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POLICIES AND SUPPORT IN RELATION TO LCA

Life cycle assessment: from industry to policy to politics

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Abstract

Purpose Life cycle assessment (LCA) has established itself as part of the sustainability toolkit of the private sector, informing environmental decision-making and improving environmental performance. However, we know less about its use in the public sector. To what extent and how do governments refer to LCA in their public policies? We review the literature on the use of LCA in public policy and gauge how LCA has penetrated public policymaking through its incorporation in different policy instruments across various sectors. We then discuss the politics of LCA use in policymaking.

Methods We review the literature on LCA from a public policy and social science perspective (1) and back our argument with information from a dozen interviews with LCA experts from government, consultancy, and academia in France, Germany, Switzerland, and the EU (2).

Results We show that, along with the growing importance of target setting and science-based environmental and climate policymaking, LCA has penetrated the realm of public policy in OECD countries in different policy sectors. Our understanding of the politics of LCA use in policymaking is however deficient, which leads us to outline a research agenda.

Conclusions With the growing importance of LCA in public policy, societal values, public/private governance, state capacity, and political agency should be addressed in further research.

Keywords Life cycle assessment · Public policy · Public/private governance · State capacity

1 Introduction

In 1991, the German government adopted the Packaging Ordinance, establishing the responsibility of manufacturers for the disposal of their products and regulating the use of disposable and reusable packaging and mandatory deposits (Groth 2010). Since 2005, the European Union (EU) has sought to increase the environmental performance of energy-using products with its Ecodesign Directive (EC 2009). The US government's 2022 General Services Administration Low-Carbon Standards require project contractors to provide environmental product declarations (EPDs), meeting 20% lower embodied carbon limits for concrete, and using "environmentally preferable techniques" for asphalt (Clean Energy Canada 2022). What do these proposals have in common? All are public policies that aim at reducing environmental harm and all are based on life cycle assessment (LCA).

LCA is an instrument to assess the potential environmental impacts and resources used throughout a product's[1] life cycle, that is, from raw material acquisition, through production and use stages, to waste management (ISO 2006). As a holistic and comprehensive approach, it comes with the promise of avoiding the displacement of environmental impacts from one stage of the life cycle to another since the entire cycle of a product is taken into consideration (Hellweg and Milà i Canals 2014).

The use of LCA has grown significantly over the past three decades to assess and improve environmental performance and inform environmental decision-making in various industries. Consumer demand for better product information explains this growing interest (Jensen et al. 1998; Valdivia et al. 2011) but also demand for quantitative science-based climate targets (Morseletto et al. 2017; Walenta 2020). Via

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[1] LCA applies to products, processes, and services. For the sake of brevity, we only refer to products in the text.

standardization processes, LCA is now part of the sustainability toolkit in the private sector, backed by big companies like Alcoa, Rio Tinto, or Unilever, while accounting firms like Deloitte, PwC, Ernst and Young, or KPMG offer LCA consultancy (Freidberg 2015b).

But what about the public sector? To what extent has LCA been added to the environmental policy toolkit of governments? With the increasing importance of target setting and science-based environmental and climate policymaking, the need for tools to measure and quantify has increased, too (Bjørn et al. 2021). We review the current state of affairs of LCA use in public policy, and gauge how, beyond anecdotal evidence, LCA has indeed penetrated public policymaking through its incorporation in different policy instruments in various sectors. We then discuss what this penetration means for environmental policymaking and sketch out a research agenda on the role of politics in the deployment of LCA.

While our focus is on LCA as an internationally standardized methodology according to the ISO 14040 and 14044 series standards for assessing environmental impacts (Bjørn et al. 2018), we include literature that occasionally refers to other life cycle connotations. This literature may include life cycle thinking (LCT) as a more ideational than quantitative way of conceiving environmental, economic, and social consequences throughout the life cycle of a product, but also other life cycle approaches like product environmental footprints (PEF) or environmental product declarations (EPDs).[2] We highlight the differences if they are important to our discussion.

When speaking of public policy, we refer to "anything a government chooses to do or not to do" (Dye 1972: 2). Governments make authoritative decisions on behalf of citizens, even though non-governmental actors from business and society regularly intervene in the policymaking process to influence decisions. In specific circumstances, the implementation of policy decisions may be left to non-governmental actors (Howlett and Cashore 2014). Governmental action relies on policy instruments, that is, on governance tools and techniques by which public authorities exercise power to structure collective action and induce social change (Acciai and Capano 2021). Our focus here is on policy instruments that relate to LCA.

We start with a short historical overview of the industrial origins of LCA (1) before reviewing the literature on LCA from a public policy and social science perspective (2). The discussion and the outline of future research directions (3) are based on a literature review backed with information from a dozen interviews that were conducted in 2022–2023 with LCA experts from government, consultancy, and academia covering France, Germany, Switzerland, and the EU.

2 The industrial origins of LCA

LCA made its appearance in the 1960s. Initially called Resource and Environmental Profile Analysis (REPA) or Ecobalance, the focus was on packaging and, from the beginning, the effort was industry-led. In 1969, for example, Coca Cola commissioned—for internal purpose—a study to compare aluminum, plastic, and glass bottles. But with the development of environmental policies in the 1970s, governments soon became involved. In 1974, the Environmental Protection Agency (EPA) commissioned the first public and peer-reviewed LCA study on beverage container alternatives with the aim to inform American regulation. The EPA concluded on its impracticability because too many products would need to be assessed, implying far-reaching micromanaging of private businesses (Bjørn et al. 2018).

After the OPEC oil embargo, in the second half of the 1970s, LCA was more prominently applied to energy use (Hunt et al. 1996). LCA lost steam in the 1980s; one reason was the lack of standardized data sets and databases, which made it difficult and expensive to perform LCAs. The approach regained popularity in the 1990s, as methodologies and sector-specific life cycle inventory databases were developed in different locations. At first, LCA addressed environmental problems like solid waste, energy use, and air and water emissions to respond to emerging and changing public concerns. LCA became the common term—even though German-speaking countries still refer to ecobalances. According to Bjørn et al. (2018, p. 20), "the ambition has since then been to quantify all relevant environmental impacts, independent of shifting public concerns, with the goal of avoiding burden shifting."

With growing interest for LCA in North America, Europe, and Japan, the need for improving and harmonizing methodology and data also increased. The Society of Environmental Toxicology and Chemistry (SETAC) backed the codification efforts of LCA practices by organizing workshops for representatives from business, government, and academia and by supporting the preparation—and later revision—of the standardization process under the International Organization for Standardization (ISO) (Fava et al. 2014). Starting in 1993, the standardization process led to the adoption of a common framework and principles (ISO 14040) in 1997, which are regularly updated. Three other ISO standards have been integrated into ISO 14044 in 2006, specifying requirements and guidelines (Hauschild and Huijbregts 2015). Aside from the ISO 14040 series, the ISO 14000 series of Environmental Management Standards about ecodesign, communication of environmental performance, and greenhouse gas reporting

[2] https://www.lifecycleinitiative.org/activities/what-is-life-cycle-thinking/

and reduction also address LCA (Bjørn et al. 2018). Freidberg (2013: 574) points out that ISO standards do not ensure uniformity in practice or interpretation of LCA but they "gave LCA a degree of much-needed credibility."

Beyond governments and experts, industry also developed links with international organizations. In the late 1990s, SETAC established a partnership with the United Nations Environment Programme (UNEP). Launched in 2002, the UNEP/SETAC Life Cycle Initiative (LCI) seeks to promote LCA on a global scale, contributing to capacity building and helping to make LCA data more accessible and consistent (Sonnemann et al. 2018). Hosted by UNEP, the Initiative is a partnership of institutional members from government, business, science, and civil society. In its 2022–2027 strategic approach, the Initiative focuses on high-impact intergovernmental or sector-specific processes for sustainable development (www.lifecycleinitiative.org).

3 LCA from a public policy perspective

In this section, we survey the literature on LCA in the context of public policy. We first indicate growing interest among LCA experts and policymakers for using LCA in public policy. Second, we turn to studies that seek to apply concepts and typologies from public policy analysis to LCA. Third, based on secondary data and analyses, we gauge the penetration of LCA in public policy.

3.1 Growing interest in public policy

As mentioned above, the EPA considered in the 1970s that the use of LCA as a regulatory tool would be impractical (Bjørn et al. 2018, p. 21). Despite this early setback, interest for LCA in public policy was never completely lost. In 1994, SETAC dedicated one of its Pellston Workshops (gathering experts from business, academia, government, and public interest groups) to public policy. The working group proposed different means to integrate LCA into the existing policy toolbox such as environmental labeling, government acquisition and procurement programs, and regulation. These experts identified barriers to the application of LCA to public policy such as the lack of education and acceptance of LCA as a decision-making tool, missing stakeholder participation, insufficient data and resources, and methodological issues (Allen et al. 1997).

More than a decade later, the 2011 UNEP/SETAC/LCI report, published ahead of the United Nations Conference on Sustainable Development (Rio+20) in 2012, alluded in general terms to the interest of LCA for governments, underscoring its potential for the promotion of more sustainable products (Valdivia et al. 2011). The 2016 UNEP/SETAC/LCI report shared results from a global survey distributed among 2500 subscribers of the UNEP/SETAC/LCI mailing list (Sonnemann et al. 2016, p. 6). One survey question directly addressed public policy: "Have life cycle approaches been used in the legislation of your country or region and if so please specify the policy area where it has been applied?" Interest seemed to be greater when approaches such as EPD, PEF, and public procurement are considered. Moreover, the report showed public authorities' involvement in supporting databases worldwide. Some databases are government-led, such as ProBas provided by the German Federal Environment Agency, Agri-BALYSE supported by the French ADEME and INRAE, or the US Life Cycle Inventory Database created by the National Renewable Energy Laboratory. Other databases are administered in public–private partnerships like the Swedish Life Cycle Center. These different reports point towards the LCA community's interest for the potential of LCA applications in public policy.

3.2 Applying public policy approaches to analyze LCA

The policy cycle model, also known as stages heuristic, is a widely used approach to analyze policymaking. It divides the policy process into functionally and temporally distinct subprocesses such as agenda setting, policy formulation, decision-making, implementation, and evaluation. Each stage feeds into the next and involves different political institutions and policy actors (Sabatier 2007).

In his PhD dissertation on LCA in US government policy, Reed (2012) uses this model to identify how LCA could contribute to policymaking at different stages of the policy process. He concludes that LCA might matter for "identifying public problems, guiding baseline policy requirements based on scientific and technical evidence and evaluating policy effectiveness using comparisons" (Reed 2012, p. 116–17). Likewise, researchers from the Joint Research Centre of the European Commission (EC-JRC) refer to the policy cycle model to analyze LCA's benefits for sustainable policy in the EU. They consider that LCA can provide support at all stages of the policymaking process but find that its main application is at the implementation stage. They see a key role in impact assessment given LCA's potential to estimate the effects of policies on supply chains and to evaluate the consequences of different policy options (Sala et al. 2016; Reale et al. 2017).

The stages heuristic helps to break down the complexity of the policymaking process and to describe LCA use in different policy contexts such as in the USA or the EU. The reality of policymaking is, however, neither as linear nor as systematic as the model assumes (Howlett and Giest 2015). These studies signal the need for a closer examination of what is going on at each stage of the policymaking cycle and how actors interact with each other to shape policies.

Another approach to policymaking is to categorize the ways in which governments seek to achieve their policy objectives. There have been several attempts to identify and classify LCA-related activities by referring to extant classifications or by establishing typologies relevant to industrial practice. In the 1990s, Curran (1997) identified and compared the use of LCA and life cycle approaches in public policy across 14 developed countries.[3] She distinguished three types of policy. First, she found that product-oriented policies, covering ecolabels and procurement, were the most frequent application for LCA. More than half of the countries then used LCA for ecolabels. Others referred to LCA for general product policy (Japan), manufacturing policy (the Netherlands), taxation (Norway), producer responsibility (Sweden), and procurement (Australia, USA). The second type of policy she observed, waste management, relates to packaging and recycling policies. The most common activity based on LCA and life cycle approaches was to set waste reduction targets and goals. Process-oriented policy was the third type reported by Curran, that is, policies that do not fit into the two former categories but go beyond end-of-pipe control or single media policies. She found substantial variation among countries, from using LCA in toxic substance management in Canada, taxation on emissions in France, substance bans in the Netherlands to alternative fuels and standards development in the USA. At the end of the 1990s, Curran's conclusion was sobering: despite a consensus within the LCA community about the value of LCA for assessing environmental strategies and despite some promising examples, LCA and life cycle approaches were not widespread in policymaking.

Since then, other scholars have investigated different ways to use LCA in public policy. Lehmann et al. (2015) have developed policy options that would allow the integration of LCA into legislation. They define four structural elements to characterize policy options, that is, the type of enforcement (mandatory vs. voluntary), levers (performance vs. process), use of LCA (direct full LCA vs. indirect LCT), and market role (market access vs. market incentive). They further prioritize policy options according to three criteria, namely, rigor of implementation, rigor of LCA, and stakeholder acceptance. These policy options were submitted to SWOT (strengths, weakness, opportunities, threats) and RACER (relevance, acceptance, credibility, easiness, robustness) analyses. Overall, Lehmann et al. (2015) develop 11 policy options, ranging from voluntary to mandatory policies, based on full or partial LCA, and playing different roles in the market. They find that differences between policy options are not very significant and that technical requirement for mandatory and voluntary policy options are similar. They consider that all policy options can theoretically guarantee credibility and robustness. Regarding acceptance, "generally, it can be assumed that if the policy options are implemented properly, the acceptance is high, but if there is a risk of poor implementation the acceptance would be low" (Lehmann et al. 2015, p. 222). Overall, they conclude that there is a theoretical range of policy options but no obvious preference for a single option.

Jegen (2020) investigates public policies that refer to LCA, LCT, and other life cycle approaches. Her database covers 14 OECD countries[4] and can be searched by jurisdiction, policy instrument, or policy category. For classification, she uses Christopher Hood's widely used NATO model—nodality, authority, treasure, organization. The model groups policy instruments according to these four types of social resources from which governments derive different capabilities (Hood 1983; Hood and Margetts 2007). Jegen identifies 146 LCA-related policy instruments and finds that all 14 countries use informational measures (included in what Hood calls "nodality"), which are overall the most popular ($n=57$). For example, the governments of France, Germany, Switzerland, and New Zealand have been directly involved in setting up LCA databases in several sectors, and most of them encourage LCA by publishing guidelines to facilitate analysis. The treasure category scores second ($n=44$). More than two-thirds of the countries refer to LCA in procurement policies and provide financial support, mostly in terms of financing LCA-related studies in different policy sectors. The organization category ranks third ($n=28$), but there is a difference between administrative practices, which are less widely reported, and strategic guidance, which is used by more than half of the countries. For instance, Ireland's main strategy document on the environment insists on the need to use LCA in regulatory approaches. The authority category, which includes legislative and regulatory frameworks, has fewer occurrences ($n=17$). Nonetheless, more than half of the countries integrate such frameworks into their policy instruments. For example, the French Grenelle II law incentivizes pilot projects for ecolabels, favoring the use of LCA and EPDs; moreover, if LCA is used to advertise a product, the legislator can hold advertisers accountable. In Switzerland, LCA is used for fiscal exemptions in the case of biofuels.

[3] Curran (1997, p. 39) specifies that her article is based on "a search of the open literature" and refers to her master thesis at the International Institute for Industrial Environmental Economics (Lund University). Given that the document is not available online, the search details could not be pinned down.

[4] The database also includes information about the EU and two subnational jurisdictions, California and Quebec. The selection of 14 countries is similar to Curran (1997)'s except from Austria and Belgium that are not covered by Jegen (2020), while Curran does not include Ireland and Italy.

Sala et al. (2021) pursue a similar goal in tracking down the evolution of LCA activities in the EU between 1990 and 2020. Their classification is based on four types of legal acts—regulations, directives, decisions, and recommendations—and non-binding communications (policy evaluations, commentary or explanations of action-programs or outlines on future policies, proposals, reports, white papers, green papers). Furthermore, they refine their classification by explicitly distinguishing life cycle thinking, life cycle assessment, life cycle costing, and the European PEF and OEF. They weigh the importance of LCA references in the documents ("at the heart" vs. "in the context"), and distinguish policy sectors. Their search on EURLex, the EU's online tool for EU law and other public documents, delivers 159 policies and 167 communications referencing life cycle approaches in the EU. Among policies there are 84 decisions, 44 regulations, 28 directives, and 3 recommendations (Sala et al. 2021, p. 2301). It is interesting to note that 57 out of 84 decisions are linked to the Ecolabel Regulation and 24 out of 44 regulations related to the Ecodesign Directive: these two legislative acts entail a series of other legislations referring to life cycle approaches.

These different attempts to identify LCA-related activities in public policy are not directly comparable because objectives and methods differ. Curran and Jegen cover more OECD countries, but their data do not stem from a finite corpus, which makes it difficult to carry out meaningful quantitative analysis. Sala et al.'s study has the advantage of focusing on a definite corpus, the EURLex database, and on distinguishing between LCA, LCT, and other life cycle approaches, but its informational value is limited to the EU.

3.3 Gauging the penetration of LCA in public policy

Overall, Jegen (2020)'s database reveals the broad application of LCA, LCT, and other life cycle approaches across policy sectors in OECD countries, from agriculture and food, to energy, transport, and building.[5] Similarly, Sala et al. (2021)'s data indicates increasing use of all life cycle–related approaches in EU policies and communications. The authors thus expect that life cycle methodologies and tools "in policy support will continue to grow in influence in the foreseeable future and that the environmental performance of MS [member states] will be improved by the time of the next review" (Sala et al. 2021, p. 2309). These studies and data suggest that LCA has by now penetrated the realm of public policymaking in advanced industrial countries. This is in stark contrast to Curran's conclusion in 1997 that LCA was not widespread in the public sector.

Where and how much? To date, Sonnemann et al. (2018, pp. 442–455) provide the most substantial overview of LCA use in public policy worldwide. According to them and mirroring Sala et al. (2021)'s findings, the EU consistently promotes LCT, LCA, and other life cycle approaches since the 1990s. These approaches have found their way into numerous strategies and directives. For instance, the EU adopted in 2003 its Integrated Product Policy (IPP), which includes LCA-based policy instruments like environmental product declarations, ecolabels, or green public procurement after several European countries had already developed their own product-oriented strategies referring to LCA methodologies (Bjørn et al. 2018: 22). Other examples include the 2005 Thematic Strategy on the Prevention and Recycling of Waste, the 2006 REACH Regulation on Chemicals, the 2009 Eco-Design directive, the 2013 Single Market for Green Products, or the 2015 Better Regulation Toolbox. Furthermore, the EC-JRC, as the European Commission's internal science and knowledge think tank, takes on an important role in providing scientific support to LCA-related activities (e.g., European Platform on Life Cycle Assessment (EPLCA), PEF, OEF), etc.). Reed (2012) and Freidberg (2015b) corroborate the EU's leading role, where LCA and related approaches have guided policies from recycling and public transport to "climate smart" food labelling.

The USA has also invested significant efforts in the development of databases such as the LCA Digital Commons Project at the UNDA National Agricultural Library or the Life Cycle Inventory Database supported by the National Renewable Energy Laboratory (Sonnemann et al. 2018). More recently, they adopted several public policies which require life cycle metrics (Feraldi 2023): the 2021 Federal Sustainability Plan and the Buy Clean Initiative compel the US government, the largest public purchaser worldwide, to use its procurement power to reduce greenhouse gas emissions; likewise, the 2022 Inflation Reduction Act entails massive investments in clean energy and in the reduction of embodied carbon impacts. Several US states like California, Colorado, or Washington have their own "buy clean" bills to enhance sustainable public procurement. These bills frequently require EPDs, typically based on LCA. Given that the US federal government on its own has a purchasing power of over $630 billion, we can expect a big boost for LCA and life cycle approaches, notably through EPDs, on public agendas.

Even though the reviewed literature does not allow to accurately quantify the use of LCA and life cycle approaches and its evolution in the public sector over time, it makes it possible to appreciate the spread of these tools across policy sectors and across jurisdictions. Interestingly, Sonnemann et al. (2018) show that the public use of LCA

[5] It should be noted that the database is a snapshot from 2019, covering material that was visible and accessible online. Most certainly, the database underestimates LCA-related activities in the public sector.

is not limited to the public sector of advanced industrial economies. Their research addresses the proliferation of LCA activities in emerging economies from China and Thailand to Brazil and South Africa. For example, China uses LCA for eco-design of industrial products, whereas Thailand invests in a national database.

4 The missing politics of LCA: filling the research gap

Our literature review confirms that LCA is far from limited to the private sector and is increasingly used in public policymaking. Freidberg (2015b, p. 175)'s interviews with practitioners reveal that they perceive governments' interest in LCA to be more significant than corporate initiatives, policy measures to be more important than efforts by consumers or retailers, and policy settings to provide better opportunities to explain complex findings. Interestingly, though, LCA is rarely visible on political agendas. Perhaps as a result, LCA also occupies very little space in the otherwise rich literature on environmental policy instruments (e.g. Mol et al. 2000; Jordan et al. 2012; Van der Heijden 2012; Wurzel et al. 2013; Parson and Kravitz 2013; Rogge et al. 2017).

Yet, being in the shadow of politics does not mean that politics does not matter. Politics can impact LCA and life cycle approaches in several ways. Social scientists have already pointed to the importance of embedding LCA and life cycle approaches in their social and institutional context. For example, Newell and Voss (2011) investigate carbon footprint modelling in the global paper industry and observe that the LCA-based approach neglects complexities of scale and scope by delineating system boundaries in a narrow way. Jordan and Bleischwitz (2020) focus on embodied emissions in the construction sector, where EPDs and PCFs can enhance the accountability of the value chain of products, and investigate how these informational devices are perceived by various actors who can promote or block their adoption. They conclude that, to fulfil their potential as sustainability devices, EPDs and PCFs require legitimation. But they also find tensions between underlying legitimation logics. Jordan (2021) examines EPDs and PCFs in the construction sector and shows how coordinated sectoral responses to environmental policy increase the availability of life cycle data: the institutional context generates incentives for an intra-sectoral exchange on the environmental impacts of production. This is conducive to the creation of sectoral life cycle data sets and leads to the reduction of transaction costs for the creation of sectoral EPDs, thereby favoring the diffusion of ecolabels.

These contributions are an important step towards understanding the social and institutional underpinnings of the use of LCA and life cycle approaches, but they do not put politics front and center. This gap needs to be filled if one is to realize the full potential of LCA in public policy, for four reasons: the importance of societal values, the challenge of private/public governance, state capacity, and political agency. Our argument is informed by insights from social and political science as well as a dozen interviews that were conducted in 2022–2023 with LCA experts from government, consultancy and academia covering France, Germany, Switzerland, and the EU (ethics approval for these interviews was obtained from our university).

The first reason has to do with the fact that policy instruments embody values which deserve political attention (Lascoumes and Le Gales 2007). The role of value judgments recurrently haunts LCA practitioners (e.g., Schmidt and Sullivan 2002; Hofstetter 2002; Nathan and Coles 2020). In *From behind the curtain: talking about values in LCA,* Freidberg (2015a) unveils the tension between the "objective" natural science ambitions and the value-based judgments of LCA practitioners and encourages the latter to take responsibility of their value choices. Inspired by the post-positivist argumentative turn that calls into question the assumption that the analysis of public policies is technical and value-independent (Fischer and Forester 1993), Bras-Klapwijk (1998) also stresses the tension between the argumentative, discourse-oriented policymaking process and LCA's aspirational logic of objectivity and quantification. She considers LCA's exclusively rational approach to be problematic for environmental policies and suggests including facts and values in the deliberation process. In the same vein, Seidel (2016) pleads in favor of a more inclusive and collaborative stakeholder process and encourages life cycle *thinking* among policy makers, even if this does not result in a full LCA.

The second reason why politics matter relates to governance. The literature and our interviews make clear that the industry has been a key driver in LCA deployment, and its interest is likely to increase in the context of supply chain governance. LCA is embedded in industries, and industries are actively involved in standardization processes. For example, it is not uncommon that firms (e.g., BASF, VW) provide the chairperson for the ISO-Committee TC207/SC5 Environmental Management – Life Cycle Assessment. The involvement of the private sector in environmental governance is neither a new nor a rare phenomenon: private actors participate in various ways, their implication in ecolabelling and certification being the most prominent example. In LCA, it can be compared to what Jessica Green (2014) calls private entrepreneurial authority, a form of polycentric governance whereby numerous private actors mobilize their shared, recognized expertise to impose rules without an explicit delegation of authority by the state. This form of authority applies well to LCA, where industries provide

data, increasingly invest in inhouse capacity, contribute to the development of methods, and frame priorities.

While self-regulation may contribute to a public good, leaving LCA implementation to private actors is in and of itself a political decision with significant consequences. For some of our respondents, there is no problem when type III environmental declarations (presenting quantified environmental information on the life cycle of a product) are mostly self-regulated, "business-to-business." But the rapid development of private entrepreneurial authority may become problematic if it is no longer seen as legitimate in the public eye. Examining the rise of LCA as a supply chain governance tool, Freidberg (2013) has shown how LCA responds to the expectations of metrics-based governance, while fostering an expert community of representatives from industry, academia, and consulting. She argues that the food industry uses footprinting to legitimate supply chain governance and to "advance an understanding of 'sustainable food', that suits their own bottom-line interests" (Freidberg 2014: 179). Still in the context of supply chains, Freidberg (2015b) has examined the challenges of producing LCA knowledge, while assuring its credibility. She illustrates how practitioners try to navigate industries both as clients and as key information providers. At a minimum, transparency should be a prerequisite to improve the credibility of processes and results.

But even if transparency is improved, there is a risk that private entrepreneurial authority ends up capturing public regulation. Some of our interviewees see the ISO standardization process as an entry point for lobbyists to establish certain accounting practices and methods, which can generate results that are not in the public interest. Interestingly, perceptions among our interviewees diverge depending on the country of origin. French respondents worry more about the potential loss of public control than respondents speaking about Germany, Switzerland, or the EU. The former are rooted in a more dirigiste tradition where the state steers industries, and where public policies are interventionist and centralized (Smith 2021). The latter are accustomed to corporatist concertation with private actors; that is, organized interests are more commonly privileged in the policymaking process and policymakers routinely deliberate, negotiate, and bargain with interest groups (Christiansen 2019).

The third reason why politics matters is that, despite the prominent role played so far by industry, state capacity is likely to be a crucial factor in the implementation of LCA-based public policy. Even when governments choose to delegate authority to private actors, they need to be able to monitor and eventually discipline private authority. Several interviewees are concerned that industry-led LCA practices might be rubberstamped by policymakers and public administrations who are ill-equipped to follow up due to their lack of expertise or resources. State capacity has multiple dimensions and definitions, but here we only focus on the effectiveness of state intervention, which requires a capable bureaucracy, good coordination, and coherence among state organizations (Rueschemeyer and Evans 1985).

In terms of expertise, we see variation between jurisdictions. French respondents in particular worry about the capacity of their authorities in term of personal resources and technical skills, or in the words of one civil servant: "My colleagues have to challenge Formula 1 drivers without having the appropriate expertise." Germans seem less worried about inhouse capacity, mentioning a significant expertise within the German Environment Agency, which oversees quality control and is complemented by an important expertise in consumer protection. Some interviewees question, however, the practice of subcontracting and the dependency on external consultancy firms. We also see variation in terms of coordination and coherence among public organizations. In France, LCA expertise is concentrated at ADEME, the public environmental transition agency, which is perceived to be remote from ministries and policymakers. But coordination and coherence are also an issue elsewhere because environmental policy tends to be organized in silos. In the context of LCA in Germany and the EU, an interviewee speaks of a "beehive organization" where focus on details can prevent a more holistic view. In this regard, the Swiss' recent attempt to establish a hub to support LCA activities within the administration could be a promising avenue.

Addressing the two key dimensions of state capacity, the 2023 White Paper from the US National Renewable Energy Laboratory recommends to establish a "dedicated and central curator for the Federal LCA Commons," to invest in "professional association program support that ensures ongoing, nonpartisan guidance from and coordination with the LCA professional community from the public and private sector," and to provide "privacy-preserving computation and secure date hosting technology platform that ensures sufficient technical tools for confidential and even-playing field participation from private industry," as well as dedicated resources and formalization of the Federal LCA Commons. The White Paper calls for new resources to maintain and expand LCA in the context of recent green industrial initiatives (Feraldi 2023).

A fourth reason to pay more attention to the politics of LCA concerns political agency, notably the role played by political parties and interest groups. For Skocpol (1985), state capacity is also the capacity to implement public goals over the actual or potential opposition of powerful social groups. Political leaders and policymakers may use life cycle thinking and rhetoric to signal their commitment to sustainability and environmental protection, as they have done with the connected concept of the circular economy (Schöggl et al. 2020). But standardization and the integration of LCA and life cycle approaches in legislation and regulation will induce costs with distributional consequences

which are likely to be opposed and politicized. Regulations on renewable energy and carbon taxes were also discreet policy instruments before they were politicized by actors who positioned themselves for or against them in the public sphere, with important consequences for the implementation (or not) of these instruments (Cheon and Urpelainen 2013; Stokes 2020). For instance, Lockwood and Lockwood (2022) show that right-wing populist parties are hostile to climate and renewable energy policies, even though they are more ambivalent about the latter. As they become more prominent in public policy, there is no reason to expect that LCA-based policies will avoid that fate. If these policies remain voluntary and industry-led, environmental NGOs and parties may deride them as cases of greenwashing, as is increasingly the case for ESG indicators. If public authorities push for more transparency or establish more stringent framework conditions for data or methods, as several interviewees wish for, economic interest groups that stand to lose out and anti-environmental parties may turn against them.

5 Conclusion

Our article makes clear that while the private sector has shown an early and growing interest, LCA and life cycle approaches have now penetrated public policy. It is likely to remain the case at a time when environmental policymaking is expected to be driven by metrics and science. As supply chains act as LCA drivers for the industry, so might public procurement and "new" green industrial policy accelerate the use of LCA and life cycle approaches for governments because they have the potential to inform decision-making and to avoid or at least attenuate environmental problem shifting. This will inevitably raise important challenges concerning societal values, the mix of public and private governance, state capacity, and political agency. There are complex technical debates on data and methods, which seem remote from public policy, but if LCA becomes a cornerstone of key policies supporting energy transitions, it will emerge from the shadow of politics. Address these challenges in further research might strengthen the role of LCA and life cycle approaches in the political process.

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Declarations

Conflict of interest The author declares no competing interests.

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