Renewable Energy Outlook for Switzerland

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Summary

The SWEET EDGE Renewable Energy Outlook investigates the Swiss electricity supply in 2035, especially with a focus on new renewable electricity targets and their technical, regional, financial, employment, and public acceptance implications. We assess four targets: 17 TWh/year, 25 TWh/year and 35 TWh/year for all new renewable electricity in 2035, as well as 25 TWh/year target for solar photovoltaics (PV) only. By comparing the results from three electricity system models, the Outlook shows that all these targets are feasible without nuclear power and without major fossil fuel plants in Switzerland in terms of hourly electricity supply-demand balancing, transmission, storage, import and export. Reaching the most ambitious target of 35 TWh/year would enable Switzerland to have a nearly or fully renewable electricity supply on an annual basis and would considerably reduce the need for winter import. As the EDGE population survey shows, socio-political acceptance of electricity import is extremely low in Switzerland, providing additional backing for the 35 TWh/year target. Having said that, hourly and seasonal electricity trade with neighboring countries remains essential to ensure sufficient flexibility for supply-demand balancing and to adapt to uncertainty in future annual electricity demand.

The rapid growth in solar PV is crucial to implementing any of these four targets. Still, there is flexibility where this solar PV could be located: on rooftops and facades only or also on the ground in open, unbuilt fields. Socio-political acceptance of rooftop PV is very high, and investment risk is low. However, acceptance of open-field PV is closer to that of small hydropower and nuclear power, indicating of a certain risk and uncertainty. The investment risk of alpine PV is similar to that of woody biomass or biogas plants. Whether on rooftops, facades or open field, solar PV requires substantial investment to be mobilized throughout the country by 2035 from utilities, household savings, project developers, and financial investors – the most common investor types in renewable energy infrastructure in Switzerland. Solar PV growth is also associated with a considerable increase in employment and it is key to ensure that the skilled workforce is available on time to avoid bottlenecks.

However, solar PV on rooftops and facades only is neither sufficient nor optimal for any of the targets. Investing into other technologies with lower socio-political acceptance and higher investment risk will be needed to reach the targets. These include wind power, alpine PV, biomass and waste. There is flexibility in the choice of which of these technologies are used and how much, but investing in them cannot be avoided altogether. Insufficient uptake of these technologies would lead to higher reliance on electricity import, which is very unpopular among the Swiss population. The Outlook eventually depicts three alternative strategies of how the technology supply mix could be designed in Switzerland with the focus on technological diversity by deploying various kinds of technologies, with the focus on solar PV with batteries as the primary technology, and with the focus on productivity to locate solar PV and wind power in most efficient locations. For each of the strategies, we describe infrastructure needs at municipal or cantonal levels as well as the associated investment needs and employment implications.

Zusammenfassung

Dieser Bericht von SWEET EDGE untersucht die Schweizer Stromversorgung im Jahr 2035, insbesondere mit dem Fokus auf neue Ziele für erneuerbaren Strom und deren technische, regionale, finanzielle und beschäftigungspolitische Auswirkungen sowie deren öffentliche Akzeptanz. Wir bewerten vier Ziele: 17 TWh/Jahr, 25 TWh/Jahr und 35 TWh/Jahr für den gesamten Strom aus neuen erneuerbaren Energien im Jahr 2035 sowie ein Ziel von 25 TWh/Jahr für Photovoltaik (PV) allein. Mit einem Vergleich von Ergebnissen aus drei Elektrizitätssystemmodellen zeigt der Bericht, dass all diese Ziele ohne Kernenergie oder grosse fossile Kraftwerke in der Schweiz und unter Berücksichtigung von stündlichem Ausgleich von Stromangebot und -nachfrage, Übertragung, Speicherung, Import und Export machbar sind. Das Erreichen des ehrgeizigsten Ziels von 35 TWh/Jahr im Jahr 2035 würde der Schweiz eine nahezu bis vollständig erneuerbare Stromversorgung auf Jahresbasis ermöglichen und den Bedarf an Importen im Winter erheblich reduzieren. Wie die EDGE-Bevölkerungsumfrage zeigt, ist die gesellschaftspolitische Akzeptanz von Stromimporten in der Schweiz äusserst gering, was das Ziel von 35 TWh/Jahr zusätzlich stützt. Dennoch bleibt der stündliche und saisonale Stromhandel mit den Nachbarländern unerlässlich, um eine ausreichende Flexibilität für den Ausgleich von Angebot und Nachfrage zu gewährleisten und sich an die Unsicherheit der jährlichen Stromnachfrage anzupassen.

Der rasche Ausbau von Photovoltaik ist entscheidend für das Erreichen der vier Ziele. Wo diese Photovoltaikanlagen installiert werden, ist jedoch flexibel: nur auf Dächern und an Fassaden oder auch auf Freiflächen in offenen, unbebauten Gebieten. Die gesellschaftliche Akzeptanz von PV auf Dächern ist sehr hoch, und das Investitionsrisiko gering. Die Akzeptanz der Freiflächen-PV ist jedoch eher mit der von Kleinwasserkraft und Atomkraft vergleichbar, was auf ein gewisses Risiko und eine gewisse Unsicherheit hindeutet. Das Investitionsrisiko der alpinen PV ist ähnlich hoch wie das von Biomasse- oder Biogasanlagen. Ob auf Dächern, an Fassaden oder auf Freiflächen: Photovoltaikanlagen erfordern erhebliche Investitionen, die bis 2035 im ganzen Land von Versorgungsunternehmen, Haushalten, Projektentwicklern und Finanzinvestoren – den gängigsten Investorentypen für Infrastruktur für erneuerbare Energien in der Schweiz – getätigt werden müssen. Der Ausbau von Photovoltaik ist auch mit einem beträchtlichen Anstieg der Beschäftigung verbunden. Um Engpässe zu vermeiden, muss sichergestellt werden, dass qualifizierte Arbeitskräfte rechtzeitig zur Verfügung stehen.

Der Ausbau von Photovoltaik auf Dächern und an Fassaden allein ist jedoch für keines der Ziele ausreichend noch optimal. Um die Ziele zu erreichen, sind Investitionen auch in andere Technologien mit geringerer gesellschaftlicher Akzeptanz und höherem Investitionsrisiko erforderlich. Dazu gehören Windenergie, alpine PV sowie Biomasse und Abfälle. Bei der Wahl, welche dieser Technologien in welchem Umfang eingesetzt werden, besteht Flexibilität. Jedoch lassen sich Investitionen in diese Technologien nicht gänzlich vermeiden. Eine unzureichende Nutzung dieser Technologien würde zu einer höheren Abhängigkeit von Stromimporten führen, was in der Schweizer Bevölkerung sehr unbeliebt ist. Der Bericht zeigt schliesslich drei alternative Strategien auf, wie der Technologiemix in der Schweiz gestaltet werden könnte: Zum einen mit dem Fokus auf Technologiediversität durch die Entwicklung verschiedener Technologien, zum anderen mit dem Fokus auf PV und Batterien als primäre Technologien sowie mit dem Fokus auf Produktivität, um PV und Windkraft an möglichst effizienten Standorten zu platzieren. Für jede dieser Strategien beschreiben wir den Bedarf an Infrastruktur auf kommunaler und kantonaler Ebene sowie den damit verbundenen Investitionsbedarf und die Auswirkungen auf die Beschäftigung.

Résumé

Ce rapport de SWEET EDGE fait le point sur l'approvisionnement en électricité de la Suisse en 2035, en mettant notamment l'accent sur les nouveaux objectifs en matière d'électricité renouvelable et leurs implications techniques, régionales, financières, en matière d'emploi et d'acceptation par l'opinion publique. Nous évaluons quatre objectifs: 17 TWh/an, 25 TWh/an et 35 TWh/an en 2035 pour toute nouvelle électricité renouvelable, ainsi qu'un objectif de 25 TWh/an pour l'électricité solaire photovoltaïque (PV) uniquement. En comparant les résultats de trois modèles de système électrique, ce rapport montre que tous ces objectifs sont atteignables sans électricité nucléaire et sans grandes centrales à combustibles fossiles en Suisse, et qu'ils sont réalistes en termes d'équilibrage horaire entre l'offre et la demande d'électricité, de transport, de stockage, d'importation et d'exportation. Atteindre l'objectif le plus ambitieux de 35 TWh/an en 2035 permettrait à la Suisse de disposer d'un approvisionnement en électricité quasiment ou entièrement renouvelable sur une base annuelle et réduirait considérablement les besoins d'importation d'électricité hivernale. Comme le montre l'enquête de EDGE auprès de la population, l'acceptation sociopolitique de l'importation d'électricité est extrêmement faible en Suisse, ce qui constitue un soutien supplémentaire à l'objectif de 35 TWh/an. Cela dit, les échanges horaires et saisonniers d'électricité avec les pays voisins restent essentiels pour garantir une flexibilité suffisante pour équilibrer l'offre et la demande et s'adapter à l'incertitude de la demande annuelle d'électricité.

La croissance rapide du solaire photovoltaïque est cruciale pour la mise en œuvre de chacun de ces quatre objectifs. L'emplacement des systèmes photovoltaïques resterait tout de même flexible : sur les toits et les façades uniquement, ou également au sol dans des champs ouverts et non construits. L'acceptation sociopolitique du photovoltaïque sur les toits est très élevée et le risque lié à l'investissement est faible. Cependant, l'acceptation du photovoltaïque en champ ouvert est plus proche de celle de la petite hydroélectricité et de l'électricité nucléaire, ce qui indique un certain risque et incertitude. Le risque d'investissement du photovoltaïque alpin est similaire à celui des installations de biomasse ligneuse ou de biogaz. Que ce soit sur les toits, les façades ou en plein champ, l'électricité solaire photovoltaïque nécessitera des investissements substantiels à mobiliser dans tout le pays d'ici 2035 de la part des services publics, des ménages, des promoteurs de projets, ainsi que des investisseurs financiers – les types d'investisseurs les plus courants dans les infrastructures d'énergies renouvelables en Suisse. La croissance de l'électricité solaire photovoltaïque est également associée à une augmentation considérable de l'emploi, et il est essentiel de veiller à ce que la main-d'œuvre qualifiée soit disponible à temps pour éviter les goulets d'étranglement.

Toutefois, la présence seule de panneaux solaires photovoltaïques sur les toits et les façades n'est ni suffisante ni optimale, pour aucun des quatre objectifs. Il faudra donc investir dans d'autres technologies moins bien acceptées sur le plan sociopolitique et présentant un risque d'investissement plus élevé pour atteindre les objectifs. Il s'agit notamment de l'électricité éolienne, de l'électricité photovoltaïque alpine, de la biomasse et des déchets. Il existe une certaine souplesse dans le choix des technologies utilisées et de leur degré d'utilisation, mais il est impossible d'éviter complètement d'investir dans ces technologies. Une utilisation insuffisante de ces technologies entraînerait une dépendance accrue vis-à-vis des importations d'électricité, ce qui est très impopulaire au sein de la population suisse. Enfin, ce rapport décrit trois stratégies alternatives sur la façon dont le mix d'offre technologique pourrait être conçu en Suisse : en mettant l'accent sur la diversité technologique en déployant différents types de technologies, en mettant l'accent sur l'électricité solaire photovoltaïque avec batteries comme technologie principale, et en mettant l'accent sur la productivité pour localiser les systèmes d'électricité solaire photovoltaïque et éoliens dans les endroits les plus efficients. Pour chacune des stratégies, nous décrivons les besoins en infrastructures au niveau municipal ou cantonal, ainsi que les besoins d'investissement et les implications en termes d'emploi qui en découlent.

Riassunto

Questo report analizza l'approvvigionamento di energia elettrica in Svizzera nel 2035, con particolare interesse ai nuovi obiettivi di produzione di elettricità rinnovabile ed alle loro implicazioni tecniche, regionali, finanziarie, occupazionali e di accettazione pubblica. Abbiamo fissato quattro obiettivi per la produzione di nuova elettricità rinnovabile: 17, 25 e 35 terawattora all'anno per le nuove rinnovabili nel loro insieme, in aggiunta all'obiettivo di 25 terawattora all'anno per il solo solare fotovoltaico. Attraverso il confronto dei risultati di tre distinti modelli elettrici, il report mostra che tutti questi obiettivi sono raggiungibili in termini di bilanciamento orario di domanda e offerta, trasmissione, stoccaggio, importazione, ed esportazione; gli obiettivi sono raggiungibili senza l'utilizzo di energia nucleare e di grandi impianti ad energia fossile. Il raggiungimento dell'obiettivo più ambizioso di 35 terawattora nell'anno 2035 permetterebbe alla Svizzera di avere una produzione di elettricità (pressoché) interamente rinnovabile e ridurrebbe notevolmente le importazioni in inverno. Come mostrato dal sondaggio svolto da EDGE, l'accettazione sociopolitica sulle importazioni di energia elettrica in Svizzera è molto bassa, fornendo un ulteriore supporto all'obiettivo di 35 TWh all'anno. Lo scambio di energia elettrica su base oraria e stagionale con le nazioni limitrofe rimane però essenziale per assicurare sufficiente flessibilità al bilanciamento di domanda e offerta, e per adattarsi all'incertezza sulla domanda annuale di energia elettrica.

La rapida crescita del solare fotovoltaico è cruciale per implementare ogniuno di questi quattro obiettivi. Tuttavia, è possibile scegliere con flessibilità dove collocare i pannelli: solo sui tetti e sulle facciate degli edifici, o anche sul terreno, in campi aperti e non edificati. L'accettazione sociopolitica del fotovoltaico sui tetti è molto alta, ed il rischio di investimento basso. Al contrario, l'accettazione del solare in campo aperto è più vicina a quella dell'energia nucleare e dell'idroelettrico di piccola taglia, indicando un certo grado di rischio e di incertezza. Il rischio di investimento sul solare alpino è simile a quello sugli impianti a biomasse legnose e biogas. Tutti i tipi di solare fotovoltaico richiedono un sostanziale investimento per poter essere sviluppati nazionalmente entro il 2035 da utenze energetiche, famiglie, sviluppatori di progetti, e investitori finanziari – i più comuni tipi di investitori per infrastrutture energetiche rinnovabili in Svizzera. La crescita del solare fotovoltaico è anche associata ad un considerevole aumento di occupazione, ed è dunque importante assicurare che forza lavoro qualificata sia disponibile per tempo per evitare colli di bottiglia.

Tuttavia, il solo solare fotovoltaico sui tetti e sulle facciate non è né sufficiente, né ottimale per qualunque degli obiettivi. Dunque, per il raggiungimento di tali obiettivi, è necessario investire in altre tecnologie a più bassa accettazione sociopolitica ed a più alto rischio di investimento. Queste includono l'energia eolica, il fotovoltaico in campo aperto, biomasse legnose e biomassa di scarto (inceneritori). C'è flessibilità sulla scelta di quali di queste tecnologie vadano impiegate e quanto, ma non si può evitare del tutto di investire in esse. Un'adozione insufficiente di queste tecnologie porterebbe ad una maggiore dipendenza dalle importazioni di elettricità, che è molto impopolare tra la popolazione svizzera. Il report mostra tre strategie alternative su come potrebbe essere progettato il mix tecnologico in Svizzera, con un'attenzione particolare sulla differenziazione tecnologica attraverso lo sviluppo di vari tipi di tecnologie, sul solare fotovoltaico e batterie come tecnologie primarie, e prioritizzando la produttività per localizzare la potenza solare ed eolica nei luoghi più efficienti. Per ciascuna delle strategie, descriviamo le esigenze infrastrutturali a livello comunale o cantonale, nonché le relative necessità di investimento ed implicazioni sull'occupazione lavorativa.

1 Introduction

Deep and rapid transformation of the Swiss electricity supply is a prerequisite for the country to reach its goals of the Energy Strategy 2050[1] and net-zero carbon emissions by mid-century[2]. Zero-carbon electricity supply is a backbone of the net-zero emissions system that includes significant shares of electric transport and heating[3]. Assuming no nuclear power in the longer run and limited potential for carbon capture and storage in the country, Switzerland hence needs to transition to fully or nearly fully renewable electricity supply by 2050. Scientific evidence is mounting on the feasibility and cost-competitiveness of high shares of renewable electricity in Switzerland[4-7] and elsewhere[8].

The legally-binding federal target from 2016 for 11.4 TWh/year[9] of new renewable electricity from solar photovoltaics (PV), wind power, biomass and waste by 2035 is therefore to be updated. In 2020, the federal message spoke of 17 TWh/year[10] by 2035 and this target was also analyzed in the Swiss Energy Perspectives 2050+[11]. In September 2023, the Parliament concluded with the Mantelerlass process and a much more ambitious target of 35 TWh/year[12] by 2035. The latter target includes a guiding maximum value of 5 TWh on net winter electricity import (1st October to 31st March).

In this context, this Renewable Electricity Outlook for Switzerland focuses on the Swiss electricity supply and its immediate transformation until 2035, especially for higher shares of new renewable technologies. In particular, the Outlook investigates technical, regional, finance, employment, and public acceptance dimensions of four alternative targets for Switzerland by 2035:

- at least 17 TWh/year[10] of new renewable electricity;
- at least 25 TWh/year of new renewable electricity as an intermediate level between 17 TWh/year and 35 TWh/year;
- at least 25 TWh/year of solar PV electricity only, because solar PV is the fastest growing technology[13] in Switzerland and because there have been propositions of up to 50 GW or around 45 TWh/year of solar PV alone by 2050[14];
- at least 35 TWh/year[12] of new renewable electricity as per latest decision of the Swiss Parliament.

For the analysis of these targets, first, we conduct a model inter-comparison[15] of three structurally different, spatially resolved electricity system models to simulate the quantities and locations of new renewable electricity projects and to investigate implications on electricity import. Section 10 provides details on methods. The three modeling teams conducted harmonized model runs, assuming final electricity demand of 61.2 TWh/year in 2035, which includes 5.0 TWh/year for electric vehicles, 8.5 TWh/year for heat pumps, and 47.7 TWh/year for other electricity uses[11,16]. Two demand sensitivity cases were investigated as well: 57.5 TWh/year and 66.8 TWh/year. In all scenarios, it is assumed that nuclear power is already completely phased out in 2035 and there are no restrictions on electricity import or export. The four targets are compared with each other without a comparison to a baseline or business-as-usual case.

The overarching consensus among the three models is then highlighted as robust conclusions (Section 2). For the rest, the three models present three different internally-consistent storylines of how these targets could be implemented: a strategy with the focus on technological diversity (Section 3), a strategy with the focus on PV with batteries (Section 4), and a strategy with the focus on productivity (Section 5). Each strategy has its pros and cons and eventually it is a societal choice to decide which strategy is more preferable.

The technical analysis is then complemented with the assessment of investment needs and investment risks (Section 6), implications on employment (Section 7), and insights from a population survey on policy preferences and technology acceptance (Section 8). The final Section 9 summarizes the overarching insights of this Outlook for policy. Section 10 describes the methods in brief.

2 Overarching consensus on technologies to reach the targets

Assuming the final demand at 61.2 TWh/year in 2035 and full nuclear power phase out, all four targets are found to be technically feasible by all three models (Figure 1). Technical feasibility here is defined as having an operable electricity system in terms of electricity supply and demand balancing at hourly timestep and accounting for transmission, storage, import and export. While the three models represent different technological and regional strategies to meet the targets (Sections 3–5), it can be observed that the more ambitious the target is — the higher is the share of domestic renewable electricity in the supply mix. In the case of the 35 TWh/year target, while Switzerland would still trade with the neighboring countries on hourly basis, it would also be able to achieve a fully or nearly fully domestic renewable electricity supply on an annual basis.

Solar PV is found to be the key technology for reaching any of the four targets, even if PV locations and installed capacities differ among specific implementation strategies (Sections 3–5): on rooftops and facades, on rooftops with batteries, or on the ground in open, unbuilt fields. A comparison of the 25 TWh/year target for all new renewable electricity with the 25 TWh/year target for solar PV only shows that enforcing 25 TWh/year of solar PV only makes all models deviate from what they would otherwise find optimal. Depending on the model and its logic, solar PV displaces optimal amounts of wind power, biomass and waste, or net import. Nonetheless, for the most ambitious target of 35 TWh/year, 25 to 31 TWh/year of solar PV electricity are required, complemented by either wind power and/or biomass and waste.

Electricity trade with neighboring countries remains key in balancing hourly and seasonal variations in electricity supply and demand and providing the necessary system flexibility in all three models for all four targets. Higher targets of new renewable electricity directly reduce net import. As compared to 3.4 TWh/year net import[13] in 2022 when nuclear power was still available in Switzerland, net annual import reliance would increase in the case of all targets, except for the 35 TWh/year target. With this target, in the case of strategies that focus on PV with batteries and on productivity, Switzerland would even become net annual exporter of electricity.
As compared to 7.8 TWh of net winter electricity import in 2021/2022[13], winter import

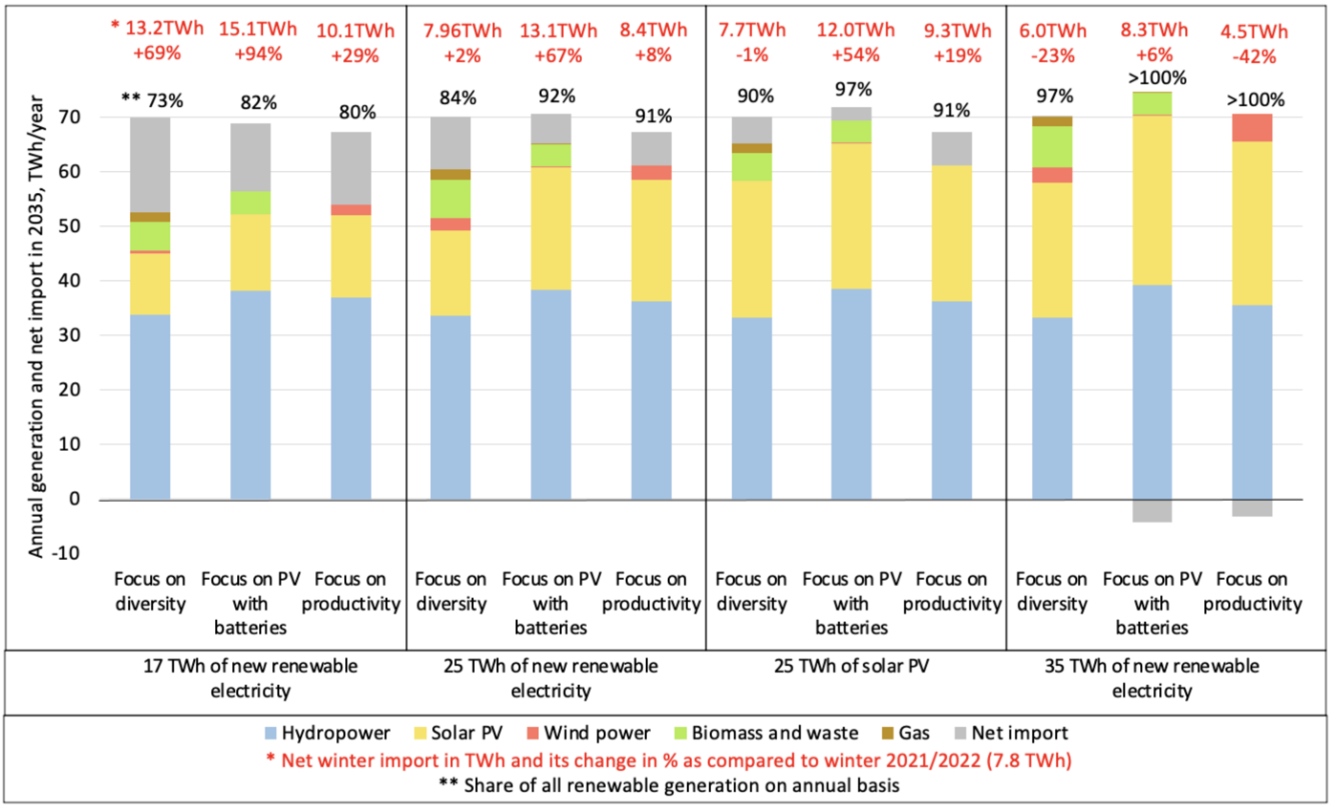

Figure 1: Electricity supply mix, share of new renewable electricity, and net winter electricity import in 2035 in the case of 61.2 TWh/year final electricity demand.

without nuclear power in Switzerland would be only reduced in the case of the highest target of 35 TWh/year in two models. With respect to the Parliament's guiding value of 5 TWh/year on net winter import[12], two of the three models lightly exceed this value even if they meet 35 TWh/year target.

Net electricity import is also the primary variable that is adjusted to react to lower or higher electricity demand when meeting any of the targets (Table 1). This finding shows the importance of electricity interconnection with the neighboring countries not only in managing hourly or seasonal demand-supply balance, but also in adapting to the demand uncertainty. For the rest, the three models have relatively minor differences as demand changes. The strategy with the focus on technological diversity practically solely relies on net electricity import for covering higher demand and, unless more ambitious targets than 17 TWh/year are set, also on increased use on gas (either natural or synthetic gas). The strategy with the focus on PV with batteries adjusts both electricity import as well as solar PV generation up and down in response to varying annual demand. In the case of lower demand, the strategy with the focus on productivity relies more on solar PV, but when annual electricity demand increases it switches to wind power instead. Nonetheless, all these changes in domestic generation in response to demand variations in all three strategies are low, compared to the main adjustment variable, which is net import.

Table 1: Changes in final electricity demand, generation, and net import in TWh/year as compared to the case of 61.2 TWh/year final electricity demand in Switzerland

Demand sensitivity case			57.5 TWh	66.8 TWh
Final electricity demand			**-3.70**	**5.60**
17 TWh of new renewable electricity	Focus on diversity	Hydropower	-0.01	0.00
		Solar PV	-0.07	-0.02
		Wind power	0.08	0.00
		Biomass and waste	-0.01	0.02
		Gas	-0.02	0.57
		Net import	-4.04	5.98
		Net winter import	-2.76	3.22
	Focus on PV with batteries	Hydropower	0.01	0.28
		Solar PV	-0.88	1.22
		Wind power	0.00	0.00
		Biomass and waste	0.00	-0.01
		Gas	0.00	0.25
		Net import	-3.12	4.70
		Net winter import	-2.52	2.81
	Focus on product.	Hydropower	-0.27	0.20
		Solar PV	0.59	-0.29
		Wind power	-0.59	0.29
		Net import	-3.69	5.96
		Net winter import	-3.35	5.90
25 TWh of new renewable electricity	Focus on diversity	Hydropower	0.00	0.03
		Solar PV	-0.01	-0.14
		Wind power	0.01	0.14
		Biomass and waste	0.00	0.00
		Gas	0.00	0.01
		Net import	-4.09	6.55
		Net winter import	-1.12	5.13
	Focus on PV with batteries	Hydropower	-0.10	0.27
		Solar PV	-1.10	1.13
		Wind power	0.00	0.00
		Biomass and waste	0.00	-0.01
		Gas	0.00	0.19
		Net import	-2.94	4.78
		Net winter import	-2.44	2.92
	Focus on product.	Hydropower	-0.24	0.25
		Solar PV	0.06	0.10
		Wind power	-0.06	-0.10
		Net import	-3.72	5.91
		Net winter import	-1.68	4.15
25 TWh of solar PV	Focus on diversity	Hydropower	0.01	0.00
		Solar PV	0.00	0.00
		Wind power	0.00	0.00
		Biomass and waste	-0.01	0.00
		Gas	0.00	0.02
		Net import	-4.10	6.59
		Net winter import	-1.55	4.73
	Focus on PV with batteries	Hydropower	-0.15	0.25
		Solar PV	-1.06	0.99
		Wind power	0.00	0.00
		Biomass and waste	0.00	-0.01
		Gas	0.00	0.17
		Net import	-2.95	4.82
		Net winter import	-2.42	2.96
	Focus on product.	Hydropower	-0.21	0.18
		Solar PV	0.00	0.00
		Wind power	0.00	0.00
		Net import	-3.75	5.98
		Net winter import	-1.99	5.99
35 TWh of new renewable electricity	Focus on diversity	Hydropower	0.01	0.02
		Solar PV	0.00	0.00
		Wind power	0.00	0.00
		Biomass and waste	0.00	0.00
		Gas	0.00	0.00
		Net import	-4.10	6.59
		Net winter import	-2.74	3.60
	Focus on PV with batteries	Hydropower	0.02	-0.04
		Solar PV	-0.76	0.07
		Wind power	0.00	-0.05
		Biomass and waste	0.00	0.00
		Gas	0.00	0.00
		Net import	-3.23	5.94
		Net winter import	-2.48	3.78
	Focus on product.	Hydropower	-0.15	0.32
		Solar PV	0.83	0.41
		Wind power	-0.83	-0.41
		Net import	-3.81	5.84
		Net winter import	-1.92	3.43

3 Strategy with the focus on technological diversity

This strategy comes from the EXPANSE model of the University of Geneva (Section 10), which quantifies electricity supply scenarios and locations of power plants to achieve the lowest total system costs in 2035. Due to its technology neutrality, EXPANSE results show the most diversified technology mixes of all the models, combining solar PV on rooftops and facades, wind power, woody, non-woody biomass[17] and waste in combined heat and power plants, as well as a small quantity of gas-based plants (Figures 1 and 2). The latter plants can use either natural gas or, in the future, also synthetic carbon-neutral gas.

The EXPANSE model covers pumped hydropower storage, batteries, and power-to-hydrogen as storage alternatives, but the least-cost solutions for all four targets only include negligible quantities of batteries and power-to-hydrogen in 2035. Sufficient supply-demand balancing is achieved through pumped hydropower storage and import and export. Combined heat and power plants and wind power additionally contribute to closing the winter electricity gap.

In terms of new renewable electricity, with up to 22.6 GW_p, solar PV is the dominant technology in this strategy, where it is used only on rooftops and facades. Hence, the model is able to meet all four targets without open-field PV. This strategy first prioritizes the most productive southern municipalities where highest capacity factors can be reached, while at higher targets it switches to more regionally balanced deployment (Figure 2). When enforcing the 25 TWh/year target for solar PV alone, wind power is not necessary and biomass use is reduced. However, a comparison with the 25 TWh/year target for all new renewable electricity technologies shows that sole focus on solar PV as a target is not optimal.

In the cases of 25 TWh/year and 35 TWh/year targets from all new renewable electricity, EXPANSE also includes moderate levels of 1.4 – 1.8 GW of wind power. New wind power deployment is first concentrated in the Jura mountains, but with higher targets also reaches to northeastern Switzerland and the Romandie.

As compared to the other three strategies, this strategy stands out for its technological diversity, which is one of the common metrics of supply security[18,19]. This strategy also includes biomass and waste in combined heat and power plants that help decarbonize heat, but it excludes open-field PV that could face acceptance issues.

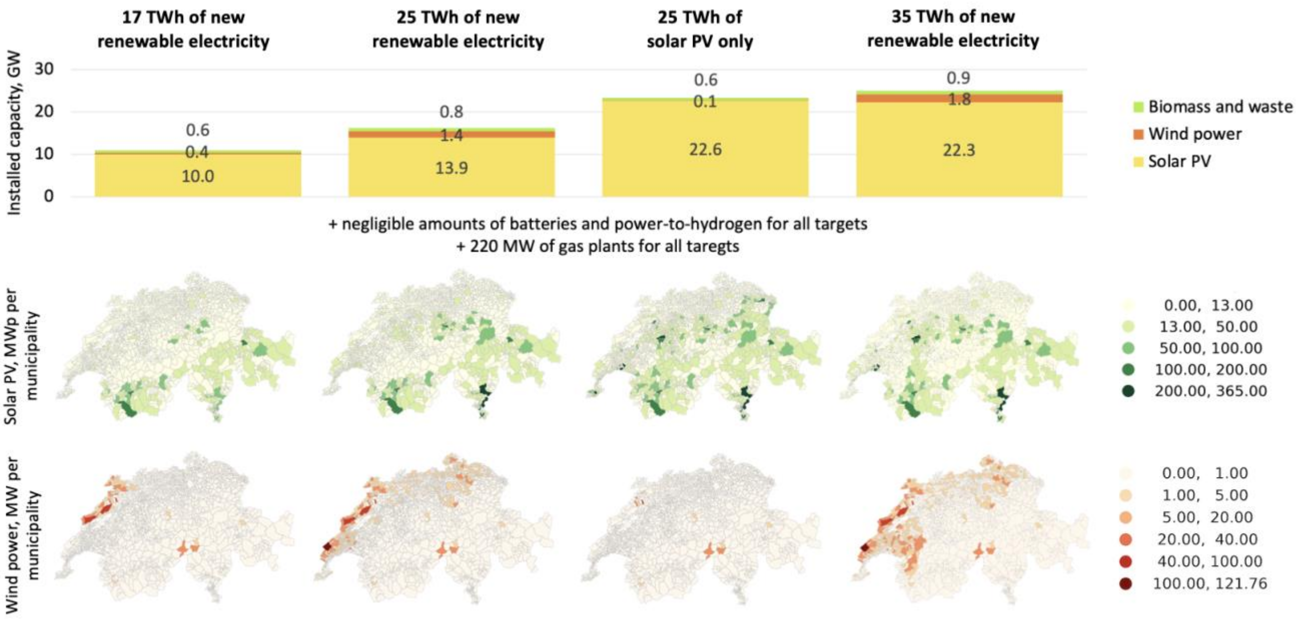

Figure 2: Installed capacities of solar PV, wind power, biomass and waste as well as regional distribution of solar PV and wind power locations in 2035 for the strategy with the focus on technological diversity (EXPANSE model).

4 Strategy with the focus on solar PV with batteries

This strategy comes from the Nexus-e model of ETH Zurich (Section 10), which combines modeling of profitability-based decision making on rooftop solar PV with batteries for self-consumption and centralized cost optimization of the rest of the system. As a result, Nexus-e scenarios almost exclusively rely on solar PV in achieving all four targets, especially rooftop PV with batteries at consumers' sites (Figures 1 and 2). For targets up to 25 TWh/year, solar PV is more heavily deployed in the cantons of Bern, Zurich, and other cantons of the Midlands, reflecting patterns in the density of buildings and assumed grid feed-in policies rather than patterns in irradiation (Figure 2). For the most ambitious 35 TWh/year target, however, the cantons of Graubünden and Wallis need to build more solar PV, including open-field PV, leading to higher capacity factor and hence lower installed capacity of PV. Enforcing 25 TWh/year target on solar PV only shows that the model needs to build more PV than what it otherwise finds optimal for the target of 25 TWh/year from all new renewable electricity.

As for the other technologies, this strategy includes existing waste incineration plants (no other types of biomass), existing wind power plants, and some gas-based power plants operated with natural gas or, in the future, also synthetic carbon-neutral gas. With a high percentage of rooftop PV for self-consumption, this strategy relies heavily on decentralized batteries, reaching a total capacity as high as 656 MW in the case of 25 TWh/year target from solar PV only. Pumped hydropower storage, batteries, and electricity import and export are the main strategies for ensuring supply-demand balance. In fact, due to high share of solar PV, this strategy relies more on net electricity import over a year and in winter than the other two strategies. Nonetheless, in the case of 35 TWh/year target, Nexus-e reaches fully domestic renewable electricity supply at least on annual basis, where Switzerland even becomes net electricity exporter.

As compared to the other three strategies, this strategy stands out for its more active engagement of citizens as they become prosumers and install rooftop PV with batteries for self-consumption. This strategy also avoids some of the technologies that face a risk of lower community acceptance locally, such as new wind power and, in the case of lower targets, also open-field solar PV.

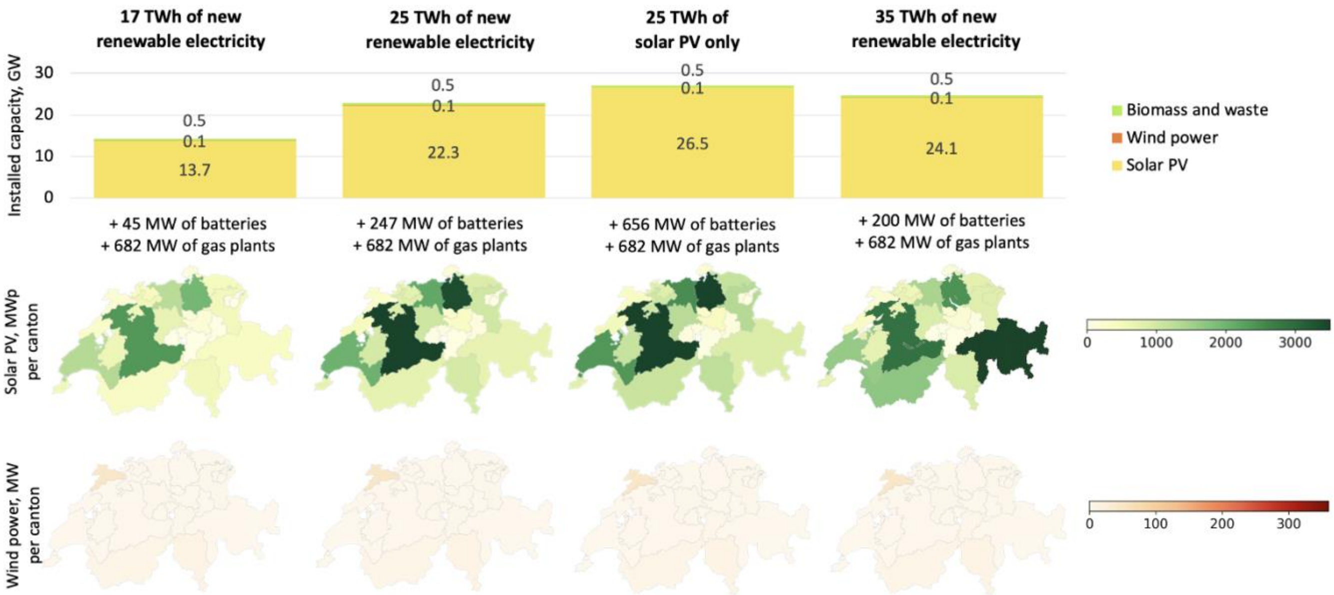

Figure 3: Installed capacities of solar PV, wind power, biomass and waste as well as regional distribution of solar PV and wind power locations in 2035 for the strategy with the focus on PV with batteries (Nexus-e model).

5 Strategy with the focus on productivity

This strategy comes from the OREES model of EPFL (Section 10), which estimates locations with the highest productivity for rooftop or open-field PV and wind power plants in order to maximize revenue from these plants in Switzerland. In the case of all four targets, OREES results in high solar PV generation, coupled with the highest shares of wind power among the three models. All targets are met without biomass and waste, gas-based generation, and other storage alternatives except for pumped hydropower because these technologies are not modeled. The model nonetheless finds feasible ways to meet the four targets by wind power, PV generation, and hydropower only (Figure 1).

With its focus on most productive locations, this strategy concentrates the largest portions of solar PV in the alpine municipalities, especially in the cantons of Graubünden and Wallis, assuming that some of these PV plants will also be built on land rather than integrated in buildings or existing infrastructures. As a result, this strategy has relatively low installed PV capacities as compared to the other two strategies, but these PV capacities achieve higher capacity factors due to technically-optimized locations and correspondingly a higher share of winter production. Enforcing 25 TWh/year target of solar PV only removes the need for wind power, which is otherwise included in the optimal supply mix when the same target can be reached by solar PV and wind power together.

The OREES model ensures supply-demand balancing by relying on electricity import and export, pumped hydropower storage, and then by exploiting the complementarity between solar PV and wind power generation. Alpine PV plants and especially wind power in the Jura mountains or in selected optimized areas of the Alps serve to reduce winter electricity gap. For the highest target of 35 TWh/year, this strategy manages to achieve fully domestic renewable electricity supply on annual basis and Switzerland even becomes net electricity exporter. While the OREES model relies the least on electricity import and export as compared to the other two models (Figure 1), electricity interconnection with neighboring countries remains necessary for balancing.

As compared to the other two strategies, this strategy stands out for prioritizing the productivity of power plants and hence concentrating PV and wind power in fewer best locations. The strategy also avoids investments into biomass and waste plants, flexible generation or other storage technologies than pumped hydropower storage.

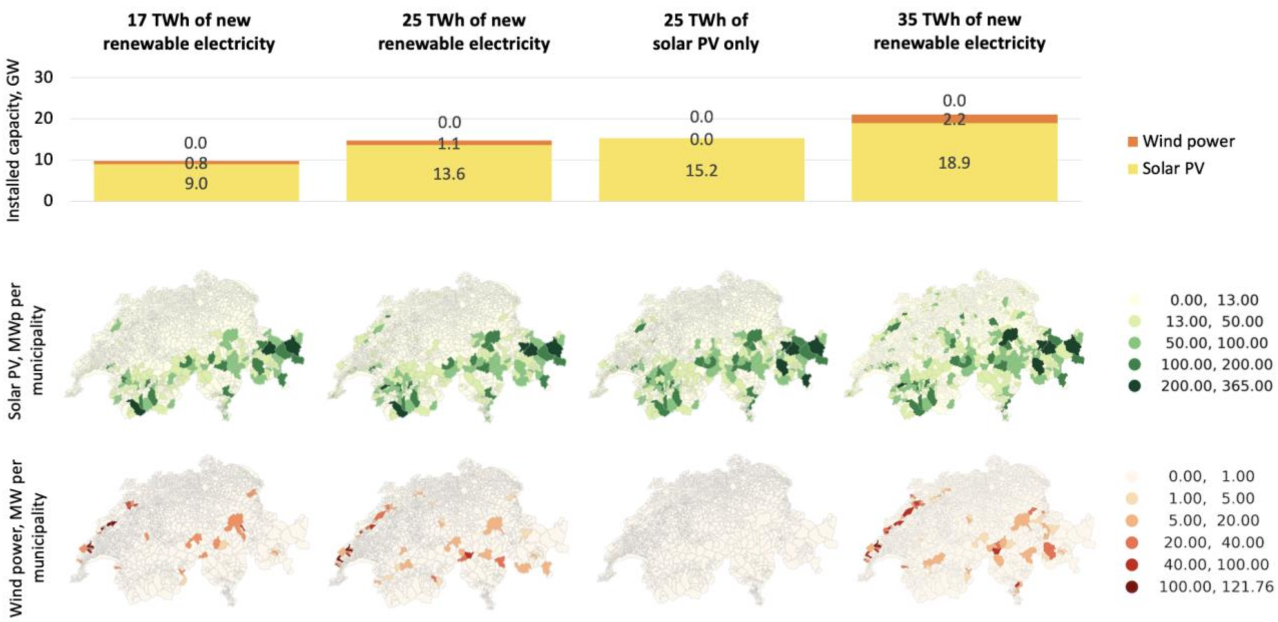

Figure 4: Installed capacities and regional distribution of solar PV and wind power in 2035 for the strategy with the focus on productivity (OREES model).

6 Investment needs and investment risk

New renewable electricity technologies are capital-intensive. Hence, the more ambitious the target is — the higher are the investments needed into additional capacity of new renewable electricity and battery storage. These investment needs reach up to 2.1 billion CHF annually until 2035 among the analyzed targets and strategies (Figure 5). For all three strategies, most investments are required into solar PV projects, accounting for at least 80% of the necessary amount. This is driven by the high installed capacities of solar PV (Sections 3–5).

The strategy with the focus on solar PV with batteries (Section 4) requires the most investment because it relies on rooftop PV in densely populated Midlands, except for the most ambitious target of 35 TWh/year, where PV is also rolled out in sunnier alpine cantons. This strategy additionally requires investment in decentralized batteries. The share of the investment in batteries becomes more substantial only if the 25 TWh/year target is reached by solar PV alone because, in the absence of other generation alternatives, daily storage requirements are the highest. By contrast, the strategy with the focus on productivity (Section 5) requires the lowest levels of annual investment as solar PV and wind power in this strategy are located in technically optimized locations where they achieve higher capacity factors, requiring lower installed capacities and hence lower investment for the same generation output. Potentially higher costs of open-field PV in alpine regions are not accounted for as this strategy does not specify which capacities would need to be constructed on the ground in the Alps rather than integrated on rooftops.

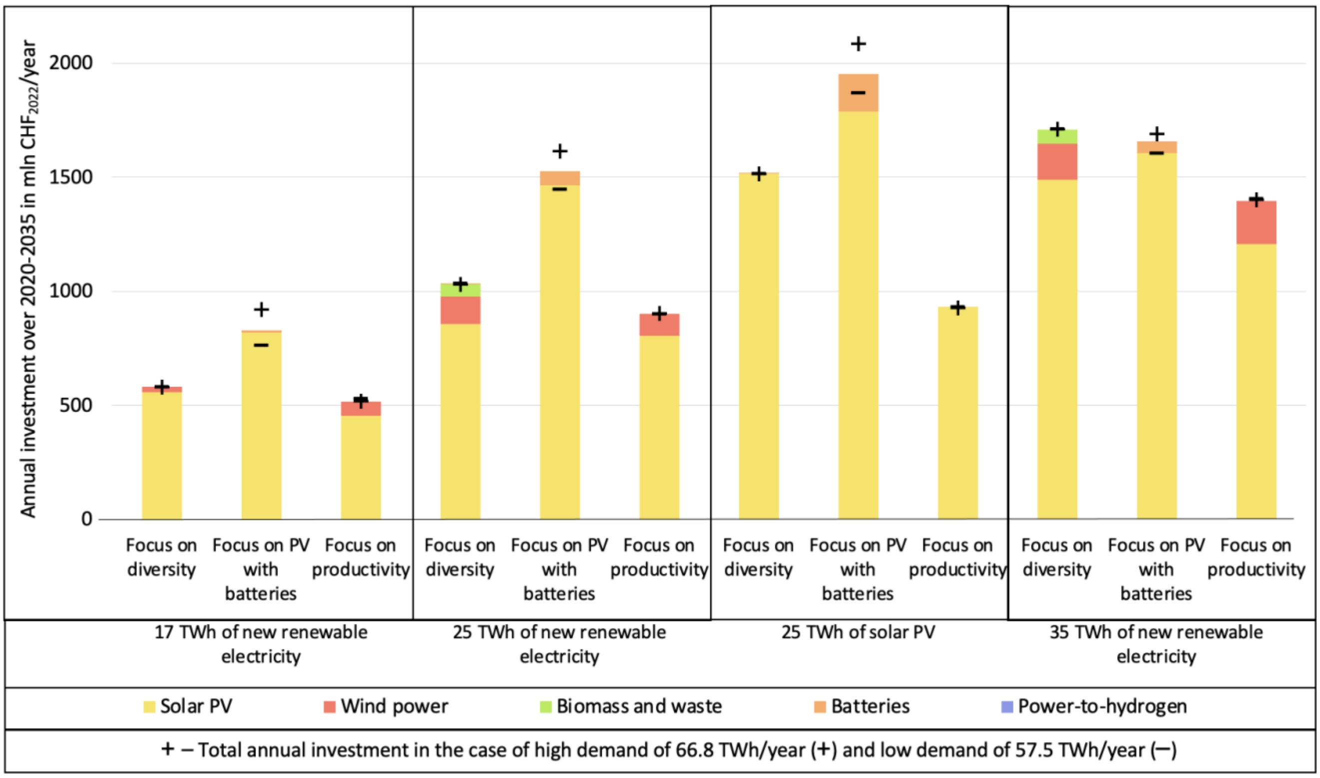

Figure 5: Annual investment needs in 2020–2035 for the three strategies and four targets, including demand sensitivity. The bar plots show investment needs in the case of 61.2 TWh/year final electricity demand.

The investment needs are also most sensitive to the electricity demand assumptions in the case of the strategy with the focus on PV with batteries, as this strategy most heavily adjusts the amount of PV in response to demand (Table 1). The investment needs for the strategy with the focus on productivity are relatively insensitive to the demand assumptions because this strategy replaces some PV plants with wind power when demand gets higher, while the differences in capital costs between these two technologies are not as substantial if adjusted by capacity factors.

In terms of the sources of finance, a scenario that assumes the continuation of current market structures in Switzerland would see 55% of the investment needs stemming from utilities, 27% from household savings and project developers, and 18 % from financial investors, such as asset managers that invest money from pension funds[20]. Financial investors are expected to contribute only at this modest extent partly because they tend to seek larger projects abroad. If the Swiss market develops in the future in the direction of the German market with more large-scale projects, the share of project developers in investments could increase to about 65%[21].

The cost of capital is crucial for the profitability of renewable electricity infrastructure[22]. In particular, the weighted average cost of capital (WACC) reflects investment risk as it shows how much return individual equity or debt

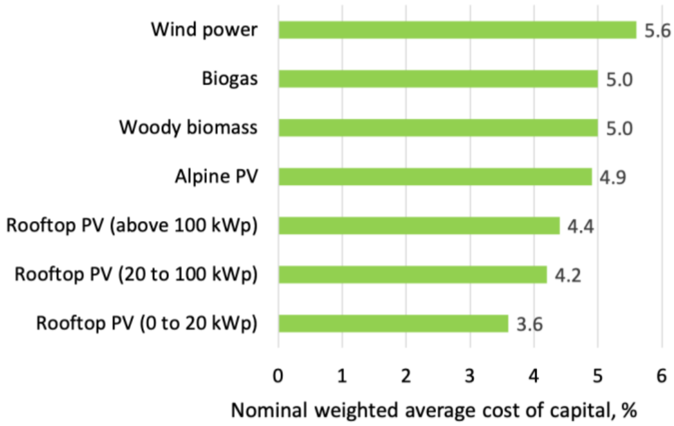

Figure 6: Weighted average cost of capital (WACC) in the first quarter of 2022[20]

investors require to invest in a project (Section 10). Currently, rooftop solar PV has the lowest financial risk in Switzerland, particularly the small rooftop PV category containing projects up to 20 kW_p (Figure 6). Alpine PV, woody biomass and biogas plants are perceived as having medium to high risk by investors, while wind power in Switzerland is the riskiest new renewable technology. The latter finding contrasts with other countries, such as Germany or France, where onshore wind power nowadays is a low-risk technology along with solar PV[23]. In Switzerland, the high weighted average cost of capital for wind power reflects the expected project delays, permitting, and public acceptance challenges. Investors in Switzerland mainly use balance sheet financing and they adjust the project's cost of capital to reflect the risks of project development, not just risks associated with operational projects.

7 Employment implications

The higher is the need to build new renewable electricity plants for reaching the targets — the higher is the associated employment (Figure 7), estimated using methods and definitions from Section 10. Employment here accounts for workplaces in manufacturing (33% of all direct employment), construction and installation (62%), operation and maintenance (4%), as well as renewal of the plants (less than 1%). The estimated levels of annual employment, which could reach as high as 18 to 57 thousand full-time jobs in an average year until 2035 depending on the strategy (Figure 7), are to be interpreted in two ways. On the one hand, this represents occupation and income for tens of thousands of workers, of which around two thirds would be in Switzerland for building or installing, operating, maintaining, and renewing the additional renewable generation capacities needed by 2035. On the other hand, these workers need to be found with the necessary skills to avoid implementation bottlenecks, ideally without taking them from other desirable activities. Some will be freed from activities replaced in the wake of the energy transition.

Like for investment needs in Figure 5, building up solar PV capacities is by far the primary driver of employment estimates in Figure 7. The employment for increasing generation in the wind power, biomass and waste sectors is comparatively low. The current number of employees in the Swiss solar industry is around 10 thousand[24]. Our estimates include jobs in related sectors and only around two thirds of the total estimates in Figure 7 can be assumed to take place domestically in Switzerland. Still, the number of domestic workplaces in new renewable electricity sector needs to increase substantially by 2035, up to three times for the 35 TWh/year target.

The employment needs are sensitive to higher or lower electricity demand only for the strategy with the focus on solar PV with batteries which heavily relies on solar PV (Figure 7). In fact, employment for batteries would additionally need to be added here, but these estimates are not yet available. The employment in the case of strategies with the focus on technological diversity or productivity are relatively robust to changes in demand for two reasons. First, the corresponding installed capacities are adjusted

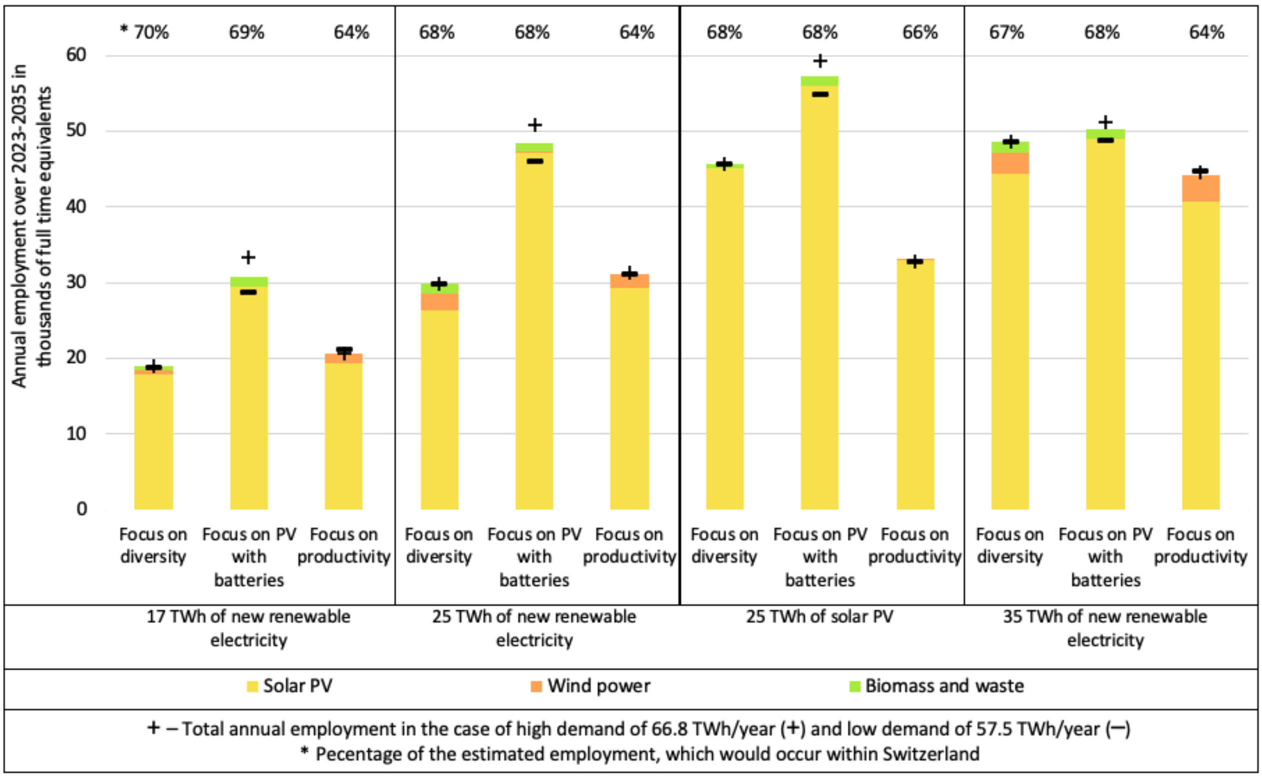

Figure 7: Annual employment in 2023–2035 for manufacturing, construction and installation, operation and maintenance, and renewing of new renewable electricity capacities for the three strategies and four targets, including demand sensitivity. The bar plots show employment in the case of 61.2 TWh/year final electricity demand.

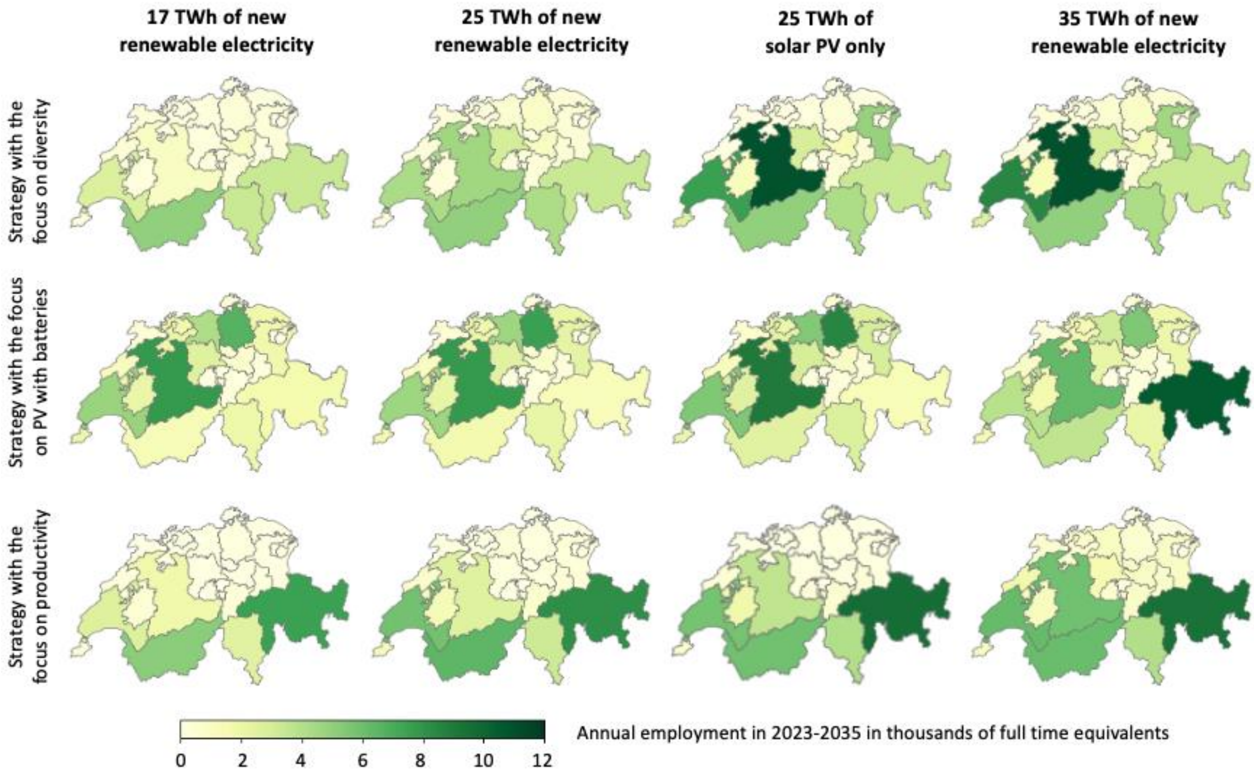

Figure 8: Regional distribution of annual employment in 2023–2035 for the three strategies and four targets.

to a lower extent (Table 1). Second, the employment estimates do not differ substantially among technologies chosen by these strategies.

Employment implications at a cantonal level in Figure 8 largely follow regional patterns in solar PV installations needed (Figures 2 – 4). Overall, the more ambitious is the target — the higher is the total employment for installing the needed capacity and the more evenly it is distributed throughout Switzerland. In the case of strategies with the focus on technological diversity or productivity, southern and southwestern cantons have higher annual employment. The strategy with the focus on productivity, however, especially needs higher employment in the alpine cantons of Graubünden and Wallis. Graubünden also stands out in the case of strategy with the focus on PV with batteries for the 35 TWh/year target where open-field PV is considered. In the case of less ambitious targets, the strategy with the focus on PV with batteries foresees higher employment in the cantons of Bern and Zurich.

8 Policy preferences and technology acceptance

A large-scale population survey in August – October 2022 (Section 10) showed that the Swiss citizens have a strong preference for the country's energy independence as a narrative (Figure 9). On the one hand, this is not that surprising because the survey was conducted in the midst of the energy crisis after the war in Ukraine started. On the other hand, strong preferences for autonomy in general[25] or for energy independence in particular have been a reoccurring pattern in various Swiss studies too[26,27]. Even if the Swiss citizens have such a strong preference for energy independence and associated negative views on electricity import, a relative majority thinks that Switzerland should more strongly collaborate with the European Union in order to secure energy supply. However, less than 20% of the surveyed citizens support the compensation of CO_2 emissions abroad, hence pointing to an overall preference for domestic climate change mitigation.

Results on socio-political acceptance of various electricity generation technologies (Figure 9) show strong support for all renewable technologies, especially for solar PV on buildings and large hydropower plants with almost no opposition, but also, albeit to a lesser extent, for biomass, geothermal, wind power, small hydropower, and open-field solar PV. While these findings are not substantially different from a comparable survey in 2016[28], in the context of the energy crisis the previous patterns have been reinforced in 2022.

Electricity imports are extremely unpopular in terms of general socio-political acceptance (Figure 9), even if the modeling in this Outlook reveals the importance of European interconnection for balancing. The citizen views towards import are even slightly more negative in 2022 than in 2016[28], but such a low level of acceptance overall is not a new finding in Swiss surveys[27,29]. The Swiss citizens also show comparatively negative opinion of natural gas, although there was no worsening of the opinion in the context of the energy crisis as compared to 2016[28]. As for nuclear power, a usual divide between acceptance and opposition has been observed. However, it is still notable that in the energy crisis of 2022, the share of citizens who were against or rather against nuclear power as an element of the future Swiss energy mix has decreased from 70% in 2016[28] to 37%.

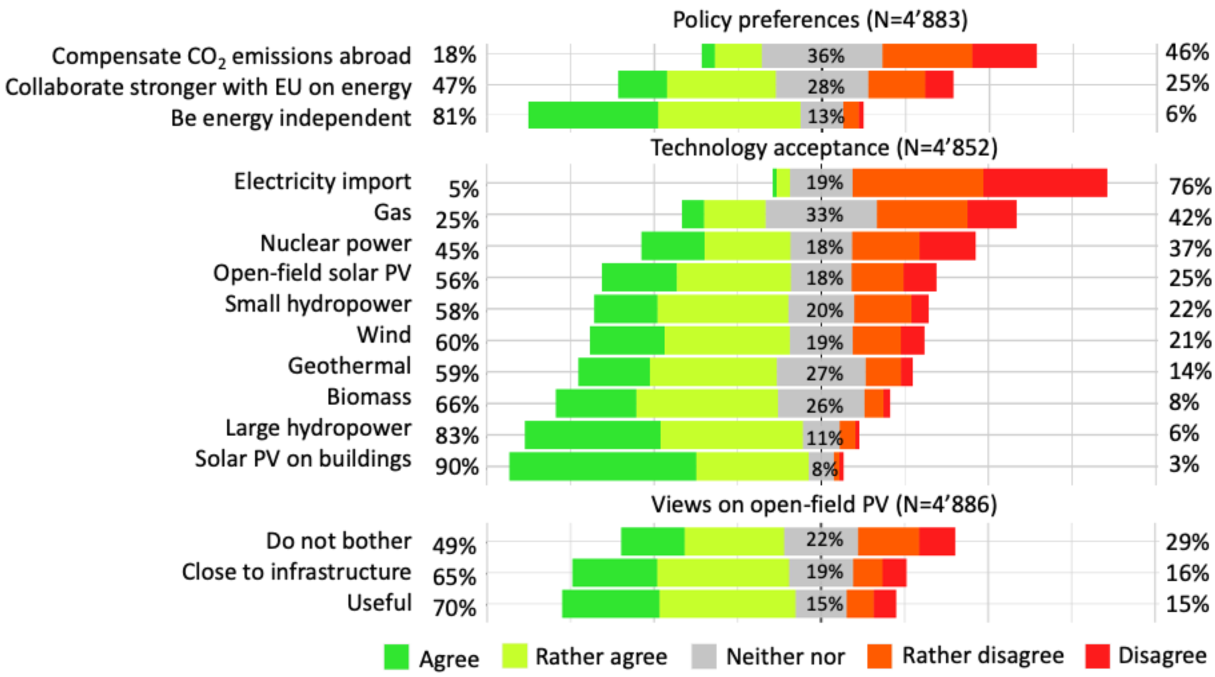

Figure 9: Policy preferences, technology acceptance, and more detailed views on open-field PV from a Swiss population survey in 2022. Percentage values on the left/right side show the percentage of surveyed citizens in favor/against (e.g. citizens in favor include those who responded that they agree or rather agree). Values in the center show the percentage of respondents that neither agree nor disagree.

Open-field PV, which recently became considered as an option in Switzerland and is included in the strategies with the focus on PV with batteries and with the focus on productivity (Sections 4 and 5), is not as strongly accepted as PV on buildings (Figure 9). In fact, open-field PV was the least favored renewable electricity technology in the survey, resembling the overall socio-political acceptance pattern in between small hydropower and nuclear power, rather than small-scale PV on buildings. The surveyed citizens in urban areas preferred to have open-space PV slightly more frequently than citizens from Midlands or alpine areas.

A more in-depth investigation into open-field PV showed that a clear majority of the Swiss citizens thinks that open-field PV is a useful technology to complement others (Figure 9). However, this acceptance level is conditional to more specific questions. A bit less than half of the respondents (rather) agree that open-field PV projects do not bother them at all, while almost a third (rather) disagree. Open-field PV plants are more acceptable if they are placed near existing infrastructure. The survey results, however, do not provide clear indication what size of open-field PV would be more acceptable.

9 Conclusions and policy implication

This SWEET EDGE Renewable Energy Outlook evaluated four alternative Swiss targets in 2035, namely 17 TWh/year, 25 TWh/year, 35 TWh/year for new renewable electricity, as well as an additional target of 25 TWh/year for solar PV only. The analysis covered the technical, regional, finance, employment and public acceptance dimensions. The main conclusions for policy are summarized here.

Results from three electricity system models show that all four targets are technically feasible without domestic nuclear power and without major fossil fuel plants in Switzerland. The most ambitious 35 TWh/year target enables Switzerland to reach nearly or fully renewable electricity supply on annual basis in 2035. The feasibility here accounts for hourly electricity supply-demand balancing, transmission, storage, and electricity exchange with neighboring countries. The higher is the new renewable electricity target — the lower is the net annual and net winter import. As the socio-political acceptance data from the EDGE survey shows, the Swiss population has clearly negative views of electricity import and a strong wish for energy independence, hence indicating of a social mandate for the ambitious targets, like 35 TWh/year.

Solar PV is the primary technology that needs to provide up to 25–31 TWh/year for the most ambitious 35 TWh/year target, hence massively driving the investment needs and employment impacts. The three electricity system models find various PV configurations possible to reach the targets: PV on rooftops and facades only, PV on rooftops combined with batteries for self-consumption, or also open-field PV on unbuilt land, especially in the alpine regions. Solar PV on buildings has very high socio-political acceptance and low investment risk, indicating of an easier implementation. Open-field solar PV is riskier as its current public acceptance pattern is similar to that of small hydropower and nuclear power. The investment risk of alpine PV is medium to high, comparable to woody biomass and biogas plants. In terms of a large increase in employment associated with the necessary PV installations for reaching the four targets, it has to be ensured that the skilled workforce is available on time to avoid implementation bottlenecks.

In terms of the rest of the technology mix, there is flexibility which technologies are used and where they are located, but in the case of all targets, solar PV alone is neither sufficient nor optimal. Hence, rooftop PV needs to be complemented with other new renewable technologies, even if these technologies do not have as high socio-political acceptance as rooftop PV: wind power, open-field PV, biomass and waste, or a combination of these. There is flexibility which of these technologies are chosen and how much, but they cannot be avoided altogether. The Outlook then describes three potential strategies: the strategy with the focus on technological diversity that distributes various technologies more evenly throughout Switzerland, the strategy with the focus on solar PV with batteries that also relies on waste and import, and the strategy with the focus on productivity that concentrates wind power and solar PV on rooftops or on the ground in open, unbuilt fields in most productive regions, including the Alps. If none of these technologies are developed to complement rooftop PV, then the missing gap needs to be filled by net electricity import, which is very unpopular among the Swiss population.

Electricity import and export yet remain key as a tool to ensure system flexibility for balancing and to adapt to uncertainty in annual electricity demand. The three electricity system models show that electricity import and export are the primary variables that respond to higher or lower electricity demand in the case of different assumptions about the uptake of heat pumps and electric vehicles. Even if growth in new renewable electricity due to higher targets is the answer to decreasing net reliance on import on annual basis, the ability to import and export electricity is key to integrating these higher shares of new renewable electricity into the Swiss system. If lower demand can be achieved through efficiency measures and saving, the reliance on net import is lower.

The more ambitious the new renewable electricity target is — the higher levels of investment need to be mobilized and the higher effects on employment are in the sector of new renewable electricity. In the case of 35 TWh/year target, the investment of 1.4–1.7 billion CHF per year is required, mainly into solar PV, along with up to additional 50 million CHF in battery storage. Investment in rooftop solar PV currently poses the smallest investment risk, while alpine PV, biogas and woody biomass projects have medium to high risk. Wind power projects in Switzerland carry the highest investment risk among the technologies analyzed because of the complex and lengthy permitting and project development process. In terms of employment in manufacturing, building or installing, operating, maintaining and renewing new renewable electricity plants, high estimates show that the equivalent of 44–50 thousand full-time workers per year are needed until 2035 for the 35 TWh/year target, mostly for the solar PV capacity. Around two thirds of these jobs would occur locally in Switzerland. This is a substantial increase from the workforce in new renewable electricity sector in Switzerland today. These estimates do not yet include jobs created or lost indirectly in other sectors.

In sum, this Outlook overall shows that more ambitious new renewable electricity targets for Switzerland, such as the 35 TWh/year target from the latest decision of the Parliament, are feasible and beneficial. The Outlook also points to several open issues that need further investigation. First, the success of any target will depend on the available policy instruments to reach this target. Evaluation of the impact of existing and new policy instruments and policy mixes should thus be done. Second, the Outlook points to the importance of electricity trade with neighboring countries even in the case of most ambitious targets for new renewable electricity. A deeper analysis of the potential implications of any electricity import constraints is warranted, such as in the case of a lacking agreement with the European Union on energy supply. Third, this Outlook focused only on the immediate actions and targets until 2035, but future analysis should also adopt the long-term view to 2050. Finally, the population survey results present only a snapshot of public opinion in autumn of 2022. Even if some of these acceptance patterns have existed for years, monitoring of the evolution of acceptance is useful in order consider public views along the more technical analysis of the transition. Future work could further explore local community acceptance in addition to the general socio-political acceptance covered here.

10 Methods in brief

The quantification of the Swiss electricity supply scenarios in 2035 was conducted as a model inter-comparison and complete results are presented by Heinisch and colleagues[15]. Three existing structurally different models were run with harmonized input assumptions, such as the renewable electricity targets and electricity demands. For the rest, model inter-comparison methodology considers that all models with their own structural and parametric assumptions present valuable, internally-consistent storylines of how the Swiss electricity supply could be transformed. Complete documentation of model structure and assumptions are available in respective peer-reviewed publications. The three strategies are hence represented separately as options for choice in Sections 3–5. Overarching consensus, regardless of the model and its set up, is highlighted as robust conclusions in Section 2.

In terms of the strategy with the focus on technological diversity, EXPANSE[5,30-32] is a single-year electricity system model with a spatial resolution of 2'148 Swiss municipalities and with temporal resolution of six hours (the time resolution is optimized for model's accuracy, municipality-level spatial detail, and computation time using hourly data). EXPANSE includes all key electricity generation technologies in Switzerland, transmission and its expansion, import and export, as well as various electricity storage technologies (pumped hydropower, batteries, and power-to-hydrogen). EXPANSE minimizes total system-wide costs, looking for the overall cheapest system configuration for 2035.

In terms of the strategy with the focus on PV with batteries, Nexus-e[33-35] is an electricity system model for 2020–2050 with cantonal spatial resolution and hourly temporal resolution. Nexus-e combines decentralized decision making at a building level on solar PV and batteries with top-down system-wide optimization of centralized electricity generation, transmission, storage, and import and export. Nexus-e simulates PV adoption decisions based on profitability and future assumptions on feed-in tariffs and electricity prices, while the centralized elements are optimized to have the lowest total system costs throughout 2020 – 2050. For the target of 35 TWh/year, Nexus-e also allows building open-field PV.

In terms of the strategy with the focus on productivity, OREES[4,36,37] is a single-year electricity system model with the spatial resolution of 1.6 x 2.3 km for solar PV and 1.1 km for wind power and with an hourly temporal resolution. OREES uses an evolution strategy to find PV and wind power locations that maximize revenue from these technologies in 2035 and then quantifies the hydropower generation, pumped storage, transmission, import and export accordingly.

Investment needs were calculated for each strategy and each target by multiplying the required new installed capacity for new renewable plants, batteries, and power-to-hydrogen from 2020 to 2035 with assumed capital costs. The specific capital costs per technology were based on the average values used in the underlying models, reflecting future rather than current costs. The average of the end-of-year currency conversion rate in 2018–2022 was used. To estimate annual investment needs, it was assumed that installed capacity will grow linearly between 2020 and 2035. To estimate investment risk, the weighted average cost of capital was derived empirically from 33 structured interviews with investors at the beginning of 2022, before the beginning of the war in Ukraine[20].

Employment estimates in new renewable electricity sector were calculated by applying employment factors[38] per unit of required installed capacity for manufacturing, construction and installation, operation and maintenance, and renewal of the plants. All these components, except for manufacturing, are considered as local employment effects that would occur domestically in Switzerland. These would constitute direct employment effect, whereas manufacturing employment could be considered as a part of indirect employment. Employment estimates for batteries and power-to-hydrogen were not included due to lack of reliable and methodologically consistent data.

Employment implications due to grid extension, policies, or phase out of existing plants are not accounted for and are a subject of future research.

For the analysis of policy preferences and technology acceptance, results from a population survey (N=4'909) in August – October 2022 are used. The survey was distributed by postal mail to a location-quota stratified random sample of 13'500 Swiss residents, achieving 37% response rate. The comparison with the official population data demonstrated that the sample closely fits the Swiss population regarding age, gender, and education, but it is slightly skewed towards higher income groups. The survey[39] included questions on general climate and environmental attitudes, environmental behavior patterns, policy goals and preferences, conjoint choice experiment, solar PV adoption, open-field solar PV, personal political attitudes, and socio-demographics. Only a selection of results relevant to the Outlook are reported here. The technology acceptance results refer to socio-political acceptance[40,41], which is a rather general stance on technology options and should not be interpreted as local community acceptance for specific projects.

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SWEET EDGE

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