Individual technology preferences for the European Union

To what extent do you agree or disagree with the development of the following options to meet the electricity needs of the European Union in 2035?

\* "carbon capture and storage" is a technology that captures CO<sub>2</sub> emissions from electricity plants and stores these emissions underground in deep rock formations.

|                                                          | Strongly<br>disagree  | Disagree              | Somewhat<br>disagree  | Neither<br>agree or<br>disagree | Somewhat<br>agree     | Agree                 | Strongly<br>agree     |
|----------------------------------------------------------|-----------------------|-----------------------|-----------------------|---------------------------------|-----------------------|-----------------------|-----------------------|
| Hydropower                                               | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Nuclear                                                  | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Solar cells<br>(photovoltaic) on<br>rooftops             | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Solar cells<br>(photovoltaic) on open<br>fields          | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Wind turbines on land                                    | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Wind turbines on sea                                     | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Gas power plants                                         | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Gas power plants with<br>carbon capture and<br>storage*  | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Coal power plants                                        | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Coal power plants with<br>carbon capture and<br>storage* | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Biomass                                                  | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Waste incineration                                       | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Net import from abroad                                   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Electricity saving and<br>efficiency                     | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

### B.1.9. Impact ratings

Based on your general opinion about electricity supply technologies, how important are the following technology attributes for you?

|                               | Not<br>important      | Slightly<br>important | Moderately<br>important | Important             | Very<br>important     |
|-------------------------------|-----------------------|-----------------------|-------------------------|-----------------------|-----------------------|
| Impact on climate change      | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>   | <input type="radio"/> | <input type="radio"/> |
| Impact on local air pollution | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>   | <input type="radio"/> | <input type="radio"/> |
| Impact on land use            | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>   | <input type="radio"/> | <input type="radio"/> |

|                      |                       |                       |                       |                       |                       |
|----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Electricity costs    | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Impact on employment | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

### B.1.10. Attention test

What are the colours of the Polish national flag? Please select all colours that apply.

| White                 | Gold                  | Orange                | Red                   | Green                 | Blue                  | Brown                 | Black                 |
|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

### B.1.11. Link to Riskmeter

On the next two pages you will see an interactive web-tool, where we ask you to create your preferred electricity mix for Poland and for the European Union in the ideal case. Every electricity mix in the web-tool is technically feasible and refers to the year 2035. The tool will also show you the impacts of your preferred electricity mix such as impacts on climate change or electricity costs.

The web-tool works with the browsers Chrome, Firefox, Safari, Edge and Internet Explorer 10+. If you have any problem with the display, please try reloading the tool or updating your browser.

Mobile phones are not yet compatible with the web-tool. For an optimal visual experience, please use a desktop computer or laptop with at least a 13" screen and maximize your browser window.

*After clicking "Next", respondents were presented with two versions of the Riskmeter: one for the electricity system of the respondent's country and for the EU27. The two versions were presented in random order to avoid anchoring and respondents had to submit a scenario in both versions in order to proceed. (see Section B.2 for screenshots of all Riskmeter versions).*

### B.1.12. Attitudes towards targets for renewable electricity

*For German version:*

Currently, the share of renewable sources in German electricity supply is around 40%. By 2030, the German government aims to increase this share to 65%.

|                                                                                                                                 | Much lower            | Lower                 | About the same        | Higher                | Much higher           |
|---------------------------------------------------------------------------------------------------------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| What do you think the target of renewable sources in 2030 for Germany should be, as compared to the government's target of 65%? | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

*For French version:*

Currently, the share of renewable sources in French electricity supply is around 20%. By 2030, the French government aims to increase this share to 40%.

|                                                                                                                                | Much lower            | Lower                 | About the same        | Higher                | Much higher           |
|--------------------------------------------------------------------------------------------------------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| What do you think the target of renewable sources in 2030 for France should be, as compared to the government's target of 40%? | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

*For Polish version:*

Currently, the share of renewable sources in Polish electricity supply is around 15-20%. By 2030, the Polish government aims to increase this share to 32%.

|                                                                                                                                | Much lower            | Lower                 | About the same        | Higher                | Much higher           |
|--------------------------------------------------------------------------------------------------------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| What do you think the target of renewable sources in 2030 for Poland should be, as compared to the government's target of 32%? | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

**B.1.13. Self-reported Riskmeter evaluation**

To what extent do you agree or disagree to the following statements?

|                                                                                                                                            | Strongly<br>disagree  | Disagree              | Somewhat<br>disagree  | Neither<br>agree or<br>disagree | Somewhat<br>agree     | Agree                 | Strongly<br>agree     |
|--------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|-----------------------|-----------------------|---------------------------------|-----------------------|-----------------------|-----------------------|
| This web-tool has filled some of my knowledge gaps about electricity supply.                                                               | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| This web-tool corrected some of my misconceptions about electricity supply.                                                                | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| This web-tool has not influenced my opinion on electricity supply.                                                                         | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| This web-tool was helpful to form an opinion about electricity supply.                                                                     | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I enjoyed using the web-tool.                                                                                                              | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I found it difficult to create an electricity mix with the web-tool.                                                                       | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| It was very interesting to use the web-tool to create an electricity mix.                                                                  | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| I saw information in the web-tool that was new to me.                                                                                      | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Overall, I like this web-tool a lot.                                                                                                       | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| Through the web-tool, I was able to get an accurate picture of electricity supply technologies and their positive and negative attributes. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>           | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |



## B.2. Riskmeter versions

The following screenshots show respectively the Riskmeter versions for France, Germany, Poland, and the EU27. Each respondent viewed one Riskmeter for her country and one for the whole EU27.

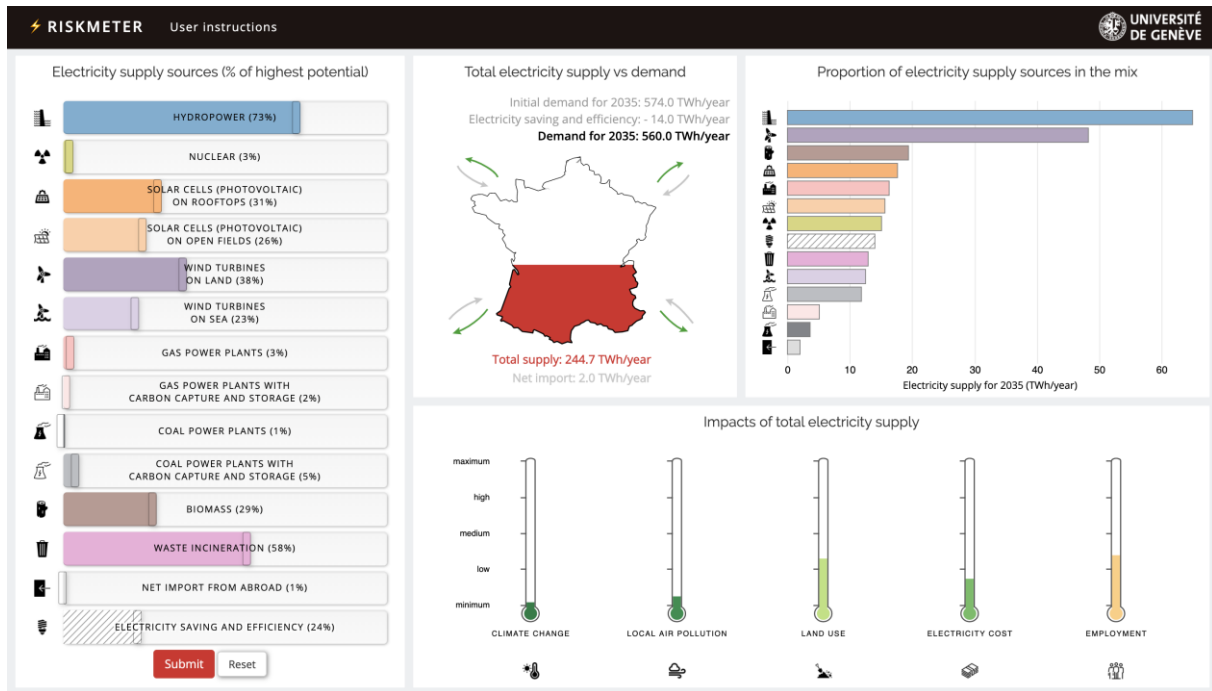


Figure B1. Riskmeter for France (Xexakis and Trutnevyte, 2020c)



Figure B2. Riskmeter for Germany (Xexakis and Trutnevyte, 2020d)

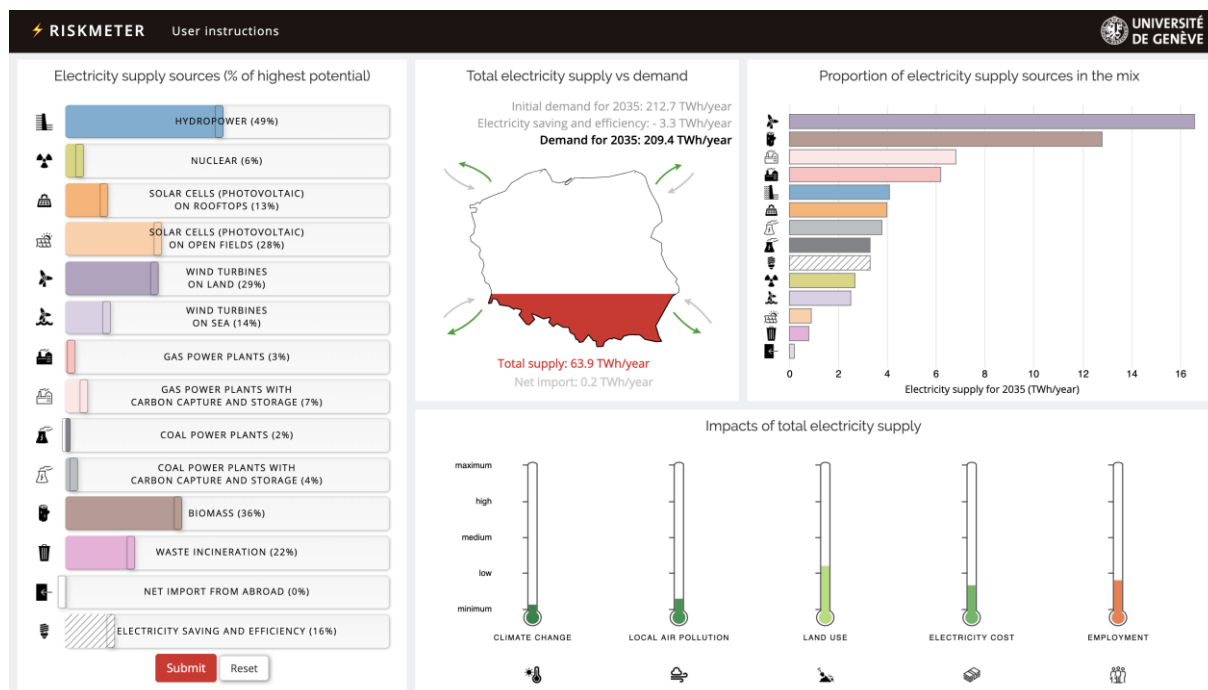


Figure B3. Riskmeter for Poland (Xexakis and Trutnevyte, 2020e)

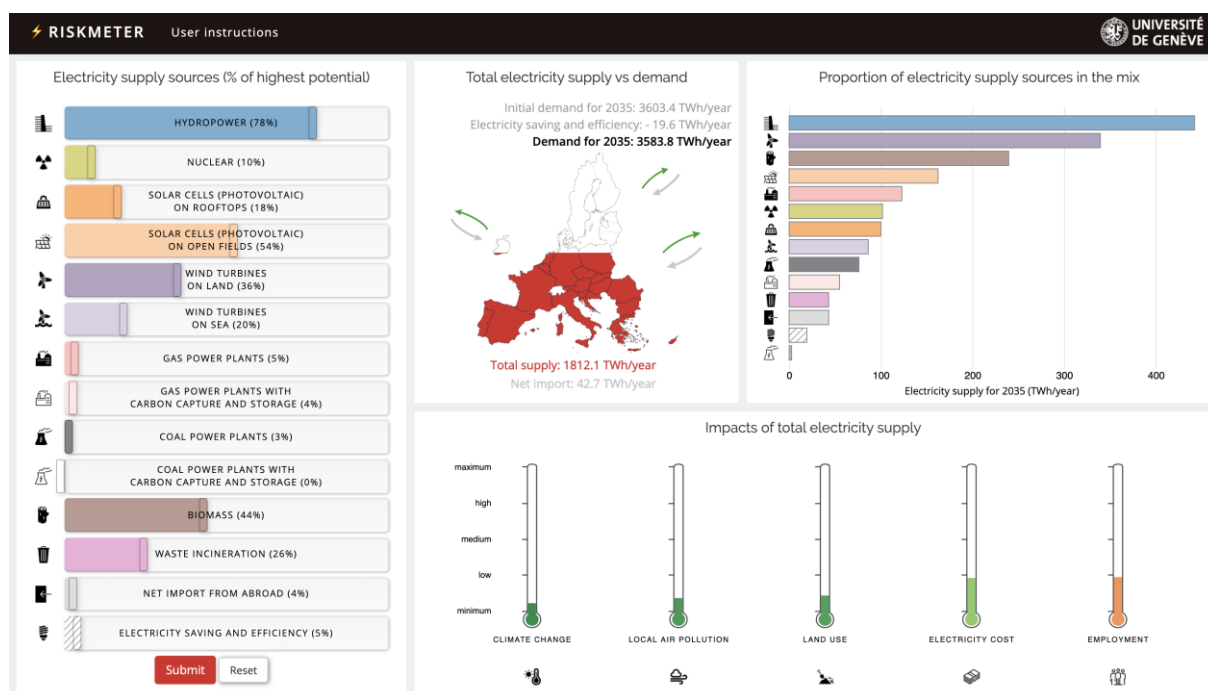


Figure B4. Riskmeter for the EU27 (Xexakis and Trutnevyte, 2020b)



## B.3. Calculation of maximum and minimum values for Riskmeter

### B.3.1. Gross demand and savings

Assumptions:

- Initial gross demand: the 75<sup>th</sup> percentile of model-based scenarios
- Savings: 10% of initial gross demand

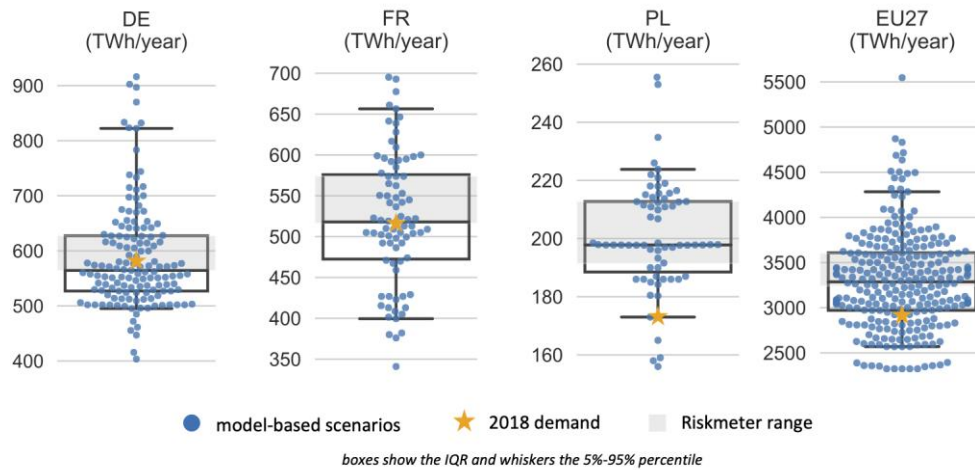


Figure B5. Comparison between the electricity demand in the Riskmeter and in model-based scenarios

### B.3.2. Supply from renewable sources (aggregated)

Assumptions:

- Maximum supply: at least the 95<sup>th</sup> percentile of model-based scenarios or the median from Sasse and Trutnevyte (Sasse and Trutnevyte, 2020).
- Minimum supply: 2018 supply (Eurostat, 2020c)

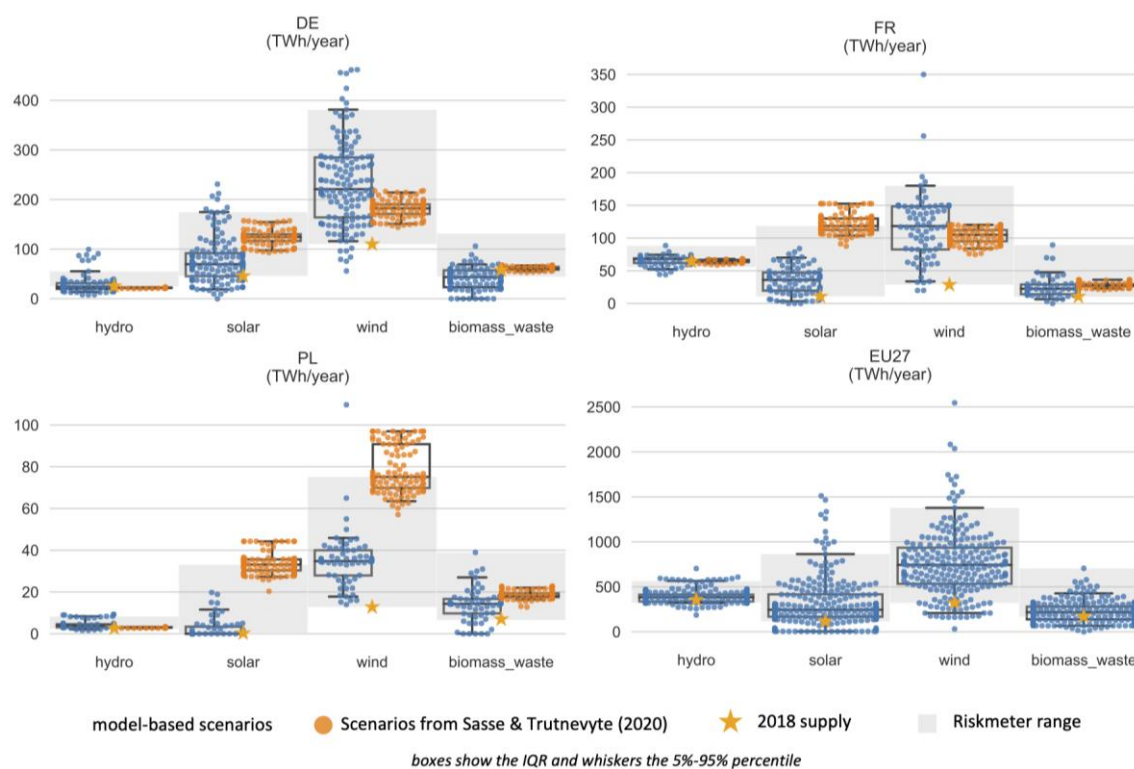


Figure B6. Comparison between the supply from aggregated renewable sources in the Riskmeter and in model-based scenarios

### B.3.3. Supply from renewable sources (disaggregated)

Most model-based scenarios did not provide disaggregated results for renewable sources (e.g., for rooftop and open field solar PV). The Riskmeter values for disaggregated renewable sources were calculated from the aggregated values based on the proportion of the disaggregated to the aggregated supply from 2018 (Eurostat, 2020c).

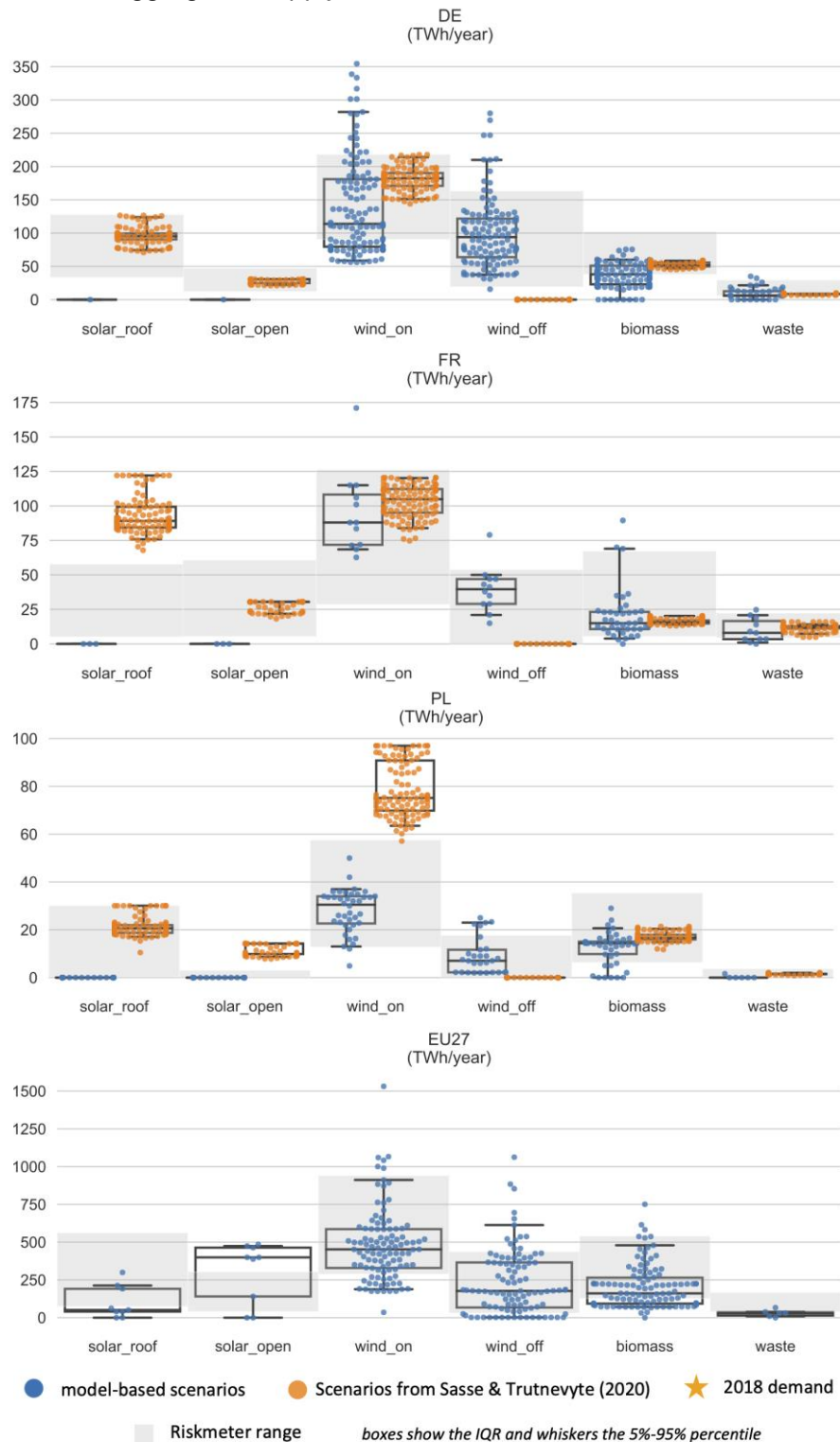


Figure B7. Comparison between the electricity supply from disaggregated renewable sources in the Riskmeter and in model-based scenarios

### B.3.4. Supply from non-renewable sources and electricity import

Assumptions:

- Maximum supply:
  - Natural gas and coal: cover all initial gross demand
  - Natural gas with CCS and coal with CCS: cover 50% of the initial gross demand
  - Import: cover 30% of the initial gross demand
  - Export: 10% of the initial gross demand
  - Nuclear: current supply in Germany, 95<sup>th</sup> percentile of model-based scenarios in other countries and the EU27
- Minimum supply: 0

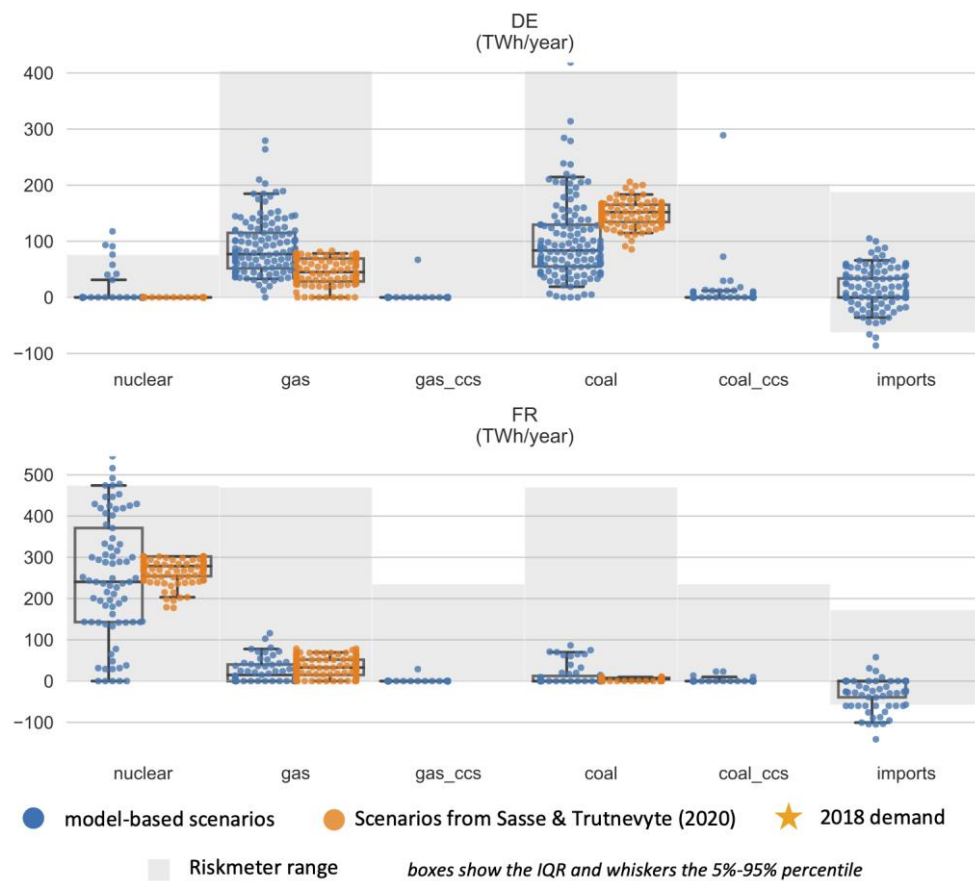


Figure B8. Comparison between the supply from non-renewable sources and net import in the Riskmeter and in model-based scenarios for Germany and France.

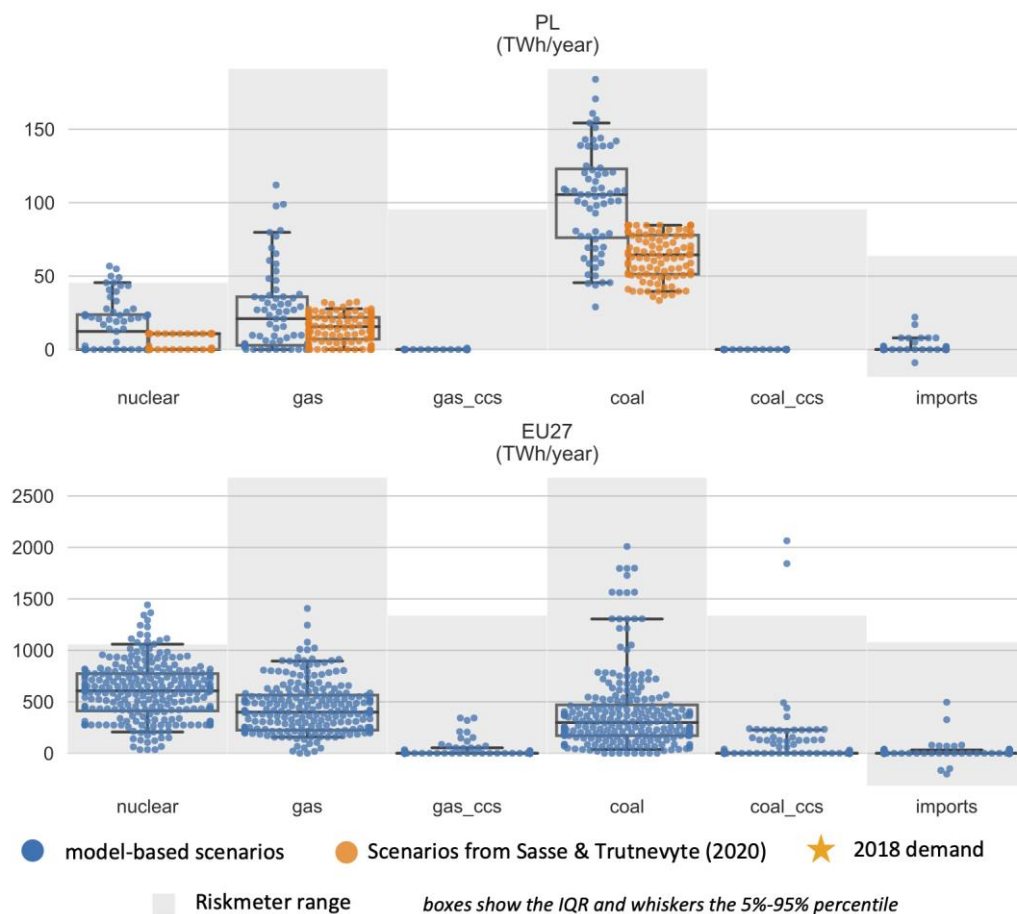


Figure B9. Comparison between the supply from non-renewable sources and net import in the Riskmeter and in model-based scenarios for Poland and the EU27.

## B.4. Detailed results for attitudes towards decision-making levels

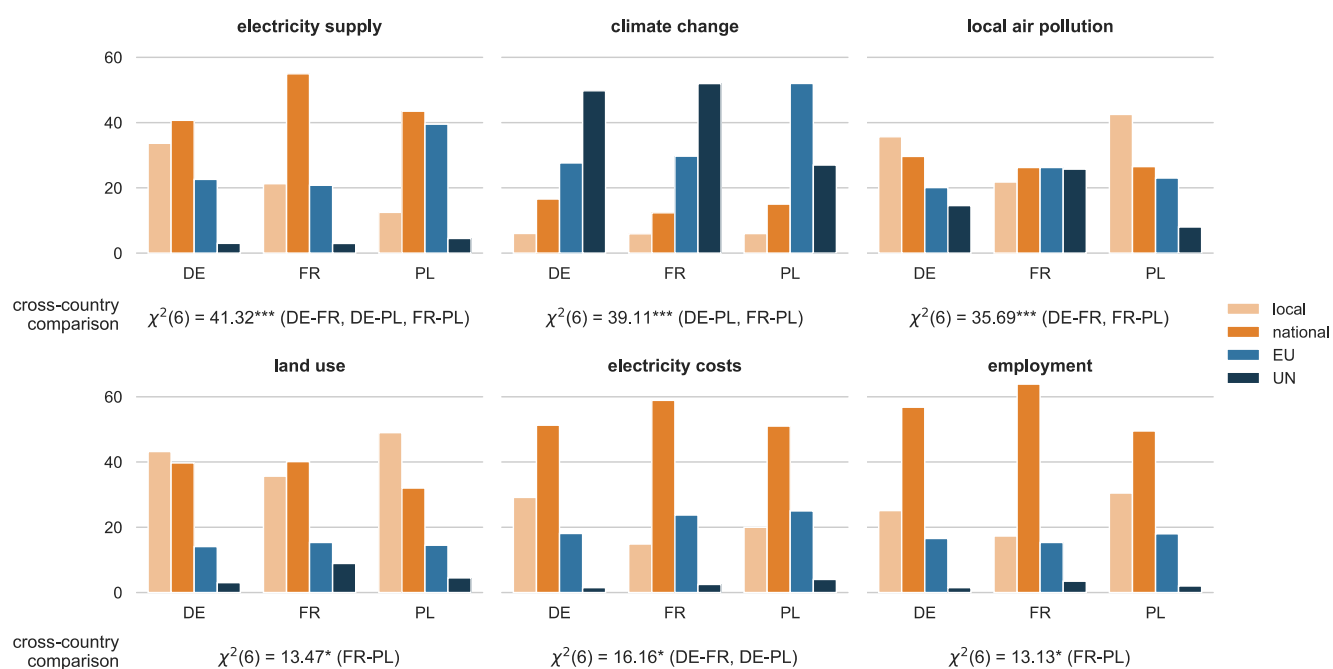


Figure B10. Analysis of the *attitudes towards decision-making levels*, in terms of percentages of respondents that selected each answer (\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ ).

## B.5. Scale items of prior interest in electricity supply topics and Riskmeter evaluation

Table B1. Results for all scale items of the *prior interest in electricity supply topics*

| Questions                                                           | <i>M (SD)</i>                     |                                  |                                  | <i>F</i><br>(2,598) | <i>post hoc</i> |
|---------------------------------------------------------------------|-----------------------------------|----------------------------------|----------------------------------|---------------------|-----------------|
|                                                                     | Germany<br>(DE)<br><i>N</i> = 199 | France<br>(FR)<br><i>N</i> = 202 | Poland<br>(PL)<br><i>N</i> = 200 |                     |                 |
| I do not find electricity supply topics exciting.                   | 3.9 (1.7)                         | 4.2 (1.7)                        | 2.7 (1.7)                        | 44.84**<br>*        | PL < DE < FR    |
| I think frequently and intensively about electricity supply topics. | 3.7 (1.6)                         | 3.3 (1.6)                        | 4.4 (1.6)                        | 24.06***            | PL > DE > FR    |
| I read articles in the newspaper about electricity supply topics.   | 4.1 (1.6)                         | 3.4 (1.6)                        | 4.4 (1.7)                        | 17.96***            | PL & DE > FR    |
| I do not follow political discussions on electricity supply topics. | 4.1 (1.8)                         | 4.4 (1.7)                        | 3.6 (1.7)                        | 11.21***            | PL & DE < FR    |
| I discuss electricity supply topics in my private environment.      | 3.5 (1.7)                         | 3.4 (1.7)                        | 4.4 (1.7)                        | 19.5***             | PL & DE > FR    |
| I am interested in learning more about electricity supply topics.   | 4.2 (1.6)                         | 4.1 (1.5)                        | 5.1 (1.4)                        | 26.04***            | PL & DE > FR    |
| In general, I am familiar with electricity supply topics.           | 4.2 (1.4)                         | 3.4 (1.5)                        | 4.8 (1.3)                        | 56.88***            | PL > DE > FR    |
| Summarized scale                                                    | 28.1 (8.3)                        | 25.0 (8.0)                       | 32.8 (7.8)                       | 48.07***            | PL > DE > FR    |

Note: \* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ . Values range from 1 = strongly disagree to 7 = strongly agree. The first and third item used negative formulation, where a high score means low *prior interest in electricity supply topics*. They were reverse coded before being added to the summarized scale.

Table B2. Results for all scale items of the *self-reported Riskmeter evaluation*

| Questions                                                                                                                                  | <i>M (SD)</i>                     |                                  |                                  | <i>F</i><br>(2,598) | <i>post hoc</i> |
|--------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|----------------------------------|----------------------------------|---------------------|-----------------|
|                                                                                                                                            | Germany<br>(DE)<br><i>N</i> = 199 | France<br>(FR)<br><i>N</i> = 202 | Poland<br>(PL)<br><i>N</i> = 200 |                     |                 |
| This web-tool has filled some of my knowledge gaps about electricity supply.                                                               | 4.4 (1.5)                         | 4.6 (1.3)                        | 4.8 (1.4)                        | 3.12*               | PL > DE         |
| This web-tool corrected some of my misconceptions about electricity supply.                                                                | 4.2 (1.5)                         | 4.6 (1.3)                        | 4.7 (1.5)                        | 6.22**              | PL & FR > DE    |
| This web-tool has not influenced my opinion on electricity supply.                                                                         | 4.2 (1.6)                         | 4.2 (1.4)                        | 4.2 (1.7)                        | 0.04                | -               |
| This web-tool was helpful to form an opinion about electricity supply.                                                                     | 4.5 (1.6)                         | 5.0 (1.3)                        | 5.1 (1.5)                        | 8.71***             | PL & FR > DE    |
| I enjoyed using the web-tool.                                                                                                              | 5.0 (1.5)                         | 5.1 (1.3)                        | 5.5 (1.4)                        | 5.92**              | PL > DE & FR    |
| I found it difficult to create an electricity mix with the web-tool.                                                                       | 3.8 (1.9)                         | 4.1 (1.7)                        | 3.9 (1.8)                        | 1.06                | -               |
| It was very interesting to use the web-tool to create an electricity mix.                                                                  | 5.4 (1.5)                         | 5.2 (1.4)                        | 5.5 (1.4)                        | 2.93                | -               |
| I saw information in the web-tool that was new to me.                                                                                      | 4.9 (1.5)                         | 4.9 (1.3)                        | 5.0 (1.5)                        | 0.7                 | -               |
| Overall, I like this web-tool a lot.                                                                                                       | 5.1 (1.4)                         | 5.0 (1.4)                        | 5.4 (1.4)                        | 6.6**               | PL > DE & FR    |
| Through the web-tool, I was able to get an accurate picture of electricity supply technologies and their positive and negative attributes. | 4.8 (1.5)                         | 4.9 (1.3)                        | 5.0 (1.4)                        | 1.67                | PL > DE         |
| Summarized scale                                                                                                                           | 46.4<br>(10.8)                    | 47.0 (9.8)                       | 49.0 (9.3)                       | 3.86*               | PL > DE & FR    |

Note: \* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ . Values range from 1 = strongly disagree to 7 = strongly agree.

The third and sixth item used negative formulation, where a high score means low (i.e., negative) *self-reported Riskmeter evaluation*. They were reverse coded before being added to the summarized scale.



## B.6. Detailed overlapping indices

| Individual technology preferences (national) | between citizens of France and Germany | between citizens of France and Poland | between citizens of Germany and Poland |
|----------------------------------------------|----------------------------------------|---------------------------------------|----------------------------------------|
| hydropower                                   | 0.74                                   | 0.65                                  | 0.77                                   |
| rooftop solar PV                             | 0.72                                   | 0.65                                  | 0.84                                   |
| open field solar PV                          | 0.76                                   | 0.56                                  | 0.74                                   |
| onshore wind                                 | 0.53                                   | 0.44                                  | 0.73                                   |
| offshore wind                                | 0.63                                   | 0.58                                  | 0.79                                   |
| biomass                                      | 0.70                                   | 0.60                                  | 0.63                                   |
| waste incineration                           | 0.74                                   | 0.69                                  | 0.76                                   |
| nuclear power                                | 0.59                                   | 0.71                                  | 0.48                                   |
| natural gas                                  | 0.56                                   | 0.46                                  | 0.76                                   |
| coal                                         | 0.83                                   | 0.61                                  | 0.71                                   |
| natural gas with CCS                         | 0.83                                   | 0.59                                  | 0.69                                   |
| coal with CCS                                | 0.88                                   | 0.65                                  | 0.70                                   |
| net import                                   | 0.71                                   | 0.61                                  | 0.82                                   |
| electricity savings and efficiency           | 0.84                                   | 0.76                                  | 0.75                                   |

| Preferred scenarios (national)     | between citizens of France and Germany | between citizens of France and Poland | between citizens of Germany and Poland |
|------------------------------------|----------------------------------------|---------------------------------------|----------------------------------------|
| hydropower                         | 0.78                                   | 0.73                                  | 0.90                                   |
| rooftop solar PV                   | 0.86                                   | 0.89                                  | 0.79                                   |
| open field solar PV                | 0.83                                   | 0.74                                  | 0.78                                   |
| onshore wind                       | 0.83                                   | 0.82                                  | 0.73                                   |
| offshore wind                      | 0.76                                   | 0.79                                  | 0.80                                   |
| biomass                            | 0.77                                   | 0.68                                  | 0.83                                   |
| waste incineration                 | 0.66                                   | 0.67                                  | 0.84                                   |
| nuclear power                      | 0.57                                   | 0.84                                  | 0.54                                   |
| natural gas                        | 0.75                                   | 0.47                                  | 0.58                                   |
| coal                               | 0.71                                   | 0.40                                  | 0.49                                   |
| natural gas with CCS               | 0.86                                   | 0.60                                  | 0.62                                   |
| coal with CCS                      | 0.80                                   | 0.56                                  | 0.57                                   |
| net import                         | 0.39                                   | 0.55                                  | 0.62                                   |
| electricity savings and efficiency | 0.67                                   | 0.88                                  | 0.77                                   |

| Impact ratings      | between citizens of France and Germany | between citizens of France and Poland | between citizens of Germany and Poland |
|---------------------|----------------------------------------|---------------------------------------|----------------------------------------|
| climate change      | 0.83                                   | 0.86                                  | 0.95                                   |
| local air pollution | 0.85                                   | 0.84                                  | 0.88                                   |
| land use            | 0.80                                   | 0.69                                  | 0.71                                   |
| electricity costs   | 0.87                                   | 0.76                                  | 0.86                                   |
| employment          | 0.82                                   | 0.78                                  | 0.75                                   |

no overlapping

full overlapping

Figure B11. Detailed overlapping indices among respondents from France, Germany, and Poland. An overlapping index of 1 indicates full overlapping among countries and 0 — no overlapping.



Figure B12. Overlapping indices among respondents with different demographics and attitudes towards electricity transition. An overlapping index of 1 indicates full overlapping among countries and 0 — no overlapping.

| Individual technology preferences (national) | attitudes towards decision-making levels (electricity supply) | attitudes towards decision-making levels (climate change) | attitudes towards decision-making levels (local air pollution) | attitudes towards decision-making levels (land use) | attitudes towards decision-making levels (electricity costs) | attitudes towards decision-making levels (employment) |
|----------------------------------------------|---------------------------------------------------------------|-----------------------------------------------------------|----------------------------------------------------------------|-----------------------------------------------------|--------------------------------------------------------------|-------------------------------------------------------|
| hydropower                                   | 0.64                                                          | 0.72                                                      | 0.83                                                           | 0.81                                                | 0.84                                                         | 0.83                                                  |
| rooftop solar PV                             | 0.74                                                          | 0.79                                                      | 0.80                                                           | 0.77                                                | 0.84                                                         | 0.81                                                  |
| open field solar PV                          | 0.72                                                          | 0.70                                                      | 0.76                                                           | 0.80                                                | 0.80                                                         | 0.79                                                  |
| onshore wind                                 | 0.70                                                          | 0.76                                                      | 0.87                                                           | 0.84                                                | 0.86                                                         | 0.79                                                  |
| offshore wind                                | 0.81                                                          | 0.75                                                      | 0.83                                                           | 0.81                                                | 0.82                                                         | 0.77                                                  |
| biomass                                      | 0.56                                                          | 0.70                                                      | 0.85                                                           | 0.75                                                | 0.78                                                         | 0.72                                                  |
| waste incineration                           | 0.87                                                          | 0.84                                                      | 0.60                                                           | 0.66                                                | 0.67                                                         | 0.67                                                  |
| nuclear power                                | 0.78                                                          | 0.89                                                      | 0.88                                                           | 0.87                                                | 0.92                                                         | 0.81                                                  |
| natural gas                                  | 0.86                                                          | 0.78                                                      | 0.93                                                           | 0.90                                                | 0.90                                                         | 0.69                                                  |
| coal                                         | 0.65                                                          | 0.82                                                      | 0.77                                                           | 0.69                                                | 0.67                                                         | 0.71                                                  |
| natural gas with CCS                         | 0.90                                                          | 0.71                                                      | 0.85                                                           | 0.73                                                | 0.82                                                         | 0.80                                                  |
| coal with CCS                                | 0.87                                                          | 0.78                                                      | 0.83                                                           | 0.70                                                | 0.80                                                         | 0.79                                                  |
| net import                                   | 0.77                                                          | 0.80                                                      | 0.81                                                           | 0.72                                                | 0.61                                                         | 0.64                                                  |
| electricity savings and efficiency           | 0.82                                                          | 0.77                                                      | 0.80                                                           | 0.73                                                | 0.81                                                         | 0.85                                                  |

| Preferred scenarios (national)     | 0.87 | 0.79 | 0.89 | 0.80 | 0.86 | 0.83 |
|------------------------------------|------|------|------|------|------|------|
| hydropower                         | 0.87 | 0.79 | 0.89 | 0.80 | 0.86 | 0.83 |
| rooftop solar PV                   | 0.76 | 0.80 | 0.85 | 0.86 | 0.84 | 0.86 |
| open field solar PV                | 0.76 | 0.80 | 0.82 | 0.71 | 0.83 | 0.88 |
| onshore wind                       | 0.80 | 0.77 | 0.88 | 0.89 | 0.88 | 0.85 |
| offshore wind                      | 0.86 | 0.83 | 0.91 | 0.81 | 0.86 | 0.83 |
| biomass                            | 0.88 | 0.85 | 0.95 | 0.83 | 0.90 | 0.85 |
| waste incineration                 | 0.91 | 0.86 | 0.85 | 0.87 | 0.91 | 0.92 |
| nuclear power                      | 0.92 | 0.84 | 0.90 | 0.87 | 0.90 | 0.78 |
| natural gas                        | 0.87 | 0.72 | 0.88 | 0.84 | 0.86 | 0.87 |
| coal                               | 0.92 | 0.72 | 0.92 | 0.81 | 0.84 | 0.82 |
| natural gas with CCS               | 0.78 | 0.86 | 0.85 | 0.86 | 0.78 | 0.90 |
| coal with CCS                      | 0.88 | 0.75 | 0.83 | 0.78 | 0.81 | 0.80 |
| net import                         | 0.70 | 0.74 | 0.74 | 0.65 | 0.72 | 0.90 |
| electricity savings and efficiency | 0.88 | 0.77 | 0.91 | 0.86 | 0.85 | 0.85 |

| Impact ratings      | 0.65 | 0.45 | 0.82 | 0.74 | 0.75 | 0.74 |
|---------------------|------|------|------|------|------|------|
| climate change      | 0.65 | 0.45 | 0.82 | 0.74 | 0.75 | 0.74 |
| local air pollution | 0.78 | 0.42 | 0.82 | 0.75 | 0.79 | 0.75 |
| land use            | 0.79 | 0.65 | 0.70 | 0.84 | 0.89 | 0.88 |
| electricity costs   | 0.85 | 0.53 | 0.89 | 0.74 | 0.78 | 0.75 |
| employment          | 0.85 | 0.65 | 0.76 | 0.85 | 0.81 | 0.82 |

no overlapping



full overlapping

Figure B13. Overlapping indices among respondents with different *attitudes towards decision-making levels*. An overlapping index of 1 indicates full overlapping among countries and 0 — no overlapping.

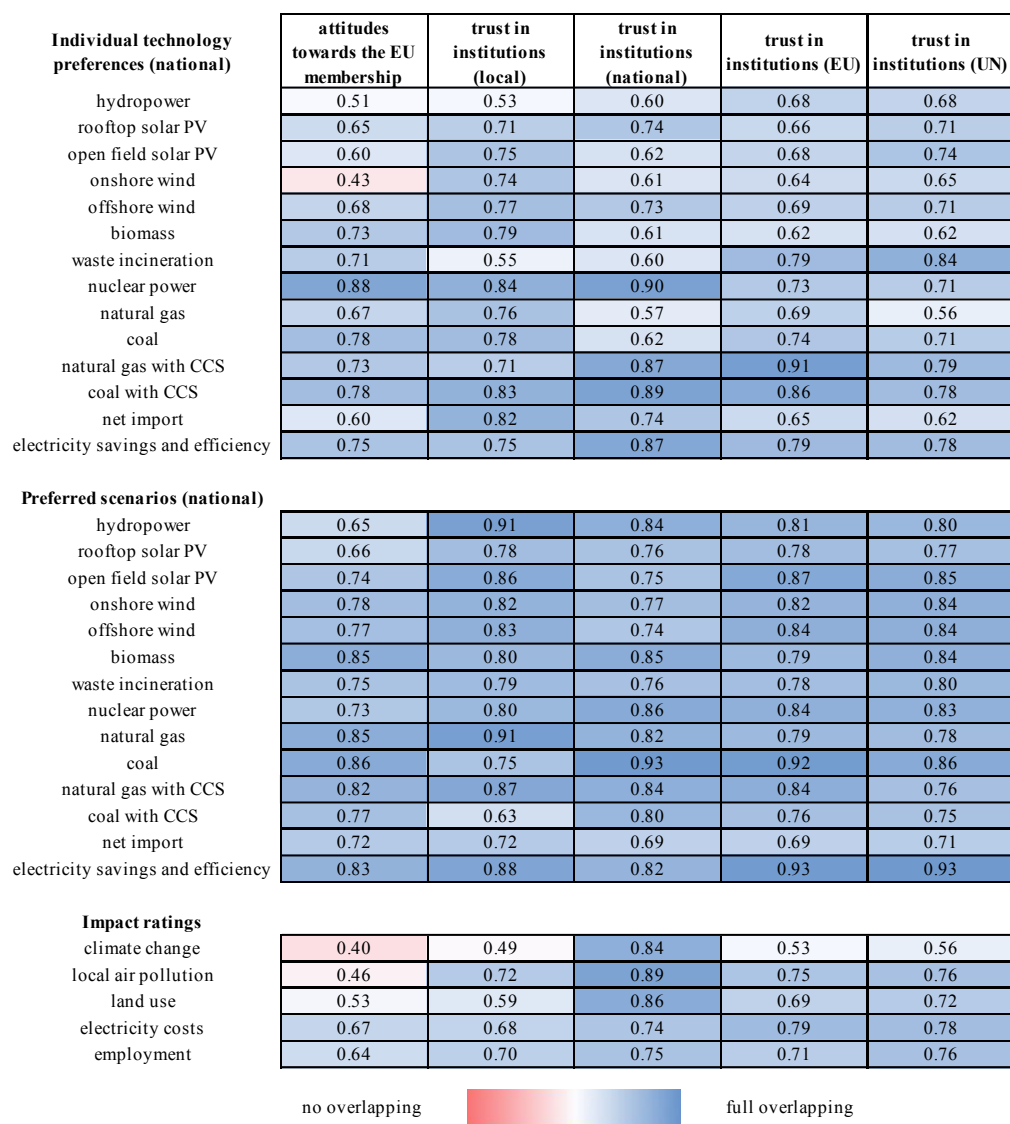


Figure B14. Overlapping indices among respondents with different *attitudes towards the EU membership* and *trust in institution*. An overlapping index of 1 indicates full overlapping among countries and 0 — no overlapping.

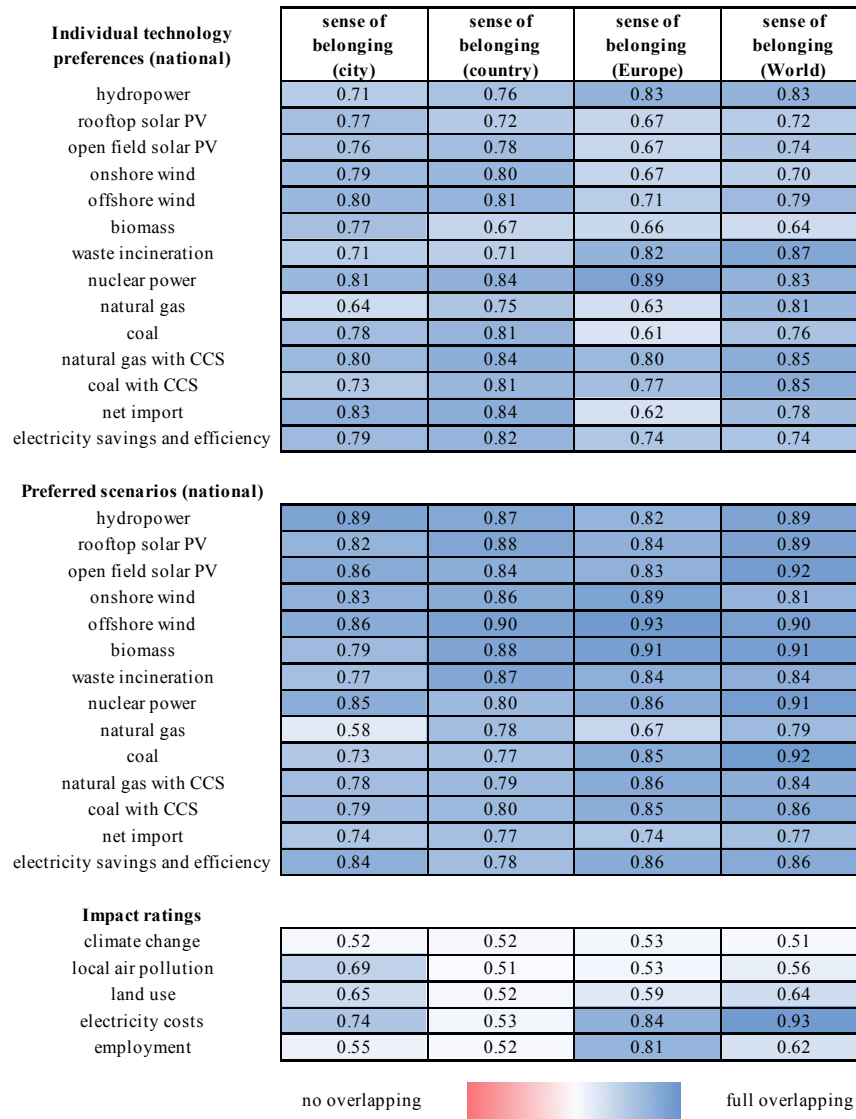


Figure B15. Overlapping indices among respondents with different *sense of belonging*. An overlapping index of 1 indicates full overlapping among countries and 0 — no overlapping.

## B.7. Consensus among citizens of France, Germany, and Poland on the EU27 electricity

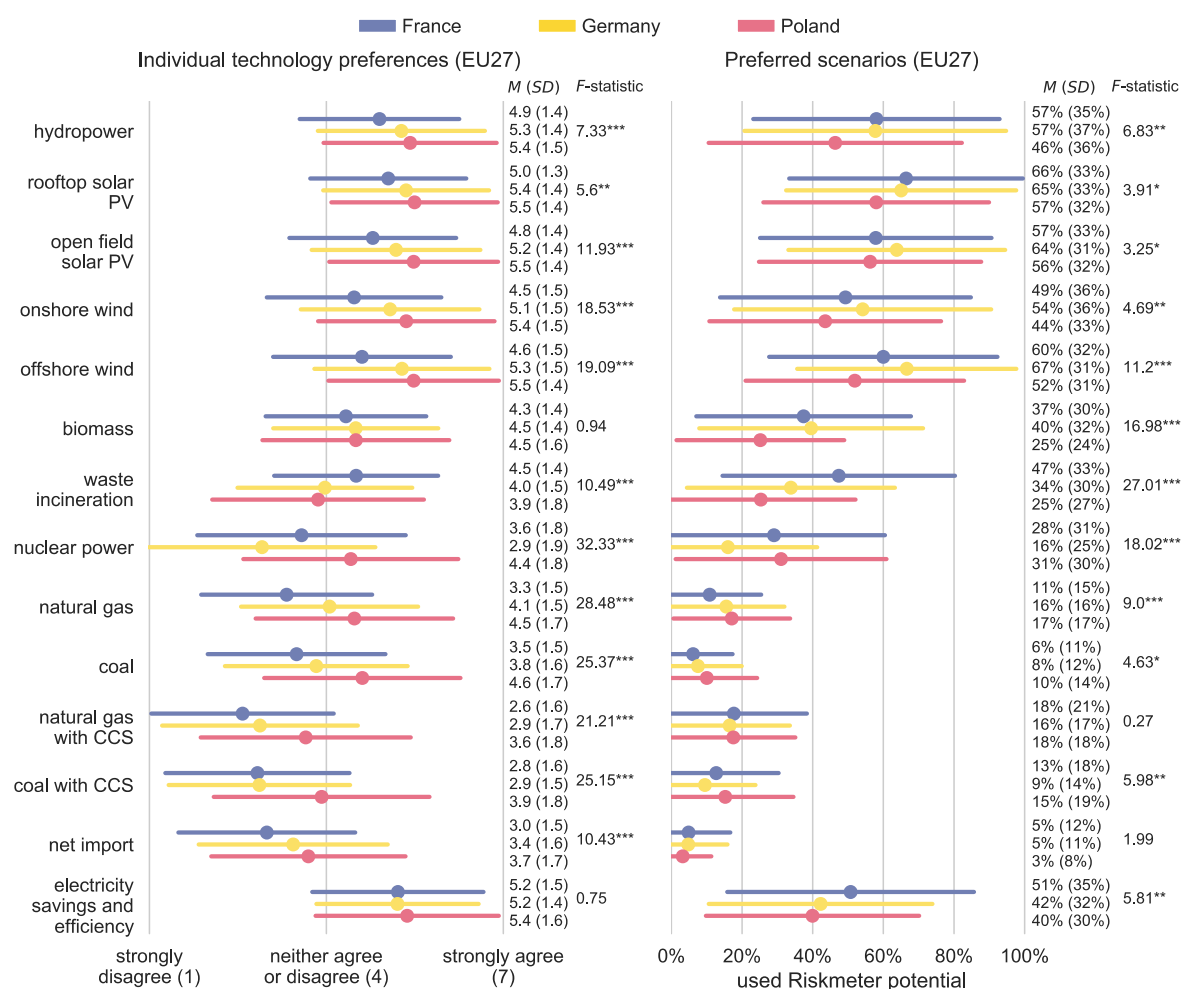


Figure B16. Comparison among respondents from France, Germany, and Poland in terms of individual technology preferences and preferred scenarios for the EU27 electricity supply. Markers depict means and lines — standard deviations. A statistical test is shown for each comparison (\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ ).

## B.8. Correlations and overlapping indices between spatial levels

Table B3. Correlations between *individual technology preferences* for the EU27 and national electricity supply

| <i>Individual technology preferences</i> | Pearson's correlation coefficients |         |         |
|------------------------------------------|------------------------------------|---------|---------|
|                                          | France                             | Germany | Poland  |
| hydropower                               | 0.54***                            | 0.71*** | 0.59*** |
| rooftop solar PV                         | 0.68***                            | 0.89*** | 0.75*** |
| open field solar PV                      | 0.71***                            | 0.65*** | 0.73*** |
| onshore wind                             | 0.9***                             | 0.85*** | 0.76*** |
| offshore wind                            | 0.88***                            | 0.85*** | 0.81*** |
| biomass                                  | 0.7***                             | 0.71*** | 0.83*** |
| waste incineration                       | 0.88***                            | 0.75*** | 0.81*** |
| nuclear power                            | 0.75***                            | 0.75*** | 0.67*** |
| natural gas                              | 0.6***                             | 0.78*** | 0.79*** |
| coal                                     | 0.74***                            | 0.78*** | 0.79*** |
| natural gas with CCS                     | 0.89***                            | 0.79*** | 0.77*** |
| coal with CCS                            | 0.92***                            | 0.79*** | 0.86*** |
| net import                               | 0.78***                            | 0.67*** | 0.8***  |
| electricity savings and efficiency       | 0.76***                            | 0.71*** | 0.8***  |

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$

Table B4. Overlapping indices between *individual technology preferences* for the EU27 and national electricity supply

| <i>Individual technology preferences</i> | Overlapping indices |         |        |
|------------------------------------------|---------------------|---------|--------|
|                                          | France              | Germany | Poland |
| hydropower                               | 0.87                | 0.90    | 0.76   |
| open field solar PV                      | 0.91                | 0.94    | 0.88   |
| rooftop solar PV                         | 0.95                | 0.95    | 0.89   |
| onshore wind                             | 0.78                | 0.93    | 0.91   |
| offshore wind                            | 0.92                | 0.90    | 0.89   |
| biomass                                  | 0.94                | 0.70    | 0.89   |
| waste incineration                       | 0.90                | 0.95    | 0.91   |
| nuclear power                            | 0.92                | 0.91    | 0.86   |
| natural gas                              | 0.73                | 0.94    | 0.91   |
| coal                                     | 0.85                | 0.89    | 0.90   |
| natural gas with CCS                     | 0.92                | 0.93    | 0.92   |
| coal with CCS                            | 0.94                | 0.91    | 0.94   |
| net import                               | 0.84                | 0.92    | 0.87   |
| electricity savings and efficiency       | 0.88                | 0.92    | 0.88   |

Note: Overlapping indices are measured from 0 (no overlap) to 1 (full overlap).

Table B5. Correlations between preferred scenarios for the EU27 and national electricity supply

| Electricity supply sources in preferred scenarios | Pearson's correlation coefficients |         |         |
|---------------------------------------------------|------------------------------------|---------|---------|
|                                                   | France                             | Germany | Poland  |
| hydropower                                        | 0.66***                            | 0.72*** | 0.6***  |
| rooftop solar PV                                  | 0.64***                            | 0.73*** | 0.67*** |
| open field solar PV                               | 0.66***                            | 0.59*** | 0.64*** |
| onshore wind                                      | 0.67***                            | 0.71*** | 0.69*** |
| offshore wind                                     | 0.69***                            | 0.69*** | 0.46*** |
| biomass                                           | 0.56***                            | 0.54*** | 0.37*** |
| waste incineration                                | 0.55***                            | 0.56*** | 0.43*** |
| nuclear power                                     | 0.69***                            | 0.75*** | 0.67*** |
| natural gas                                       | 0.4***                             | 0.6***  | 0.4***  |
| coal                                              | 0.37***                            | 0.73*** | 0.49*** |
| natural gas with CCS                              | 0.59***                            | 0.34*** | 0.48*** |
| coal with CCS                                     | 0.3***                             | 0.15*   | 0.47*** |
| net import                                        | 0.3***                             | 0.44*** | 0.38*** |
| electricity savings and efficiency                | 0.62***                            | 0.64*** | 0.53*** |

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$

Note: Preferred scenarios were quantified in terms of used Riskmeter potential.

Table B6. Overlapping indices between preferred scenarios for the EU27 and national electricity supply

| Electricity supply sources in preferred scenarios | Overlapping indices |         |        |
|---------------------------------------------------|---------------------|---------|--------|
|                                                   | France              | Germany | Poland |
| hydropower                                        | 0.82                | 0.85    | 0.69   |
| open field solar PV                               | 0.84                | 0.75    | 0.81   |
| rooftop solar PV                                  | 0.91                | 0.83    | 0.80   |
| onshore wind                                      | 0.94                | 0.71    | 0.78   |
| offshore wind                                     | 0.82                | 0.75    | 0.76   |
| biomass                                           | 0.92                | 0.73    | 0.85   |
| waste incineration                                | 0.87                | 0.92    | 0.89   |
| nuclear power                                     | 0.80                | 0.62    | 0.87   |
| natural gas                                       | 0.87                | 0.80    | 0.78   |
| coal                                              | 0.83                | 0.79    | 0.84   |
| natural gas with CCS                              | 0.82                | 0.89    | 0.66   |
| coal with CCS                                     | 0.79                | 0.84    | 0.84   |
| net import                                        | 0.72                | 0.68    | 0.73   |
| electricity savings and efficiency                | 0.95                | 0.87    | 0.83   |

Note: Overlapping indices are measured from 0 (no overlap) to 1 (full overlap). Preferred scenarios were measured in terms of used Riskmeter potential.



## B.9. Consensus among citizens of different demographics and attitudes

### B.9.1. Detailed MANCOVA results

Table B7. Effects of demographics and attitudes towards electricity transition on *individual technology preferences* (national)

| Individual technology preferences<br>Pillai's <i>V</i> | gender<br>0.064*** |           |                 | age<br>0.085*** |           |           |  | <i>F</i> -stat. |
|--------------------------------------------------------|--------------------|-----------|-----------------|-----------------|-----------|-----------|--|-----------------|
|                                                        | male               | female    | <i>F</i> -stat. | 18 – 35         | 36 – 55   | 55 – 69   |  |                 |
| hydropower                                             | 5.3 (1.4)          | 5.0 (1.4) | 4.12            | 5.2 (1.3)       | 5.1 (1.5) | 5.3 (1.4) |  | 1.08            |
| rooftop solar PV                                       | 5.6 (1.4)          | 5.2 (1.4) | 7.01**          | 5.5 (1.3)       | 5.4 (1.4) | 5.3 (1.5) |  | 9.13**          |
| open field solar PV                                    | 5.4 (1.4)          | 5.0 (1.5) | 8.48**          | 5.1 (1.4)       | 5.2 (1.5) | 5.2 (1.5) |  | 0.67            |
| onshore wind                                           | 5.1 (1.6)          | 4.9 (1.5) | 2.80            | 5.1 (1.4)       | 5.0 (1.5) | 5.0 (1.8) |  | 6.45*           |
| offshore wind                                          | 5.4 (1.5)          | 5.0 (1.5) | 11.9**          | 5.2 (1.4)       | 5.1 (1.6) | 5.3 (1.6) |  | 2.48            |
| biomass                                                | 4.5 (1.5)          | 4.4 (1.3) | 0.81            | 4.3 (1.4)       | 4.5 (1.5) | 4.5 (1.3) |  | 0.61            |
| waste incineration                                     | 4.2 (1.7)          | 4.0 (1.5) | 0.00            | 3.7 (1.6)       | 4.2 (1.6) | 4.4 (1.5) |  | 11.72**         |
| nuclear power                                          | 3.9 (2.0)          | 3.3 (1.8) | 16.14***        | 3.6 (1.9)       | 3.7 (1.9) | 3.6 (1.9) |  | 0.03            |
| natural gas                                            | 4.1 (1.6)          | 3.8 (1.4) | 2.07            | 3.7 (1.5)       | 4.1 (1.6) | 4.1 (1.4) |  | 4.01*           |
| coal                                                   | 4.2 (1.6)          | 4.0 (1.5) | 0.17            | 3.9 (1.6)       | 4.2 (1.6) | 4.2 (1.5) |  | 1.02            |
| natural gas with CCS                                   | 2.8 (1.8)          | 3.1 (1.6) | 3.82            | 3.0 (1.7)       | 3.1 (1.7) | 2.7 (1.7) |  | 1.12            |
| coal with CCS                                          | 3.1 (1.8)          | 3.3 (1.7) | 3.83            | 3.2 (1.7)       | 3.4 (1.8) | 3.0 (1.8) |  | 1.21            |
| net import                                             | 3.2 (1.6)          | 3.3 (1.5) | 0.02            | 3.3 (1.5)       | 3.2 (1.6) | 3.1 (1.5) |  | 0.99            |
| electricity savings and efficiency                     | 5.5 (1.3)          | 5.2 (1.4) | 1.06            | 5.2 (1.5)       | 5.4 (1.3) | 5.4 (1.3) |  | 0.15            |

| Pillai's <i>V</i>                  | education level<br>0.048**  |                 |           |                 | political orientation<br>0.032 |           |           |  | <i>F</i> -stat. |
|------------------------------------|-----------------------------|-----------------|-----------|-----------------|--------------------------------|-----------|-----------|--|-----------------|
|                                    | primary and lower secondary | upper secondary | tertiary  | <i>F</i> -stat. | left                           | center    | right     |  |                 |
| hydropower                         | 5.1 (1.4)                   | 5.3 (1.3)       | 5.3 (1.4) | 4.47*           | 5.4 (1.2)                      | 5.2 (1.4) | 5.1 (1.6) |  | -               |
| rooftop solar PV                   | 5.3 (1.5)                   | 5.4 (1.3)       | 5.6 (1.3) | 2.2             | 5.6 (1.4)                      | 5.4 (1.4) | 5.2 (1.4) |  | -               |
| open field solar PV                | 5.1 (1.5)                   | 5.2 (1.5)       | 5.3 (1.4) | 0.09            | 5.4 (1.5)                      | 5.2 (1.4) | 5.0 (1.5) |  | -               |
| onshore wind                       | 5.0 (1.6)                   | 4.8 (1.5)       | 5.2 (1.4) | 0.46            | 5.2 (1.6)                      | 5.0 (1.5) | 4.7 (1.6) |  | -               |
| offshore wind                      | 5.2 (1.6)                   | 5.1 (1.5)       | 5.3 (1.5) | 0.24            | 5.4 (1.6)                      | 5.1 (1.5) | 5.0 (1.6) |  | -               |
| biomass                            | 4.4 (1.5)                   | 4.5 (1.3)       | 4.6 (1.5) | 1.76            | 4.5 (1.5)                      | 4.4 (1.4) | 4.5 (1.3) |  | -               |
| waste incineration                 | 4.1 (1.6)                   | 4.2 (1.5)       | 4.0 (1.6) | 1.24            | 4.0 (1.7)                      | 4.1 (1.5) | 4.3 (1.6) |  | -               |
| nuclear power                      | 3.4 (1.9)                   | 3.8 (1.9)       | 3.6 (2.0) | 1.88            | 3.3 (1.9)                      | 3.5 (1.9) | 3.7 (1.8) |  | -               |
| natural gas                        | 4.1 (1.6)                   | 4.0 (1.5)       | 3.7 (1.5) | 4.12*           | 3.7 (1.6)                      | 4.0 (1.5) | 4.1 (1.6) |  | -               |
| coal                               | 4.2 (1.6)                   | 4.2 (1.5)       | 3.8 (1.6) | 7.48**          | 3.9 (1.8)                      | 4.1 (1.5) | 4.2 (1.5) |  | -               |
| natural gas with CCS               | 3.2 (1.8)                   | 3.0 (1.7)       | 2.5 (1.5) | 15.51***        | 2.5 (1.7)                      | 3.0 (1.6) | 3.4 (1.7) |  | -               |
| coal with CCS                      | 3.4 (1.8)                   | 3.3 (1.7)       | 2.9 (1.8) | 11.92**         | 2.8 (1.8)                      | 3.3 (1.7) | 3.5 (1.8) |  | -               |
| net import                         | 3.4 (1.7)                   | 3.2 (1.5)       | 2.9 (1.5) | 7.18**          | 3.2 (1.6)                      | 3.2 (1.5) | 3.1 (1.6) |  | -               |
| electricity savings and efficiency | 5.2 (1.4)                   | 5.4 (1.3)       | 5.5 (1.3) | 0.8             | 5.5 (1.3)                      | 5.3 (1.4) | 5.3 (1.3) |  | -               |

| Pillai's <i>V</i>                  | prior interest in electricity supply topics<br>0.110*** |           |           |                 | attitudes towards current targets for renewable electricity<br>0.166*** |              |                |  | <i>F</i> -stat. |
|------------------------------------|---------------------------------------------------------|-----------|-----------|-----------------|-------------------------------------------------------------------------|--------------|----------------|--|-----------------|
|                                    | low                                                     | medium    | high      | <i>F</i> -stat. | lower targets                                                           | same targets | higher targets |  |                 |
| hydropower                         | 5.1 (1.3)                                               | 5.0 (1.3) | 5.8 (1.4) | 12.47***        | 4.6 (1.7)                                                               | 5.0 (1.3)    | 5.4 (1.4)      |  | 14.06***        |
| rooftop solar PV                   | 5.2 (1.4)                                               | 5.2 (1.3) | 6.2 (1.2) | 17.98***        | 4.6 (1.7)                                                               | 5.0 (1.2)    | 5.7 (1.3)      |  | 29.98***        |
| open field solar PV                | 4.8 (1.5)                                               | 5.1 (1.4) | 5.9 (1.4) | 14.49***        | 4.3 (1.7)                                                               | 4.8 (1.3)    | 5.5 (1.4)      |  | 34.62***        |
| onshore wind                       | 4.7 (1.5)                                               | 4.9 (1.5) | 5.7 (1.6) | 6.53*           | 4.5 (1.8)                                                               | 4.6 (1.5)    | 5.3 (1.5)      |  | 18.67***        |
| offshore wind                      | 4.9 (1.7)                                               | 5.0 (1.4) | 6.0 (1.3) | 15.57***        | 4.5 (1.7)                                                               | 4.8 (1.4)    | 5.5 (1.5)      |  | 26.8***         |
| biomass                            | 4.2 (1.4)                                               | 4.4 (1.4) | 4.9 (1.5) | 1.31            | 4.0 (1.6)                                                               | 4.4 (1.2)    | 4.5 (1.5)      |  | 0.73            |
| waste incineration                 | 3.9 (1.7)                                               | 4.1 (1.5) | 4.2 (1.8) | 2.06            | 4.2 (1.7)                                                               | 4.2 (1.4)    | 4.0 (1.7)      |  | 1.02            |
| nuclear power                      | 3.3 (1.8)                                               | 3.7 (1.8) | 3.7 (2.2) | 1.57            | 3.9 (2.1)                                                               | 3.9 (1.7)    | 3.4 (2.0)      |  | 33.07***        |
| natural gas                        | 3.5 (1.4)                                               | 3.9 (1.4) | 4.5 (1.8) | 5.75*           | 3.8 (1.6)                                                               | 4.0 (1.2)    | 4.0 (1.7)      |  | 4.69*           |
| coal                               | 3.5 (1.5)                                               | 4.1 (1.4) | 4.7 (1.9) | 15.31***        | 3.8 (1.7)                                                               | 4.2 (1.2)    | 4.1 (1.7)      |  | 1.02            |
| natural gas with CCS               | 2.9 (1.6)                                               | 3.0 (1.6) | 2.9 (2.1) | 0.02            | 3.4 (1.9)                                                               | 3.3 (1.5)    | 2.7 (1.7)      |  | 31.16***        |
| coal with CCS                      | 2.8 (1.5)                                               | 3.3 (1.6) | 3.4 (2.2) | 5.63*           | 3.2 (1.6)                                                               | 3.6 (1.6)    | 3.1 (1.8)      |  | 16.58***        |
| net import                         | 2.9 (1.5)                                               | 3.3 (1.5) | 3.2 (1.7) | 0.82            | 3.0 (1.6)                                                               | 3.4 (1.4)    | 3.1 (1.6)      |  | 5.81*           |
| electricity savings and efficiency | 4.9 (1.5)                                               | 5.2 (1.3) | 6.2 (1.1) | 40.37***        | 4.7 (1.6)                                                               | 4.9 (1.3)    | 5.6 (1.3)      |  | 31.96***        |

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ . Note: Values range from 1 = strongly disagree to 7 = strongly agree. Statistical significance was calculated with MANCOVA using the respondents' country as a fixed factor and the respondents' demographics, political orientations, and attitudes towards electricity transition and governance as covariates.

Table B8. Effects of *attitudes towards decision-making levels* on *individual technology preferences* (national)

| Individual technology preferences<br>(national)<br>Pillai's $V$ | attitudes towards decision-making levels<br>(electricity supply)<br>0.027 |           |                | attitudes towards decision-making levels (climate change)<br>-    |           |            | attitudes towards decision-making levels (local air pollution)<br>- |           |                |
|-----------------------------------------------------------------|---------------------------------------------------------------------------|-----------|----------------|-------------------------------------------------------------------|-----------|------------|---------------------------------------------------------------------|-----------|----------------|
|                                                                 | local/<br>national                                                        | EU/UN     | $F$ -<br>stat. | local/<br>national                                                | EU/UN     | $F$ -stat. | local/<br>national                                                  | EU/UN     | $F$ -<br>stat. |
| hydropower                                                      | 5.1 (1.4)                                                                 | 5.4 (1.3) | -              | 5.0 (1.6)                                                         | 5.3 (1.3) | -          | 5.3 (1.3)                                                           | 5.1 (1.5) | -              |
| rooftop solar PV                                                | 5.3 (1.4)                                                                 | 5.7 (1.2) | -              | 5.2 (1.5)                                                         | 5.4 (1.3) | -          | 5.5 (1.4)                                                           | 5.2 (1.4) | -              |
| open field solar PV                                             | 5.0 (1.5)                                                                 | 5.6 (1.2) | -              | 4.8 (1.8)                                                         | 5.3 (1.4) | -          | 5.3 (1.5)                                                           | 5.0 (1.4) | -              |
| onshore wind                                                    | 4.8 (1.6)                                                                 | 5.5 (1.3) | -              | 4.6 (1.8)                                                         | 5.1 (1.5) | -          | 5.1 (1.6)                                                           | 4.9 (1.6) | -              |
| offshore wind                                                   | 5.1 (1.6)                                                                 | 5.5 (1.4) | -              | 4.9 (1.7)                                                         | 5.3 (1.5) | -          | 5.3 (1.5)                                                           | 5.1 (1.5) | -              |
| biomass                                                         | 4.4 (1.4)                                                                 | 4.6 (1.4) | -              | 4.3 (1.6)                                                         | 4.5 (1.4) | -          | 4.5 (1.4)                                                           | 4.4 (1.4) | -              |
| waste incineration                                              | 4.1 (1.6)                                                                 | 4.1 (1.6) | -              | 4.0 (1.7)                                                         | 4.1 (1.6) | -          | 4.0 (1.5)                                                           | 4.3 (1.6) | -              |
| nuclear power                                                   | 3.5 (1.9)                                                                 | 3.9 (1.8) | -              | 3.6 (1.9)                                                         | 3.6 (1.9) | -          | 3.5 (1.9)                                                           | 3.8 (1.9) | -              |
| natural gas                                                     | 3.9 (1.6)                                                                 | 4.1 (1.5) | -              | 4.0 (1.8)                                                         | 4.0 (1.5) | -          | 4.0 (1.5)                                                           | 4.0 (1.5) | -              |
| coal                                                            | 4.0 (1.6)                                                                 | 4.3 (1.6) | -              | 4.1 (1.7)                                                         | 4.1 (1.5) | -          | 4.0 (1.6)                                                           | 4.2 (1.6) | -              |
| natural gas with CCS                                            | 3.0 (1.7)                                                                 | 2.9 (1.7) | -              | 3.5 (1.9)                                                         | 2.8 (1.6) | -          | 2.8 (1.7)                                                           | 3.1 (1.7) | -              |
| coal with CCS                                                   | 3.2 (1.8)                                                                 | 3.3 (1.8) | -              | 3.5 (1.9)                                                         | 3.2 (1.7) | -          | 3.1 (1.7)                                                           | 3.4 (1.8) | -              |
| net import                                                      | 3.1 (1.6)                                                                 | 3.6 (1.5) | -              | 3.2 (1.8)                                                         | 3.2 (1.5) | -          | 3.1 (1.6)                                                           | 3.4 (1.5) | -              |
| electricity savings and efficiency                              | 5.2 (1.4)                                                                 | 5.6 (1.2) | -              | 5.1 (1.6)                                                         | 5.4 (1.3) | -          | 5.5 (1.4)                                                           | 5.1 (1.4) | -              |
| Pillai's $V$                                                    | attitudes towards decision-making levels<br>(land use)<br>-               |           |                | attitudes towards decision-making levels (electricity costs)<br>- |           |            | attitudes towards decision-making levels (employment)<br>-          |           |                |
|                                                                 | local/<br>national                                                        | EU/UN     | $F$ -<br>stat. | local/<br>national                                                | EU/UN     | $F$ -stat. | local/<br>national                                                  | EU/UN     | $F$ -<br>stat. |
| hydropower                                                      | 5.3 (1.4)                                                                 | 5.0 (1.5) | -              | 5.2 (1.4)                                                         | 5.1 (1.4) | -          | 5.2 (1.4)                                                           | 5.1 (1.3) | -              |
| rooftop solar PV                                                | 5.5 (1.4)                                                                 | 5.1 (1.3) | -              | 5.4 (1.4)                                                         | 5.4 (1.3) | -          | 5.4 (1.4)                                                           | 5.3 (1.2) | -              |
| open field solar PV                                             | 5.2 (1.5)                                                                 | 5.0 (1.4) | -              | 5.2 (1.5)                                                         | 5.2 (1.3) | -          | 5.2 (1.5)                                                           | 5.1 (1.3) | -              |
| onshore wind                                                    | 5.0 (1.6)                                                                 | 5.0 (1.4) | -              | 5.0 (1.6)                                                         | 5.1 (1.4) | -          | 5.0 (1.6)                                                           | 5.0 (1.4) | -              |
| offshore wind                                                   | 5.2 (1.5)                                                                 | 5.1 (1.5) | -              | 5.2 (1.6)                                                         | 5.2 (1.4) | -          | 5.2 (1.6)                                                           | 5.1 (1.4) | -              |
| biomass                                                         | 4.5 (1.4)                                                                 | 4.4 (1.4) | -              | 4.4 (1.4)                                                         | 4.6 (1.4) | -          | 4.5 (1.4)                                                           | 4.4 (1.5) | -              |
| waste incineration                                              | 4.0 (1.6)                                                                 | 4.5 (1.5) | -              | 4.0 (1.6)                                                         | 4.4 (1.6) | -          | 4.0 (1.6)                                                           | 4.5 (1.4) | -              |
| nuclear power                                                   | 3.6 (1.9)                                                                 | 3.6 (1.8) | -              | 3.6 (1.9)                                                         | 3.7 (1.9) | -          | 3.5 (1.9)                                                           | 4.0 (1.9) | -              |
| natural gas                                                     | 4.0 (1.5)                                                                 | 4.0 (1.5) | -              | 4.0 (1.6)                                                         | 4.0 (1.5) | -          | 3.9 (1.5)                                                           | 4.2 (1.5) | -              |
| coal                                                            | 4.1 (1.6)                                                                 | 4.3 (1.6) | -              | 4.0 (1.6)                                                         | 4.3 (1.6) | -          | 4.0 (1.6)                                                           | 4.4 (1.7) | -              |
| natural gas with CCS                                            | 2.8 (1.7)                                                                 | 3.4 (1.8) | -              | 2.9 (1.7)                                                         | 3.1 (1.8) | -          | 2.9 (1.7)                                                           | 3.2 (1.7) | -              |
| coal with CCS                                                   | 3.1 (1.7)                                                                 | 3.7 (1.8) | -              | 3.2 (1.7)                                                         | 3.5 (1.8) | -          | 3.2 (1.7)                                                           | 3.5 (1.8) | -              |
| net import                                                      | 3.1 (1.5)                                                                 | 3.6 (1.6) | -              | 3.0 (1.6)                                                         | 3.7 (1.5) | -          | 3.1 (1.6)                                                           | 3.7 (1.4) | -              |
| electricity savings and efficiency                              | 5.4 (1.4)                                                                 | 5.1 (1.3) | -              | 5.3 (1.4)                                                         | 5.3 (1.3) | -          | 5.3 (1.4)                                                           | 5.4 (1.3) | -              |

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Note: Values range from 1 = strongly disagree to 7 = strongly agree. Statistical significance was calculated with MANCOVA using the respondents' country as a fixed factor and the respondents' demographics, political orientations, and attitudes towards electricity transition and governance as covariates.

## B.9 Consensus among citizens of different demographics and attitudes

Table B9. Effects of *attitudes towards the EU membership* and *trust in institutions* on *individual technology preferences* (national)

| Individual technology preferences (national)<br>Pillai's $V$ | attitudes towards the EU membership |           |           |            | trust in institutions (local) |           |           |            |
|--------------------------------------------------------------|-------------------------------------|-----------|-----------|------------|-------------------------------|-----------|-----------|------------|
|                                                              | 0.021                               |           |           |            | 0.046*                        |           |           |            |
|                                                              | negative                            | neutral   | positive  | $F$ -stat. | low                           | medium    | high      | $F$ -stat. |
| hydropower                                                   | 5.3 (1.7)                           | 4.8 (1.4) | 5.4 (1.3) | -          | 5.1 (1.7)                     | 4.9 (1.4) | 5.4 (1.2) | 1.05       |
| rooftop solar PV                                             | 5.0 (1.9)                           | 5.0 (1.3) | 5.7 (1.2) | -          | 5.1 (1.7)                     | 5.1 (1.4) | 5.7 (1.2) | 4.39*      |
| open field solar PV                                          | 4.7 (2.0)                           | 4.7 (1.5) | 5.5 (1.2) | -          | 5.0 (1.8)                     | 5.0 (1.4) | 5.4 (1.3) | 0.01       |
| onshore wind                                                 | 4.4 (2.0)                           | 4.5 (1.5) | 5.4 (1.3) | -          | 4.7 (1.9)                     | 4.8 (1.5) | 5.3 (1.4) | 0.6        |
| offshore wind                                                | 4.9 (1.8)                           | 4.7 (1.5) | 5.5 (1.4) | -          | 5.0 (1.7)                     | 5.0 (1.5) | 5.4 (1.4) | 2.01       |
| biomass                                                      | 4.4 (1.8)                           | 4.2 (1.3) | 4.6 (1.4) | -          | 4.4 (1.7)                     | 4.3 (1.3) | 4.6 (1.4) | 0.13       |
| waste incineration                                           | 4.3 (1.9)                           | 4.0 (1.4) | 4.1 (1.5) | -          | 3.9 (1.8)                     | 4.1 (1.5) | 4.3 (1.5) | 0.66       |
| nuclear power                                                | 3.6 (2.0)                           | 3.5 (1.7) | 3.7 (1.9) | -          | 3.5 (2.0)                     | 3.5 (1.8) | 3.8 (1.9) | 3.03       |
| natural gas                                                  | 3.7 (1.9)                           | 3.8 (1.3) | 4.1 (1.5) | -          | 3.7 (1.7)                     | 3.9 (1.5) | 4.1 (1.4) | 0.26       |
| coal                                                         | 3.8 (1.8)                           | 3.9 (1.4) | 4.3 (1.6) | -          | 3.8 (1.8)                     | 4.1 (1.5) | 4.2 (1.5) | 0.29       |
| natural gas with CCS                                         | 3.2 (2.1)                           | 3.0 (1.5) | 2.8 (1.7) | -          | 3.3 (1.9)                     | 3.0 (1.6) | 2.8 (1.6) | 7.28**     |
| coal with CCS                                                | 3.1 (2.1)                           | 3.3 (1.6) | 3.3 (1.8) | -          | 3.4 (1.9)                     | 3.2 (1.7) | 3.2 (1.8) | 2.91       |
| net import                                                   | 2.7 (1.9)                           | 3.0 (1.4) | 3.4 (1.5) | -          | 3.0 (1.7)                     | 3.2 (1.5) | 3.3 (1.6) | 2.78       |
| electricity savings and efficiency                           | 5.4 (1.5)                           | 4.9 (1.4) | 5.6 (1.3) | -          | 5.2 (1.5)                     | 5.1 (1.4) | 5.6 (1.2) | 3.94*      |

| Pillai's $V$                       | trust in institutions (national) |           |           |            | trust in institutions (EU) |           |           |            |
|------------------------------------|----------------------------------|-----------|-----------|------------|----------------------------|-----------|-----------|------------|
|                                    | 0.036                            |           |           |            | 0.024                      |           |           |            |
|                                    | low                              | medium    | high      | $F$ -stat. | low                        | medium    | high      | $F$ -stat. |
| hydropower                         | 5.2 (1.6)                        | 5.0 (1.3) | 5.5 (1.2) | -          | 5.1 (1.6)                  | 5.0 (1.3) | 5.6 (1.2) | -          |
| rooftop solar PV                   | 5.3 (1.5)                        | 5.2 (1.3) | 5.7 (1.2) | -          | 5.1 (1.7)                  | 5.3 (1.2) | 5.8 (1.2) | -          |
| open field solar PV                | 5.1 (1.6)                        | 5.1 (1.4) | 5.4 (1.3) | -          | 4.9 (1.8)                  | 5.1 (1.2) | 5.6 (1.3) | -          |
| onshore wind                       | 4.9 (1.8)                        | 4.9 (1.3) | 5.3 (1.4) | -          | 4.6 (1.9)                  | 4.9 (1.3) | 5.6 (1.2) | -          |
| offshore wind                      | 5.2 (1.7)                        | 5.0 (1.4) | 5.5 (1.4) | -          | 4.9 (1.8)                  | 5.0 (1.4) | 5.6 (1.4) | -          |
| biomass                            | 4.4 (1.5)                        | 4.3 (1.3) | 4.7 (1.3) | -          | 4.2 (1.6)                  | 4.5 (1.2) | 4.6 (1.4) | -          |
| waste incineration                 | 4.0 (1.8)                        | 4.1 (1.4) | 4.3 (1.5) | -          | 4.1 (1.8)                  | 4.0 (1.3) | 4.2 (1.6) | -          |
| nuclear power                      | 3.6 (2.0)                        | 3.5 (1.7) | 3.8 (2.0) | -          | 3.4 (2.1)                  | 3.6 (1.7) | 4.0 (1.8) | -          |
| natural gas                        | 3.8 (1.7)                        | 4.0 (1.3) | 4.3 (1.5) | -          | 3.7 (1.7)                  | 4.0 (1.3) | 4.4 (1.5) | -          |
| coal                               | 4.0 (1.7)                        | 4.1 (1.5) | 4.3 (1.5) | -          | 3.8 (1.8)                  | 4.1 (1.3) | 4.5 (1.6) | -          |
| natural gas with CCS               | 2.9 (1.8)                        | 3.0 (1.5) | 2.9 (1.7) | -          | 2.9 (1.9)                  | 3.0 (1.5) | 3.1 (1.7) | -          |
| coal with CCS                      | 3.1 (1.9)                        | 3.3 (1.6) | 3.3 (1.8) | -          | 3.0 (1.9)                  | 3.3 (1.5) | 3.5 (1.9) | -          |
| net import                         | 3.0 (1.7)                        | 3.3 (1.4) | 3.4 (1.6) | -          | 2.7 (1.7)                  | 3.3 (1.3) | 3.7 (1.6) | -          |
| electricity savings and efficiency | 5.4 (1.4)                        | 5.2 (1.3) | 5.4 (1.3) | -          | 5.2 (1.6)                  | 5.2 (1.4) | 5.6 (1.2) | -          |

| Pillai's $V$                       | trust in institutions (UN) |           |           |            |
|------------------------------------|----------------------------|-----------|-----------|------------|
|                                    | -                          |           |           |            |
|                                    | low                        | medium    | high      | $F$ -stat. |
| hydropower                         | 5.1 (1.6)                  | 5.0 (1.3) | 5.6 (1.2) | -          |
| rooftop solar PV                   | 5.1 (1.7)                  | 5.3 (1.2) | 5.8 (1.2) | -          |
| open field solar PV                | 4.8 (1.8)                  | 5.1 (1.3) | 5.6 (1.2) | -          |
| onshore wind                       | 4.5 (1.9)                  | 4.9 (1.3) | 5.6 (1.2) | -          |
| offshore wind                      | 5.0 (1.8)                  | 5.1 (1.4) | 5.7 (1.3) | -          |
| biomass                            | 4.3 (1.7)                  | 4.5 (1.2) | 4.6 (1.4) | -          |
| waste incineration                 | 4.1 (1.8)                  | 4.1 (1.4) | 4.2 (1.6) | -          |
| nuclear power                      | 3.3 (2.1)                  | 3.5 (1.7) | 4.0 (2.0) | -          |
| natural gas                        | 3.6 (1.7)                  | 3.9 (1.3) | 4.3 (1.6) | -          |
| coal                               | 3.8 (1.8)                  | 4.0 (1.4) | 4.4 (1.6) | -          |
| natural gas with CCS               | 2.8 (1.9)                  | 2.9 (1.5) | 2.9 (1.8) | -          |
| coal with CCS                      | 3.0 (1.9)                  | 3.2 (1.5) | 3.3 (1.9) | -          |
| net import                         | 2.7 (1.7)                  | 3.3 (1.3) | 3.6 (1.7) | -          |
| electricity savings and efficiency | 5.2 (1.5)                  | 5.2 (1.3) | 5.6 (1.2) | -          |

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ . Note: Values range from 1 = strongly disagree to 7 = strongly agree. Statistical significance was calculated with MANCOVA using the respondents' country as a fixed factor and the respondents' demographics, political orientations, and attitudes towards electricity transition and governance as covariates.

Table B10. Effects of *sense of belonging* on *individual technology preferences* (national)

| Individual technology preferences<br>(national)<br>Pillai's $V$ | sense of belonging (city) |           |           |            | sense of belonging (country) |           |           |            |
|-----------------------------------------------------------------|---------------------------|-----------|-----------|------------|------------------------------|-----------|-----------|------------|
|                                                                 | 0.015                     |           |           |            | 0.026                        |           |           |            |
|                                                                 | weak                      | medium    | strong    | $F$ -stat. | weak                         | medium    | strong    | $F$ -stat. |
| hydropower                                                      | 5.1 (1.6)                 | 4.9 (1.3) | 5.3 (1.4) | -          | 5.1 (1.7)                    | 5.1 (1.3) | 5.3 (1.4) | -          |
| rooftop solar PV                                                | 5.2 (1.7)                 | 5.1 (1.3) | 5.5 (1.3) | -          | 5.2 (1.7)                    | 5.4 (1.4) | 5.4 (1.3) | -          |
| open field solar PV                                             | 5.0 (1.8)                 | 4.9 (1.3) | 5.3 (1.4) | -          | 5.0 (1.7)                    | 5.0 (1.5) | 5.3 (1.4) | -          |
| onshore wind                                                    | 4.8 (1.7)                 | 4.9 (1.4) | 5.1 (1.5) | -          | 5.0 (1.7)                    | 4.9 (1.5) | 5.0 (1.5) | -          |
| offshore wind                                                   | 5.1 (1.7)                 | 4.9 (1.5) | 5.3 (1.5) | -          | 5.2 (1.7)                    | 5.0 (1.6) | 5.3 (1.5) | -          |
| biomass                                                         | 4.2 (1.6)                 | 4.4 (1.2) | 4.6 (1.4) | -          | 4.4 (1.5)                    | 4.3 (1.4) | 4.5 (1.4) | -          |
| waste incineration                                              | 3.8 (1.8)                 | 4.2 (1.3) | 4.1 (1.6) | -          | 3.9 (1.8)                    | 4.1 (1.5) | 4.2 (1.5) | -          |
| nuclear power                                                   | 3.5 (2.0)                 | 3.5 (1.8) | 3.7 (1.9) | -          | 3.5 (1.9)                    | 3.5 (1.9) | 3.7 (1.9) | -          |
| natural gas                                                     | 3.5 (1.6)                 | 3.8 (1.3) | 4.2 (1.5) | -          | 3.8 (1.8)                    | 3.7 (1.4) | 4.1 (1.5) | -          |
| coal                                                            | 3.8 (1.8)                 | 3.9 (1.4) | 4.3 (1.6) | -          | 4.0 (1.8)                    | 3.8 (1.5) | 4.2 (1.5) | -          |
| natural gas with CCS                                            | 2.7 (1.8)                 | 2.9 (1.6) | 3.0 (1.7) | -          | 3.0 (1.8)                    | 2.7 (1.7) | 3.0 (1.7) | -          |
| coal with CCS                                                   | 2.7 (1.8)                 | 3.2 (1.6) | 3.4 (1.8) | -          | 3.1 (1.8)                    | 2.9 (1.6) | 3.4 (1.8) | -          |
| net import                                                      | 3.1 (1.7)                 | 3.3 (1.4) | 3.2 (1.6) | -          | 3.3 (1.7)                    | 3.0 (1.5) | 3.3 (1.6) | -          |
| electricity savings and efficiency                              | 5.1 (1.5)                 | 5.3 (1.3) | 5.4 (1.4) | -          | 5.2 (1.5)                    | 5.3 (1.4) | 5.4 (1.3) | -          |

| Pillai's $V$                       | sense of belonging (Europe) |           |           |            | sense of belonging (World) |           |           |            |
|------------------------------------|-----------------------------|-----------|-----------|------------|----------------------------|-----------|-----------|------------|
|                                    | 0.029                       |           |           |            | 0.022                      |           |           |            |
|                                    | weak                        | medium    | strong    | $F$ -stat. | weak                       | medium    | strong    | $F$ -stat. |
| hydropower                         | 5.1 (1.5)                   | 5.1 (1.3) | 5.3 (1.4) | -          | 5.2 (1.4)                  | 5.1 (1.3) | 5.3 (1.5) | -          |
| rooftop solar PV                   | 5.0 (1.6)                   | 5.3 (1.3) | 5.7 (1.2) | -          | 5.0 (1.6)                  | 5.5 (1.2) | 5.6 (1.3) | -          |
| open field solar PV                | 4.8 (1.7)                   | 5.1 (1.3) | 5.5 (1.4) | -          | 4.9 (1.7)                  | 5.2 (1.3) | 5.4 (1.4) | -          |
| onshore wind                       | 4.5 (1.8)                   | 5.0 (1.4) | 5.3 (1.5) | -          | 4.6 (1.7)                  | 5.1 (1.4) | 5.3 (1.5) | -          |
| offshore wind                      | 4.9 (1.8)                   | 5.1 (1.4) | 5.5 (1.4) | -          | 4.9 (1.7)                  | 5.3 (1.3) | 5.3 (1.5) | -          |
| biomass                            | 4.3 (1.6)                   | 4.4 (1.3) | 4.6 (1.4) | -          | 4.4 (1.5)                  | 4.4 (1.2) | 4.6 (1.5) | -          |
| waste incineration                 | 4.0 (1.8)                   | 4.1 (1.4) | 4.2 (1.6) | -          | 4.1 (1.7)                  | 4.0 (1.4) | 4.3 (1.6) | -          |
| nuclear power                      | 3.5 (2.0)                   | 3.7 (1.8) | 3.6 (1.9) | -          | 3.7 (1.9)                  | 3.6 (1.8) | 3.6 (2.0) | -          |
| natural gas                        | 3.6 (1.6)                   | 3.9 (1.5) | 4.3 (1.5) | -          | 3.8 (1.6)                  | 4.0 (1.4) | 4.1 (1.6) | -          |
| coal                               | 3.8 (1.7)                   | 4.0 (1.5) | 4.4 (1.5) | -          | 3.9 (1.7)                  | 4.1 (1.4) | 4.3 (1.7) | -          |
| natural gas with CCS               | 2.7 (1.8)                   | 3.0 (1.6) | 3.0 (1.7) | -          | 2.9 (1.9)                  | 3.0 (1.5) | 3.0 (1.8) | -          |
| coal with CCS                      | 2.9 (1.9)                   | 3.3 (1.6) | 3.4 (1.8) | -          | 3.0 (1.9)                  | 3.3 (1.6) | 3.3 (1.8) | -          |
| net import                         | 2.7 (1.7)                   | 3.3 (1.4) | 3.5 (1.5) | -          | 2.9 (1.7)                  | 3.3 (1.3) | 3.3 (1.6) | -          |
| electricity savings and efficiency | 5.1 (1.5)                   | 5.2 (1.3) | 5.6 (1.3) | -          | 5.1 (1.5)                  | 5.3 (1.3) | 5.6 (1.3) | -          |

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Note: Values range from 1 = strongly disagree to 7 = strongly agree. Statistical significance was calculated with MANCOVA using the respondents' country as a fixed factor and the respondents' demographics, political orientations, and attitudes towards electricity transition and governance as covariates.

## B.9 Consensus among citizens of different demographics and attitudes

Table B11. Effects of demographics and attitudes towards electricity transition on preferred scenarios  
(national)

| Preferred scenarios (national)     | gender                                      |                    |                 |                 | age                                                            |                 |                   |                 |
|------------------------------------|---------------------------------------------|--------------------|-----------------|-----------------|----------------------------------------------------------------|-----------------|-------------------|-----------------|
| Pillai's <i>V</i>                  | 0.072***                                    |                    |                 |                 | 0.063**                                                        |                 |                   |                 |
|                                    | male                                        | female             | <i>F</i> -stat. | 18 – 35         | 36 – 55                                                        | 55 – 69         | <i>F</i> -stat.   |                 |
| hydropower                         | 54 (35)                                     | 62 (35)            | 4.29            | 66 (34)         | 56 (36)                                                        | 51 (34)         | 10.29**           |                 |
| rooftop solar PV                   | 56 (33)                                     | 56 (33)            | 0.25            | 59 (33)         | 56 (33)                                                        | 53 (32)         | 11.54**           |                 |
| open field solar PV                | 62 (32)                                     | 64 (33)            | 0.13            | 68 (32)         | 65 (32)                                                        | 55 (33)         | 2.14              |                 |
| onshore wind                       | 45 (34)                                     | 49 (36)            | 0.71            | 53 (36)         | 45 (35)                                                        | 43 (34)         | 9.98**            |                 |
| offshore wind                      | 59 (31)                                     | 57 (31)            | 0.35            | 62 (31)         | 56 (32)                                                        | 57 (30)         | 3.16              |                 |
| biomass                            | 28 (28)                                     | 34 (30)            | 3.16            | 32 (28)         | 33 (31)                                                        | 28 (26)         | 0.05              |                 |
| waste incineration                 | 32 (30)                                     | 38 (32)            | 5.04*           | 35 (34)         | 35 (30)                                                        | 34 (30)         | 0.11              |                 |
| nuclear power                      | 34 (32)                                     | 22 (27)            | 24.09***        | 27 (32)         | 27 (28)                                                        | 30 (28)         | 1.41              |                 |
| natural gas                        | 15 (17)                                     | 14 (16)            | 0.2             | 13 (15)         | 14 (16)                                                        | 17 (19)         | 7.09**            |                 |
| coal                               | 7 (14)                                      | 8 (13)             | 0.34            | 9 (16)          | 8 (14)                                                         | 6 (9)           | 4.16              |                 |
| natural gas with CCS               | 18 (20)                                     | 19 (19)            | 1.7             | 17 (18)         | 20 (19)                                                        | 19 (22)         | 1.65              |                 |
| coal with CCS                      | 10 (14)                                     | 14 (19)            | 9.91**          | 12 (17)         | 12 (17)                                                        | 12 (17)         | 3.59              |                 |
| net import                         | 4 (12)                                      | 4 (12)             | 0.47            | 4 (13)          | 4 (11)                                                         | 4 (11)          | 0.02              |                 |
| electricity savings and efficiency | 41 (31)                                     | 48 (35)            | 3.68            | 51 (37)         | 44 (33)                                                        | 39 (28)         | 4.49*             |                 |
|                                    | education level                             |                    |                 |                 | political orientation                                          |                 |                   |                 |
| Pillai's <i>V</i>                  | 0.028                                       |                    |                 |                 | 0.014                                                          |                 |                   |                 |
|                                    | primary<br>and lower<br>secondary           | upper<br>secondary | tertiary        | <i>F</i> -stat. | left                                                           | center          | right             | <i>F</i> -stat. |
| hydropower                         | 56 (36)                                     | 55 (36)            | 62 (33)         | -               | 67 (33)                                                        | 55 (36)         | 55 (34)           | -               |
| rooftop solar PV                   | 56 (32)                                     | 54 (34)            | 60 (32)         | -               | 62 (34)                                                        | 56 (33)         | 51 (32)           | -               |
| open field solar PV                | 60 (34)                                     | 62 (33)            | 69 (30)         | -               | 69 (33)                                                        | 63 (33)         | 56 (32)           | -               |
| onshore wind                       | 46 (34)                                     | 46 (35)            | 51 (37)         | -               | 54 (36)                                                        | 46 (35)         | 42 (35)           | -               |
| offshore wind                      | 57 (30)                                     | 56 (32)            | 63 (31)         | -               | 65 (33)                                                        | 57 (31)         | 54 (30)           | -               |
| biomass                            | 28 (28)                                     | 31 (28)            | 37 (31)         | -               | 36 (31)                                                        | 31 (28)         | 27 (27)           | -               |
| waste incineration                 | 32 (28)                                     | 36 (33)            | 37 (33)         | -               | 42 (35)                                                        | 33 (30)         | 32 (30)           | -               |
| nuclear power                      | 26 (28)                                     | 28 (30)            | 30 (32)         | -               | 25 (28)                                                        | 27 (28)         | 35 (32)           | -               |
| natural gas                        | 15 (16)                                     | 16 (18)            | 12 (15)         | -               | 13 (16)                                                        | 14 (17)         | 17 (18)           | -               |
| coal                               | 9 (14)                                      | 8 (14)             | 5 (11)          | -               | 6 (10)                                                         | 7 (13)          | 10 (17)           | -               |
| natural gas with CCS               | 19 (19)                                     | 19 (19)            | 19 (20)         | -               | 19 (20)                                                        | 17 (18)         | 21 (22)           | -               |
| coal with CCS                      | 11 (16)                                     | 13 (18)            | 11 (16)         | -               | 12 (17)                                                        | 11 (16)         | 13 (19)           | -               |
| net import                         | 4 (11)                                      | 3 (11)             | 5 (14)          | -               | 5 (14)                                                         | 4 (13)          | 2 (7)             | -               |
| electricity savings and efficiency | 40 (30)                                     | 45 (34)            | 51 (36)         | -               | 51 (36)                                                        | 43 (32)         | 42 (32)           | -               |
|                                    | prior interest in electricity supply topics |                    |                 |                 | attitudes towards current targets for<br>renewable electricity |                 |                   |                 |
| Pillai's <i>V</i>                  | 0.024                                       |                    |                 |                 | 0.147***                                                       |                 |                   |                 |
|                                    | low                                         | medium             | high            | <i>F</i> -stat. | lower<br>targets                                               | same<br>targets | higher<br>targets | <i>F</i> -stat. |
| hydropower                         | 61 (37)                                     | 56 (35)            | 61 (33)         | -               | 45 (38)                                                        | 51 (35)         | 63 (34)           | 23.01***        |
| rooftop solar PV                   | 57 (34)                                     | 55 (33)            | 59 (32)         | -               | 40 (32)                                                        | 46 (31)         | 64 (32)           | 52.58***        |
| open field solar PV                | 66 (34)                                     | 61 (32)            | 66 (33)         | -               | 47 (32)                                                        | 54 (33)         | 71 (31)           | 50.83***        |
| onshore wind                       | 48 (37)                                     | 46 (35)            | 49 (34)         | -               | 33 (34)                                                        | 36 (32)         | 56 (35)           | 52.45***        |
| offshore wind                      | 57 (33)                                     | 59 (30)            | 60 (33)         | -               | 45 (28)                                                        | 50 (31)         | 65 (30)           | 43.7***         |
| biomass                            | 32 (31)                                     | 32 (28)            | 28 (27)         | -               | 27 (28)                                                        | 30 (27)         | 33 (31)           | 3.14            |
| waste incineration                 | 39 (35)                                     | 35 (30)            | 32 (28)         | -               | 35 (28)                                                        | 32 (28)         | 36 (33)           | 4.41            |
| nuclear power                      | 26 (28)                                     | 28 (31)            | 26 (30)         | -               | 38 (35)                                                        | 31 (30)         | 25 (28)           | 24.28***        |
| natural gas                        | 12 (15)                                     | 14 (16)            | 18 (19)         | -               | 12 (16)                                                        | 18 (18)         | 13 (16)           | 9.69**          |
| coal                               | 7 (14)                                      | 7 (12)             | 9 (17)          | -               | 13 (21)                                                        | 9 (15)          | 6 (11)            | 19.44***        |
| natural gas with CCS               | 15 (19)                                     | 19 (19)            | 21 (22)         | -               | 20 (24)                                                        | 17 (16)         | 19 (20)           | 0.7             |
| coal with CCS                      | 11 (17)                                     | 13 (18)            | 10 (14)         | -               | 11 (18)                                                        | 12 (18)         | 12 (16)           | 0.68            |
| net import                         | 2 (10)                                      | 4 (10)             | 6 (17)          | -               | 5 (14)                                                         | 2 (7)           | 5 (13)            | 0.28            |
| electricity savings and efficiency | 45 (35)                                     | 44 (32)            | 48 (35)         | -               | 43 (34)                                                        | 38 (31)         | 49 (34)           | 9.35**          |

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ . Note: Values denote percentages and range from 0 to 100%.

Statistical significance was calculated with MANCOVA using the respondents' country as a fixed factor and the respondents' demographics, political orientations, and attitudes towards electricity transition and governance as covariates.

Table B12. Effects of *attitudes towards decision-making levels* on preferred scenarios (national)

| Preferred scenarios<br>(national)<br>Pillai's $V$ | attitudes towards<br>decision-making levels<br>(electricity supply)<br>0.017 |         |                | attitudes towards decision-<br>making levels (climate<br>change)<br>- |         |            | attitudes towards<br>decision-making levels<br>(local air pollution)<br>- |         |                |
|---------------------------------------------------|------------------------------------------------------------------------------|---------|----------------|-----------------------------------------------------------------------|---------|------------|---------------------------------------------------------------------------|---------|----------------|
|                                                   | local/<br>national                                                           | EU/UN   | $F$ -<br>stat. | local/<br>national                                                    | EU/UN   | $F$ -stat. | local/<br>national                                                        | EU/UN   | $F$ -<br>stat. |
| hydropower                                        | 56 (36)                                                                      | 61 (33) | -              | 51 (36)                                                               | 60 (35) | -          | 59 (35)                                                                   | 56 (36) | -              |
| rooftop solar PV                                  | 53 (33)                                                                      | 64 (32) | -              | 50 (34)                                                               | 57 (32) | -          | 57 (33)                                                                   | 54 (33) | -              |
| open field solar PV                               | 60 (33)                                                                      | 69 (32) | -              | 56 (35)                                                               | 65 (32) | -          | 65 (31)                                                                   | 60 (35) | -              |
| onshore wind                                      | 44 (35)                                                                      | 53 (35) | -              | 40 (36)                                                               | 49 (35) | -          | 47 (34)                                                                   | 48 (36) | -              |
| offshore wind                                     | 57 (31)                                                                      | 61 (31) | -              | 54 (31)                                                               | 60 (31) | -          | 60 (31)                                                                   | 57 (32) | -              |
| biomass                                           | 32 (30)                                                                      | 31 (28) | -              | 28 (28)                                                               | 32 (28) | -          | 31 (28)                                                                   | 31 (28) | -              |
| waste incineration                                | 35 (31)                                                                      | 35 (32) | -              | 32 (31)                                                               | 36 (31) | -          | 33 (31)                                                                   | 37 (31) | -              |
| nuclear power                                     | 28 (30)                                                                      | 27 (30) | -              | 30 (30)                                                               | 27 (30) | -          | 27 (30)                                                                   | 30 (31) | -              |
| natural gas                                       | 14 (17)                                                                      | 15 (17) | -              | 19 (21)                                                               | 14 (15) | -          | 15 (17)                                                                   | 13 (16) | -              |
| coal                                              | 8 (14)                                                                       | 7 (13)  | -              | 10 (16)                                                               | 7 (13)  | -          | 8 (13)                                                                    | 8 (14)  | -              |
| natural gas with CCS                              | 18 (19)                                                                      | 21 (20) | -              | 18 (20)                                                               | 19 (19) | -          | 19 (20)                                                                   | 17 (19) | -              |
| coal with CCS                                     | 12 (16)                                                                      | 12 (18) | -              | 14 (19)                                                               | 11 (16) | -          | 11 (15)                                                                   | 13 (20) | -              |
| net import                                        | 3 (11)                                                                       | 5 (13)  | -              | 4 (13)                                                                | 4 (11)  | -          | 4 (13)                                                                    | 3 (10)  | -              |
| electricity savings<br>and efficiency             | 44 (34)                                                                      | 46 (33) | -              | 37 (30)                                                               | 47 (34) | -          | 44 (34)                                                                   | 45 (33) | -              |

| Pillai's $V$                          | attitudes towards<br>decision-making levels<br>(land use)<br>- |         |                | attitudes towards decision-<br>making levels (electricity<br>costs)<br>- |         |            | attitudes towards<br>decision-making levels<br>(employment)<br>- |         |                |
|---------------------------------------|----------------------------------------------------------------|---------|----------------|--------------------------------------------------------------------------|---------|------------|------------------------------------------------------------------|---------|----------------|
|                                       | local/<br>national                                             | EU/UN   | $F$ -<br>stat. | local/<br>national                                                       | EU/UN   | $F$ -stat. | local/<br>national                                               | EU/UN   | $F$ -<br>stat. |
| hydropower                            | 60 (35)                                                        | 51 (36) | -              | 59 (36)                                                                  | 55 (34) | -          | 59 (35)                                                          | 54 (36) | -              |
| rooftop solar PV                      | 56 (33)                                                        | 56 (31) | -              | 55 (33)                                                                  | 60 (32) | -          | 56 (33)                                                          | 56 (32) | -              |
| open field solar PV                   | 64 (32)                                                        | 57 (36) | -              | 63 (32)                                                                  | 62 (35) | -          | 64 (33)                                                          | 61 (34) | -              |
| onshore wind                          | 47 (35)                                                        | 47 (35) | -              | 46 (35)                                                                  | 50 (35) | -          | 48 (36)                                                          | 45 (33) | -              |
| offshore wind                         | 60 (31)                                                        | 55 (31) | -              | 59 (31)                                                                  | 59 (31) | -          | 60 (31)                                                          | 55 (30) | -              |
| biomass                               | 30 (28)                                                        | 35 (30) | -              | 31 (30)                                                                  | 31 (28) | -          | 31 (28)                                                          | 31 (28) | -              |
| waste incineration                    | 34 (31)                                                        | 38 (32) | -              | 34 (31)                                                                  | 37 (33) | -          | 35 (31)                                                          | 35 (31) | -              |
| nuclear power                         | 28 (31)                                                        | 27 (28) | -              | 28 (31)                                                                  | 27 (28) | -          | 28 (30)                                                          | 30 (28) | -              |
| natural gas                           | 15 (17)                                                        | 14 (17) | -              | 15 (17)                                                                  | 15 (16) | -          | 15 (17)                                                          | 15 (17) | -              |
| coal                                  | 7 (13)                                                         | 9 (15)  | -              | 7 (13)                                                                   | 9 (14)  | -          | 8 (13)                                                           | 8 (14)  | -              |
| natural gas with CCS                  | 19 (19)                                                        | 19 (21) | -              | 18 (19)                                                                  | 20 (21) | -          | 19 (19)                                                          | 18 (20) | -              |
| coal with CCS                         | 11 (15)                                                        | 15 (22) | -              | 11 (16)                                                                  | 13 (20) | -          | 12 (15)                                                          | 13 (22) | -              |
| net import                            | 4 (11)                                                         | 5 (15)  | -              | 4 (11)                                                                   | 5 (13)  | -          | 4 (12)                                                           | 3 (9)   | -              |
| electricity savings<br>and efficiency | 46 (34)                                                        | 41 (31) | -              | 46 (34)                                                                  | 41 (31) | -          | 46 (34)                                                          | 40 (31) | -              |

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Note: Values denote percentages and range from 0 to 100%. Statistical significance was calculated with MANCOVA using the respondents' country as a fixed factor and the respondents' demographics, political orientations, and attitudes towards electricity transition and governance as covariates.

## B.9 Consensus among citizens of different demographics and attitudes

Table B13. Effects of *attitudes towards the EU membership* and *trust in institutions* on preferred scenarios (national)

| Preferred scenarios<br>(national)<br>Pillai's $V$ | attitudes towards the EU membership |         |          |            | trust in institutions (local) |         |         |            |
|---------------------------------------------------|-------------------------------------|---------|----------|------------|-------------------------------|---------|---------|------------|
|                                                   | 0.041                               |         |          |            | 0.023                         |         |         |            |
|                                                   | negative                            | neutral | positive | $F$ -stat. | low                           | medium  | high    | $F$ -stat. |
| hydropower                                        | 51 (41)                             | 54 (36) | 61 (33)  | -          | 61 (35)                       | 54 (37) | 59 (34) | -          |
| rooftop solar PV                                  | 46 (35)                             | 54 (33) | 60 (32)  | -          | 61 (35)                       | 52 (33) | 57 (32) | -          |
| open field solar PV                               | 55 (36)                             | 61 (33) | 66 (32)  | -          | 66 (33)                       | 60 (34) | 64 (31) | -          |
| onshore wind                                      | 42 (37)                             | 45 (35) | 49 (35)  | -          | 47 (38)                       | 48 (35) | 46 (34) | -          |
| offshore wind                                     | 53 (33)                             | 56 (32) | 61 (30)  | -          | 56 (33)                       | 56 (32) | 61 (30) | -          |
| biomass                                           | 32 (31)                             | 32 (30) | 31 (28)  | -          | 33 (31)                       | 31 (30) | 30 (27) | -          |
| waste incineration                                | 39 (35)                             | 36 (33) | 33 (30)  | -          | 37 (34)                       | 36 (32) | 33 (28) | -          |
| nuclear power                                     | 33 (33)                             | 30 (30) | 26 (28)  | -          | 33 (34)                       | 25 (28) | 28 (28) | -          |
| natural gas                                       | 15 (18)                             | 14 (17) | 15 (16)  | -          | 14 (18)                       | 16 (17) | 14 (16) | -          |
| coal                                              | 8 (16)                              | 9 (14)  | 7 (13)   | -          | 10 (17)                       | 7 (12)  | 7 (12)  | -          |
| natural gas with CCS                              | 18 (22)                             | 16 (18) | 20 (20)  | -          | 18 (21)                       | 19 (20) | 18 (18) | -          |
| coal with CCS                                     | 13 (17)                             | 12 (18) | 12 (16)  | -          | 15 (20)                       | 12 (19) | 10 (13) | -          |
| net import                                        | 3 (10)                              | 3 (11)  | 5 (12)   | -          | 3 (11)                        | 4 (14)  | 4 (10)  | -          |
| electricity savings and efficiency                | 39 (31)                             | 45 (32) | 46 (34)  | -          | 47 (35)                       | 44 (33) | 44 (33) | -          |
| Pillai's $V$                                      | trust in institutions (national)    |         |          |            | trust in institutions (EU)    |         |         |            |
|                                                   | 0.022                               |         |          |            | 0.04                          |         |         |            |
|                                                   | low                                 | medium  | high     | $F$ -stat. | low                           | medium  | high    | $F$ -stat. |
| hydropower                                        | 60 (36)                             | 55 (36) | 59 (33)  | -          | 55 (38)                       | 56 (34) | 62 (34) | -          |
| rooftop solar PV                                  | 59 (34)                             | 54 (33) | 53 (31)  | -          | 55 (35)                       | 53 (32) | 62 (31) | -          |
| open field solar PV                               | 65 (34)                             | 63 (32) | 60 (31)  | -          | 61 (35)                       | 62 (32) | 66 (32) | -          |
| onshore wind                                      | 50 (37)                             | 47 (34) | 43 (33)  | -          | 45 (37)                       | 44 (33) | 53 (36) | -          |
| offshore wind                                     | 60 (33)                             | 56 (32) | 59 (27)  | -          | 57 (33)                       | 56 (31) | 63 (28) | -          |
| biomass                                           | 32 (31)                             | 32 (28) | 28 (27)  | -          | 33 (32)                       | 33 (28) | 28 (26) | -          |
| waste incineration                                | 37 (34)                             | 36 (30) | 30 (27)  | -          | 39 (35)                       | 35 (28) | 30 (28) | -          |
| nuclear power                                     | 32 (32)                             | 24 (28) | 26 (28)  | -          | 31 (33)                       | 27 (28) | 27 (28) | -          |
| natural gas                                       | 16 (18)                             | 14 (17) | 13 (15)  | -          | 13 (17)                       | 15 (17) | 16 (16) | -          |
| coal                                              | 8 (14)                              | 7 (11)  | 8 (16)   | -          | 9 (15)                        | 7 (11)  | 8 (14)  | -          |
| natural gas with CCS                              | 19 (21)                             | 19 (19) | 17 (18)  | -          | 18 (21)                       | 19 (18) | 19 (20) | -          |
| coal with CCS                                     | 13 (18)                             | 12 (18) | 10 (14)  | -          | 13 (19)                       | 12 (16) | 10 (15) | -          |
| net import                                        | 5 (15)                              | 2 (9)   | 4 (9)    | -          | 3 (10)                        | 3 (10)  | 6 (15)  | -          |
| electricity savings and efficiency                | 47 (35)                             | 48 (33) | 38 (31)  | -          | 43 (33)                       | 48 (34) | 43 (33) | -          |
| Pillai's $V$                                      | trust in institutions (UN)          |         |          |            |                               |         |         |            |
|                                                   | -                                   |         |          |            |                               |         |         |            |
|                                                   | low                                 | medium  | high     | $F$ -stat. |                               |         |         |            |
| hydropower                                        | 56 (38)                             | 55 (34) | 62 (34)  | -          |                               |         |         |            |
| rooftop solar PV                                  | 54 (36)                             | 55 (32) | 61 (31)  | -          |                               |         |         |            |
| open field solar PV                               | 60 (35)                             | 64 (32) | 65 (32)  | -          |                               |         |         |            |
| onshore wind                                      | 45 (37)                             | 45 (33) | 51 (36)  | -          |                               |         |         |            |
| offshore wind                                     | 56 (33)                             | 59 (31) | 62 (30)  | -          |                               |         |         |            |
| biomass                                           | 31 (30)                             | 33 (30) | 30 (27)  | -          |                               |         |         |            |
| waste incineration                                | 37 (34)                             | 37 (31) | 31 (28)  | -          |                               |         |         |            |
| nuclear power                                     | 31 (33)                             | 26 (30) | 27 (28)  | -          |                               |         |         |            |
| natural gas                                       | 13 (17)                             | 15 (17) | 16 (16)  | -          |                               |         |         |            |
| coal                                              | 9 (16)                              | 6 (10)  | 8 (14)   | -          |                               |         |         |            |
| natural gas with CCS                              | 17 (20)                             | 19 (19) | 20 (19)  | -          |                               |         |         |            |
| coal with CCS                                     | 12 (18)                             | 13 (18) | 10 (14)  | -          |                               |         |         |            |
| net import                                        | 2 (9)                               | 4 (12)  | 5 (14)   | -          |                               |         |         |            |
| electricity savings and efficiency                | 43 (33)                             | 48 (34) | 42 (33)  | -          |                               |         |         |            |

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ . Note: Values denote percentages and range from 0 to 100%.

Statistical significance was calculated with MANCOVA using the respondents' country as a fixed factor and the respondents' demographics, political orientations, and attitudes towards electricity transition and governance as covariates.

Table B14. Effects of *sense of belonging* on preferred scenarios (national)

| Preferred scenarios<br>(national)<br>Pillai's $V$ | sense of belonging (city)<br>0.028 |          |         |            | sense of belonging (country)<br>0.031 |          |            |            |
|---------------------------------------------------|------------------------------------|----------|---------|------------|---------------------------------------|----------|------------|------------|
|                                                   | weak                               | moderate | strong  | $F$ -stat. | weak                                  | moderate | strong     | $F$ -stat. |
|                                                   |                                    |          |         |            |                                       | e        |            |            |
| hydropower                                        | 62 (35)                            | 53 (38)  | 59 (34) | -          | 63<br>(34)                            | 56 (37)  | 56 (35)    | -          |
| rooftop solar PV                                  | 59 (35)                            | 56 (33)  | 56 (32) | -          | 53 (33)                               | 61 (34)  | 55 (33)    | -          |
| open field solar PV                               | 66 (33)                            | 62 (34)  | 63 (32) | -          | 65 (33)                               | 65 (35)  | 62 (32)    | -          |
| onshore wind                                      | 49 (37)                            | 48 (36)  | 46 (35) | -          | 49 (35)                               | 50 (37)  | 46 (35)    | -          |
| offshore wind                                     | 62 (32)                            | 59 (32)  | 57 (31) | -          | 60 (31)                               | 62 (33)  | 57 (31)    | -          |
| biomass                                           | 34 (33)                            | 36 (31)  | 28 (27) | -          | 28 (28)                               | 35 (32)  | 31 (28)    | -          |
| waste incineration                                | 37 (34)                            | 41 (33)  | 32 (28) | -          | 33 (32)                               | 41 (34)  | 33<br>(30) | -          |
| nuclear power                                     | 30 (33)                            | 26 (28)  | 28 (30) | -          | 32 (31)                               | 26 (32)  | 28 (28)    | -          |
| natural gas                                       | 9 (13)                             | 13 (17)  | 17 (17) | -          | 11 (14)                               | 13 (16)  | 16 (17)    | -          |
| coal                                              | 6 (14)                             | 9 (14)   | 8 (13)  | -          | 9 (16)                                | 8 (15)   | 7 (12)     | -          |
| natural gas with<br>CCS                           | 18 (23)                            | 16 (18)  | 20 (19) | -          | 17 (21)                               | 20 (19)  | 19 (19)    | -          |
| coal with CCS                                     | 14 (21)                            | 13 (19)  | 11 (15) | -          | 13 (18)                               | 13 (19)  | 11 (16)    | -          |
| net import                                        | 3 (12)                             | 4 (12)   | 4 (12)  | -          | 6 (18)                                | 5 (14)   | 3 (9)      | -          |
| electricity savings<br>and efficiency             | 47 (34)                            | 49 (35)  | 43 (32) | -          | 51 (35)                               | 48 (35)  | 43 (32)    | -          |

| Pillai's $V$                          | sense of belonging (Europe)<br>0.035 |          |            |            | sense of belonging (World)<br>0.019 |          |            |            |
|---------------------------------------|--------------------------------------|----------|------------|------------|-------------------------------------|----------|------------|------------|
|                                       | weak                                 | moderate | strong     | $F$ -stat. | weak                                | moderate | strong     | $F$ -stat. |
|                                       |                                      |          |            |            |                                     | e        |            |            |
| hydropower                            | 56 (38)                              | 57 (35)  | 57 (34)    | -          | 57 (36)                             | 59 (35)  | 56 (35)    | -          |
| rooftop solar PV                      | 53 (35)                              | 56 (33)  | 57 (32)    | -          | 56 (34)                             | 56 (33)  | 56 (32)    | -          |
| open field solar PV                   | 60 (34)                              | 64 (33)  | 65 (32)    | -          | 64<br>(33)                          | 61 (34)  | 65 (32)    | -          |
| onshore wind                          | 48 (37)                              | 46 (34)  | 48 (35)    | -          | 45 (37)                             | 47 (35)  | 49<br>(34) | -          |
| offshore wind                         | 56 (32)                              | 60 (30)  | 59 (32)    | -          | 60 (31)                             | 56 (31)  | 59 (31)    | -          |
| biomass                               | 33 (30)                              | 28 (28)  | 32 (28)    | -          | 31 (28)                             | 31 (30)  | 31 (28)    | -          |
| waste incineration                    | 38 (34)                              | 33 (31)  | 34<br>(30) | -          | 36<br>(33)                          | 33 (30)  | 37 (31)    | -          |
| nuclear power                         | 32 (32)                              | 26 (28)  | 27 (30)    | -          | 30 (31)                             | 26 (30)  | 28 (30)    | -          |
| natural gas                           | 11 (15)                              | 14 (17)  | 17 (17)    | -          | 13 (16)                             | 15 (17)  | 16 (17)    | -          |
| coal                                  | 8 (15)                               | 8 (14)   | 7 (12)     | -          | 8 (15)                              | 8 (13)   | 7 (12)     | -          |
| natural gas with<br>CCS               | 18 (21)                              | 18 (18)  | 20 (20)    | -          | 18 (21)                             | 20 (19)  | 18 (18)    | -          |
| coal with CCS                         | 11 (15)                              | 12 (17)  | 12 (18)    | -          | 11 (17)                             | 14 (19)  | 10 (14)    | -          |
| net import                            | 2 (8)                                | 5 (13)   | 5 (13)     | -          | 2 (9)                               | 5 (12)   | 4 (13)     | -          |
| electricity savings<br>and efficiency | 46 (32)                              | 43 (34)  | 46<br>(33) | -          | 43 (32)                             | 43 (33)  | 48 (34)    | -          |

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Note: Values denote percentages and range from 0 to 100%. Statistical significance was calculated with MANCOVA using the respondents' country as a fixed factor and the respondents' demographics, political orientations, and attitudes towards electricity transition and governance as covariates.



## B.9 Consensus among citizens of different demographics and attitudes

Table B15. Effects of demographics and attitudes towards electricity transition on *impact ratings*

| Impact ratings<br>Pillai's <i>V</i> | gender<br>0.032**                                       |                 |                 | age<br>0.009    |                                                                         |              |                 | <i>F</i> -stat. |
|-------------------------------------|---------------------------------------------------------|-----------------|-----------------|-----------------|-------------------------------------------------------------------------|--------------|-----------------|-----------------|
|                                     | male                                                    | female          | <i>F</i> -stat. | 18 – 35         | 36 – 55                                                                 | 55 – 69      | <i>F</i> -stat. |                 |
| climate change                      | 4.0 (1.1)                                               | 4.2 (0.9)       | 9.31**          | 4.1 (1.0)       | 4.1 (1.0)                                                               | 4.1 (1.0)    | -               |                 |
| local air pollution                 | 4.2 (1.0)                                               | 4.2 (1.0)       | 1.9             | 4.1 (1.0)       | 4.3 (1.0)                                                               | 4.2 (0.9)    | -               |                 |
| land use                            | 3.8 (1.0)                                               | 4.0 (0.9)       | 10.93**         | 3.8 (1.1)       | 3.9 (1.0)                                                               | 4.0 (0.9)    | -               |                 |
| electricity costs                   | 4.2 (0.9)                                               | 4.1 (0.9)       | 0.1             | 4.0 (1.0)       | 4.2 (0.8)                                                               | 4.3 (0.9)    | -               |                 |
| employment                          | 3.9 (1.0)                                               | 4.0 (0.9)       | 3               | 3.8 (1.0)       | 3.9 (0.9)                                                               | 4.1 (0.9)    | -               |                 |
| Pillai's <i>V</i>                   | education level<br>0.012                                |                 |                 |                 | political orientation<br>0.017                                          |              |                 |                 |
|                                     | primary and lower secondary                             | upper secondary | tertiary        | <i>F</i> -stat. | left                                                                    | center       | right           | <i>F</i> -stat. |
| climate change                      | 4.0 (1.1)                                               | 4.1 (1.0)       | 4.3 (0.9)       | -               | 4.4 (0.9)                                                               | 4.1 (0.9)    | 3.8 (1.2)       | -               |
| local air pollution                 | 4.1 (1.1)                                               | 4.2 (0.9)       | 4.4 (0.8)       | -               | 4.4 (0.8)                                                               | 4.2 (0.9)    | 3.9 (1.2)       | -               |
| land use                            | 3.9 (1.0)                                               | 3.9 (1.0)       | 4.0 (1.0)       | -               | 4.1 (0.9)                                                               | 3.9 (1.0)    | 3.7 (1.0)       | -               |
| electricity costs                   | 4.2 (0.9)                                               | 4.1 (0.9)       | 4.1 (0.8)       | -               | 4.3 (0.8)                                                               | 4.2 (0.9)    | 4.0 (1.0)       | -               |
| employment                          | 3.9 (1.0)                                               | 4.0 (0.8)       | 3.8 (1.0)       | -               | 4.1 (1.0)                                                               | 3.9 (1.0)    | 3.9 (0.9)       | -               |
| Pillai's <i>V</i>                   | prior interest in electricity supply topics<br>0.029*** |                 |                 |                 | attitudes towards current targets for renewable electricity<br>0.065*** |              |                 |                 |
|                                     | low                                                     | medium          | high            | <i>F</i> -stat. | lower targets                                                           | same targets | higher targets  | <i>F</i> -stat. |
| climate change                      | 3.9 (1.2)                                               | 4.1 (0.9)       | 4.5 (0.9)       | 13.83**<br>*    | 3.8 (1.3)                                                               | 3.7 (1.1)    | 4.4 (0.8)       | 40.42***        |
| local air pollution                 | 4.0 (1.1)                                               | 4.1 (0.9)       | 4.6 (0.7)       | 12.22**         | 3.9 (1.1)                                                               | 3.8 (1.1)    | 4.4 (0.7)       | 34.99***        |
| land use                            | 3.8 (1.1)                                               | 3.8 (0.9)       | 4.2 (1.0)       | 17.59**<br>*    | 3.8 (1.0)                                                               | 3.7 (1.0)    | 4.0 (1.0)       | 12.18**         |
| electricity costs                   | 4.2 (0.8)                                               | 4.0 (0.9)       | 4.5 (0.7)       | 8.1**           | 4.0 (1.0)                                                               | 4.0 (0.9)    | 4.3 (0.8)       | 13.98***        |
| employment                          | 4.0 (0.9)                                               | 3.8 (0.9)       | 4.3 (0.9)       | 7.14**          | 3.6 (1.0)                                                               | 3.8 (0.9)    | 4.0 (0.9)       | 4.8*            |

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Note: Values range from 1 = not important to 5 = very important. Statistical significance was calculated with MANCOVA using the respondents' country as a fixed factor and the respondents' demographics, political orientations, and attitudes towards electricity transition and governance as covariates.

Table B16. Effects of *attitudes towards decision-making levels on impact ratings*

| Impact ratings      | attitudes towards decision-making levels<br>(electricity supply) |           |                 | attitudes towards decision-making levels (climate change)    |           |                 | attitudes towards decision-making levels<br>(local air pollution) |           |                 |
|---------------------|------------------------------------------------------------------|-----------|-----------------|--------------------------------------------------------------|-----------|-----------------|-------------------------------------------------------------------|-----------|-----------------|
|                     | Pillai's <i>V</i>                                                | -         |                 | 0.064***                                                     |           |                 | 0.02                                                              |           |                 |
|                     | local/<br>national                                               | EU/UN     | <i>F</i> -stat. | local/<br>national                                           | EU/UN     | <i>F</i> -stat. | local/<br>national                                                | EU/UN     | <i>F</i> -stat. |
| climate change      | 4.0 (1.1)                                                        | 4.4 (0.8) | -               | 3.5 (1.3)                                                    | 4.3 (0.9) | 28.55***        | 4.0 (1.1)                                                         | 4.3 (0.8) | -               |
| local air pollution | 4.1 (1.0)                                                        | 4.4 (0.8) | -               | 3.7 (1.3)                                                    | 4.3 (0.8) | 26.38***        | 4.1 (1.0)                                                         | 4.3 (0.8) | -               |
| land use            | 3.8 (1.0)                                                        | 4.0 (0.9) | -               | 3.7 (1.1)                                                    | 4.0 (1.0) | 0.79            | 3.8 (1.1)                                                         | 4.1 (0.8) | -               |
| electricity costs   | 4.1 (0.9)                                                        | 4.2 (0.8) | -               | 4.0 (1.1)                                                    | 4.2 (0.8) | 5.88*           | 4.1 (0.9)                                                         | 4.2 (0.8) | -               |
| employment          | 3.9 (0.9)                                                        | 4.0 (0.9) | -               | 3.8 (1.1)                                                    | 4.0 (0.9) | 1.52            | 3.8 (1.0)                                                         | 4.1 (0.8) | -               |
|                     | attitudes towards decision-making levels (land use)              |           |                 | attitudes towards decision-making levels (electricity costs) |           |                 | attitudes towards decision-making levels<br>(employment)          |           |                 |
|                     | Pillai's <i>V</i>                                                | 0.003     |                 | 0.009                                                        |           |                 | 0.005                                                             |           |                 |
|                     | local/<br>national                                               | EU/UN     | <i>F</i> -stat. | local/<br>national                                           | EU/UN     | <i>F</i> -stat. | local/<br>national                                                | EU/UN     | <i>F</i> -stat. |
| climate change      | 4.1 (1.0)                                                        | 4.3 (0.9) | -               | 4.0 (1.0)                                                    | 4.3 (0.9) | -               | 4.1 (1.0)                                                         | 4.3 (0.8) | -               |
| local air pollution | 4.2 (1.0)                                                        | 4.3 (0.8) | -               | 4.2 (1.0)                                                    | 4.3 (0.8) | -               | 4.2 (1.0)                                                         | 4.3 (0.9) | -               |
| land use            | 3.8 (1.0)                                                        | 4.1 (0.8) | -               | 3.9 (1.0)                                                    | 4.0 (0.9) | -               | 3.9 (1.0)                                                         | 4.0 (0.8) | -               |
| electricity costs   | 4.2 (0.9)                                                        | 4.2 (0.9) | -               | 4.2 (0.9)                                                    | 4.1 (0.9) | -               | 4.2 (0.9)                                                         | 4.2 (0.9) | -               |
| employment          | 3.9 (1.0)                                                        | 4.1 (0.9) | -               | 3.9 (1.0)                                                    | 3.9 (0.9) | -               | 3.9 (1.0)                                                         | 4.0 (0.9) | -               |

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ . Note: Values range from 1 = not important to 5 = very important.

Statistical significance was calculated with MANCOVA using the respondents' country as a fixed factor and the respondents' demographics, political orientations, and attitudes towards electricity transition and governance as covariates.

## B.9 Consensus among citizens of different demographics and attitudes

Table B17. Effects of *attitudes towards the EU membership* and *trust in institutions* on *impact ratings*

| Impact ratings<br>Pillai's $V$ | attitudes towards the EU membership<br>0.017 |           |           |            | trust in institutions (local)<br>0.008 |           |           |            |
|--------------------------------|----------------------------------------------|-----------|-----------|------------|----------------------------------------|-----------|-----------|------------|
|                                | negative                                     | neutral   | positive  | $F$ -stat. | low                                    | medium    | high      | $F$ -stat. |
| climate change                 | 3.5 (1.3)                                    | 3.9 (1.0) | 4.3 (0.8) | -          | 3.8 (1.3)                              | 4.0 (1.0) | 4.3 (0.8) | -          |
| local air pollution            | 3.9 (1.2)                                    | 4.0 (1.0) | 4.3 (0.8) | -          | 4.0 (1.2)                              | 4.1 (0.9) | 4.4 (0.8) | -          |
| land use                       | 3.8 (1.2)                                    | 3.8 (1.0) | 4.0 (0.9) | -          | 3.8 (1.2)                              | 3.8 (1.0) | 4.0 (0.9) | -          |
| electricity costs              | 4.4 (0.8)                                    | 4.0 (1.0) | 4.2 (0.8) | -          | 4.3 (0.9)                              | 4.1 (0.9) | 4.2 (0.8) | -          |
| employment                     | 3.8 (1.1)                                    | 3.9 (0.9) | 4.0 (0.9) | -          | 4.0 (1.0)                              | 3.9 (1.0) | 4.0 (0.9) | -          |
| Pillai's $V$                   | trust in institutions (national)<br>0.016    |           |           |            | trust in institutions (EU)<br>0.007    |           |           |            |
|                                | low                                          | medium    | high      | $F$ -stat. | low                                    | medium    | high      | $F$ -stat. |
| climate change                 | 4.0 (1.1)                                    | 4.0 (1.0) | 4.3 (0.9) | -          | 3.9 (1.2)                              | 4.1 (1.0) | 4.4 (0.8) | -          |
| local air pollution            | 4.2 (1.0)                                    | 4.1 (1.0) | 4.3 (0.9) | -          | 4.1 (1.1)                              | 4.1 (1.0) | 4.4 (0.8) | -          |
| land use                       | 3.9 (1.0)                                    | 3.9 (1.0) | 3.9 (1.0) | -          | 3.9 (1.1)                              | 3.8 (1.0) | 4.0 (0.9) | -          |
| electricity costs              | 4.3 (0.8)                                    | 4.0 (1.0) | 4.1 (0.8) | -          | 4.3 (0.9)                              | 4.0 (0.9) | 4.2 (0.8) | -          |
| employment                     | 4.0 (0.9)                                    | 3.8 (1.0) | 3.9 (0.9) | -          | 4.0 (1.0)                              | 3.8 (0.9) | 4.0 (0.9) | -          |
| Pillai's $V$                   | trust in institutions (UN)<br>-              |           |           |            |                                        |           |           |            |
|                                | low                                          | medium    | high      | $F$ -stat. |                                        |           |           |            |
| climate change                 | 3.9 (1.2)                                    | 4.1 (0.9) | 4.4 (0.8) | -          |                                        |           |           |            |
| local air pollution            | 4.1 (1.1)                                    | 4.1 (1.0) | 4.4 (0.8) | -          |                                        |           |           |            |
| land use                       | 3.9 (1.0)                                    | 3.8 (1.0) | 4.0 (1.0) | -          |                                        |           |           |            |
| electricity costs              | 4.3 (1.0)                                    | 4.1 (0.8) | 4.2 (0.8) | -          |                                        |           |           |            |
| employment                     | 3.9 (1.0)                                    | 3.9 (0.9) | 4.0 (0.9) | -          |                                        |           |           |            |

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Note: Values range from 1 = not important to 5 = very important. Statistical significance was calculated with MANCOVA using the respondents' country as a fixed factor and the respondents' demographics, political orientations, and attitudes towards electricity transition and governance as covariates.

Table B18. Effects of *sense of belonging* on *impact ratings*

| Impact ratings<br>Pillai's $V$ | sense of belonging (city)<br>0.003 |           |           |            | sense of belonging (country)<br>0.022* |           |           |            |
|--------------------------------|------------------------------------|-----------|-----------|------------|----------------------------------------|-----------|-----------|------------|
|                                | weak                               | moderate  | strong    | $F$ -stat. | weak                                   | moderate  | strong    | $F$ -stat. |
|                                |                                    |           |           |            |                                        |           |           |            |
| climate change                 | 4.0 (1.2)                          | 4.0 (1.0) | 4.2 (0.9) | -          | 4.0 (1.2)                              | 4.0 (1.0) | 4.2 (1.0) | 0.01       |
| local air pollution            | 4.1 (1.2)                          | 4.0 (1.0) | 4.3 (0.9) | -          | 4.1 (1.2)                              | 4.1 (1.0) | 4.3 (0.9) | 0.51       |
| land use                       | 3.8 (1.2)                          | 3.8 (0.9) | 4.0 (1.0) | -          | 3.7 (1.2)                              | 3.8 (1.0) | 4.0 (0.9) | 4.63*      |
| electricity costs              | 4.1 (1.0)                          | 4.0 (0.9) | 4.2 (0.8) | -          | 4.1 (1.1)                              | 4.1 (0.9) | 4.2 (0.8) | 8.73*      |
| employment                     | 3.8 (1.1)                          | 3.8 (0.9) | 4.0 (0.9) | -          | 3.8 (1.2)                              | 3.8 (0.9) | 4.0 (0.9) | 4.45*      |

| Pillai's $V$        | sense of belonging (Europe)<br>0.014 |           |           |            | sense of belonging (World)<br>0.021* |           |           |            |
|---------------------|--------------------------------------|-----------|-----------|------------|--------------------------------------|-----------|-----------|------------|
|                     | weak                                 | moderate  | strong    | $F$ -stat. | weak                                 | moderate  | strong    | $F$ -stat. |
|                     |                                      |           |           |            |                                      |           |           |            |
| climate change      | 3.8 (1.2)                            | 4.1 (0.9) | 4.3 (0.9) | -          | 3.8 (1.2)                            | 4.1 (0.9) | 4.4 (0.9) | 5.86*      |
| local air pollution | 4.0 (1.2)                            | 4.1 (0.9) | 4.4 (0.8) | -          | 4.0 (1.1)                            | 4.1 (0.9) | 4.5 (0.8) | 1.2        |
| land use            | 3.8 (1.2)                            | 3.9 (0.9) | 4.0 (1.0) | -          | 3.8 (1.1)                            | 3.8 (0.9) | 4.1 (1.0) | 0.18       |
| electricity costs   | 4.3 (0.9)                            | 4.1 (0.8) | 4.2 (0.9) | -          | 4.2 (0.9)                            | 4.2 (0.8) | 4.2 (1.0) | 0.03       |
| employment          | 3.9 (1.1)                            | 3.9 (0.9) | 4.0 (1.0) | -          | 3.8 (1.1)                            | 3.9 (0.9) | 4.1 (0.9) | 5.03*      |

\* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Note: Values range from 1 = not important to 5 = very important. Statistical significance was calculated with MANCOVA using the respondents' country as a fixed factor and the respondents' demographics, political orientations, and attitudes towards electricity transition and governance as covariates.



| % of respondents per education level |          |     |     |                           |     |     |       |     |                                                   |           |     |     |
|--------------------------------------|----------|-----|-----|---------------------------|-----|-----|-------|-----|---------------------------------------------------|-----------|-----|-----|
| Individual technology preferences    |          |     |     |                           |     |     |       |     | Preferred scenarios<br>(used Riskmeter potential) |           |     |     |
|                                      | 1st      | 2nd | 3rd | 1st                       | 2nd | 3rd | 1st   | 2nd | 3rd                                               | 1st       | 2nd | 3rd |
|                                      | disagree |     |     | neither agree or disagree |     |     | agree |     |                                                   | 0 – 33%   |     |     |
|                                      |          |     |     |                           |     |     |       |     |                                                   | 34 – 66%  |     |     |
|                                      |          |     |     |                           |     |     |       |     |                                                   | 67 – 100% |     |     |
| hydropower                           | 9        | 6   | 11  | 26                        | 23  | 13  | 65    | 71  | 76                                                | 29        | 31  | 20  |
| rooftop solar PV                     | 9        | 4   | 3   | 22                        | 22  | 18  | 69    | 74  | 79                                                | 28        | 36  | 22  |
| open field solar PV                  | 11       | 9   | 8   | 22                        | 24  | 21  | 67    | 67  | 71                                                | 27        | 23  | 15  |
| onshore wind                         | 13       | 14  | 10  | 22                        | 25  | 17  | 65    | 61  | 73                                                | 42        | 42  | 39  |
| offshore wind                        | 12       | 7   | 14  | 21                        | 27  | 15  | 67    | 66  | 72                                                | 24        | 30  | 22  |
| biomass                              | 21       | 13  | 17  | 33                        | 44  | 34  | 46    | 43  | 49                                                | 69        | 63  | 55  |
| waste incineration                   | 27       | 26  | 32  | 35                        | 35  | 31  | 37    | 39  | 37                                                | 54        | 56  | 52  |
| nuclear power                        | 45       | 38  | 46  | 23                        | 27  | 17  | 31    | 35  | 37                                                | 69        | 65  | 66  |
| natural gas                          | 28       | 31  | 40  | 34                        | 35  | 32  | 38    | 34  | 28                                                | 83        | 82  | 90  |
| coal                                 | 27       | 24  | 37  | 33                        | 38  | 29  | 39    | 39  | 34                                                | 93        | 95  | 97  |
| natural gas with CCS                 | 52       | 56  | 74  | 26                        | 28  | 16  | 23    | 16  | 10                                                | 80        | 81  | 83  |
| coal with CCS                        | 50       | 48  | 64  | 26                        | 30  | 17  | 24    | 22  | 19                                                | 92        | 90  | 88  |
| net import                           | 42       | 48  | 60  | 34                        | 39  | 28  | 24    | 14  | 12                                                | 97        | 96  | 95  |
| electricity savings and efficiency   | 8        | 4   | 5   | 27                        | 27  | 20  | 65    | 70  | 75                                                | 50        | 47  | 43  |

| % of respondents per political orientation |               |     |     |                    |     |     |                      |     |                                                   |           |     |     |
|--------------------------------------------|---------------|-----|-----|--------------------|-----|-----|----------------------|-----|---------------------------------------------------|-----------|-----|-----|
| Individual technology preferences          |               |     |     |                    |     |     |                      |     | Preferred scenarios<br>(used Riskmeter potential) |           |     |     |
|                                            | 1st           | 2nd | 3rd | 1st                | 2nd | 3rd | 1st                  | 2nd | 3rd                                               | 1st       | 2nd | 3rd |
|                                            | not important |     |     | slightly important |     |     | moderately important |     |                                                   | important |     |     |
|                                            |               |     |     |                    |     |     |                      |     |                                                   |           |     |     |
|                                            |               |     |     |                    |     |     |                      |     |                                                   |           |     |     |
| climate change                             | 4             | 3   | 1   | 8                  | 4   | 3   | 12                   | 15  | 10                                                | 39        | 36  | 33  |
| local air pollution                        | 3             | 1   | 1   | 7                  | 5   | 2   | 9                    | 11  | 9                                                 | 36        | 40  | 35  |
| land use                                   | 3             | 1   | 3   | 7                  | 5   | 6   | 16                   | 25  | 15                                                | 47        | 38  | 43  |
| electricity costs                          | 2             | 1   | 0   | 2                  | 2   | 3   | 10                   | 18  | 18                                                | 40        | 38  | 43  |
| employment                                 | 2             | 0   | 2   | 6                  | 5   | 6   | 19                   | 22  | 23                                                | 41        | 43  | 44  |

Figure B19. Grouping of respondents' *individual technology preferences*, preferred scenarios, and *impact ratings* in terms of *education level*

| % of respondents per political orientation |          |        |       |                           |        |       |       |        |                                                   |           |        |       |
|--------------------------------------------|----------|--------|-------|---------------------------|--------|-------|-------|--------|---------------------------------------------------|-----------|--------|-------|
| Individual technology preferences          |          |        |       |                           |        |       |       |        | Preferred scenarios<br>(used Riskmeter potential) |           |        |       |
|                                            | left     | center | right | left                      | center | right | left  | center | right                                             | left      | center | right |
|                                            | disagree |        |       | neither agree or disagree |        |       | agree |        |                                                   | 0 – 33%   |        |       |
|                                            |          |        |       |                           |        |       |       |        |                                                   | 34 – 66%  |        |       |
|                                            |          |        |       |                           |        |       |       |        |                                                   | 67 – 100% |        |       |
| hydropower                                 | 4        | 8      | 13    | 20                        | 23     | 22    | 76    | 69     | 66                                                | 19        | 32     | 26    |
| rooftop solar PV                           | 5        | 6      | 6     | 14                        | 22     | 26    | 81    | 72     | 68                                                | 21        | 31     | 35    |
| open field solar PV                        | 10       | 8      | 11    | 14                        | 24     | 27    | 76    | 67     | 62                                                | 19        | 20     | 31    |
| onshore wind                               | 12       | 11     | 18    | 15                        | 25     | 21    | 73    | 65     | 61                                                | 33        | 43     | 46    |
| offshore wind                              | 10       | 10     | 13    | 15                        | 24     | 23    | 76    | 66     | 63                                                | 22        | 26     | 30    |
| biomass                                    | 20       | 16     | 16    | 30                        | 39     | 40    | 50    | 44     | 44                                                | 56        | 63     | 69    |
| waste incineration                         | 32       | 27     | 25    | 29                        | 39     | 29    | 39    | 34     | 46                                                | 48        | 54     | 62    |
| nuclear power                              | 50       | 44     | 32    | 17                        | 25     | 23    | 33    | 30     | 45                                                | 73        | 68     | 57    |
| natural gas                                | 40       | 29     | 31    | 28                        | 38     | 31    | 32    | 33     | 38                                                | 87        | 85     | 79    |
| coal                                       | 35       | 26     | 28    | 28                        | 35     | 37    | 37    | 39     | 36                                                | 97        | 95     | 91    |
| natural gas with CCS                       | 72       | 56     | 51    | 14                        | 29     | 24    | 14    | 15     | 25                                                | 83        | 83     | 75    |
| coal with CCS                              | 64       | 50     | 49    | 19                        | 29     | 23    | 17    | 21     | 28                                                | 90        | 92     | 87    |
| net import                                 | 49       | 48     | 50    | 31                        | 37     | 31    | 20    | 15     | 19                                                | 96        | 96     | 98    |
| electricity savings and efficiency         | 3        | 6      | 7     | 20                        | 27     | 25    | 76    | 67     | 67                                                | 42        | 47     | 51    |

| % of respondents per political orientation |               |        |       |                    |        |       |                      |        |                                                   |           |        |       |
|--------------------------------------------|---------------|--------|-------|--------------------|--------|-------|----------------------|--------|---------------------------------------------------|-----------|--------|-------|
| Individual technology preferences          |               |        |       |                    |        |       |                      |        | Preferred scenarios<br>(used Riskmeter potential) |           |        |       |
|                                            | left          | center | right | left               | center | right | left                 | center | right                                             | left      | center | right |
|                                            | not important |        |       | slightly important |        |       | moderately important |        |                                                   | important |        |       |
|                                            |               |        |       |                    |        |       |                      |        |                                                   |           |        |       |
|                                            |               |        |       |                    |        |       |                      |        |                                                   |           |        |       |
| climate change                             | 3             | 2      | 6     | 3                  | 4      | 10    | 6                    | 14     | 16                                                | 31        | 39     | 36    |
| local air pollution                        | 1             | 1      | 6     | 3                  | 4      | 7     | 6                    | 10     | 13                                                | 32        | 40     | 37    |
| land use                                   | 3             | 2      | 4     | 3                  | 6      | 10    | 11                   | 20     | 25                                                | 41        | 45     | 39    |
| electricity costs                          | 1             | 1      | 1     | 1                  | 2      | 5     | 13                   | 16     | 16                                                | 38        | 40     | 43    |
| employment                                 | 3             | 1      | 0     | 4                  | 5      | 7     | 13                   | 23     | 24                                                | 43        | 43     | 41    |

Figure B20. Grouping of respondents' *individual technology preferences*, preferred scenarios, and *impact ratings* in terms of *political orientation*

## B.9 Consensus among citizens of different demographics and attitudes

**% of respondents per prior interest in electricity supply topics**

|                                    | Individual technology preferences |      |      |                           |      |      |       |      |      | Preferred scenarios<br>(used Riskmeter potential) |      |      |          |      |      |           |      |      |
|------------------------------------|-----------------------------------|------|------|---------------------------|------|------|-------|------|------|---------------------------------------------------|------|------|----------|------|------|-----------|------|------|
|                                    | low                               | med. | high | low                       | med. | high | low   | med. | high | low                                               | med. | high | low      | med. | high | low       | med. | high |
|                                    | disagree                          |      |      | neither agree or disagree |      |      | agree |      |      | 0 – 33%                                           |      |      | 34 – 66% |      |      | 67 – 100% |      |      |
| hydropower                         | 7                                 | 9    | 8    | 30                        | 25   | 3    | 63    | 66   | 90   | 27                                                | 29   | 22   | 21       | 27   | 31   | 52        | 43   | 47   |
| rooftop solar PV                   | 7                                 | 6    | 3    | 25                        | 24   | 7    | 68    | 70   | 90   | 30                                                | 30   | 26   | 25       | 33   | 29   | 45        | 37   | 45   |
| open field solar PV                | 16                                | 8    | 8    | 23                        | 26   | 9    | 61    | 65   | 83   | 20                                                | 23   | 23   | 24       | 29   | 17   | 56        | 48   | 60   |
| onshore wind                       | 19                                | 11   | 10   | 22                        | 26   | 7    | 59    | 62   | 83   | 43                                                | 42   | 38   | 22       | 28   | 30   | 35        | 31   | 32   |
| offshore wind                      | 20                                | 9    | 5    | 18                        | 27   | 8    | 62    | 64   | 87   | 24                                                | 25   | 29   | 37       | 33   | 26   | 39        | 42   | 45   |
| biomass                            | 19                                | 17   | 15   | 44                        | 38   | 26   | 37    | 45   | 58   | 61                                                | 62   | 67   | 23       | 24   | 22   | 17        | 14   | 11   |
| waste incineration                 | 31                                | 26   | 30   | 34                        | 37   | 26   | 35    | 37   | 44   | 48                                                | 54   | 62   | 27       | 30   | 23   | 25        | 16   | 15   |
| nuclear power                      | 48                                | 41   | 43   | 28                        | 24   | 14   | 24    | 35   | 42   | 66                                                | 67   | 67   | 22       | 16   | 17   | 12        | 17   | 16   |
| natural gas                        | 40                                | 32   | 26   | 40                        | 36   | 21   | 20    | 32   | 53   | 88                                                | 84   | 81   | 12       | 15   | 15   | 0         | 1    | 3    |
| coal                               | 41                                | 26   | 25   | 42                        | 38   | 14   | 17    | 37   | 61   | 93                                                | 96   | 92   | 6        | 3    | 4    | 1         | 1    | 4    |
| natural gas with CCS               | 61                                | 57   | 64   | 27                        | 28   | 10   | 12    | 15   | 26   | 85                                                | 80   | 78   | 12       | 16   | 16   | 3         | 4    | 6    |
| coal with CCS                      | 61                                | 49   | 57   | 30                        | 29   | 8    | 10    | 22   | 35   | 90                                                | 90   | 92   | 7        | 7    | 8    | 3         | 3    | 1    |
| net import                         | 54                                | 46   | 53   | 37                        | 37   | 25   | 10    | 18   | 23   | 99                                                | 96   | 93   | 0        | 4    | 4    | 1         | 0    | 3    |
| electricity savings and efficiency | 9                                 | 6    | 3    | 31                        | 29   | 7    | 60    | 65   | 91   | 50                                                | 47   | 44   | 23       | 26   | 25   | 27        | 27   | 31   |

| Impact ratings      | low           | med. | high | low                | med. | high | low                  | med. | high | low       | med. | high | low            | med. | high |
|---------------------|---------------|------|------|--------------------|------|------|----------------------|------|------|-----------|------|------|----------------|------|------|
|                     | not important |      |      | slightly important |      |      | moderately important |      |      | important |      |      | very important |      |      |
| climate change      | 8             | 2    | 3    | 6                  | 5    | 3    | 12                   | 16   | 4    | 36        | 39   | 28   | 38             | 38   | 63   |
| local air pollution | 3             | 2    | 0    | 8                  | 4    | 3    | 10                   | 12   | 3    | 37        | 41   | 28   | 42             | 40   | 65   |
| land use            | 4             | 1    | 3    | 11                 | 5    | 3    | 15                   | 23   | 10   | 40        | 45   | 37   | 30             | 24   | 46   |
| electricity costs   | 0             | 2    | 0    | 3                  | 2    | 3    | 14                   | 19   | 5    | 43        | 43   | 28   | 39             | 35   | 64   |
| employment          | 2             | 1    | 2    | 5                  | 6    | 3    | 19                   | 25   | 9    | 43        | 44   | 36   | 30             | 23   | 49   |

Figure B21. Grouping of respondents' *individual technology preferences*, preferred scenarios, and *impact ratings* in terms of *prior interest in electricity supply topics*

**% of respondents per attitudes towards current targets for renewable electricity**

|                                    | Individual technology preferences |      |        |                           |      |        |       |      |        | Preferred scenarios<br>(used Riskmeter potential) |      |        |          |      |        |           |      |        |
|------------------------------------|-----------------------------------|------|--------|---------------------------|------|--------|-------|------|--------|---------------------------------------------------|------|--------|----------|------|--------|-----------|------|--------|
|                                    | lower                             | same | higher | lower                     | same | higher | lower | same | higher | lower                                             | same | higher | lower    | same | higher | lower     | same | higher |
|                                    | disagree                          |      |        | neither agree or disagree |      |        | agree |      |        | 0 – 33%                                           |      |        | 34 – 66% |      |        | 67 – 100% |      |        |
| hydropower                         | 24                                | 8    | 6      | 22                        | 31   | 16     | 54    | 61   | 77     | 44                                                | 34   | 22     | 20       | 29   | 27     | 36        | 38   | 52     |
| rooftop solar PV                   | 20                                | 5    | 4      | 24                        | 33   | 14     | 56    | 63   | 82     | 52                                                | 37   | 22     | 26       | 36   | 28     | 22        | 27   | 50     |
| open field solar PV                | 26                                | 9    | 7      | 28                        | 33   | 16     | 46    | 58   | 77     | 42                                                | 31   | 15     | 24       | 32   | 23     | 34        | 37   | 62     |
| onshore wind                       | 28                                | 13   | 10     | 14                        | 37   | 14     | 58    | 50   | 76     | 66                                                | 57   | 29     | 10       | 24   | 31     | 24        | 19   | 40     |
| offshore wind                      | 22                                | 11   | 9      | 28                        | 36   | 13     | 50    | 53   | 79     | 38                                                | 35   | 19     | 38       | 35   | 30     | 24        | 31   | 51     |
| biomass                            | 30                                | 12   | 18     | 32                        | 47   | 32     | 38    | 41   | 49     | 74                                                | 64   | 61     | 16       | 27   | 23     | 10        | 10   | 16     |
| waste incineration                 | 30                                | 20   | 32     | 28                        | 45   | 29     | 42    | 35   | 39     | 60                                                | 54   | 54     | 26       | 34   | 25     | 14        | 13   | 21     |
| nuclear power                      | 46                                | 31   | 49     | 16                        | 35   | 17     | 38    | 34   | 34     | 50                                                | 62   | 72     | 26       | 19   | 15     | 24        | 18   | 13     |
| natural gas                        | 42                                | 24   | 35     | 28                        | 45   | 28     | 30    | 30   | 37     | 88                                                | 79   | 87     | 10       | 20   | 12     | 2         | 2    | 1      |
| coal                               | 40                                | 20   | 31     | 26                        | 47   | 28     | 34    | 33   | 41     | 84                                                | 93   | 97     | 12       | 6    | 2      | 4         | 2    | 1      |
| natural gas with CCS               | 50                                | 46   | 67     | 24                        | 37   | 17     | 26    | 17   | 16     | 74                                                | 84   | 80     | 16       | 14   | 15     | 10        | 2    | 5      |
| coal with CCS                      | 56                                | 39   | 60     | 26                        | 37   | 19     | 18    | 24   | 21     | 90                                                | 90   | 90     | 8        | 7    | 8      | 2         | 3    | 2      |
| net import                         | 58                                | 40   | 52     | 32                        | 44   | 29     | 10    | 15   | 19     | 94                                                | 99   | 95     | 6        | 1    | 4      | 0         | 0    | 1      |
| electricity savings and efficiency | 16                                | 6    | 4      | 28                        | 39   | 17     | 56    | 56   | 79     | 46                                                | 55   | 43     | 32       | 24   | 25     | 22        | 21   | 32     |

| Impact ratings      | lower         | same | higher | lower              | same | higher | lower                | same | higher | lower     | same | higher | lower          | same | higher |
|---------------------|---------------|------|--------|--------------------|------|--------|----------------------|------|--------|-----------|------|--------|----------------|------|--------|
|                     | not important |      |        | slightly important |      |        | moderately important |      |        | important |      |        | very important |      |        |
| climate change      | 8             | 5    | 1      | 12                 | 8    | 2      | 12                   | 23   | 7      | 32        | 35   | 38     | 36             | 28   | 52     |
| local air pollution | 2             | 4    | 1      | 14                 | 7    | 3      | 14                   | 18   | 5      | 36        | 38   | 37     | 34             | 32   | 55     |
| land use            | 2             | 3    | 2      | 10                 | 7    | 5      | 18                   | 31   | 13     | 50        | 38   | 44     | 20             | 21   | 35     |
| electricity costs   | 2             | 1    | 1      | 4                  | 3    | 2      | 10                   | 24   | 11     | 50        | 38   | 40     | 32             | 34   | 46     |
| employment          | 2             | 1    | 1      | 12                 | 7    | 4      | 24                   | 28   | 17     | 44        | 37   | 45     | 18             | 28   | 32     |

Figure B22. Grouping of respondents' *individual technology preferences*, preferred scenarios, and *impact ratings* in terms of *attitudes towards current targets for renewable electricity*

| % of respondents per attitudes towards decision-making levels (electricity supply) |                    |       |                              |       |                    |                                                   |                    |       |                    |       |                    |       |
|------------------------------------------------------------------------------------|--------------------|-------|------------------------------|-------|--------------------|---------------------------------------------------|--------------------|-------|--------------------|-------|--------------------|-------|
| Individual technology preferences                                                  |                    |       |                              |       |                    | Preferred scenarios<br>(used Riskmeter potential) |                    |       |                    |       |                    |       |
|                                                                                    | local/<br>national | EU/UN | local/<br>national           | EU/UN | local/<br>national | EU/UN                                             | local/<br>national | EU/UN | local/<br>national | EU/UN | local/<br>national | EU/UN |
|                                                                                    | disagree           |       | neither agree or<br>disagree |       | agree              |                                                   | 0 – 33%            |       | 34 – 66%           |       | 67 – 100%          |       |
| hydropower                                                                         | 10                 | 4     | 22                           | 20    | 68                 | 75                                                | 29                 | 24    | 26                 | 29    | 45                 | 48    |
| rooftop solar PV                                                                   | 7                  | 2     | 22                           | 19    | 71                 | 79                                                | 33                 | 22    | 32                 | 28    | 36                 | 50    |
| open field solar PV                                                                | 12                 | 3     | 23                           | 21    | 64                 | 76                                                | 25                 | 17    | 29                 | 20    | 46                 | 63    |
| onshore wind                                                                       | 16                 | 5     | 22                           | 19    | 62                 | 75                                                | 45                 | 34    | 26                 | 28    | 29                 | 38    |
| offshore wind                                                                      | 12                 | 7     | 23                           | 18    | 65                 | 74                                                | 26                 | 25    | 35                 | 27    | 40                 | 48    |
| biomass                                                                            | 18                 | 16    | 37                           | 37    | 45                 | 47                                                | 63                 | 62    | 23                 | 24    | 14                 | 14    |
| waste incineration                                                                 | 28                 | 29    | 36                           | 30    | 36                 | 41                                                | 54                 | 55    | 29                 | 27    | 17                 | 19    |
| nuclear power                                                                      | 47                 | 35    | 23                           | 23    | 30                 | 42                                                | 66                 | 68    | 18                 | 17    | 16                 | 15    |
| natural gas                                                                        | 34                 | 28    | 34                           | 33    | 32                 | 39                                                | 85                 | 83    | 14                 | 15    | 1                  | 2     |
| coal                                                                               | 30                 | 24    | 36                           | 29    | 34                 | 47                                                | 94                 | 95    | 4                  | 3     | 1                  | 2     |
| natural gas with CCS                                                               | 59                 | 59    | 24                           | 24    | 17                 | 17                                                | 82                 | 79    | 15                 | 16    | 3                  | 5     |
| coal with CCS                                                                      | 53                 | 51    | 26                           | 24    | 21                 | 25                                                | 89                 | 92    | 8                  | 5     | 2                  | 3     |
| net import                                                                         | 53                 | 40    | 33                           | 37    | 14                 | 23                                                | 96                 | 96    | 3                  | 3     | 0                  | 1     |
| electricity savings and efficiency                                                 | 8                  | 1     | 26                           | 22    | 66                 | 77                                                | 47                 | 46    | 25                 | 26    | 28                 | 28    |

| Impact ratings      | local/<br>national | EU/UN | local/<br>national | EU/UN | local/<br>national      | EU/UN | local/<br>national | EU/UN | local/<br>national | EU/UN |
|---------------------|--------------------|-------|--------------------|-------|-------------------------|-------|--------------------|-------|--------------------|-------|
|                     | not important      |       | slightly important |       | moderately<br>important |       | important          |       | very important     |       |
| climate change      | 4                  | 1     | 6                  | 2     | 16                      | 6     | 36                 | 36    | 37                 | 55    |
| local air pollution | 2                  | 1     | 7                  | 1     | 11                      | 7     | 37                 | 39    | 43                 | 52    |
| land use            | 2                  | 3     | 8                  | 2     | 20                      | 18    | 42                 | 44    | 28                 | 33    |
| electricity costs   | 1                  | 1     | 3                  | 2     | 16                      | 13    | 39                 | 41    | 41                 | 43    |
| employment          | 1                  | 2     | 7                  | 3     | 20                      | 22    | 43                 | 41    | 29                 | 32    |

Figure B23. Grouping of respondents' *individual technology preferences*, preferred scenarios, and *impact ratings* in terms of *attitudes towards decision-making levels* for electricity supply

| % of respondents per attitudes towards decision-making levels (climate change) |                    |       |                              |       |                    |                                                   |                    |       |                    |       |                    |       |
|--------------------------------------------------------------------------------|--------------------|-------|------------------------------|-------|--------------------|---------------------------------------------------|--------------------|-------|--------------------|-------|--------------------|-------|
| Individual technology preferences                                              |                    |       |                              |       |                    | Preferred scenarios<br>(used Riskmeter potential) |                    |       |                    |       |                    |       |
|                                                                                | local/<br>national | EU/UN | local/<br>national           | EU/UN | local/<br>national | EU/UN                                             | local/<br>national | EU/UN | local/<br>national | EU/UN | local/<br>national | EU/UN |
|                                                                                | disagree           |       | neither agree or<br>disagree |       | agree              |                                                   | 0 – 33%            |       | 34 – 66%           |       | 67 – 100%          |       |
| hydropower                                                                     | 11                 | 8     | 30                           | 19    | 59                 | 73                                                | 34                 | 26    | 27                 | 27    | 39                 | 48    |
| rooftop solar PV                                                               | 6                  | 5     | 26                           | 20    | 68                 | 75                                                | 39                 | 27    | 27                 | 31    | 34                 | 42    |
| open field solar PV                                                            | 16                 | 8     | 27                           | 21    | 57                 | 71                                                | 29                 | 21    | 27                 | 26    | 44                 | 53    |
| onshore wind                                                                   | 19                 | 11    | 24                           | 21    | 56                 | 68                                                | 52                 | 39    | 24                 | 28    | 24                 | 34    |
| offshore wind                                                                  | 15                 | 9     | 27                           | 20    | 57                 | 71                                                | 28                 | 25    | 35                 | 31    | 36                 | 44    |
| biomass                                                                        | 21                 | 16    | 36                           | 37    | 43                 | 47                                                | 69                 | 61    | 20                 | 24    | 10                 | 14    |
| waste incineration                                                             | 30                 | 27    | 37                           | 34    | 33                 | 39                                                | 58                 | 53    | 26                 | 29    | 16                 | 18    |
| nuclear power                                                                  | 42                 | 43    | 28                           | 22    | 30                 | 35                                                | 64                 | 68    | 21                 | 17    | 15                 | 16    |
| natural gas                                                                    | 31                 | 32    | 33                           | 34    | 35                 | 34                                                | 76                 | 87    | 20                 | 13    | 4                  | 0     |
| coal                                                                           | 28                 | 29    | 38                           | 33    | 34                 | 39                                                | 94                 | 95    | 4                  | 4     | 2                  | 1     |
| natural gas with CCS                                                           | 44                 | 63    | 31                           | 22    | 25                 | 15                                                | 81                 | 81    | 16                 | 15    | 2                  | 4     |
| coal with CCS                                                                  | 44                 | 55    | 31                           | 24    | 26                 | 21                                                | 87                 | 91    | 9                  | 7     | 4                  | 2     |
| net import                                                                     | 47                 | 49    | 33                           | 35    | 20                 | 16                                                | 96                 | 96    | 3                  | 3     | 1                  | 1     |
| electricity savings and efficiency                                             | 12                 | 4     | 23                           | 25    | 65                 | 71                                                | 56                 | 45    | 25                 | 25    | 19                 | 30    |

| Impact ratings      | local/<br>national | EU/UN | local/<br>national | EU/UN | local/<br>national      | EU/UN | local/<br>national | EU/UN | local/<br>national | EU/UN |
|---------------------|--------------------|-------|--------------------|-------|-------------------------|-------|--------------------|-------|--------------------|-------|
|                     | not important      |       | slightly important |       | moderately<br>important |       | important          |       | very important     |       |
| climate change      | 9                  | 1     | 14                 | 3     | 22                      | 10    | 31                 | 38    | 25                 | 47    |
| local air pollution | 6                  | 1     | 10                 | 3     | 20                      | 7     | 29                 | 40    | 33                 | 49    |
| land use            | 5                  | 2     | 11                 | 5     | 19                      | 19    | 38                 | 44    | 27                 | 30    |
| electricity costs   | 2                  | 1     | 6                  | 1     | 16                      | 15    | 31                 | 42    | 44                 | 41    |
| employment          | 3                  | 1     | 10                 | 4     | 20                      | 21    | 40                 | 43    | 27                 | 30    |

Figure B24. Grouping of respondents' *individual technology preferences*, preferred scenarios, and *impact ratings* in terms of *attitudes towards decision-making levels* for climate change impacts



## B.9 Consensus among citizens of different demographics and attitudes

| % of respondents per attitudes towards decision-making levels (local air pollution) |                    |       |                              |       |                    |                                                   |                    |       |                    |       |                    |       |
|-------------------------------------------------------------------------------------|--------------------|-------|------------------------------|-------|--------------------|---------------------------------------------------|--------------------|-------|--------------------|-------|--------------------|-------|
| Individual technology preferences                                                   |                    |       |                              |       |                    | Preferred scenarios<br>(used Riskmeter potential) |                    |       |                    |       |                    |       |
|                                                                                     | local/<br>national | EU/UN | local/<br>national           | EU/UN | local/<br>national | EU/UN                                             | local/<br>national | EU/UN | local/<br>national | EU/UN | local/<br>national | EU/UN |
|                                                                                     | disagree           |       | neither agree or<br>disagree |       | agree              |                                                   | 0 – 33%            |       | 34 – 66%           |       | 67 – 100%          |       |
| hydropower                                                                          | 7                  | 10    | 19                           | 25    | 73                 | 65                                                | 26                 | 30    | 27                 | 26    | 47                 | 44    |
| rooftop solar PV                                                                    | 5                  | 6     | 18                           | 26    | 77                 | 68                                                | 27                 | 33    | 32                 | 29    | 41                 | 38    |
| open field solar PV                                                                 | 9                  | 11    | 19                           | 28    | 73                 | 61                                                | 19                 | 27    | 28                 | 22    | 52                 | 51    |
| onshore wind                                                                        | 12                 | 14    | 20                           | 23    | 68                 | 63                                                | 41                 | 42    | 30                 | 22    | 29                 | 36    |
| offshore wind                                                                       | 9                  | 12    | 21                           | 23    | 70                 | 64                                                | 24                 | 28    | 33                 | 31    | 43                 | 41    |
| biomass                                                                             | 18                 | 17    | 36                           | 39    | 47                 | 44                                                | 62                 | 64    | 24                 | 23    | 14                 | 14    |
| waste incineration                                                                  | 32                 | 22    | 34                           | 35    | 34                 | 43                                                | 58                 | 49    | 25                 | 32    | 17                 | 19    |
| nuclear power                                                                       | 45                 | 40    | 22                           | 24    | 33                 | 36                                                | 68                 | 65    | 17                 | 18    | 15                 | 17    |
| natural gas                                                                         | 32                 | 32    | 33                           | 35    | 35                 | 33                                                | 84                 | 86    | 15                 | 14    | 2                  | 0     |
| coal                                                                                | 31                 | 25    | 34                           | 33    | 35                 | 42                                                | 95                 | 94    | 4                  | 5     | 1                  | 1     |
| natural gas with CCS                                                                | 62                 | 54    | 22                           | 27    | 16                 | 19                                                | 78                 | 85    | 18                 | 11    | 4                  | 5     |
| coal with CCS                                                                       | 56                 | 47    | 24                           | 27    | 19                 | 26                                                | 91                 | 89    | 8                  | 7     | 1                  | 4     |
| net import                                                                          | 53                 | 42    | 30                           | 41    | 17                 | 17                                                | 96                 | 97    | 4                  | 3     | 1                  | 0     |
| electricity savings and efficiency                                                  | 5                  | 6     | 22                           | 30    | 73                 | 64                                                | 47                 | 47    | 25                 | 25    | 28                 | 28    |

| Impact ratings      | local/<br>national | EU/UN | local/<br>national | EU/UN | local/<br>national      | EU/UN | local/<br>national | EU/UN | local/<br>national | EU/UN |
|---------------------|--------------------|-------|--------------------|-------|-------------------------|-------|--------------------|-------|--------------------|-------|
|                     | not important      |       | slightly important |       | moderately<br>important |       | important          |       | very important     |       |
| climate change      | 4                  | 1     | 6                  | 3     | 14                      | 11    | 34                 | 40    | 41                 | 45    |
| local air pollution | 2                  | 1     | 5                  | 4     | 13                      | 6     | 35                 | 42    | 45                 | 47    |
| land use            | 3                  | 1     | 8                  | 3     | 20                      | 17    | 41                 | 46    | 27                 | 33    |
| electricity costs   | 1                  | 0     | 3                  | 1     | 16                      | 14    | 39                 | 42    | 41                 | 42    |
| employment          | 2                  | 0     | 7                  | 3     | 22                      | 19    | 42                 | 44    | 27                 | 34    |

Figure B25. Grouping of respondents' *individual technology preferences*, preferred scenarios, and *impact ratings* in terms of *attitudes towards decision-making levels* for local air pollution

| % of respondents per attitudes towards decision-making levels (land use) |                    |       |                              |       |                    |                                                   |                    |       |                    |       |                    |       |
|--------------------------------------------------------------------------|--------------------|-------|------------------------------|-------|--------------------|---------------------------------------------------|--------------------|-------|--------------------|-------|--------------------|-------|
| Individual technology preferences                                        |                    |       |                              |       |                    | Preferred scenarios<br>(used Riskmeter potential) |                    |       |                    |       |                    |       |
|                                                                          | local/<br>national | EU/UN | local/<br>national           | EU/UN | local/<br>national | EU/UN                                             | local/<br>national | EU/UN | local/<br>national | EU/UN | local/<br>national | EU/UN |
|                                                                          | disagree           |       | neither agree or<br>disagree |       | agree              |                                                   | 0 – 33%            |       | 34 – 66%           |       | 67 – 100%          |       |
| hydropower                                                               | 8                  | 10    | 20                           | 26    | 72                 | 64                                                | 26                 | 33    | 26                 | 28    | 48                 | 39    |
| rooftop solar PV                                                         | 5                  | 6     | 20                           | 26    | 75                 | 68                                                | 30                 | 27    | 30                 | 34    | 40                 | 39    |
| open field solar PV                                                      | 9                  | 11    | 21                           | 30    | 70                 | 60                                                | 20                 | 32    | 28                 | 18    | 52                 | 50    |
| onshore wind                                                             | 14                 | 9     | 20                           | 29    | 67                 | 62                                                | 41                 | 40    | 27                 | 27    | 32                 | 32    |
| offshore wind                                                            | 11                 | 8     | 20                           | 28    | 69                 | 64                                                | 25                 | 30    | 32                 | 31    | 43                 | 39    |
| biomass                                                                  | 17                 | 17    | 37                           | 37    | 46                 | 46                                                | 64                 | 58    | 23                 | 26    | 13                 | 17    |
| waste incineration                                                       | 30                 | 18    | 34                           | 35    | 35                 | 47                                                | 56                 | 49    | 27                 | 33    | 18                 | 18    |
| nuclear power                                                            | 44                 | 40    | 22                           | 26    | 34                 | 33                                                | 66                 | 69    | 17                 | 18    | 16                 | 13    |
| natural gas                                                              | 32                 | 32    | 33                           | 36    | 35                 | 31                                                | 85                 | 81    | 14                 | 18    | 1                  | 1     |
| coal                                                                     | 30                 | 21    | 33                           | 37    | 37                 | 41                                                | 96                 | 91    | 3                  | 7     | 1                  | 2     |
| natural gas with CCS                                                     | 62                 | 45    | 23                           | 30    | 15                 | 25                                                | 81                 | 81    | 16                 | 13    | 4                  | 6     |
| coal with CCS                                                            | 57                 | 37    | 24                           | 31    | 20                 | 31                                                | 91                 | 86    | 7                  | 8     | 2                  | 6     |
| net import                                                               | 52                 | 33    | 32                           | 44    | 16                 | 23                                                | 97                 | 94    | 3                  | 4     | 0                  | 2     |
| electricity savings and efficiency                                       | 6                  | 4     | 23                           | 33    | 71                 | 63                                                | 45                 | 55    | 26                 | 22    | 29                 | 23    |

| Impact ratings      | local/<br>national | EU/UN | local/<br>national | EU/UN | local/<br>national      | EU/UN | local/<br>national | EU/UN | local/<br>national | EU/UN |
|---------------------|--------------------|-------|--------------------|-------|-------------------------|-------|--------------------|-------|--------------------|-------|
|                     | not important      |       | slightly important |       | moderately<br>important |       | important          |       | very important     |       |
| climate change      | 3                  | 2     | 6                  | 2     | 14                      | 8     | 35                 | 41    | 42                 | 46    |
| local air pollution | 2                  | 1     | 5                  | 3     | 10                      | 8     | 36                 | 42    | 46                 | 45    |
| land use            | 2                  | 2     | 8                  | 1     | 19                      | 18    | 42                 | 45    | 28                 | 35    |
| electricity costs   | 1                  | 2     | 3                  | 0     | 16                      | 12    | 39                 | 45    | 41                 | 40    |
| employment          | 1                  | 2     | 6                  | 2     | 21                      | 18    | 42                 | 45    | 29                 | 33    |

Figure B26. Grouping of respondents' *individual technology preferences*, preferred scenarios, and *impact ratings* in terms of *attitudes towards decision-making levels* for land use

| % of respondents per attitudes towards decision-making levels (electricity costs) |                    |       |                              |       |                    |                                                   |                    |       |                    |       |                    |       |
|-----------------------------------------------------------------------------------|--------------------|-------|------------------------------|-------|--------------------|---------------------------------------------------|--------------------|-------|--------------------|-------|--------------------|-------|
| Individual technology preferences                                                 |                    |       |                              |       |                    | Preferred scenarios<br>(used Riskmeter potential) |                    |       |                    |       |                    |       |
|                                                                                   | local/<br>national | EU/UN | local/<br>national           | EU/UN | local/<br>national | EU/UN                                             | local/<br>national | EU/UN | local/<br>national | EU/UN | local/<br>national | EU/UN |
|                                                                                   | disagree           |       | neither agree or<br>disagree |       | agree              |                                                   | 0 – 33%            |       | 34 – 66%           |       | 67 – 100%          |       |
| hydropower                                                                        | 8                  | 9     | 20                           | 27    | 72                 | 64                                                | 27                 | 29    | 26                 | 30    | 47                 | 41    |
| rooftop solar PV                                                                  | 7                  | 2     | 20                           | 25    | 74                 | 73                                                | 31                 | 26    | 30                 | 31    | 39                 | 43    |
| open field solar PV                                                               | 11                 | 5     | 20                           | 29    | 69                 | 65                                                | 21                 | 26    | 27                 | 21    | 51                 | 53    |
| onshore wind                                                                      | 14                 | 8     | 20                           | 26    | 66                 | 66                                                | 42                 | 38    | 27                 | 25    | 30                 | 37    |
| offshore wind                                                                     | 12                 | 5     | 20                           | 28    | 68                 | 67                                                | 25                 | 26    | 33                 | 30    | 41                 | 44    |
| biomass                                                                           | 19                 | 12    | 36                           | 41    | 45                 | 47                                                | 63                 | 63    | 23                 | 25    | 14                 | 12    |
| waste incineration                                                                | 30                 | 21    | 34                           | 35    | 35                 | 45                                                | 54                 | 54    | 28                 | 27    | 17                 | 19    |
| nuclear power                                                                     | 44                 | 40    | 23                           | 24    | 33                 | 36                                                | 67                 | 67    | 17                 | 19    | 16                 | 14    |
| natural gas                                                                       | 33                 | 31    | 33                           | 37    | 34                 | 33                                                | 84                 | 85    | 14                 | 15    | 1                  | 1     |
| coal                                                                              | 30                 | 23    | 33                           | 37    | 37                 | 41                                                | 95                 | 93    | 3                  | 6     | 1                  | 1     |
| natural gas with CCS                                                              | 61                 | 51    | 23                           | 28    | 16                 | 21                                                | 81                 | 81    | 16                 | 13    | 3                  | 6     |
| coal with CCS                                                                     | 56                 | 44    | 24                           | 29    | 20                 | 27                                                | 90                 | 89    | 8                  | 7     | 2                  | 4     |
| net import                                                                        | 53                 | 35    | 32                           | 41    | 15                 | 25                                                | 96                 | 95    | 3                  | 3     | 0                  | 1     |
| electricity savings and efficiency                                                | 6                  | 3     | 24                           | 29    | 70                 | 67                                                | 45                 | 53    | 25                 | 26    | 30                 | 21    |

|                     | local/<br>national | EU/UN | local/<br>national | EU/UN | local/<br>national      | EU/UN | local/<br>national | EU/UN | local/<br>national | EU/UN |
|---------------------|--------------------|-------|--------------------|-------|-------------------------|-------|--------------------|-------|--------------------|-------|
| Impact ratings      | not important      |       | slightly important |       | moderately<br>important |       | important          |       | very important     |       |
| climate change      | 4                  | 1     | 6                  | 3     | 13                      | 12    | 37                 | 33    | 40                 | 51    |
| local air pollution | 2                  | 1     | 5                  | 4     | 11                      | 8     | 36                 | 41    | 45                 | 47    |
| land use            | 3                  | 1     | 6                  | 5     | 19                      | 20    | 43                 | 42    | 29                 | 31    |
| electricity costs   | 1                  | 1     | 2                  | 3     | 14                      | 19    | 40                 | 39    | 42                 | 39    |
| employment          | 2                  | 0     | 6                  | 4     | 18                      | 29    | 43                 | 39    | 30                 | 28    |

Figure B27. Grouping of respondents' *individual technology preferences*, preferred scenarios, and *impact ratings* in terms of *attitudes towards decision-making levels* for electricity costs

| % of respondents per attitudes towards decision-making levels (employment) |                    |       |                              |       |                    |                                                   |                    |       |                    |       |                    |       |
|----------------------------------------------------------------------------|--------------------|-------|------------------------------|-------|--------------------|---------------------------------------------------|--------------------|-------|--------------------|-------|--------------------|-------|
| Individual technology preferences                                          |                    |       |                              |       |                    | Preferred scenarios<br>(used Riskmeter potential) |                    |       |                    |       |                    |       |
|                                                                            | local/<br>national | EU/UN | local/<br>national           | EU/UN | local/<br>national | EU/UN                                             | local/<br>national | EU/UN | local/<br>national | EU/UN | local/<br>national | EU/UN |
|                                                                            | disagree           |       | neither agree or<br>disagree |       | agree              |                                                   | 0 – 33%            |       | 34 – 66%           |       | 67 – 100%          |       |
| hydropower                                                                 | 9                  | 5     | 20                           | 30    | 71                 | 65                                                | 27                 | 30    | 26                 | 29    | 47                 | 41    |
| rooftop solar PV                                                           | 6                  | 2     | 19                           | 31    | 75                 | 68                                                | 30                 | 26    | 30                 | 35    | 40                 | 39    |
| open field solar PV                                                        | 10                 | 6     | 20                           | 32    | 70                 | 61                                                | 22                 | 25    | 26                 | 25    | 52                 | 51    |
| onshore wind                                                               | 14                 | 9     | 20                           | 30    | 67                 | 61                                                | 41                 | 43    | 27                 | 28    | 32                 | 29    |
| offshore wind                                                              | 11                 | 7     | 20                           | 31    | 69                 | 62                                                | 25                 | 26    | 31                 | 37    | 43                 | 37    |
| biomass                                                                    | 17                 | 17    | 37                           | 39    | 46                 | 44                                                | 63                 | 64    | 23                 | 24    | 14                 | 12    |
| waste incineration                                                         | 30                 | 18    | 34                           | 35    | 36                 | 47                                                | 54                 | 54    | 28                 | 28    | 18                 | 18    |
| nuclear power                                                              | 45                 | 33    | 22                           | 26    | 33                 | 40                                                | 68                 | 61    | 17                 | 21    | 15                 | 18    |
| natural gas                                                                | 34                 | 25    | 33                           | 39    | 33                 | 36                                                | 84                 | 84    | 15                 | 14    | 1                  | 2     |
| coal                                                                       | 30                 | 23    | 34                           | 34    | 37                 | 43                                                | 95                 | 93    | 3                  | 6     | 1                  | 1     |
| natural gas with CCS                                                       | 61                 | 49    | 23                           | 31    | 16                 | 20                                                | 80                 | 83    | 16                 | 11    | 4                  | 5     |
| coal with CCS                                                              | 55                 | 44    | 24                           | 30    | 21                 | 26                                                | 91                 | 89    | 8                  | 5     | 2                  | 6     |
| net import                                                                 | 52                 | 34    | 32                           | 43    | 16                 | 23                                                | 96                 | 97    | 3                  | 3     | 1                  | 0     |
| electricity savings and efficiency                                         | 6                  | 3     | 24                           | 30    | 70                 | 68                                                | 46                 | 50    | 24                 | 29    | 30                 | 21    |

|                     | local/<br>national | EU/UN | local/<br>national | EU/UN | local/<br>national      | EU/UN | local/<br>national | EU/UN | local/<br>national | EU/UN |
|---------------------|--------------------|-------|--------------------|-------|-------------------------|-------|--------------------|-------|--------------------|-------|
| Impact ratings      | not important      |       | slightly important |       | moderately<br>important |       | important          |       | very important     |       |
| climate change      | 4                  | 0     | 5                  | 4     | 13                      | 12    | 37                 | 34    | 41                 | 50    |
| local air pollution | 2                  | 1     | 5                  | 4     | 10                      | 11    | 38                 | 34    | 44                 | 51    |
| land use            | 3                  | 0     | 7                  | 4     | 18                      | 22    | 43                 | 43    | 29                 | 31    |
| electricity costs   | 1                  | 1     | 3                  | 1     | 15                      | 16    | 39                 | 42    | 42                 | 39    |
| employment          | 2                  | 0     | 6                  | 4     | 20                      | 24    | 43                 | 39    | 29                 | 34    |

Figure B28. Grouping of respondents' *individual technology preferences*, preferred scenarios, and *impact ratings* in terms of *attitudes towards decision-making levels* for employment

## B.9 Consensus among citizens of different demographics and attitudes

| % of respondents per attitudes towards the EU membership |                       |    |    |                           |    |    |                       |    |                                                   |                       |    |    |
|----------------------------------------------------------|-----------------------|----|----|---------------------------|----|----|-----------------------|----|---------------------------------------------------|-----------------------|----|----|
| Individual technology preferences                        |                       |    |    |                           |    |    |                       |    | Preferred scenarios<br>(used Riskmeter potential) |                       |    |    |
|                                                          | negat. neutral posit. |    |    | negat. neutral posit.     |    |    | negat. neutral posit. |    |                                                   | negat. neutral posit. |    |    |
|                                                          | disagree              |    |    | neither agree or disagree |    |    | agree                 |    |                                                   | 0 – 33%               |    |    |
|                                                          | negat. neutral posit. |    |    | negat. neutral posit.     |    |    | negat. neutral posit. |    |                                                   | 34 – 66%              |    |    |
|                                                          | 0 – 33%               |    |    | 34 – 66%                  |    |    | 67 – 100%             |    |                                                   | 67 – 100%             |    |    |
| hydropower                                               | 9                     | 12 | 6  | 22                        | 35 | 15 | 69                    | 53 | 79                                                | 42                    | 31 | 23 |
| rooftop solar PV                                         | 14                    | 6  | 3  | 17                        | 34 | 16 | 69                    | 61 | 81                                                | 45                    | 32 | 25 |
| open field solar PV                                      | 21                    | 15 | 4  | 19                        | 35 | 17 | 60                    | 50 | 79                                                | 35                    | 25 | 19 |
| onshore wind                                             | 27                    | 18 | 7  | 17                        | 31 | 18 | 56                    | 50 | 76                                                | 47                    | 46 | 38 |
| offshore wind                                            | 17                    | 16 | 7  | 18                        | 30 | 18 | 65                    | 54 | 75                                                | 31                    | 28 | 23 |
| biomass                                                  | 22                    | 18 | 16 | 29                        | 46 | 34 | 49                    | 36 | 50                                                | 65                    | 64 | 62 |
| waste incineration                                       | 27                    | 27 | 28 | 23                        | 40 | 34 | 49                    | 33 | 38                                                | 47                    | 54 | 56 |
| nuclear power                                            | 47                    | 42 | 43 | 17                        | 34 | 19 | 36                    | 25 | 38                                                | 58                    | 63 | 70 |
| natural gas                                              | 44                    | 34 | 28 | 25                        | 43 | 32 | 31                    | 23 | 40                                                | 88                    | 83 | 84 |
| coal                                                     | 35                    | 31 | 26 | 31                        | 41 | 31 | 34                    | 28 | 43                                                | 94                    | 93 | 96 |
| natural gas with CCS                                     | 57                    | 51 | 63 | 16                        | 37 | 20 | 27                    | 12 | 17                                                | 79                    | 86 | 79 |
| coal with CCS                                            | 58                    | 47 | 54 | 14                        | 37 | 22 | 27                    | 16 | 24                                                | 87                    | 89 | 91 |
| net import                                               | 66                    | 48 | 45 | 17                        | 44 | 33 | 17                    | 8  | 22                                                | 96                    | 97 | 96 |
| electricity savings and efficiency                       | 6                     | 10 | 3  | 18                        | 35 | 22 | 75                    | 55 | 75                                                | 52                    | 44 | 47 |

| % of respondents per attitudes towards the EU membership |                       |   |   |                       |    |   |                       |    |                                                   |                       |    |    |
|----------------------------------------------------------|-----------------------|---|---|-----------------------|----|---|-----------------------|----|---------------------------------------------------|-----------------------|----|----|
| Individual technology preferences                        |                       |   |   |                       |    |   |                       |    | Preferred scenarios<br>(used Riskmeter potential) |                       |    |    |
|                                                          | negat. neutral posit. |   |   | negat. neutral posit. |    |   | negat. neutral posit. |    |                                                   | negat. neutral posit. |    |    |
|                                                          | not important         |   |   | slightly important    |    |   | moderately important  |    |                                                   | important             |    |    |
|                                                          | negat. neutral posit. |   |   | negat. neutral posit. |    |   | negat. neutral posit. |    |                                                   | negat. neutral posit. |    |    |
|                                                          | not important         |   |   | slightly important    |    |   | moderately important  |    |                                                   | important             |    |    |
| climate change                                           | 12                    | 2 | 2 | 9                     | 10 | 2 | 22                    | 16 | 9                                                 | 29                    | 38 | 38 |
| local air pollution                                      | 4                     | 2 | 1 | 12                    | 7  | 2 | 14                    | 16 | 6                                                 | 27                    | 38 | 39 |
| land use                                                 | 5                     | 1 | 2 | 8                     | 10 | 4 | 23                    | 19 | 18                                                | 26                    | 43 | 46 |
| electricity costs                                        | 0                     | 2 | 1 | 4                     | 3  | 2 | 8                     | 19 | 15                                                | 34                    | 36 | 43 |
| employment                                               | 4                     | 1 | 1 | 9                     | 7  | 4 | 21                    | 23 | 20                                                | 32                    | 40 | 46 |

Figure B29. Grouping of respondents' *individual technology preferences*, preferred scenarios, and *impact ratings* in terms of *attitudes towards the EU membership*

| % of respondents per trust in institutions (local) |               |    |    |                           |    |    |               |    |                                                   |               |    |    |
|----------------------------------------------------|---------------|----|----|---------------------------|----|----|---------------|----|---------------------------------------------------|---------------|----|----|
| Individual technology preferences                  |               |    |    |                           |    |    |               |    | Preferred scenarios<br>(used Riskmeter potential) |               |    |    |
|                                                    | low med. high |    |    | low med. high             |    |    | low med. high |    |                                                   | low med. high |    |    |
|                                                    | disagree      |    |    | neither agree or disagree |    |    | agree         |    |                                                   | 0 – 33%       |    |    |
|                                                    | low med. high |    |    | low med. high             |    |    | low med. high |    |                                                   | 34 – 66%      |    |    |
|                                                    | 0 – 33%       |    |    | 34 – 66%                  |    |    | 67 – 100%     |    |                                                   | 67 – 100%     |    |    |
| hydropower                                         | 12            | 9  | 6  | 25                        | 30 | 13 | 63            | 61 | 81                                                | 23            | 35 | 24 |
| rooftop solar PV                                   | 11            | 6  | 3  | 22                        | 30 | 14 | 67            | 65 | 84                                                | 27            | 34 | 27 |
| open field solar PV                                | 17            | 10 | 6  | 21                        | 29 | 18 | 62            | 61 | 76                                                | 22            | 28 | 18 |
| onshore wind                                       | 21            | 13 | 9  | 19                        | 28 | 17 | 60            | 59 | 74                                                | 42            | 43 | 40 |
| offshore wind                                      | 15            | 11 | 8  | 19                        | 29 | 16 | 65            | 60 | 76                                                | 27            | 28 | 23 |
| biomass                                            | 24            | 15 | 15 | 29                        | 47 | 32 | 47            | 37 | 52                                                | 67            | 65 | 60 |
| waste incineration                                 | 38            | 27 | 24 | 30                        | 40 | 31 | 32            | 32 | 45                                                | 52            | 52 | 58 |
| nuclear power                                      | 48            | 44 | 39 | 19                        | 29 | 20 | 32            | 27 | 41                                                | 60            | 70 | 67 |
| natural gas                                        | 39            | 35 | 27 | 31                        | 35 | 34 | 31            | 30 | 39                                                | 87            | 80 | 86 |
| coal                                               | 36            | 27 | 26 | 28                        | 39 | 32 | 35            | 34 | 42                                                | 90            | 96 | 96 |
| natural gas with CCS                               | 50            | 56 | 66 | 26                        | 30 | 18 | 24            | 14 | 16                                                | 83            | 79 | 81 |
| coal with CCS                                      | 49            | 53 | 55 | 23                        | 31 | 22 | 27            | 17 | 24                                                | 84            | 88 | 95 |
| net import                                         | 55            | 44 | 50 | 31                        | 41 | 30 | 15            | 15 | 20                                                | 97            | 95 | 97 |
| electricity savings and efficiency                 | 12            | 6  | 3  | 20                        | 33 | 21 | 68            | 62 | 76                                                | 45            | 46 | 48 |

| % of respondents per trust in institutions (local) |               |   |   |                    |   |   |                      |    |                                                   |               |    |    |
|----------------------------------------------------|---------------|---|---|--------------------|---|---|----------------------|----|---------------------------------------------------|---------------|----|----|
| Individual technology preferences                  |               |   |   |                    |   |   |                      |    | Preferred scenarios<br>(used Riskmeter potential) |               |    |    |
|                                                    | low med. high |   |   | low med. high      |   |   | low med. high        |    |                                                   | low med. high |    |    |
|                                                    | not important |   |   | slightly important |   |   | moderately important |    |                                                   | important     |    |    |
|                                                    | low med. high |   |   | low med. high      |   |   | low med. high        |    |                                                   | low med. high |    |    |
|                                                    | not important |   |   | slightly important |   |   | moderately important |    |                                                   | important     |    |    |
| climate change                                     | 7             | 2 | 2 | 11                 | 6 | 2 | 15                   | 15 | 10                                                | 27            | 39 | 39 |
| local air pollution                                | 4             | 1 | 1 | 10                 | 6 | 2 | 10                   | 13 | 7                                                 | 31            | 40 | 38 |
| land use                                           | 5             | 2 | 2 | 9                  | 6 | 5 | 15                   | 24 | 17                                                | 37            | 43 | 45 |
| electricity costs                                  | 0             | 2 | 0 | 4                  | 1 | 2 | 10                   | 17 | 16                                                | 31            | 42 | 43 |
| employment                                         | 2             | 2 | 1 | 10                 | 5 | 4 | 15                   | 24 | 21                                                | 36            | 42 | 46 |

Figure B30. Grouping of respondents' *individual technology preferences*, preferred scenarios, and *impact ratings* in terms of *trust in institutions* (local public authorities)

| % of respondents per trust in institutions (national) |          |  |  |  |  |  |  |  |                           |  |  |  |  |  |                                                   |  |          |                    |  |  |  |  |  |  |          |  |                      |  |  |  |  |  |  |          |  |               |  |  |  |  |  |  |          |  |                |  |  |  |  |  |  |  |  |
|-------------------------------------------------------|----------|--|--|--|--|--|--|--|---------------------------|--|--|--|--|--|---------------------------------------------------|--|----------|--------------------|--|--|--|--|--|--|----------|--|----------------------|--|--|--|--|--|--|----------|--|---------------|--|--|--|--|--|--|----------|--|----------------|--|--|--|--|--|--|--|--|
| Individual technology preferences                     |          |  |  |  |  |  |  |  |                           |  |  |  |  |  | Preferred scenarios<br>(used Riskmeter potential) |  |          |                    |  |  |  |  |  |  |          |  |                      |  |  |  |  |  |  |          |  |               |  |  |  |  |  |  |          |  |                |  |  |  |  |  |  |  |  |
| low med. high                                         |          |  |  |  |  |  |  |  | low med. high             |  |  |  |  |  |                                                   |  |          | low med. high      |  |  |  |  |  |  |          |  |                      |  |  |  |  |  |  |          |  |               |  |  |  |  |  |  |          |  |                |  |  |  |  |  |  |  |  |
| disagree                                              |          |  |  |  |  |  |  |  | neither agree or disagree |  |  |  |  |  |                                                   |  |          | agree              |  |  |  |  |  |  |          |  | 0 – 33%              |  |  |  |  |  |  |          |  | 34 – 66%      |  |  |  |  |  |  |          |  | 67 – 100%      |  |  |  |  |  |  |  |  |
| hydropower                                            | 11 7 5   |  |  |  |  |  |  |  | 20 32 13                  |  |  |  |  |  |                                                   |  | 69 61 82 |                    |  |  |  |  |  |  | 28 30 24 |  |                      |  |  |  |  |  |  | 23 28 32 |  |               |  |  |  |  |  |  | 50 42 45 |  |                |  |  |  |  |  |  |  |  |
| rooftop solar PV                                      | 7 5 4    |  |  |  |  |  |  |  | 21 29 12                  |  |  |  |  |  |                                                   |  | 72 66 85 |                    |  |  |  |  |  |  | 28 29 31 |  |                      |  |  |  |  |  |  | 26 33 35 |  |               |  |  |  |  |  |  | 45 38 34 |  |                |  |  |  |  |  |  |  |  |
| open field solar PV                                   | 12 10 5  |  |  |  |  |  |  |  | 21 29 17                  |  |  |  |  |  |                                                   |  | 67 61 77 |                    |  |  |  |  |  |  | 22 21 24 |  |                      |  |  |  |  |  |  | 22 26 32 |  |               |  |  |  |  |  |  | 56 52 45 |  |                |  |  |  |  |  |  |  |  |
| onshore wind                                          | 18 9 9   |  |  |  |  |  |  |  | 17 33 15                  |  |  |  |  |  |                                                   |  | 65 58 76 |                    |  |  |  |  |  |  | 40 40 45 |  |                      |  |  |  |  |  |  | 22 31 30 |  |               |  |  |  |  |  |  | 38 29 24 |  |                |  |  |  |  |  |  |  |  |
| offshore wind                                         | 13 9 8   |  |  |  |  |  |  |  | 19 32 14                  |  |  |  |  |  |                                                   |  | 68 59 78 |                    |  |  |  |  |  |  | 26 28 23 |  |                      |  |  |  |  |  |  | 31 28 38 |  |               |  |  |  |  |  |  | 43 44 38 |  |                |  |  |  |  |  |  |  |  |
| biomass                                               | 22 14 13 |  |  |  |  |  |  |  | 30 49 34                  |  |  |  |  |  |                                                   |  | 48 36 54 |                    |  |  |  |  |  |  | 64 60 63 |  |                      |  |  |  |  |  |  | 20 26 26 |  |               |  |  |  |  |  |  | 16 13 10 |  |                |  |  |  |  |  |  |  |  |
| waste incineration                                    | 36 21 23 |  |  |  |  |  |  |  | 26 45 34                  |  |  |  |  |  |                                                   |  | 38 33 43 |                    |  |  |  |  |  |  | 52 51 62 |  |                      |  |  |  |  |  |  | 26 31 28 |  |               |  |  |  |  |  |  | 23 18 10 |  |                |  |  |  |  |  |  |  |  |
| nuclear power                                         | 44 44 40 |  |  |  |  |  |  |  | 20 30 19                  |  |  |  |  |  |                                                   |  | 36 26 41 |                    |  |  |  |  |  |  | 61 72 69 |  |                      |  |  |  |  |  |  | 20 14 18 |  |               |  |  |  |  |  |  | 19 14 13 |  |                |  |  |  |  |  |  |  |  |
| natural gas                                           | 40 30 22 |  |  |  |  |  |  |  | 28 41 35                  |  |  |  |  |  |                                                   |  | 32 29 43 |                    |  |  |  |  |  |  | 84 83 86 |  |                      |  |  |  |  |  |  | 14 16 14 |  |               |  |  |  |  |  |  | 2 1 0    |  |                |  |  |  |  |  |  |  |  |
| coal                                                  | 35 26 22 |  |  |  |  |  |  |  | 28 41 34                  |  |  |  |  |  |                                                   |  | 37 34 44 |                    |  |  |  |  |  |  | 94 98 93 |  |                      |  |  |  |  |  |  | 6 1 5    |  |               |  |  |  |  |  |  | 1 1 2    |  |                |  |  |  |  |  |  |  |  |
| natural gas with CCS                                  | 60 53 65 |  |  |  |  |  |  |  | 20 34 19                  |  |  |  |  |  |                                                   |  | 20 13 16 |                    |  |  |  |  |  |  | 80 80 84 |  |                      |  |  |  |  |  |  | 16 17 13 |  |               |  |  |  |  |  |  | 5 3 4    |  |                |  |  |  |  |  |  |  |  |
| coal with CCS                                         | 56 47 55 |  |  |  |  |  |  |  | 21 36 20                  |  |  |  |  |  |                                                   |  | 23 18 25 |                    |  |  |  |  |  |  | 89 88 95 |  |                      |  |  |  |  |  |  | 8 9 4    |  |               |  |  |  |  |  |  | 3 3 1    |  |                |  |  |  |  |  |  |  |  |
| net import                                            | 55 41 48 |  |  |  |  |  |  |  | 29 46 29                  |  |  |  |  |  |                                                   |  | 16 13 23 |                    |  |  |  |  |  |  | 94 97 98 |  |                      |  |  |  |  |  |  | 4 3 2    |  |               |  |  |  |  |  |  | 2 0 0    |  |                |  |  |  |  |  |  |  |  |
| electricity savings and efficiency                    | 6 4 6    |  |  |  |  |  |  |  | 22 34 19                  |  |  |  |  |  |                                                   |  | 72 61 75 |                    |  |  |  |  |  |  | 45 42 55 |  |                      |  |  |  |  |  |  | 25 27 23 |  |               |  |  |  |  |  |  | 30 31 21 |  |                |  |  |  |  |  |  |  |  |
|                                                       |          |  |  |  |  |  |  |  |                           |  |  |  |  |  |                                                   |  |          |                    |  |  |  |  |  |  |          |  |                      |  |  |  |  |  |  |          |  |               |  |  |  |  |  |  |          |  |                |  |  |  |  |  |  |  |  |
| low med. high                                         |          |  |  |  |  |  |  |  | low med. high             |  |  |  |  |  |                                                   |  |          | low med. high      |  |  |  |  |  |  |          |  | low med. high        |  |  |  |  |  |  |          |  | low med. high |  |  |  |  |  |  |          |  |                |  |  |  |  |  |  |  |  |
| Impact ratings                                        |          |  |  |  |  |  |  |  | not important             |  |  |  |  |  |                                                   |  |          | slightly important |  |  |  |  |  |  |          |  | moderately important |  |  |  |  |  |  |          |  | important     |  |  |  |  |  |  |          |  | very important |  |  |  |  |  |  |  |  |
| climate change                                        | 5 2 1    |  |  |  |  |  |  |  | 5 6 3                     |  |  |  |  |  |                                                   |  | 12 17 10 |                    |  |  |  |  |  |  | 36 35 38 |  |                      |  |  |  |  |  |  | 42 40 48 |  |               |  |  |  |  |  |  |          |  |                |  |  |  |  |  |  |  |  |
| local air pollution                                   | 2 3 1    |  |  |  |  |  |  |  | 6 4 4                     |  |  |  |  |  |                                                   |  | 8 16 6   |                    |  |  |  |  |  |  | 36 39 38 |  |                      |  |  |  |  |  |  | 48 39 50 |  |               |  |  |  |  |  |  |          |  |                |  |  |  |  |  |  |  |  |
| land use                                              | 2 2 3    |  |  |  |  |  |  |  | 6 7 5                     |  |  |  |  |  |                                                   |  | 16 23 19 |                    |  |  |  |  |  |  | 42 40 47 |  |                      |  |  |  |  |  |  | 33 28 26 |  |               |  |  |  |  |  |  |          |  |                |  |  |  |  |  |  |  |  |
| electricity costs                                     | 0 2 1    |  |  |  |  |  |  |  | 2 3 2                     |  |  |  |  |  |                                                   |  | 10 22 16 |                    |  |  |  |  |  |  | 38 36 47 |  |                      |  |  |  |  |  |  | 49 37 35 |  |               |  |  |  |  |  |  |          |  |                |  |  |  |  |  |  |  |  |
| employment                                            | 1 2 1    |  |  |  |  |  |  |  | 5 7 4                     |  |  |  |  |  |                                                   |  | 17 27 20 |                    |  |  |  |  |  |  | 42 39 48 |  |                      |  |  |  |  |  |  | 34 26 27 |  |               |  |  |  |  |  |  |          |  |                |  |  |  |  |  |  |  |  |

## B.9 Consensus among citizens of different demographics and attitudes

|                                    |  |  | % of respondents per trust in institutions (UN) |      |      |                           |      |      |                      |      |      |                                                   |      |      |                |      |      |
|------------------------------------|--|--|-------------------------------------------------|------|------|---------------------------|------|------|----------------------|------|------|---------------------------------------------------|------|------|----------------|------|------|
|                                    |  |  | Individual technology preferences               |      |      |                           |      |      |                      |      |      | Preferred scenarios<br>(used Riskmeter potential) |      |      |                |      |      |
|                                    |  |  | low                                             | med. | high | low                       | med. | high | low                  | med. | high | low                                               | med. | high | low            | med. | high |
|                                    |  |  | disagree                                        |      |      | neither agree or disagree |      |      | agree                |      |      | 0 – 33%                                           |      |      | 34 – 66%       |      |      |
| hydropower                         |  |  | 12                                              | 9    | 3    | 25                        | 25   | 14   | 63                   | 66   | 82   | 31                                                | 30   | 21   | 23             | 28   | 29   |
| rooftop solar PV                   |  |  | 11                                              | 3    | 3    | 20                        | 27   | 14   | 69                   | 70   | 82   | 35                                                | 30   | 23   | 26             | 31   | 34   |
| open field solar PV                |  |  | 17                                              | 7    | 5    | 21                        | 26   | 19   | 62                   | 67   | 76   | 27                                                | 22   | 18   | 25             | 25   | 28   |
| onshore wind                       |  |  | 25                                              | 10   | 4    | 15                        | 30   | 17   | 60                   | 60   | 79   | 45                                                | 43   | 36   | 22             | 30   | 28   |
| offshore wind                      |  |  | 19                                              | 7    | 6    | 18                        | 28   | 16   | 63                   | 65   | 78   | 29                                                | 25   | 22   | 30             | 32   | 34   |
| biomass                            |  |  | 24                                              | 14   | 14   | 34                        | 43   | 32   | 42                   | 43   | 54   | 69                                                | 59   | 62   | 18             | 26   | 26   |
| waste incineration                 |  |  | 32                                              | 27   | 25   | 29                        | 41   | 31   | 39                   | 32   | 44   | 51                                                | 53   | 59   | 27             | 28   | 28   |
| nuclear power                      |  |  | 50                                              | 43   | 36   | 18                        | 30   | 19   | 32                   | 27   | 45   | 63                                                | 70   | 67   | 18             | 15   | 20   |
| natural gas                        |  |  | 42                                              | 30   | 24   | 29                        | 42   | 28   | 29                   | 27   | 48   | 88                                                | 83   | 82   | 10             | 16   | 18   |
| coal                               |  |  | 39                                              | 24   | 24   | 29                        | 44   | 25   | 33                   | 32   | 51   | 91                                                | 98   | 94   | 6              | 2    | 5    |
| natural gas with CCS               |  |  | 63                                              | 58   | 56   | 21                        | 28   | 22   | 17                   | 14   | 21   | 83                                                | 79   | 81   | 13             | 17   | 15   |
| coal with CCS                      |  |  | 59                                              | 52   | 47   | 20                        | 32   | 22   | 21                   | 16   | 31   | 90                                                | 88   | 94   | 7              | 9    | 5    |
| net import                         |  |  | 62                                              | 45   | 40   | 27                        | 43   | 31   | 11                   | 13   | 29   | 97                                                | 96   | 95   | 3              | 3    | 4    |
| electricity savings and efficiency |  |  | 11                                              | 4    | 2    | 22                        | 31   | 19   | 67                   | 65   | 79   | 47                                                | 43   | 52   | 28             | 24   | 23   |
|                                    |  |  | low                                             | med. | high | low                       | med. | high | low                  | med. | high | low                                               | med. | high | low            | med. | high |
| <b>Impact ratings</b>              |  |  | not important                                   |      |      | slightly important        |      |      | moderately important |      |      | important                                         |      |      | very important |      |      |
| climate change                     |  |  | 6                                               | 2    | 1    | 7                         | 5    | 3    | 17                   | 14   | 6    | 33                                                | 38   | 38   | 37             | 41   | 51   |
| local air pollution                |  |  | 3                                               | 2    | 1    | 7                         | 4    | 3    | 12                   | 13   | 5    | 35                                                | 39   | 38   | 43             | 42   | 53   |
| land use                           |  |  | 2                                               | 2    | 3    | 8                         | 5    | 5    | 17                   | 25   | 13   | 39                                                | 42   | 47   | 33             | 25   | 32   |
| electricity costs                  |  |  | 1                                               | 2    | 1    | 4                         | 0    | 3    | 10                   | 20   | 14   | 33                                                | 44   | 42   | 52             | 34   | 40   |
| employment                         |  |  | 2                                               | 1    | 1    | 8                         | 4    | 5    | 18                   | 25   | 18   | 39                                                | 43   | 45   | 33             | 26   | 31   |

Figure B33. Grouping of respondents' *individual technology preferences*, preferred scenarios, and *impact ratings* in terms of *trust in institutions* (UN)

|                                    |  |  | % of respondents per sense of belonging (city) |      |        |                           |      |        |                      |      |        |                                                   |      |        |                |      |        |
|------------------------------------|--|--|------------------------------------------------|------|--------|---------------------------|------|--------|----------------------|------|--------|---------------------------------------------------|------|--------|----------------|------|--------|
|                                    |  |  | Individual technology preferences              |      |        |                           |      |        |                      |      |        | Preferred scenarios<br>(used Riskmeter potential) |      |        |                |      |        |
|                                    |  |  | weak                                           | mod. | strong | weak                      | mod. | strong | weak                 | mod. | strong | weak                                              | mod. | strong | weak           | mod. | strong |
|                                    |  |  | disagree                                       |      |        | neither agree or disagree |      |        | agree                |      |        | 0 – 33%                                           |      |        | 34 – 66%       |      |        |
| hydropower                         |  |  | 11                                             | 10   | 7      | 27                        | 28   | 18     | 62                   | 63   | 75     | 22                                                | 36   | 26     | 30             | 21   | 28     |
| rooftop solar PV                   |  |  | 11                                             | 5    | 4      | 18                        | 30   | 18     | 71                   | 66   | 77     | 27                                                | 29   | 30     | 31             | 29   | 31     |
| open field solar PV                |  |  | 15                                             | 10   | 8      | 23                        | 28   | 20     | 62                   | 62   | 72     | 18                                                | 26   | 22     | 26             | 22   | 28     |
| onshore wind                       |  |  | 19                                             | 10   | 12     | 23                        | 27   | 19     | 58                   | 63   | 69     | 43                                                | 41   | 41     | 18             | 26   | 29     |
| offshore wind                      |  |  | 15                                             | 11   | 9      | 20                        | 28   | 19     | 65                   | 61   | 72     | 22                                                | 26   | 27     | 30             | 30   | 34     |
| biomass                            |  |  | 28                                             | 14   | 16     | 31                        | 46   | 35     | 41                   | 41   | 49     | 63                                                | 59   | 64     | 17             | 23   | 25     |
| waste incineration                 |  |  | 40                                             | 22   | 27     | 29                        | 39   | 34     | 31                   | 39   | 39     | 52                                                | 48   | 58     | 27             | 28   | 28     |
| nuclear power                      |  |  | 48                                             | 46   | 40     | 24                        | 25   | 22     | 28                   | 29   | 38     | 63                                                | 69   | 67     | 18             | 16   | 18     |
| natural gas                        |  |  | 46                                             | 36   | 27     | 37                        | 38   | 32     | 17                   | 26   | 41     | 94                                                | 83   | 83     | 6              | 16   | 16     |
| coal                               |  |  | 33                                             | 30   | 27     | 37                        | 39   | 31     | 30                   | 32   | 42     | 95                                                | 93   | 95     | 4              | 6    | 3      |
| natural gas with CCS               |  |  | 66                                             | 57   | 58     | 20                        | 29   | 23     | 14                   | 14   | 19     | 80                                                | 88   | 78     | 13             | 10   | 18     |
| coal with CCS                      |  |  | 63                                             | 52   | 50     | 19                        | 26   | 26     | 17                   | 21   | 23     | 85                                                | 88   | 92     | 11             | 8    | 6      |
| net import                         |  |  | 53                                             | 46   | 48     | 34                        | 38   | 33     | 13                   | 16   | 19     | 96                                                | 97   | 96     | 3              | 2    | 4      |
| electricity savings and efficiency |  |  | 10                                             | 6    | 5      | 25                        | 24   | 25     | 66                   | 70   | 70     | 43                                                | 42   | 50     | 28             | 26   | 24     |
|                                    |  |  | weak                                           | mod. | strong | weak                      | mod. | strong | weak                 | mod. | strong | weak                                              | mod. | strong | weak           | mod. | strong |
| <b>Impact ratings</b>              |  |  | not important                                  |      |        | slightly important        |      |        | moderately important |      |        | important                                         |      |        | very important |      |        |
| climate change                     |  |  | 6                                              | 2    | 2      | 8                         | 6    | 4      | 14                   | 17   | 11     | 22                                                | 38   | 40     | 51             | 37   | 43     |
| local air pollution                |  |  | 4                                              | 3    | 1      | 9                         | 5    | 4      | 10                   | 14   | 8      | 27                                                | 40   | 39     | 51             | 37   | 48     |
| land use                           |  |  | 6                                              | 1    | 2      | 12                        | 6    | 5      | 14                   | 24   | 18     | 33                                                | 49   | 42     | 34             | 20   | 32     |
| electricity costs                  |  |  | 2                                              | 2    | 0      | 2                         | 2    | 2      | 16                   | 20   | 13     | 37                                                | 41   | 40     | 42             | 34   | 44     |
| employment                         |  |  | 5                                              | 1    | 0      | 8                         | 7    | 4      | 17                   | 27   | 19     | 40                                                | 43   | 43     | 30             | 22   | 33     |

Figure B34. Grouping of respondents' *individual technology preferences*, preferred scenarios, and *impact ratings* in terms of *sense of belonging* in the respondents' city

|                                    |  | % of respondents per sense of belonging (country) |      |        |                           |      |        |       |      |        |                                                   |      |          |      |           |        |
|------------------------------------|--|---------------------------------------------------|------|--------|---------------------------|------|--------|-------|------|--------|---------------------------------------------------|------|----------|------|-----------|--------|
|                                    |  | Individual technology preferences                 |      |        |                           |      |        |       |      |        | Preferred scenarios<br>(used Riskmeter potential) |      |          |      |           |        |
|                                    |  | weak                                              | mod. | strong | weak                      | mod. | strong | weak  | mod. | strong | weak                                              | mod. | strong   | weak | mod.      | strong |
|                                    |  | disagree                                          |      |        | neither agree or disagree |      |        | agree |      |        | 0 – 33%                                           |      | 34 – 66% |      | 67 – 100% |        |
| hydropower                         |  | 14                                                | 6    | 8      | 23                        | 30   | 18     | 63    | 64   | 74     | 21                                                | 33   | 27       | 29   | 20        | 29     |
| rooftop solar PV                   |  | 13                                                | 4    | 4      | 21                        | 24   | 20     | 67    | 71   | 75     | 35                                                | 26   | 30       | 32   | 26        | 32     |
| open field solar PV                |  | 14                                                | 12   | 8      | 26                        | 24   | 21     | 60    | 64   | 71     | 19                                                | 24   | 22       | 26   | 20        | 28     |
| onshore wind                       |  | 17                                                | 12   | 12     | 23                        | 22   | 21     | 60    | 66   | 67     | 41                                                | 41   | 41       | 23   | 20        | 30     |
| offshore wind                      |  | 13                                                | 13   | 9      | 23                        | 24   | 21     | 64    | 64   | 70     | 24                                                | 24   | 26       | 31   | 29        | 34     |
| biomass                            |  | 23                                                | 19   | 15     | 33                        | 40   | 37     | 44    | 41   | 48     | 65                                                | 66   | 61       | 22   | 16        | 26     |
| waste incineration                 |  | 36                                                | 29   | 26     | 32                        | 36   | 34     | 32    | 36   | 40     | 56                                                | 48   | 56       | 27   | 27        | 28     |
| nuclear power                      |  | 46                                                | 44   | 42     | 24                        | 29   | 20     | 29    | 26   | 38     | 59                                                | 71   | 67       | 26   | 14        | 17     |
| natural gas                        |  | 41                                                | 39   | 28     | 29                        | 36   | 34     | 29    | 25   | 38     | 91                                                | 86   | 83       | 9    | 14        | 16     |
| coal                               |  | 32                                                | 34   | 26     | 32                        | 36   | 33     | 36    | 29   | 41     | 91                                                | 94   | 96       | 8    | 4         | 3      |
| natural gas with CCS               |  | 60                                                | 64   | 57     | 22                        | 26   | 24     | 18    | 11   | 19     | 82                                                | 80   | 81       | 13   | 16        | 15     |
| coal with CCS                      |  | 59                                                | 61   | 49     | 22                        | 24   | 26     | 19    | 15   | 25     | 86                                                | 91   | 91       | 12   | 5         | 7      |
| net import                         |  | 50                                                | 51   | 48     | 29                        | 36   | 34     | 21    | 13   | 18     | 94                                                | 95   | 97       | 3    | 4         | 3      |
| electricity savings and efficiency |  | 9                                                 | 6    | 5      | 26                        | 24   | 25     | 65    | 70   | 70     | 40                                                | 45   | 49       | 27   | 23        | 26     |
|                                    |  | 40                                                | 45   | 49     | 27                        | 23   | 26     | 33    | 32   | 25     |                                                   |      |          |      |           |        |

|                     |  | weak          | mod. | strong | weak               | mod. | strong | weak                 | mod. | strong | weak      | mod. | strong | weak           | mod. | strong |
|---------------------|--|---------------|------|--------|--------------------|------|--------|----------------------|------|--------|-----------|------|--------|----------------|------|--------|
| Impact ratings      |  | not important |      |        | slightly important |      |        | moderately important |      |        | important |      |        | very important |      |        |
| climate change      |  | 5             | 3    | 3      | 9                  | 6    | 4      | 14                   | 12   | 13     | 26        | 40   | 37     | 46             | 39   | 44     |
| local air pollution |  | 5             | 3    | 1      | 8                  | 7    | 3      | 13                   | 12   | 9      | 26        | 36   | 40     | 49             | 42   | 46     |
| land use            |  | 6             | 3    | 1      | 9                  | 8    | 5      | 19                   | 22   | 18     | 35        | 44   | 44     | 31             | 24   | 32     |
| electricity costs   |  | 3             | 2    | 0      | 4                  | 2    | 2      | 18                   | 17   | 14     | 28        | 38   | 43     | 46             | 41   | 40     |
| employment          |  | 5             | 1    | 1      | 9                  | 6    | 4      | 23                   | 24   | 19     | 31        | 44   | 44     | 32             | 24   | 31     |

Figure B35. Grouping of respondents' *individual technology preferences*, preferred scenarios, and *impact ratings* in terms of *sense of belonging* in the respondents' country

|                                    |  | % of respondents per sense of belonging (Europe) |      |        |                           |      |        |       |      |        |                                                   |      |          |      |           |        |
|------------------------------------|--|--------------------------------------------------|------|--------|---------------------------|------|--------|-------|------|--------|---------------------------------------------------|------|----------|------|-----------|--------|
|                                    |  | Individual technology preferences                |      |        |                           |      |        |       |      |        | Preferred scenarios<br>(used Riskmeter potential) |      |          |      |           |        |
|                                    |  | weak                                             | mod. | strong | weak                      | mod. | strong | weak  | mod. | strong | weak                                              | mod. | strong   | weak | mod.      | strong |
|                                    |  | disagree                                         |      |        | neither agree or disagree |      |        | agree |      |        | 0 – 33%                                           |      | 34 – 66% |      | 67 – 100% |        |
| hydropower                         |  | 9                                                | 9    | 7      | 27                        | 21   | 18     | 64    | 70   | 74     | 32                                                | 28   | 24       | 22   | 25        | 31     |
| rooftop solar PV                   |  | 10                                               | 6    | 2      | 25                        | 20   | 20     | 64    | 74   | 78     | 34                                                | 31   | 25       | 29   | 30        | 32     |
| open field solar PV                |  | 16                                               | 10   | 5      | 28                        | 22   | 19     | 56    | 68   | 75     | 25                                                | 23   | 21       | 31   | 23        | 26     |
| onshore wind                       |  | 23                                               | 11   | 8      | 22                        | 24   | 19     | 55    | 66   | 73     | 42                                                | 42   | 40       | 23   | 29        | 28     |
| offshore wind                      |  | 16                                               | 11   | 7      | 23                        | 23   | 20     | 61    | 66   | 74     | 27                                                | 24   | 27       | 32   | 33        | 32     |
| biomass                            |  | 24                                               | 17   | 13     | 37                        | 38   | 36     | 39    | 45   | 50     | 62                                                | 67   | 60       | 23   | 20        | 27     |
| waste incineration                 |  | 29                                               | 27   | 28     | 32                        | 37   | 33     | 38    | 35   | 39     | 47                                                | 57   | 56       | 30   | 28        | 26     |
| nuclear power                      |  | 46                                               | 42   | 42     | 24                        | 24   | 21     | 30    | 34   | 37     | 60                                                | 70   | 68       | 23   | 16        | 16     |
| natural gas                        |  | 44                                               | 35   | 23     | 36                        | 30   | 36     | 20    | 35   | 42     | 88                                                | 84   | 82       | 12   | 14        | 16     |
| coal                               |  | 34                                               | 32   | 22     | 38                        | 33   | 32     | 28    | 35   | 46     | 94                                                | 95   | 95       | 4    | 4         | 4      |
| natural gas with CCS               |  | 66                                               | 56   | 57     | 20                        | 29   | 23     | 14    | 15   | 20     | 80                                                | 85   | 77       | 14   | 12        | 18     |
| coal with CCS                      |  | 62                                               | 49   | 50     | 18                        | 32   | 24     | 19    | 19   | 26     | 89                                                | 91   | 90       | 10   | 6         | 7      |
| net import                         |  | 62                                               | 47   | 42     | 26                        | 36   | 37     | 12    | 17   | 20     | 97                                                | 95   | 97       | 3    | 4         | 3      |
| electricity savings and efficiency |  | 8                                                | 6    | 4      | 26                        | 26   | 23     | 66    | 68   | 73     | 42                                                | 50   | 47       | 29   | 23        | 24     |
|                                    |  | 28                                               | 27   | 29     |                           |      |        |       |      |        |                                                   |      |          |      |           |        |

|                     |  | weak          | mod. | strong | weak               | mod. | strong | weak                 | mod. | strong | weak      | mod. | strong | weak           | mod. | strong |
|---------------------|--|---------------|------|--------|--------------------|------|--------|----------------------|------|--------|-----------|------|--------|----------------|------|--------|
| Impact ratings      |  | not important |      |        | slightly important |      |        | moderately important |      |        | important |      |        | very important |      |        |
| climate change      |  | 6             | 2    | 2      | 7                  | 6    | 3      | 20                   | 13   | 8      | 30        | 43   | 34     | 37             | 36   | 52     |
| local air pollution |  | 5             | 1    | 0      | 8                  | 6    | 2      | 14                   | 12   | 6      | 30        | 42   | 37     | 43             | 38   | 54     |
| land use            |  | 5             | 1    | 2      | 9                  | 7    | 3      | 21                   | 20   | 17     | 33        | 47   | 44     | 32             | 24   | 33     |
| electricity costs   |  | 2             | 0    | 1      | 2                  | 2    | 3      | 12                   | 17   | 16     | 34        | 47   | 37     | 50             | 34   | 43     |
| employment          |  | 4             | 0    | 0      | 5                  | 6    | 5      | 21                   | 23   | 19     | 38        | 47   | 41     | 32             | 24   | 34     |

Figure B36. Grouping of respondents' *individual technology preferences*, preferred scenarios, and *impact ratings* in terms of *sense of belonging* in Europe

Figure B37. Grouping of respondents' *individual technology preferences*, preferred scenarios, and *impact ratings* in terms of *sense of belonging* in the World

**B.9.3. MANCOVA including trust in the UN instead of trust in the EU**Table B19. Statistically significant effects of demographics, political orientations, and attitudes on *individual technology preferences* and preferred scenarios for national electricity supply.

|                                                                    | <i>Individual technology preferences</i><br>(from 1 = strongly disagree to 7 = strongly agree) |                                                                                                                                                                                                                                                                                   | Preferred scenarios<br>(used Riskmeter potential in %) |                                                                                                                                                                                                                                                      |
|--------------------------------------------------------------------|------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                                                    | V                                                                                              | Statistically significant effects ( <i>betas</i> )                                                                                                                                                                                                                                | V                                                      | Statistically significant effects ( <i>betas</i> )                                                                                                                                                                                                   |
| <i>gender</i> (female)                                             | 0.06**                                                                                         | rooftop solar PV (-0.28), open field solar PV (-0.3), offshore wind (-0.4), nuclear power (-0.58)                                                                                                                                                                                 | 0.07***                                                | hydropower (6.2%), waste incineration (5.6%), nuclear power (-12.1%), coal with CCS (4.2%), electricity savings and efficiency (5.6%)                                                                                                                |
| <i>age</i>                                                         | 0.09***                                                                                        | rooftop solar PV (-0.01), onshore wind (-0.01), waste incineration (0.02), natural gas (0.09)                                                                                                                                                                                     | 0.06***                                                | hydropower (-0.4%), rooftop solar PV (-0.3%), onshore wind (-0.3%), natural gas (0.1%), electricity savings and efficiency (-0.2%)                                                                                                                   |
| <i>education level</i>                                             | 0.05***                                                                                        | natural gas (-0.17), coal (-0.24), natural gas with CCS (-0.35), coal with CCS (-0.32), net imports (-0.24)                                                                                                                                                                       | 0.03                                                   | -                                                                                                                                                                                                                                                    |
| <i>political orientation</i>                                       | 0.04                                                                                           | -                                                                                                                                                                                                                                                                                 | 0.02                                                   | -                                                                                                                                                                                                                                                    |
| <i>prior interest in electricity supply topics</i>                 | 0.11***                                                                                        | hydropower (0.03), rooftop solar PV (0.03), open field solar PV (0.03), onshore wind (0.02), offshore wind (0.03), natural gas (0.02), coal (0.03), coal with CCS (0.02), electricity savings and efficiency (0.04)                                                               | 0.02                                                   | -                                                                                                                                                                                                                                                    |
| <i>attitudes towards current targets for renewable electricity</i> | 0.17***                                                                                        | hydropower (0.24), rooftop solar PV (0.03), open field solar PV (0.38), onshore wind (0.3), offshore wind (0.35), nuclear power (-0.48), natural gas (-0.15), natural gas with CCS (-0.42), coal with CCS (-0.32), net imports (-0.17), electricity savings and efficiency (0.34) | 0.15***                                                | hydropower (7.9%), rooftop solar PV (10.8%), open field solar PV (10.7%), onshore wind (11.6%), offshore wind (9.5%), waste incineration (3.1%), nuclear power (-6.7%), natural gas (-2.4%), coal (-2.7%), electricity savings and efficiency (4.8%) |
| <i>attitudes towards decision-making levels electricity supply</i> | 0.03                                                                                           | -                                                                                                                                                                                                                                                                                 | 0.02                                                   | -                                                                                                                                                                                                                                                    |
| <i>attitudes towards the EU membership trust in institutions</i>   | 0.03                                                                                           | -                                                                                                                                                                                                                                                                                 | 0.04                                                   | -                                                                                                                                                                                                                                                    |
| local public authorities                                           | 0.05**                                                                                         | rooftop solar PV (0.07), natural gas with CCS (-0.12), net imports (-0.07)                                                                                                                                                                                                        | 0.02                                                   | -                                                                                                                                                                                                                                                    |
| national government                                                | 0.04                                                                                           | -                                                                                                                                                                                                                                                                                 | 0.02                                                   | -                                                                                                                                                                                                                                                    |
| UN                                                                 | 0.03                                                                                           | -                                                                                                                                                                                                                                                                                 | 0.02                                                   | -                                                                                                                                                                                                                                                    |
| <i>sense of belonging</i>                                          |                                                                                                |                                                                                                                                                                                                                                                                                   |                                                        |                                                                                                                                                                                                                                                      |
| city or region                                                     | 0.01                                                                                           | -                                                                                                                                                                                                                                                                                 | 0.03                                                   | -                                                                                                                                                                                                                                                    |
| country                                                            | 0.03                                                                                           | -                                                                                                                                                                                                                                                                                 | 0.03                                                   | -                                                                                                                                                                                                                                                    |
| Europe                                                             | 0.03                                                                                           | -                                                                                                                                                                                                                                                                                 | 0.03                                                   | -                                                                                                                                                                                                                                                    |
| the World                                                          | 0.02                                                                                           | -                                                                                                                                                                                                                                                                                 | 0.02                                                   | -                                                                                                                                                                                                                                                    |
| country (fixed variable)                                           | 0.32***                                                                                        | -                                                                                                                                                                                                                                                                                 | 0.62***                                                | -                                                                                                                                                                                                                                                    |
| intercept                                                          | 0.31***                                                                                        | -                                                                                                                                                                                                                                                                                 | 0.54***                                                | -                                                                                                                                                                                                                                                    |

Note: \*p < 0.05, \*\*p < 0.01, \*\*\*p < 0.001. Statistical significance was calculated with MANCOVA using the respondents' country as a fixed factor and the respondents' demographics, political orientations, and attitudes towards electricity transition and governance as covariates. In terms of *attitudes towards decision-making levels*, only relevant items were added for each dependent variable, i.e., attitudes towards decisions related to electricity supply for *individual technology preferences* and preferred scenarios and attitudes towards decisions related to impacts for *impact ratings*.



Table B20. Statistically significant effects of demographics, political orientations, and attitudes on *impact ratings*.

|                                                                    | <i>Impact ratings</i><br>(from 1 = not important to 5 = very important) |                                                                                                                 |
|--------------------------------------------------------------------|-------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------|
|                                                                    | <i>V</i>                                                                | Statistically significant effects ( <i>betas</i> )                                                              |
| <i>gender</i>                                                      | 0.03**                                                                  | climate change (0.24), land use (0.26)                                                                          |
| <i>age</i>                                                         | 0.01                                                                    | -                                                                                                               |
| <i>education level</i>                                             | 0.01                                                                    | -                                                                                                               |
| <i>political orientation</i>                                       | 0.02                                                                    | -                                                                                                               |
| <i>prior interest in electricity supply topics</i>                 | 0.04***                                                                 | climate change (0.02), local air pollution (0.02), land use (0.02), electricity costs (0.01), employment (0.01) |
| <i>attitudes towards current targets for renewable electricity</i> | 0.08***                                                                 | climate change (0.27), local air pollution (0.25), land use (0.16), electricity costs (0.15), employment (0.10) |
| <i>attitudes towards decision-making levels</i>                    |                                                                         |                                                                                                                 |
| climate change impacts                                             | 0.06***                                                                 | climate change (0.53), local air pollution (0.51), electricity costs (0.23)                                     |
| local air pollution impacts                                        | 0.02                                                                    | -                                                                                                               |
| land use impacts                                                   | 0.01                                                                    | -                                                                                                               |
| electricity costs impacts                                          | 0.01                                                                    | -                                                                                                               |
| employment impacts                                                 | 0.01                                                                    | -                                                                                                               |
| <i>attitudes towards the EU membership</i>                         | 0.02*                                                                   | climate change (0.14)                                                                                           |
| <i>trust in institutions</i>                                       |                                                                         |                                                                                                                 |
| local public authorities                                           | 0.01                                                                    | -                                                                                                               |
| national government                                                | 0.02*                                                                   | land use (0.05), electricity costs (0.05), employment (0.05)                                                    |
| UN                                                                 | 0.01                                                                    | -                                                                                                               |
| <i>sense of belonging</i>                                          |                                                                         |                                                                                                                 |
| city or region                                                     | 0.01                                                                    | -                                                                                                               |
| country                                                            | 0.02*                                                                   | land use (0.10), electricity costs (0.13), employment (0.10)                                                    |
| Europe                                                             | 0.01                                                                    | -                                                                                                               |
| the World                                                          | 0.02*                                                                   | climate change (0.10), employment (0.10)                                                                        |
| country (fixed variable)                                           | 0.07***                                                                 | n/a                                                                                                             |
| intercept                                                          | 0.18***                                                                 | n/a                                                                                                             |

Note: \* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Statistical significance was calculated with MANCOVA using the respondents' country as a fixed factor and the respondents' demographics, political orientations, and attitudes towards electricity transition and governance as covariates. In terms of *attitudes towards decision-making levels*, only relevant items were added for each dependent variable, i.e., attitudes towards decisions related to electricity supply for *individual technology preferences* and preferred scenarios and attitudes towards decisions related to impacts for *impact ratings*.

## B.10. Shares of electricity supply in preferred Riskmeter scenarios

Table B21. Comparison between electricity supply statistics for 2018 and preferred scenarios for the EU27 for 2035 in terms of shares of the total supply (%)

| Electricity supply sources for the EU27 (% of the total supply) | 2018 statistics (Eurostat, 2020c) | preferred by French            | <i>M (SD)</i><br><i>Median [IQR]</i><br>preferred by German | preferred by Polish            |
|-----------------------------------------------------------------|-----------------------------------|--------------------------------|-------------------------------------------------------------|--------------------------------|
| hydropower                                                      | 12.8                              | 13.2 (2.7)<br>13.3 [11.0,15.7] | 13.1 (2.8)<br>13.4 [10.7,15.7]                              | 12.1 (2.7)<br>11.7 [9.6,14.3]  |
| solar PV                                                        | 4.0                               | 16.8 (6.7)<br>17.8 [12.1,22.9] | 16.9 (6.6)<br>17.6 [11.4,22.7]                              | 15.2 (6.5)<br>15.5 [9.2,20.4]  |
| wind                                                            | 11.0                              | 25.2 (9.4)<br>24.7 [17.2,33.1] | 26.7 (9.9)<br>26.8 [18.8,36.1]                              | 22.7 (9.1)<br>21.6 [14.5,29.0] |
| biomass and waste incineration                                  | 5.9                               | 10.8 (4.3)<br>9.7 [7.6,13.4]   | 10.5 (4.4)<br>9.5 [7.0,13.0]                                | 8.4 (3.2)<br>8.0 [6.2,9.8]     |
| nuclear power                                                   | 26.2                              | 8.7 (9.4)<br>3.7 [1.0,14.5]    | 4.7 (7.3)<br>1.8 [0.2,3.6]                                  | 9.1 (8.7)<br>6.0 [1.8,15.3]    |
| natural gas                                                     | 18.8                              | 7.9 (10.4)<br>3.0 [0.8,12.6]   | 11.4 (11.8)<br>6.9 [1.5,18.7]                               | 12.4 (11.7)<br>8.5 [2.5,20.4]  |
| coal                                                            | 21                                | 4.5 (8.1)<br>1.8 [0.2,3.2]     | 5.5 (8.9)<br>2.1 [0.4,5.6]                                  | 7.2 (10.0)<br>2.9 [1.0,10.3]   |
| fossil fuels with CCS                                           | 0                                 | 10.8 (10.7)<br>7.2 [3.3,16.2]  | 9.3 (8.3)<br>7.1 [2.7,13.8]                                 | 11.6 (10.1)<br>8.2 [3.8,16.7]  |
| net imports                                                     | 0.1                               | -1.7 (6.3)<br>-0.8 [-7.9,1.1]  | -1.5 (6.0)<br>-0.8 [-6.9,1.4]                               | -3.4 (5.7)<br>-3.6 [-9.2,0.6]  |

Table B22. Comparison between electricity supply statistics for 2018 and preferred scenarios for France for 2035 in terms of shares of the total supply (%)

| Electricity supply sources for France (% of the total supply) | 2018 statistics (Eurostat, 2020c) | <i>M (SD)</i><br><i>Median [IQR]</i><br>preferred scenarios |
|---------------------------------------------------------------|-----------------------------------|-------------------------------------------------------------|
| hydropower                                                    | 12.3                              | 12.9 (2.6)<br>12.6 [10.7,15.2]                              |
| solar PV                                                      | 1.8                               | 13.1 (6.5)<br>13.1 [7.5,19.0]                               |
| wind                                                          | 4.9                               | 18.7 (9.2)<br>16.5 [10.1,25.6]                              |
| biomass and waste incineration                                | 1.9                               | 7.4 (4.4)<br>6.0 [4.1,9.8]                                  |
| nuclear power                                                 | 71.3                              | 25.2 (23.0)<br>20.1 [2.7,43.9]                              |
| natural gas                                                   | 6.3                               | 7.6 (10.7)<br>2.4 [0.2,12.1]                                |
| coal                                                          | 1.5                               | 3.6 (6.6)<br>1.7 [0.2,3.1]                                  |
| fossil fuels with CCS                                         | 0                                 | 10.6 (10.6)<br>7.0 [2.8,15.2]                               |
| net imports                                                   | -10.9                             | -4.0 (5.1)<br>-3.0 [-9.1,-0.9]                              |

Table B23. Comparison between electricity supply statistics for 2018 and preferred scenarios for Germany for 2035 in terms of shares of the total supply (%)

| Electricity supply sources for Germany<br>(% of the total supply) | 2018 statistics<br>(Eurostat, 2020c) | <i>M (SD)</i><br><i>Median [IQR]</i><br>preferred scenarios |
|-------------------------------------------------------------------|--------------------------------------|-------------------------------------------------------------|
| hydropower                                                        | 3.8                                  | 6.8 (1.8)<br>6.9 [5.4,8.3]                                  |
| solar PV                                                          | 7.3                                  | 19.1 (6.3)<br>19.5 [14.1,24.6]                              |
| wind                                                              | 17.4                                 | 39.1 (11.1)<br>40.3 [30.9,48.2]                             |
| biomass and waste incineration                                    | 9.1                                  | 11.2 (3.6)<br>10.5 [8.5,13.3]                               |
| nuclear power                                                     | 12.1                                 | 2.1 (3.2)<br>0.7 [0.0,3.1]                                  |
| natural gas                                                       | 14.1                                 | 8.4 (9.9)<br>3.4 [1.1,13.5]                                 |
| coal                                                              | 36.2                                 | 4.5 (8.8)<br>1.7 [0.3,3.3]                                  |
| fossil fuels with CCS                                             | 0                                    | 7.5 (6.5)<br>5.4 [2.8,11.8]                                 |
| net imports                                                       | -7.7                                 | -2.2 (5.9)<br>-1.0 [-9.0,1.0]                               |

Table B24. Comparison between electricity supply statistics for 2018 and preferred scenarios for Poland for 2035 in terms of shares of the total supply (%)

| Electricity supply sources for Poland<br>(% of the total supply) | 2018 statistics<br>(Eurostat, 2020c) | <i>M (SD)</i><br><i>Median [IQR]</i><br>preferred scenarios |
|------------------------------------------------------------------|--------------------------------------|-------------------------------------------------------------|
| hydropower                                                       | 1.4                                  | 2.9 (1.0)<br>2.8 [2.1,3.8]                                  |
| solar PV                                                         | 0.2                                  | 10.5 (4.9)<br>11.3 [6.7,14.8]                               |
| wind                                                             | 7.6                                  | 22.7 (9.9)<br>22.3 [12.6,32.1]                              |
| biomass and waste incineration                                   | 4.2                                  | 7.3 (4.0)<br>6.0 [4.5,9.0]                                  |
| nuclear power                                                    | 0                                    | 7.5 (7.0)<br>5.4 [1.6,11.8]                                 |
| natural gas                                                      | 8.6                                  | 19.1 (15.8)<br>18.5 [3.3,29.1]                              |
| coal                                                             | 78.0                                 | 10.1 (13.6)<br>3.8 [1.1,14.4]                               |
| fossil fuels with CCS                                            | 0                                    | 17.4 (12.4)<br>15.5 [8.5,23.5]                              |
| net imports                                                      | 0.1                                  | -2.1 (7.8)<br>-3.0 [-9.2,1.6]                               |

## Appendix C      Supplementary materials for Chapter 5

Table C1. Details of reviewed scenario studies for France

| Pub.<br>year | Number of<br>scenarios<br>reviewed | Reference                       | Organization type                    | Publication<br>type | Year(s) for<br>which scenario<br>results were<br>extracted |
|--------------|------------------------------------|---------------------------------|--------------------------------------|---------------------|------------------------------------------------------------|
| 2020         | 2                                  | (McGowan et al., 2019)          | public organization                  | report              | (2030-2040)                                                |
| 2020         | 1                                  | (Milot et al., 2020)            | academia or research<br>organization | journal article     | (2030-2040)                                                |
| 2020         | 10                                 | (Seck et al., 2020)             | academia or research<br>organization | journal article     | (2030-2040)                                                |
| 2020         | 4                                  | (Sasse and<br>Trutnevyte, 2020) | academia or research<br>organization | journal article     | 2035                                                       |
| 2018         | 5                                  | (Collins et al.,<br>2018a)      | academia or research<br>organization | journal article     | (2015-2030)                                                |
| 2018         | 1                                  | (Association<br>négaWatt, 2017) | NGO, platform or<br>network          | report              | (2030-2040)                                                |
| 2017         | 1                                  | (ANCRE, 2017)                   | academia or research<br>organization | report              | (2030-2040)                                                |
| 2017         | 4                                  | (RTE, 2017)                     | public organization                  | report              | (2030-2040)                                                |
| 2016         | 2                                  | (IRENA, 2016)                   | NGO, platform or<br>network          | report              | (2010-2030)                                                |
| 2016         | 4                                  | (ADEME, 2016)                   | NGO, platform or<br>network          | report              | 2035                                                       |
| 2016         | 3                                  | (Maire et al., 2015)            | academia or research<br>organization | report              | 2035                                                       |
| 2016         | 1                                  | (European<br>Commission, 2016)  | public organization                  | report              | (2030-2040)                                                |
| 2016         | 13                                 | (Krakowski et al.,<br>2016)     | academia or research<br>organization | journal article     | (2030-2040)                                                |
| 2015         | 2                                  | (Criqui et al., 2015)           | academia or research<br>organization | report              | 2035                                                       |
| 2014         | 3                                  | (Maïzi and<br>Assoumou, 2014)   | academia or research<br>organization | journal article     | 2035                                                       |

## C.1. Details of reviewed scenario studies (model-based)

|      |   |                                       |                                          |        |             |
|------|---|---------------------------------------|------------------------------------------|--------|-------------|
| 2014 | 4 | (Grandjean et al., 2014)              | public organization                      | report | (2030-2040) |
| 2013 | 1 | (Greenpeace, 2013a)                   | NGO, platform or network                 | report | 2035        |
| 2013 | 1 | (Association négaWatt, 2011)          | NGO, platform or network                 | report | 2035        |
| 2013 | 3 | (ADEME, 2013)                         | NGO, platform or network                 | report | (2030-2040) |
| 2013 | 4 | (Alazard-Toux et al., 2013)           | academia or research organization        | report | (2030-2040) |
| 2012 | 1 | (Bibas et al., 2012)                  | NGO, platform or network                 | report | 2035        |
| 2011 | 5 | (Centre d'Analyse Stratégique, 2012)† | Company (AREVA)                          | report | (2010-2030) |
| 2011 | 2 | (Centre d'Analyse Stratégique, 2012)† | public organization (CEA)                | report | (2010-2030) |
| 2011 | 4 | (Centre d'Analyse Stratégique, 2012)† | public organization (Enerdata)           | report | (2010-2030) |
| 2011 | 1 | (Centre d'Analyse Stratégique, 2012)† | NGO, platform or network (Global chance) | report | (2010-2030) |
| 2011 | 3 | (Centre d'Analyse Stratégique, 2012)† | NGO, platform or network (UFE)           | report | (2010-2030) |
| 2011 | 2 | (Centre d'Analyse Stratégique, 2012)† | public organization (RTE)                | report | (2030-2040) |
| 2010 | 1 | (Acket and Bacher, 2010)              | academia or research organization        | report | (2020-2050) |

Note: If a study did not report results for 2035, then an approximation for 2035 was calculated using linear interpolation between the closest years available (given in parenthesis).

† The review study of Centre d'Analyse Stratégique (2012) included scenario results from six studies that could not be found independently and were therefore extracted from the review study. The names of the organizations that performed the studies are given in the "Organization type" column in parentheses.

Table C2. Details of reviewed scenario studies for Germany

| Pub. year | Number of scenarios reviewed | Reference                    | Organization type                 | Publication type | Year(s) for which scenario results were extracted |
|-----------|------------------------------|------------------------------|-----------------------------------|------------------|---------------------------------------------------|
| 2020      | 2                            | (Kemmler et al., 2020)       | public organization               | report           | 2035                                              |
| 2020      | 4                            | (Eising et al., 2020)        | academia or research organization | journal article  | 2035                                              |
| 2020      | 2                            | (McGowan et al., 2019)       | public organization               | report           | (2030-2040)                                       |
| 2020      | 4                            | (Sterchele et al., 2020)     | academia or research organization | report           | (2030-2040)                                       |
| 2020      | 2                            | (Hof et al., 2020)           | academia or research organization | journal article  | (2030-2050)                                       |
| 2020      | 5                            | (Kittel et al., 2020)        | academia or research organization | journal article  | (2018-2030)                                       |
| 2020      | 2                            | (Rogge et al., 2020)         | academia or research organization | journal article  | (2030-2040)                                       |
| 2020      | 4                            | (Sasse and Trutnevyte, 2020) | academia or research organization | journal article  | 2035                                              |
| 2019      | 5                            | (Rippel et al., 2019)        | public organization               | report           | (2018-2030)                                       |
| 2019      | 3                            | (Bartholdsen et al., 2019)   | academia or research organization | journal article  | 2035                                              |
| 2019      | 1                            | (Boblenz et al., 2019)       | academia or research organization | journal article  | (2015-2030)                                       |
| 2019      | 1                            | (Öko-Institut, 2019)         | academia or research organization | report           | 2035                                              |
| 2019      | 1                            | (Siala et al., 2019)         | academia or research organization | journal article  | (2030-2050)                                       |
| 2018      | 3                            | (Gerbert et al., 2018)       | NGO, platform or network          | report           | (2030-2040)                                       |
| 2018      | 6                            | (Gils et al., 2018)          | public organization               | report           | (2030-2050)                                       |
| 2018      | 5                            | (Collins et al., 2018a)      | academia or research organization | journal article  | (2015-2030)                                       |
| 2017      | 8                            | (F. Ausfelder et al., 2017)  | academia or research organization | report           | (2014-2050)                                       |
| 2017      | 1                            | (Pfluger et al., 2017)       | public organization               | report           | (2014-2050)                                       |
| 2017      | 1                            | (Pietroni et al., 2017)      | NGO, platform or network          | report           | 2035                                              |

## C.1. Details of reviewed scenario studies (model-based)

|      |   |                                                    |                                   |                 |             |
|------|---|----------------------------------------------------|-----------------------------------|-----------------|-------------|
| 2017 | 3 | (Nitsch, 2017)                                     | academia or research organization | report          | (2030-2040) |
| 2017 | 8 | (Öko-Institut and Prognos, 2017)                   | NGO, platform or network          | report          | (2030-2040) |
| 2016 | 3 | (Maire et al., 2015)                               | academia or research organization | report          | 2035        |
| 2016 | 1 | (European Commission, 2016)                        | public organization               | report          | 2035        |
| 2016 | 6 | (Knaut et al., 2016)                               | academia or research organization | journal article | (2030-2040) |
| 2015 | 3 | (Enervis energy advisors, 2015)                    | NGO, platform or network          | report          | 2035        |
| 2015 | 3 | (Öko-Institut and Fraunhofer ISI, 2015)            | public organization               | report          | (2030-2040) |
| 2015 | 1 | (Gerhardt et al., 2015)                            | public organization               | report          | (2014-2050) |
| 2015 | 4 | (Fais et al., 2015)                                | academia or research organization | journal article | (2010-2030) |
| 2015 | 1 | (Henning and Palzer, 2015)                         | academia or research organization | report          | (2014-2050) |
| 2015 | 2 | (IRENA, 2015)                                      | NGO, platform or network          | report          | (2010-2030) |
| 2015 | 2 | (Ueckerdt et al., 2015)                            | academia or research organization | journal article | 2035        |
| 2014 | 2 | (Prognos AG et al., 2014)                          | public organization               | report          | (2030-2040) |
| 2014 | 2 | (Nitsch, 2014)                                     | academia or research organization | report          | (2030-2040) |
| 2014 | 3 | (Spiecker et al., 2014)                            | academia or research organization | journal article | (2030-2040) |
| 2012 | 5 | (Nitsch et al., 2012)                              | public organization               | report          | (2030-2040) |
| 2012 | 2 | (Grave et al., 2012)                               | academia or research organization | journal article | (2010-2030) |
| 2012 | 3 | (Schmid and Knopf, 2012)                           | academia or research organization | journal article | 2035        |
| 2011 | 2 | (Prognos AG et al., 2011)                          | public organization               | report          | (2008-2030) |
| 2011 | 7 | (German Advisory Council on the Environment, 2011) | academia or research organization | report          | 2035        |

|      |   |                                     |                                   |                 |             |
|------|---|-------------------------------------|-----------------------------------|-----------------|-------------|
| 2010 | 3 | (Nitsch et al., 2010)               | public organization               | report          | (2030-2040) |
| 2010 | 1 | (Klaus et al., 2010)                | public organization               | report          | (2010-2050) |
| 2010 | 9 | (Prognos AG et al., 2010)           | public organization               | report          | (2030-2040) |
| 2010 | 1 | (FVEE, 2010)                        | academia or research organization | report          | (2030-2040) |
| 2010 | 1 | (Greenpeace, 2010)                  | NGO, platform or network          | report          | (2030-2040) |
| 2009 | 1 | (Nitsch and Wenzel, 2009)           | public organization               | report          | (2030-2040) |
| 2009 | 2 | (Sands and Schumacher, 2009)        | academia or research organization | journal article | 2035        |
| 2009 | 4 | (Prognos AG and Öko-Institut, 2009) | NGO, platform or network          | report          | 2035        |
| 2008 | 6 | (Nitsch and DLR, 2008)              | public organization               | report          | (2030-2040) |
| 2008 | 1 | (Odenberger et al., 2008)           | academia or research organization | journal article | 2035        |

Note: If a study did not report results for 2035, then an approximation for 2035 was calculated using linear interpolation between the closest years available (given in parenthesis).



Table C3. Details of reviewed scenario studies for Poland

| Pub. year | Number of scenarios reviewed | Reference                                              | Organization type                 | Publication type | Year(s) for which scenario results were extracted |
|-----------|------------------------------|--------------------------------------------------------|-----------------------------------|------------------|---------------------------------------------------|
| 2020      | 2                            | (McGowan et al., 2019)                                 | public organization               | report           | (2030-2040)                                       |
| 2020      | 1                            | (Ministry of State Assets, 2020)                       | public organization               | report           | 2035                                              |
| 2020      | 4                            | (Sasse and Trutnevyte, 2020)                           | academia or research organization | journal article  | 2035                                              |
| 2019      | 1                            | (Ministry of Energy, 2019)                             | public organization               | report           | 2035                                              |
| 2018      | 1                            | (Burchart-Korol et al., 2018; IEA, 2017a)              | academia or research organization | journal article  | 2035                                              |
| 2018      | 1                            | (Gawlik and Mokrzycki, 2019; Ministry of Energy, 2018) | public organization               | report           | 2035                                              |
| 2018      | 2                            | (Skoczkowski et al., 2018)                             | academia or research organization | journal article  | 2035                                              |
| 2017      | 4                            | (Ecke et al., 2017)                                    | academia or research organization | report           | 2035                                              |
| 2017      | 6                            | (Wierzbowski et al., 2017)                             | academia or research organization | journal article  | 2035                                              |
| 2016      | 1                            | (Budzianowski and Gomes, 2016)                         | academia or research organization | journal article  | (2010-2030)                                       |
| 2016      | 1                            | (European Commission, 2016)                            | public organization               | report           | 2035                                              |
| 2016      | 8                            | (Jaskólski, 2016)                                      | academia or research organization | journal article  | 2035                                              |
| 2015      | 8                            | (Głąbski et al., 2015)                                 | public organization               | report           | (2030-2040)                                       |

|      |    |                                   |                                         |                    |             |
|------|----|-----------------------------------|-----------------------------------------|--------------------|-------------|
| 2015 | 3  | (Wyrwa et al., 2015)              | academia or<br>research<br>organization | journal<br>article | 2035        |
| 2015 | 4  | (Wyrwa, 2015)                     | academia or<br>research<br>organization | journal<br>article | 2035        |
| 2013 | 2  | (Greenpeace, 2013b)               | NGO, platform or<br>network             | report             | 2035        |
| 2013 | 16 | (Gawlik et al., 2013)             | NGO, platform or<br>network             | report             | 2035        |
| 2012 | 4  | (EnergSys, 2012)                  | NGO, platform or<br>network             | report             | (2030-2040) |
| 2011 | 2  | (Bukowski and<br>Śniegocki, 2011) | public<br>organization                  | report             | (2030-2050) |

Note: If a study did not report results for 2035, then an approximation for 2035 was calculated using linear interpolation between the closest years available (given in parenthesis).

Table C4. Details of reviewed scenario studies for the EU

| Pub. year | Number of scenarios reviewed | Reference                        | Organization type                 | Publication type | Year(s) for which scenario results were extracted | Electricity networks covered in the study |
|-----------|------------------------------|----------------------------------|-----------------------------------|------------------|---------------------------------------------------|-------------------------------------------|
| 2020      | 2                            | (McGowan et al., 2019)           | public organization               | report           | (2030-2040)                                       | EU28                                      |
| 2020      | 3                            | (Gaffney et al., 2020)           | academia or research organization | journal article  | (2018-2050)                                       | EU28                                      |
| 2020      | 1                            | (Guidehouse, 2020)               | NGO, platform or network          | report           | (2030-2040)                                       | EU28                                      |
| 2020      | 2                            | (Helgeson and Peter, 2020)       | academia or research organization | journal article  | (2030-2040)                                       | EU27 + NO + CH                            |
| 2020      | 4                            | (Hof et al., 2020)               | academia or research organization | journal article  | (2030-2050)                                       | EU28 + NO + CH                            |
| 2020      | 1                            | (IRENA, 2020)                    | NGO, platform or network          | report           | 2035                                              | EU28                                      |
| 2020      | 3                            | (Korkmaz et al., 2020)           | academia or research organization | journal article  | (2030-2040)                                       | EU28                                      |
| 2020      | 6                            | (Louis et al., 2020)             | academia or research organization | journal article  | 2035                                              | EU28 + NO + CH - LT - LV - EE             |
| 2020      | 2                            | (Mier and Weissbart, 2020, 2018) | academia or research organization | journal article  | 2035                                              | EU28 + NO + CH - CY - MT                  |
| 2020      | 1                            | (Shell, 2020)                    | company                           | report           | 2035                                              | EU28                                      |
| 2020      | 3                            | (van Sluisveld et al., 2020)     | academia or research organization | journal article  | (2030-2050)                                       | EU28 + NO + CH                            |
| 2019      | 2                            | (Antenucci et al., 2019)         | academia or research organization | journal article  | 2035                                              | EU28 + RS + BA + NO + CH - CY - ME        |

|      |   |                                    |                                         |                    |             |                                |
|------|---|------------------------------------|-----------------------------------------|--------------------|-------------|--------------------------------|
| 2019 | 1 | (Blanco et al., 2019)              | academia or<br>research<br>organization | journal<br>article | 2035        | EU28                           |
| 2019 | 2 | (Child et al., 2019)               | academia or<br>research<br>organization | journal<br>article | 2035        | ENTSOE +<br>TR                 |
| 2019 | 1 | (European<br>Commission,<br>2019c) | public organization                     | report             | 2035        | EU28                           |
| 2019 | 4 | (Evangelopoulou<br>et al., 2019)   | academia or<br>research<br>organization | journal<br>article | (2030-2050) | EU28                           |
| 2019 | 2 | (Navigant, 2019)                   | NGO, platform or<br>network             | report             | (2014-2050) | EU28                           |
| 2019 | 3 | (Keramidas et al.,<br>2020)        | academia or<br>research<br>organization | report             | (2030-2040) | EU28                           |
| 2019 | 1 | (Gerbaulet et al.,<br>2019)        | academia or<br>research<br>organization | journal<br>article | 2035        | ENTSOE                         |
| 2019 | 3 | (IEA, 2019)                        | NGO, platform or<br>network             | report             | (2030-2040) | EU28                           |
| 2019 | 1 | (Morris et al.,<br>2019)           | academia or<br>research<br>organization | journal<br>article | 2035        | EU28 + NO<br>+ CH + IS         |
| 2019 | 2 | (Ritter et al., 2019)              | academia or<br>research<br>organization | journal<br>article | (2030-2040) | ENTSOE +<br>TR                 |
| 2019 | 4 | (Schmid et al.,<br>2019)           | academia or<br>research<br>organization | journal<br>article | (2030-2040) | EU28                           |
| 2019 | 1 | (Siala et al., 2019)               | academia or<br>research<br>organization | journal<br>article | (2030-2050) | EU28 + NO<br>+ CH - CY -<br>MT |
| 2019 | 3 | (Teske, 2019)                      | academia or<br>research<br>organization | book               | (2030-2040) | OECD<br>Europe                 |
| 2019 | 7 | (Zappa et al.,<br>2019)            | academia or<br>research<br>organization | journal<br>article | (2015-2050) | EU28 + NO<br>+ CH              |

## C.1. Details of reviewed scenario studies (model-based)

|      |   |                                                   |                                   |                 |             |                     |
|------|---|---------------------------------------------------|-----------------------------------|-----------------|-------------|---------------------|
| 2018 | 1 | (Capros et al., 2018)                             | academia or research organization | journal article | 2035        | EU28                |
| 2018 | 5 | (Collins et al., 2018a)                           | academia or research organization | journal article | 2030        | EU28 + NO + CH      |
| 2018 | 3 | (ECF and Climact, 2018)                           | NGO, platform or network          | report          | 2035        | EU28                |
| 2018 | 3 | (ENTSO-E and ENTSG, 2018)                         | public organization               | report          | (2030-2040) | ENTSOE              |
| 2018 | 3 | (Eurelectric, 2018)                               | NGO, platform or network          | report          | 2035        | EU28 + NO + CH + IS |
| 2018 | 9 | (Capros et al., 2019; European Commission, 2018b) | public organization               | report          | (2030-2050) | EU28                |
| 2018 | 3 | (FTI Consulting, 2018)                            | NGO, platform or network          | report          | 2035        | EU28                |
| 2018 | 3 | (Tchung-Ming et al., 2018)                        | academia or research organization | report          | (2030-2040) | EU28                |
| 2018 | 1 | (Matthes et al., 2018)                            | public organization               | report          | (2030-2040) | EU28                |
| 2018 | 3 | (Held et al., 2018)                               | academia or research organization | journal article | (2030-2050) | EU28                |
| 2018 | 3 | (IEA, 2018)                                       | NGO, platform or network          | report          | (2030-2040) | EU28                |
| 2018 | 1 | (IRENA, 2018)                                     | NGO, platform or network          | report          | (2030-2040) | EU28                |
| 2018 | 4 | (Nijs et al., 2018)                               | public organization               | report          | (2030-2040) | EU28                |
| 2018 | 2 | (Pöyry, 2018)                                     | company                           | report          | (2030-2040) | EU28 + NO + CH      |
| 2018 | 2 | (Siskos et al., 2018)                             | academia or research organization | journal article | 2035        | EU28                |
| 2018 | 1 | (Pineda et al., 2018)                             | NGO, platform or network          | report          | 2035        | EU28 + NO + CH + IS |
| 2017 | 2 | (Fragkos et al., 2018, 2017)                      | academia or research organization | journal article | (2030-2050) | EU28                |

|      |   |                                 |                                         |                    |             |                        |
|------|---|---------------------------------|-----------------------------------------|--------------------|-------------|------------------------|
| 2017 | 3 | (Keramidas and Kitous, 2017)    | academia or<br>research<br>organization | report             | (2030-2040) | EU28                   |
| 2017 | 2 | (Goop et al., 2017)             | academia or<br>research<br>organization | journal<br>article | 2035        | EU27 + NO<br>+ CH      |
| 2017 | 3 | (Haasz et al., 2018)            | academia or<br>research<br>organization | journal<br>article | (2030-2040) | EU28                   |
| 2017 | 3 | (IEA, 2017b).                   | NGO, platform or<br>network             | report             | (2030-2040) | EU28                   |
| 2017 | 1 | (Pleßmann and Blechinger, 2017) | academia or<br>research<br>organization | journal<br>article | 2035        | ENTSOE                 |
| 2017 | 8 | (Simoes et al., 2017)           | academia or<br>research<br>organization | journal<br>article | (2030-2050) | EU28 + NO<br>+ CH + IS |
| 2016 | 2 | (J. Bertsch et al., 2016)       | academia or<br>research<br>organization | journal<br>article | (2030-2040) | EU28 + NO<br>+ CH      |
| 2016 | 5 | (Duscha et al., 2016)           | academia or<br>research<br>organization | journal<br>article | (2010-2030) | EU28                   |
| 2016 | 1 | (Enerdata, 2016)                | company                                 | report             | 2035        | EU28                   |
| 2016 | 1 | (European Commission, 2016)     | public organization                     | report             | 2035        | EU28                   |
| 2016 | 3 | (Kitous and Keramidas, 2016)    | academia or<br>research<br>organization | report             | (2030-2040) | EU28                   |
| 2016 | 2 | (Huber, 2016)                   | academia or<br>research<br>organization | doctoral<br>thesis | 2035        | ENTSOE                 |
| 2016 | 3 | (IEA, 2016)                     | NGO, platform or<br>network             | report             | (2030-2040) | EU28                   |
| 2016 | 1 | (Knaut et al., 2016)            | academia or<br>research<br>organization | journal<br>article | (2030-2040) | EU28                   |
| 2016 | 2 | (Solano Rodriguez et al., 2016) | academia or<br>research<br>organization | journal<br>article | (2030-2040) | EU28                   |

## C.1. Details of reviewed scenario studies (model-based)

|      |   |                                |                                         |                    |             |                   |
|------|---|--------------------------------|-----------------------------------------|--------------------|-------------|-------------------|
| 2015 | 3 | (Capros et al., 2015)          | academia or<br>research<br>organization | journal<br>article | (2030-2050) | EU28              |
| 2015 | 2 | (Labat et al., 2015)           | academia or<br>research<br>organization | report             | (2030-2040) | EU28              |
| 2015 | 3 | (IEA, 2015a)                   | NGO, platform or<br>network             | report             | (2030-2040) | EU28              |
| 2015 | 1 | (IEA, 2015b)                   | NGO, platform or<br>network             | report             | (2030-2050) | EU28              |
| 2015 | 2 | (Mima and Criqui, 2015)        | academia or<br>research<br>organization | journal<br>article | (2030-2040) | EU27 (2013)       |
| 2014 | 3 | (Capros et al., 2014a, 2014b)  | academia or<br>research<br>organization | journal<br>article | 2035        | EU27 (2013)       |
| 2014 | 1 | (Château, 2014)                | academia or<br>research<br>organization | journal<br>article | 2035        | EU27 (2013)       |
| 2014 | 7 | (De-Llano Paz et al., 2014)    | academia or<br>research<br>organization | journal<br>article | (2010-2030) | EU27 (2013)       |
| 2014 | 3 | (Gracceva and Zeniewski, 2014) | academia or<br>research<br>organization | journal<br>article | 2035        | EU27 (2013)       |
| 2014 | 2 | (Greenpeace, 2014)             | NGO, platform or<br>network             | report             | (2030-2040) | EU28              |
| 2014 | 2 | (Hagspiel et al., 2014)        | academia or<br>research<br>organization | journal<br>article | (2030-2050) | EU27 + NO<br>+ CH |
| 2014 | 2 | (Huppmann and Egging, 2014)    | academia or<br>research<br>organization | journal<br>article | (2030-2040) | EU27 (2013)       |
| 2014 | 3 | (IEA, 2014)                    | NGO, platform or<br>network             | report             | (2030-2040) | EU28              |
| 2014 | 1 | (Nahmmacher et al., 2014)      | academia or<br>research<br>organization | report             | 2035        | ENTSOE            |

|      |    |                             |                                         |                    |             |                   |
|------|----|-----------------------------|-----------------------------------------|--------------------|-------------|-------------------|
| 2014 | 3  | (Spiecker and Weber, 2014)  | academia or<br>research<br>organization | journal<br>article | (2030-2040) | EU28              |
| 2013 | 2  | (van Stralen et al., 2013)  | academia or<br>research<br>organization | journal<br>article | (2030-2040) | ENTSOE            |
| 2013 | 1  | (Dii, 2013)                 | NGO, platform or<br>network             | report             | (2030-2040) | ENTSOE +<br>TR    |
| 2013 | 6  | (Dowling, 2013)             | academia or<br>research<br>organization | journal<br>article | 2035        | EU27 (2013)       |
| 2013 | 1  | (IRENE-40, 2013)            | public organization                     | report             | (2030-2050) | EU27 + NO<br>+ CH |
| 2013 | 5  | (European Commission, 2013) | public organization                     | report             | 2035        | EU28              |
| 2013 | 2  | (Fürsch et al., 2013)       | academia or<br>research<br>organization | journal<br>article | (2030-2040) | EU27 (2013)       |
| 2013 | 3  | (IEA, 2013)                 | NGO, platform or<br>network             | report             | 2035        | EU28              |
| 2013 | 36 | (Jägemann et al., 2013)     | academia or<br>research<br>organization | journal<br>article | (2010-2050) | EU27 + NO<br>+ CH |
| 2013 | 5  | (Selosse et al., 2013)      | academia or<br>research<br>organization | journal<br>article | (2020-2050) | EU27 (2013)       |
| 2013 | 3  | (van Stralen et al., 2013)  | academia or<br>research<br>organization | journal<br>article | (2010-2030) | EU27 (2013)       |
| 2012 | 5  | (Blesl et al., 2012)        | academia or<br>research<br>organization | journal<br>article | (2030-2040) | EU27 (2013)       |
| 2012 | 2  | (Capros et al., 2012)       | academia or<br>research<br>organization | journal<br>article | (2030-2040) | EU27 (2013)       |
| 2012 | 1  | (Criqui and Mima, 2012)     | academia or<br>research<br>organization | journal<br>article | (2030-2040) | EU27 (2013)       |
| 2012 | 1  | (Greenpeace, 2012)          | NGO, platform or<br>network             | report             | (2030-2040) | EU27 (2013)       |



### C.1. Details of reviewed scenario studies (model-based)

|      |    |                                 |                                   |                 |             |             |
|------|----|---------------------------------|-----------------------------------|-----------------|-------------|-------------|
| 2012 | 3  | (IEA, 2012a)                    | NGO, platform or network          | report          | 2035        | EU27 (2013) |
| 2012 | 2  | (IEA, 2012b)                    | NGO, platform or network          | report          | (2030-2050) | EU28        |
| 2011 | 2  | (Eurelectric, 2011)             | NGO, platform or network          | report          | 2035        | EU27 (2013) |
| 2011 | 11 | (European Commission, 2011)     | public organization               | report          | 2035        | EU27 (2013) |
| 2011 | 3  | (IEA, 2011)                     | NGO, platform or network          | report          | 2035        | EU27 (2013) |
| 2011 | 4  | (Joode et al., 2011)            | academia or research organization | report          | (2030-2040) | ENTSOE      |
| 2010 | 3  | (ECF, 2020)                     | NGO, platform or network          | report          | 2035        | EU27 (2013) |
| 2010 | 3  | (IEA, 2010)                     | NGO, platform or network          | report          | 2035        | EU27 (2013) |
| 2010 | 1  | (Odenberger and Johnsson, 2010) | academia or research organization | journal article | 2035        | EU27+NO     |
| 2008 | 1  | (DESERTEC, 2008)                | NGO, platform or network          | report          | 2035        | ENTSOE + TR |
| 2008 | 1  | (Odenberger et al., 2008)       | academia or research organization | journal article | 2035        | EU25        |
| 2008 | 2  | (Resch et al., 2008)            | academia or research organization | journal article | (2030-2050) | EU27 (2013) |

Note: If a study did not report results for 2035, then an approximation for 2035 was calculated using linear interpolation between the closest years available (given in parenthesis). Acronyms of countries and spatial areas: EU28 = current EU27 and the UK, EU27 (2013) = current EU27 and the UK and excluding Croatia, EU25 = current EU27 and the UK and excluding Bulgaria, Croatia, and Romania, ENTSOE = current EU27, Albania, Bosnia and Herzegovina, Iceland, Norway, Republic of North Macedonia, Serbia, Switzerland, and the UK, BA = Bosnia and Herzegovina, CH = Switzerland, CY = Cyprus, EE = Estonia, IS = Iceland, LT = Lithuania, LV = Latvia, ME = Montenegro, MT = Malta, NO = Norway, TR = Turkey

## Appendix D Supplementary materials for Chapter 6

### D.1. Online survey script

*Note: the survey was presented to the participants originally in German and it has been translated below into English.*

#### D.1.1. Introduction

Thank you for your participation in this survey. Electricity supply in Switzerland: how should it look like in 2035? Do you know which electricity supply sources can be used and what impacts they might have on the environment, safety and economy? In the next 10-15 minutes, you have the chance to broaden your knowledge about them through an information website. In this way, we will test which information format works best in communicating information about the energy transition to the public.

This survey is conducted by the Renewable Energy Systems group at the University of Geneva as part of a Swiss National Science Foundation project (No 160563). The aim of the project is to understand the preferences of the public, stakeholders, and experts for the Swiss electricity supply in the future.

Your participation is voluntary. All your information will be evaluated anonymously and treated in accordance with the provisions of data protection. Your details cannot be associated with your person and will not be disclosed to third parties.

#### D.1.2. Demographics

What is your gender?

- Female
- Male

What year were you born?

Please indicate your highest level of education.

- Compulsory education, e.g. primary or lower secondary education
- Basic vocational education
- High school or higher vocational education
- Professional education and training, e.g. professional colleges
- Higher education, e.g. universities or universities of applied science

What is the best description of your current employment situation?

- In education
- Employed (up to 50%)
- Employed (50-100%)
- Job seeking
- Self-employed
- Retired

### **D.1.3. Prior interest in electricity supply topics**

To what extent do you agree or disagree with the following statements? (7-point Likert scale: 1 = Strongly disagree, 2 = Disagree, 3 = Somewhat disagree, 4 = Neither agree or disagree, 5 = Somewhat agree, 6 = Agree, 7 = Strongly agree)

- If I lack knowledge about electricity supply topics in Switzerland, I will inform myself.
- I think frequently and intensively about electricity supply topics in Switzerland.
- I discuss about electricity supply topics in my private environment.
- I read articles in the media about electricity supply topics.
- I do not follow political discussions on electricity supply topics.
- Public events, television broadcasts or documentaries about electricity supply topics arouse my curiosity.
- In general, electricity supply in Switzerland is an exciting topic for me.

### **D.1.4. Prior knowledge of electricity supply topics**

To what extent do you agree or disagree with the following statements? (7-point Likert scale: 1 = Strongly disagree, 2 = Disagree, 3 = Somewhat disagree, 4 = Neither agree or disagree, 5 = Somewhat agree, 6 = Agree, 7 = Strongly agree)

- I do not feel well informed about the different electricity supply sources in Switzerland.
- Within my circle of friends, I am one of the 'experts' on electricity supply sources.
- Compared to most other people, I know less about electricity supply.
- I am well informed about the advantages and disadvantages of electricity supply sources.
- I know more than most people about the plans and possibilities to develop the Swiss electricity supply in the future.
- I don't know the approximate proportions of individual sources in the total electricity supply of Switzerland.
- In general, I know a lot about the different electricity supply sources in Switzerland.

### **D.1.5. Frequency of media use to inform on electricity supply topics**

How often do you use these resources to get general information on electricity supply topics? (7-point Likert scale: 1 = Never, 2 = Hardly ever, 3 = Rarely, 4 = Occasionally, 5 = Often, 6 = Very often, 7 = Always)

- Newspapers, magazines, books
- Acquaintances and family
- Internet search
- Social media (e.g. Twitter, Facebook)
- News websites
- TV and radio
- Public events or direct contact with experts

### **D.1.6. Website navigation skills**

To what extent do you agree or disagree with the following statements? (7-point Likert scale: 1 = Strongly disagree, 2 = Disagree, 3 = Somewhat disagree, 4 = Neither agree or disagree, 5 = Somewhat agree, 6 = Agree, 7 = Strongly agree)

- I find it easy to find a website I visited before.
- I get tired when looking for information online.
- Sometimes I end up on websites without knowing how I got there.
- I find the way in which many websites are designed confusing.
- I find it hard to decide what the best keywords are to use for online searches. (e.g. Google).

### **D.1.7. Subjective numeracy**

To what extent do you agree or disagree with the following statements? (7-point Likert scale: 1 = Strongly disagree, 2 = Disagree, 3 = Somewhat disagree, 4 = Neither agree or disagree, 5 = Somewhat agree, 6 = Agree, 7 = Strongly agree)

- I am good at calculating fractions. (e.g. a quarter).
- I am good at calculating percentages.
- I am not good at calculating a 15% tip.
- When I am reading the newspaper, I find tables and graphs helpful.
- I often find numerical information useful.

### **D.1.8. Link and invitation to visit the interactive web-tool or the website with four scenarios with storylines**

To expand or refresh your knowledge for the electricity supply in Switzerland, we have created the following information website. Please visit the website, explore it for about 2-3 minutes, and then return to the survey to continue.

Do not close the information website yet, as we will ask you to use it later to answer some questions.

The website works in the following browsers: Chrome, Firefox, Safari, Edge and Internet Explorer 10+. If you have any problems with the website, please try reloading it or updating your browser.

#### **D.1.9. Understanding – tested**

Now that you are familiar with the information website, we would like to ask you to answer the following questions about electricity supply sources and their impacts in Switzerland. All questions refer to the information of the website. (Scale: True, False, I don't know)

1. Every electricity supply scenario for 2035 includes small hydropower.
2. The impact of electricity supply on local air pollution is low in any scenario.
3. There is at least one scenario where the Swiss electricity demand is covered without imports and nuclear power.
4. The impacts to climate change are high in every scenario.
5. Scenarios with large gas power plants have minimal accidental impacts.
6. Scenarios with only renewable electricity sources (solar cells, wind, hydropower, biogas, woody biomass, waste incineration and deep geothermal) lead to high impacts on electricity supply reliability.
7. The website shows that almost a tenth of the total electricity demand in Switzerland can be reduced by electricity saving and efficiency measures.

#### **D.1.10. Understanding – self-reported**

To what extent do you agree or disagree with the following statements? (7-point Likert scale: 1 = Strongly disagree, 2 = Disagree, 3 = Somewhat disagree, 4 = Neither agree or disagree, 5 = Somewhat agree, 6 = Agree, 7 = Strongly agree)

- I learned something new about the electricity supply in Switzerland from this website.
- On the whole, it was easy to understand the information.
- The website corrected some of my misconceptions about Switzerland's electricity supply.
- The website explained the complex issue of electricity supply in a simple and understandable way.
- The website is not adequate to clearly inform about electricity supply and its impacts.
- Certain information was too simplistic in my opinion.
- Overall, electricity supply and its impacts are presented clearly on the website.

#### **D.1.11. Trust – self-reported**

To what extent do you agree or disagree with the following statements? (7-point Likert scale: 1 = Strongly disagree, 2 = Disagree, 3 = Somewhat disagree, 4 = Neither agree or disagree, 5 = Somewhat agree, 6 = Agree, 7 = Strongly agree)

- The website is not objective.
- The website is coming from a reliable source.
- If it was publicly available, people would trust the website.
- The website is based on expert knowledge.
- On the website I received accurate information.
- This website could provide information for decisions on electricity supply.
- The website is of dubious credibility.

#### **D.1.12. Engagement – self-reported**

To what extent do you agree or disagree with the following statements? (7-point Likert scale: 1 = Strongly disagree, 2 = Disagree, 3 = Somewhat disagree, 4 = Neither agree or disagree, 5 = Somewhat agree, 6 = Agree, 7 = Strongly agree)

- I enjoyed using this website to learn more about electricity supply.
- I would be willing to share this website on social media.
- Using the information website was a valuable use of my time.
- I would not want to spend any more time with this website.
- Overall, I like this website.
- If I would want to know something about Switzerland's electricity supply in the future, I would return to this website.
- The website was an exciting way to find out about electricity supply.

#### **D.1.13. End of the survey**

Thank you for your participation! Your data has been saved, you can now close this window.

## D.2. Storylines and compositions of the four electricity supply scenarios

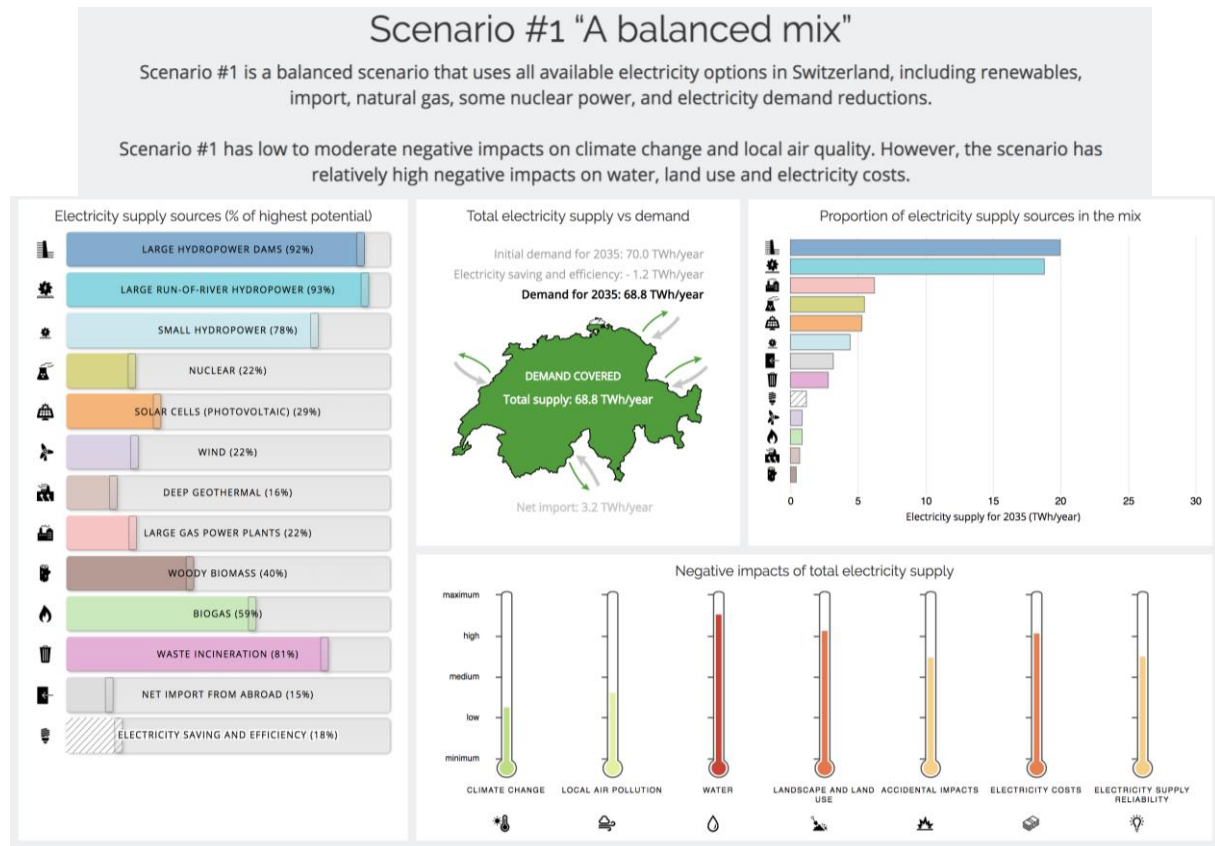


Figure C1. Storyline and composition of the first electricity supply scenario in the four scenarios condition.

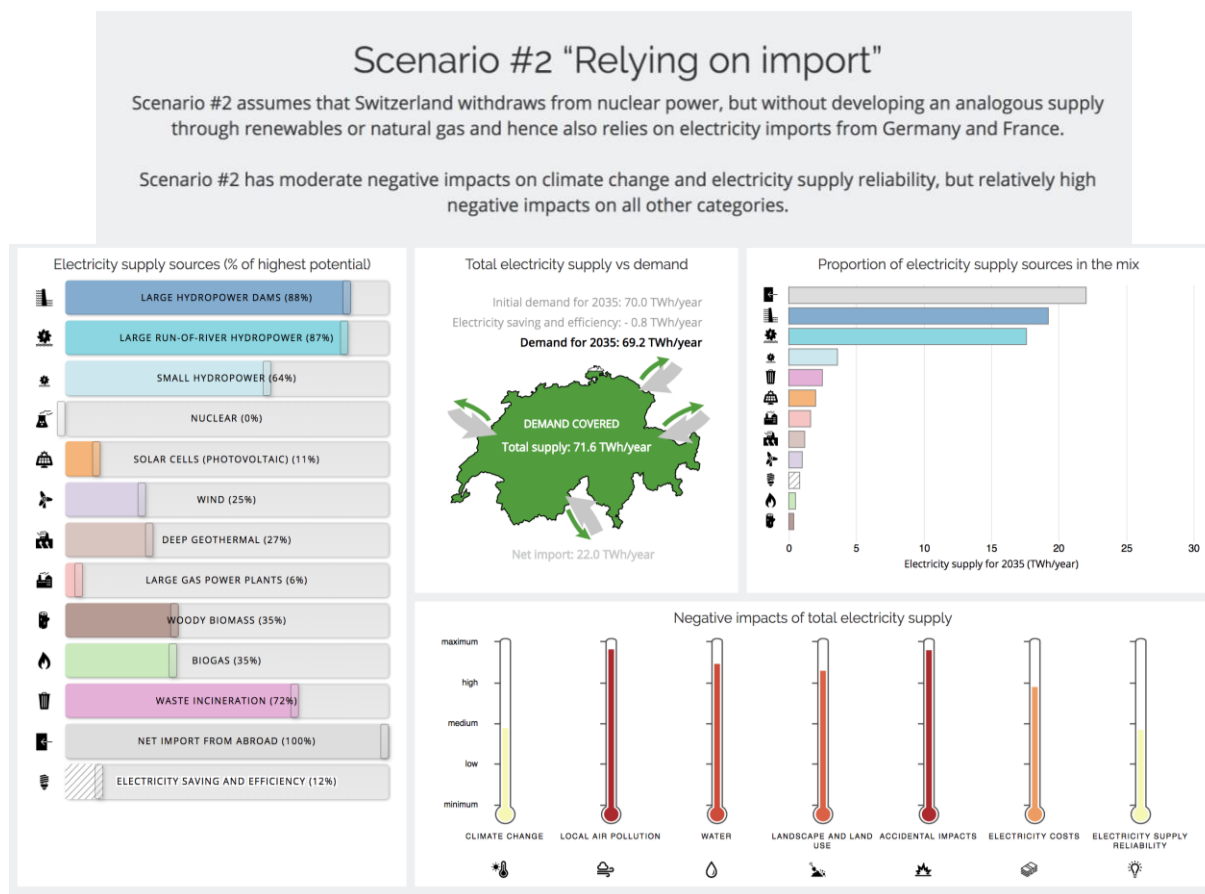


Figure C2. Storyline and composition of the second electricity supply scenario in the four scenarios condition.



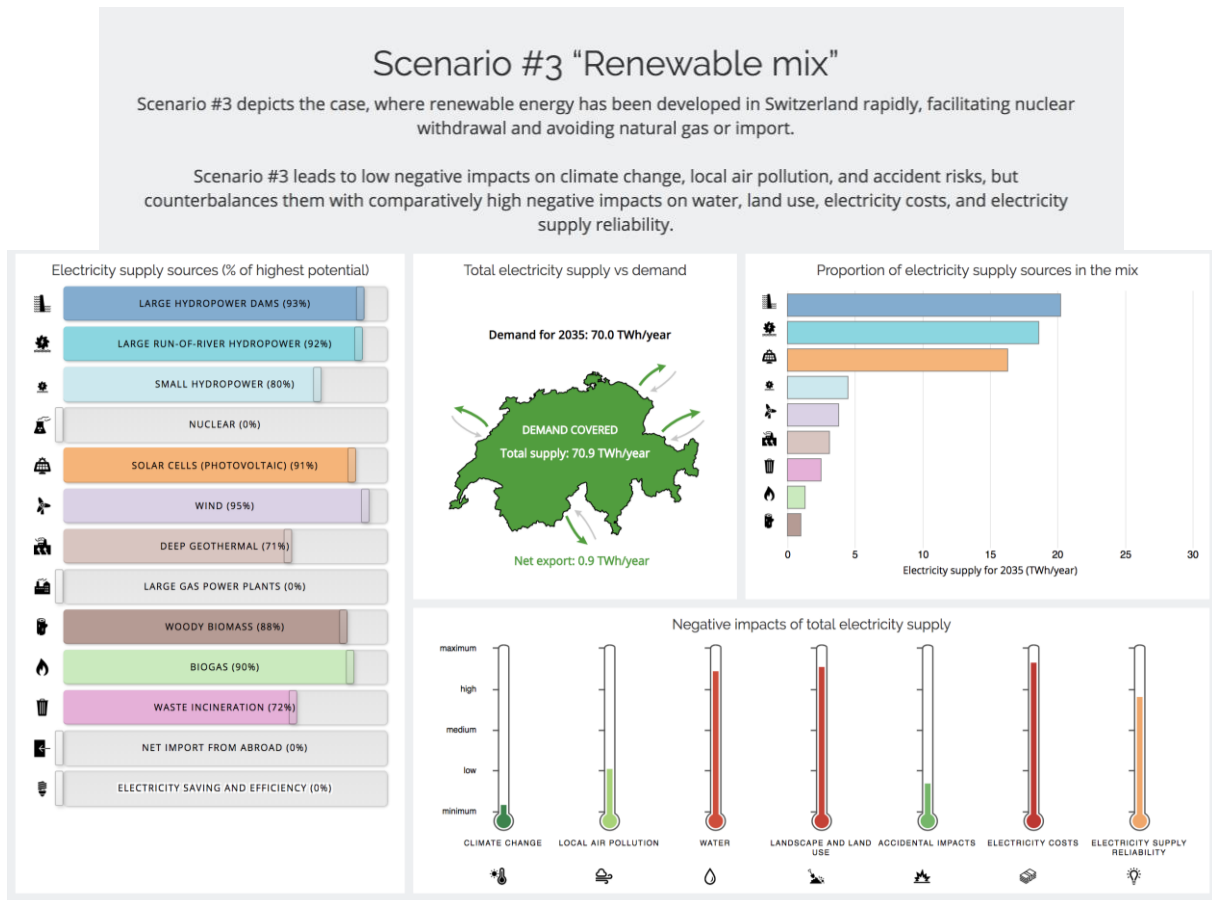


Figure C3. Storyline and composition of the third electricity supply scenario in the four scenarios condition.

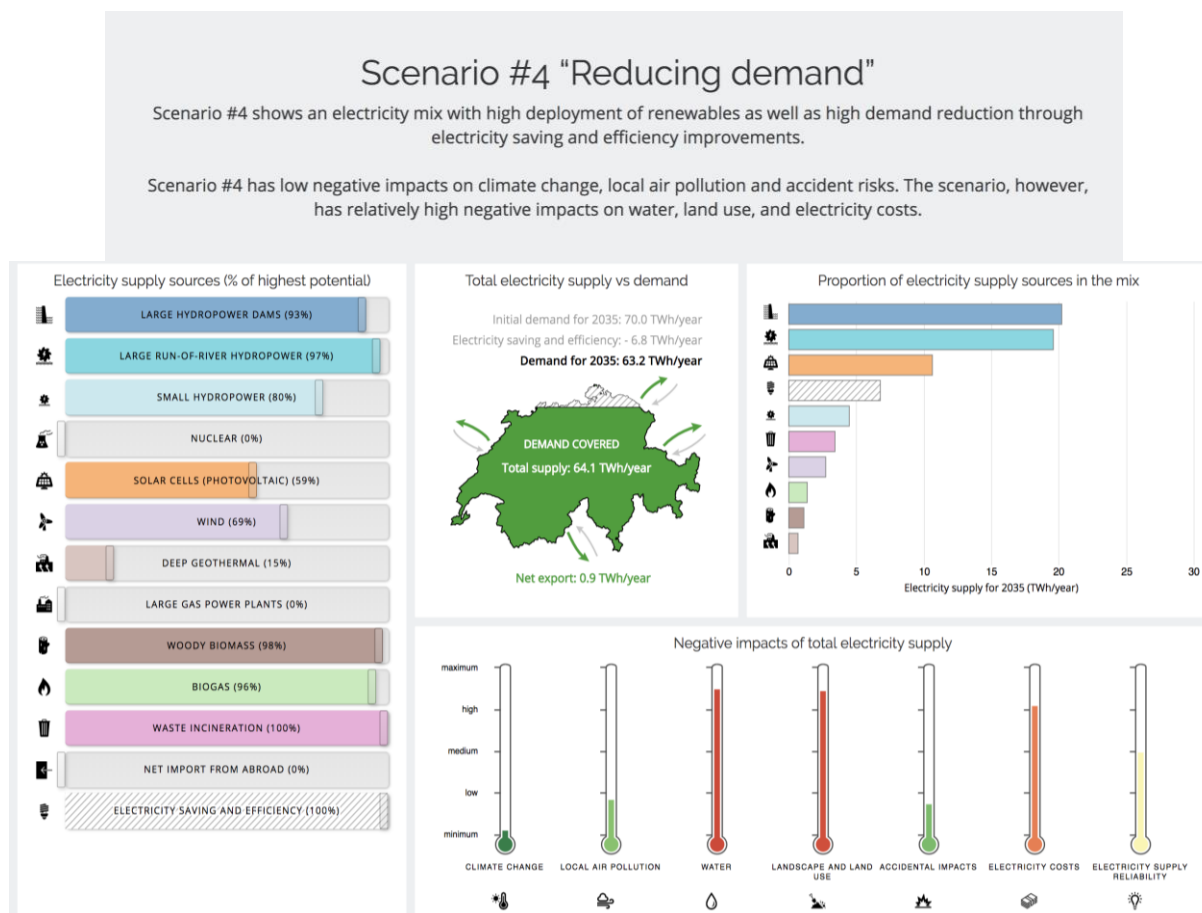


Figure C4. Storyline and composition of the fourth electricity supply scenario in the four scenarios condition.

### D.3. Detailed answers to the quiz for tested understanding

Table C7. Detailed answers to the quiz for tested understanding

| Quiz questions for tested understanding<br>(score scale is 0-1 for every question)                                                                                                                       | Experimental conditions<br>Four scenarios<br>with storylines<br>( <i>n</i> = 157)<br><i>M</i> ± <i>SD</i> | Interactive<br>web-tool<br>( <i>n</i> = 156)<br><i>M</i> ± <i>SD</i> | Statistic    |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------|--------------|
| Every electricity supply scenario for 2035 includes small hydropower.                                                                                                                                    |                                                                                                           |                                                                      |              |
| Correct answers                                                                                                                                                                                          | 0.64 ± 0.48                                                                                               | 0.58 ± 0.49                                                          | t = 0.971    |
| Wrong answers                                                                                                                                                                                            | 0.18 ± 0.38                                                                                               | 0.26 ± 0.44                                                          | t = -1.676   |
| Don't know answers                                                                                                                                                                                       | 0.18 ± 0.39                                                                                               | 0.16 ± 0.37                                                          | t = 0.571    |
| The impact of electricity supply on local air pollution is low in any scenario.                                                                                                                          |                                                                                                           |                                                                      |              |
| Correct answers                                                                                                                                                                                          | 0.62 ± 0.49                                                                                               | 0.42 ± 0.50                                                          | t = 3.624**  |
| Wrong answers                                                                                                                                                                                            | 0.17 ± 0.37                                                                                               | 0.37 ± 0.49                                                          | t = -4.219** |
| Don't know answers                                                                                                                                                                                       | 0.22 ± 0.41                                                                                               | 0.21 ± 0.41                                                          | t = 0.108    |
| There is at least one scenario where the Swiss electricity demand is covered without imports and nuclear power.                                                                                          |                                                                                                           |                                                                      |              |
| Correct answers                                                                                                                                                                                          | 0.72 ± 0.45                                                                                               | 0.68 ± 0.47                                                          | t = 0.775    |
| Wrong answers                                                                                                                                                                                            | 0.13 ± 0.33                                                                                               | 0.13 ± 0.34                                                          | t = -0.189   |
| Don't know answers                                                                                                                                                                                       | 0.15 ± 0.36                                                                                               | 0.19 ± 0.39                                                          | t = -0.777   |
| The impacts to climate change are high in every scenario.                                                                                                                                                |                                                                                                           |                                                                      |              |
| Correct answers                                                                                                                                                                                          | 0.63 ± 0.49                                                                                               | 0.57 ± 0.50                                                          | t = 1.083    |
| Wrong answers                                                                                                                                                                                            | 0.25 ± 0.44                                                                                               | 0.26 ± 0.44                                                          | t = -0.162   |
| Don't know answers                                                                                                                                                                                       | 0.11 ± 0.32                                                                                               | 0.17 ± 0.37                                                          | t = 1.323    |
| Scenarios with large gas power plants have minimal accidental impacts.                                                                                                                                   |                                                                                                           |                                                                      |              |
| Correct answers                                                                                                                                                                                          | 0.42 ± 0.50                                                                                               | 0.49 ± 0.50                                                          | t = -1.299   |
| Wrong answers                                                                                                                                                                                            | 0.29 ± 0.45                                                                                               | 0.30 ± 0.46                                                          | t = -0.284   |
| Don't know answers                                                                                                                                                                                       | 0.29 ± 0.46                                                                                               | 0.21 ± 0.41                                                          | t = 1.800    |
| Scenarios with only renewable electricity sources (solar cells, wind, hydropower, biogas, woody biomass, waste incineration and deep geothermal) lead to high impacts on electricity supply reliability. |                                                                                                           |                                                                      |              |
| Correct answers                                                                                                                                                                                          | 0.43 ± 0.50                                                                                               | 0.34 ± 0.48                                                          | t = 1.584    |
| Wrong answers                                                                                                                                                                                            | 0.38 ± 0.49                                                                                               | 0.49 ± 0.50                                                          | t = -1.993*  |
| Don't know answers                                                                                                                                                                                       | 0.19 ± 0.39                                                                                               | 0.17 ± 0.37                                                          | t = 0.562    |
| The website shows that almost a tenth of the total electricity demand in Switzerland can be reduced by electricity saving and efficiency measures.                                                       |                                                                                                           |                                                                      |              |
| Correct answers                                                                                                                                                                                          | 0.57 ± 0.50                                                                                               | 0.46 ± 0.50                                                          | t = 1.984*   |
| Wrong answers                                                                                                                                                                                            | 0.16 ± 0.38                                                                                               | 0.28 ± 0.45                                                          | t = -2.211*  |
| Don't know answers                                                                                                                                                                                       | 0.25 ± 0.44                                                                                               | 0.26 ± 0.44                                                          | t = -0.162   |

Note: \**p* < 0.05; \*\**p* < 0.001. All statistics assume the four scenarios condition as the reference group.

## Appendix E    Supplementary materials for Chapter 7

### E.1.    Survey script

*The following survey script was used for all three samples in Germany, Poland, and France and was translated in the respective language for each country. Each sub-section below signifies a different webpage. The sub-section titles and all text in italics were not shown in the survey. The script uses the experimental condition of a table as an example of the visualization format shown.*

#### E.1.1. Introduction

Thank you for your participation.

You may have noticed that global warming has been getting increasing attention in the news around the world. Global warming refers to the idea that the world's average temperature has been increasing over the past 150 years and may be increasing more in the future.

In the following 15 minutes we will show you some information on actions that are expected to limit global warming and ask your opinion about this information.

This survey is conducted by the University of Geneva, Switzerland. Your participation is voluntary. All your information will be evaluated anonymously, treated in accordance with the European Union provisions of data protection (GDPR), and it will only be used for scientific purpose. Your details cannot be associated with you as a person and will not be disclosed to third parties.

#### E.1.2. Demographics (1/2)

What is your gender?

- Female
- Male

How old are you? (in years, for example 35)

Please indicate your highest level of education.

- Compulsory education, e.g. primary or lower secondary education
- Basic vocational education

- High school or higher vocational education
- Higher education, e.g. universities or universities of applied science

### E.1.3. Belief in global warming

To what extent do you agree or disagree with the following statements?

|                                                                         | Strongly disagree     | Moderately disagree   | Neither agree or disagree | Moderately agree      | Strongly agree        |
|-------------------------------------------------------------------------|-----------------------|-----------------------|---------------------------|-----------------------|-----------------------|
| Global warming is occurring now.                                        | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |
| I have already noticed some signs of global warming.                    | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |
| The main causes of global warming are human activities.                 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |
| The consequences of global warming will be harmful for the environment. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |
| Global warming will bring about some serious negative consequences.     | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |

### E.1.4. Perceived efficacy of humanity to reduce CO<sub>2</sub> emissions (prior measurement)

Scientists have argued that greenhouse gas emissions and in particular carbon dioxide (CO<sub>2</sub>) are the main contributor to global warming.

To what extent do you agree or disagree with the following statements?

|                                                                                          | Strongly disagree     | Moderately disagree   | Neither agree or disagree | Moderately agree      | Strongly agree        |
|------------------------------------------------------------------------------------------|-----------------------|-----------------------|---------------------------|-----------------------|-----------------------|
| Humans have the ability to cut CO <sub>2</sub> emissions to reduce global warming.       | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |
| Humans are willing to cut CO <sub>2</sub> emissions to reduce global warming.            | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |
| Humans will be successful in cutting CO <sub>2</sub> emissions to reduce global warming. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |

### E.1.5. Perceived efficacy of electricity industry to reduce CO<sub>2</sub> emissions (prior measurement)

Electricity industry globally is one of the main sources of CO<sub>2</sub> emissions.

To what extent do you agree or disagree with the following statements?

|                                                                                                        | Strongly disagree     | Moderately disagree   | Neither agree or disagree | Moderately agree      | Strongly agree        |
|--------------------------------------------------------------------------------------------------------|-----------------------|-----------------------|---------------------------|-----------------------|-----------------------|
| Electricity industry has the ability to cut CO <sub>2</sub> emissions to reduce global warming.        | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |
| Electricity industry is willing to cut CO <sub>2</sub> emissions to reduce global warming.             | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |
| Electricity industry will be successful in cutting CO <sub>2</sub> emissions to reduce global warming. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |

### E.1.6. Affective responses (prior measurement)

Please rate how you feel towards efforts to limit global warming. For each set of adjectives, move the slider to the direction of your feelings.

|                   |                                                                                      |                |
|-------------------|--------------------------------------------------------------------------------------|----------------|
| Hopeless          |    | Hopeful        |
| Discouraged       |  | Empowered      |
| Indifferent       |  | Engaged        |
| Not Guilty        |  | Guilty         |
| Calm              |  | Outraged/Angry |
| Unconcerned       |  | Alarmed        |
| Not afraid at all |  | Very afraid    |

### E.1.7. Belief about the need to cut CO<sub>2</sub> emissions and belief about the required percentage of CO<sub>2</sub> emissions cuts (prior measurement)

Recently, scientists concluded that limiting global warming to 1.5°C above pre-industrial levels would significantly reduce negative impacts, such as heat waves, sea-level rise, floods or biodiversity loss.

In your own opinion, to what extent do you agree that CO<sub>2</sub> should be cut globally to limit global warming to 1.5°C?

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree or disagree
- Somewhat agree
- Agree
- Strongly agree

Based on your current knowledge, by what percentage do the scientists suggest cutting CO<sub>2</sub> emissions globally by 2030 and 2050 as compared to today to limit global warming to 1.5°C?

0%      -25%      -50%      -75%      -100%

☒ ☐ ☐ ☐ ☐

☐ Don't know

0%      -25%      -50%      -75%      -100%

☒ ☐ ☐ ☐ ☐

☐ Don't know

### E.1.8. Belief about the required electricity supply (prior measurement)

Currently, the electricity industry mostly uses fossil fuels (coal, gas, and oil), nuclear power or renewable energy (hydropower, solar photovoltaics, wind, biomass, etc.) to produce electricity. Based on your knowledge, to what extent do the scientists suggest expanding or reducing these electricity generation alternatives in order to limit global warming to 1.5°C?

|                      | Significantly<br>reduce | Moderately<br>reduce  | Slightly<br>reduce    | Keep<br>constant      | Slightly<br>increase  | Moderately<br>increase | Significantly<br>increase |
|----------------------|-------------------------|-----------------------|-----------------------|-----------------------|-----------------------|------------------------|---------------------------|
| Fossil fuels         | <input type="radio"/>   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>  | <input type="radio"/>     |
| Nuclear<br>power     | <input type="radio"/>   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>  | <input type="radio"/>     |
| Renewable<br>sources | <input type="radio"/>   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>  | <input type="radio"/>     |

☐ Don't know (fossil fuels)      ☐ Don't know (nuclear power)      ☐ Don't know (renewable sources)

### E.1.9. Attention test and task introduction

What are the colours of the ... national flag? Please select all colours that apply.

White    Yellow    Orange    Red    Green    Blue    Brown    Black

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

#### Task introduction

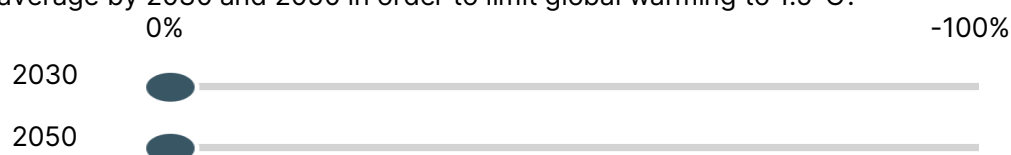
Now we will show you the latest scientific information on how much CO<sub>2</sub> emissions need to be cut globally to limit global warming to 1.5°C above pre-industrial levels. Due to uncertainties, scientists use computer models to calculate many different scenarios of CO<sub>2</sub> emissions and their impact on global warming. In the following pages, you will see information from these many scenarios.

**E.1.10. Graph/table of CO<sub>2</sub> emissions cuts**

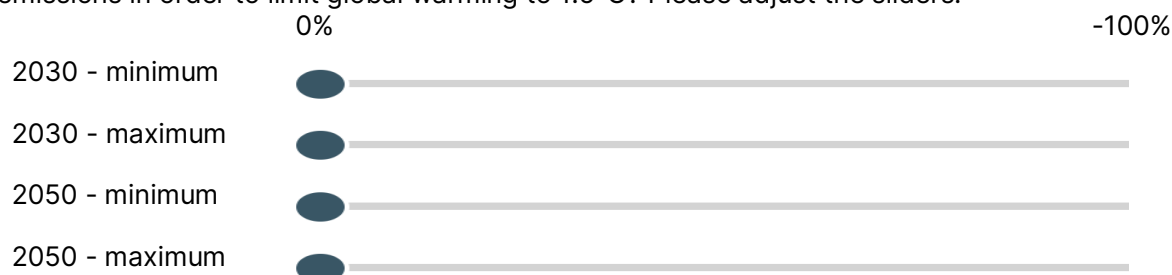
Please briefly examine the information and then answer the questions beneath.

| Year | Global CO <sub>2</sub> emissions (in % compared to 2020) |                                          |                            |
|------|----------------------------------------------------------|------------------------------------------|----------------------------|
|      | Range of all scenarios that meet 1.5°C                   | Average of all scenarios that meet 1.5°C | Business-as-usual scenario |
| 2020 | -                                                        | -                                        | -                          |
| 2030 | 0% to -70%                                               | -40%                                     | Increase of 12%            |
| 2040 | -44% to -100%                                            | -77%                                     | Increase of 23%            |
| 2050 | -75% to -100%                                            | -100%                                    | Increase of 30%            |

Based on the information above, by how much do CO<sub>2</sub> emissions need to be cut globally on average by 2030 and 2050 in order to limit global warming to 1.5°C?



Given the uncertainties, what is the minimum and the maximum value of needed cuts in CO<sub>2</sub> emissions in order to limit global warming to 1.5°C? Please adjust the sliders.



To what extent do you judge these scenario projections credible?

|            |                       |                       |                       |                       |                       |                       |                       |           |
|------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------|
| Not at all | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | Extremely |
|------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------|

To what extent do you judge these scenario projections uncertain?

|            |                       |                       |                       |                       |                       |                       |                       |           |
|------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------|
| Not at all | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | Extremely |
|------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------|

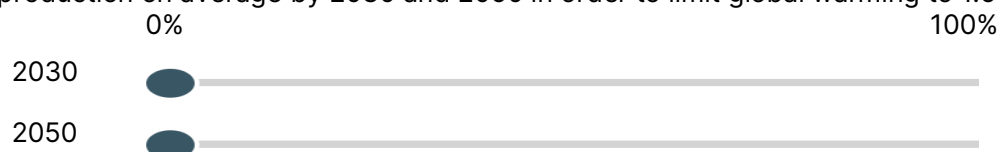
**E.1.11. Graph/table of share of fossil fuels in electricity industry**

Please briefly examine the information and then answer the questions beneath.

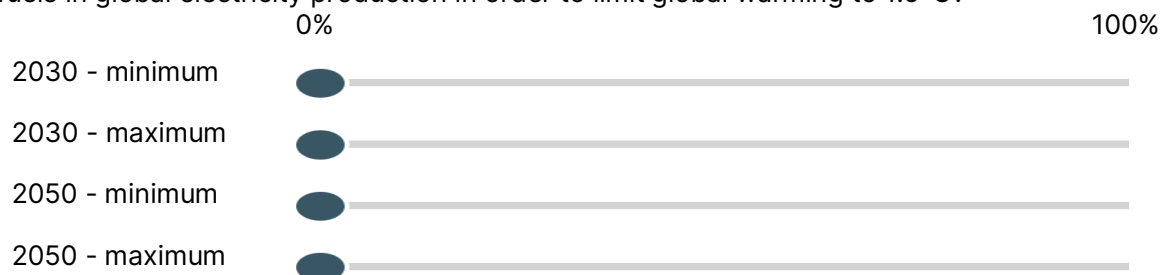
| Year | Global share of fossil fuels in electricity industry (in %) |                                          |                            |
|------|-------------------------------------------------------------|------------------------------------------|----------------------------|
|      | Range of all scenarios that meet 1.5°C                      | Average of all scenarios that meet 1.5°C | Business-as-usual scenario |
| 2020 | 35% to 68%                                                  | 59%                                      | 62%                        |
| 2030 | 0% to 60%                                                   | 30%                                      | 64%                        |
| 2040 | 0% to 28%                                                   | 6%                                       | 64%                        |
| 2050 | 0% to 10%                                                   | 0%                                       | 62%                        |



Based on the information above, what share of fossil fuels is needed in global electricity production on average by 2030 and 2050 in order to limit global warming to 1.5°C?



Given the uncertainties, what is the minimum and the maximum value of needed share of fossil fuels in global electricity production in order to limit global warming to 1.5°C?



### E.1.12. Graph/table of share of nuclear power in electricity industry

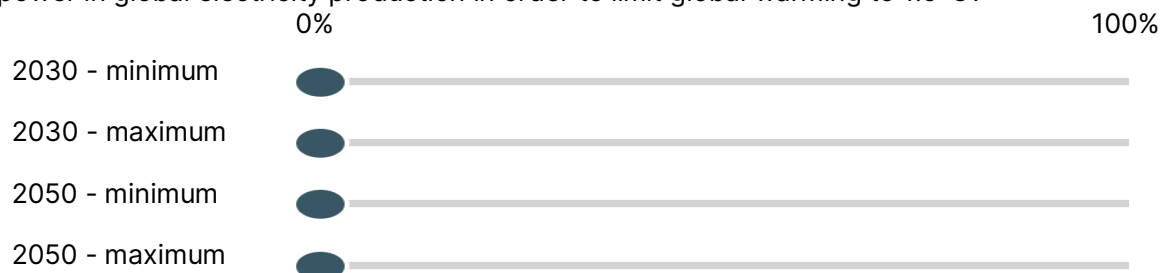
Please briefly examine the information and then answer the questions beneath.

| Year | Global share of nuclear power in electricity industry (in %) |                                          |                            |
|------|--------------------------------------------------------------|------------------------------------------|----------------------------|
|      | Range of all scenarios that meet 1.5°C                       | Average of all scenarios that meet 1.5°C | Business-as-usual scenario |
| 2020 | 9% to 18%                                                    | 12%                                      | 13%                        |
| 2030 | 5% to 30%                                                    | 15%                                      | 12%                        |
| 2040 | 2% to 36%                                                    | 13%                                      | 11%                        |
| 2050 | 0% to 40%                                                    | 10%                                      | 11%                        |

Based on the information above, what share of nuclear power is needed in global electricity production on average by 2030 and 2050 in order to limit global warming to 1.5°C?



Given the uncertainties, what is the minimum and the maximum value of needed share of nuclear power in global electricity production in order to limit global warming to 1.5°C?

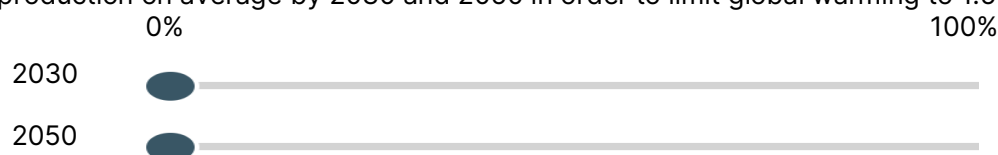


### E.1.13. Graph/table of share of renewable sources in electricity industry

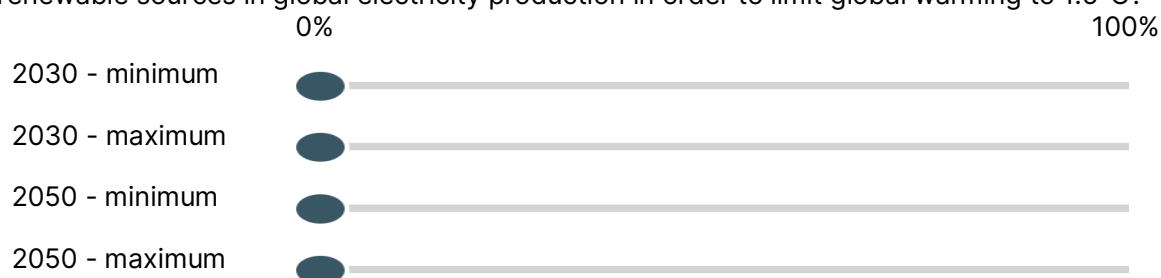
Please briefly examine the information and then answer the questions beneath.

| Year | Global share of renewable sources in electricity industry (in %) |                                          |                            |
|------|------------------------------------------------------------------|------------------------------------------|----------------------------|
|      | Range of all scenarios that meet 1.5°C                           | Average of all scenarios that meet 1.5°C | Business-as-usual scenario |
| 2020 | 17% to 42%                                                       | 28%                                      | 20%                        |
| 2030 | 25% to 80%                                                       | 50%                                      | 20%                        |
| 2040 | 33% to 93%                                                       | 73%                                      | 20%                        |
| 2050 | 40% to 100%                                                      | 80%                                      | 22%                        |

Based on the information above, what share of renewable sources is needed in global electricity production on average by 2030 and 2050 in order to limit global warming to 1.5°C?



Given the uncertainties, what is the minimum and the maximum value of needed share of renewable sources in global electricity production in order to limit global warming to 1.5°C?



### E.1.14. Subjective evaluation of graphs/tables

*For the German sample*

Please tell us your opinion about the scientific information that you received.

|                                                              | Strongly disagree     | Moderately disagree   | Neither agree or disagree | Moderately agree      | Strongly agree        |
|--------------------------------------------------------------|-----------------------|-----------------------|---------------------------|-----------------------|-----------------------|
| This information has filled some of my knowledge gaps.       | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |
| This information has not influenced my opinion.              | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |
| I found it difficult to understand this information.         | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |
| It was not very interesting for me to read this information. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |
| Overall, I like this information.                            | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |

*For the French and Polish samples*

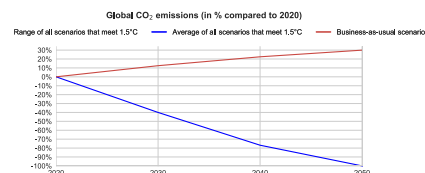
There are various formats to present the same scientific information.

Please compare the format that you received before (Format 1) with two other alternatives that present the exact same information (Formats 2 and 3).

Format 1

| Year | Global CO <sub>2</sub> emissions (in % compared to 2020) |                                          |                            |
|------|----------------------------------------------------------|------------------------------------------|----------------------------|
|      | Range of all scenarios that meet 1.5°C                   | Average of all scenarios that meet 1.5°C | Business-as-usual scenario |
| 2020 | -                                                        | -                                        | -                          |
| 2030 | 0% to -70%                                               | -40%                                     | Increase of 12%            |
| 2040 | -44% to -100%                                            | -77%                                     | Increase of 23%            |
| 2050 | -75% to -100%                                            | -100%                                    | Increase of 30%            |

Format 2



Which of these two formats looks  
the most...

Format 1

Format 2

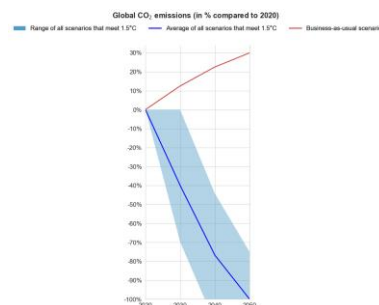
No difference

|                                         |                       |                       |                       |
|-----------------------------------------|-----------------------|-----------------------|-----------------------|
| ...trustworthy?                         | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| ...concerning?                          | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| ...exact in presenting the information? | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| ...easy to understand?                  | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| ...interesting to read?                 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

Format 1

| Year | Global CO <sub>2</sub> emissions (in % compared to 2020) |                                          |                            |
|------|----------------------------------------------------------|------------------------------------------|----------------------------|
|      | Range of all scenarios that meet 1.5°C                   | Average of all scenarios that meet 1.5°C | Business-as-usual scenario |
| 2020 | -                                                        | -                                        | -                          |
| 2030 | 0% to -70%                                               | -40%                                     | Increase of 12%            |
| 2040 | -44% to -100%                                            | -77%                                     | Increase of 23%            |
| 2050 | -75% to -100%                                            | -100%                                    | Increase of 30%            |

Format 3



Which of these two formats looks  
the most...

Format 1

Format 3

No difference

|                                         |                       |                       |                       |
|-----------------------------------------|-----------------------|-----------------------|-----------------------|
| ...trustworthy?                         | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| ...concerning?                          | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| ...exact in presenting the information? | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| ...easy to understand?                  | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| ...interesting to read?                 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

### E.1.15. Perceived efficacy of humanity to reduce CO<sub>2</sub> emissions (posterior measurement)

To what extent do you agree or disagree with the following statements?

|                                                                                          | Strongly disagree     | Moderately disagree   | Neither agree or disagree | Moderately agree      | Strongly agree        |
|------------------------------------------------------------------------------------------|-----------------------|-----------------------|---------------------------|-----------------------|-----------------------|
| Humans have the ability to cut CO <sub>2</sub> emissions to reduce global warming.       | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |
| Humans are willing to cut CO <sub>2</sub> emissions to reduce global warming.            | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |
| Humans will be successful in cutting CO <sub>2</sub> emissions to reduce global warming. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |

### E.1.16. Perceived efficacy of electricity industry to reduce CO<sub>2</sub> emissions (posterior measurement)

To what extent do you agree or disagree with the following statements?

|                                                                                                        | Strongly disagree     | Moderately disagree   | Neither agree or disagree | Moderately agree      | Strongly agree        |
|--------------------------------------------------------------------------------------------------------|-----------------------|-----------------------|---------------------------|-----------------------|-----------------------|
| Electricity industry has the ability to cut CO <sub>2</sub> emissions to reduce global warming.        | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |
| Electricity industry is willing to cut CO <sub>2</sub> emissions to reduce global warming.             | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |
| Electricity industry will be successful in cutting CO <sub>2</sub> emissions to reduce global warming. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |

### E.1.17. Affective responses (posterior measurement)

Please rate how you feel towards efforts to limit global warming. For each set of adjectives, move the slider to the direction of your feelings.

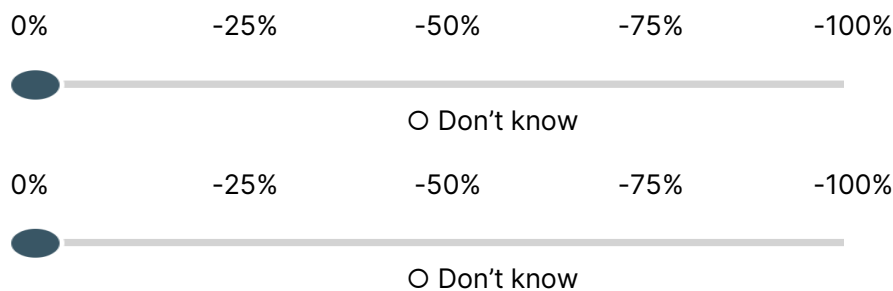
|                   |                       |                |
|-------------------|-----------------------|----------------|
| Hopeless          | <input type="range"/> | Hopeful        |
| Discouraged       | <input type="range"/> | Empowered      |
| Indifferent       | <input type="range"/> | Engaged        |
| Not Guilty        | <input type="range"/> | Guilty         |
| Calm              | <input type="range"/> | Outraged/Angry |
| Unconcerned       | <input type="range"/> | Alarmed        |
| Not afraid at all | <input type="range"/> | Very afraid    |

### E.1.18. Belief about the need to cut CO<sub>2</sub> emissions and belief about the required percentage of CO<sub>2</sub> emissions cuts (posterior measurement)

In your own opinion, to what extent do you agree that CO<sub>2</sub> should be cut globally to limit global warming to 1.5°C?

- Strongly disagree
- Disagree
- Somewhat disagree
- Neither agree or disagree
- Somewhat agree
- Agree
- Strongly agree

Based on your current knowledge, by what percentage do the scientists suggest cutting CO<sub>2</sub> emissions globally by 2030 and 2050 as compared to today to limit global warming to 1.5°C?



### E.1.19. Belief about the required electricity supply (posterior measurement)

Based on your knowledge, to what extent do the scientists suggest expanding or reducing these electricity generation alternatives in order to limit global warming to 1.5°C?

|                   | Significantly reduce  | Moderately reduce     | Slightly reduce       | Keep constant         | Slightly increase     | Moderately increase   | Significantly increase |
|-------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|------------------------|
| Fossil fuels      | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>  |
| Nuclear power     | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>  |
| Renewable sources | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>  |

☐ Don't know (fossil fuels)      ☐ Don't know (nuclear power)      ☐ Don't know (renewable sources)

### E.1.20. Numeracy

To what extent do you agree or disagree with the following statements?

|                                                                    | Strongly disagree     | Moderately disagree   | Neither agree or disagree | Moderately agree      | Strongly agree        |
|--------------------------------------------------------------------|-----------------------|-----------------------|---------------------------|-----------------------|-----------------------|
| I am good at calculating fractions (e.g. a quarter).               | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |
| I am good at calculating percentages.                              | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |
| I am not good at calculating a 15% tip.                            | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |
| When I am reading the newspaper, I find tables and graphs helpful. | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |
| I often do not find numerical information useful.                  | <input type="radio"/> | <input type="radio"/> | <input type="radio"/>     | <input type="radio"/> | <input type="radio"/> |

### E.1.21. Graph literacy

Please choose the answer that applies most for you.

|                                                                                 | Not at all good       |                       |                       |                       |                       | Extremely good        |
|---------------------------------------------------------------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| How good are you at working with bar charts?                                    | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| How good are you at working with line charts?                                   | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| How good are you at working with pie charts?                                    | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| How good are you at inferring the size of a bar in a bar chart?                 | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |
| How good are you at determining the difference between two bars in a bar chart? | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> | <input type="radio"/> |

### E.1.22. Demographics (2/2)

Many people use the terms “left” and “right” when they want to describe different political views. Thinking of your own political views, where would you place these on this scale?

left ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ right

### E.1.23. Survey end

Thank you for your participation! Please click on the “Continue” button below to finish the survey. If you have any comments for the survey team, please leave them here.

## **E.2. Preparatory study: comparison between scenario ranges and three scenarios with storylines**

### **E.2.1. Introduction**

This section presents the results of a preparatory study of a between-groups experiment, where two groups of respondents from the EU (total N = 145; convenience sample with climate experts and stakeholders) received two different formats for visualizing scenarios of greenhouse gas emissions (GHG) for meeting the target of net zero emissions by 2050 in European Union: (1) a range graph (n = 80); (2) a selection of only three illustrative scenarios with storylines (n = 65). This survey was embedded at the end of a larger online survey for collecting feedback on a Research and Innovation (R&I) strategy for decarbonizing the EU [for more details, see Xexakis and Trutnevyte (2019b)]. The two groups were evaluated in terms of tested understanding and anchoring effects from the visualization and in terms of their subjective evaluation of the visualization.

### **E.2.2. Sample and procedure**

The respondents were recruited between March and June 2019 using two methods: 1) advertisements in email databases, mailing lists, and social media groups of academic and professional organisations (*academic and professional groups* subsample, n = 73) and 2) access panels in four EU countries: Germany, France, UK, and Italy (*access panels* subsample, n = 72). In sum, the total valid sample included 145 respondents. After finishing the first part of the survey on the R&I strategy (Xexakis and Trutnevyte, 2019b), respondents received a visualization of GHG emissions cuts for one EU climate change mitigation scenario and an ensemble of global mitigation scenarios to limit global warming to 1.5°C (Figures E.1 and E.2). The format of the global scenarios in the visualization was the main experimental manipulation and was randomly assigned to the respondents. One experimental group received a visualization showing uncertainty ranges from the global scenario ensemble (*range graph*, Figure E.1, n = 80), while the other showed three illustrative scenarios from this ensemble along with storylines (*three illustrative scenarios*, Figure E.2, n = 65). The data for the EU scenario were sourced from the climate change mitigation strategy of the EU (European Commission, 2018d), while the global scenarios came from the scenario database of IPCC Special Report on Global Warming of 1.5°C (IPCC, 2018a; Rogelj et al., 2018a).

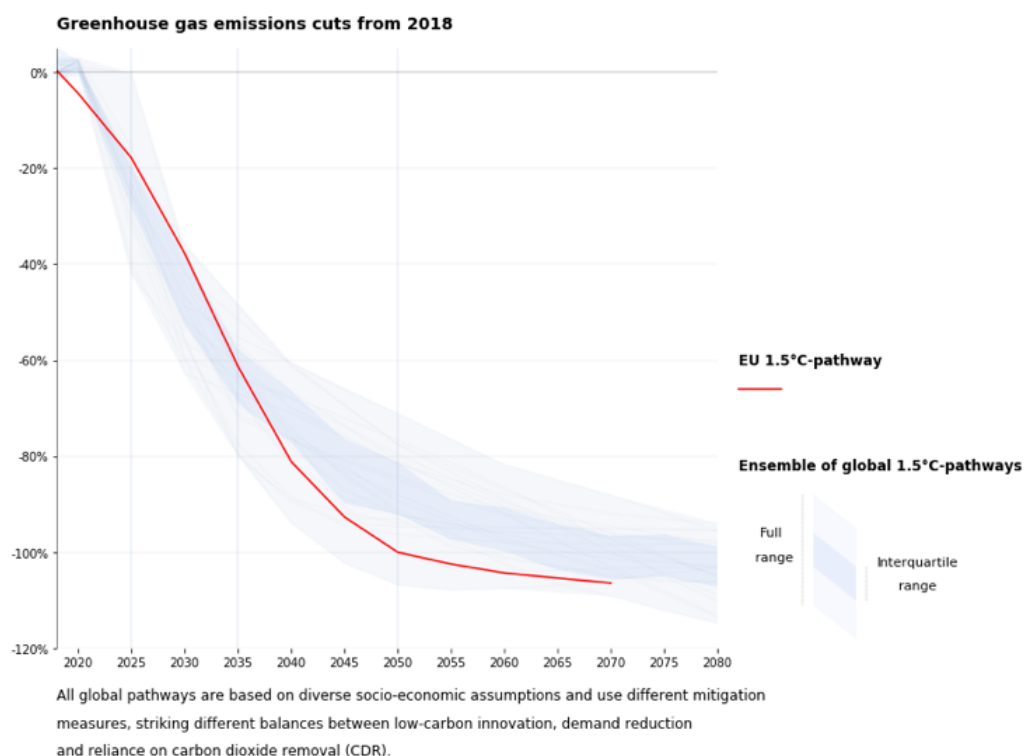


Figure E.1. The *range graph* experimental condition, showing the full range and interquartile range of global scenarios (mentioned as “pathways” in the graph) and the EU scenario (n = 80)

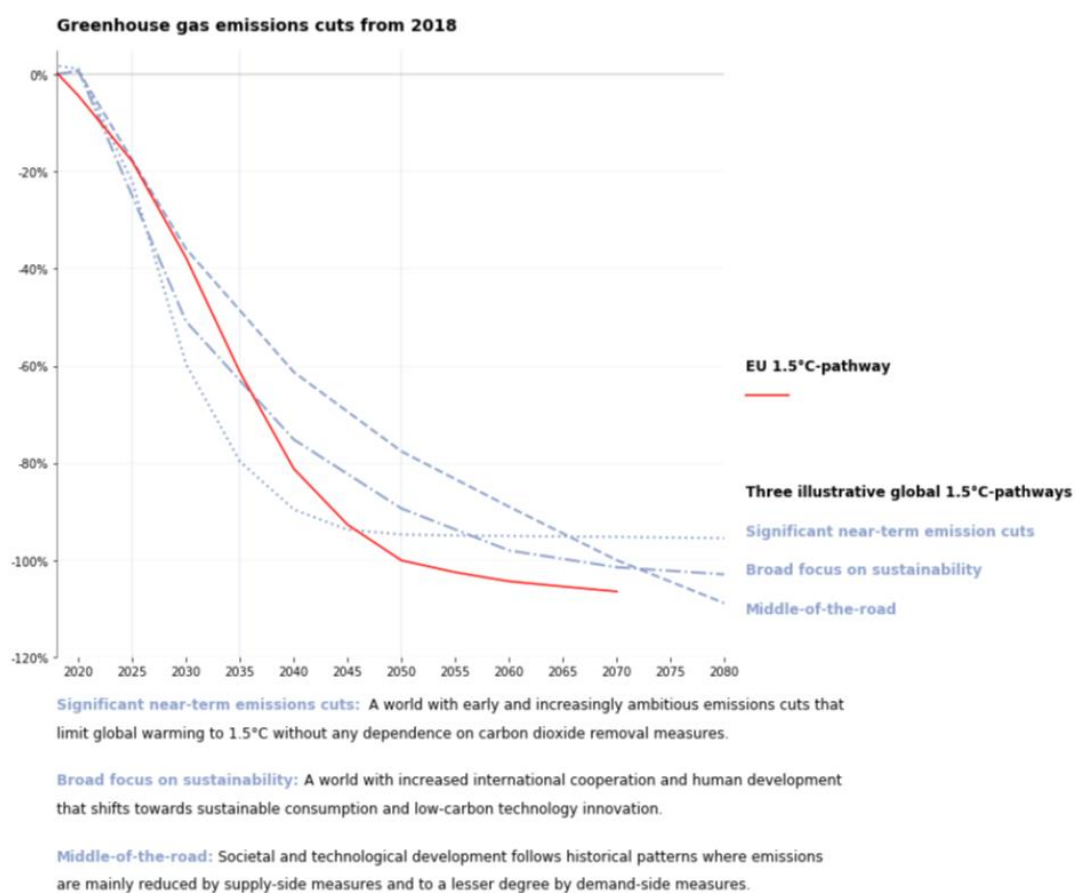


Figure E.2. The *three illustrative scenarios* experimental condition, showing three illustrative global scenarios with storylines and the EU scenario (n = 65)



### E.2.3. Results and discussion

Experimental conditions were more or less balanced in terms of previous characteristics of the respondents, as there was no statistically significant difference between the conditions (Table E.1). However, there were many differences between the subsamples, with the *access panels* respondents being statistically significantly less frequent scenario users than the respondents from *academic and professional groups* [4.3 (0.9) versus 4.6 (1.0), Mann-Whitney  $U = 2173$ ,  $p = 0.028$ ] and less knowledgeable of the mitigation pathways of the IPCC Special Report on global warming of 1.5°C [3.2 (1.1) versus 3.5 (0.9),  $U = 2202$ ,  $p = 0.038$ ]. The *access panels* also included less respondents from academia and more respondents from business or industry than the *academic and professional groups* (see Table E.1).

Table E.1. Characteristics of the respondents, split by experimental condition and by recruitment subsample

| Variable names and survey questions                                                                            | Experimental condition                                           |                                      |                    | Recruitment subsample                |                                         |                    |   |
|----------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------|--------------------------------------|--------------------|--------------------------------------|-----------------------------------------|--------------------|---|
|                                                                                                                | <i>range graph</i>                                               | <i>three illustrative scenarios</i>  | <i>U-statistic</i> | <i>access panels</i>                 | <i>academic and professional groups</i> | <i>U-statistic</i> |   |
|                                                                                                                | n = 80<br><i>M (SD) / percentage</i>                             | n = 65<br><i>M (SD) / percentage</i> |                    | n = 73<br><i>M (SD) / percentage</i> | n = 72<br><i>M (SD) / percentage</i>    |                    |   |
| <i>scenario use frequency</i>                                                                                  |                                                                  |                                      |                    |                                      |                                         |                    |   |
| How frequently do you use scenarios/pathways in your everyday work?                                            | 3.2 (1.0)                                                        | 3.4 (0.9)                            | 2569               | 3.2 (1.1)                            | 3.5 (0.9)                               | 2173*              |   |
| 1 = never to 5 = almost all the time                                                                           |                                                                  |                                      |                    |                                      |                                         |                    |   |
| <i>IPCC 1.5C knowledge</i>                                                                                     |                                                                  |                                      |                    |                                      |                                         |                    |   |
| How knowledgeable are you about the mitigation pathways of the IPCC Special Report on global warming of 1.5°C? | 4.4 (1.0)                                                        | 4.4 (0.9)                            | 2257               | 4.3 (0.9)                            | 4.6 (1.0)                               | 2202*              |   |
| 1 = not at all knowledgeable to 5 = very knowledgeable                                                         |                                                                  |                                      |                    |                                      |                                         |                    |   |
| <i>organization type</i>                                                                                       |                                                                  |                                      |                    |                                      |                                         |                    |   |
| Which of the following best describes your organization?                                                       | Academia or research organization                                | 39%                                  | 48%                | -                                    | 28%                                     | 53%                | - |
|                                                                                                                | Business or industry                                             | 23%                                  | 26%                | -                                    | 36%                                     | 17%                | - |
|                                                                                                                | Non-governmental organization, platform or network               | 21%                                  | 14%                | -                                    | 12%                                     | 21%                | - |
|                                                                                                                | Public organization (international, national, regional or local) | 9%                                   | 8%                 | -                                    | 16%                                     | 4%                 | - |
|                                                                                                                | Other                                                            | 8%                                   | 3%                 | -                                    | 7%                                      | 5%                 | - |
|                                                                                                                |                                                                  |                                      |                    |                                      |                                         |                    |   |

Note: \* $p < 0.05$ ; \*\* $p < 0.01$ , \*\*\* $p < 0.001$ . The  $U$ -statistics refer to Mann-Whitney tests between the experimental conditions and between the recruitment subsamples (separate test for each variable).

While there were almost no statistically significant differences between experimental conditions in the evaluation questions (Table E.2), there were many statistically significant differences between respondents from the *access panels* and the *academic and professional groups*. In terms of *tested understanding*, respondents from the *academic and professional groups* correctly identified that the ambition levels of the EU scenario changed for each target year in comparison with the global scenarios, while *access panels* respondents selected on average a similar ambition level for all years. A Mann-Whitney test showed that respondents from *academic and professional groups* chose statistically significantly lower ambition levels for 2025 [4.9 (1.5) versus 3.5 (1.9),  $U = 1497$ ,  $p < 0.001$ ] and for 2035 [4.9 (1.3) versus 4.2 (1.7),  $U = 1983$ ,  $p = 0.006$ ] than the *access panels* respondents. *Compatibility* was statistically significantly lower for the *access panels* respondents than the respondents from *academic and professional groups* for all the years asked [2025: 4.7 (1.4) versus 5.1 (1.4),  $U = 2011$ ,  $p = 0.03$ ; 2035: 4.6 (1.2) versus 5.1 (1.3),  $U = 1899$ ,  $p = 0.007$ ; 2050: 4.6 (1.5) versus 5.2 (1.6),  $U = 1928$ ,  $p = 0.005$ ]. In terms of *likelihood of net zero EU target*, *access panels* respondents selected a statistically significantly higher likelihood than respondents from the *academic and professional groups* [4.4 (1.3) versus 3.6 (1.3),  $U = 1698$ ,  $p < 0.001$ ]. In contrast, there was no statistically significant difference between the subsamples for the *earliest EU net zero* and the *subjective evaluation*.

Table E.2. Results split by experimental condition and by recruitment subsample

| Variable names and survey questions                                                                                |          | Experimental condition |                                         |                         | Recruitment subsample |                                                                       |                         |
|--------------------------------------------------------------------------------------------------------------------|----------|------------------------|-----------------------------------------|-------------------------|-----------------------|-----------------------------------------------------------------------|-------------------------|
|                                                                                                                    |          | <i>range</i>           | <i>three</i>                            | <i>U</i> -<br>statistic | <i>access</i>         | <i>academic</i><br><i>and</i><br><i>professional</i><br><i>groups</i> | <i>U</i> -<br>statistic |
|                                                                                                                    |          | <i>graph</i>           | <i>illustrative</i><br><i>scenarios</i> |                         | <i>panels</i>         | <i>n = 72</i>                                                         |                         |
|                                                                                                                    |          | n = 80                 | n = 65                                  |                         | n = 73                | n = 72                                                                |                         |
|                                                                                                                    |          | <i>M (SD)</i>          |                                         |                         | <i>M (SD)</i>         |                                                                       |                         |
| <i>tested understanding</i>                                                                                        |          |                        |                                         |                         |                       |                                                                       |                         |
| How ambitious are the emissions cuts of the EU pathway in comparison to the emissions cuts of the global pathways? | for 2025 | 4.1 (1.8)              | 4.3 (1.8)                               | 2482                    | 4.9 (1.5)             | 3.5 (1.8)                                                             | 1498***                 |
|                                                                                                                    | for 2035 | 4.4 (1.6)              | 4.6 (1.4)                               | 2429                    | 4.9 (1.3)             | 4.2 (1.7)                                                             | 1983**                  |
|                                                                                                                    | for 2050 | 4.9 (1.5)              | 5.2 (1.5)                               | 2272                    | 5.0 (1.3)             | 5.0 (1.7)                                                             | 2473                    |
| 1 = not ambitious at all to 7 = very ambitious                                                                     |          |                        |                                         |                         |                       |                                                                       |                         |
| <i>compatibility</i>                                                                                               |          |                        |                                         |                         |                       |                                                                       |                         |
| How compatible are the HLP R&I priorities with the emissions cuts required in the EU pathway?                      | for 2025 | 4.9 (1.5)              | 4.9 (1.2)                               | 2322                    | 4.7 (1.4)             | 5.1 (1.4)                                                             | 2011*                   |
|                                                                                                                    | for 2035 | 4.9 (1.4)              | 4.8 (1.2)                               | 2194                    | 4.6 (1.2)             | 5.1 (1.3)                                                             | 1899**                  |
|                                                                                                                    | for 2050 | 5.2 (1.5)              | 4.6 (1.6)                               | 2019                    | 4.6 (1.5)             | 5.2 (1.6)                                                             | 1928**                  |
| 1 = not compatible at all to 7 = very compatible                                                                   |          |                        |                                         |                         |                       |                                                                       |                         |

## E.2 Preparatory study: comparison between scenario ranges and three scenarios with storylines

Table E.2. (continued)

|                                                                                                         |                                                     |            |            |           |            |            |      |
|---------------------------------------------------------------------------------------------------------|-----------------------------------------------------|------------|------------|-----------|------------|------------|------|
| <i>likelihood of net zero EU target</i>                                                                 |                                                     |            |            |           |            |            |      |
| In your opinion, what is the chance that the target of net zero emissions in the EU is reached by 2050? |                                                     |            |            |           |            |            |      |
|                                                                                                         | 3.9 (1.2)                                           | 4.2 (1.3)  | 2401       | 4.4 (1.3) | 3.6 (1.1)  | 1698***    |      |
| 1 = exceptionally unlikely to 7 = virtually certain                                                     |                                                     |            |            |           |            |            |      |
| <i>earliest EU net zero</i>                                                                             |                                                     |            |            |           |            |            |      |
| What is the earliest date when net-zero emissions can be realistically achieved in the EU?              |                                                     |            |            |           |            |            |      |
|                                                                                                         | 2055 (22)                                           | 2054 (21)  | 2845       | 2054 (21) | 2055 (21)  | 2789       |      |
| 2020 to 2100 (or "net zero is not feasible before 2100")                                                |                                                     |            |            |           |            |            |      |
| <i>subjective evaluation</i>                                                                            |                                                     |            |            |           |            |            |      |
| What is your opinion of the previous figure of emissions pathways?                                      | easy to understand                                  | 3.5 (1.0)  | 3.4 (1.0)  | 2292      | 3.5 (1.0)  | 3.5 (0.9)  | 2349 |
|                                                                                                         | helpful                                             | 3.7 (0.9)  | 3.7 (0.8)  | 2399      | 3.6 (0.9)  | 3.7 (0.8)  | 2361 |
|                                                                                                         | useful                                              | 3.6 (0.8)  | 3.5 (0.8)  | 2292      | 3.5 (0.9)  | 3.6 (0.7)  | 2349 |
|                                                                                                         | self-explanatory                                    | 3.6 (0.9)  | 3.7 (0.8)  | 2369      | 3.6 (0.9)  | 3.7 (0.9)  | 2265 |
|                                                                                                         | gave a broader sense of the required emissions cuts | 3.6 (1.0)  | 3.6 (0.8)  | 2360      | 3.6 (0.9)  | 3.6 (0.9)  | 2270 |
| 1 = strongly disagree to 5 = strongly agree                                                             |                                                     |            |            |           |            |            |      |
|                                                                                                         | sum scale (max. 25)                                 | 18.0 (3.6) | 17.2 (4.4) | 2330      | 17.3 (4.7) | 18.0 (3.2) | 2492 |

Note: \* $p < 0.05$ ; \*\* $p < 0.01$ , \*\*\* $p < 0.001$ . The  $U$ -statistics refer to Mann-Whitney tests between the experimental conditions and between the recruitment methods (separate test for each variable).

A possible explanation for the differences between the subsamples could be that *access panels* respondents had on average less knowledge in the visualization's topic than *academic and professional groups* respondents, as they were using scenarios less frequently and had less knowledge about the mitigation pathways of the IPCC Special Report on global warming of 1.5°C. This difference in knowledge might explain the fact that *academic and professional groups* respondents selected the correct pattern of ambition levels for different years in the *tested understanding* test. Additionally, knowledge differences might also explain the difference in *compatibility* questions: *academic and professional groups* respondents might have been better informed about the R&I priorities that were included in the *compatibility* questions and selected a higher compatibility with the EU decarbonisation scenario. Overall, results indicate that prior knowledge in the visualization's topic may play a much more significant role than the format in the interpretation of the visualization. Nevertheless, this experiment had also significant limitations such as the limited sample size, the lack of representativeness to any specific population, and the fact that it was performed after a long survey which might have led to respondents' fatigue.

### E.3. Experimental check

The experimental conditions were balanced in terms of sample size with each including 73–78 respondents. The conditions were more or less comparable in terms of demographics, prior beliefs, *numeracy*, and *graph literacy* (Tables E.3–E.5). An exception to this was the German sample where the conditions differed in terms of *gender* and *education level*, although none of these differences were statistically significant (female ratio: 48% for *table*, 45% for *gradual range*, 52% for *steep range*, 66% *gradual ensemble*, 52% *steep ensemble*,  $\chi^2 = 8.00$ ,  $p = 0.092$ ; percentage with high school diploma: 29% for *table*, 37% for *gradual range*, 47% for *steep range*, 27% *gradual ensemble*, 35% *steep ensemble*,  $\chi^2 = 7.20$ ,  $p = 0.126$ ). Nevertheless, to ensure the robustness of the experimental design, all statistical analyses between experimental conditions were validated by adding demographics as covariates

Table E.3. Experimental check for the German sample

| Characteristics<br>of the<br>respondents                                   | Measurement                                            | <i>M (SD) / percentages</i> |                          |                        |                             |                           | Statistic          |
|----------------------------------------------------------------------------|--------------------------------------------------------|-----------------------------|--------------------------|------------------------|-----------------------------|---------------------------|--------------------|
|                                                                            |                                                        | <i>table</i>                | <i>gradual<br/>range</i> | <i>steep<br/>range</i> | <i>gradual<br/>ensemble</i> | <i>steep<br/>ensemble</i> |                    |
| <i>German sample</i>                                                       |                                                        | n = 77                      | n = 75                   | n = 75                 | n = 77                      | n = 75                    |                    |
| <i>gender</i>                                                              | % of female respondents                                | 48                          | 45                       | 52                     | 66                          | 52                        | $\chi^2(4) = 8.00$ |
| <i>age</i>                                                                 | age in years                                           | 49.8<br>(17.4)              | 50.0<br>(19.1)           | 47.4<br>(15.5)         | 50.9<br>(16.2)              | 48.5<br>(16.5)            | $F(4,374) = 0.49$  |
| <i>education level</i>                                                     | % of respondents with high school diploma              | 29                          | 37                       | 47                     | 27                          | 35                        | $\chi^2(4) = 7.20$ |
| <i>numeracy</i>                                                            | 4 = low to 20 = high                                   | 13.5<br>(3.5)               | 13.5<br>(3.0)            | 13.4<br>(2.9)          | 12.9 (3.3)                  | 13.2 (3.3)                | $F(4,374) = 0.43$  |
| <i>graph literacy</i>                                                      | 5 = low to 35 = high                                   | 20.4<br>(8.0)               | 21.8<br>(7.8)            | 20.4<br>(8.1)          | 19.6 (8.3)                  | 21.3 (9.0)                | $F(4,374) = 0.80$  |
| <i>political orientation</i>                                               | 1 = left to 10 = right                                 | 4.8<br>(1.9)                | 4.4<br>(1.8)             | 4.7<br>(2.0)           | 4.5 (1.9)                   | 4.4 (1.9)                 | $F(4,374) = 0.74$  |
| <i>belief in global warming</i>                                            | 5 = low to 25 = high                                   | 20.9<br>(4.3)               | 21.1<br>(3.7)            | 20.7<br>(4.2)          | 20.6 (3.6)                  | 20.7 (4.3)                | $F(4,374) = 0.21$  |
| <i>belief about the need to cut CO<sub>2</sub> emissions</i>               | 1 = strongly disagree to 7 = strongly agree            | 5.6<br>(1.7)                | 5.8<br>(1.3)             | 5.5<br>(1.5)           | 5.5 (1.5)                   | 5.7 (1.5)                 | $F(4,374) = 0.59$  |
| <i>belief about the required electricity supply from fossil fuels</i>      | 1 = significantly reduce to 7 = significantly increase | 1.9<br>(1.3)                | 1.9 (1.3)                | 2.1<br>(1.6)           | 2.1 (1.5)                   | 2.1 (1.3)                 | $F(4,359) = 0.44$  |
| <i>belief about the required electricity supply from nuclear</i>           | 1 = significantly reduce to 7 = significantly increase | 2.5<br>(1.6)                | 2.4<br>(1.4)             | 2.3<br>(1.6)           | 2.7 (1.8)                   | 2.7 (1.7)                 | $F(4,345) = 0.84$  |
| <i>belief about the required electricity supply from renewable sources</i> | 1 = significantly reduce to 7 = significantly increase | 6.2<br>(1.4)                | 6.2 (1.1)                | 6.1<br>(1.4)           | 6.3 (1.1)                   | 6.2 (1.1)                 | $F(4,357) = 0.4$   |

Table E.4. Experimental check for the Polish sample

| Characteristics of the respondents                                         | Measurement                                            | <i>M (SD) / percentages</i> |                      |                    | Statistic           |
|----------------------------------------------------------------------------|--------------------------------------------------------|-----------------------------|----------------------|--------------------|---------------------|
|                                                                            |                                                        | <i>table</i>                | <i>gradual range</i> | <i>steep range</i> |                     |
|                                                                            | <i>Polish sample</i>                                   | n = 74                      | n = 73               | n = 76             |                     |
| <i>gender</i>                                                              | % of female respondents                                | 58                          | 41                   | 53                 | $\chi^2 (2) = 4.43$ |
| <i>age</i>                                                                 | age in years                                           | 40.1<br>(13.8)              | 42.3<br>(13.3)       | 43.0<br>(13.0)     | $F (2,220) = 0.99$  |
| <i>education level</i>                                                     | % of respondents with high school diploma              | 61                          | 71                   | 66                 | $\chi^2 (2) = 1.78$ |
| <i>numeracy</i>                                                            | 4 = low to 20 = high                                   | 14.2 (3.0)                  | 13.6 (3.3)           | 13.3 (3.4)         | $F (2,220) = 1.53$  |
| <i>graph literacy</i>                                                      | 5 = low to 35 = high                                   | 24.8 (7.5)                  | 23.6 (8.5)           | 22.9 (8.8)         | $F (2,220) = 1.02$  |
| <i>political orientation</i>                                               | 1 = left to 10 = right                                 | 5.2 (2.5)                   | 5.5 (2.6)            | 5.4 (2.8)          | $F (2,220) = 0.16$  |
| <i>belief in global warming</i>                                            | 5 = low to 25 = high                                   | 20.3 (5.2)                  | 21.1 (4.6)           | 20.3 (5.6)         | $F (2,220) = 0.61$  |
| <i>belief about the need to cut CO<sub>2</sub> emissions</i>               | 1 = strongly disagree to<br>7 = strongly agree         | 5.6 (1.4)                   | 5.8 (1.4)            | 5.4 (1.6)          | $F (2,220) = 1.19$  |
| <i>belief about the required electricity supply from fossil fuels</i>      | 1 = significantly reduce to 7 = significantly increase | 2.3 (1.6)                   | 2.4 (1.6)            | 2.2 (1.6)          | $F (2,213) = 0.17$  |
| <i>belief about the required electricity supply from nuclear</i>           | 1 = significantly reduce to 7 = significantly increase | 4.0 (1.8)                   | 4.1 (2.0)            | 4.0 (1.9)          | $F (2,211) = 0.01$  |
| <i>belief about the required electricity supply from renewable sources</i> | 1 = significantly reduce to 7 = significantly increase | 5.9 (1.7)                   | 6.2 (1.4)            | 5.9 (1.5)          | $F (2,211) = 0.70$  |

Table E.5. Experimental check for the French sample

| Characteristics of the respondents                                         | Measurement                                            | <i>M (SD) / percentages</i> |                      |                    | Statistic          |
|----------------------------------------------------------------------------|--------------------------------------------------------|-----------------------------|----------------------|--------------------|--------------------|
|                                                                            |                                                        | <i>table</i>                | <i>gradual range</i> | <i>steep range</i> |                    |
| <i>French sample</i>                                                       |                                                        | n = 74                      | n = 78               | n = 73             |                    |
| <i>gender</i>                                                              | % of female respondents                                | 51                          | 53                   | 52                 | $\chi^2(2) = 0.02$ |
| <i>age</i>                                                                 | age in years                                           | 44.6<br>(13.9)              | 44.8<br>(15.8)       | 45.8<br>(14.0)     | $F(2,222) = 0.14$  |
| <i>education level</i>                                                     | % of respondents with high school diploma              | 81                          | 78                   | 78                 | $\chi^2(2) = 0.26$ |
| <i>numeracy</i>                                                            | 4 = low to 20 = high                                   | 13.5 (3.5)                  | 13.7 (3.8)           | 13.6 (3.6)         | $F(2,222) = 0.03$  |
| <i>graph literacy</i>                                                      | 5 = low to 35 = high                                   | 17.8 (8.2)                  | 19.1 (8.4)           | 17.9 (8.5)         | $F(2,222) = 0.59$  |
| <i>political orientation</i>                                               | 1 = left to 10 = right                                 | 4.6 (2.7)                   | 5.2 (2.4)            | 4.9 (2.5)          | $F(2,222) = 1.27$  |
| <i>belief in global warming</i>                                            | 5 = low to 25 = high                                   | 21.8 (2.8)                  | 21.2 (3.6)           | 21.4 (2.9)         | $F(2,222) = 0.57$  |
| <i>belief about the need to cut CO<sub>2</sub> emissions</i>               | 1 = strongly disagree to 7 = strongly agree            | 6.1 (1.0)                   | 5.9 (1.4)            | 5.8 (1.3)          | $F(2,222) = 1.49$  |
| <i>belief about the required electricity supply from fossil fuels</i>      | 1 = significantly reduce to 7 = significantly increase | 2.2 (1.5)                   | 2.2 (1.5)            | 2.3 (1.6)          | $F(2,200) = 0.25$  |
| <i>belief about the required electricity supply from nuclear</i>           | 1 = significantly reduce to 7 = significantly increase | 2.8 (1.6)                   | 2.7 (1.5)            | 3.0 (1.7)          | $F(2,205) = 1.00$  |
| <i>belief about the required electricity supply from renewable sources</i> | 1 = significantly reduce to 7 = significantly increase | 6.0 (1.3)                   | 5.9 (1.6)            | 5.5 (1.9)          | $F(2,205) = 1.72$  |

#### E.4. Distribution of answers to reading accuracy and knowledge gains questions

The answering patterns in *reading accuracy* across different *value types* and years indicated that respondents may have confused correct answers between maximum and minimum values (Figure E.3). For example, for the questions over the maximum and minimum values for 2050 in fossil fuels, some respondents seemed to have used the correct value for the minimum to the question for the maximum and vice versa. Additionally, a number of respondents seemed to have answered randomly, shown by the almost continuous distribution of answers throughout the range of 0-100%. The concentration of answers at the 50%-point may also indicate satisficing effects or uncertainty about the correct answer by the respondents in both *reading accuracy* and *knowledge gains* questions (Table E.6 and E.7). For the few respondents that consistently selected the 50% and 0%-point, *graph literacy*, *education level*, and congruence between prior beliefs and visualizations were statistically significantly lower than other respondents (Tables E.8 and E.9).

## E.4 Distribution of answers to reading accuracy and knowledge gains questions



Figure E.3. Distributions of answers to all *reading accuracy* questions. Red lines show the correct answer for each question.

Table E.6. Types of answers to *reading accuracy* questions

|                                                 | % of total respondents (N = 827) |                   |                  |               |
|-------------------------------------------------|----------------------------------|-------------------|------------------|---------------|
|                                                 | Correct                          | Wrong (50%-point) | Wrong (0%-point) | Wrong (other) |
| Individual questions on <i>reading accuracy</i> |                                  |                   |                  |               |
| CO <sub>2</sub> emissions cuts                  |                                  |                   |                  |               |
| average - 2030                                  | 48%                              | 11%               | 2%               | 39%           |
| average - 2050                                  | 48%                              | 10%               | 1%               | 41%           |
| minimum - 2030                                  | 31%                              | 12%               | 0%               | 57%           |
| maximum - 2030                                  | 37%                              | 14%               | 0%               | 49%           |
| minimum - 2050                                  | 34%                              | 14%               | 1%               | 51%           |
| maximum - 2050                                  | 51%                              | 10%               | 1%               | 38%           |
| fossil fuels                                    |                                  |                   |                  |               |
| average - 2030                                  | 45%                              | 10%               | 2%               | 43%           |
| average - 2050                                  | 34%                              | 9%                | 0%               | 57%           |
| minimum - 2030                                  | 37%                              | 10%               | 0%               | 53%           |
| maximum - 2030                                  | 41%                              | 11%               | 0%               | 48%           |
| minimum - 2050                                  | 41%                              | 11%               | 0%               | 48%           |
| maximum - 2050                                  | 39%                              | 10%               | 0%               | 51%           |
| nuclear power                                   |                                  |                   |                  |               |
| average - 2030                                  | 42%                              | 9%                | 2%               | 47%           |
| average - 2050                                  | 42%                              | 10%               | 4%               | 44%           |
| minimum - 2030                                  | 46%                              | 9%                | 1%               | 44%           |
| maximum - 2030                                  | 43%                              | 11%               | 1%               | 45%           |
| minimum - 2050                                  | 43%                              | 10%               | 0%               | 47%           |
| maximum - 2050                                  | 40%                              | 10%               | 0%               | 50%           |

Table E.6. (continued)

|                                                   |     |     |    |     |
|---------------------------------------------------|-----|-----|----|-----|
| renewable sources                                 |     |     |    |     |
| average - 2030                                    | 48% | 0%  | 1% | 51% |
| average - 2050                                    | 42% | 13% | 1% | 44% |
| minimum - 2030                                    | 44% | 13% | 1% | 42% |
| maximum - 2030                                    | 43% | 15% | 1% | 41% |
| minimum - 2050                                    | 42% | 13% | 1% | 44% |
| maximum - 2050                                    | 48% | 9%  | 1% | 43% |
| <hr/>                                             |     |     |    |     |
| % of respondents with the same type of answer to: |     |     |    |     |
| 25% of the questions                              | 50% | 11% | 1% | 68% |
| 50% of the questions                              | 35% | 3%  | 0% | 50% |
| 75% of the questions                              | 25% | 1%  | 0% | 18% |
| 100% of the questions                             | 8%  | 0%  | 0% | 0%  |

Table E.7. Types of answers to *knowledge gains (CO<sub>2</sub>)* questions

|                                                                 | % of total respondents (N = 827) |                   |                  |               |
|-----------------------------------------------------------------|----------------------------------|-------------------|------------------|---------------|
|                                                                 | Correct                          | Wrong (50%-point) | Wrong (0%-point) | Wrong (other) |
| <hr/>                                                           |                                  |                   |                  |               |
| Individual questions on <i>knowledge gains (CO<sub>2</sub>)</i> |                                  |                   |                  |               |
| prior                                                           |                                  |                   |                  |               |
| 2030                                                            | 12%                              | 14%               | 8%               | 66%           |
| 2050                                                            | 5%                               | 16%               | 7%               | 72%           |
| posterior                                                       |                                  |                   |                  |               |
| 2030                                                            | 24%                              | 16%               | 5%               | 55%           |
| 2050                                                            | 21%                              | 9%                | 5%               | 65%           |
| <hr/>                                                           |                                  |                   |                  |               |
| % of respondents with the same type of answer to:               |                                  |                   |                  |               |
| both prior questions                                            | 1%                               | 5%                | 5%               | 53%           |
| both posterior questions                                        | 7%                               | 3%                | 4%               | 41%           |



## E.4 Distribution of answers to reading accuracy and knowledge gains questions

Table E.8. Characteristics of respondents with the same type of answer to more than half of *reading accuracy* questions

|                                                                                                                            | <i>M (SD) / percentages</i> |                       |                   | Statistic                 | Post-hoc      |
|----------------------------------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|-------------------|---------------------------|---------------|
|                                                                                                                            | Correct [1]                 | Wrong (50%-point) [2] | Wrong (other) [3] |                           |               |
|                                                                                                                            | n = 290                     | n = 28                | n = 410           |                           |               |
| <i>gender</i><br>(female)                                                                                                  | 48%                         | 61%                   | 55%               | $\chi^2(2) = 4.11$        | -             |
| <i>age</i><br>(years)                                                                                                      | 42.6 (15.9)                 | 46.1 (14.2)           | 48.3 (15.3)       | $F(2,725) = 11.576^{***}$ | 1-3           |
| <i>education level</i><br>(high school diploma)                                                                            | 71%                         | 39%                   | 48%               | $\chi^2(2) = 38.41^{***}$ | 1-2, 1-3      |
| <i>numeracy</i><br>(4 = low to 20 = high)                                                                                  | 14.6 (3.3)                  | 12.3 (2.2)            | 12.9 (3.3)        | $F(2,725) = 24.98^{***}$  | 1-2, 1-3      |
| <i>graph literacy</i><br>(5 = low to 35 = high)                                                                            | 24.6 (7.1)                  | 15.5 (8.4)            | 19.1 (8.6)        | $F(2,725) = 47.443^{***}$ | 1-2, 1-3, 2-3 |
| <i>political orientation</i><br>(1 = left to 10 = right)                                                                   | 4.6 (2.2)                   | 4.4 (1.5)             | 5.0 (2.5)         | $F(2,725) = 2.642$        | -             |
| <i>belief in global warming</i><br>(5 = low to 25 = high)                                                                  | 21.8 (3.7)                  | 19.5 (4.8)            | 20.5 (4.3)        | $F(2,725) = 11.141^{***}$ | 1-2, 1-3      |
| <i>belief about the need to cut CO<sub>2</sub> emissions</i><br>(1 = strongly disagree to 7 = strongly agree)              | 6.1 (1.3)                   | 5.0 (1.5)             | 5.6 (1.4)         | $F(2,725) = 14.521^{***}$ | 1-2, 1-3, 2-3 |
| <i>belief about the required electricity supply from fossil fuels</i><br>(1 = signif. reduce to 7 = signif. increase)      | 1.6 (1.2)                   | 3.3 (1.3)             | 2.5 (1.6)         | $F(2,691) = 40.445^{***}$ | 1-2, 1-3, 2-3 |
| <i>belief about the required electricity supply from nuclear</i><br>(1 = signif. reduce to 7 = signif. increase)           | 3.0 (1.8)                   | 3.1 (1.6)             | 3.2 (1.9)         | $F(2,679) = 1.038$        | -             |
| <i>belief about the required electricity supply from renewable sources</i><br>(1 = signif. reduce to 7 = signif. increase) | 6.5 (1.1)                   | 5.2 (1.4)             | 5.8 (1.5)         | $F(2,690) = 28.562^{***}$ | 1-2, 1-3, 2-3 |
| <i>feelings of hope</i><br>(2 = low to 20 = high)                                                                          | 10.2 (3.8)                  | 10.5 (2.8)            | 11.0 (4.1)        | $F(2,725) = 3.876^*$      | 1-3           |
| <i>feelings of urgency</i><br>(5 = low to 50 = high)                                                                       | 29.5 (8.3)                  | 28.6 (6.4)            | 28.6 (8.9)        | $F(2,725) = 1.006$        | -             |
| <i>perceived efficacy</i><br>(6 = low to 30 = high)                                                                        | 19.9 (4.1)                  | 21.1 (3.9)            | 20.8 (4.3)        | $F(2,725) = 4.229^*$      | 1-3           |

Note: \* $p < 0.05$ ; \*\* $p < 0.01$ , \*\*\* $p < 0.001$ . There were only two respondents with wrong answers at the 0%-point for more than half of the questions and, thus, they were omitted from this analysis.

Table E.9. Characteristics of respondents with the same type of answer to both *knowledge gains* (CO<sub>2</sub>) questions

|                                                                                                                         | <i>M (SD) / percentages</i> |                       |                      |                   | Statistic                 | Post-hoc                |
|-------------------------------------------------------------------------------------------------------------------------|-----------------------------|-----------------------|----------------------|-------------------|---------------------------|-------------------------|
|                                                                                                                         | Correct [1]                 | Wrong (50%-point) [2] | Wrong (0%-point) [3] | Wrong (other) [4] |                           |                         |
|                                                                                                                         | n = 57                      | n = 26                | n = 33               | n = 340           |                           |                         |
| <i>gender</i> (female)                                                                                                  | 42%                         | 73%                   | 64%                  | 54%               | $\chi^2(3) = 8.32^*$      | 1-2                     |
| <i>age</i> (years)                                                                                                      | 43.8 (15.9)                 | 45.0 (15.4)           | 53.2 (18.0)          | 46.3 (15.5)       | $F(3,452) = 2.609$        | -                       |
| <i>education level</i> (high school diploma)                                                                            | 72%                         | 50%                   | 33%                  | 54%               | $\chi^2(3) = 13.16^{**}$  | 1-3, 2-3, 3-4           |
| <i>numeracy</i> (4 = low to 20 = high)                                                                                  | 14.7 (3.5)                  | 12.3 (2.5)            | 12.5 (3.6)           | 13.2 (3.5)        | $F(3,452) = 4.647^{**}$   | 1-2, 1-3, 1-4           |
| <i>graph literacy</i> (5 = low to 35 = high)                                                                            | 26.1 (6.7)                  | 19.7 (8.7)            | 14.1 (9.0)           | 19.9 (8.5)        | $F(3,452) = 15.526^{***}$ | 1-2, 1-3, 1-4, 3-4, 2-3 |
| <i>political orientation</i> (1 = left to 10 = right)                                                                   | 4.5 (2.2)                   | 5.5 (1.8)             | 5.4 (2.1)            | 4.9 (2.4)         | $F(3,452) = 1.617$        | -                       |
| <i>belief in global warming</i> (5 = low to 25 = high)                                                                  | 21.4 (3.7)                  | 21.2 (4.0)            | 17.8 (5.5)           | 20.8 (4.0)        | $F(3,452) = 6.126^{***}$  | 1-3, 2-3, 3-4           |
| <i>belief about the need to cut CO<sub>2</sub> emissions</i> (1 = strongly disagree to 7 = strongly agree)              | 5.8 (1.5)                   | 5.5 (1.4)             | 4.2 (2.0)            | 5.7 (1.4)         | $F(3,452) = 10.833^{***}$ | 1-3, 2-3, 3-4           |
| <i>belief about the required electricity supply from fossil fuels</i> (1 = signif. reduce to 7 = signif. increase)      | 1.5 (1.4)                   | 3.2 (1.4)             | 2.7 (1.3)            | 2.2 (1.5)         | $F(3,420) = 9.549^{***}$  | 1-2, 1-3, 1-4, 2-4      |
| <i>belief about the required electricity supply from nuclear</i> (1 = signif. reduce to 7 = signif. increase)           | 3.0 (1.7)                   | 2.9 (1.5)             | 2.8 (2.0)            | 3.0 (1.8)         | $F(3,416) = 0.126$        | -                       |
| <i>belief about the required electricity supply from renewable sources</i> (1 = signif. reduce to 7 = signif. increase) | 6.8 (0.5)                   | 5.2 (1.6)             | 5.2 (1.5)            | 5.9 (1.5)         | $F(3,423) = 10.5^{***}$   | 1-2, 1-3, 1-4, 3-4, 2-4 |
| <i>feelings of hope</i> (2 = low to 20 = high)                                                                          | 10.2 (3.6)                  | 11.0 (4.1)            | 10.8 (4.3)           | 10.4 (4.0)        | $F(3,452) = 0.36$         | -                       |
| <i>feelings of urgency</i> (5 = low to 50 = high)                                                                       | 27.9 (8.8)                  | 26.0 (6.4)            | 23.0 (11.6)          | 28.9 (8.5)        | $F(3,452) = 5.282^{**}$   | 1-3, 3-4                |
| <i>perceived efficacy</i> (6 = low to 30 = high)                                                                        | 19.8 (4.2)                  | 22.8 (5.2)            | 18.2 (5.3)           | 20.2 (3.9)        | $F(3,452) = 6.46^{***}$   | 1-2, 2-4, 2-3, 3-4, 2-4 |

Note: \* $p < 0.05$ ; \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

## E.5. Dominance analysis on reading accuracy per country

Table E.10. Results of regression and dominance analysis on the error in *reading accuracy* for each country.

|                                                                     | German sample |                    |          | Error in reading accuracy |                    |          | French sample |                    |          |
|---------------------------------------------------------------------|---------------|--------------------|----------|---------------------------|--------------------|----------|---------------|--------------------|----------|
|                                                                     |               |                    |          | Polish sample             |                    |          |               |                    |          |
| <i>F</i> -statistic                                                 | 10.94***      |                    |          | 7.7***                    |                    |          | 6.33***       |                    |          |
| <i>R</i> <sup>2</sup>                                               | 0.38          |                    |          | 0.39                      |                    |          | 0.3           |                    |          |
| <i>R</i> <sup>2</sup> adjusted                                      | 0.34          |                    |          | 0.34                      |                    |          | 0.35          |                    |          |
| Predictors                                                          | $\beta$       | Dominance analysis |          | $\beta$                   | Dominance analysis |          | $\beta$       | Dominance analysis |          |
|                                                                     |               | rank               | $\rho^2$ |                           | rank               | $\rho^2$ |               | rank               | $\rho^2$ |
| prior error                                                         | -             | -                  | -        | -                         | -                  | -        | -             | -                  | -        |
| visualization formats                                               |               |                    |          |                           |                    |          |               |                    |          |
| gradual range (vs. table)                                           | 0.14*         | 13                 | 0.00     | 0.04                      | >15                | 0.00     | -0.07         | 10                 | 0.01     |
| steep range (vs. table)                                             | 0.14*         | >15                | 0.00     | 0.06                      | 12 <sup>CD</sup>   | 0        | -0.01         | 12                 | 0.00     |
| gradual ensemble (vs. table)                                        | 0.11          | 15                 | 0.00     | -                         | -                  | -        | -             | -                  | -        |
| steep ensemble (vs. table)                                          | 0.11*         | >15                | 0.00     | -                         | -                  | -        | -             | -                  | -        |
| demographics                                                        |               |                    |          |                           |                    |          |               |                    |          |
| gender                                                              | 0.04          | 11                 | 0.01     | -0.02                     | 13                 | 0.00     | 0.01          | 14 <sup>CD</sup>   | 0.00     |
| age                                                                 | 0.12*         | 6                  | 0.02     | 0.2**                     | 5                  | 0.04     | 0.2**         | 4                  | 0.03     |
| education level                                                     | -0.19***      | 3                  | 0.05     | -0.33***                  | 1 <sup>CD</sup>    | 0.11     | -0.21**       | 2 <sup>CD</sup>    | 0.07     |
| abilities                                                           |               |                    |          |                           |                    |          |               |                    |          |
| numeracy                                                            | -0.08         | 9                  | 0.02     | -0.25**                   | 2                  | 0.06     | -0.02         | 9                  | 0.01     |
| graph literacy                                                      | -0.05         | 4                  | 0.03     | 0.06                      | 6                  | 0.03     | -0.12         | 3                  | 0.05     |
| prior beliefs                                                       |               |                    |          |                           |                    |          |               |                    |          |
| political orientation                                               | 0.03          | 14 <sup>CD</sup>   | 0.00     | 0.0                       | 15                 | 0.00     | 0.02          | 15                 | 0.00     |
| belief in global warming                                            | -0.14*        | 5                  | 0.03     | -0.02                     | 10                 | 0.00     | 0.01          | 11                 | 0.01     |
| belief about the need to cut CO <sub>2</sub> emissions              | -0.07         | 10                 | 0.01     | -0.12                     | 7                  | 0.02     | -0.16*        | 6                  | 0.02     |
| belief about the required electricity supply from fossil fuels      | 0.24***       | 1 <sup>CD</sup>    | 0.09     | 0.19**                    | 3                  | 0.06     | 0.09          | 8                  | 0.02     |
| belief about the required electricity supply from nuclear           | 0.02          | >15                | 0.00     | 0.04                      | 11                 | 0.00     | 0.15*         | 7                  | 0.02     |
| belief about the required electricity supply from renewable sources | -0.17***      | 2                  | 0.05     | -0.14*                    | 4                  | 0.04     | -0.28***      | 1                  | 0.07     |
| prior perceived efficacy and affective responses                    |               |                    |          |                           |                    |          |               |                    |          |
| perceived efficacy                                                  | 0.18**        | 7                  | 0.02     | 0.15                      | 9                  | 0.01     | 0.19*         | 5                  | 0.03     |
| feelings of urgency                                                 | 0.04          | 12                 | 0.00     | 0.03                      | 14                 | 0.00     | 0.15          | >15                | 0.00     |
| feelings of hope                                                    | 0.07          | 8                  | 0.02     | -0.11                     | 8                  | 0.01     | -0.03         | 13 <sup>CD</sup>   | 0.00     |

Note: \* $p < 0.05$ ; \*\* $p < 0.01$ , \*\*\* $p < 0.001$ ;  $\beta$  = standardized *beta* coefficients. The statistical significance of  $\beta$  is based on 1000 bootstrap samples. Predictors with the symbol "CD" are *completely dominating* predictors with lower rank. All other predictors are assumed to *generally dominate* predictors with lower rank.

Table E.11. Results of regression and dominance analysis on the error in *knowledge gains* in the required percentage of CO<sub>2</sub> emissions cuts for each country.

| Error in knowledge gains (% CO <sub>2</sub> )                              |         |                         |          |               |                         |          |               |                         |          |
|----------------------------------------------------------------------------|---------|-------------------------|----------|---------------|-------------------------|----------|---------------|-------------------------|----------|
| German sample                                                              |         |                         |          | Polish sample |                         |          | French sample |                         |          |
| <i>F</i> -statistic                                                        | 7.9***  |                         |          | 3.07***       |                         |          | 2.89***       |                         |          |
| <i>R</i> <sup>2</sup>                                                      | 0.44    |                         |          | 0.27          |                         |          | 0.30          |                         |          |
| <i>R</i> <sup>2</sup> adjusted                                             | 0.38    |                         |          | 0.18          |                         |          | 0.19          |                         |          |
| Predictors                                                                 | $\beta$ | Dominance analysis rank | $\rho^2$ | $\beta$       | Dominance analysis rank | $\rho^2$ | $\beta$       | Dominance analysis rank | $\rho^2$ |
| prior error                                                                | 0.44*** | 1 <sup>CD</sup>         | 0.19     | 0.24**        | 1                       | 0.05     | 0.3***        | 1                       | 0.08     |
| visualization formats                                                      |         |                         |          |               |                         |          |               |                         |          |
| <i>gradual range (vs. table)</i>                                           | 0.04    | >15                     | 0.00     | 0.07          | >15                     | 0.00     | -0.1          | 10                      | 0.01     |
| <i>steep range (vs. table)</i>                                             | -0.07   | 13                      | 0.01     | 0.06          | 13                      | 0.00     | -0.02         | 14                      | 0        |
| <i>gradual ensemble (vs. table)</i>                                        | 0.01    | >15                     | 0.00     | -             | -                       | -        | -             | -                       | -        |
| <i>steep ensemble (vs. table)</i>                                          | 0.12    | 6                       | 0.02     | -             | -                       | -        | -             | -                       | -        |
| demographics                                                               |         |                         |          |               |                         |          |               |                         |          |
| <i>gender</i>                                                              | 0.09    | 12                      | 0.01     | -0.07         | 14                      | 0.00     | -0.01         | 13                      | 0        |
| <i>age</i>                                                                 | 0.12    | 14                      | 0.01     | 0.1           | 9                       | 0.01     | 0.01          | >15                     | 0.00     |
| <i>education level</i>                                                     | -0.07   | 9                       | 0.01     | -0.1          | 6                       | 0.02     | -0.01         | 5                       | 0.02     |
| abilities                                                                  |         |                         |          |               |                         |          |               |                         |          |
| <i>numeracy</i>                                                            | 0.01    | 10                      | 0.01     | -0.14         | 2                       | 0.03     | -0.02         | 6                       | 0.02     |
| <i>graph literacy</i>                                                      | -0.04   | 7                       | 0.01     | -0.07         | 4                       | 0.03     | -0.17         | 3                       | 0.04     |
| prior beliefs                                                              |         |                         |          |               |                         |          |               |                         |          |
| <i>political orientation</i>                                               | -0.1    | >15                     | 0.00     | 0.06          | 12                      | 0.00     | 0.11          | 9                       | 0.01     |
| <i>belief in global warming</i>                                            | -0.0    | 5                       | 0.02     | 0.1           | 10                      | 0.01     | -0.2          | 4                       | 0.02     |
| <i>belief about the need to cut CO<sub>2</sub> emissions</i>               | -0.13   | 3                       | 0.03     | -0.11         | 8                       | 0.02     | -0.07         | 7                       | 0.02     |
| <i>belief about the required electricity supply from fossil fuels</i>      | 0.15*   | 2                       | 0.04     | 0.14          | 5                       | 0.03     | -0.01         | 11                      | 0.00     |
| <i>belief about the required electricity supply from nuclear</i>           | 0.13*   | 11                      | 0.01     | -0.11         | 7                       | 0.02     | 0.05          | 12                      | 0.00     |
| <i>belief about the required electricity supply from renewable sources</i> | -0.1    | 4                       | 0.03     | -0.15         | 3                       | 0.03     | -0.25**       | 2 <sup>CD</sup>         | 0.06     |
| prior perceived efficacy and affective responses                           |         |                         |          |               |                         |          |               |                         |          |
| <i>perceived efficacy</i>                                                  | 0.11    | >15                     | 0.00     | -0.05         | 11                      | 0        | 0.1           | >15                     | 0.00     |
| <i>feelings of urgency</i>                                                 | -0.13   | 8                       | 0.01     | 0.02          | >15                     | 0.00     | 0.25*         | 8                       | 0.01     |
| <i>feelings of hope</i>                                                    | 0.01    | 15                      | 0.01     | 0.02          | 15                      | 0        | 0.1           | >15                     | 0.00     |

Note: \* $p < 0.05$ ; \*\* $p < 0.01$ , \*\*\* $p < 0.001$ ;  $\beta$  = standardized *beta* coefficients. The statistical significance of  $\beta$  is based on 1000 bootstrap samples. Predictors with the symbol "CD" are *completely dominating* predictors with lower rank. All other predictors are assumed to *generally dominate* predictors with lower rank.

## E.6. Individual effects of readers' characteristics on reading accuracy

Younger respondents and respondents with higher *education level*, *numeracy*, and *graph literacy* achieved a higher *reading accuracy* across all samples in Germany (DE), Poland (PL), and France (FR). As shown by the similar gradients of lines for each variable in Figure E.4, these results were mostly consistent across all *scenario themes* and across all *value types* read from visualizations, i.e., averages, maximum and minimum values. A median split for each demographic variable, *numeracy*, and *graph literacy* showed that *reading accuracy* on average for all *themes* and for all *value types* dropped between younger to older respondents (DE: from 55% to 40% of correct answers, PL: from 39% to 27%, FR: from 49% to 36%), while it increased between respondents with lower to higher *education level* (38% to 61%, 17% to 43%, 30% to 45%), *numeracy* (39% to 54%, 26% to 43%, 37% to 48%), and *graph literacy* (32% to 60%, 19% to 43%, 34% to 57%). Logistic regressions on the *reading accuracy*, using demographic and other prior variables as a single predictor, revealed that effects were statistically significant for *age*, *education*, *numeracy*, and *graph literacy* ( $\chi^2$  ranged between 77.37 and 602.74 for all variables and countries,  $p < 0.001$  for all; Figure E.4). The effects of *gender* differences on *reading accuracy* were less consistent across countries and were statistically significant only for the German sample ( $\chi^2 = 118.00$ ,  $p < 0.001$ ), where female respondents had lower *reading accuracy* than male respondents (41% versus 52%).

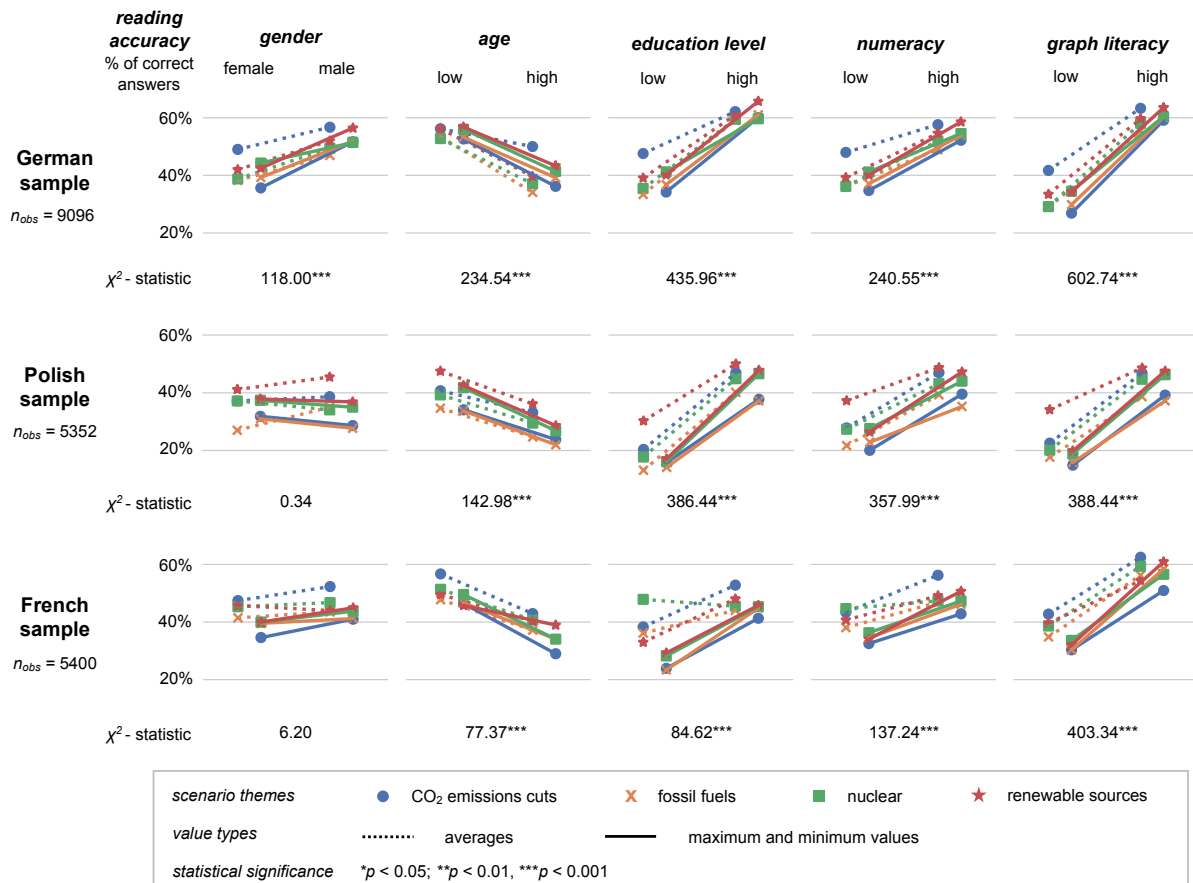


Figure E.4. *Reading accuracy* for different levels of demographics, *numeracy*, and *graph literacy*. Each  $\chi^2$ -statistic refers to a logistic regression model on the overall *reading accuracy* (averaged across *scenario themes* and *value types*), using each readers' characteristic as a single predictor. A Bonferroni correction factor of 14 was applied due to the total number of comparisons with the characteristics of the readers.

In terms of prior beliefs, *reading accuracy* was consistently higher for respondents with higher *belief in global warming*, for respondents with higher *belief about the need to cut CO<sub>2</sub> emissions*, and for respondents that stated that electricity from fossil fuels and renewable sources has to decrease and increase respectively ( $\chi^2$  ranged between 47.73 and 777.65 for all variables and countries,  $p < 0.001$  for all; Figure E.5). A median split for each demographic variable, *numeracy*, and *graph literacy* revealed that *reading accuracy* increased between respondents with lower to higher *belief in global warming* (DE: from 36% to 57% of correct answers, PL: from 30% to 39%, FR: from 35% to 50%) and *belief about the need to cut CO<sub>2</sub> emissions* (from 38% to 55%; from 30% to 40%; from 33% to 50%). *Reading accuracy* was higher for respondents that stated that *fossil fuels* need to decrease (from 30% to 60%; from 26% to 43%; from 34% to 52%) and that *renewable sources* need to increase (from 35% to 56%; from 30% to 40%; from 36% to 49%). All effects from the *belief about the need to cut CO<sub>2</sub> emissions* and the *beliefs about the required electricity supply* are likely related to prior knowledge of the required climate change mitigation, suggesting that the respondents that already knew the correct patterns had higher *reading accuracy* too.

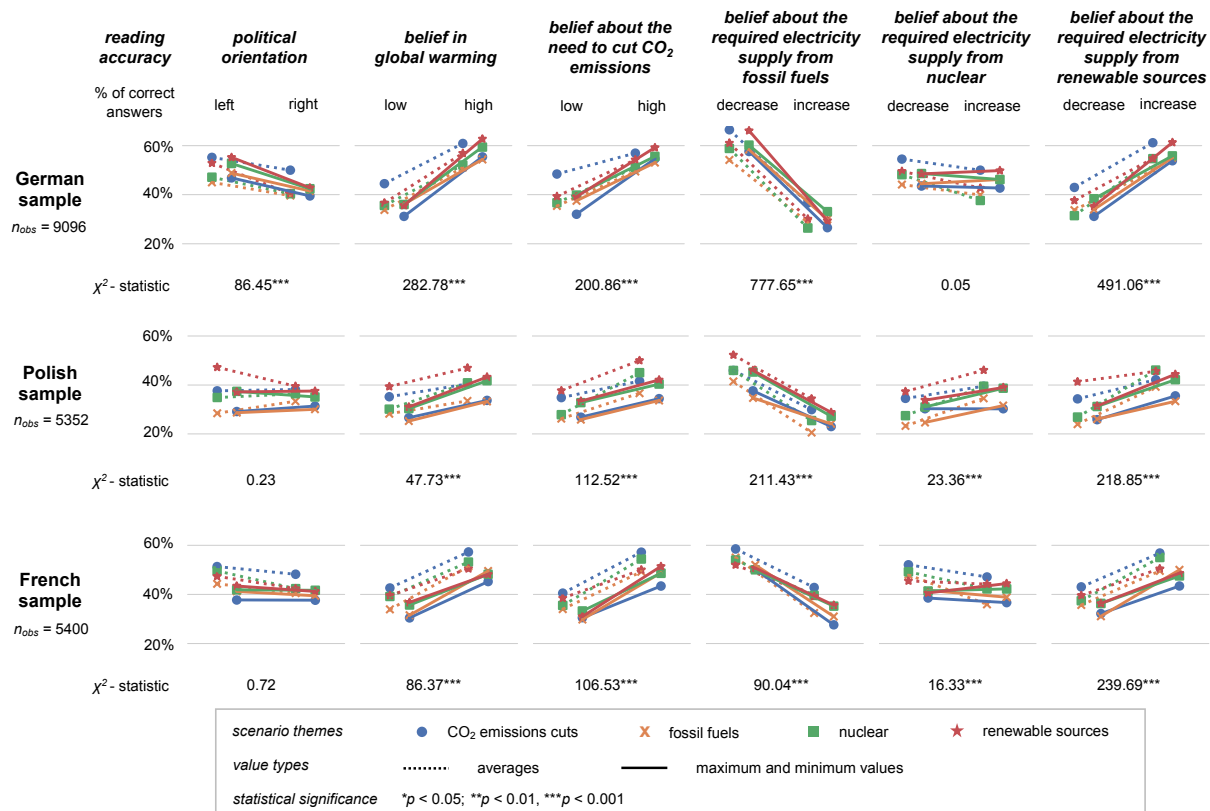


Figure E.5. *Reading accuracy* for different levels of prior beliefs. Each  $\chi^2$ -statistic refers to a logistic regression model on the overall *reading accuracy* (averaged across *scenario themes* and *value types*), using each readers' characteristic as a single predictor. A Bonferroni correction factor of 14 was applied due to the total number of comparisons with the characteristics of the readers.

The effects of *political orientation* and *belief about the required electricity supply from nuclear* on *reading accuracy* were less consistent across countries (Figure E.5). *Political orientation* was statistically significant only for the German sample ( $\chi^2 = 86.45$ ,  $p < 0.001$ ), where respondents with leftwing orientation had higher *reading accuracy* than respondents with rightwing orientation (51% versus 42%). Differences in *reading accuracy* were rather small between the respondents with different answers about the *belief about the required electricity supply from nuclear* (DE: 47% for decrease versus 45% for increase; PL: 30% versus 37%; FR: 43% versus 41%), but they were statistically significant in the French and Polish sample (PL:  $\chi^2 = 23.36$ ; FR:  $\chi^2 = 16.33$ ;  $p < 0.001$ ). The opposite direction of interactions observed between the French and Polish samples may be due to differences on whether nuclear power is perceived a part of the climate change mitigation response in each country.

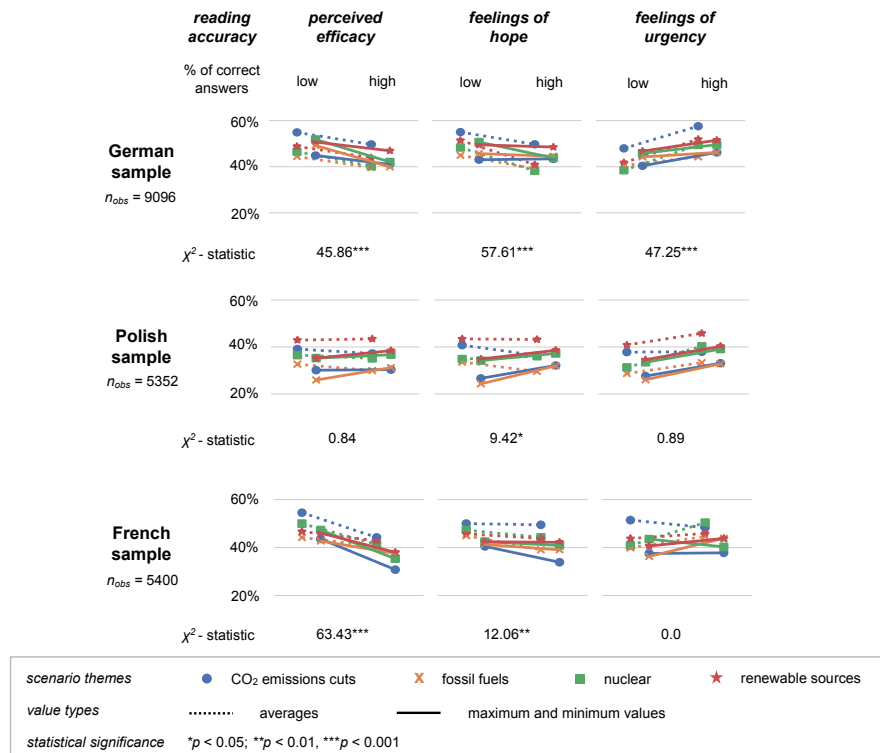


Figure E.6. *Reading accuracy* for different levels of *perceived efficacy*, *feelings of urgency* and *hope*. Each  $\chi^2$ -statistic refers to a logistic regression model on the overall *reading accuracy* (averaged across *scenario themes* and *value types*), using each readers' characteristic as a single predictor. A Bonferroni correction factor of 14 was applied due to the total number of comparisons with the characteristics of the readers.



## **E.7. Interactions among readers' characteristics, scenario themes, and value types**

Independently from the effects of the readers' characteristics, the effects of *value types* and *scenario themes* on *reading accuracy* were weaker and not consistent across countries. In terms of the *value types*, the French respondents had statistically significantly lower accuracy in reading maximum and minimum values than reading averages (41% versus 46%;  $\chi^2 = 13.41$ ;  $p = 0.002$ ), whereas *reading accuracy* was similar between *value types* in the other samples. *Reading accuracy* was also similar between *scenario themes* in all samples, except for the Polish sample where *reading accuracy* was statistically significantly higher in the renewable sources theme than in the CO<sub>2</sub> emissions and fossil fuels themes (39% versus 33% and 30%;  $\chi^2 = 29.36$ ;  $p < 0.001$ ). For almost all characteristics of the readers, their effects on *reading accuracy* mostly did not interact with the effects of *scenario themes* and *value types*. For the few exceptions of *value types* interacting with *age* in Poland, with *education level* in France, and with the *belief about the required electricity supply from nuclear* in Germany, none of these exceptions were consistent across countries (see Figures E.7–E.9) for more details).

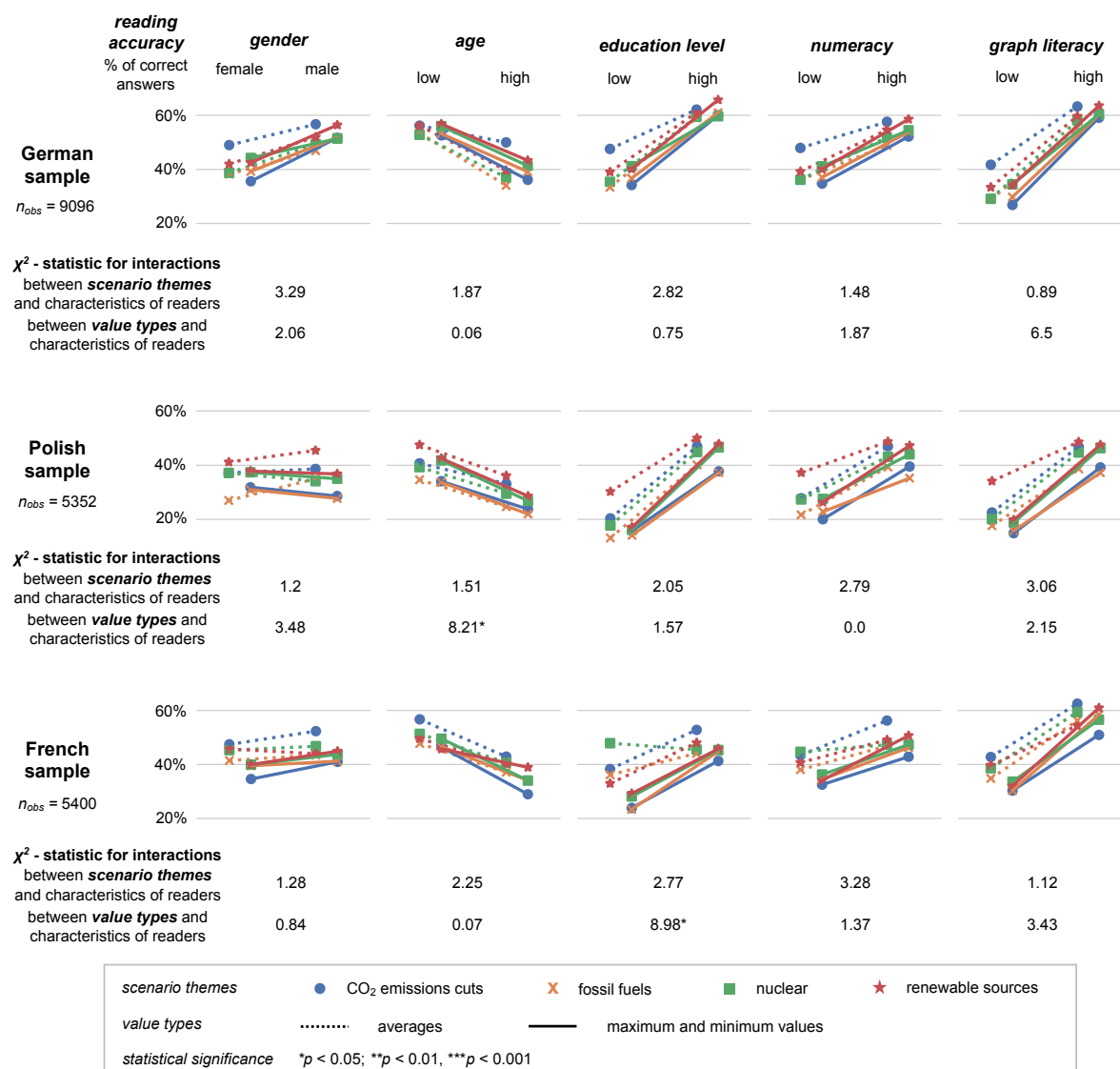


Figure E.7. Interactions between demographics, *numeracy*, *graph literacy*, *scenario themes*, and *value types*. Each  $\chi^2$ -statistic refers to a logistic regression model for these interactions. The  $n_{obs}$  is the total number of observations for *reading accuracy*. A Bonferroni correction factor of 14 was applied due to the total number of comparisons with the characteristics of the readers.

## E.7 Interactions among readers' characteristics, scenario themes, and value types

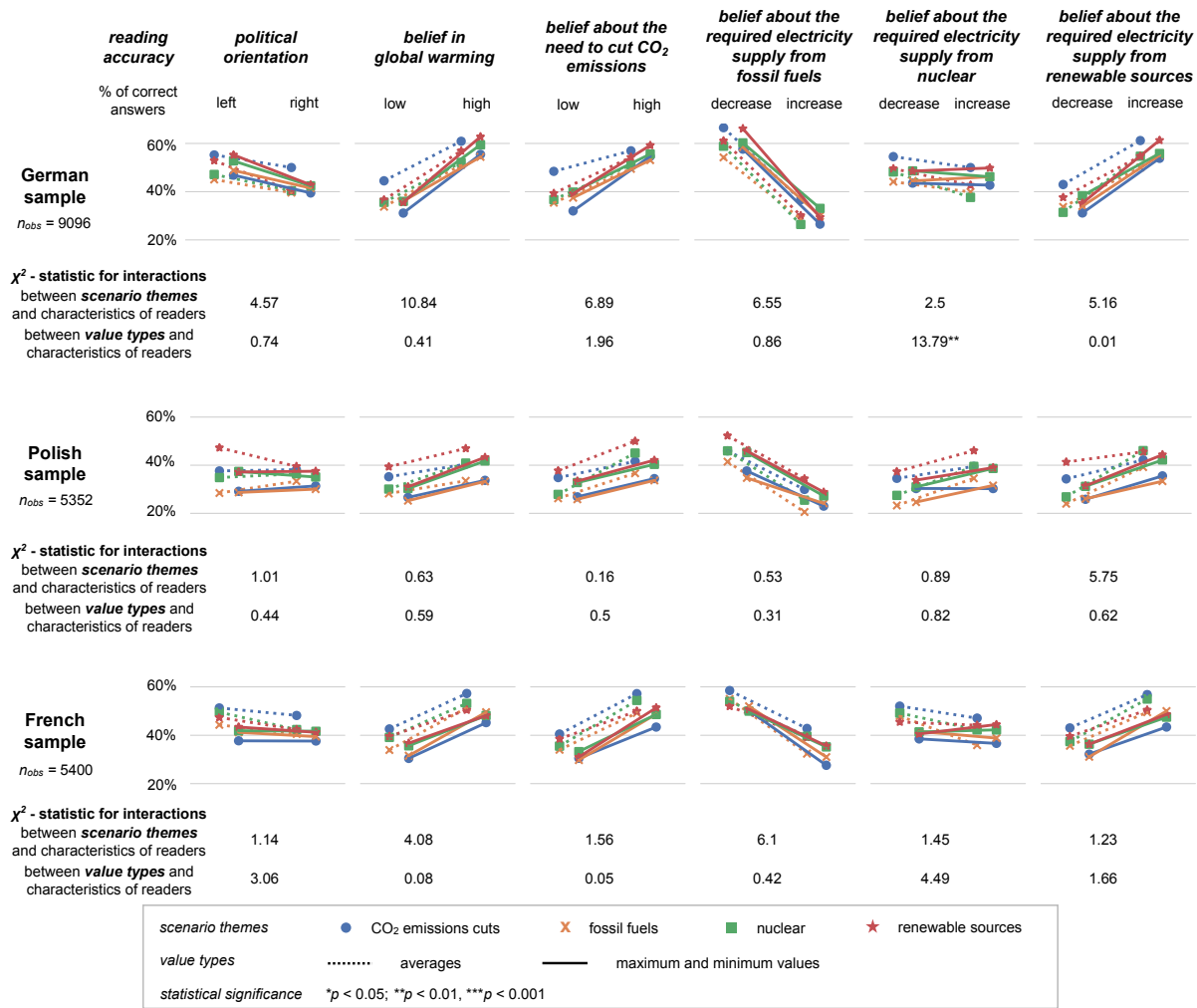


Figure E.8. Interactions between prior beliefs, *scenario themes*, and *value types*. Each  $\chi^2$ -statistic refers to a logistic regression model for these interactions. The  $n_{obs}$  is the total number of observations for *reading accuracy*. A Bonferroni correction factor of 14 was applied due to the total number of comparisons with the characteristics of the readers.

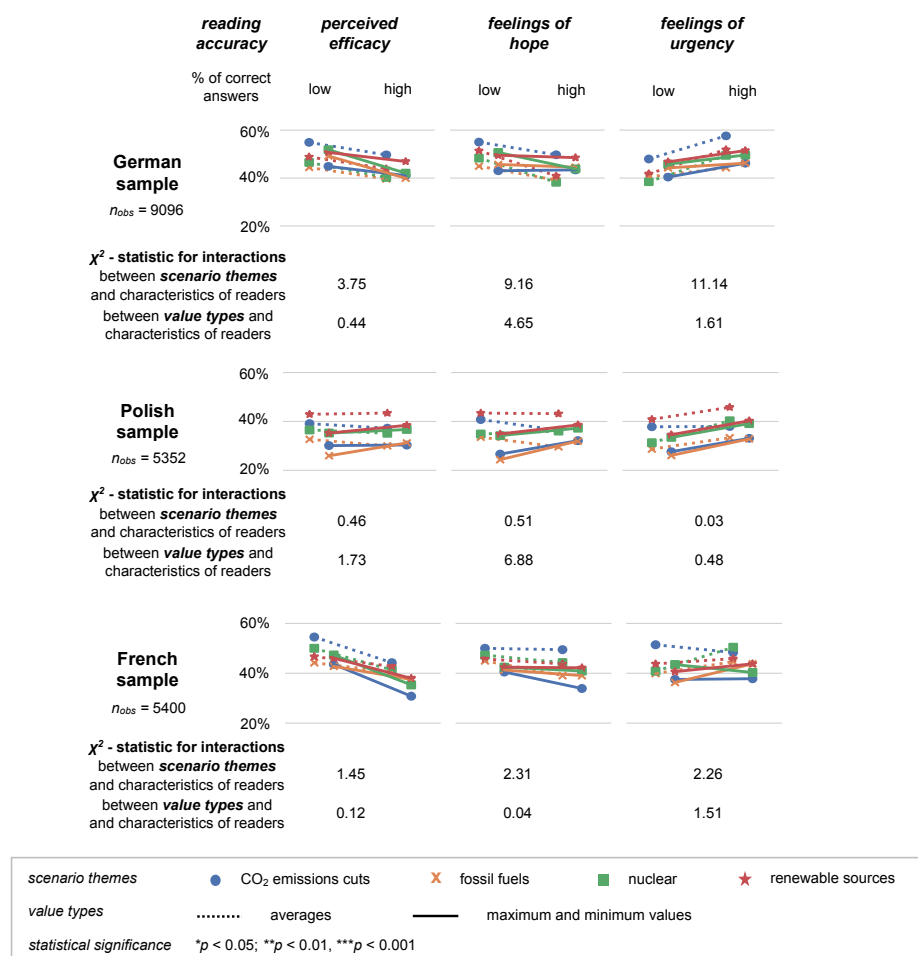


Figure E.9. Interactions between *perceived efficacy*, *feelings of urgency*, *feelings of hope*, *scenario themes*, and *value types*. Each  $\chi^2$ -statistic refers to a logistic regression model for these interactions. The  $n_{obs}$  is the total number of observations for *reading accuracy*. A Bonferroni correction factor of 14 was applied due to the total number of comparisons with the characteristics of the readers.

## E.8. Dominance analysis on reading accuracy for different graph and slope types

Table E.12. Results of regression and dominance analysis on the error in *reading accuracy* and the error in *knowledge gains* in the required percentage of CO<sub>2</sub> emissions cuts.

|                                                                     | Error in reading accuracy |                    |          | Error in knowledge gains (CO <sub>2</sub> ) |                    |          |
|---------------------------------------------------------------------|---------------------------|--------------------|----------|---------------------------------------------|--------------------|----------|
| <i>F</i> -statistic                                                 | 16.53***                  |                    |          | 8.87***                                     |                    |          |
| <i>R</i> <sup>2</sup>                                               | 0.37                      |                    |          | 0.34                                        |                    |          |
| <i>R</i> <sup>2</sup> adjusted                                      | 0.35                      |                    |          | 0.30                                        |                    |          |
| Predictors                                                          | $\beta$                   | Dominance analysis |          | $\beta$                                     | Dominance analysis |          |
|                                                                     |                           | rank               | $\rho^2$ |                                             | rank               | $\rho^2$ |
| prior error                                                         | -                         | -                  | -        | 0.3***                                      | 1 <sup>CD</sup>    | 0.10     |
| country context                                                     |                           |                    |          |                                             |                    |          |
| Polish sample (vs. German sample)                                   | 0.15**                    | 7                  | 0.02     | 0.09                                        | >15                | 0.00     |
| French sample (vs. German sample)                                   | 0.06                      | >15                | 0.00     | 0.09                                        | 13                 | 0.00     |
| visualization format                                                |                           |                    |          |                                             |                    |          |
| range (vs. ensemble)                                                | 0.01                      | 13                 | 0.00     | -0.04                                       | >15                | 0.00     |
| gradual (vs. steep)                                                 | -0.01                     | >15                | 0.00     | 0.15                                        | 15                 | 0.00     |
| interaction between graph and slope types                           | 0.06                      | 14                 | 0.00     | -0.19                                       | >15                | 0.00     |
| demographics                                                        |                           |                    |          |                                             |                    |          |
| gender                                                              | -0.02                     | 15                 | 0.00     | -0.02                                       | 14                 | 0.00     |
| age                                                                 | 0.12**                    | 11                 | 0.01     | 0.02                                        | >15                | 0.00     |
| education level                                                     | -0.26***                  | 1 <sup>CD</sup>    | 0.07     | -0.07                                       | 8                  | 0.01     |
| abilities                                                           |                           |                    |          |                                             |                    |          |
| numeracy                                                            | -0.13**                   | 5                  | 0.03     | -0.06                                       | 5                  | 0.02     |
| graph literacy                                                      | -0.03                     | 4                  | 0.03     | -0.14*                                      | 4 <sup>CD</sup>    | 0.03     |
| prior beliefs                                                       |                           |                    |          |                                             |                    |          |
| political orientation                                               | 0.04                      | >15                | 0.00     | 0.06                                        | 9                  | 0.01     |
| belief in global warming                                            | -0.09                     | 10                 | 0.01     | -0.06                                       | 7                  | 0.01     |
| belief about the need to cut CO <sub>2</sub> emissions              | -0.13**                   | 8                  | 0.02     | -0.22***                                    | 3 <sup>CD</sup>    | 0.05     |
| belief about the required electricity supply from fossil fuels      | 0.18***                   | 3 <sup>CD</sup>    | 0.06     | 0.1*                                        | 6                  | 0.02     |
| belief about the required electricity supply from nuclear           | 0.07                      | 12 <sup>CD</sup>   | 0.01     | 0.03                                        | 12                 | 0.00     |
| belief about the required electricity supply from renewable sources | -0.21***                  | 2                  | 0.06     | -0.17***                                    | 2 <sup>CD</sup>    | 0.05     |
| prior perceived efficacy and affective responses                    |                           |                    |          |                                             |                    |          |
| perceived efficacy                                                  | 0.2***                    | 6                  | 0.02     | 0.09                                        | >15                | 0.00     |
| feelings of urgency                                                 | 0.08                      | >15                | 0.00     | 0.11                                        | 10                 | 0.01     |
| feelings of hope                                                    | 0.03                      | 9                  | 0.01     | 0.02                                        | 11                 | 0.00     |

Note: \* $p < 0.05$ ; \*\* $p < 0.01$ , \*\*\* $p < 0.001$ ;  $\beta$  = standardized *beta* coefficients. The statistical significance of  $\beta$  is based on 1000 bootstrap samples. Predictors with the symbol "CD" are *completely dominating* predictors with lower rank. All other predictors are assumed to *generally dominate* predictors with lower rank.

## E.9. Comparison among visualization formats for reading accuracy

The respondents in the graph conditions had lower *reading accuracy* for maximum and minimum values than respondents in the *table* condition across all countries and almost all *scenario themes* (Table E.13). There were statistically significant differences between experimental conditions on the average *reading accuracy* for all *scenario themes* (DE:  $\chi^2 = 86.31$ ; PL:  $\chi^2 = 15.55$ ; FR:  $\chi^2 = 34.81$ , all  $p < 0.001$ ), but the magnitude of these effects varied between graph conditions. Respondents in the *steep range* condition had statistically significantly lower *reading accuracy* than respondents in the *table* condition in all countries (DE: 58% for *table* versus 44% for *steep range*; PL: 37% versus 29%; FR: 44% versus 34%;  $p < 0.001$ ). The respondents in the *gradual range* condition had statistically significantly lower *reading accuracy* than respondents in the *table* condition only for the German sample (58% for *table* versus 46% for *gradual range*,  $p < 0.001$ ). For the case of the *ensemble* graph that was tested only in the German sample, both *ensemble* conditions had statistically significantly lower *reading accuracy* than the *table* condition (58% for *table* versus 41% for *gradual ensemble* and 43% for *steep ensemble*;  $p < 0.001$ ).

Table E.13. Comparison of *reading accuracy* between the *table* and each graph condition.

| Value types                | Samples and scenario themes | % of correct answers / (n) |                             |                           |                                |                              | $\chi^2$ -statistic | Statistically significant simple effects |
|----------------------------|-----------------------------|----------------------------|-----------------------------|---------------------------|--------------------------------|------------------------------|---------------------|------------------------------------------|
|                            |                             | <i>table</i><br>(1)        | <i>gradual range</i><br>(2) | <i>steep range</i><br>(3) | <i>gradual ensemble</i><br>(4) | <i>steep ensemble</i><br>(5) |                     |                                          |
| maximum and minimum values | German sample               | (77)                       | (75)                        | (75)                      | (77)                           | (75)                         |                     |                                          |
|                            | CO <sub>2</sub> emissions   | 56                         | 44                          | 38                        | 39                             | 39                           | 29.21***            | 1-2,1-3,1-4,1-5                          |
|                            | fossil fuels                | 56                         | 44                          | 40                        | 45                             | 40                           | 21.40***            | 1-2,1-3,1-4,1-5                          |
|                            | nuclear                     | 60                         | 48                          | 45                        | 39                             | 46                           | 28.44***            | 1-2,1-3,1-4,1-5                          |
|                            | renewable sources           | 59                         | 47                          | 51                        | 42                             | 46                           | 19.98***            | 1-2,1-3,1-4,1-5                          |
|                            | average for all themes      | 58                         | 46                          | 44                        | 41                             | 43                           | 86.31***            | 1-2,1-3,1-4,1-5                          |
|                            | Polish sample               | (74)                       | (73)                        | (76)                      |                                |                              |                     |                                          |
|                            | CO <sub>2</sub> emissions   | 35                         | 33                          | 23                        |                                |                              | 13.00**             | 1-3                                      |
|                            | fossil fuels                | 33                         | 31                          | 24                        |                                |                              | 5.81                | -                                        |
|                            | nuclear                     | 38                         | 35                          | 35                        |                                | -                            | 0.74                | -                                        |
|                            | renewable sources           | 41                         | 36                          | 35                        |                                |                              | 2.87                | -                                        |
|                            | average for all themes      | 37                         | 34                          | 29                        |                                |                              | 15.55***            | 1-3                                      |
|                            | French sample               | (74)                       | (78)                        | (73)                      |                                |                              |                     |                                          |
|                            | CO <sub>2</sub> emissions   | 45                         | 38                          | 30                        |                                |                              | 14.39***            | 1-3                                      |
|                            | fossil fuels                | 42                         | 47                          | 31                        |                                |                              | 16.61***            | 1-3                                      |
|                            | nuclear                     | 43                         | 46                          | 36                        |                                | -                            | 6.68*               | 1-3                                      |
|                            | renewable sources           | 46                         | 44                          | 37                        |                                |                              | 4.61                | -                                        |
|                            | average for all themes      | 44                         | 44                          | 34                        |                                |                              | 34.81***            | 1-3                                      |

Table E.13. (continued)

|                   |                           |      |      |      |      |      |          |     |
|-------------------|---------------------------|------|------|------|------|------|----------|-----|
| average<br>values | German sample             | (77) | (75) | (75) | (77) | (75) |          |     |
|                   | CO <sub>2</sub> emissions | 50   | 52   | 56   | 55   | 51   | 1.59     | -   |
|                   | fossil fuels              | 41   | 46   | 43   | 41   | 41   | 1.31     | -   |
|                   | nuclear                   | 49   | 45   | 45   | 30   | 51   | 16.71*** | 1-4 |
|                   | renewable sources         | 47   | 48   | 49   | 55   | 51   | 4.13     | -   |
|                   | average for all themes    | 47   | 48   | 48   | 41   | 48   | 8.55     | -   |
|                   | Polish sample             | (74) | (73) | (76) |      |      |          |     |
|                   | CO <sub>2</sub> emissions | 38   | 42   | 34   |      |      | 1.81     | -   |
|                   | fossil fuels              | 29   | 36   | 28   |      |      | 2.24     | -   |
|                   | nuclear                   | 34   | 37   | 36   | -    |      | 0.36     | -   |
|                   | renewable sources         | 41   | 47   | 41   |      |      | 1.41     | -   |
|                   | average for all themes    | 35   | 40   | 35   |      |      | 4.52     | -   |
|                   | French sample             | (74) | (78) | (73) |      |      |          |     |
|                   | CO <sub>2</sub> emissions | 47   | 58   | 45   |      |      | 6.11     | -   |
|                   | fossil fuels              | 41   | 47   | 40   |      |      | 1.87     | -   |
|                   | nuclear                   | 45   | 53   | 40   | -    |      | 5.05     | -   |
|                   | renewable sources         | 41   | 47   | 46   |      |      | 1.23     | -   |
|                   | average for all themes    | 43   | 51   | 42   |      |      | 11.1**   | 1-2 |

Note: \* $p < 0.05$ ; \*\* $p < 0.01$ , \*\*\* $p < 0.001$ . A respondent's answer was considered to be correct if it fell within a margin of  $\pm 5\%$  from the correct answer. The  $n$  is the group size.

Similar effects were found by comparing between graph types and graph slopes (Table E.14). Respondents in the *gradual* conditions had statistically significantly higher *reading accuracy* than respondents in the *steep* conditions in the Polish and French samples, but not in the German sample (DE: 43% for *gradual* versus 43% for *steep*,  $\chi^2 = 0$ ; PL: 34% versus 29%,  $\chi^2 = 5.08$ ,  $p = 0.024$ ; FR = 44% versus 34%,  $\chi^2 = 26.34$ ,  $p < 0.001$ ). In terms of comparing between graph types, there were no statistically significant differences.

Table E.14. Comparison of *reading accuracy* between slope types and graph types

| Value types                | Samples and scenario themes | Slope types                            |                                      | $\chi^2$ -statistic | Graph types                          |                                         | $\chi^2$ -statistic |
|----------------------------|-----------------------------|----------------------------------------|--------------------------------------|---------------------|--------------------------------------|-----------------------------------------|---------------------|
|                            |                             | % of correct answers<br><i>gradual</i> | % of correct answers<br><i>steep</i> |                     | % of correct answers<br><i>range</i> | % of correct answers<br><i>ensemble</i> |                     |
| maximum and minimum values | German sample               |                                        |                                      |                     |                                      |                                         |                     |
|                            | CO <sub>2</sub> emissions   | 41                                     | 38                                   | 0.86                | 41                                   | 39                                      | 0.7                 |
|                            | fossil fuels                | 45                                     | 40                                   | 2.22                | 42                                   | 43                                      | 0.11                |
|                            | nuclear                     | 43                                     | 46                                   | 0.53                | 46                                   | 43                                      | 1.71                |
|                            | renewable sources           | 44                                     | 49                                   | 2.2                 | 49                                   | 44                                      | 2.94                |
|                            | overall for all themes      | 43                                     | 43                                   | 0                   | 45                                   | 42                                      | 3.23                |
|                            | Polish sample               |                                        |                                      |                     |                                      |                                         |                     |
|                            | CO <sub>2</sub> emissions   | 33                                     | 23                                   | 7.21**              |                                      |                                         |                     |
|                            | fossil fuels                | 31                                     | 24                                   | 3.13                |                                      |                                         |                     |
|                            | nuclear                     | 35                                     | 35                                   | 0                   |                                      |                                         |                     |
|                            | renewable sources           | 36                                     | 35                                   | 0                   |                                      |                                         |                     |
|                            | overall for all themes      | 34                                     | 29                                   | 5.08*               |                                      |                                         |                     |

Table E.14. (continued)

|                                     |                           |    |    |          |    |    |      |
|-------------------------------------|---------------------------|----|----|----------|----|----|------|
| maximum<br>and<br>minimum<br>values | French sample             |    |    |          |    |    |      |
|                                     | CO <sub>2</sub> emissions | 38 | 30 | 4.31*    |    |    |      |
|                                     | fossil fuels              | 47 | 31 | 15.41*** |    |    |      |
|                                     | nuclear                   | 46 | 36 | 6.06*    |    | -  |      |
|                                     | renewable sources         | 44 | 37 | 2.44     |    |    |      |
|                                     | overall for all<br>themes | 44 | 34 | 26.34*** |    |    |      |
| average<br>values                   | German sample             |    |    |          |    |    |      |
|                                     | CO <sub>2</sub> emissions | 53 | 53 | 0.01     | 54 | 53 | 0.06 |
|                                     | fossil fuels              | 43 | 42 | 0.07     | 45 | 41 | 0.78 |
|                                     | nuclear                   | 37 | 48 | 6.81**   | 45 | 40 | 1.27 |
|                                     | renewable sources         | 44 | 49 | 1.67     | 48 | 45 | 0.65 |
|                                     | overall for all<br>themes | 44 | 48 | 3.28     | 48 | 45 | 2.72 |
|                                     | Polish sample             |    |    |          |    |    |      |
|                                     | CO <sub>2</sub> emissions | 42 | 34 | 1.51     |    |    |      |
|                                     | fossil fuels              | 36 | 28 | 1.52     |    |    |      |
|                                     | nuclear                   | 37 | 36 | 0.0      |    | -  |      |
|                                     | renewable sources         | 47 | 41 | 0.8      |    |    |      |
|                                     | overall for all<br>themes | 40 | 35 | 3.44     |    |    |      |
|                                     | French sample             |    |    |          |    |    |      |
|                                     | CO <sub>2</sub> emissions | 58 | 45 | 4.72*    |    |    |      |
|                                     | fossil fuels              | 47 | 40 | 1.26     |    |    |      |
|                                     | nuclear                   | 53 | 40 | 4.50*    |    | -  |      |
|                                     | renewable sources         | 47 | 46 | 0.02     |    |    |      |
|                                     | overall for all<br>themes | 51 | 42 | 8.73**   |    |    |      |

Note: \* $p < 0.05$ ; \*\* $p < 0.01$ , \*\*\* $p < 0.001$ . A respondent's answer is considered to be correct if it falls within a margin of  $\pm 5$  from the correct answer to the test.

In contrast to the results for reading maximum and minimum values from the results, there were no consistent statistically significant differences in *reading accuracy* for averages between the experimental conditions (Table E.13). The only two exceptions were in the French sample, where the *gradual range* condition had the highest reading accuracy as compared to both the *table* and the *steep range* condition (51% for *gradual range*, 43% for *table*, 42% for *steep range*,  $\chi^2 = 11.1$ ,  $p = 0.004$ ), and in the German sample, where the *gradual ensemble* had the lowest reading accuracy in the nuclear theme (30% for *gradual ensemble*, 45–51% for all other conditions,  $\chi^2 = 16.71$ ,  $p < 0.001$ ). A similarly low value of *reading accuracy* of maximum and minimum values was found in the *gradual ensemble* condition in the nuclear theme and it could have been due to the concentrated lines of the *ensemble* in the nuclear theme that were harder to read.

Each *scenario theme* showed similar patterns of differences between the *table* and graph conditions for maximum and minimum values, but with a different magnitude (Table E.13). For the CO<sub>2</sub> emissions theme, the respondents in the *table* condition had consistently a statistically significantly higher *reading accuracy* of maximum and minimum values than respondents in the graph conditions (DE: 56% for *table* versus 38–44% for graphs,  $\chi^2 = 29.21$ ; PL: 35% versus 23–33%,  $\chi^2 = 13.00$ ; FR: 45% versus 30–38%,  $\chi^2 = 14.39$ ;  $p < 0.001$  for all). These differences were



smaller and yet statistically significant in the fossil fuels and nuclear themes of the German sample (fossil fuels: 56% versus 40-45%,  $\chi^2 = 21.40$ ; nuclear: 60% versus 39-48%,  $\chi^2 = 28.44$ ;  $p < 0.001$  for all). For the fossil fuels and nuclear theme of the French sample, respondents in the *steep range* condition had a statistically significantly lower *reading accuracy* of maximum and minimum values than respondents of both *table* and *gradual range* conditions (fossil fuels: 31% versus 42% and 47%,  $\chi^2 = 16.61$  and  $14.41$ ,  $p < 0.001$ ; nuclear: 35% versus 43% and 46%,  $\chi^2 = 6.68$  and  $6.06$ ,  $p = 0.01$  and  $0.013$  respectively). Differences in the renewable sources theme were statistically significant only for the German sample (59% versus 42-51%,  $\chi^2 = 19.98$ ,  $p < 0.001$ ).

## E.10. Knowledge gains in the required percentage of CO<sub>2</sub> emissions cuts

Table E.15. Error in the *belief about the required percentage of CO<sub>2</sub> emissions cuts* (German sample)

|                         | German sample                              |                  |             |                                            |                  |          |                                           |                       |          |
|-------------------------|--------------------------------------------|------------------|-------------|--------------------------------------------|------------------|----------|-------------------------------------------|-----------------------|----------|
|                         | Error in CO <sub>2</sub> cuts for 2030 (%) |                  |             | Error in CO <sub>2</sub> cuts for 2050 (%) |                  |          | Error in CO <sub>2</sub> cuts overall (%) |                       |          |
|                         | <i>M (SD)</i>                              |                  |             | <i>M (SD)</i>                              |                  |          | <i>M (SD)</i>                             |                       |          |
|                         | prior                                      | posterior        | <i>t</i>    | prior                                      | posterior        | <i>t</i> | prior                                     | posterior<br><i>r</i> | <i>t</i> |
| <i>table</i>            | 19.62<br>(13.02)                           | 19.24<br>(13.74) | -0.14       | 48.36<br>(30.58)                           | 36.23<br>(34.6)  | -3.71*** | 33.61<br>(27.3)                           | 27.66<br>(27.5)       | -3.21**  |
| <i>gradual range</i>    | 13.83<br>(9.57)                            | 14.92<br>(14.78) | 0.86        | 46.64<br>(26.13)                           | 26.92<br>(26.67) | -3.41**  | 29.67<br>(25.39)                          | 20.78<br>(22.18)      | -2.58*   |
| <i>steep range</i>      | 18.92<br>(11.71)                           | 12.76<br>(12.26) | -<br>2.94** | 47.23<br>(25.58)                           | 28.33<br>(30.69) | -4.46*** | 32.51<br>(24.15)                          | 20.55<br>(24.55)      | -5.09*** |
| <i>gradual ensemble</i> | 18.61<br>(12.78)                           | 14.83<br>(13.11) | -0.75       | 46.33<br>(31.44)                           | 26.43<br>(29.05) | -2.95**  | 31.21<br>(26.92)                          | 20.48<br>(22.99)      | -2.82**  |
| <i>steep ensemble</i>   | 17.79<br>(14.14)                           | 17.08<br>(13.92) | 0.51        | 47.61<br>(27.03)                           | 36.59<br>(35.42) | -1.74    | 32.26<br>(26.02)                          | 26.76<br>(28.47)      | -1.17    |

Table E.16. Error in the *belief about the required percentage of CO<sub>2</sub> emissions cuts* (Polish sample)

|                      | Polish sample                              |                  |          |                                            |                  |          |                                           |                  |          |
|----------------------|--------------------------------------------|------------------|----------|--------------------------------------------|------------------|----------|-------------------------------------------|------------------|----------|
|                      | Error in CO <sub>2</sub> cuts for 2030 (%) |                  |          | Error in CO <sub>2</sub> cuts for 2050 (%) |                  |          | Error in CO <sub>2</sub> cuts overall (%) |                  |          |
|                      | <i>M (SD)</i>                              |                  |          | <i>M (SD)</i>                              |                  |          | <i>M (SD)</i>                             |                  |          |
|                      | prior                                      | posterior        | <i>t</i> | prior                                      | posterior        | <i>t</i> | prior                                     | posterior        | <i>t</i> |
| <i>table</i>         | 17.76<br>(12.8)                            | 13.08<br>(11.34) | -1.83    | 50.66<br>(24.08)                           | 35.74<br>(21.91) | -2.94**  | 34.08<br>(25.3)                           | 24.05<br>(20.63) | -3.44*** |
| <i>gradual range</i> | 17.52<br>(13.33)                           | 15.56<br>(14.03) | -0.5     | 45.44<br>(22.28)                           | 32.97<br>(27.58) | -2.86**  | 31.01<br>(22.91)                          | 24.19<br>(23.43) | -2.66**  |
| <i>steep range</i>   | 16.8<br>(12.39)                            | 15.32<br>(12.67) | -0.66    | 54.63<br>(25.21)                           | 38.61<br>(27.06) | -3.86*** | 35.42<br>(27.36)                          | 26.88<br>(24.03) | -3.62*** |

Table E.17. Error in the *belief about the required percentage of CO<sub>2</sub> emissions cuts* (French sample)

|                          | French sample                              |                  |          |                                            |                  |          |                                           |                  |          |
|--------------------------|--------------------------------------------|------------------|----------|--------------------------------------------|------------------|----------|-------------------------------------------|------------------|----------|
|                          | Error in CO <sub>2</sub> cuts for 2030 (%) |                  |          | Error in CO <sub>2</sub> cuts for 2050 (%) |                  |          | Error in CO <sub>2</sub> cuts overall (%) |                  |          |
|                          | <i>M (SD)</i>                              |                  | <i>t</i> | <i>M (SD)</i>                              |                  | <i>t</i> | <i>M (SD)</i>                             |                  | <i>t</i> |
|                          | prior                                      | posterior        |          | prior                                      | posterior        |          | prior                                     | posterior        |          |
| <i>table</i>             | 19.52<br>(14.14)                           | 14.45<br>(11.37) | -1.86    | 58.98<br>(25.24)                           | 43.98<br>(29.48) | -3.53*** | 39.08<br>(28.39)                          | 28.84<br>(26.55) | -3.9***  |
| <i>gradual<br/>range</i> | 19.18<br>(12.71)                           | 14.35<br>(12.8)  | -2.21*   | 60.53<br>(25.97)                           | 39.03<br>(29.04) | -4.69*** | 39.69<br>(29.04)                          | 26.39<br>(25.39) | -4.92*** |
| <i>steep<br/>range</i>   | 20.34<br>(14.41)                           | 16.46<br>(13.84) | -0.72    | 53.54<br>(28.09)                           | 40.23<br>(30.6)  | -2.22*   | 36.64<br>(27.68)                          | 27.51<br>(25.97) | -2.28*   |

Note: \* $p < 0.05$ ; \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

## E.11. Knowledge gains in the required electricity supply

Table E.18. *Knowledge gains* in the required electricity supply, given as the difference between prior and posterior in the *belief about the required electricity supply from fossil fuels / nuclear / renewable sources*.

| <i>Belief about the required electricity supply from fossil fuels / nuclear / renewable sources</i> |                           | Germany   |           | Poland    |           | France    |           |
|-----------------------------------------------------------------------------------------------------|---------------------------|-----------|-----------|-----------|-----------|-----------|-----------|
|                                                                                                     |                           | prior     | posterior | prior     | posterior | prior     | posterior |
|                                                                                                     | <i>n<sub>obs</sub></i>    | 364       | 363       | 216       | 213       | 203       | 199       |
|                                                                                                     | statistics of raw answers |           |           |           |           |           |           |
|                                                                                                     | <i>mode</i>               | 1         | 1         | 1         | 1         | 1         | 1         |
|                                                                                                     | <i>mean (SD)</i>          | 2.0 (1.4) | 2.1 (1.5) | 2.3 (1.6) | 2.5 (1.8) | 2.2 (1.5) | 2.2 (1.6) |
|                                                                                                     | error from correct answer |           |           |           |           |           |           |
|                                                                                                     | <i>mean (SD)</i>          | 1.0 (1.4) | 1.1 (1.5) | 1.3 (1.6) | 1.5 (1.8) | 1.2 (1.5) | 1.2 (1.6) |
|                                                                                                     | <i>t</i> -statistic       | -0.46     |           | -1.22     |           | 0.38      |           |
|                                                                                                     | % of answers that:        |           |           |           |           |           |           |
|                                                                                                     | stayed the same           | 73%       |           | 71%       |           | 75%       |           |
|                                                                                                     | improved                  | 12%       |           | 9%        |           | 15%       |           |
|                                                                                                     | worsen                    | 15%       |           | 16%       |           | 14%       |           |
|                                                                                                     | <i>n<sub>obs</sub></i>    | 350       | 361       | 214       | 210       | 208       | 199       |
|                                                                                                     | statistics of raw answers |           |           |           |           |           |           |
|                                                                                                     | <i>mode</i>               | 1         | 1         | 4         | 4         | 1         | 1         |
|                                                                                                     | <i>mean (SD)</i>          | 2.5 (1.6) | 2.6 (1.7) | 4.1 (1.9) | 4.2 (1.8) | 2.8 (1.6) | 2.9 (1.5) |
|                                                                                                     | error from correct answer |           |           |           |           |           |           |
|                                                                                                     | <i>mean (SD)</i>          | 1.9 (1.1) | 1.9 (1.1) | 1.5 (1.0) | 1.5 (1.0) | 1.7 (1.1) | 1.6 (1.1) |
|                                                                                                     | <i>t</i> -statistic       | 0.30      |           | 0.47      |           | 0.93      |           |
|                                                                                                     | % of answers that:        |           |           |           |           |           |           |
|                                                                                                     | stayed the same           | 62%       |           | 59%       |           | 64%       |           |
|                                                                                                     | improved                  | 21%       |           | 22%       |           | 19%       |           |
|                                                                                                     | worsen                    | 16%       |           | 19%       |           | 16%       |           |
|                                                                                                     | <i>n<sub>obs</sub></i>    | 362       | 363       | 214       | 212       | 208       | 201       |
|                                                                                                     | statistics of raw answers |           |           |           |           |           |           |
|                                                                                                     | <i>mode</i>               | 7         | 7         | 7         | 7         | 7         | 7         |
|                                                                                                     | <i>mean (SD)</i>          | 6.2 (1.2) | 6.3 (1.2) | 6.0 (1.6) | 6.0 (1.6) | 5.8 (1.6) | 5.8 (1.7) |
|                                                                                                     | error from correct answer |           |           |           |           |           |           |
|                                                                                                     | <i>mean (SD)</i>          | 0.8 (1.2) | 0.7 (1.2) | 1.0 (1.6) | 1.0 (1.6) | 1.2 (1.6) | 1.2 (1.7) |
|                                                                                                     | <i>t</i> -statistic       | -0.77     |           | 0         |           | 0.19      |           |
|                                                                                                     | % of answers that:        |           |           |           |           |           |           |
|                                                                                                     | stayed the same           | 81%       |           | 70%       |           | 72%       |           |
|                                                                                                     | improved                  | 10%       |           | 15%       |           | 13%       |           |
|                                                                                                     | worsen                    | 9%        |           | 15%       |           | 16%       |           |

Note: \* $p < 0.05$ ; \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

Table E.19. Prior and posterior answers in the *belief about the required electricity supply* for each visualization format

| <i>Belief about the required electricity supply</i> |                     | <i>M (SD) of answers from 1 = significantly reduce to 7 = significantly increase</i> |                      |                    |                         |                       |
|-----------------------------------------------------|---------------------|--------------------------------------------------------------------------------------|----------------------|--------------------|-------------------------|-----------------------|
|                                                     |                     | <i>table</i>                                                                         | <i>gradual range</i> | <i>steep range</i> | <i>gradual ensemble</i> | <i>steep ensemble</i> |
| German sample                                       |                     |                                                                                      |                      |                    |                         |                       |
| fossil fuels                                        | prior               | 1.9 (1.3)                                                                            | 1.9 (1.3)            | 2.1 (1.6)          | 2.1 (1.5)               | 2.1 (1.3)             |
|                                                     | posterior           | 2.0 (1.4)                                                                            | 2.1 (1.5)            | 2.1 (1.5)          | 2.3 (1.8)               | 2.0 (1.4)             |
|                                                     | <i>t</i> -statistic | 0.36                                                                                 | 1.3                  | -0.11              | 1.14                    | -0.2                  |
| nuclear                                             | prior               | 2.6 (1.6)                                                                            | 2.4 (1.4)            | 2.3 (1.6)          | 2.7 (1.8)               | 2.7 (1.7)             |
|                                                     | posterior           | 2.4 (1.5)                                                                            | 2.8 (1.7)            | 2.5 (1.8)          | 2.6 (1.8)               | 2.6 (1.7)             |
|                                                     | <i>t</i> -statistic | -0.93                                                                                | 2.1*                 | 0.66               | -0.23                   | 0.24                  |
| renewable sources                                   | prior               | 6.2 (1.4)                                                                            | 6.2 (1.1)            | 6.1 (1.4)          | 6.3 (1.1)               | 6.2 (1.1)             |
|                                                     | posterior           | 6.2 (1.4)                                                                            | 6.2 (1.2)            | 6.2 (1.1)          | 6.3 (1.2)               | 6.3 (1.1)             |
|                                                     | <i>t</i> -statistic | 1.21                                                                                 | 0.3                  | 0.85               | 0.11                    | 0.26                  |
| Polish sample                                       |                     |                                                                                      |                      |                    |                         |                       |
| fossil fuels                                        | prior               | 2.3 (1.6)                                                                            | 2.4 (1.6)            | 2.2 (1.6)          |                         |                       |
|                                                     | posterior           | 2.5 (1.9)                                                                            | 2.6 (1.9)            | 2.4 (1.8)          |                         |                       |
|                                                     | <i>t</i> -statistic | 1.4                                                                                  | 1.6                  | 0.84               |                         |                       |
| nuclear                                             | prior               | 4.0 (1.8)                                                                            | 4.1 (2.0)            | 4.0 (1.9)          |                         |                       |
|                                                     | posterior           | 3.9 (1.8)                                                                            | 4.4 (1.9)            | 4.3 (1.7)          | -                       |                       |
|                                                     | <i>t</i> -statistic | -0.23                                                                                | 1.87                 | 0.96               |                         |                       |
| renewable sources                                   | prior               | 5.9 (1.7)                                                                            | 6.2 (1.4)            | 5.9 (1.6)          |                         |                       |
|                                                     | posterior           | 5.9 (1.7)                                                                            | 6.3 (1.3)            | 5.8 (1.8)          |                         |                       |
|                                                     | <i>t</i> -statistic | 0.44                                                                                 | 1.25                 | -0.84              |                         |                       |
| French sample                                       |                     |                                                                                      |                      |                    |                         |                       |
| fossil fuels                                        | prior               | 2.2 (1.5)                                                                            | 2.2 (1.5)            | 2.3 (1.6)          |                         |                       |
|                                                     | posterior           | 2.1 (1.6)                                                                            | 2.3 (1.8)            | 2.2 (1.5)          |                         |                       |
|                                                     | <i>t</i> -statistic | 0.44                                                                                 | -0.18                | -0.84              |                         |                       |
| nuclear                                             | prior               | 2.8 (1.6)                                                                            | 2.7 (1.5)            | 3.0 (1.7)          |                         |                       |
|                                                     | posterior           | 2.9 (1.7)                                                                            | 2.7 (1.4)            | 3.0 (1.5)          |                         |                       |
|                                                     | <i>t</i> -statistic | 0.64                                                                                 | 0.72                 | -0.11              |                         |                       |
| renewable sources                                   | prior               | 6.0 (1.3)                                                                            | 5.9 (1.6)            | 5.5 (1.9)          |                         |                       |
|                                                     | posterior           | 6.0 (1.5)                                                                            | 5.8 (1.7)            | 5.5 (1.9)          |                         |                       |
|                                                     | <i>t</i> -statistic | 0.11                                                                                 | 0.59                 | 0.0                |                         |                       |

Note: \* $p < 0.05$ ; \*\* $p < 0.01$ , \*\*\* $p < 0.001$ . Correct answers for the test were: 1-significantly reduce for fossil fuels, 4-keep constant for nuclear, and 7-significantly increase for renewable sources.

### E.13. Dominance analysis on knowledge gains in the required electricity supply

Table E.20. Results of dominance analysis on the error in *knowledge gains* in the required electricity supply.

|                                                                            | Error in knowledge gain<br>(fossil fuels) |                    |          | Error in knowledge gain<br>(nuclear) |                    |          | Error in knowledge gain<br>(renewable sources) |                    |          |
|----------------------------------------------------------------------------|-------------------------------------------|--------------------|----------|--------------------------------------|--------------------|----------|------------------------------------------------|--------------------|----------|
| <i>F</i> -statistic                                                        | 29.89***                                  |                    |          | 24.81***                             |                    |          | 42.37***                                       |                    |          |
| <i>R</i> <sup>2</sup>                                                      | 0.46                                      |                    |          | 0.41                                 |                    |          | 0.54                                           |                    |          |
| <i>R</i> <sup>2</sup> adjusted                                             | 0.44                                      |                    |          | 0.39                                 |                    |          | 0.53                                           |                    |          |
| <u>Predictors</u>                                                          | $\beta$                                   | Dominance analysis |          | $\beta$                              | Dominance analysis |          | $\beta$                                        | Dominance analysis |          |
|                                                                            |                                           | rank               | $\rho^2$ |                                      | rank               | $\rho^2$ |                                                | rank               | $\rho^2$ |
| prior error                                                                | 0.58***                                   | 1 <sup>CD</sup>    | 0.34     | 0.6***                               | 1 <sup>CD</sup>    | 0.36     | 0.63***                                        | 1 <sup>CD</sup>    | 0.40     |
| country context                                                            |                                           |                    |          |                                      |                    |          |                                                |                    |          |
| <i>Polish sample (vs. German sample)</i>                                   | 0.05                                      | 8                  | 0.00     | -0.08*                               | 2 <sup>CD</sup>    | 0.01     | 0.04                                           | >15                | 0.00     |
| <i>French sample (vs. German sample)</i>                                   | -0.0                                      | >15                | 0.00     | -0.08*                               | 3                  | 0.01     | 0.07*                                          | 8                  | 0.01     |
| visualization format                                                       |                                           |                    |          |                                      |                    |          |                                                |                    |          |
| <i>gradual range (vs. table)</i>                                           | 0.02                                      | 14                 | 0.00     | -0.05                                | >15                | 0.00     | 0.01                                           | >15                | 0.00     |
| <i>steep range (vs. table)</i>                                             | -0.03                                     | >15                | 0.00     | -0.02                                | >15                | 0.00     | 0.05                                           | 11 <sup>CD</sup>   | 0.01     |
| <i>gradual ensemble (vs. table)</i>                                        | 0.03                                      | >15                | 0.00     | -0.04                                | 15                 | 0.00     | 0.01                                           | >15                | 0.00     |
| <i>steep ensemble (vs. table)</i>                                          | -0.01                                     | 15                 | 0.00     | -0.03                                | >15                | 0.00     | 0.02                                           | >15                | 0.00     |
| demographics                                                               |                                           |                    |          |                                      |                    |          |                                                |                    |          |
| <i>gender</i>                                                              | -0.01                                     | 11                 | 0.00     | 0.01                                 | 6                  | 0.00     | 0.04                                           | 6                  | 0.01     |
| <i>age</i>                                                                 | -0.05                                     | 7                  | 0.01     | 0.03                                 | 11                 | 0.00     | -0.04                                          | 9                  | 0.01     |
| <i>education level</i>                                                     | -0.08*                                    | 3                  | 0.01     | -0.05                                | 4                  | 0.01     | -0.04                                          | 7                  | 0.01     |
| abilities                                                                  |                                           |                    |          |                                      |                    |          |                                                |                    |          |
| <i>numeracy</i>                                                            | -0.02                                     | 6                  | 0.01     | -0.02                                | 12                 | 0.00     | -0.01                                          | 5                  | 0.01     |
| <i>graph literacy</i>                                                      | -0.01                                     | 9                  | 0.00     | 0.0                                  | 13                 | 0.00     | -0.07                                          | 3                  | 0.02     |
| prior beliefs                                                              |                                           |                    |          |                                      |                    |          |                                                |                    |          |
| <i>political orientation</i>                                               | 0.0                                       | >15                | 0.00     | 0.02                                 | >15                | 0.00     | 0.02                                           | 14 <sup>CD</sup>   | 0.00     |
| <i>belief in global warming</i>                                            | 0.02                                      | 12                 | 0.00     | 0.01                                 | 10                 | 0.00     | -0.0                                           | 10                 | 0.01     |
| <i>belief about the need to cut CO<sub>2</sub> emissions</i>               | -0.07                                     | 5                  | 0.01     | 0.06                                 | 8                  | 0.00     | -0.09**                                        | 4 <sup>CD</sup>    | 0.02     |
| <i>belief about the required electricity supply from fossil fuels</i>      | -                                         | -                  | -        | 0.03                                 | >15                | 0.00     | 0.08**                                         | 2 <sup>CD</sup>    | 0.03     |
| <i>belief about the required electricity supply from nuclear</i>           | 0.04                                      | 10                 | 0.00     | -                                    | -                  | -        | -0.04                                          | 12                 | 0.00     |
| <i>belief about the required electricity supply from renewable sources</i> | -0.15***                                  | 2 <sup>CD</sup>    | 0.04     | 0.05                                 | 5                  | 0.00     | -                                              | -                  | -        |
| prior perceived efficacy and affective responses                           |                                           |                    |          |                                      |                    |          |                                                |                    |          |
| <i>perceived efficacy</i>                                                  | 0.12**                                    | 4                  | 0.01     | 0.02                                 | 9                  | 0.00     | 0.03                                           | 15                 | 0.00     |
| <i>feelings of urgency</i>                                                 | 0.06                                      | >15                | 0.00     | -0.02                                | 14                 | 0.00     | 0.04                                           | 13                 | 0.00     |
| <i>feelings of hope</i>                                                    | -0.05                                     | 13 <sup>CD</sup>   | 0.00     | 0.06                                 | 7                  | 0.00     | -0.01                                          | >15                | 0.00     |

Note: \* $p < 0.05$ ; \*\* $p < 0.01$ , \*\*\* $p < 0.001$ ;  $\beta$  = standardized *beta* coefficients. The statistical significance of  $\beta$  is based on 1000 bootstrap samples. Predictors with the symbol "CD" are *completely dominating* predictors with lower rank. All other predictors are assumed to *generally dominate* predictors with lower rank.

## E.14. Individual interactions between characteristics and formats on reading accuracy

### E.14.1. Interaction effects on the correct answers for reading accuracy

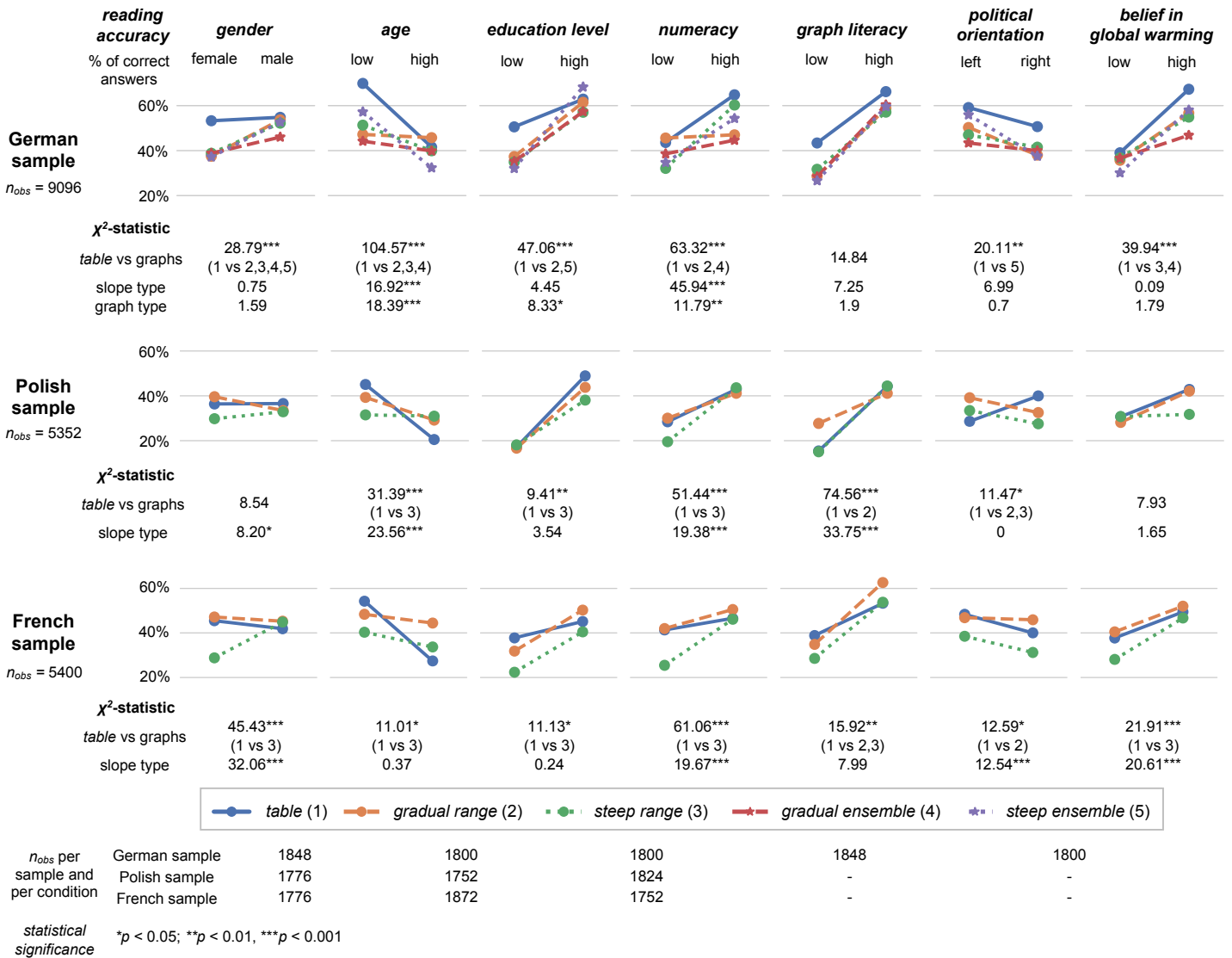


Figure E.10. Interactions between visualization formats and demographics, prior beliefs, *numeracy*, and *graph literacy* on *reading accuracy* (averaged across *scenario themes* and *value types*). Numbers in parentheses after the  $\chi^2$ -statistics denote statistically significant simple effects between the *table* and a specific graph. A Bonferroni correction factor of 14 was applied due to the total number of comparisons with the characteristics of the readers.

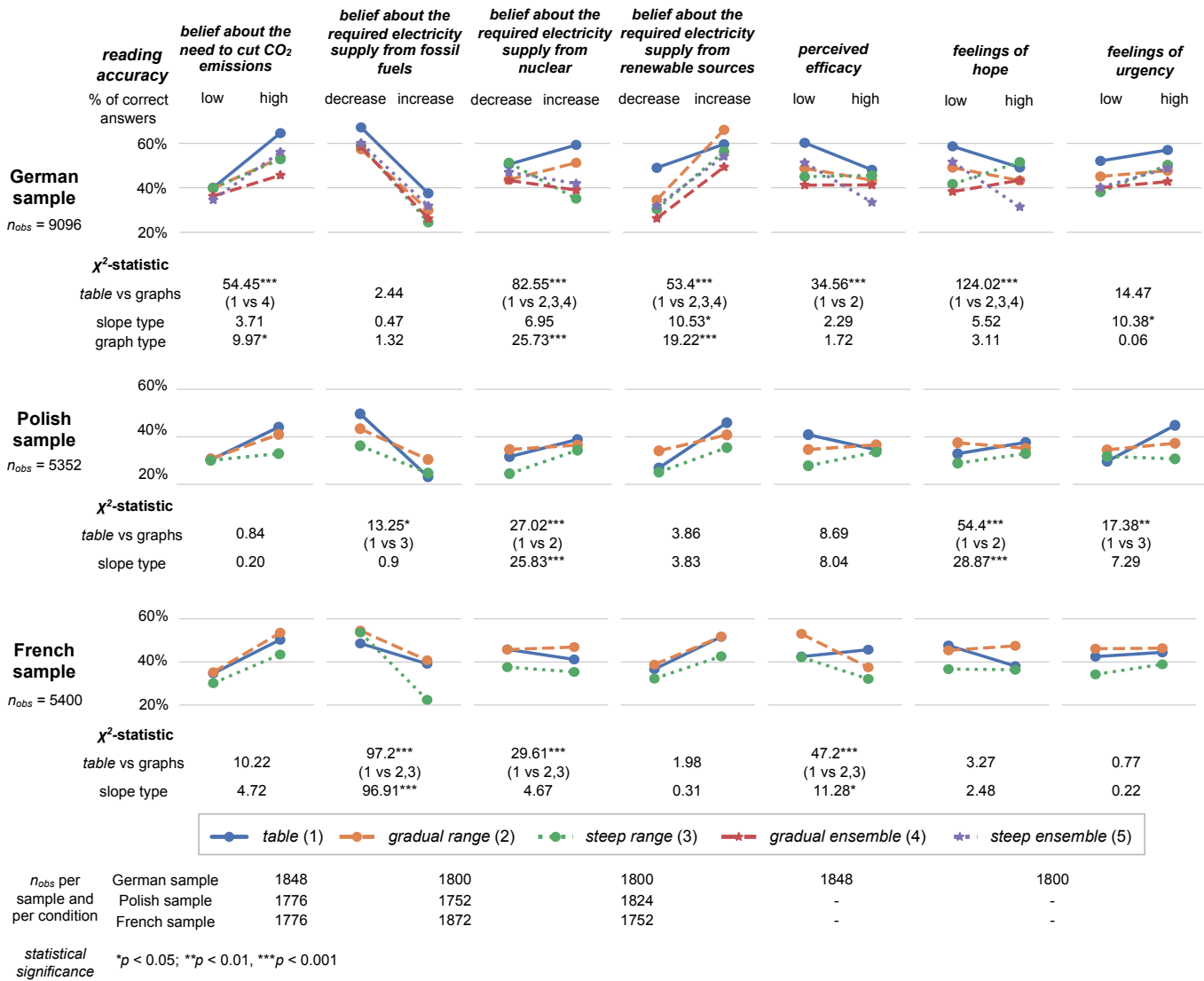


Figure E.11. Interactions between visualization formats and prior beliefs, *perceived efficacy*, *feelings of hope* and *urgency* on *reading accuracy* (averaged across *scenario themes* and *value types*). Numbers in parentheses after the  $\chi^2$ -statistics denote statistically significant simple effects between the *table* and a specific graph. A Bonferroni correction factor of 14 was applied due to the total number of comparisons with the characteristics of the readers.



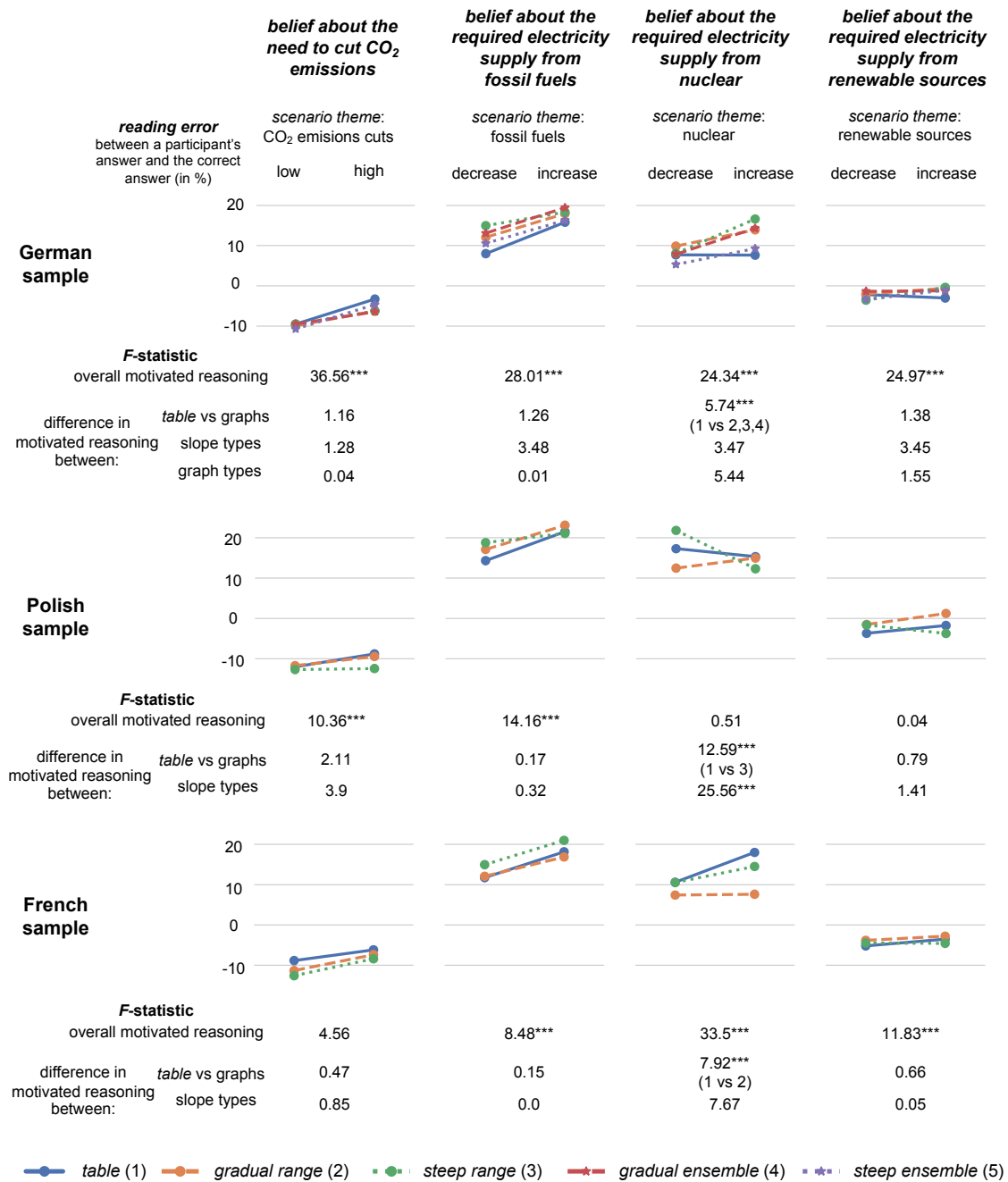


Figure E.12. Results of interactions between formats, the *belief about the need to cut CO<sub>2</sub> emissions* and the *beliefs about the required electricity supply* on the *reading accuracy* (motivated reasoning). For each *scenario theme*, two types of *F*-statistics are shown: (1) whether *reading accuracy* changes for different levels of prior beliefs (overall motivated reasoning), (2) whether there is a difference in motivated reasoning between experimental conditions. The parentheses after the *F*-statistics denote statistically significant simple effects between the *table* and a specific graph. A Bonferroni correction factor of 14 has been applied to control the familywise error rate. \* $p < 0.05$ ; \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

**E.14.2. Interaction effects on the error in reading accuracy**Table E.21. Individual interactions between readers' characteristics and visualization formats on the error in *reading accuracy* for all countries.

| Readers' characteristics                                                           | Dependent variable: error in <i>reading accuracy</i> |                             |                             |
|------------------------------------------------------------------------------------|------------------------------------------------------|-----------------------------|-----------------------------|
|                                                                                    | Interactions with all visualization formats          | Interaction with slope type | Interaction with graph type |
| <i>gender</i>                                                                      | F (4,817) = 1.289                                    | F (1,598) = 3.346           | F (1,598) = 0.0             |
| <i>age</i>                                                                         | F (4,817) = 1.383                                    | F (1,598) = 0.004           | F (1,598) = 0.799           |
| <i>educational level</i>                                                           | F (4,817) = 0.968                                    | F (1,598) = 0.195           | F (1,598) = 0.029           |
| <i>numeracy</i>                                                                    | F (4,817) = 2.54                                     | F (1,598) = 7.678           | F (1,598) = 1.78            |
| <i>graph literacy</i>                                                              | F (4,817) = 1.015                                    | F (1,598) = 3.812           | F (1,598) = 0.21            |
| <i>political orientation</i>                                                       | F (4,817) = 0.329                                    | F (1,598) = 0.0             | F (1,598) = 0.173           |
| <i>belief in global warming</i>                                                    | F (4,817) = 0.226                                    | F (1,598) = 0.037           | F (1,598) = 0.052           |
| <i>belief about the need to cut CO2 emissions (prior)</i>                          | F (4,817) = 1.432                                    | F (1,598) = 1.157           | F (1,598) = 1.233           |
| <i>belief about the required electricity supply from fossil fuels (prior)</i>      | F (4,773) = 0.218                                    | F (1,566) = 0.448           | F (1,566) = 0.237           |
| <i>belief about the required electricity supply from nuclear (prior)</i>           | F (4,762) = 0.701                                    | F (1,555) = 0.64            | F (1,555) = 0.749           |
| <i>belief about the required electricity supply from renewable sources (prior)</i> | F (4,774) = 0.246                                    | F (1,565) = 0.168           | F (1,565) = 0.001           |
| <i>feelings of urgency (prior)</i>                                                 | F (4,817) = 0.603                                    | F (1,598) = 1.393           | F (1,598) = 1.154           |
| <i>feelings of hope (prior)</i>                                                    | F (4,817) = 2.35                                     | F (1,598) = 2.925           | F (1,598) = 0.22            |
| <i>perceived efficacy (prior)</i>                                                  | F (4,817) = 1.413                                    | F (1,598) = 2.034           | F (1,598) = 0.006           |

Note: All results are non-statistically significant. The interactions were calculated using multiple linear regressions including the visualization formats, each respective readers' characteristic, and their interactions as predictors. The *F-statistic* shown corresponds to the interaction term. A Bonferroni correction factor of 14 was applied due to the number of comparisons.

## E.15. Individual interactions between characteristics and formats on knowledge gains

### E.15.1. Interaction effects on the correct answers for knowledge gains

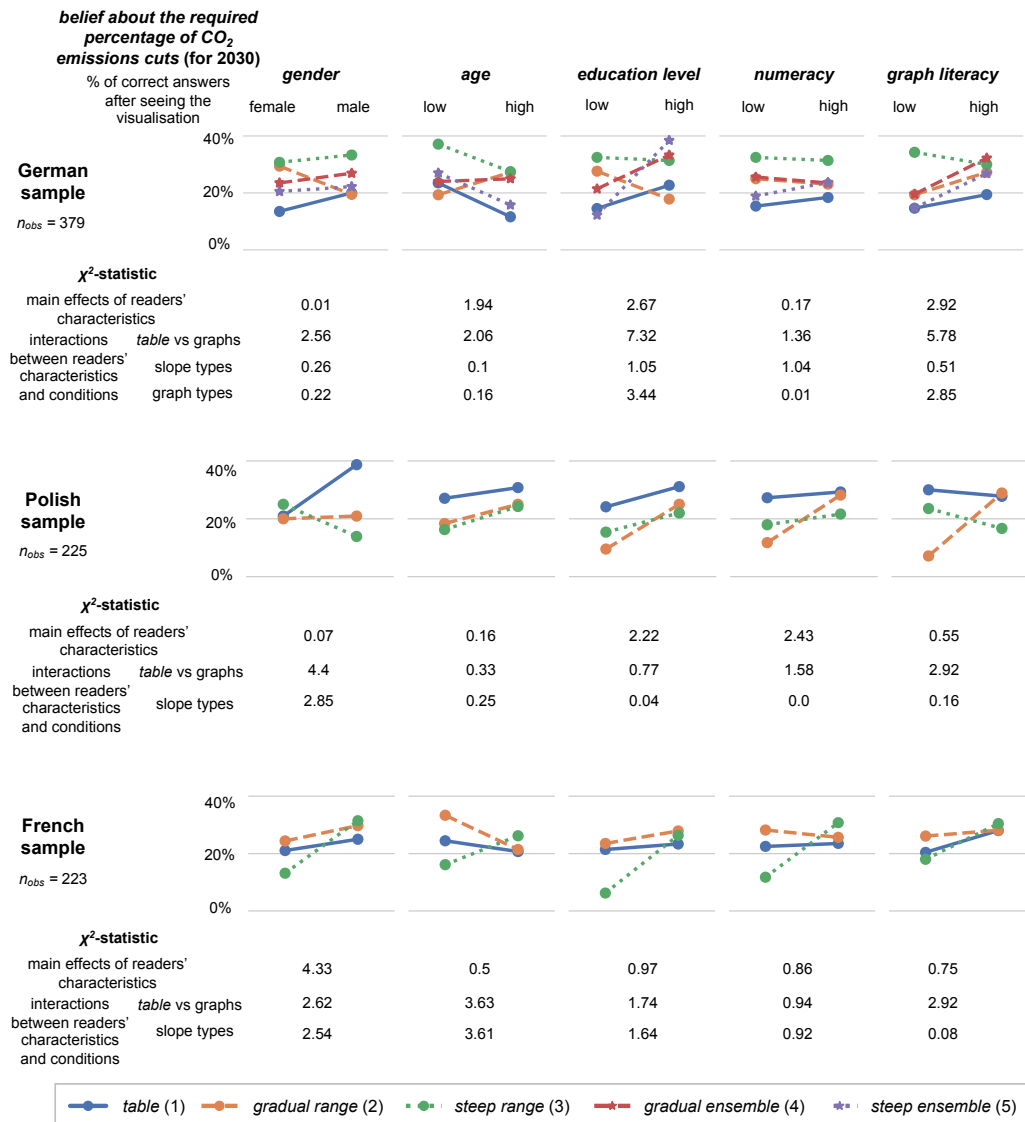


Figure E.13. Effects of demographics, *numeracy* and *graph literacy* on the percentage of correct answers for the *belief about the required percentage of CO<sub>2</sub> for 2030*. Each  $\chi^2$ -statistic refers to a logistic regression model using each readers' characteristic and its interactions with the experimental conditions as predictors. The  $n_{obs}$  is the total number of observations for the *belief about the required percentage of CO<sub>2</sub> for 2030* which is equal to the sample size. \* $p < 0.05$ ; \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

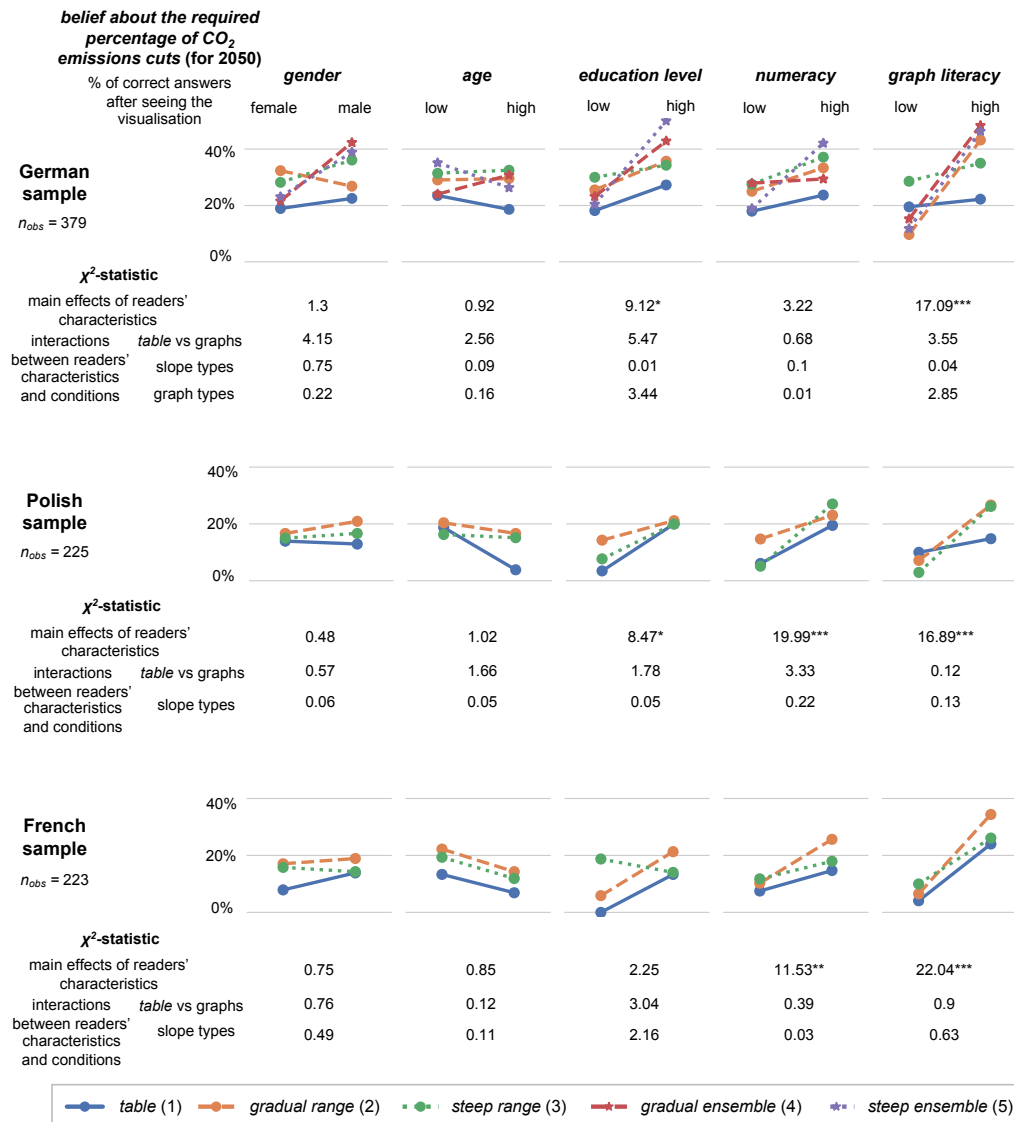


Figure E.14. Effects of demographics, *numeracy* and *graph literacy* on the percentage of correct answers for the *belief about the required percentage of CO<sub>2</sub> for 2050*. Each  $\chi^2$ -statistic refers to a logistic regression model using each readers' characteristic variable and its interactions with the experimental conditions as predictors. The  $n_{obs}$  is the total number of observations for the *belief about the required percentage of CO<sub>2</sub> for 2050* which is equal to the sample size. \* $p < 0.05$ ; \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

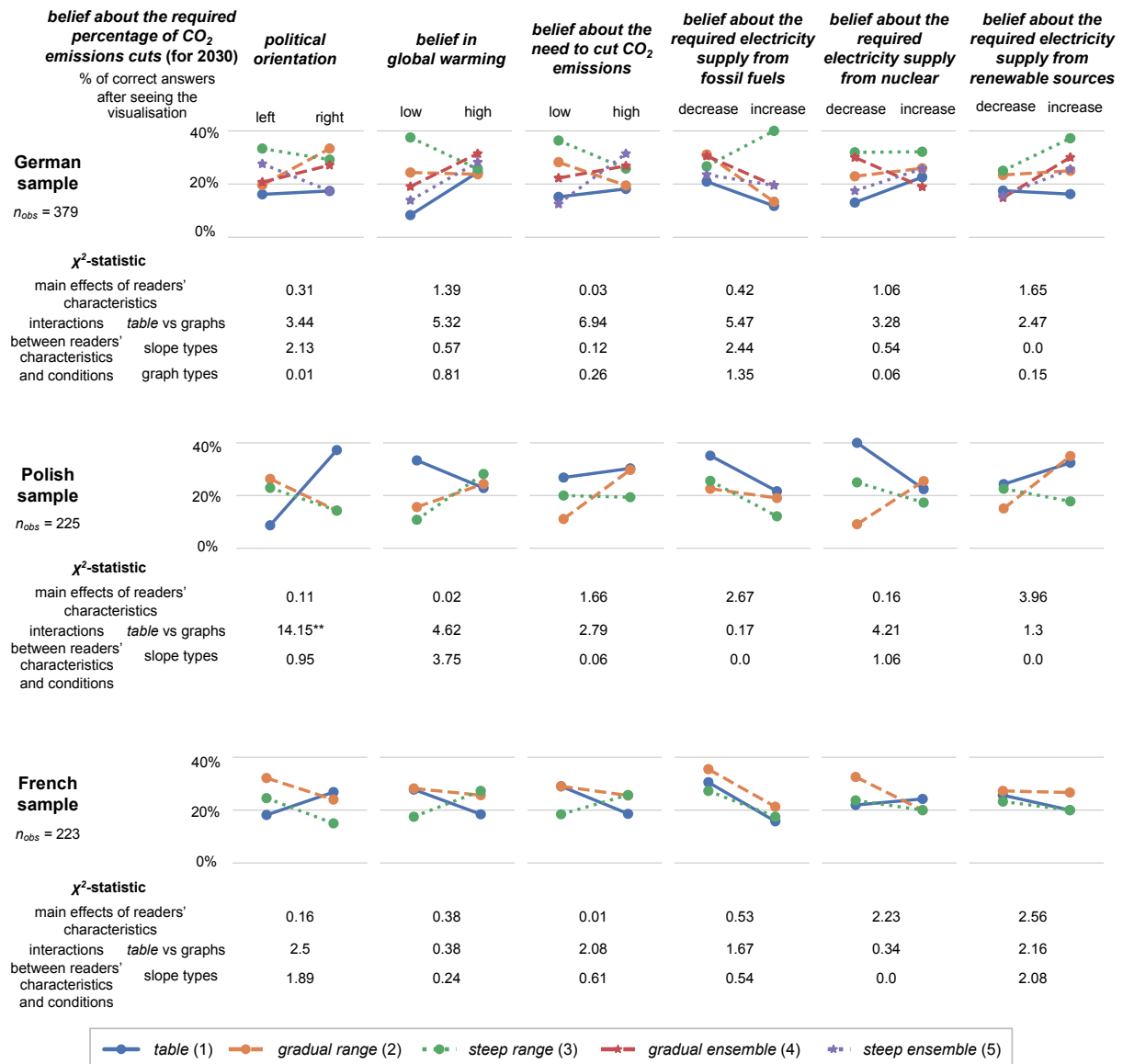


Figure E.15. Effects of prior beliefs on the percentage of correct answers for the *belief about the required percentage of CO<sub>2</sub> for 2030*. Each  $\chi^2$ -statistic refers to a logistic regression model using each readers' characteristic variable and its interactions with the experimental conditions as predictors. The  $n_{obs}$  is the total number of observations for the *belief about the required percentage of CO<sub>2</sub> for 2030* which is equal to the sample size. \* $p < 0.05$ ; \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

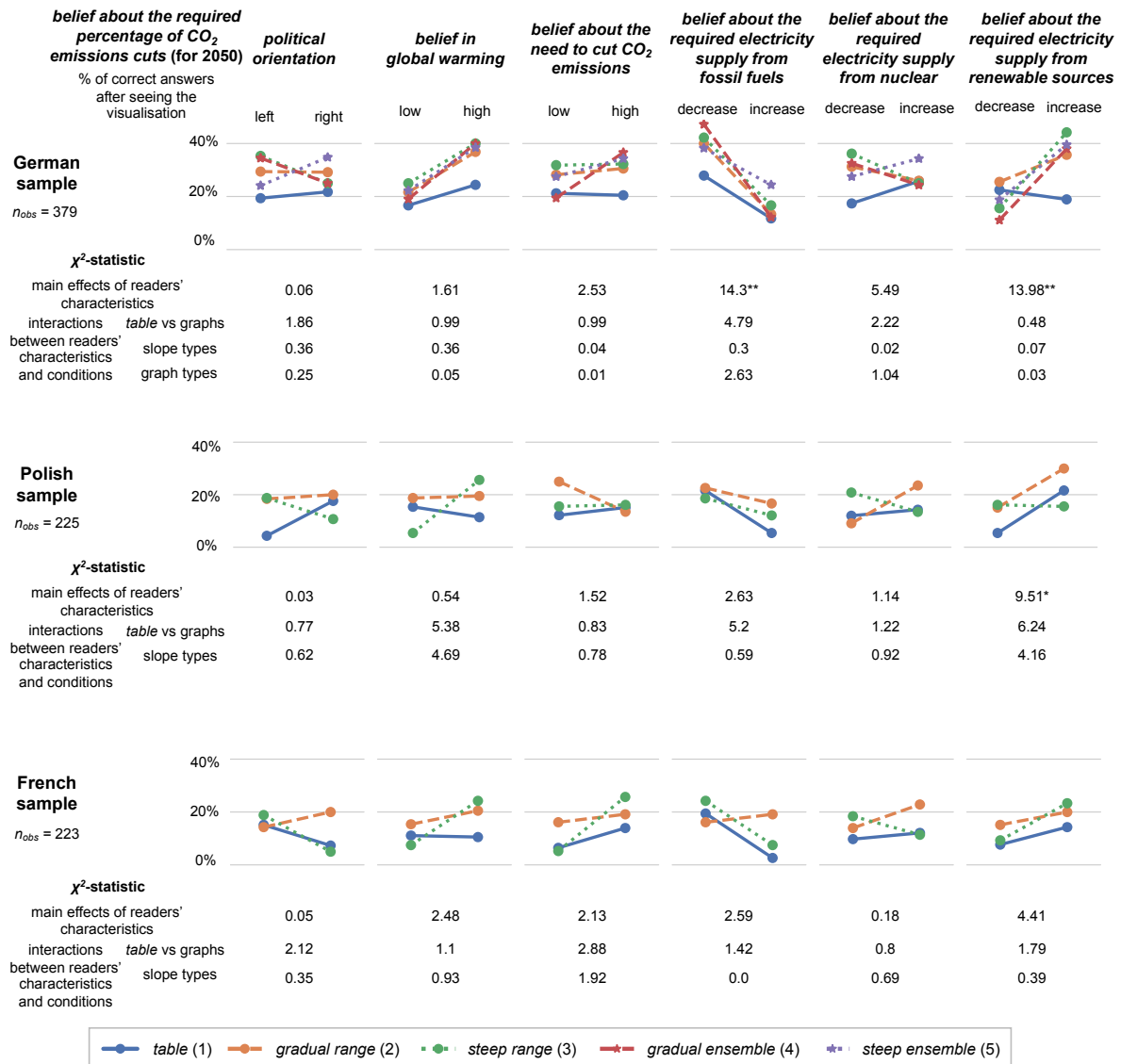


Figure E.16. Effects of prior beliefs on the percentage of correct answers for the *belief about the required percentage of CO<sub>2</sub> for 2050*. Each  $\chi^2$ -statistic refers to a logistic regression model using each readers' characteristic variable and its interactions with the experimental conditions as predictors. The  $n_{obs}$  is the total number of observations for the *belief about the required percentage of CO<sub>2</sub> for 2050* which is equal to the sample size. \* $p < 0.05$ ; \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

**E.15.2. Interaction effects on the error in knowledge gains**Table E.22. Individual interactions between readers' characteristics and visualization formats on the error in *knowledge gains* in the required percentage of CO<sub>2</sub> emissions cuts for all countries.

| Readers' characteristics                                                                              | Dependent variable: error in <i>reading accuracy</i> |                             |                             |
|-------------------------------------------------------------------------------------------------------|------------------------------------------------------|-----------------------------|-----------------------------|
|                                                                                                       | Interactions with all visualization formats          | Interaction with slope type | Interaction with graph type |
| <i>gender</i>                                                                                         | F (4,520) = 1.371                                    | F (1,375) = 0.234           | F (1,375) = 3.55            |
| <i>age</i>                                                                                            | F (4,520) = 0.951                                    | F (1,375) = 0.037           | F (1,375) = 1.152           |
| <i>educational level</i>                                                                              | F (4,520) = 0.615                                    | F (1,375) = 2.628           | F (1,375) = 0.03            |
| <i>numeracy</i>                                                                                       | F (4,520) = 1.72                                     | F (1,375) = 4.73            | F (1,375) = 0.417           |
| <i>graph literacy</i>                                                                                 | F (4,520) = 0.486                                    | F (1,375) = 0.133           | F (1,375) = 0.431           |
| <i>political orientation</i>                                                                          | F (4,520) = 0.901                                    | F (1,375) = 1.776           | F (1,375) = 0.482           |
| <i>belief in global warming</i>                                                                       | F (4,520) = 1.299                                    | F (1,375) = 1.748           | F (1,375) = 0.223           |
| <i>belief about the need to cut CO<sub>2</sub> emissions (prior)</i>                                  | F (4,520) = 1.501                                    | F (1,375) = 2.226           | F (1,375) = 0.111           |
| <i>belief about the required electricity supply from fossil fuels (prior)</i>                         | F (4,507) = 0.904                                    | F (1,366) = 0.702           | F (1,366) = 0.413           |
| <i>belief about the required electricity supply from nuclear (prior)</i>                              | F (4,502) = 1.279                                    | F (1,361) = 1.178           | F (1,361) = 0.536           |
| <i>belief about the required electricity supply from renewable sources (prior)</i>                    | F (4,508) = 0.513                                    | F (1,367) = 0.001           | F (1,367) = 0.005           |
| <i>feelings of urgency (prior)</i>                                                                    | F (4,520) = 1.394                                    | F (1,375) = 5.124           | F (1,375) = 0.134           |
| <i>feelings of hope (prior)</i>                                                                       | F (4,520) = 1.762                                    | F (1,375) = 0.159           | F (1,375) = 1.39            |
| <i>perceived efficacy of humanity/electricity industry to reduce CO<sub>2</sub> emissions (prior)</i> | F (4,520) = 0.647                                    | F (1,375) = 2.002           | F (1,375) = 0.081           |

Note: All results are non-statistically significant. The interactions were calculated using multiple linear regressions including the visualization formats, each respective readers' characteristic, and their interactions as predictors. The *F-statistic* shown corresponds to the interaction term. A Bonferroni correction factor of 14 was applied due to the number of comparisons.

## E.16. Subjective evaluation for the German sample

Table E.23. Results of the *subjective evaluation* of formats for the German sample.

| <i>Subjective evaluation</i><br>for the German sample                       | <i>M (SD)</i> |                          |                        |                             |                           | <i>F</i> -statistic |
|-----------------------------------------------------------------------------|---------------|--------------------------|------------------------|-----------------------------|---------------------------|---------------------|
|                                                                             | <i>table</i>  | <i>gradual<br/>range</i> | <i>steep<br/>range</i> | <i>gradual<br/>ensemble</i> | <i>steep<br/>ensemble</i> |                     |
| 5-point Likert scale from<br>1 = strongly disagree to<br>5 = strongly agree |               |                          |                        |                             |                           |                     |
| German sample                                                               |               |                          |                        |                             |                           |                     |
| filled my knowledge gaps                                                    | 3.3 (1.2)     | 3.5 (0.9)                | 3.1 (1.1)              | 3.2 (1.0)                   | 3.3 (1.1)                 | 1.13                |
| influenced my opinion                                                       | 2.6 (1.2)     | 2.6 (1.1)                | 2.7 (1.1)              | 2.6 (1.1)                   | 2.6 (1.1)                 | 0.27                |
| easy to understand                                                          | 2.5 (1.1)     | 2.7 (1.2)                | 2.4 (1.2)              | 2.5 (1.2)                   | 2.7 (1.2)                 | 1.11                |
| interesting to read                                                         | 3.1 (1.3)     | 3.3 (1.2)                | 3.1 (1.2)              | 2.9 (1.2)                   | 3.1 (1.3)                 | 0.71                |
| I liked it                                                                  | 3.2 (1.0)     | 3.3 (1.0)                | 3.1 (1.0)              | 3.2 (1.1)                   | 3.4 (1.1)                 | 1.04                |
| sum of the scale                                                            | 14.7<br>(3.7) | 15.4<br>(3.5)            | 14.4<br>(3.6)          | 14.3 (3.9)                  | 15.2 (3.7)                | 0.90                |

Note: \* $p < 0.05$ ; \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .



## E.17. Effects of format on perceived efficacy and affective responses

Table E.24. *Perceived efficacy and affective responses* for the German sample

|                                                                                      |                    | <i>table</i> | <i>gradual range</i> | <i>M (SD)</i>      |           | <i>gradual ensemble</i> | <i>steep ensemble</i> | <i>F</i> -statistic | Simple effects between <i>table</i> and each graph |
|--------------------------------------------------------------------------------------|--------------------|--------------|----------------------|--------------------|-----------|-------------------------|-----------------------|---------------------|----------------------------------------------------|
|                                                                                      |                    | [1]          | [2]                  | <i>steep range</i> | [3]       | [4]                     | [5]                   |                     |                                                    |
| German sample                                                                        |                    |              |                      |                    |           |                         |                       |                     |                                                    |
| <i>perceived efficacy of humanity to reduce CO<sub>2</sub> emissions</i>             | <i>ability</i>     | 4.1 (0.9)    | 4.2 (0.8)            | 3.9 (0.9)          | 4.0 (0.9) | 4.1 (1.0)               | 2.95*                 |                     | 1-3                                                |
|                                                                                      | <i>willingness</i> | 3.1 (1.1)    | 3.0 (1.0)            | 3.0 (1.0)          | 3.2 (0.9) | 2.9 (0.9)               | 0.52                  |                     | -                                                  |
|                                                                                      | <i>success</i>     | 3.1 (1.2)    | 3.1 (1.0)            | 2.8 (1.0)          | 3.1 (1.0) | 2.8 (1.0)               | 1.19                  |                     | -                                                  |
| <i>perceived efficacy of electricity industry to reduce CO<sub>2</sub> emissions</i> | <i>ability</i>     | 4.1 (0.9)    | 4.0 (0.7)            | 3.9 (0.9)          | 3.9 (0.9) | 4.0 (1.0)               | 0.51                  |                     | -                                                  |
|                                                                                      | <i>willingness</i> | 3.2 (1.0)    | 3.1 (1.0)            | 2.9 (0.9)          | 3.1 (1.0) | 2.9 (1.0)               | 1.27                  |                     | -                                                  |
|                                                                                      | <i>success</i>     | 3.0 (1.1)    | 3.1 (0.9)            | 2.8 (1.0)          | 3.2 (0.9) | 2.9 (1.0)               | 2.99                  |                     | -                                                  |
| <i>affective responses</i>                                                           | <i>hope</i>        | 5.6 (2.4)    | 5.6 (2.1)            | 4.8 (2.1)          | 5.4 (2.1) | 5.1 (2.4)               | 0.73                  |                     | -                                                  |
|                                                                                      | <i>empowerment</i> | 5.1 (2.4)    | 5.3 (1.9)            | 4.8 (1.9)          | 5.4 (1.8) | 4.9 (2.1)               | 0.31                  |                     | -                                                  |
|                                                                                      | <i>engagement</i>  | 5.9 (2.2)    | 6.3 (2.1)            | 6.2 (2.5)          | 6.1 (2.0) | 5.9 (2.4)               | 0.21                  |                     | -                                                  |
|                                                                                      | <i>guilt</i>       | 4.8 (2.5)    | 5.3 (2.2)            | 5.5 (2.5)          | 4.5 (2.6) | 5.1 (2.7)               | 0.31                  |                     | -                                                  |
|                                                                                      | <i>anger</i>       | 4.6 (2.6)    | 5.3 (2.3)            | 5.4 (2.6)          | 4.8 (2.6) | 5.4 (2.5)               | 1.05                  |                     | -                                                  |
|                                                                                      | <i>alarm</i>       | 6.5 (2.3)    | 6.2 (2.3)            | 6.5 (2.6)          | 6.1 (2.5) | 6.3 (2.5)               | 0.88                  |                     | -                                                  |
|                                                                                      | <i>fear</i>        | 4.8 (2.6)    | 5.1 (2.3)            | 5.8 (2.5)          | 5.0 (2.4) | 5.1 (2.5)               | 2.60*                 |                     | 1-3                                                |

Note: \* $p < 0.05$ ; \*\* $p < 0.01$ , \*\*\* $p < 0.001$ . *Perceived efficacy* items are measured in a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree). *Affective responses* are measured in a 10-point scale (e.g. for the hope item: 1 = hopeless to 10 = hopeful). The statistical testing controls for prior values of the *perceived efficacy* and *affective responses*. Statistically significant results were similar when also controlling for demographics, prior beliefs, *numeracy*, and *graph literacy*.

Table E.25. *Perceived efficacy and affective responses* for the French and Polish sample

|                                        |                    | <i>table</i> | <i>M (SD)</i><br><i>gradual</i><br><i>range</i> | <i>steep</i><br><i>range</i> | <i>F</i> -statistic |
|----------------------------------------|--------------------|--------------|-------------------------------------------------|------------------------------|---------------------|
| Polish sample                          |                    |              |                                                 |                              |                     |
| <i>perceived efficacy of</i>           | <i>ability</i>     | 4.0 (1.0)    | 4.1 (0.9)                                       | 3.9 (1.0)                    | 1.40                |
| <i>humanity to reduce</i>              | <i>willingness</i> | 3.8 (1.0)    | 3.6 (1.0)                                       | 3.6 (1.1)                    | 0.09                |
| <i>CO<sub>2</sub> emissions</i>        | <i>success</i>     | 3.5 (1.0)    | 3.4 (1.0)                                       | 3.4 (1.0)                    | 0.24                |
| <i>perceived efficacy of</i>           | <i>ability</i>     | 3.9 (1.0)    | 4.0 (0.9)                                       | 3.8 (1.1)                    | 2.81                |
| <i>electricity industry to</i>         | <i>willingness</i> | 3.7 (0.9)    | 3.6 (0.9)                                       | 3.4 (1.0)                    | 0.45                |
| <i>reduce CO<sub>2</sub> emissions</i> | <i>success</i>     | 3.7 (1.0)    | 3.4 (0.9)                                       | 3.5 (1.1)                    | 0.48                |
| <i>affective responses</i>             | <i>hope</i>        | 6.1 (2.1)    | 5.9 (2.1)                                       | 5.7 (2.2)                    | 0.38                |
|                                        | <i>empowerment</i> | 5.9 (2.1)    | 5.9 (2.1)                                       | 5.7 (2.2)                    | 0.80                |
|                                        | <i>engagement</i>  | 6.2 (2.0)    | 6.1 (1.9)                                       | 6.1 (2.0)                    | 0.14                |
|                                        | <i>guilt</i>       | 5.1 (2.0)    | 5.2 (2.2)                                       | 5.2 (2.1)                    | 0.49                |
|                                        | <i>anger</i>       | 5.1 (2.2)    | 5.2 (2.0)                                       | 5.4 (2.2)                    | 0.25                |
|                                        | <i>alarm</i>       | 6.1 (2.0)    | 6.2 (1.9)                                       | 6.0 (2.1)                    | 0.87                |
|                                        | <i>fear</i>        | 5.9 (2.2)    | 6.0 (2.3)                                       | 6.1 (2.1)                    | 0.13                |
| French sample                          |                    |              |                                                 |                              |                     |
| <i>perceived efficacy of</i>           | <i>ability</i>     | 4.0 (0.9)    | 4.0 (1.0)                                       | 4.1 (0.9)                    | 0.47                |
| <i>humanity to reduce</i>              | <i>willingness</i> | 2.9 (1.1)    | 3.1 (1.0)                                       | 3.2 (1.1)                    | 2.24                |
| <i>CO<sub>2</sub> emissions</i>        | <i>success</i>     | 2.9 (1.0)    | 3.1 (1.0)                                       | 3.2 (0.9)                    | 0.74                |
| <i>perceived efficacy of</i>           | <i>ability</i>     | 3.8 (0.9)    | 3.7 (1.1)                                       | 3.8 (0.8)                    | 0.24                |
| <i>electricity industry to</i>         | <i>willingness</i> | 3.1 (1.0)    | 3.0 (0.9)                                       | 3.3 (1.0)                    | 0.82                |
| <i>reduce CO<sub>2</sub> emissions</i> | <i>success</i>     | 3.0 (0.9)    | 3.0 (1.0)                                       | 3.2 (0.8)                    | 0.67                |
| <i>affective responses</i>             | <i>hope</i>        | 4.9 (2.4)    | 5.2 (2.0)                                       | 5.3 (1.8)                    | 0.46                |
|                                        | <i>empowerment</i> | 4.8 (2.3)    | 5.1 (2.0)                                       | 5.2 (1.8)                    | 0.48                |
|                                        | <i>engagement</i>  | 6.9 (2.1)    | 6.5 (2.3)                                       | 6.4 (1.8)                    | 0.15                |
|                                        | <i>guilt</i>       | 5.1 (2.5)    | 5.0 (2.3)                                       | 4.9 (2.4)                    | 0.03                |
|                                        | <i>anger</i>       | 5.6 (2.7)    | 4.7 (2.3)                                       | 5.3 (2.5)                    | 0.24                |
|                                        | <i>alarm</i>       | 6.6 (2.4)    | 5.8 (2.2)                                       | 6.0 (2.3)                    | 0.21                |
|                                        | <i>fear</i>        | 6.0 (2.4)    | 5.3 (2.1)                                       | 5.6 (2.1)                    | 1.37                |

Note: \* $p < 0.05$ ; \*\* $p < 0.01$ , \*\*\* $p < 0.001$ . *Perceived efficacy items* are measured in a 5-point Likert scale (1 = strongly disagree to 5 = strongly agree). *Affective responses* are measured in a 10-point scale (e.g. for the hope item: 1 = hopeless to 10 = hopeful). Statistically significant results were similar when controlling for demographics, prior beliefs, *numeracy*, and *graph literacy*.

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# Curriculum Vitae

## PERSONAL INFORMATION

Georgios Xexakis



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📅 Date of birth 12.08.1987 | 🇬🇷 Nationality Greek

## WORK EXPERIENCE

01.05.2021 - CURRENT

### Researcher and Software Developer (Freelancer)

Client: [HOLISTIC S.A.](#) (Greece)

- Project management of the company's contributions to the EU Horizon 2020 projects [NDC ASPECTS](#) & [ENCLUDE](#); research contributions at [PARIS REINFORCE](#) project
- Development of the data exchange platform [I<sup>2</sup>AM PARIS](#) for hosting modelling results of climate change mitigation research
- Grant writing for Horizon Europe projects
- Research in energy transition and public engagement on energy topics

🏢 Business or sector Consultancy / IT services

01.01.2017 - 28.02.2021

### Research Assistant

[Renewable Energy Systems group](#) at the University of Geneva (Switzerland)

[Transdisciplinarity Lab](#) at ETH Zurich (Switzerland)

- Developed an [interactive web tool Riskmeter](#) for informing stakeholders about risk trade-offs in electricity supply scenarios in the EU and Switzerland and measuring preferences for these scenarios
- Performed systematic meta-analyses of scenarios and models for electricity supply in different European countries and compared them with stakeholder perspectives
- Part of the EU Horizon 2020 [DEEDS](#) project for low/zero-carbon innovation

🏢 Business or sector Academia

01.05.2016 - 31.12.2016

### Software Developer and Co-founder

getZED (Netherlands)

Co-founded a start-up to design data-driven renovations for the Dutch housing sector.

🏢 Business or sector Consultancy / IT services

01.12.2013 - 30.04.2016

### Software Developer

[White Lioness Technologies](#) (Netherlands)

- Developed apps using distributed and parallel computing to support multi-objective optimization and modelling for various engineering analyses
- Developed a large-scale information management system including enterprise integration of multiple APIs, data pipelines, and web user interfaces
- Analysed data sets, deployed software, supported customers, assisted operations and QA

🏢 Business or sector Consultancy / IT services

**01.12.2012 - 30.08.2014 Project Engineer**

Prêt-à-Loger, Delft University of Technology (Netherlands)

- Co-founded the university's entry for the Solar Decathlon 2014 competition, the international "Olympic games" of sustainable building design
- Our project won the 1st prize in Sustainability, Communication, and Social Awareness and the 3rd prize overall in the competition, among 20 projects from all over the world
- Our project won the 2nd prize in Energy efficiency, a category whereby I designed, created energy simulations, and officially presented the project to the competition jury

**Business or sector** Architecture, Engineering, and Construction

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**EDUCATION****01.01.2017 - CURRENT Ph.D. in Environmental Sciences**

University of Geneva (Switzerland)

- Research focus: Empirically evaluating the desirability and usability of model-based scenarios for informing energy and low-carbon transitions
- Supervisor: Prof. Evelina Trutnevyte

**25.08.2012 - 01.07.2015 M.Sc. in Building Engineering**

Delft University of Technology (Netherlands)

- Focus on parametric design, climate design, and energy-efficient building renovations
- Graduated with a research thesis in detecting heat loss parameters of existing houses by coupling Internet of Things sensors with energy simulations and genetic algorithms
- Received my M.Sc. degree with distinction (Cum Laude)

**20.09.2005 - 22.07.2011 Diploma in Civil Engineering (M.Sc. equivalent)**

Aristotle University of Thessaloniki (Greece)

- Focus on information technologies for analysis and design of structures, non-linear analysis, numerical methods, and structural modelling
- Received a scholarship for an Erasmus exchange at the University of Ghent, Belgium
- Elected as a secretary in the Erasmus Student Network section of the Aristotle University, organized conferences and events on student mobility

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**ACADEMIC WORK****Journal articles  
(peer-reviewed)**

1. Nikas, A., Xexakis, G., Koasidis, K., Acosta-Fernández, J., Arto, I., Calzadilla, A., Domenech, T., Gambhir, A., Giljum, S., Gonzalez-Eguino, M., Herbst, A., Ivanova, O., van Sluisveld, M. A. E., Van De Ven, D.-J., Karamaneas, A., & Doukas, H. (2022). Coupling circularity performance and climate action: From disciplinary silos to transdisciplinary modelling science. *Sustainable Production and Consumption*, 30, 269–277. <https://doi.org/10.1016/j.spc.2021.12.011>
2. Xexakis, G., & Trutnevyte, E. (2022). Model-based scenarios of EU27 electricity supply are not aligned with the perspectives of French, German, and Polish citizens. *Renewable and Sustainable Energy Transition*, 2, 100031. <https://doi.org/10.1016/j.rset.2022.100031>
3. Xexakis, G., & Trutnevyte, E. (2021). Consensus on future EU electricity supply among citizens of France, Germany, and Poland: Implications for modeling. *Energy Strategy Reviews*, 38, 100742. <https://doi.org/10.1016/j.esr.2021.100742>
4. Xexakis, G., & Trutnevyte, E. (2021). Empirical testing of the visualizations of climate change mitigation scenarios with citizens: A comparison among Germany, Poland, and France. *Global Environmental Change*, 70, 102324. <https://doi.org/10.1016/j.gloenvcha.2021.102324>
5. Xexakis, G., Hansmann, R., Volken, S. P., & Trutnevyte, E. (2020). Models on the wrong track: Model-based electricity supply scenarios in Switzerland are not aligned with the perspectives of energy experts and the public. *Renewable and Sustainable*

*Energy Reviews*, 134, 110297. <https://doi.org/10.1016/j.rser.2020.110297>

6. Xexakis, G., & Trutnevyte, E. (2019). Are interactive web-tools for environmental scenario visualization worth the effort? An experimental study on the Swiss electricity supply scenarios 2035. *Environmental Modelling & Software*, 119(May), 124-134. <https://doi.org/10.1016/j.envsoft.2019.05.014>
7. Dubois, A., Holzer, S., Xexakis, G., Cousse, J., & Trutnevyte, E. (2019). Informed citizen panels on the Swiss electricity mix 2035: Longer-term evolution of citizen preferences and affect in two cities. *Energies*, 12(22), 4231. <https://doi.org/10.3390/en12224231>
8. Volken, S. P., Xexakis, G., & Trutnevyte, E. (2018). Perspectives of Informed Citizen Panel on Low-Carbon Electricity Portfolios in Switzerland and Longer-Term Evaluation of Informational Materials. *Environmental Science & Technology*, 52(20), 11478-11489. <https://doi.org/10.1021/acs.est.8b01265>

#### Master theses supervised

1. Dubois, A. & Holzer, S. (2019). Informed public preferences for energy portfolios in the French-speaking part of Switzerland. Co-supervised with Prof. Evelina Trutnevyte, University of Geneva.
2. Stadler, M. (2017). Assessing electricity pathways for Switzerland for the year 2035 using Multi-Criteria Decision Analysis. Co-supervised with Prof. Evelina Trutnevyte, ETH Zurich.

#### Conference presentations

1. Xexakis, G., Hansmann, R., Volken, S.P. and Trutnevyte, E. Models on the wrong track: Model-based electricity supply scenarios in Switzerland are not aligned with the perspectives of energy experts and the public, 10th International Congress on Environmental Modelling & Software (iEMSs 2020), online, 14-18 September 2020.
2. Xexakis, G., Trutnevyte, E. Empirical testing of the visualizations of climate change mitigation scenarios with citizens: A comparison among Germany, Poland, and France, 10th International Congress on Environmental Modelling and Software (iEMSs 2020), online, 14-18 September 2020.
3. Xexakis G., Trutnevyte E. Are Interactive Web-Tools with Large Scenario Databases Worth the Effort? An Experimental Study with Non-Experts, 11th Annual Meeting of the Integrated Assessment Modelling Consortium (IAMC 2018), Seville, Spain, 13-15 November 2018.
4. Xexakis G., Trutnevyte E. Are Interactive Web-Tools for the Public Worth the Effort? An Experimental Study on the Electricity Supply Transition in Switzerland, 9th International Congress on Environmental Modelling & Software (iEMSs 2018), Fort-Collins, Colorado, USA, 24-28 June 2018.
5. Xexakis G., Volken S. and Trutnevyte E., RISKMETER: An Interactive Tool for Integrating Public Preferences into Long-range Electricity Supply Planning, 2017 INFORMS Annual Meeting, Houston, Texas, USA, 22-25 October 2017.
6. Xexakis G., Volken S. and Trutnevyte E., Understanding Informed Public Preferences for Electricity Generation Portfolios through an Interactive RISKMETER, 12th Conference on Sustainable Development of Energy, Water and Environment Systems (SDEWES), Dubrovnik, Croatia, 4-8 October 2017.
7. Xexakis, G., Van den Dobbelsteen, A., 2015. The Gap between Plan and Practice: Actual energy performance of the zero-energy refurbishment of a terraced house, In: Proceedings of Architecture and Resilience on the Human Scale: Cross-Disciplinary Conference, Sheffield, United Kingdom, 10-12 September 2015.

#### Scholarships

1. Fondation Ernst et Lucie Schmidheiny, scholarship for funding the final phase of the PhD thesis, 15,000.00 CHF, 2021.
2. Swiss Academy of Humanities and Social Sciences, travel and accommodation scholarship for the iEMSs 2018 conference, 1,000.00 CHF, 2018.
3. EU DG-CLIMA and ICF, travel and accommodation scholarship for the IAMC 2018 conference, 682.21 CHF, 2018.

#### PERSONAL SKILLS

Mother tongue(s)      Greek

| Other language(s) | UNDERSTANDING                                                                |         | SPEAKING           |                   | WRITING |
|-------------------|------------------------------------------------------------------------------|---------|--------------------|-------------------|---------|
|                   | Listening                                                                    | Reading | Spoken interaction | Spoken production |         |
| English           | C2                                                                           | C2      | C2                 | C2                | C2      |
|                   | IELTS band 8, Certificate of Proficiency in English (University of Michigan) |         |                    |                   |         |
| Spanish           | B2                                                                           | B2      | B1                 | B1                | B1      |
|                   | State Certificate in Language Proficiency - B2 level                         |         |                    |                   |         |

Levels: A1/2: Basic user - B1/2: Independent user - C1/2 Proficient user  
Common European Framework of Reference for Languages

- Communication skills**
- Good writing skills (scientific articles, blogs, grants)
  - Good presentation skills (scientific conferences, competitions, business pitching)
  - Teaching (workshops and classes for university level students)

- Organisational / managerial skills**
- Leadership (currently responsible for a team of two people)
  - Supervision skills (supervised three M.Sc. students)
  - Project management skills

- Computer skills**
- Programming languages: Python, JavaScript, Matlab, Bash, C#
  - Web development: Django, d3, HTML, CSS
  - Databases: SQLite, PostgreSQL, DynamoDB, InfluxDB
  - Data analysis: Pandas, Numpy, Scipy, Jupyter Notebook, Scikit-learn
  - Frameworks: Git, Chef, AWS infrastructure, Azure cloud, Hadoop, REST
  - Structural/energy analysis: ETABS, SAP, ATENA, EnergyPlus, DesignBuilder
  - CAD/BIM: AutoCAD, Revit, Rhino, Grasshopper
  - Operating systems: Unix/Linux, Windows, Mac

- Other skills**
- Statistical analysis
  - Experimental design
  - Questionnaire development, testing, and programming

## ADDITIONAL INFORMATION

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**Memberships** Professional licence as a Civil Engineer (Technical Chamber of Greece)

**Career gaps** Compulsory Greek military service (November 2011 - August 2012)

**Interests** Long-distance running and swimming, lindy hop dancing, hiking