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# White paper in a greening world

## *A journey through struggles over substitutes for chlorine bleaching*

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For the pulp and paper industry, the end of the twentieth century was marked by major upheavals in production conditions. This is particularly true of new production constraints resulting from emerging health and environmental concerns, which led, beginning in the 1980s, to the withdrawal of chlorine from the chemical sequences that had been used to bleach kraft pulp since the 1940s (Rosenberg et al., 1990; Collins, 1998). The challenge of finding a substitute entailed finding a way to respond to new effluent quality objectives while still being able to meet market product quality standards set by chlorine in terms of whiteness and fibre strength. Over the 1990s, elemental chlorine-free (ECF) bleaching, a set of techniques first developed in Sweden, became the preferred alternative process, coming to dominate the pulp market. However, ECF was not the only replacement option. So-called totally chlorine-free (TCF) bleaching, also developed in Sweden and championed worldwide by Greenpeace and other environmental groups, promised a cleaner pathway towards a global chlorine phase-out. But TCF pulp never became anything more than a relatively major, but nevertheless niche green product, produced and commercialised mainly in Europe. While they have not disappeared, TCF solutions have coexisted with ECF techniques and old elementary chlorine processes in a restricted 'technological pluralism' (Hermitte, 2008). The resulting configuration cannot be understood without considering the transnational controversy over the respective (dis)advantages of the two substitution techniques that marked the innovation dynamic surrounding the removal of chlorine from the main pulp and paper production chains, in northern Europe, North America, and beyond.

In this chapter, I revisit the trajectory of this innovation through withdrawal (Goulet and Vinck, 2012) at the level of production processes in the main pulp producing countries focusing on the conflict between alternative substitution options (ECF and TCF techniques) and

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its role in the reconfiguration of the global market *agencement* (Callon, 2021) between 1980 and 2000. To do so, I draw on a wide range of first-hand documentary sources of various kinds, including the core industry journals, technical documents, grey literature, and domain-specific scientific literature, and on an exhaustive review of the secondary literature (Baya-Laffite, 2015a). The development and adoption of ECF and TCF technologies has led to many accounts. These either focus on national case studies or on country comparisons, and engage in divergent causal reductions, pointing alternatively at either consumer or community pressures, or at regulatory or industry trajectories and initiatives separate from those pressures, as playing the ultimately determinant role in innovation. Most studies, however, recognise the interplay of multiple factors, including path dependency, geography, regulatory styles, market configurations, political cultures, cultures of expertise, and corporate R&D cultures, among others. In light of this interplay, I follow a series of struggles in different arenas where ECF and TCF came to be associated with larger, persistent socio-political antagonisms about environmental protection and precaution, in order to better characterize the resulting restricted technological pluralism and its effects.

The chapter proceeds like a journey, following the trajectory of chlorine's withdrawal, its substitutes and struggles over them. The journey begins in northern Europe. Section 1 focuses on Sweden, where ECF and TCF techniques were first developed and adopted in response to the conclusions of new research on the toxic effects of the chlorinated effluents of pulp mills and to new regulatory measures informed by those conclusions. Section 2 then follows how Finland reacted to the Swedish approach to the problem with pulp mill effluents in the Baltic Sea, as Greenpeace strove to sensitise consumers. Crossing the ocean to follow the ECF vs TCF debate in North America, section 3 focuses on the reactions to the US Environmental Protection Agency's own findings on dioxin pollution from pulp mill effluents, while Canada framed and dealt with the problem based on new research challenging the Swedish understanding of the problem. Section 4 considers the US pulp and chemical industries' efforts to avert a forced, radical withdrawal, and their challenges to arguments for establishing TCF as a new standard. The last section concludes the journey by explaining how, despite a certain stabilisation attained in the main producer

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countries' markets and regulations, conflicts remain open in the new global market *agencement.*

## 1. Dioxin, AOX, and the alternatives for chlorine withdrawal in Sweden

In Nordic countries, the problem with chlorine-bleached kraft pulp mills had its roots in the results of a study conducted by Swedish scientists and the conclusions drawn on the basis of it by Swedish authorities. In a political context that was sensitive to environmental and health concerns, the authorities took a precautionary approach, imposing strict limits on pulp mills' organochlorine compound discharges beginning in 1986. ECF and TCF bleaching techniques emerged as two responses to these regulatory measures.

### The AOX Correlation: Precautionary Responses to New Associations

Although the accumulation of toxic biochemicals in the aquatic environment of bleached kraft pulp mills was a known phenomenon, scientific knowledge about the composition and toxicity of these effluents was limited. In 1982, the Environment/Cellulose project, funded by Swedish Environmental Agency and directed by biologist Anders Södergren, set out to change this situation by examining the physiological responses of fish exposed to organochlorine compounds, including dioxins and furans, but also other molecules, from pulp mill effluents on the marine environment.

Between 1984 and 1986, the project collected data from the site of a bleached pulp mill on the Gulf of Bothnia and from an unbleached pulp mill chosen as a control site. The results (Södergren et al., 1988) showed a correlation between a series of adverse effects on fish, including alterations in growth, metabolism, maturation, mortality and community structure, and the presence of organochlorine compounds in effluents from the chlorine bleached pulp mill plant and in sediments near the plant. Despite critiques of the research design and the consistency of the study's conclusions from Canadian and Finnish scientists, the Swedish researchers concluded that the findings provided a credible warning of the dangers of organochlorine compounds. Considering the uncertainties about the toxic potential of organochlorines and the possibility of irreversible damage, they called

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on the authorities to adopt a precautionary approach to regulating them. Beginning in 1986, the study's preliminary findings, containing images of deformed fish, were presented in a series of public meetings organised by the Swedish Environmental Agency, and disseminated by Greenpeace, giving the matter a strong political impetus in the following electoral campaigns (Rajotte, 2000). As a result, the release of chlorinated compounds from bleaching plants, including dioxins and furans, emerged as an environmental and health problem that needed to be addressed at the source.

By the late 1980s, the Swedish government set mid- and long-term environmental quality objectives and introduced progressively stricter limits for organochlorine compounds in discharges in the permits for its mills. The limits were set in a regulatory parameter named since the early 1990's AOX, for adsorbable organically bound halogens, measuring the concentration of halogens, including dioxins and furans, that can be adsorbed from water onto activated carbon. Most AOX molecules contain chlorine. To meet AOX emission limits, the focus was placed on preventing pollution through process-integrated measures, rather than end-of-pipe treatments, in keeping with the Swedish regulatory approach. No specific technology was required. Emission limits based on 'best available techniques' (BAT) standards were used to encourage innovation, allowing the new environmental quality objectives to be attained on a schedule. As BAT-based permit conditions could vary from plant to plant depending on the circumstances, each mill licensing process allowed conditions and measures to be negotiated between the Environmental Agency, industry, environmental groups and other interested parties (OECD, 1999a, b).

## ECF and TCF: Incremental and Breakthrough Innovations Through Withdrawal

Despite disagreements on the scientific basis for the new regulatory measures, Swedish industry worked with the authorities and its technology providers on the development of solutions. Two alternative techniques emerged during the 1980s. Their common structural feature was the non-use of elemental chlorine as the main bleaching agent in the chemical sequences used to bleach the pulp. But they differed in many other respects.

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Alternative 'elemental chlorine free' (ECF) bleaching sequences, which use chlorine dioxide as the main bleaching agent, emerged as an incremental innovation resulting from the combination of a series of pre-bleaching techniques already in use in Swedish mills. This innovation was the fruit of a well-established research and development culture. With the use of extended cooking and/or oxygen delignification prior to bleaching, chlorine could be replaced with chlorine dioxide, a chemical that was already part of the bleaching sequence. This new process produced a pulp that met the prevailing quality standard without requiring a major overhaul of production processes, know-how, and equipment. Depending on the combination and quality of the chemicals used, this allowed a near-total elimination of dioxins from the effluent, and considerable reductions in organochlorines. As the environmental results associated with these ECF pulps were seen as satisfactory, while the associated product remained competitive and of good quality in terms of prevalent pulp whiteness and resistance standards, its adoption was quick and generalised. However, ECF sequences were not able to meet stringent AOX limits; this would require more radical changes.

Totally chlorine free (TCF) bleaching techniques emerged as the result of experiments between the authorities and industry in Sweden. It all began at the Swedish pulp mill Aspa Bruk (O'Brian, 1996). To meet the ambitious targets set by the authorities when renewing its permit in 1986, Aspa Bruk sought to withdraw both chlorine and chlorine dioxide from the bleaching sequence and replace them with peroxide, oxygen, and ozone. Collaboration with multiple actors was needed to develop suitable chemicals, equipment, engineering, and other relevant knowledge. Success came in 1989, and in the following years the technique was adopted by some important Swedish producers, like Södra. But TCF's adoption was poor in comparison to that of ECF. Switching to TCF was costly, as it required major modifications not only to the pulp mills themselves, but also to the entire production chain. And importantly, TCF fibres were not only weaker, but also less bright – an aspect that led to some reluctance among consumers.

Swedish firms' pioneering role in the development of both incremental and radical alternatives for the withdrawal of chlorine drew on a longstanding industry-wide system of R&D collaboration for innovation at the process level. This system dated back to the early twentieth century but gained momentum with the introduction of

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effluent limits for AOX in the late 1980s. As we will see, Sweden's tradition of process-level innovation stood in sharp contrast to Finland, where the historical focus was on end-of-pipe technologies, designed in response to regulatory parameters other than AOX (Bergquist & Söderholm, 2018).

## 2. Finnish Responses to Internationalised Norms and Sensitised Markets

The innovations introduced by Swedish companies to tackle the organochlorine problem required large investments. As Sweden sought to export its industry's solutions, pushing for the integration of AOX standards into the Helsinki Convention, a controversy arose between the country and Finland, which was resistant to Sweden's approach. As experts and diplomats were mobilised to settle the issue, new market incentives emerged for some Finnish mills to adopt TCF bleaching techniques, as Greenpeace's campaigns in northern Europe bore fruit.

### Finnish Resistance to Swedish AOX Measures and Process Solutions

In 1984, Sweden and Finland began to discuss the problem of organochlorine pollutants in the Gulf of Bothnia within the Helsinki Commission for Baltic Sea Protection, or HELCOM. HELCOM is the governing body of the 1974 Convention on the Protection of the Marine Environment of the Baltic Sea Area (or Helsinki Convention), an instrument whose measures cover all sources of pollution inside the territory of its Contracting Parties. In 1988, the discussions turned into a diplomatic conflict, as Sweden recommended new discharge limits for AOX and suggested oxygen delignification – a Swedish process technology – for all HELCOM countries. The Finnish position was that it had not been proven that all organochlorines were responsible for effluent toxicity, and that compliance with a severe AOX restriction requiring pre-bleaching process measures could result in excessive costs that would imperil its industry (Auer, 1996). The conflict led to mediation by the Nordic Council of Ministers and the establishment of an expert group, which commissioned a study by the Finnish engineering firm Jaakko Pöyry. The study ended the debate, finding that only 5% of organochlorines in pulp mill discharges were of a hazardous type – and not 20% as claimed by Sweden. This weakened the argument

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for oxygen delignification as a necessary step to reduce effluent toxicity at the process level in favour of including solutions based on end-of-pipe control in the HELCOM recommendations, in keeping with the Finnish regulatory focus (Auer, 2010). In 1989 the Commission recommended a first set of modest AOX reduction targets, which made more stringent in 1992 and again in 1996. Finland introduced new AOX regulations that could be attained through combinations of (new) process and (available) end-of-the pipe measures.

In this context, the withdrawal of chlorine bleaching techniques in Finland over the 1990s was somewhat slower than in Sweden, but not less effective. Though reluctant at first, pulp producers in Finland ended up responding to the new AOX targets integrated into Finland's own case-by-case permit system – which were as strict as Sweden's (OECD, 1999a,b). Conversion investments were largely financed by the forest industry associations, which were often co-owners of the pulp and paper companies. Most Finnish mills turned to ECF bleaching sequences in combination with external effluent treatment technologies, such as secondary treatment or optimised activated sludge treatment. However, despite the official Finnish position that TCF techniques were not environmentally necessary, some Finnish mills invested in them nonetheless. This choice was driven by a combination of regulatory constraints, social demands, and emerging market trends. At the local level, reporting on the AOX pollution debates in the Finnish media led some local communities to mobilise during the public hearings for the renewal of the mills' licenses, pressing for stricter AOX measures involving TCF bleaching. At the market level, some large industrial consumers began demanding TCF products, following Greenpeace's plea for a total chlorine phase-out. Investing in TCF enabled some Finnish producers to compete in the new TCF markets, with no need to believe that this was a necessary measure to protect the environment.

## Greenpeace, Ikea, and the making of a TCF market for Nordic pulp

When Sweden's Aspa Bruk started producing the new TCF pulps in 1989, Greenpeace saw an opportunity to present and defend an alternative of total chlorine phase-out. A 'win-win' alliance was gradually formed between some Nordic producers willing to invest in TCF and Greenpeace (O'Brian, 1996). The challenge remained to enrol

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the main industrial consumers of Nordic paper products, namely German publishers, who considered TCF paper to be neither strong enough nor white enough. In 1991, to prove them wrong, Greenpeace printed a fake *Der Spiegel*, which they called '*Das Plagiat'*, using TCF pulp from the Aspa mill. Thousands of copies were sent to key policy and industry players in northern Europe and Scandinavia. A cover letter made the point: as *Das Plagiat* proved, TCF paper from Aspa Bruk was as strong and printable as the original (albeit less bright), while having a lower environmental impact. The action was a success, and *Spiegel* and some other publishers announced a switch to TCF pulps. As a small TCF market emerged, a few Finnish pulp mills followed the emerging trend (Smith & Rajotte, 2001). In 1991, Metsä-Botnia's Kaskinen pulp mill in Finland launched new TCF pulps in the aim of responding to emerging demand. The Swedish furniture producer Ikea wanted to make its hundreds of millions of annual catalogues greener by using recycled fibres and 100% TCF paper. Although they did not share Ikea's view that TCF was necessary, Metsä-Botnia accepted the challenge. This implied major investments to achieve maximum brightness and comparable strength to ECF pulps. This was achieved by introducing enzymes into the chemical sequence – an innovation resulting from a close collaboration among multiple private and public partners (Håkansson and Waluszewski, 2002).

With AOX regulations in place, the emergence of a TCF market was facilitated by Greenpeace's campaign actions, which contributed to framing the public problem for a public that was already sensitised to environmental hazards (Reinstaller, 2005). Drawing on the Swedish findings on risks associated to chlorine use in pulp and paper products, Greenpeace championed TCF as the answer to the problem, thus linking Swedish TCF innovations to sensitised social and market demands, locally in some mill communities and internationally in export markets like Germany. In this context, some European industrial pulp consumers started marketing TCF paper products as 'premium' to their customers. New product labelling schemes allowed consumers to distinguish products based on manufacturing processes, providing information on bleaching and on chlorine content in paper products – setting standards that could be met either with ECF or TCF bleaching techniques. While ECF was the dominant choice, some Nordic pulp producers like the Swedish giant Södra and the Finnish Metsä-Botnia followed the trend of switching to TCF pulps and launching marketing

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strategies focused on environmental concerns, which had thus become a major competitive factor.

In sum, by the late 1990s the Swedish and Finnish industries had replaced all elemental chlorine bleaching facilities to meet their respective AOX discharge limits. Most turned to ECF sequences in combination with other either process (in Sweden) or end-of-pipe (in Finland) measures. Some producers operating in vulnerable locations had no choice but to adopt TCF to meet their AOX limits. But other producers chose TCF as a move to respond to emerging demands from sensitised pulp consumers and mill communities. Thus, during the transition phase, the question of whether conversion would be to ECF or to TCF was somewhat open, leading to competition between the two alternatives in a context of relative uncertainty concerning risk, environmental policy, and market opportunities. As the Nordic mills made their choice, on the other side of the Atlantic the conflict between ECF and TCF was evolving at a slower pace.

## 3. ECF vs TCF in North America: Struggles Over the Framing of the Problem

Across the Atlantic, chlorine withdrawal emerged as a public issue in 1987, when the US Environmental Protection Agency (EPA) announced that a new study had found bleached kraft pulp mills to be a previously unacknowledged dioxin pollution source, which now had to be dealt with. Attention turned to the possibility that dioxine traces in paper products themselves might be directly hazardous to consumers. As Greenpeace sought to enlarge the problem to all organochlorines, invoking the Swedish conclusions, new Canadian research limited the problem to dioxins – an issue that the country's pulp and paper industry addressed without federal AOX regulations.

### From Dioxins to All AOX: A Struggle over Scope

The US National Dioxin Study was mandated by the US Congress in 1983 to track down the sources of dioxin pollution, following the discovery of dioxin contamination in several states. In 1985, the results reframed the problem, as fish samples showing high levels of dioxins were collected from a set of unexpected sites. Upstream of these sites were not pesticide plants or waste disposal sites, but bleached kraft pulp

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mills. Dioxins appeared to be present in sewage sludge and effluent, later confirming that dioxin was a by-product of bleaching processes using chlorine. Faced with the prospect of a major public crisis about dioxin-contaminated paper products, the pulp and paper and chemical industries, represented by trade associations, acted to counter the threat. A confidential agreement for a joint industry-EPA study of dioxin pollution at five chlorine-bleached kraft mills was drawn up by the American Paper Institute (API). Under its terms, the EPA agreed to submit the study data for review by industry scientists, to ensure that the data would be treated confidentially, as a trade secret, and that the API would be able to contribute to the final report, including a different opinion on the data, if necessary. Anticipating the EPA's release of the results, the API had established a 'Dioxin Public Affairs Plan' aimed at keeping allegations of health risks out of the public arena, avoiding confrontation with government agencies, and achieving an 'appropriate' regulatory climate. The plan included an extensive public relations campaign targeting workers, individual consumers, industrial customers, and local communities, as well as urging the EPA to prepare its own communications strategy, with an emphasis on the need for balance and restraint in the presentation of findings (von Stackelberg, 1989).

These efforts were undermined when, in August 1987, a month before the EPA's official announcement of the pulp mill dioxin study results, Greenpeace released the report *No Margin for Security: A Preliminary Report on Dioxin Pollution and the Need for Emergency Action in the Pulp and Paper Industry* via its regional office in Toronto (van Strum & Merrell, 1987). Investigating the EPA's delays in banning 2,4,5-T (Agent Orange) and addressing dioxin contamination, the authors had accessed EPA documents detailing the emerging results, as well as the confidential agreement with the API to conduct the joint pulp mill study. By unveiling these documents, Greenpeace made public not only the problems linking the paper industry to dioxin, but also the industry's efforts to cover up the results and delay any urgent and necessary action. Arguing that there are no safe levels of dioxin, the authors warned that the discovery of this link required immediate action. When the EPA officially announced its findings, the *New York Times* presented the case linking dioxins and pulp mills to the public, drawing on the Greenpeace report and highlighting possible dioxin contamination of paper products (Shabecoff, 1987). Shortly afterwards,

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based on a new set of confidential documents released by Greenpeace, the *Washington Post* published a report on the paper industry's campaign to defuse the dioxin contamination issue (Weisskopf, 1987). The association between the paper industry and dioxin was now a public issue.

With the dioxin link established, Greenpeace strove to impose a more comprehensive framing of the issue. In Greenpeace's vision, supported by the Swedish findings, the problem was not limited to dioxin, but concerned the whole range of organochlorines discharged by bleached kraft mills – most of which remained understudied despite their high potential toxicity, low biodegradation, and tendency to bioaccumulate. This required not piecemeal regulation, but an overhaul of regulation on the sector, moving toward a total elimination of chlorine and chlorinated chemicals. They rejected the designation 'elemental chlorine-free' as a euphemism because ECF processes still produce organochlorines and dioxins, albeit at lower levels. They thus took the position that conversion to ECF was not sufficiently protective, and argued for the total elimination of organochlorines through the Swedish industry's new TCF bleaching process as a safer path. This was the plea made in 1988 to the House Subcommittee on Water Resources by Renate Kroesa, the international pulp and paper director for Greenpeace. By engaging in a much broader struggle, Greenpeace raised the economic stakes even higher for the industry.

## Canadian Challenges to the Focus on AOX Regulation

In Canada, as Greenpeace promoted regulatory measures based on TCF bleaching, a scientific controversy came to undermine this framing: new Canadian research challenged the correlation between AOX concentrations and adverse environmental effects found by the Swedish Environment/Cellulose project. Greenpeace put chlorine bleaching on the agenda in Canada in 1987 as it disseminated the US and Swedish findings, along with information about the detection of dioxins around Canadian pulp mills and a leak of a federal government study that revealed that most mills were not in compliance even with existing federal regulations. In this context, Canada announced new regulations, well before the US, and launched an assessment process involving the federal government, provincial governments and the pulp and paper industry. While the assessment confirmed the high toxicity of dioxin

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and bleached kraft mill effluents, it also concluded that focus on AOX failed to distinguish the degree of toxicity of different organochlorine compounds. As a result, regulatory measures to reduce dioxin to undetectable levels were recommended, but no AOX limits were to be set for effluents (Harrison, 2002).

This was in keeping with new research from Environment Canada, the federal environmental protection agency, which severely questioned the Swedish approach to organochlorines. The debate between Swedish and Canadian scientists evolved over the late 1980s, reaching its peak in 1991 at the first edition of the conference 'Environmental Fate and Effects of Bleached Pulp Mill Effluent', which would become the main forum for the associated community of experts. At the conference, Canadian scientists presented comparative studies on mills that did or did not use chlorine bleaching, showing similar toxicological effects in both cases. This suggested that focusing on AOX as a regulatory parameter was wrong, because reducing AOX discharges did not decrease the toxicity of effluents. While Swedish scientists continued to defend their focus on AOX, new studies on the effects of the AOX regulations and related technological measures presented at the second edition of the conference in 1994 showed that effluent toxicity was also associated with the organic wood compounds they contained, suggesting a need to expand the focus of research, and that regulation and technological measures now had to target not only the bleaching plant.

The 1992 Canadian regulations for the pulp and paper industry set a minimum federal standard for dioxin, allowing provinces to enact more stringent requirements, if necessary. No federal limits were set on AOX. Four of the ten provinces nevertheless set limits for AOX emissions with varying degrees of stringency, first among them British Columbia. Conversion to ECF was sufficient to comply with the federal dioxin standard. The Canadian industry attained this objective over the decade. No Canadian pulp and paper producers adopted a TCF process. However, in response to local social pressures or environmental constraints, some producers adopted measures to improve the environmental performance of ECF bleaching, which further reduced AOX in effluents. No specific demand for TCF bleaching emerged either nationally or in the US, Canada's main export market (OECD, 1999a,b). Not only did product labelling schemes incorporate criteria

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for paper product late and without specific requirements on AOX limits, but industrial consumers in Canada were not convinced by Greenpeace's plea. The situation in the US was no different.

## 4. Sound Science and the Struggle over the New Rules for the US Pulp and Paper Industry

Following a court settlement in 1988, the US EPA launched a process for setting new, integrated and revised federal air and water emission limits for the pulp and paper sector based on the 'best available technology', a regulation known as the Cluster Rule. The EPA submitted a first ambitious proposal for comment in 1993, triggering a massive counterstrike from an industry determined to avoid measures entailing unacceptable costs. The battles were fought in the regulatory and legal arenas, but also in the markets, where Greenpeace, attempting to replicate its German strategy, came up against the ideology of sound science.

### At the Courts, on the Market: Industry Efforts to Avert a TCF Standard

As other industries had done before (Oreskes and Conway, 2010), the pulp and paper industry mobilised scientific controversy and uncertainties to cast doubt on risk assessments and causal claims. It did so, first, by attacking EPA's dioxin risk assessment with a view to obtaining less stringent regulation and, second, by using controversy to challenge any potential causal link between its products and processes and any negative environmental or health impacts in the courts. At stake was not only potential legal liability for property value loss and cancer risk alleged by affected populations who were claiming millions of dollars in damages, but the possibility that unfavourable settlements could lead to the imposition of an overly ambitious, costly technology standard, affecting the whole industry. The landmark case against the Louisiana Pacific's Samoa mill crystallised this fear. Located on a fragile aquatic environment on the northern coast of California, the mill was the subject of a complaint about recurring violations of a permissive emission permit, allegedly resulting in environmental harm. Following a 1989 court settlement, the mill had to comply with stringent emission limits, and transitioned to TCF bleaching in order to secure regulatory approval and obtain the local community's social licence to operate. The mill, which ultimately went bankrupt, was the

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first of a few that implemented TCF bleaching in the US (Albert, 1994). This remained an exception, and the industry sought to prevent such radical outcomes from setting a possible standard for the whole industry, and instead to secure regulation involving less costly, incremental changes (Norberg-Bohm and Rossi, 1998).

In parallel, the industrial lobby and Greenpeace clashed on the markets, another battlefield where a new standard could potentially be set. In 1991, concerned about the newly discovered dioxin-related hazards, *Time* magazine, part of the Time Warner media group, and other major global buyers of paper such as Starbucks and McDonald's, announced that they were assessing options for a possible switch to chlorine-free bleached pulp for their paper products. Hoping that their conversion would create an initial TCF market, Greenpeace organised a mass mailing campaign targeting *Time* and its largest advertisers, warning them that the very paper on which the magazine was printed was a cause of serious pollution, resulting in environmental and health hazards. To solve this problem, they argued, their providers had to be required to use TCF paper. In January 1992, the magazine responded that it would switch to alternative paper 'as soon as it is practical to do so' (Palter and Weinberg, 1994). Greenpeace saw this as a positive signal that markets for TCF products were also emerging in the US. To counter these efforts, in 1993 pulp producers and chemical manufacturers established the Alliance for Environmental Technology (AET). Under the leadership of Douglas C. Pryke, one of the leading technology consultants to the global paper industry, AET's sole focus was on promoting the benefits of chlorine dioxide-based processes over TCF methods, challenging the environmental superiority of TCF as a myth based on flawed and outdated science. On this view, to adopt ECF technologies was simply to follow sound science, as the AET's website made clear. To this end, it provided access to grey literature on ECF bleaching, including reviews by the Canadian Environmental Agency, and to yearly reports on market trends, showing a constantly growing curve for ECF bleaching and a stagnant line of TCF processes worldwide.

## The Alignment Behind an ECF Transition

Between 1993 and 1997, these battles came to an end. On the market side, AET's efforts paid off. New product standards for the paper sector

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set specific restrictions on the use of chlorine for personal care products and for printing paper. In all cases, these product standards could be met by using ECF bleaching at the process level (Popp, Hafner and Johnstone, 2011). In light of these product standards, *Time*'s decision came in 1994. Contrary to Greenpeace's expectations, after consultations with its suppliers, the magazine decided not to require TCF paper. ECF, *Time* claimed, was environmentally safe, dioxin-removing, more cost-effective and of higher quality. Greenpeace contested the choice, and when negotiations failed, took direct action aimed at maximising media impact. As with *Der Spiegel*, they produced a parody of *Time* on TCF paper, and activists climbed the Time-Life building in New York to unfurl a banner reading 'Chlorine Kills – Take the Poison out of Paper' during morning rush hour. However, the action did not have the expected impact. Not only did *Time* not change its position, but Greenpeace was publicly criticised by its detractors for not being up to date with the state-of-the-art technology and scientific facts. These included, among other arguments, a report by the EPA concluding that its own standard model had overestimated dioxin cancer risk.

On the regulation side, the final Cluster Rule was published in April 1998 after several years of negotiations. While the EPA had been aiming for stringent AOX limits based on either ECF bleaching with prior oxygen delignification or TCF bleaching, the industry considered such standards scientifically unfounded and economically unfeasible, and recommended AOX levels not requiring oxygen delignification. The Final Cluster Rule set emission limits slightly less stringent than those in the Nordic countries, and a generous compliance schedule. While the EPA recognised that AOX was a flawed parameter for effluent toxicity, AOX limits were set on the basis that testing for AOX was less expensive than for dioxins, and that it provided a means to check whether individual mills had adopted the necessary protection measures. AOX limits for new plants entailed the adoption of ECF bleaching with prior oxygen delignification. Less stringent AOX limits for existing mills did not require such measures, thereby limiting economic risk – although by the late 1990s one third of US kraft mills had already adopted this technology.

These regulations were just being implemented in the US when Canada and the Nordic countries had already completed their transition to non-

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chlorine bleaching. The Cluster Rule came late and did little to change the paper industry. Rather, it enshrined in regulations what the industry had already achieved in practice between 1987 and 1995. Through a close relationship with the EPA cultivated since 1985, the pulp and paper industry was able to defend its interests by challenging the science behind regulatory proposals, thereby shaping outcomes (Boyd, 2002). By delaying regulation, the industry managed to buy time to respond to the problem on its own terms.

## 5. A Restricted Technological Pluralism and the Persistence of Antagonisms

Since the end of the 1990s, trajectories on both sides of the Atlantic have converged towards a common result: a steady reduction in the use of elemental chlorine as a bleaching agent, with the subsequent reduction in effluent toxicity in the main developed pulp and paper producer countries and beyond. This has not meant the absence of producers whose performance has struggled to meet minimum standards, but it points to an impressive conflictual innovation through withdrawal process, at least for a 'mature' industrial sector (Rosenberg et al., 1990). A relative stabilisation across markets led many to consider that the ECF vs TCF debate was over. After years of struggles among promoters of one or another of these competing substitution solutions, a new market *agencement* emerged. A coexistence arrangement advocated by some observers as early as 1995 came to be seen as the way forward, with 'ECF and TCF' reconciled in a 'technology cafeteria' where each company could choose from a variety of options according to its needs and constraints (Patrick, 1995). This image was intended to defuse tensions by valuing the coexistence of the two families of techniques resulting from the chlorine subtraction innovation process. In reality, however, this alignment did not entail the end of antagonisms: the ECF vs TCF debate remained a proxy for persistently conflicting views about environmental protection.

This persistence is well illustrated by the conflict that emerged within the European Technical Working Group (TWG) charged with defining the list of techniques to be considered as best available techniques (BAT) for setting permit conditions for the pulp and paper industry in the 2001 BAT Reference Document, or BREF (European Commission, 2001). Between 1997 and 2000, two ultimately unresolved, antagonistic

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positions emerged as to the question of which solution was (not) *normatively* in line with European environmental and industrial policy in the light of the state of the art in the sector. On the one hand, ECF sequences had become the new global market standard. Competitiveness and product quality standards – fibre strength and pulp brightness – prevailed as defining criteria, leading many companies to invest in enhancing the environmental performance of ECF processes. By the turn of the century, some fifteen ECF variants were in use in combination with other processes and end-of-pipe measures, resulting in varying environmental performance and costs. Among them, sequences marketed as 'ECF light' made it possible to achieve undetectable levels of dioxins and to meet ambitious AOX targets for the reduction – but not the total elimination – of all other organochlorines. These environmental results consolidated ECF sequences as the industry's preferred alternative to chlorine bleaching. On the other hand, TCF was an available technology that totally eliminated dioxins and other AOXs. But the market share of TCF products remained under 10% despite cost and quality improvements. As the prospect of steadily expanding TCF markets faded away, a few mills were sufficient to meet the unchanging demand. And with the opening of new Asian markets and increasing demand for higher-end products, some European TCF mills had to adapt, initially by manufacturing both ECF and TCF according to demand, and later by switching entirely to ECF production. This was the case of the Metsä-Botnia Rauma mill, a pioneer in the implementation of TCF bleaching in Finland. As a result, in this 'technological cafeteria', the actual choice between ECF and TCF proved in practice to be limited by global market trends.

Far from ensuring peaceful coexistence, this configuration entailed further conflict, particularly as the market conditions did not exist for TCF, which remained the preferred option of environmental groups, to become a standard for every mill. On the one side were the European Environmental Bureau and some EU Member States in the TWG, who argued that ECF bleaching's market dominance did not imply that the BREF should endorse it as a BAT. This, they argued, would be contrary to the principles of prevention and precaution that should guide the industry's technological adaptation. Only TCF would meet the objective of a 'high level of protection' set out in new European pollution prevention legislation. But this remained a minority position

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within the TWG. For the industry and most EU Member States, ECF bleaching was satisfactory in terms of costs, product quality and environmental performance. Excluding it, they argued, would fail the test of the competitiveness criteria that are key to determining what techniques are considered BAT. They considered the consequences of generalising TCF bleaching as the BAT standard for the whole European industry and beyond to be unacceptable, both in terms of costs for plant operators and in terms of product quality for expanding markets. Indeed, in a context of global expansion of consumption and the industry, and with Europe playing a leading role in the transition to sustainability, the BREF was intended to guide the industry toward the adoption of state-of-the-art techniques not only within Europe, but beyond. This was particularly important for parts of the developing world with weak or no specific regulation, where small-scale old integrated pulp and paper mills continued to use elemental chlorine as the main bleaching agent for products commercialised in the internal market. The BREF thus served as a means of extending the European technological zone (Barry, 2006).

Facing a persistent disagreement among the participants in the TWG, the European Commission solved the dilemma by fostering a coexistence policy, as it did on other matters (Doganova & Laurent, 2016). This entailed including both ECF bleaching with low AOX levels and TCF bleaching in the list of BATs to be taken into account when setting permit conditions, while taking due note in the conclusions of the BREF about the ongoing disagreement between the parties on this regard, among other matters on which consensus could not be reached. The 2001 Pulp and Paper BREF (European Commission, 2001) thus enshrined a tension between, on the one hand, the political ideal of the ‘technology cafeteria’, normatively (and nominally) leaving open a variety of competing options in the process technology market and, on the other hand, the market *agencement* described in the document, in which there was clearly a trend towards the loss of TCF as an option. While the processes and products in the sector as a whole could be considered diverse, the reality of the ‘technological cafeteria’ for bleaching plants was one in which TCF was only available to be served to selected customers. The lock-in created by the global alignment on the ECF option made the option of TCF methods, if not purely theoretical, at least one that was reserved for mills operating in exceptional circumstances. Accordingly, the use

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of one or the other technique – to meet emission limits set in the permit and environmental quality objectives set for the receiving environment – was to be decided on a case-by-case basis within the framework of each permitting process. This was in line with the EU's flexible, decentralised and subsidiarity-based approach. In other words, the determination of whether an individual mill needed to implement TCF bleaching instead of the now-standard ECF would depend on the conclusions drawn in the light of an environmental impact assessment, and thus on the characterisation of the circumstances of the mill (Baya-Laffite, 2015b). And if it is found that the extreme vulnerability of the receiving environment justifies AOX limits entailing TCF, then certain companies producing for the global market may simply be forced to consider moving their mill elsewhere.

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