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Abstract

The social and political barriers to sustainability are often presumed to boil down to misalignments of power and motivation. If only those who have the power to initiate sustainability transitions could be motivated to do so – or conversely; those who have the motivation could be empowered to do so – then sustainability would presumably follow. This presumption is problematic. Not only because it skirts the difficulties in operationalizing and evaluating sustainability. But also because it neglects the social and political processes through which some behaviors and technologies come to be coded as 'sustainable' and others as 'unsustainable'.

Over the past few decades, life cycle assessments (LCA) have come to take center-stage in these processes. The upside of this trend has been a shift in emphasis, away from face-sustainability[1] and direct emissions; towards supply chains and displacement effects. The downsides have included all the predictable pitfalls of governance by numbers: operational definitions with poor construct validity; black boxes that are hard for non-experts to challenge; quarrels over conflicting evidence, etc.

Over the same period, an extensive literature has accrued, dealing with the validity, limitations, and appropriate use of LCA. The impacts particular LCAs have had on particular sustainability discourses and decision-making processes, by contrast, have largely been neglected as a topic of research. This thesis seeks to bridge this hole in the extant literature, by examining the impacts LCA has had on Norwegian sustainability discourse and policy-making; by synthesizing insights from social constructivism (i.e. how taken-for-granted realities congeal through social practices), science and technology studies (e.g. black-boxing, epistemic authority, and boundary work), and the ethics and sociology of quantifications (e.g. mathiness, metric fixation, and data inertia).

The thesis begins by assessing the validity of LCA through a critical appraisal of the extant literature on climate metrics and life cycle assessments. It then goes on to describe the role of LCA in sustainability discourses through two case studies: the 2021 debate about a managed decline of petroleum production; and the 2007 - 2019 debate about a managed transition from plastic to paper bags. Finally, it addresses the role of LCA in policymaking through a combination of document analysis and unstructured interviews with representatives of local authorities in the Norwegian county of Rogaland[2].

This examination provides a basis for arguing that: (1) the boundaries between 'sustainable' and 'unsustainable' activities cannot in general be drawn objectively – but they nonetheless have to be drawn somehow; (2) LCA can serve this purpose and *may* facilitate rational decision making; (3) but tends – as a general rule – to be short on validity and susceptible to reification, co-option, and technocratic decision making.

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[1] i.e. evaluating sustainability based on appearances

[2] NB! The thesis builds upon a research proposal developed for the course "MEE115-1 21V Social Science Research Methods" in the spring of 2021. Some text, particularly in sections 1-2, stems from this proposal.

Abbreviations

The following table describes the abbreviations and acronyms used throughout the thesis.

Abbreviation	**Meaning**
ALCA	Attributional Life Cycle Assessment
AR4	IPCC Forth Assessment Report
AR5	IPCC Fifth Assessment Report
ARMA	Alberta Recycling Management Authority
CGE	Computable General Equilibrium
CLCA	Consequential Life Cycle Assessment
CO_2e	CO_2-Equivalent
EF	Ecological Footprint
EPD	Environmental Product Declarations
FAR	IPCC First Assessment Report
GHG	Greenhouse Gas
GTP	Global Temperature Change Potential
GWP	Global Warming Potential
GWP*	Global Warming Potential Star
HDPE	High-density Polyethylene
IEA	International Energy Agency
ILCD	International Reference Life Cycle Data System
ILUC	Indirect Land Use Change
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel On Climate Change
ISO	International Organization For Standardization
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LDPE	Low-density Polyethylene
MDG	Miljøpartiet De Grønne (The Norwegian Green Party)
NGO	Non-Governmental Organization
NMBU	Norges Miljø- Og Biovitenskapelige Universitet (Norwegian University Of Life Sciences)
Norog	Norsk Olje Og Gass
NOU	Norwegian Public Commissions
NRK	Norsk Rikskringkasting (The Norwegian Broadcasting Corporation)
NVE	The Norwegian Water Resources And Energy Directorate
OPEC	Organization Of The Petroleum Exporting Countries
PCR	Product Category Rules
S-LCA	Social Life Cycle Assessment
SAR	IPCC Second Assessment Report
SFT	Statens Forurensningstilsyn (The Norwegian Environmental Agency)
SLCP	Short-Lived Climate Pollutant
SSB	Statistisk Sentralbyrå (The Norwegian Census Bureau)
STS	Science And Technology Studies
TAR	IPCC Third Assessment Report
UNFCCC	United Nations Framework Convention On Climate Change
WGI	IPCC Working Group I

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1 Introduction

Sustainability transitions can be said to have three prerequisites: the will to pursue them; the means to pursue them; and the expertise to distinguish sustainable from unsustainable transition pathways. Misalignments of means and will have traditionally been the main barriers to overcome: those who had the means to pursue sustainability lacked the motivation to do so; while those who had the motivation lacked the means. Transitions scholars have thus hitherto devoted most of their ink to addressing these two prerequisites. Less attention has been paid to the expert knowledge on which motivated actors rely to make informed decisions. Or to the social processes through which this knowledge gets constructed and reified.

As a multifaceted construct in perpetual evolution, the “Sustainability” of a given behavior or technology can be hard to assess. Indeed, it is not always possible, even in principle, to do so objectively. A classic example is the trade-off between NO_x and CO_2 emissions from gas turbines. The turbine inlet temperature (i.e. the temperature at which the gas is burned) correlates positively with NO_x emissions, and negatively with CO_2 emissions (Freeman et al., 2018). The environmentally optimal inlet temperature is thus a function of the weights one assigns each pollutant.

Much of the controversy surrounding sustainability transitions consequently boils down to divergent “rankings of environmental problems” and “the right balance between social, economic, and environmental sustainability” (Geels, 2010: 500). One example is the debate about windmills, which pits concerns about climate change against concerns about nature preservation. Another is the debate about degrowth, which pits environmental sustainability against social and economic sustainability.

Motivated actors moreover differ with regard to the impacts they associate with particular behaviors and technologies. A survey by Bostrom et. al (2012), for instance, found respondents to hold a wide array of divergent beliefs regarding which technologies contribute to climate change – ranging from aerosol spray cans to nuclear power plants. By arresting the development of a shared vision among potential coalition members, such disagreements act as barriers to sustainability (Geels, 2010).

Even in the most straightforward of cases – in which all the relevant actors agree on the goals, impacts, and how to weigh these impacts – sustainability transitions can derail due to unforeseen displacements effects. A transition from gasoline to biofuels in one country may spark the conversion into sugarcane plantations of rainforests in another. A premature transition to electric vehicles may drive up emissions from lead-acid battery production and coal-fired power plants[3]. A transition from dog waste bags made of fossil plastic to ones made of bioplastic may render their contents unusable at the local biowaste-to-biogas plant[4].

The common denominator of these examples is a failure to account for the broader contexts in which local sustainability transitions are embedded. In response to such failures, life cycle assessments (LCA) have emerged, since the mid-1990’s, as the de facto standard for assessing

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[3] This example is based on a case study from California, provided by Matthews, Hendrickson, and Matthews (2014).

[4] This example is based on IVAR’s biowaste-to-biogas plant in Rogaland, Norway, which handles dog waste bags made of plastic, but not ones made of bioplastic (IVAR, 2018).

environmental sustainability. By quantifying environmental impacts in an ostensibly objective manner, these assessments should in principle provide us with complete pictures of the consequences of adapting any particular behavior or technology – reducing the selection problem to one of weighing different kinds of impacts against one another. Consequently, LCAs are now frequently invoked in sustainability discourses[5] and decision-making processes. Often in good faith, to identify optimal courses of action. Other times opportunistically, to advance vested or ideological interests.

Yet despite their rising prominence – both in decision-making processes, and in the discourses through which some behaviors and technologies come to be coded as 'sustainable' and others as 'unsustainable' – scarce attention has been paid to the role of LCAs as political and discursive instruments. Or to the epistemic power wielded by those who influence their production and interpretation. LCA seems to fly, as Merry (2016) writes of the production of numbers in general, "under the radar of social and political analysis as a form of power" (p.5).

Aguste Comte famously described the purpose of social science as 'know in order to predict, predict in order to control [the societal consequences of decisions]'. The impetus for this theses is the hope that a fuller understanding of the uses and abuses of LCAs might allow us to better predict (and ultimately avert) their unintended negative consequences. Against this backdrop, this thesis will address how LCAs are used by different actors to advance or undermine particular transition pathways; how calculated impacts correlate with physical 'real-life' impacts; and how they influence attitudes, behaviors, and decision-making. In short: the role of LCA in the social construction of sustainability. This problem is broken down into three research questions:

1) How valid is LCA as a mechanism of sustainability metrication[6]?
2) How are LCAs used in sustainability discourses?
3) How are LCAs used in decision-making processes?

The first question is addressed through a critical appraisal of the extant literature on climate metrics and life cycle assessments. The second question is addressed through two case studies from Norwegian sustainability discourse: the 2019 debate about a managed decline of petroleum production; and the 2007 – 2019 debate about a managed transition from plastic to paper bags. The third question is addressed through a combination of document analysis and open-ended interviews with representatives of local authorities in the county of Rogaland. Due to space restrictions, the assessment is limited to LCAs of climate impacts.

The thesis is organized into eight main sections. Section 2 outlines the conceptional lenses through which the research questions will be assessed. These are social constructionism, science and technology studies (STS), and the ethics and sociology of quantification. Section 3 describes how data was collected. Section 4 reviews the extant literature on the quantification of climate impacts, and critically appraises its validity and societal consequences. Sections 5 and 6 describe the role of LCA in Norwegian sustainability debates and policymaking, respectively. Section 7 examines these findings through the conceptual lenses outlined in section 2. Finally, section 8 closes the ring by applying this examination to answer the research questions and propose further avenues for research.

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[5] This term will be used in the broad sense suggested by Jasanoff (2021) as "how we talk about a set of issues".

[6] I.e. as a means for operationalizing "sustainability" as a rank-ordered metric

2 Theory

This section outlines the conceptual lenses through which the research questions will be assessed. It consists of three subsections. The first (2.1) addresses social constructivism and its applications to sustainability. The second (2.2) addresses the role and nature of expertise as depicted by science and technology studies (STS) and recent scholarship about expertise in Norway. The third (2.3) addresses some key insights from the ethics and sociology of quantification. With a slight mix of metaphors, these lenses may be described as assembled into a series circuit (as opposed to a parallel circuit); or a single "telescope" through which the empirical findings of sections 4 through 6 will be examined.

2.1 Social constructionism

Social constructionism is a theoretical framework for understanding the development, transmission, and maintenance of ‘knowledge’ – defined, not in an ontological sense, but as “whatever passes for 'knowledge' in society” (Berger and Luckmann, 1967: 26). This thesis will apply what Burningham and Cooper (1999) refer to as ‘mild’ constructionism, which – unlike its ‘radical’ counterpart – acknowledges the existence of a material reality, independent of our conceptions. For present purposes: that certain technologies and behaviors truly are more environmentally, economically, and/or socially benign than others. Yet this material reality will be of secondary interest. Instead, the emphasis will be on how knowledge about sustainability emerges through discourses, solidifies into taken-for-granted assumptions, and comes to ‘structure’ our behavior (roughly speaking: influence the routines and habits that make up most of our day-to-day behavior).

Adopting the terminology of Sismondo (2010), the noun ‘construct’ will refer to the conceptual edifices (or ‘representations’) we impose upon phenomena in the world, while the verb ‘to construct’ will refer to the process of erecting such edifices. Hacking (1999) illustrates the concept by contrasting the abstraction ‘*women refugees*’ with a particular woman in flight. Although he finds it absurd to describe the particular flesh-and-blood woman as a construct, he sees our conception of her as a ‘*women refugee*’ as one. As a ‘*women refugee*’, we know her to be, among other things, more helpless, and worthy of compassion and trust than her male counterparts, and importantly “not violent, so there is no need for guns, but there is a great need for paper, paper, paper” (p.10).

By influencing the meanings and assumptions we attach to phenomena, constructs affect the ways in which we think about, talk about, and ultimately act upon the world. In the prose of Demeritt, (2001), they “make existence manifest, throwing us into a particular world of order and intelligibility” (p. 311). One example, provided by Kuhn (1979), is a person who is unfamiliar with the construct ‘electricity’. This person may observe the movements of an ammeter needle, but cannot see that ‘an electric current is passing through the circuit’. Another example, provided by Searle (2006), is a person[7] who is unfamiliar with American football. This person may observe a man “carry the ball across the line”, but cannot see him “score a touchdown” (p. 20).

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[7] Originally dog

The term ‘social construction’ was coined by Berger and Luckmann (1967), in reference to the processes through which knowledge is “developed, transmitted, and maintained in social situations (..) in such a way that a taken-for-granted ‘reality’ congeals for the man in the street” (p. 15). Their discussion centered on ‘social reality’; the institutions and structures that arise as emergent properties of collective (but often uncoordinated) action. Later works extended the metaphor to a range of other phenomena.

For Hacking (1999), the proposition “X is a social construct” roughly translates into “in the present state of affairs, X is taken for granted, [yet] X need not have existed, or need not be at all as it is. X, or X as it is at present, is not determined by the nature of things; it is not inevitable” (pp. 6-12). He then urges his readers not to get too hung up on the definition, but instead ask “what’s the point?” (p. 5). Describing X as a social construct, he suggests, is first and foremost an attempt to challenge the status quo, by unmasking our prevailing conceptions of X as upshots of historical contingencies, rather than the one true way of looking at X.

Consider ‘*the climate’* as an example. Defined as “the average weather conditions of a region over a period,” (Mayhew and Penny, 1992: 37), a ‘*climate*’ is a statistical abstraction. ‘*The climate’* (i.e. the aggregate of all regional climates) is thus an aggregate of statistical abstractions. The apparent matter-of-fact existence of this aggregate, as a governable entity in the world, imbued with moral significance, and worthy of our concern; may be seen as “an artifact of certain social practices and conventions” (Demeritt, 2001: 312). The ongoing changes to ‘the climate’ (i.e., ‘climate change’) are roughly speaking constructed as a ‘global problem’, caused by ‘human activity’, confronting an undifferentiated, global ‘us’ (if not ‘future generations’), in need of more research, and something ‘we’ (or again, ‘future generations’) will have deal with eventually (but, importantly, not right now!).

This construct has been criticized on several accounts. Some (e.g. Agarwal and Narain, 1991; Demeritt, 2001) have criticized it for masking regional differences in burdens and responsibilities. For many southern and island nations, climate change represents an existential threat. For many northern ones, it represents merely an inconvenience. For some, it might even represent an opportunity. Since the expected temperature rise in any given region correlates inversely with the region’s own accumulated greenhouse gas emissions (see Figure 2.1.1), climate change might more appropriately have been constructed as ‘a problem confronting people in the Global South, caused by people in the Global North’.

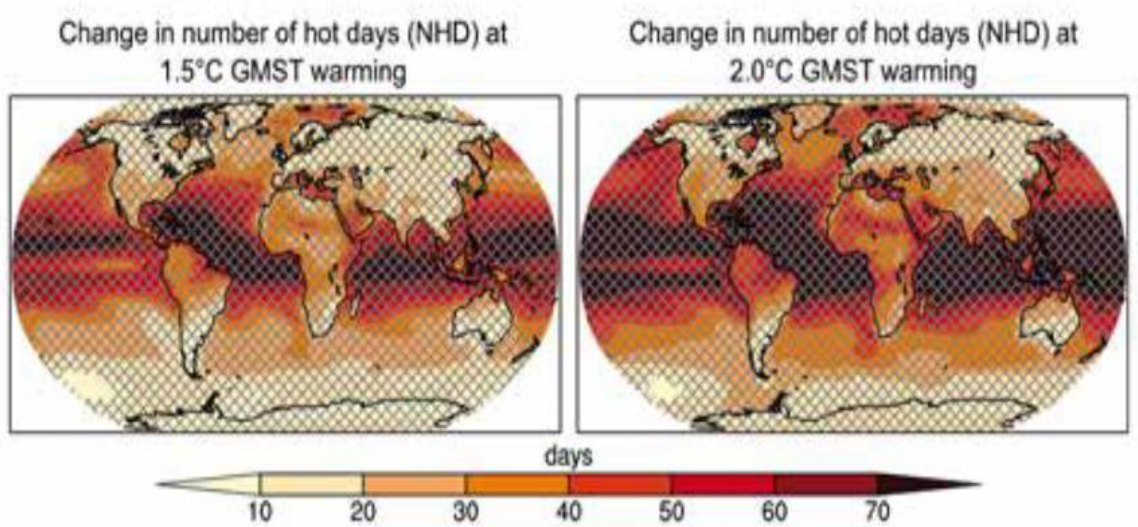

Figure 2.1 1 Projected changes in the number of hot days (Hoegh-Guldberg et al., 2018: 193)

2.1.1 The social construction of Sustainability

"Sustainability" is a remarkably volatile and elusive construct. Over decades of unrelenting concept creep, it has evolved from its origins in Our Common Future – as a term for "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*" (WCED, 1987: 37) – into a sprawling, nested hierarchy of different environmental, economic, and social subconstructs; encompassing more or less everything of societal value. Environmental sustainability[8], for instance, encompasses such subconstructs as decarbonization, circularity, and preservation. Decarbonization, in turns, encompasses such lower-tier subconstructs as near-zero carbon, net-zero carbon, and carbon neutrality – all defined in terms of even-lower-tier subconstructs like CO_2-equivalents, and carbon offsets.

In many cases, the behaviors and technologies that are conceived of as 'environmentally sustainable' map more or less perfectly onto those that cause the least environmental degradation. Photovoltaic cells, for instance, are appropriately conceived of as more sustainable than coal-fired power plants. In other cases, the mapping is less than perfect. Although sustainability is more appropriately conceptualized as a spectrum than a dichotomy, Figure 2.1.2 provides a stylized illustration of this partial overlap.

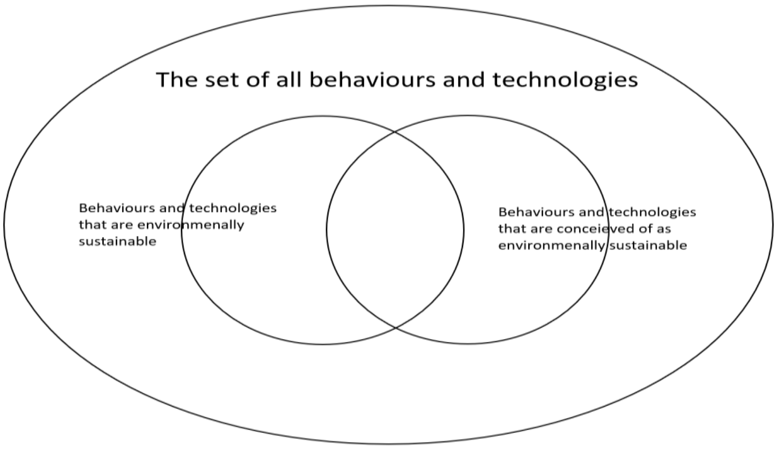

Figure 2.1 2 Venn diagram of behaviors and technologies that are sustainable or conceived of as sustainable

Consider, as an example, the choice between driving a car and riding a bus. According to our collectively taken-for-granted assumptions, the bus ride should entail less environmental impacts than the car ride. The bus ride is, in other words, socially constructed as the more sustainable option. This assumption will often, but not categorically, be correct. The relative impacts of these modes of transportation will depend, among other factors, on the sizes, fuel sources, and fuel efficiencies of the particular vehicles in question, as well as on the average number of passengers for the particular buss-route.

According to the Norwegian Census Bureau (SSB), the average carbon intensity of transporting one person one kilometer tends to be slightly higher for cars than for busses

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[8] If I were to be meticulous, I would again put quotation marks around "sustainability", as well as around "circularity", "near-zero carbon", etc., and do so every time I refer to the concepts, rather than their referents. Yet this would be stylistically awkward. Instead, I will take a cue from Berger and Lockman (1967) and sacrifice a little meticulousness for a little style, and (mostly) let the quotation marks be there "logically, if not stylistically" (p. 14).

(SSB, 2019). But in 2018, the opposite was true. That year, the carbon intensity of an average bus ride was 4,3 % higher than that of an equivalent car ride. One might furthermore expect certain underutilized bus routes to have consistently higher carbon intensities than an equivalent car ride.

Yet making such judgments on a case-by-case basis, every time I need to get somewhere, would be unfeasible. While I am surely "capable of engaging in doubt about [the sustainability of riding the bus]", to put it in the words of Berger and Luckmann (1967), and might indeed sometimes do so, I am nonetheless "obliged to suspend such doubt as I routinely exist in everyday life" (p. 37). The bus "proclaims itself" as the more sustainable option, and I can only challenge this proclamation by engaging "in a deliberate, by no means easy effort" (p. 37), which I never do in the spur of the moment. As I go through my everyday life, I act as though I knew the bus to be the more sustainable option.

As another example, I may intellectually doubt the environmental benefits of recycling my household waste. Yet I routinely suspend of this doubt anytime I need to dispense of it, letting the established knowledge that 'recycling is sustainable' structure my everyday behavior, regardless of any intellectual doubt.

Knowledge of this sort is "shared unproblematically with others" in my life, and in sum constitutes our shared understanding of what it means to lead a sustainable lifestyle (Andrews, 2012:41). For those of us who self-identify as environmentalists, these choices become opportunities to enact our identity, and signal loyalty towards in-groups. Hence, we experience them as our default options. The real-life environmental benefits of said options – or our intellectual doubts thereof – become secondary concerns.

The ability to influence which behaviors and technologies are coded as 'sustainable', and which are not, thus entails considerable amounts of power. Some of this power is vested in public officials, scientists, and pundits. Some, inevitably, in "those with the deepest pockets [who] can purchase the most evidence and disseminate it more efficiently" (Di Fiore et. al, 2021:16) As discussed in the following section, the wielders of this power can be sorted into the partially overlapping categories of 'experts' and 'claims-makers' (Andrews, 2012; Yearley, 1991).

2.2 The role and nature of expertise[9]

Expertise, as defined by Sismondo (2010), is "the ability to make (what are perceived as) good judgments" within a particular domain (p 139). In contemporary societies, this ability is largely vested in accredited professionals who devote themselves full-time to understanding some narrow topic, and in turns "lay claim to novel status and claim ultimate jurisdiction over that knowledge" (Andrews, 2012: 40). For present purposes, LCA practitioners can be considered as experts; and their produce as expert knowledge.

The term 'claim makers' refers to actors who introduce new claims into debates or decision-making processes, or who signal boost (i.e., help spread) or challenge claims that have already been introduced (Yearley, 1991). This group partly overlaps with that of experts, but not all

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[9] This section draws in part on STS literature, in part on the book 'Ekspertenes inntog' (Christensen and Holst, 2020). All quotations from this book are original translations from Norwegian.

experts partake in these processes; and not all those who do partake are experts. For present purposes, policymakers, bureaucrats, activists, lobbyist, academics – and anyone else who might introduce a new LCA into an environmental debate or signal boost or challenge ones that have already been introduced – constitute claims makers.

Members of these groups enjoy different levels of 'epistemic authority', i.e., the ability to make respected claims. The more epistemic authority someone has with regard to a particular topic, the more their voice is heard over those of others in conversations about this topic (Sismondo, 2010). Epistemic authority is gained and monopolized through 'boundary work': i.e., the processes of constructing, challenging, or defending the boundaries between those whose opinion matter and those whose opinion may be discarded. Examples include the boundaries between 'experts' and 'laymen'; and between 'science' and 'pseudo-science'. Attempts to gain epistemic authority are referred to as 'expansionary' boundary work, while attempts to monopolize it are referred to as 'exclusionary' boundary work. Creationists engage in the former when they vie for scientific legitimacy, while Darwinian biologists engage in the latter when they sabotage these efforts.

Boundary work is by no means a trivial exercise, but one with profound consequences for decisions about school curriculums, research funding, and who gets "called before courts and government hearing rooms to provide putatively truthful and reliable contexts for decision making" (Gieryn, 1983: 784). Those who are regarded as experts are, moreover, often called upon to help solve policy issues within their domains of expertise. During the Great Recession governments sought the expertise of economists. During the Covid-19 pandemic, they sought the expertise of epidemiologists.

Experts may also be called upon for more symbolic or 'ceremonial' reasons. Legislators may already have decided on a policy – perhaps for ideological or partisan reasons – but enlist experts in order to create the appearance of evidence-based policymaking (Christensen and Holst, 2020). If the expert advice happens to align with their predetermined policy, this can now be framed as technical and evidence-based. This shields it from criticism, and helps legislators off the hook if something goes wrong. If it fails to align, it can often just be stuffed away in a drawer. Examples from Norwegian policymaking include the recommendations of the expert commissions 'Lavutslippsutvalget' to launch a national information campaign about climate change (NOU 2006: 18); and of 'Barnefamilieutvalget' to implement tuition-free kindergartens (NOU 2017: 6). Both stuffed away by the legislators who commissioned the reports.

2.2.1 Pitfalls of expertise

Since experts rarely speak with one voice, any particular piece of 'expert knowledge' can be seen as colored by the particular biases of the particular experts who produced it. Economists are, for instance, often accused of producing knowledge with a right-wing bias, while sociologists are accused of producing knowledge with a left-wing bias. The power to select the experts who get to produce the evidence on which some particular evidence-based policy will be based, thus often entails the power to predetermine the resulting evidence.

This inversion of the ostensible purpose of expert advice is sometimes derisively referred to as 'policy-based evidence making'. Christensen and Holst (2020) give the example of an expert commission on capital tax reform. If the government leans left, it may pick experts who advocate capital taxes. If it leans right, it may pick ones who oppose them. In either case, policymakers can reasonably expect to receive "expert advice" that aligns with their own agenda.

For Christensen and Holst, policy-based evidence making is a concern – not only with regard to expert commissions – but also for what they refer to as the broader 'knowledge regime': "the entire landscape of organizations and institutions that produce and distribute knowledge to decisionmakers" (ibid: 56). One example is think tanks. These institutions are often financed by donors, who expect a return on their investments in the form of knowledge that vindicates their vested or ideological interests. The labor union 'Fagforbundet', for instance, once threatened to withdraw its funding of the think tank Agenda, after its assessment of the European Economic Area (EEA) reached the "wrong conclusion". (ibid: 118). One representative of a Norwegian think tank, interviewed by Christensen and Holst (2020), even explicitly described his own employer as "a political ammunition factory", and its research methodology as "cherry picking research that supports our own world view" (p. 118).

Similar concerns have been raised about the knowledge produced by for-profit research institutions and consultancies. According to Lundh et al. (2017), writing about the pharmaceutical industry in particular, "several systematic reviews have documented that pharmaceutical industry sponsorship of drug studies is associated with findings that are favorable to the sponsor's product» (p. 5). Industry sponsors can influence the outcome of such studies through "the framing of the question, the design of the study, the conduct of the study, how data are analyzed, selective reporting of favorable results, and spin in reporting conclusions" (p. 5).

Or consider, as another example, ecological consultants working for windfarm projects. Thunold at al. (2021) interviewed several members of this profession, who shared their experiences of feeling pressured by project managers to tone down their findings, and of being passed over for future projects if they refused to play ball. Indeed, a 2015 investigation by the Norwegian Energy Authorities (NVE) found independent ecologists to report, on average, "more than twelve times as many red-listed species" as those employed directly by windfarm developers (Thunold, 2021).

Oreskes and Conway (2010) coined the term "Merchants of Doubt" to describe experts who rent out their epistemic authority to help clients cast doubt on inconvenient scientific findings. Examples include the Tobacco Industry Research Committee which, for decades, funded contrarian research that challenged the mounting scientific consensus about the hazards of tobacco smoke.

Some STS scholars even go so far as to suggest that "science in the policy setting is *always* colored by values [emphasis added]" (Jasanoff, 1990: 7). From this point of view, "mandated" or "regulatory" science – that is science produced for regulatory purposes – has distinctive features, relative to "pure" or "research" science, that "must be attributed to the fact that scientific and policy considerations are closely integrated at every step in its production and use" (p. 6).

Claims that are coded as 'scientific' generally command more epistemic authority than those that are not. Describing a claim as 'scientific' is thus not simply a way of saying: 'this claim was produced by an epistemic practice that conforms to a set of necessary and sufficient conditions that unequivocally demarcates science from non-science'. Often, it is a way of saying: ‘please treat this claim with respect!’ Due, in part, to the intimate bond between science and numbers, some of this authority rubs off on quantitative claims in general. Those who wish to enhance the authority of their claims may thus want to formulate them quantitatively. Against this background, the following section will outline some key theorical and empirical insights about the role and authority of quantitative claims in contemporary societies.

2.3 The Ethics and Sociology of Quantification

Quantification is by no means a novel phenomenon. Bones dating back as far as 30,000 BCE bear scratch marks thought to represent quantities (Stewart, 2020), and every civilization in history was to some extent ruled through data: “data about people’s incomes and possessions; data about payments made; data about arrears, debts and fines; data about discounts and exemptions” (Harari, 2011: 137). Neither is our reverence for numbers new. Throughout the ancient world, traditions like numerology, gematria, and astronomy employed numbers as arbiters of divine Truth (Ravetz, 1997). Philosophical schools like the Platonists revered them as more real than material objects. Cults like the Pythagoreans venerated them as one might a deity.

What *is* new, is the volume, standardization, and authority of quantitative claims. These trends can be traced back to the scientific revolution, but were brought into full gear by the digital one, which allowed “data to be amassed, stored, searched and processed at once unimaginable speeds and volumes” (Jasanoff, 2011: 23). In response to these trends, new academic subdisciplines like ‘the sociology of quantification’ (Espeland and Steven, 2008) and ‘the ethics of quantification’ (Saltelli, 2020), have emerged. Although social scientists have studied quantification as a social phenomenon since, at least, the 1970’s (see, e.g. Campbell, 1976), the emergence of these specialized subdisciplines were in large spurred by the landmark publication of Theodor Porter’s 1995 book “Trust in numbers”.

In this seminal work, Porter chronicles how the role and nature of quantification evolved over the past two centuries. One example he provides is the bushel of grain. Traditionally, every region, sometimes every town, had its own local bushel standard. Any particular bushel could in principle be verified by having its contents poured into the official one. Yet defining the size of ‘a bushel of grain’ was never an objective or impersonal task. The mass of grain contained by a bushel depended, among other factors, on the height from which the grain was poured (greater height entailed denser packing), and the size of the heap. “Even flattened bushels would contain variable amounts depending on whether the strickle was applied with or without pressure. There was always room for power, negotiation, and fraud in determining the size of the heap” (Porter, 1995: 24). It furthermore depended on ones standing in local hierarchies of privilege and power. “Noble seigneurs almost always received their rents and feudal dues in heaped bushels. The more enterprising ones would periodically introduce a new bushel vessel. Even if it had the same interior volume as its predecessor, it might be made lower and flatter, so that it could support a larger heap” (p.25).

Porter attributes the transition to standardized units of measurement to the centralization of political authority and the rise of capitalism. The idiosyncratic and perpetually evolving nature of traditional units constituted, not only a grievance to local peasants, but also a barrier to centralized tax collection and trade. Even comparatively centralized states, like Ancien Régime France, “faced innumerable jurisdictions with their own measures. (..) Silk would be exchanged in different measures from linen, and milk from wine. None of the measures were decimalized. Neither was coinage. The arithmetic could be so complicated that even local merchants would be pressed to the limit of their skills" (ibid: 25).

Many professions that are now conceived of as more or less constituted by standardized methods of calculation (e.g., accountancy, engineering, and actuary) traditionally relied more on expert judgment, to which calculation was used as an ad hoc supplement. The transition to standardized regimes of calculation was, by Porter's account, not initiated by the disciplinary experts themselves as a means to improve the quality of their work. On the contrary; these practitioners generally detested standardized calculation, both as a poor substitute for expert judgment, and as a threat to their status as gentlemanly professionals. Instead, they were initiated by powerful outsiders – such as parliamentary commissions – who sought standardization as a means of oversight and regulation.

In the terminology of Searle (2006), these outsiders favored epistemic over ontological objectivity. Consider, as an example, the calculation of discharge into a river. Central authorities require all polluters to calculate their discharge in the same manner, so that these can be aggregated and compared against safe limits. If some particular agent decided to unilaterally implement a more stringent and ontologically objective approach, this might well have improved the validity of the numbers produced. But since these numbers would have been incommensurable with all others, they would have been of little use. Less valid numbers, produced by a standardized methodology, are preferable from a regulatory point of view.

Porter attributes the devaluation of ontological objectivity, more generally, to the breakdown of traditional hierarchies. "The willingness to insist on standardizability, even where it violates the best judgment of expert practitioners will rarely be found except in fields that are highly vulnerable to criticism from outsiders" (ibid: 97). Where experts are elites, he concludes, "they are trusted to exercise judgment wisely and fairly"; where they are not, "they are expected to follow rules" (ibid: 195). Merry (2016) similarly sees this transition as a result of democratization. In a democracy "the producers of knowledge must be held accountable, which requires information to be produced in a 'correct' manner and not sullied by the vested or ideological interests of the practitioner" (p. 3).

2.3.1 Pitfalls of quantification

The ethics and sociology of quantification is replete with examples of the pitfalls of their subject matter. Recurrent themes include operational definitions with poor construct validity vis-à-vis the colloquial meanings of terms; the 'black-box' nature of models which makes them hard for non-experts to challenge; the crowding out of non-quantifiable knowledge; and the often unwarranted authority commanded by quantitative truth claims.

Merry (2016) attributes the poor construct validity of many prominent metrics to a sort of Gresham's law of metrics. Competing attempts to quantify the same phenomenon have to compete for prominence in a "competitive marketplace of indicators", in which simplicity, coherence, and narrative fidelity are in higher demand than validity (p. 13). Metric creators can optimize for either construct validity or market competitiveness; and those who opt for the latter tend to outcompete those who opt for the former. The winners tend to be "highly simplifying composites, which present information in a simple and unambiguous way without a great array of qualification and methodological discussion" (ibid). Through frequent repetition by the media, politicians, and over the lunch table, these winners come to socially construct the concepts they espouse to indicate, providing “an apparently objective way of understanding the world. (p. 138).

One example, provided by Saltelli (2020), is the Ecological Footprint (EF) which he criticizes by asserting that “the impact of human activity on the planet is too complex to be captured by a single number”. He describes the concept of an annual ecological budget as “incredibly optimist against all those impacts which are irreversible”; and dismisses the calculated footprint of ‘1.75 planets’ by claiming that this number could just as well have been “twenty or two hundred or infinity (…) depending on what impacts are measured” (p. 3). More nuanced metrics of ecological impact are indeed proposed from time to time; only to be crushed by EF in the marketplace of indicators (Zhang et al., 2017).

Once an indicator has taken root in the popular imagination, it often gets reified (i.e., mistaken for a perfect representation of that which it was meant to indicate). If the unemployment rate is calculated as 5 %, then it becomes true that ‘5 % of the workforce is unemployed’. If GDP growth is calculated as 3 %, then it becomes true that ‘the economy grew by 3 %’. If the EF is calculated as 1,75 planets, then it becomes true that ‘we would need 1,75 planets to sustain our current level of consumption’. Alternative conceptualizations of ‘unemployment’, ‘the economy’, or ‘ecological capacity’ become irrelevant, as the dominant metric “gradually becomes an accepted ‘black box’ that no longer needs to be explained or justified” (Merry, 2016: 85). A campaign-promise to stimulate the economy is not fulfilled unless GDP rises. A promise to create jobs is not fulfilled unless the unemployment rate falls. Defending one’s record by appealing to alternative metrics, would come across as bad faith.

Merry (2016) attributes the hegemony of established metrics to what she terms ‘data inertia’ (new ways of measuring phenomena are costly, time consuming, and undermines comparison over time), and ‘expertise inertia’ (past decisions about who counts as experts and how experts are trained influences future expert pools). She illustrates these concepts be detailing her first-hand account of the sausage-making that went into constructing the UN indicators for violence against women, human trafficking, and human rights compliance. Experts from “countries with a history of statistical work” (p. 209), i.e. the Global North, tended to dominate these processes, frame the questions, and propose the answers. The new indicators often ended up being derived from domestic ones that they had previously been involved in constructing. Representatives from the Global South, who often lacked this experience, were largely sidelined. This set in motion a vicious cycle whereby members of the former group gained experience in leading international indicator projects, further widening their expertise gap vis-à-vis those of the latter group. These experts would then go on to lead future international indicator projects, or train the next generation of indicator creators.

As the status of quantitative knowledge claims rose over the past century, so did the influence of those who produced them. This was particularly true for the most quantitative of social sciences; economics. Christensen and Holst (2020) describe how the representation of economists in Norwegian Public Commissions (NOU) doubled over the past 50 years, from roughly 15 % in the 1970s to more than 30 % in the 2010s. The authors see this concentration of epistemic power as problematic on three grounds. Firstly, empirical studies have shown economists to be more technocratic than other social scientists – that is, more likely to think that they know best what the true interests of society are. Secondly, economist tend to be blinder than other social scientists to the methodological limitations of their own discipline. Thirdly, they are often seen as dismissive of the contributions of other social scientists.

Poor construct validity is also endemic in economics, including in environmental cost-benefit analysis. Examples include Nordhaus (2006), who tried to calculate the economic cost of climate change by extrapolating historical correlations between regional temperature variations and economic outputs – to scenarios of multiple degrees of global warming. By assuming an invariant "cross-sectional relation between temperature and output" (i.e., that the functional relationship between regional average temperature and economic output would hold for any amount of global warming), he calculated the economic cost of 3°C warming as "on the order of a few percent of global GDP", and found the optimal amount of warming to be 3,5°C (Royal Swedish Academy of Sciences, 2018: 40).

According to critics like Pindyck (2013), such calculations rely on "completely ad hoc" estimates of economic impact "with no theoretical or empirical foundation", while ignoring "the most important driver of the [social cost of carbon], the possibility of a catastrophic climate outcome" (p. 36). It is perhaps telling that the two most cited IAM-based estimates of the social cost of carbon – 'Nordhaus's best parameter guess' and 'The Stern Review' – deviate by an order of magnitude: USD 29.50 vs. USD 256.50 per ton, respectively (Royal Swedish Academy of Sciences, 2018: 37). Anyone who wants to advocate a particular level of carbon taxation is thus free to cherry pick the study that vindicates one's predetermined conclusion.

Sarewitz (2015) attributes the authority such numbers nonetheless command to the cultural conditioning of moderns to interpret numbers "derived from the scientific study of something real in the world" as directly corresponding to that something (p. 135). I.e., our conditioning to expect quantitative claims like "electrons weigh 9,11E-31 kg" to track reality more closely than qualitative claims like "electrons are like tiny marbles". When such nebulous constructs as 'the social cost of carbon' – whose best estimates vary by an order of magnitude – are nonetheless expressed numerically with three or more significant figures; they leech onto the "social and epistemological status" of scientific measurements and our "conventional notions of what numbers are supposed to tell us about real worlds" – to make unwarranted claims to authority (ibid: 143).

From a regulatory perspective, the essential characteristic of such numbers is that they "really are the creation of true science, carried out by the best experts, using the latest knowledge and methods, often involving enormous amounts of carefully measured data, vetted through the appropriate review processes and so on" (ibid: 140). These activities, Sarewitz describes as ritualistic; "the activity that a modern, rational society is supposed to undertake in order to help structure and focus action in the world" (ibid). While the resulting numbers are described as "the sacred product of the ritual, a totemic symbol whose value is ensured and protected by the shared scientific norms that govern the conduct of the ritual, norms which in turn imbue the number with the legitimacy that allows so much activity to be organized around it" (ibid).

Romer (2015) criticizes what he refers to as the "mathiness" of much contemporary modelling. Unlike traditional modelling, which "used math to explore abstractions (..) with clarity, precision, and rigor" (p. 93), he sees contemporary modelling as littered with oversimplification, false premises, poor construct validity, and theoretical constructs with no referent in the real world. Mathiness, he argues, allows modelers to 'prove' any given proposition with ostensive mathematical rigor.

The rationale for mathiness, he takes to be partially political. Since academics tend to ignore arguments that are transparently political, those who seek to promote an agenda may decide to dress it up in the language of mathematical formalism. The apparent objectivity of this language then permits such arguments to be taken seriously. Many prominent metrics have indeed been accused of being politics masquerading as science. One example is the Freedom in the World index, published by Freedom House, which was described by Herman and Chomsky (1988) as a "virtual propaganda arm of the [US] government" (p. 28) and accused of systematically inflating the scores of nations aligned to US interests. Another example is the Index of Economic Freedom, published by the Heritage Foundation, which was accused by Miller (2005) of artificially inflating the scores of prosperous countries in order to fabricate a statistical correlation between 'economic freedom' and 'prosperity'.

The main rationale for Mathiness, however, Romer takes to be careerism. Why put in "the hard work that it takes to supply real mathematical theory" (Romer, 2015: 90), if your competitors don't, and readers don't care? Putting in this extra work would just slow down your rate of publication and leave you behind less scrupulous peers. Projecting forward, he envisions an imminent collapse of the market for rigorous modelling, comparing the budding market equilibrium to that of card tricks. "Everybody knows that there will be some sleight of hand. There is no intent to deceive because no one takes it seriously. Perhaps our norms will soon be like those in professional magic; it will be impolite, perhaps even an ethical breach, to reveal how someone's trick works" (p. 93).

Quantitative truth claims moreover have a tendency of hiding, like a smoke screen, the ambiguities of real-life decision making contexts; and of crowding out their qualitative counterparts. "What gets counted counts", as the saying goes; "while what doesn't get counted doesn't count". One example, provided by Taleb (2010), is the trust financial regulators tend to put in macroeconomic models, which – by their very nature – cannot account for non-quantifiable risks. He attributes the Great Recission, in part, to the unwarranted trust put in the forecasting abilities of such models.

Such models, as well as their outputs, are often referred to as 'black boxes'; a term derived from the boxes used in flowcharts to denote devices or systems for which the reader doesn't need to know anything except the inputs and outputs (Latour, 1987). Metaphorically speaking, any fact "whose ultimate source is not understood by those who apply it" (ibid: 131) may be regarded as a black box. Within the confines of disciplinary expert communities, metrics for economic freedom, ecological footprints, and human rights compliance are open boxes whose inner workings are understood and hotly debated. Outside of these confines, they are matters of fact that structure the worlds we inhabit. Not only do most of us lack the time and expertise required to challenge them. We may not even conceive of them as social constructs subject to challenge; but simply as truth.

A final pitfall is what Muller (2018) refers to as 'metric fixation': goal displacements due to misaligned incentives among "workers who are rewarded for the accomplishment of measurable tasks [and therefore] reduce the effort devoted to other tasks" (p. 169). A corollary of this pitfall is known as either Goodhart's law or Campbell's law, after the two social scientists who formulated it independently. It states that as soon as an indicator gets used to evaluate performance, it ceases to be a valid indicator, because at that point subjects will begin to game it. The textbook example is high-stakes testing in schools. For Campbell (1976), such testing "may well be valuable indicators of general school achievement under conditions of normal teaching aimed at general competence" but loses this value "when test scores become the goal of the teaching process," and educators start to "teach to the test" (p. 87).

3 Materials and methods

This section describes the empirical work that lays the foundation for the subsequent sections. In short: qualitative data was collected through a combination of document analysis and unstructured interviews and analyzed with the concepts introduced in section 2.

Section 4 reviews the extant academic literature on the quantification of climate impacts. The assessment aims to demonstrate that climate impacts cannot, in general, be quantified in an objective way, but that the prevailing way of doing so has congealed as a taken-for-granted 'reality' in the popular imagination. I.e., that it is a social construct. It furthermore aims to assess the validity and consequences of the prevailing ways of constructing climate impacts.

Section 4.1 describes the challenge of rendering different types of GHG emissions commensurable and expressed in a common unit (conventionally, tons of CO_2-equivalents). Materials are culled primarily from the first five IPCC Assessment Reports (FAR, SAR, TAR, AR4 and AR5), as well as from more recent papers. Further materials are draw from debates among climate scientists and commentators over the pros and cons of competing ways of operationalizing climate impacts.

Section 4.2 follows this up by outlining the LCA methodology, and reviewing the extant literature on its validity and limitations. This review was conducted by searching academic databases and search engines (e.g., JSTOR and Google Scholar) for phrases like 'LCA criticism', 'LCA validity', and 'LCA policy'. Initial papers were selected based on their apparent relevance, based on titles, abstracts, and citation counts. Subsequent papers were then culled from the reference lists of these initial papers.

Section 5 addresses the role of LCA in the Norwegian sustainability discourse. Media content was culled from the database Retriever ATEKST, while documents from agencies and NGOs were culled from their respective websites. Searched phrases included 'LCA', 'Livssyklusanalyse', 'Livsløpsanalyse', 'CO2e', 'Klimaavtrykk', 'Klimagassavtrykk' and 'Klimagassregnksap'. Due to time and space limitations, the search was limited to the period 2010-2022. Earlier publications were only included if they were cited by publications from this period.

The sustainability debates in which LCA seems to have played a substantial role, include those related to transportation, nutrition, petroleum, clothing, grocery bags, and construction materials. Space limitations compelled the choice between a brief description of each debate, or a deeper dive into a few selected cases. The former alternative might have entailed more external validity, and rendered a greater set of patterns, commonalities and variety open for discovery. Yet since this is an exploratory inquiry into a largely neglected and undertheorized subject matter, the latter alternative was chosen. The cases selected for assessment are the 2021 debate about a managed decline of Norwegian petroleum production, and the 2007 - 2019 debate about a managed transition from plastic bags to paper bags. These were selected due to their contrasting characteristics; in order to showcase some of the richness of the set of possible roles LCA might play in such debates.

The cases are assessed through the conceptual lenses outlined in the section 1. For this purpose, 'thick' descriptions are given, i.e. ones that tries to account for "the context of the action, the intentions of the social actors, and the processes through which social action and interaction are sustained and/or changed" (Blaikie and Priest, 2019: 206). The exact use of these lenses varies depending on the particular characteristics of the particular cases. Most of the referenced texts were originally published in Norwegian, and direct quotations are thus original translations into English.

Subsection 5.1 addresses the 2021 debate about a managed decline of Norwegian petroleum production. This is an interesting case study for several reasons. Firstly, because its participants actually invoked consequential LCAs (CLCA), rather than attributional LCAs (ALCA). As discussed in section 4.2.2, the appropriate use of ALCA is for allocating environmental burdens in an accounting sense, while the appropriate use of CLCA is for comparing the environmental impacts of alternative decisions. Yet all the other cases surveyed for this thesis involved the use of ALCA, which were presented as if these revealed the environmental impacts of alternative decisions. Secondly, the debate was a interesting display of two rival epistemic communities duking it out in front of a mainstream audience, often sliding into semi-technical discussions about price elasticities and absolute vs. marginal values, while competing for epistemic authority. It was furthermore surrounded by an interesting meta-debate about motives, credibility, and the power to decide who gets to decide on the evidence.

Subsection 5.2 addresses the 2007 - 2019 debate about a managed transition from plastic to paper bags. This debate is interesting due to its idiosyncrasies vis-à-vis the other cases surveyed. Firstly, it seems for the most part to have been a good-faith attempt by all sides to get at the truth. As such, it provides some insight – unique among the cases surveyed – into how such debates may play out in the absence of claim makers with proverbial ‘dogs in the fight’; i.e., incentives to manufacture doubt or self-serving truth claims. Consequently, the debate never disintegrated into a tug-of-war between opposing camps who commissioned or propped up contradictory studies, nor a meta-debate about the motives and credibility of these camps. Instead it remained focused on the object-level question of which carrier bags sustainability minded consumers ought to choose. Secondly, it was an illustrative display of public trust in science and the authority of quantitative truth claims, with arguments essentially boiling down to ‘a research paper has concluded X, therefore X is true’.

Attempts are made in section 7 to gauge how public attitudes changed over the course of the debates. This includes comparing surveys conducted at different points, where such were available. For the case of grocery bags, an attempt was made to gauge changes in consumer behavior from sales data for different types of bags. Sales data were requested from SSB, the Norwegian Environmental Directorate, Norsus and Grønt Punkt; neither of which were able to provide it. In the absence of harder data, this evaluation mostly consisted of gauging how different claim makers wrote about the topics in op-eds, blogs, interviews, etc. The limitation of this approach, as expressed by Sovacool et al. (2018), is that it only reflects the “agenda and biases of those who produced the documents” (p. 29), which might not be a statistically representative sample of the general population. But, insofar as the opinions expressed online influence those of its audience, these opinions might nonetheless be expected to have some external validity beyond the limited sample of claim makers.

Due to space limitations, only a modest subset of the claims made in each debate are included. Since many of the claim makers merely rehashed the same arguments over and over, non-random samples were selected. This ensures that all central claims are covered, and avoids redundant repetition of claims that were echoed by disparate voices. The alternative – selecting a random sample of claim makers from each debate – might have resulted in less representative accounts of the debates, as particularly interesting claims, or particularly loud voices (e.g., those of policy makers, celebrities, or experts) might have been randomly left out. Based on the assumption that such voices bear more weight than those of other claim makers, these were disproportionally selected for during the sampling. An effort was also made to cite claim makers who seemed to capture the distinct moods of the respective debates particularly well.

Although an assessment of the role of LCAs in academic sustainability discourses would have been interesting (see the discussion about nuclear power in section 4.2.3), this will not be included due to space limitations. Individual academic papers and claim makers will only be addressed in so far as their claims bled into public debates and decision-making processes.

Section 6 addresses the role of LCA in decision-making processes. Its object of study is the day-to-day implementation of climate policies among public administrators in the region of Rogaland; particularly those of municipalities (In Norwegian: 'kommuner'). These are interesting in part because many of them have politically mandated, quantitative targets for GHG reductions. E.g., in the case of Stavanger: 80 % reductions by 2030. One might thus expect the administrations to quantify the climate impacts of a range of different activities and projects, in order to find the most cost-efficient path to achieving the mandated cuts. And if this turned out not to be the case, that would be an interesting finding in and of itself.

Data was collected primarily though unstructured interviews with representatives from governmental agencies and municipalities. The sample was limited to the 9 municipalities in Rogaland whose population exceeds 15 000 (see Table 3.1.1) and Rogaland Fylkeskommune (Rogaland county municipality). The municipalities were coded based on population size, as 'small' (< 30 000), 'medium' (30 000 – 60 000) or 'large' (> 60 000), as depicted in table 3.1.1.

Representatives from Klepp, Hå, and Karmøy kommune, declined their invitations for interviews. The representatives from Klepp and Hå kommune responded by writing what amounts to "*we have little to no experience with these tools and therefore don't feel like we have anything to contribute*". The representative from Karmøy wrote a slightly longer response: "*we don't have much experience with LCA and climate budgets. This is something we in the administration wants to use, but the political interest is missing. We are working to implement LCA in construction projects and procurements*". These organizations were thus excluded from the sample through self-deselection.

Municipality	**Population (2020 census)**	**Coding**
Stavanger	145 000	Large
Sandnes	81 000	Large
~~Karmøy~~	~~43 000~~	~~Medium~~
Haugesund	37 000	Medium
Sola	28 000	Small
~~Klepp~~	~~20 000~~	~~Small~~
~~Hå~~	~~19 000~~	~~Small~~
Time	19 000	Small
Eigersund	15 000	Small

Table 3.1.1 Municipalities in Rogaland with a population of 15 000 or more (SSB[10])

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[10] Retrieved from SSB database 07459: «Alders- og kjønnsfordeling i kommuner, fylker og hele landets befolkning (K) 1986 – 2022» Available at: https://www.ssb.no/statbank/table/07459/

For the large and medium municipalities (Stavanger, Sandnes and Haugesund), two or more representatives from different sections of the administration were interviewed. For the small ones (Sola, Time, and Eigersund), a single representative was interviewed.

Interviews were conducted over the period March – May 2022. The interviews were not recorded, out of concern that this might make the interviewees feel self-conscious and hesitant to speak freely. Instead, responses were typed in short-hand form during the interviews, and transcribed immediately after they ended. The interviews were conducted in Norwegian, and all quotations are translations. Only quotes that were typed verbatim during the interviews are cited in quotation marks. Other statements are paraphrased.

Some smaller municipalities only have a single employee who is responsible for all climate gas reporting and abatement efforts. In order to assure anonymity, all interviewees from small municipalities are therefore introduced as e.g. ‘a representative from a small municipality’, and otherwise referred to by the gender-neutral pronoun ‘they’. Interviewees from large and medium municipalities, with multiple employees involved in these efforts, are introduced as e.g., ‘a representative from Stavanger kommune’.

Preparations for the interviews were conducted as follows. (1) reading through the energy and environmental plans of their organizations, and noting any explicit ambitions to calculate or reduce GHG emissions. (2) examining their municipal GHG accounts on the website of the Environmental Directorate, to get a sense of the sectoral distribution and temporal trendlines of their estimated GHG emissions. (3) looking through their recent invoices on the Norwegian database for public procurements (Dofin), to see if they have asked bidders to calculate the carbon emissions of their contract deliverables. (4) searching their websites for phrases like “LCA”, “CO_2” and “klimagassregnskap”. (5) searching the web for the names of the interviewees, to get a sense of their backgrounds and experience with LCA.

4 The quantification of climate impacts

This section describes the scientific and methodological foundation for quantifying climate impacts. It consists of two subsections. The first (4.1) addresses the difficulties in rendering different GHG emissions commensurable and aggregable. The second (4.2) reviews the methodological and critical literature on life cycle assessments (LCA).

4.1 The social construction of CO_2 equivalence

Before emissions of different greenhouse gasses (GHG) can be aggregated or compared, they must first be made commensurable through conversion into a common unit (conventionally, ‘tons of CO_2-equivalents’). Given the heterogeneity of these substances – with respect to absorption rates along the electromagnetic spectrum, atmospheric lifetimes, and patterns of spread and accumulation – this is less than straightforward. As expressed by the IPCC First Assessment Report (FAR), “there is no universally accepted methodology for combining all the relevant factors into a single global warming potential for greenhouse gas emissions” (IPCC, 1990: 58).

CO_2 equivalence might, in principle, have been defined with regard to any step on the causal chain leading from emissions to changes in atmospheric concentrations to radiative forcing[11] to temperature response (Fuglestvedt et. al, 2001). For reasons that will become apparent in subsequent sections, emissions that are deemed ‘equivalent’ in terms of higher steps (e.g. radiative forcing), may differ considerably in their contributions to climate change. The further down the chain one defines CO_2-equivalency, the “greater policy or societal relevance” one thus obtains (Forster et al., 2021: 188). But at the same time, the more uncertainty creeps into ones calculations “because each step in the chain includes more modelling systems, each of which brings its own uncertainty” (ibid). The definition of CO_2 equivalence, in short, “cannot be based on science alone” (IPCC, 2013: 711), but has to strike a delicate balance between the contradictory ideals of policy relevance and empirical accuracy.

Several approaches have been proposed (e.g., GWP, GWP*, GTP), the most prominent of which is Global Warming Potential (GWP). Colloquially speaking, the GWP of a given substance tells us how much CO_2 we would have to emit in order to perturb the planetary energy balance as much, over a given time period, as we would by emitting one ton of this substance. Formally, it tells us “the time-integrated radiative forcing due to a pulse emission of a unit mass of a given substance, normalized to that of CO^2” (Young et al., 2008: 1). When this metric is applied, the climate impacts of different activities are constructed as equivalent if the total GWP of their resultant emissions are identical. E.g., if Substance A has a GWP of 20 and Substance B has a GWP of 40; then an activity that emits 2 tons of Substance A is constructed as equivalent to one that emits 1 ton of Substance B.

GWP was first introduced in the IPCC First Assessment Report (FAR) as a “simple approach [adopted] to illustrate the difficulties inherent in the concept [of CO_2-equivalency]”, “to illustrate the importance of some of the current gaps in understanding” and “to demonstrate

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[11] Defined as “a change in net irradiance at the tropopause caused by a change in an external driver of the climate system” (Young et al., 2008: 1). Roughly speaking: a change in the planetary balance of incoming to outgoing radiation.

the current range of uncertainties" (IPCC, 1990: 58). Some of the choices involved in its construction were scientific (e.g., "type of model, and how processes are included or parameterized in the models"), while others were political (e.g., "choices of time frames and climate impact") (IPCC, 2013: 711).

The choice of emission metric was long a bone of contention among climate scientists and commentators. Some criticized GWP on scientific grounds, for inaccurately describing the impact of short-lived climate pollutants (SLCPs). "For cumulative pollutants like CO_2, radiative forcing largely scales with the total stock (cumulative integral) of emissions to date", Allen et al. (2018) explains, "while for SLCPs like methane, it scales with the current flow (emission rate) multiplied by the SLCP lifetime" (p. 2). Others (e.g. Skodvin, 1999) questioned the construct validity of operationalizing climate impact in terms of cumulative radiative forcing rather than temperature response.

Others criticized GWP on political and moral grounds. Agarwal and Narain (1991), for instance, criticized its failure to distinguish the 'luxury emissions' of the rich from the 'survival emissions' of the poor. Instead of constructing carbon footprints by mapping from emission rates to radiative forcing, they proposed to construct them in terms of contribution to increased atmospheric concentrations.

For any atmospheric substance, the annual change in concentration equals annual global emissions minus annual global absorptions. For CO_2 and methane, respectively, annual global absorptions were estimated as 18 billion tons and 212 million tons. As long as global emissions were kept below these thresholds, atmospheric concentrations – and by extension the climate – should remain stable. Put differently: The first 18 billion tons of CO_2 and 212 million tons of methane emitted each year does not contribute to climate change. Climate change is entirely caused by those additional emissions that overshoot these thresholds.

The authors consequently suggested that each country should be allotted its "just and fair share of the oceanic and tropospheric sinks—a common heritage of humankind" (p. 83), and permitted an equivalent amount of annual emissions. Carbon accounts should then only reflect those emissions that exceed the amount absorbed by the nation's shares of global sinks (i.e., the only emissions that actually contribute to increased atmospheric concentrations).

India, for instance, was home to 16.2 % of the global population, yet its annual CO_2 and methane emissions amounted to only 6 % and 14.4 %, respectively, of the amounts absorbed by the global sinks. India, the authors suggested, should thus be considered 'carbon negative', in the sense of being accountable for more GHG absorption than emissions. Rich countries, by contrast, were using all of their allotted sink-capacity, as well as most of the capacity of poor nations – and then some. These emissions were "totally out of proportion to their populations and that of the world's absorptive capacity" and "entirely responsible for the accumulation of unabsorbed CO_2 and methane in the atmosphere" (p. 86). The US, in particular, home to only 4.7 per cent of the world's population, "emits as much as 26 per cent of the CO_2 and 20 per cent of the methane that is absorbed every year" (p. 86). Figure 4.1.1 depicts the permissible and excess emissions suggested by the authors.

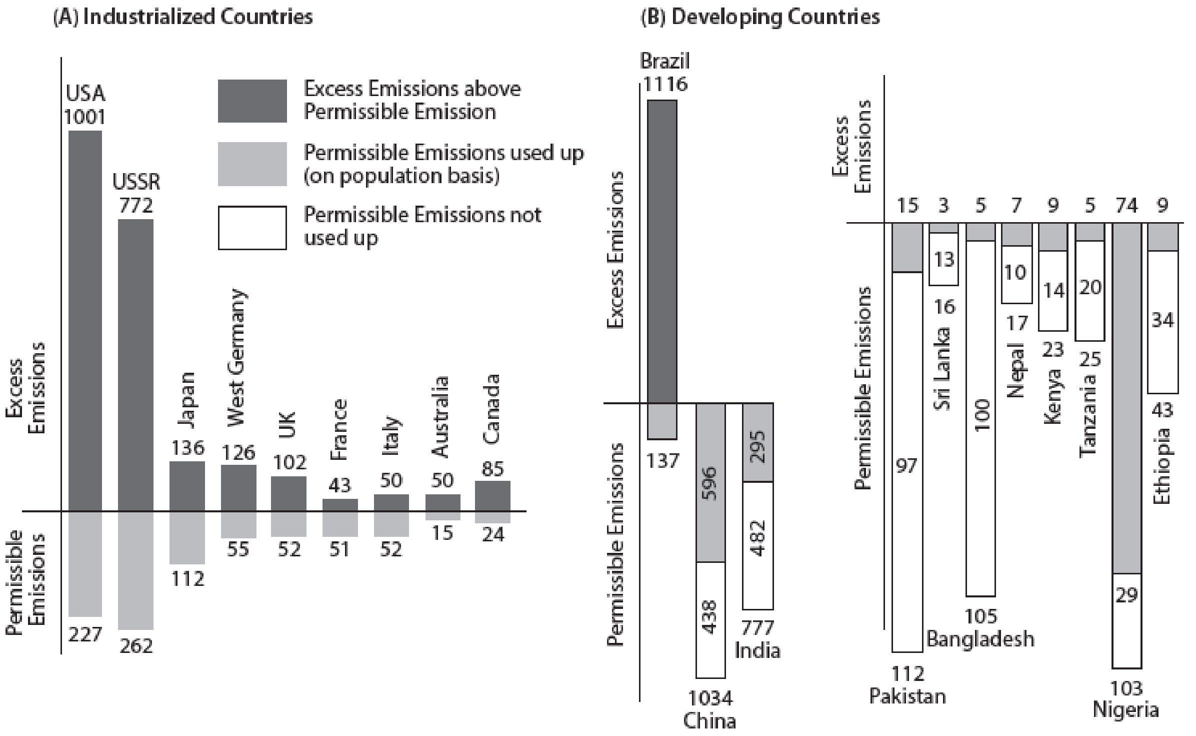

Figure 4.1 1 Permissible Emissions versus Total Emissions of CO2 of Select Countries on the Basis of Population (in million tons of CO2-eqv. Source: Agarwal and Narain, 1991

Proposed alternatives to GWP include GWP*, which was designed to more accurately capture the climate impacts of SLCPs; and the more prominent Global Temperature change Potential (GTP). Unlike GWP and GWP* – which define CO_2-equivalency in terms of cumulative radiative forcing – GTP defines it in terms of net contribution to *global temperature increase*. Formally, it is defined as “the ratio of change in global mean surface temperature at a chosen point in time from the substance of interest relative to that from CO_2” (IPCC, 2013: 663). GTP thus defines CO_2-equivalency one step down the causal chain relative to GWP.

According to Forster et al. (2021), the appropriateness of a given climate metric “depends on the purposes for which gases or forcing agents are being compared. (..) The choice of metric will depend on which aspects of climate change are most important to a particular application or stakeholder and over which time-horizons” (p: 125).

Following its integration into the UNFCCC, Kyoto Protocol, and eventually Paris Accord, however, GWP now seems locked-in as our default metric for constructing the relative climate impacts of different GHGs. For Skodvin (1999), “the rapid and relatively uncritical political endorsement of [GWP] seems to imply (..) that a political meaning for the concept is generated, and that the scientific community thus in a sense loses its control over the concept” (p. 7). Research aimed at generating more robust GWP estimates hence flourished at the expense of “research on the applicability of the concept as a measure for climatic response, which also includes the more critical perspectives” (ibid).

The debate plods on in academic journals (see Allen et al., 2018), and recent IPCC Assessment Reports (AR4 and AR5) provides estimates for GTP alongside those for GWP. Outside of the ivory tower, however, GWP remains the taken-for-granted truth about how to compare the potency of different GHGs. If a given greenhouse gas has a GWP of 20, it is – as a matter of socially constructed fact – 20 times more potent than CO_2.

4.1.1 The climate impact of methane emissions[12]

The difficulties in establishing CO_2-equivalence are well illustrated by methane. The two first IPCC Assessment Reports (FAR and SAR) estimated the GWP_{100} (GWP over a hundred-year period) of methane as 21. In other words, one ton of methane was constructed as having the same climate impact as 21 tons of CO_2. This value was updated in the following three Assessment Reports (TAR, AR4, and AR5) to 23, 25 and finally 28. More recent studies suggest it might be as high as 35.

Source	***GWP_{100}(methane)*** ***[Tons of CO2e per ton]***
IPCC FAR (1990)	21
IPCC SAR (1995)	21
IPCC TAR (2001)	23
IPCC AR4 (2007)	25
IPCC AR5 (2013)	28
Muñoz and Schmidt (2016)	28
Etminan et al. (2016)	32
Gasser et al. (2017)	34
Sterner and Johansson (2017)	35

Table 4.1 1 Estimates of the GWP100 of methane. Numbers are from Aamaas and Myhre (2018)

The evolution of the GWP_{100} of methane is depicted in Table 4.1.1 and Figure 4.1.2.˙ Over the period 1990 - 2017, it rose by approximately 0,5 tons of CO_2-equivalents per year. All else equal, older LCAs of methane-emitting activities should thus be expected to construct these as more environmentally sustainable than more recent ones. In practice, however, GWP is subject to substantial data inertia and the GWP values of AR4 remains widely used.

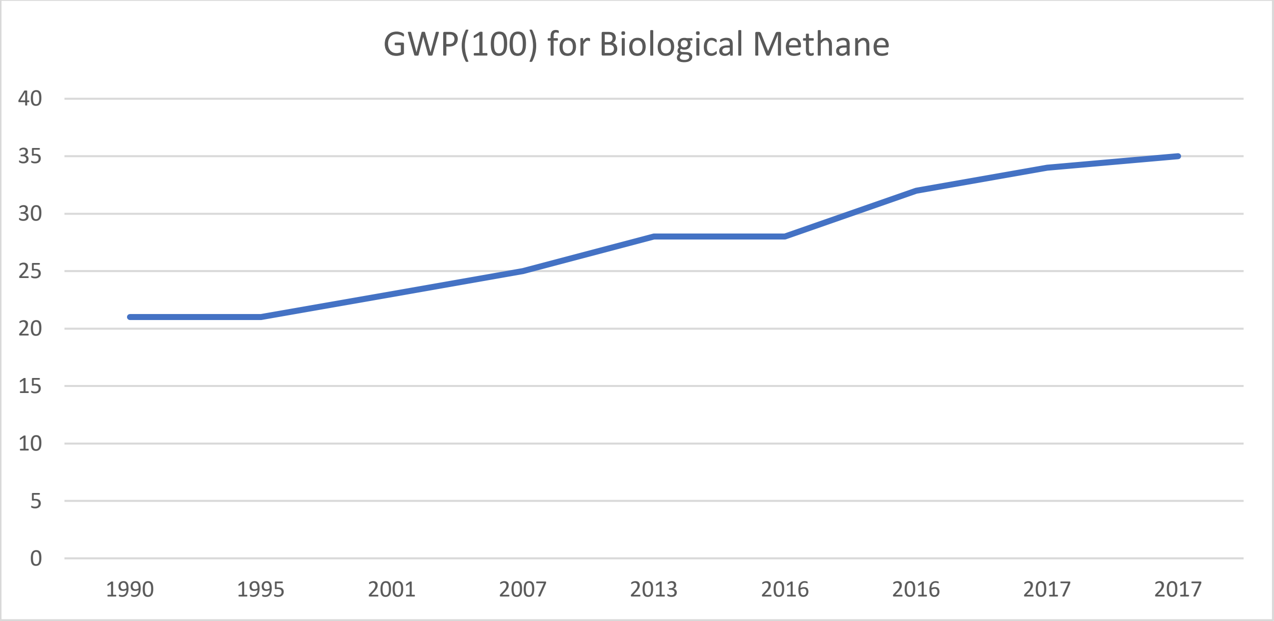

Figure 4.1 2 Estimates of the GWP(100) of methane. Numbers are from Aamaas and Myhre (2018)

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[12] This example draws heavily on the CICERO whitepaper “Kunnskapsstatus på metan” (Aamaas and Myhre, 2018). Quotations are my translations from Norwegian

The updates in TAR, AR4, and AR5 largely resulted from decisions to account for a growing set of second-order effects. When methane disintegrates in the atmosphere, for example, its carbon atoms become the raw materials for the formation of new atmospheric CO_2 molecules. Since carbon constitutes 60 % of the molecular weight of methane, but less than 30 % of the molecular weight of CO_2 – each ton of methane that disintegrates in the atmosphere releases 0,6 tons of carbon which might in principle form as much as 2 tons of CO_2[13] (though in practice "this yield is less than 100% (on a molar basis) due to uptake by soils") (Forster et al., 2021: 122). Their hydrogen atoms, likewise, become the raw materials for the formation of new stratospheric H_2O molecules, which – unlike 'ordinary' (i.e., tropospheric) vapor – remains in the atmosphere for years (IPCC, 2013).

The post-AR5 increase was partly due to the 2016 discovery that methane absorbs some radiation in the low-frequency spectrum, in addition to its well-established absorption of high-frequency radiation. Etminan et al. (2016), who made the discovery, estimated the radiance forcings from methane to be 14 % larger than previously assumed. Older estimates furthermore accounted for feedback effects on the carbon cycle (i.e. second-order radiative forcings due to disturbances to the carbon cycle, caused by the radiative forcings of the initial pulse emission), but not on the methane cycle. Gasser et al. (2017) describes this as inconsistent: either both feedback effects should be accounted for, or neither should. By including feedback effects on the methane cycle, they estimated the GWP_{100} of methane to be 6 – 10 % greater than previously assumed (Gasser et al., 2017; Sterner and Johansson, 2017).

These complexities are only compounded by the fact that GWP is generally considered to be a poor metric for the climate impact of SLCPs such as methane. According to Forster et al. (2021), "expressing methane emissions as CO2 equivalent emissions using GWP_{100} overstates the effect of constant methane emissions on global surface temperature by a factor of 3 - 4 over a 20-year time horizon", while "understating the effect of any new methane emission source by a factor of 4 - 5 over the 20 years following the introduction of the new source" (p. 123).

Further complicating the matter is the poorly understood relation between methane emissions and changes in atmospheric methane concentration. According to Aamaas and Myhre (2018), atmospheric methane concentrations remained stable throughout the 1990s, even though global methane emissions kept rising, before beginning – for unknown reasons – to surge in the mid-2000s. Some of the upsurge may be attributed to changes in atmospheric OH-concentration, which has weakened methane sinks. But Aamaas and Myhre (2018) sees this as unlikely to explain much of the rise. Instead they attribute it to complex and poorly understood interactions between seasonal and annual variations and 'internal variability' like El Niño (p. 7). Regardless of the cause, methane emissions appear to have caused less climate impact in the 1990's than they currently do; and only time will tell how this is going to change over the coming decades.

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[13] The molecular weight of CH3 is 20 u, out of which 12 u is carbon. The molecular weight of CO2 is 44 u, out of which 12 is carbon

4.1.2 Policy implications

The choice of metric and time horizon greatly affects how carbon footprints are constructed. Consider the generic GHG depicted in figure 4.1.3 as an example. Because of the delay between cause (radiative forcing) and effect (temperature change), most of the radiative forcing caused by this GHG occurs over the first 20 years, whereas most of the resulting temperature change occurs over the following 80 years. As such, its GWP is relatively large over a 20-year period and small over a 100-year period; while the converse is true for its GTP.

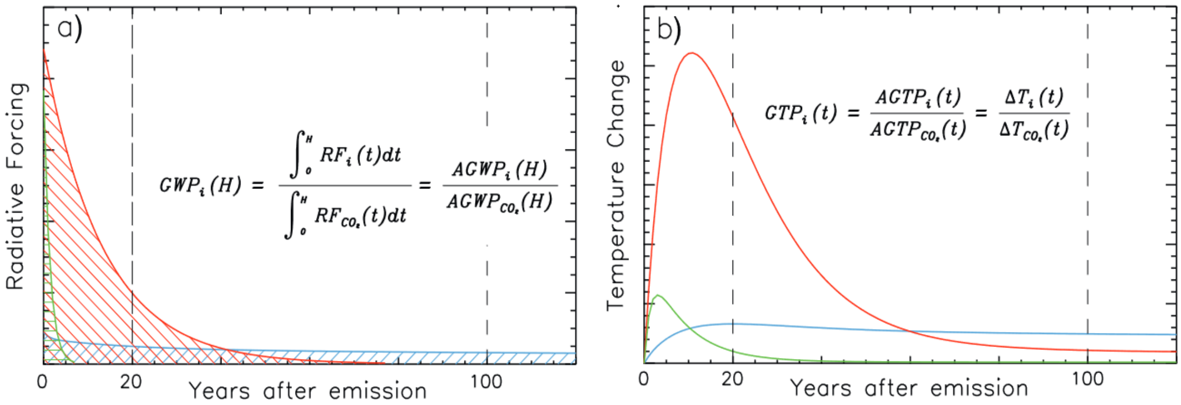

Figure 4.1 3 Temporalities of radiative forcing and temperature change in response to pulse emission (IPCC, 2013: 711).

Figure 4.1.4 depicts global GHG emissions in 2008, weighted by GWP and GTP for different time horizons. Two conclusions are evident. Firstly, the fraction of global GHG emissions that are attributed to CO_2 grows as a function of time horizon. While CO_2 is by far the most important GHG over the conventional 100-year time horizon, it is roughly equivalent to methane over a 20-year time horizon. Secondly, GWP and GTP provides compatible constructions of climate impact over the short run, but deviate substantially in the long run. For a 100-year time horizon, GTP constructs climate change as all but exclusively attributed by CO_2, while GWP still attributes a moderate fraction to methane, and minor fractions to N_2O, CO, and black carbon.

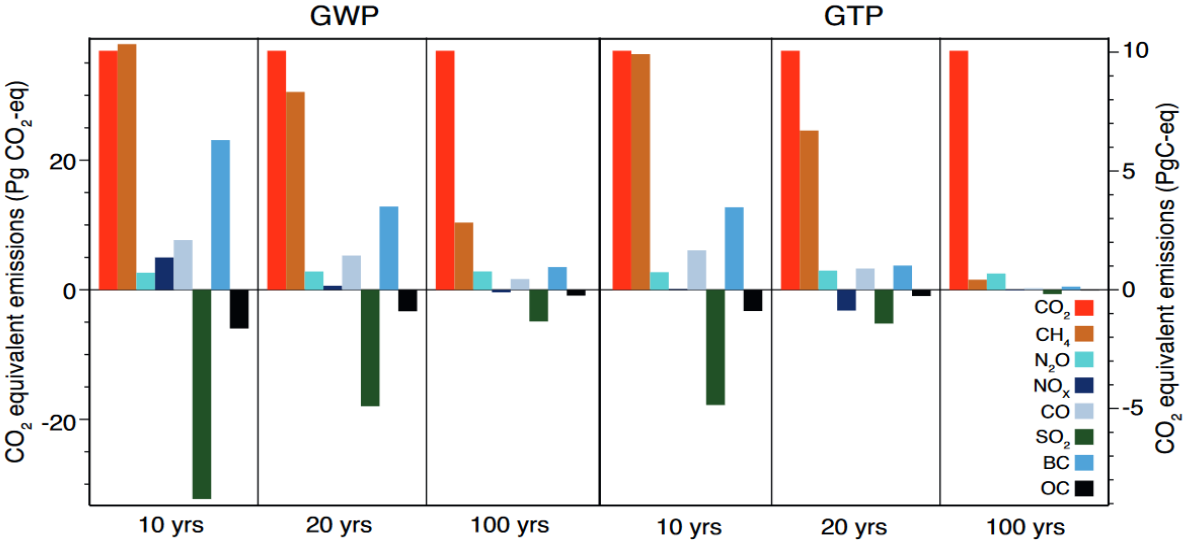

Figure 4.1 4 Global anthropogenic emissions in 2008, weighted by GWP and GTP for chosen time horizons (IPCC, 2013: 719).

As such, the choice of time horizon is particularly significant. In many cases, this choice dictates the allocation of responsibility for global GHG emissions among different economic sectors, and thus which sectors are constructed as more or less ‘sustainable’. See figure 4.1.5. This is particularly the case with respect to the distribution of responsibility among sectors with high CO_2 emissions (e.g., energy, industry, and transportation) and sectors with high methane emissions (e.g., animal husbandry, landfills, and agriculture). While the former has “the largest contributions to global mean warming over long time horizons” (e.g., 100 year), this spread narrows over shorter time horizons (e.g., 20 years or less) (IPCC, 2013).

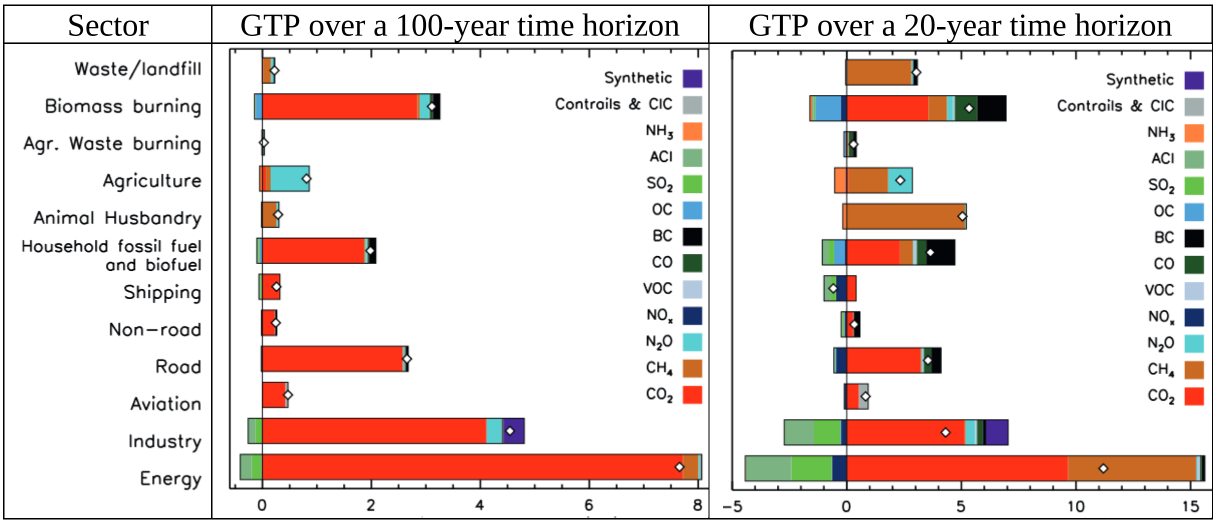

Figure 4.1 5 Net global mean temperature change by source sector for time horizons of 100 and 20 years. Adopted from AR5 (IPCC, 2013), Figure 8.34

This has major policy implications. Consider, as an example, a policy that reduces annual CO_2 emissions by 500 tons, while increasing annual methane emissions by 10 tons. This policy would be constructed as ‘climate positive’ if CO_2-equivalency is calculated over 100 years, but ‘climate negative’ if it is calculated over 20 years. By extension, the choice of time horizon also affects the allocation of responsibility among nations. New Zealand, which has a methane-intensive economy, was for instance found to have its GHG emissions “reduced by 70% when the time horizon is changed from 20 to 500 years” (Skodvin, 1999: 10).

One troubling aspect of defining CO_2-equivalency in terms of GWP, is the failure of this metric to map a unique temperature response onto a given carbon budget. According to Skovin (1999), “if a given reduction target is implemented by reducing short-lived gases (such as methane) instead of CO_2, the short-term climatic effect may be a reduced *rate* of temperature increase, [while] the long-term effect will be a significantly higher magnitude of temperature increase” (pp. 14 – 15). As such, “we do not *know* the actual climatic effect, for instance of the Kyoto target, until *after* it has been effectively implemented and we thus *know* the composition of the basket of gases whose emissions are reduced” (p. 15).

If our primary policy concern is to minimize the peak of the global temperature rise, and thus the risk of runaway climate change, the most policy-relevant time horizon might be 50 years (which would presumably imply GWP values somewhere in the middle of those depicted in figure 4.1.6). But because IPCC only publishes GWP for 20, 100 and 500 years – for which 20 years seems too short and 500 years too long from a policy point of view – policymakers have little choice but to compare the potency of different GHGs over the conventional 100-year period.

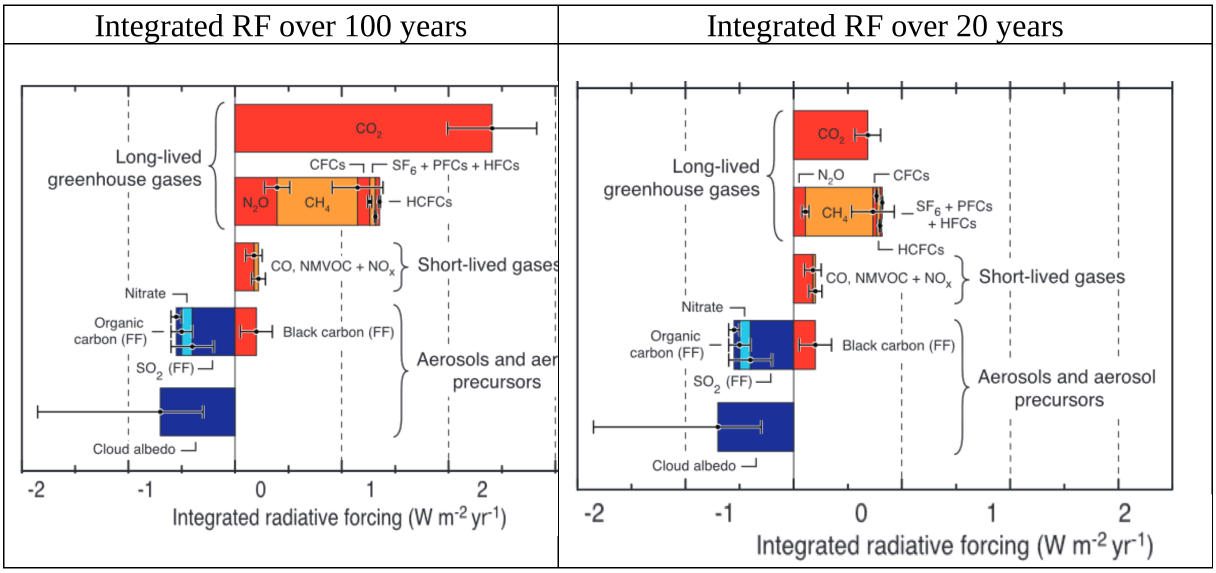

Figure 4.1 6 Integrated RF of year 2000 emissions over 20- and 100-year horizons (Forster, 2007: 206)

The existence of competing climate metrics means that different GHG accounts may not be commensurable. The impact factors used for national GHG accounting (UNFCCC), for example, were, until 2018, the GWP_{100} values from AR4. Those recommended by the leading standard for corporate GHG accounting (the GHG Protocol), meanwhile, have long been the GWP_{100} values from AR5 (GHG Protocol, 2016). National and corporate GHG accounts thus long used to construct the climate impact of methane emissions as respectively 25 and 28 times greater than that of CO_2 emissions. Methane-emitting activities were, in other words, constructed as less sustainable in corporate than in national GHG accounts. And, as implied by recent publications, the *physical* climate impacts of such activities may be greater than implied by either.

The difficulties in rendering different GHG emissions commensurable are only compounded by those of calculating the amounts of GHG emissions that are attributable to any particular activity. The following section will discuss the de facto global standard for such calculations; that of life cycle assessments (LCA).

4.2 Life Cycle Assessments[14]

The term “life-cycle” stems from biology (Matthews et al., 2014). The journey of the butterfly – from egg to larva to caterpillar to butterfly to dirt – constitutes a life cycle. So does the journey of the chicken – from egg to hatchling to nestlings to fledgling to nugget. Likewise, we may conceptualize the journey of a manmade product, e.g., that of the plastic bottle – from oil field to refinery to factory to refrigerator to incinerator (or the Pacific Ocean!) – as a life cycle.

The generalized life cycle of an industrial product is depicted in Figure 4.2.1. Starting from the left-hand side, raw materials (e.g., ores, biomass, petroleum) are extracted and transported to a processing facility. Here, they are transformed into processed materials (e.g., metals,

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[14] This section draws heavily on the textbook “Life Cycle Assessment: Quantitative Approaches for Decisions that Matter” (Matthews et al., 2014).

pulp, plastics), which are further transported to a factory, and turned into end-use products (e.g., toasters, paper towels, barbie dolls). These are then transported to end users, who will use them for a while, before disposing of them. Some products are then reused, recycled, or remanufactured. Others end up in landfills, incinerators, or the oceans. Each stage of the life cycle generally entails the consumption of some resources and/ or disposal of some waste products; and by extension some environmental impacts (Matthews et al., 2014).

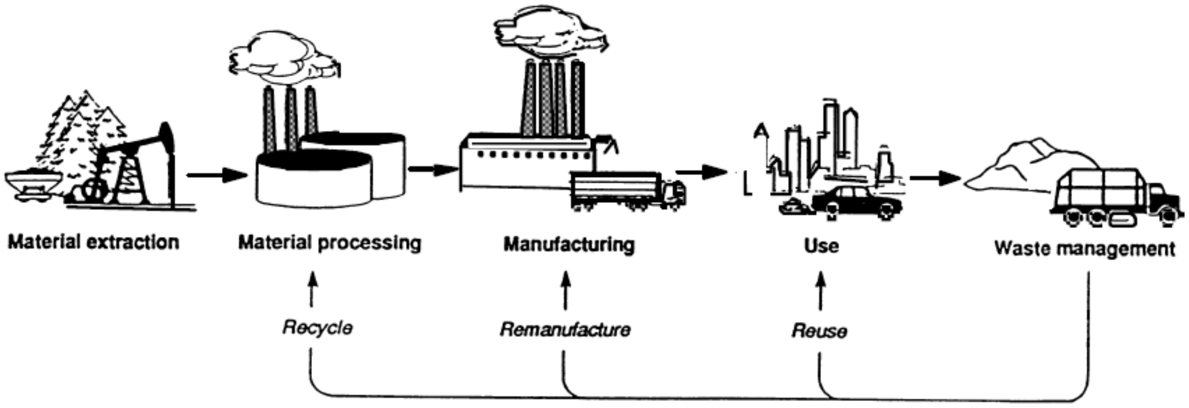

Figure 4.2 1 Life cycle of an industrial product (Matthews et al., 2014)

The literature describes three types of life cycle analysis, corresponding to the three pillars of sustainability (e.g., Matthews et al., 2014). Life Cycle Assessments (LCA), which assess environmental impacts. Life Cycle Costing (LCC), which assess economic impacts. And Social Life Cycle Assessments (S-LCA), which assess social impacts. Due to space limitations, this thesis will only address LCA.

The basic formula for LCA is given as (ISO, 2006):

$$Life\ cycle\ impacts = \sum_{k=1}^{n} (\text{[Input factor}_k\text{] x [Impact factor}_k\text{]})$$

Input factor$_k$ is the amount of input k (e.g., steel, energy, etc.) required to produce one ‘functional unit’ of the assessed product. *Impact factor$_k$* is the environmental impacts of using one unit amount of Input factor$_k$. Impact factors are positive for environmental burdens (e.g., carbon emissions) and negative for environmental improvements (e.g., carbon capture and storage). A *Functional unit* is a unit amount of the assessed product that “fulfills its function”, e.g. “1 kWh of electricity” or “1 undecorated Christmas tree over 1 holiday season” (Matthews et al., 2014: 88). *n* denotes the total number of unique inputs.

The inputs considered may be limited to the production process (“cradle to gate”); include the entire life cycle (“cradle to grave”); or extend to the product’s afterlife as inputs to new production processes (“cradle to cradle”).

Since 2006, LCA has been standardized through the ISO 14040-series; which is centered on the two documents ISO 14040 (general principles and framework) and ISO 14044 (specific requirements and guidelines). It structures the process of conducting an LCA into four phases: (1) Goal and scope definition; (2) Inventory analysis; (3) Impact assessment;, and (4) Interpretation. Goal definition consists of articulating the intended applications and target audience of the study. Scope definition consists of deciding which processes and life cycle stages to include. Inventory analysis consists of collecting input data (e.g., material and energy flows).

Impact assessment consists of using this data to calculate environmental impacts. Finally, the interpretation phase consists of evaluating these results against the goals, assess the quality of the study, and give recommendations. As indicated by the double arrows on figure 4.2.2, this is intended as an iterative process.

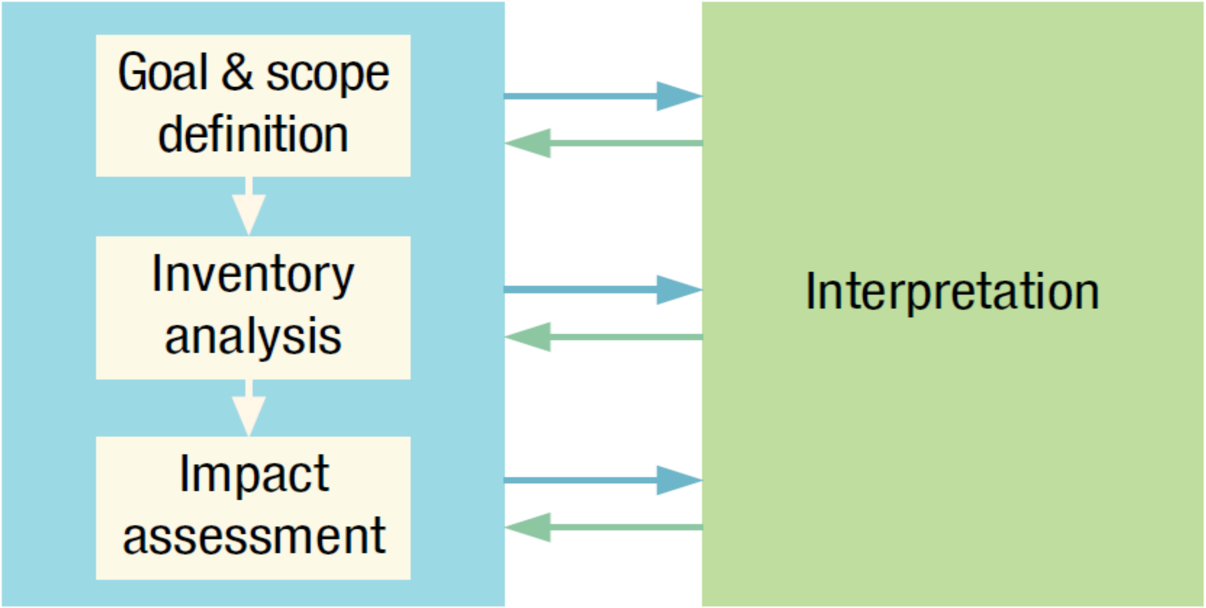

Figure 4.2 2 The four phases of the ISO LCA Standard (ISO 14044)

The ISO 14040-series is further operationalized and elaborated upon through a host of national and international standards. These include the 'International Reference Life Cycle Data System' (ILCD) which suggests best practices for conducting and using LCAs; and 'Product Category Rules' (PCR), which standardizes the scopes and system boundaries for assessments of particular product groups.

4.2.1 Applications of LCA

The most straightforward application of LCA might be to inform decision making, by rendering the environmental impacts of alternative choices commensurable. If the choices under assessment only entail a single category of impacts (e.g., only GHG emissions), this is fairly straightforward. Consider, for instance, the choice between Product A which has a large carbon footprint from its production stage, and a small carbon footprint from use stage; and Product B with the opposite distribution of impacts. By quantifying all emissions throughout the entire life cycles of both products, LCA enables decisionmakers to compare such products head-to-head.

If, on the other hand, the products under assessment entail impacts of more than one category, LCA cannot, in general, be used to identify the most sustainable one. Consider the choice between Product A, which causes a lot of GHG emissions and a bit of ozone depletion; and Product B, which has the opposite distribution of impacts. The relative sustainability of these products depends on the weights one assigns to each impact category; which, as Finnveden (2000) writes, "requires political, ideological and/or ethical values" (p.233). Only in rare cases, in which one alternative outperforms its competitors with respect to every impact category, can it be said to be objectively more sustainable.

One subset of this application of LCA is for assessing the environmental impacts of adopting new technologies. To do so, the assessed technology must be compared against a baseline that represents what would have happened in its absence. This entails some scenario uncertainty. Consider, as an example, a biowaste-to-biofuel plant. The environmental impacts of this plant will be a function of the alternative usages of the biowaste. The most plausible alternative might have been to let the biowaste decompose and emit methane. Or it might have been to incinerate it in a combined heat and power (CHP) plant. The environmental benefits of constructing the plant would be quite different for the two alternatives

Another application of LCA is for marketing and public relations, e.g., for signaling environmental concern and willingness to improve. According to Freidberg (2014), the target audiences for these assessments often lack the means to appraise the numbers, but may still "appreciate companies that disclose new information even if they ignore its content" (p. 184). He cites, as an example, the British potato chip manufacturer Walker's. "The actual number (75 g of CO2 per packet) meant nothing to most shoppers, but the company's overall image benefited" (ibid: 184).

LCA may also be used for benchmarking. Once Walker's had begun to disclose its carbon footprint, for example, this created a "sense of urgency" to improve it (Freidberg, 2014). LCA can be used to guide such efforts through 'hot spot analysis' which seeks to identify stages in a product's life cycle with particularly high environmental impacts (i.e., 'hot spots'). The purpose thereof is to pinpoint low-hanging fruits, on which the manufacturer might focus its environmental efforts (Matthews et al., 2014).

4.2.2 Attributional and Consequential LCA

The distinction between Attributional LCA (ALCA) and Consequential LCA (CLCA) was drawn in the late 1990s, in response to debates among LCA practitioners about whether to use average or marginal data (Ekvall, 2020). Consider, as an example, a factory which consumes X kWh to produce one functional unit of a good. The per unit carbon emissions from its energy consumption are equal to X times the impact factor of the energy source. This impact factor could be defined as the answer to either (a) 'what is the carbon footprint of an average kWh consumed in this area?' or (b) 'what is the carbon footprint of increasing the total energy consumption in this area by 1 kWh?'.

The answer to question (a) can be calculated as the sumproduct of the annual outputs and impact factors of all power plants on the grid, divided by the total output across all plants. The answer to question (b) might be a short-term increase in the output of a local gas-fired power plant; while the long-term answer might be that all new capacity will come from windmills. The impact factor of this marginal energy consumption would thus be equal to that of gas-fired power plants in the short-term; and that of windmills in the long-term.

Attributional LCA (ALCA), which applies the first definition of impact factors, is the most common form of LCA (Plevin et al., 2014). It calculates the 'environmental footprint' of a product, by adding together all impacts along its supply chain, service life and disposal. With the exception of "extremely unlikely cases" in which all market-mediated effects – like "nonlinear scaling effects, and system truncation effects" – are negligible, ALCA does not tell us anything about the environmental impacts of our decisions (Plevin et al., 2014: 74). It only tells us which impacts these decisions will be responsible for, in an accounting sense

(Tillman, 2000). As such, ILCD recommends ALCA "only in contexts where no decision is to be made based on the results of the analysis" (Plevin et al., 2014: 74).

Consequential LCA (CLCA), on the other hand, is used to calculate the environmental impacts of decisions. It does so by applying the second definition of impact factor and accounting for ripple-effects "in processes to which the product is not linked through physical flows or contractual obligations", such as market responses (Ekvall, 2020: 17). For simple cases, this means identifying a single marginal producer whose demand function is affected by the production of the assessed product. For more complicated cases it means integrating the LCA model into an economic model; either a partial equilibrium model of a portion of the economy, or a general equilibrium model of the entire economy. ILCD recommends CLCA "for analyses that will inform policy making" (Plevin et al., 2014: 74).

Consequences to be considered in a CLCA includes both 'displacement effects', which occur when "the production of a [product] displaces (offsets) production of another product in the market", and 'pecuniary externalities' which occur when the assessed product affects market prices of other products (Matthews et al., 2014: 183). Consider, as an example, the indirect land use change (ILUC) of first-generation biofuels. Traditional LCAs of biofuels used to account for direct land use change, only (e.g., of plowing, fertilizing, and harvesting the feedstock). As critics (e.g., Searchinger, 2008; Fargione, 2008) pointed out, however, conversion of croplands into biofuel plantations in one part of the world can drive up the global market price of crops and thereby indirectly cause the conversion into cropland of virgin land in other parts of the world. The net environmental impacts of producing biofuels, they argued, may thus be far greater than those calculated by traditional LCAs.

In principle, the choice of assessment methodology (attributional or consequential) ought to follow from the purpose of the study. If the purpose is to make gain "recognition for good environmental performance" (Ekvall, 2020: 17), then ALCA is preferrable. If the purpose is to "actually improve the environment" (ibid), then CLCA is preferrable. In practice, however, there are often (sound or unsound) reasons for using ALCA even when one is trying to "actually improve the environment".

One reason is the scenario uncertainty of CLCA, which is "inherent to all projections of the future" (Plevin et al., 2014: 78). The more comprehensively a CLCA model accounts for higher-order consequences, "the more uncertain are the results, with the result that no model should be expected to produce a single, definitive quantitative assessment of environmental outcomes" (p. 78-79). According to Ekvall (2020), if the practitioner transparently addresses the uncertainty entailed in the modelling, "the study will rarely reach clear conclusions. This increases the risk of decisions and actions not being taken, especially if the actions are expensive or undesirable in other ways" (p. 17). This furthermore makes CLCA vulnerability to vested or ideological biases.

Other concerns include sensitivity to "subjective methodological choices made by the modeler", such as "how exactly to model consequences, for example, whether to use partial or general economic models and how these models are configured and parameterized (..) how the expanded use of a new technology affects the use of the incumbent technology, the interactions of these technologies with the broader economy, and the choice of the climate-change metric itself" (Plevin et al., 2014: 75). These voluminous degrees of freedom open the door for 'Texas sharpshooters' who start with a predetermined conclusion, and then tweaks their model until the sought-after conclusion pops out.

Even when CLCA is used in good faith, "the results might shift from positive to negative depending on system boundaries and assumptions" (Ekvall, 2020: 16). Refining the model to account for more causal relationships, "does not necessarily mean that the results converge toward a final answer" (Ekvall, 2020: 16), but can cause them to fluctuate between different ones. In such cases, ALCA might be more apt to guide decision makers in the right direction.

A final reason is data inertia (ref. section 2.3.1). The LCA databases currently in use "usually include average data, but few include marginal data", which means that CLCA "risks becoming unfeasible or at least significantly more expensive than an ALCA" (Ekvall, 2020: 15). Even when CLCAs are conducted, budgetary and temporal limitations often compel "limiting the study to the consequences expected to be the most important for the conclusions" (p. 16). As such, Ekvall (2020) argues, "CLCA should probably not be presented as a method to estimate the actual consequences. Instead the results are the consequences foreseeable within the methodological framework we choose to use in the study" (p. 18).

LCA has received much criticism over the years. Some concerns its validity and reliability. Some, its applicability. Some, its potential for misunderstanding and abuse. The following three subsections will outline some of these.

4.2.3 Validity and reliability

Matthews et al. (2014) describe two sources of poor validity and reliability for LCAs: uncertainty and variability.

Uncertainty results from "using inputs or methods that imperfectly capture the characteristics of the product system " (Matthews et al., 2014: 193). For ALCA, uncertainty is mostly 'parametric'. That is: uncertainty associated with imperfect information about activities, and/or their emission factors. E.g., ignorance about the means of transportation used to bring the assessed product from the factory to the warehouse. This uncertainty is often related to knowledge gaps in other disciplines, such as chemistry, on which LCA depends. One example, provided by Wikström et. al. (1996), is our imperfect understanding of how the formation of chlorinated dioxin compounds, during incineration, varies as a function of chlorine content and heat value; which creeps into LCAs of incineration processes. Parametric uncertainty can typically be reduced by conducting additional research.

Primary data (i.e., data collected for the specific purposes of the study) are considered as the "gold standard" of LCA. Due to time and cost constraints, however, most real-life LCAs rely on data from commercial or open-access databases (Matthews et al., 2014). One problem with these databases is that they sometimes harbor erroneous data. One example is the NREL database, which long had an "error in the CO2 emissions of its air transportation process". This was only brought to the attention of administrators when "observant users noted that this value was less than the per-ton-km emissions for truck transportation, which went against common sense" (Matthews et al., 2014: 124). Erroneous data in these databases are regularly found and fixed, but by the time this happens, studies using them may already have been published, and had time to lock-in decisions.

A more fundamental problem is that different databases, due to differences in scopes and assumptions, can provide conflicting impact factors for identical products or processes. Finnveden and Lindfors (1998), for instance, compared the emission factors for PVC found in different LCA databases, and found these to vary by more than an order of magnitude. When LCA practitioners assess products containing PVC, the results obtained are thus largely a function of the database they happened to use. The authors did, however, only assess databases from the early and mid-1990s, and so their findings might not be relevant for contemporary databases.

Returning to the example of biofuels, Matthews et al. (2014) argue that LCA practitioners who apply conservative estimates of ILUC effects (e.g., US EPA), tend to construct biofuels as more sustainable than petro fuels, whereas those who apply higher estimates tend to reach the opposite conclusion. Since ILUC cannot be measured directly, there is “no objective way to tell which estimate (if any) is correct” (p 195). The construction of biofuels as sustainable or unsustainable thus follows from the subjective choice of ILUC estimate. Depicting any particular choice as ‘the truth’ ”creates a very narrow (and perhaps misleading) conclusion” (ibid).

Variability results from “randomness in the data (or potentially the methods)”, which may lead to “different values (..) even from technically identical processes” (Matthews et al., 2014: 193). Variability is generally not reduceable and “may exist purely due to natural or other factors outside of our control” (p. 41). One example, illustrated by Figure 4.2.3, is the temporal variations in energy mix on an electrical grid. Since photovoltaics are only productive during daytime, nighttime demand is mostly met by coal. The impact factor of electrical energy from this grid thus varies as a function of time. These temporal variations are then transferred to all grid-connected manufacturers, with the result that goods, produced during nightshifts, have greater impact factors than those produced during dayshifts.

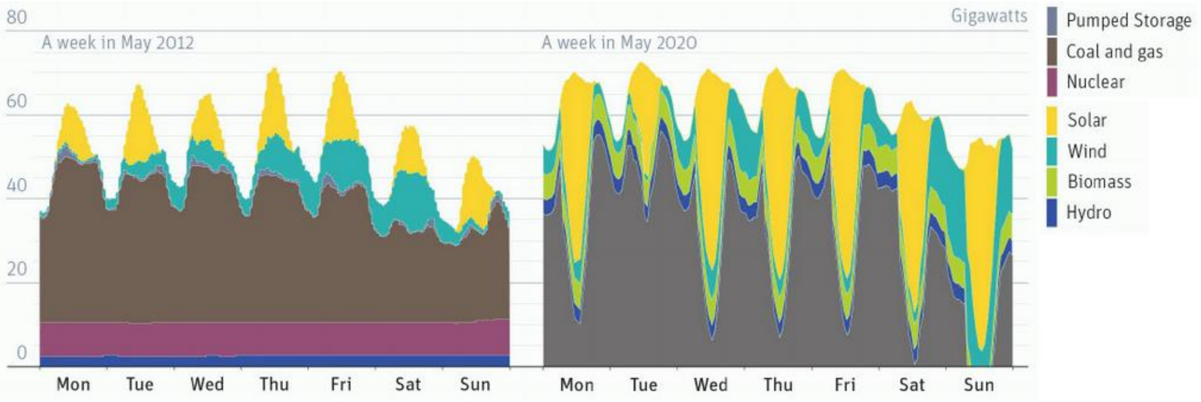

Figure 4.2 3 Estimated power demand over a week in Germany. Adapted from Jungjohann and Morris (2014).

According to Plevin et. al (2013), data gaps in LCAs often result in “systematic underestimation of environmental effects”, often on an order of magnitude of 20 - 50 % (p. 76). According to Jensen et al. (1997), the data-intensive nature of the LCA methodology makes it “very easy to make a mistake – and much harder to find it” (p.23). “Using the data and methods available to LCA”, Matthews et al., (2014) conclude, “nothing can be known with certainty” (p. 194), and it “may be impossible to produce an objective LCA, one where no value judgments have been made” (p. 84).

According to Plevin et al. (2014) there is no “universally accepted, precisely defined, single method for conducting an LCA” (p. 74). The operational definition of “life cycle environmental impact” thus differs slightly from study to study, depending on “subjective choices regarding system boundaries, data sources, aggregation methods, treatment of coproducts, and more” (p.74). Heijungs (1997) describes how different models can produce equally sound, but conflicting, results from the same data. Plevin et. al (2013) describes the results of different LCAs as “generally incommensurable” due to diverging choices regarding “methods, assumptions, and data” (p. 78). According to Ekvall (2020), it was “clear almost from the start that results from different LCAs can contradict each other” and “it is not realistic to expect LCA to deliver a unique and objective result” (p. 1).

Finnveden (2000) cites – as an example of the subjective choices that goes into conducting an LCA – the choice of time horizon used to calculate end-of-life impacts from landfilling. The LCA practitioner has to integrate the annual impacts from landfilling over a certain number of years. Accumulated impacts thus vary as a function of the number of years one choses to account for. At the time of his writing, there were “no international agreement on this question” (p. 231). The SETAC-Europe working group on Life Cycle Impact Assessments, for instance, decided that assessments should be repeated for several time horizons for landfilling: an infinite period; a period of 100 years; and any other period deemed relevant for the particular assessment (Udo De Haes, et al., 1999). Finnveden (2000) suggests two alternative time horizons: the "surveyable time-perspective" (roughly one century) and the "hypothetical infinite time perspective" (the time needed for complete degradation and spreading of all landfilled material) (p.231).

As discussed in section 4.2.2, CLCA are considered particularly dependent upon subjective choices due to the leeway in selecting scenarios. In the words of Plevin et al. (2014), different CLCAs “may generate as many distinct numerical results as there are scenarios”. (p.79).

4.2.3.1 The allocation problem

The allocation problem refers to the problem of allocating environmental impacts among different products (Wardenaar et. al, 2012, Finnveden, 2000). The literature discusses two varieties of this problem: the ‘*multifunctional process allocation problem’*; and the ‘*multi-input process allocation problem*’.

The multifunctional process allocation problem occurs when one process results in two or more products, among which the environmental impact of the process needs to be allocated (Wardenaar et. al., 2012). Consider as an example an oil refinery which distils crude oil into gasoline, diesel, asphalt, and kerosene. How should the environmental impacts of the distillation process be allocated among these products? According to Guinée et al. (2004), “there is no ‘correct’ way of solving the multi-functionality problem, not even in theory.” When LCAs are used for policy purposes, the question of allocation is thus largely a political one.

To illustrate this point, Wardenaar et. al. (2004) calculate the carbon footprint of the rapeseed-to-bio-electricity chain, by using the allocation methods prescribed by different policy standards – including the European “Renewable Energy Directive” and the US’ “Renewable Fuel Standard”. In doing so, they demonstrate how the chain gets constructed as significantly more sustainable under the US’ scheme than under the European one. Different prescribed allocation methods, they conclude, “intentionally or unintentionally, result in very different outcomes” regarding policy recommendations (p. 1066).

The allocation problem is especially critical for CLCA, due to the larger set of effects to be accounted for. Consider, as an example, a production chain that uses kerosene as an input. The first-order consequence of this production chain would be increased global demand for kerosine. This would drive the marked price of kerosene upwards, and the demand for kerosene in other sectors downwards. Assuming that there was not already an oversupply of kerosene, it would also increase the global demand for crude oil (as an input to kerosine production), and thus increase the supply of all other outputs of the refining process (gasoline, diesel, etc.). All else equal, this would drive the market price of the other outputs downwards, and thus increase the demand for them in other sectors. Et cetera. The CLCA practitioner thus has to quantify an array of (sometimes conflicting) economic ripple effects, as well as the environmental impacts of each effect, and decide on how to allocate them among different products. And as Saltelli and Funtowicz (2015) writes of modeling in general, "the larger the model, the easier it is to fiddle with its parameters to obtain whatever result one might wish" (p. 154).

The multi-input process allocation problem occurs when a process uses several products as inputs, and one needs to allocate its emissions to the end-of-life stages of these different input products (Finnveden, 2000). Consider, as an example, an incinerator which incinerates municipal waste and emits a given amount of chlorinated dioxins. How should these emissions be allocated among the different waste products incinerated? Finnveden (2000) outlines two common solutions to the problem: allocate emissions among the incoming waste components, "in relation to their chlorine content", or "in relation to their heat value, or something similar e.g. carbon content or flue gas volume" (p.232).

There is mixed support for both approaches in the scientific literature (Wikström et al., 1996). Some studies have found correlations between the chlorine content of materials and the amount of chlorinated dioxins produced by their incineration. Others have not. Unlike the allocation problem for multifunctional processes, however, this problem is largely one of scientific ignorance, and should in principle be solved as science progresses. In the meantime, however, LCA practitioners have to make subjective judgement calls. Ones that, according to Finnveden (2000), "can have a significant influence on the results" (p.232).

4.2.4 Limitations of LCA in environmental discourses and decision-making processes

Until the early 1990s, LCAs were largely confined to specialized academic journals. As concerns about climate change began to pick up steam in the wake of the 1992 Earth Summit, however, the work of these early LCA practitioners suddenly "escaped from the laboratory and into the real world" (Elkington & Hailes, 1993:20).

This newfound interest in LCA is reflected in the 1995 'Synthesis Report on the Social Value of LCA', which surveyed a group of "industry practitioners, standard setting organizations, ecolabelling boards, industry associations, research institutes, consultants, non-governmental organizations (NGOs), students, the environmental media and financial institutions", and found that LCA, "is now seen by all stakeholders as a necessary, integral part of the environmental management tool-kit" (Jensen, et al., 1997: 14). Since then, concerns about the vulnerability of LCA, to co-option and misinterpretation, have proliferated.

One line of criticism concerned the tendency of decision makers to rely on ALCA rather than CLCA. Plevin et. al (2013), for instance, criticize LCA practitioners for presenting their

ALCAs “in a way that suggests that policy decisions based on these results will yield the quantitative benefits estimated by ALCA”, as if these assessments were ”an estimate of the effect of increasing or decreasing system output” (pp. 73-74). As they put it, ALCA – because of its inherent simplifications – “is not predictive of real-world impacts on climate change, and hence the usual quantitative interpretation of ALCA results is not valid” (p. 73).

CLCA, on the other hand, has been criticized for being too scenario sensitive to inform decision making. Decisions that are constructed as environmentally sustainable based on any single scenario “may produce an undesirable outcome under another scenario” (ibid: 79). Ideally, environmental impacts should be assessed “under a wide range of plausible scenarios” (ibid). This would not only allow for averages to be calculated across scenarios, but also enable decisionmakers to more explicitly account for different levels of uncertainty. Consider e.g., the difference between Transition Pathways A and B, depicted in Figure 4.2.4.

This level of detail is, however, not generally feasible due to time and cost constraints. In order to be useful, an LCA typically has to be conducted within a narrow window of opportunity in which decisions may still be influenced. One example, provided by Matthews et al. (2014), was a mid-1990s LCA of the U.S. auto industry. By the time the analysis was completed, years after it first began, “the design and materials had changed significantly”; making the assessment outdated and irrelevant before it was even published (p. 21).

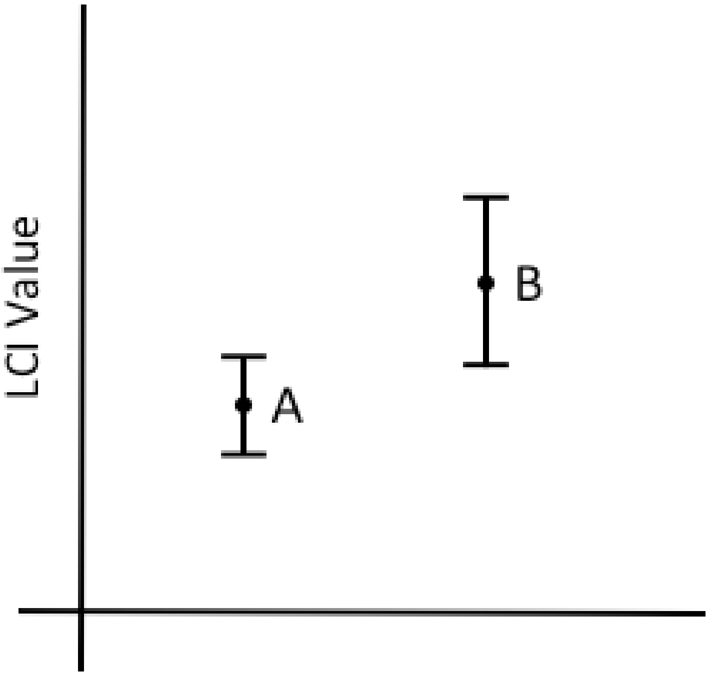

Figure 4.2 4 Graphical representation of LCA with ranges (Matthews, Hendrickson, and Matthews, 2014)

Others have expressed more general reservations about LCA as a decision-making tool. Tim Jenkins, from Friends of the Earth, for instance has described LCA as “a justification for products, rather than an objective analysis” (Jensen et al., 1997: 18). These concerns were mirrored by a 2018 whitepaper by Zero Waste Europe, on the use of LCA in food packaging policy, titled “Justifying plastic pollution”. According to Seidel (2006), “LCA results have [historically] tended to support the interests of the study sponsor (..)leaving the potential perception that it can be tailored to produce information that supports a specific agenda" (p. 340)

Finnveden (2000) diagnoses LCA as a "defensive and conservative tool" (p. 235). If a product or policy is under attack, he argues, vested interests may commission an LCA, to "confuse the debate" (p. 235), and stall action until alternatives can be shown to be better (which is often difficult or impossible). Kassatly (2020) warns that LCAs that become part of public discourses and policymaking processes often are unrepresentative, outdated, and cherry picked to validate a predetermined decision.

Seidel (2016) reviews an initiative by the Alberta Recycling Management Authority (ARMA) to compare the environmental impacts of alternative waste processing technologies. On the one hand, she praises the rigor of the assessments and the decision to involve "decision-makers early in the LCA process" (p. 344). On the other hand, she interprets feedback from ARMA board members as suggesting "a lack of buy-in and acceptance of the results", which she attributes to insufficient "active updates and involvement of the Board throughout the project" and insufficient "efforts to present results in a format understandable to the Board" (p. 345).

A number of articles, blog posts and op-eds have discussed particular cases in which LCAs have (purportedly) had an adverse effect on environmental discourses (e.g., Zero Waste Europe, 2018; Kvitrud, 2019a; Kvitrud, 2019b; Kassatly, 2020).

Examples from academic discourse include debates about the sustainability of nuclear power. Sovacool et al. (2017), for instance, argue against the notion of nuclear power as a 'sustainable energy source' by claiming that "some nuclear power plants currently emit the equivalent of 337 gCO_2/kWh, making them already as environmentally damaging as emissions from equivalent-sized natural gas-fired power plants" (p. 687). The authors attribute the number "337 gCO_2/kWh" to Beerten et al. (2009), who in turns attribute it to van Leeuwen and Smith (2005), while cautioning their readers that "a large fraction of [these emissions] results from the mining, milling and clean-up of the mine site for which the intensities are calculated based on a hypothetical model *which is not found in current day practice* [emphasis added]*"* (p. 5067). Sovacool et al. (2017) are, in other words, arguing against the notion of nuclear power as 'sustainable energy' by claiming that some plants "currently emit" an amount of carbon that their own source informs us is "not found in current day practice".

A meta-analysis by Turconi et al. (2013), by contrast, found the impact factor of nuclear energy – as calculated by a range of LCAs using different assumptions and methodological choices – to range from 7,6 to 170 g CO_2e per kWh. If one includes the number from Beerten et al. (2009), the impact factor of nuclear power is thus either slightly lower than that of PV (7,6 g CO_2e per kWh), roughly the same as gas-powered power plants (337 g CO_2e per kWh); or anything in between. In other words, some LCAs construct nuclear power as remarkably sustainable, while others construct them as fairly unsustainable. Anyone who wants to present their stance on nuclear power as evidence-based is thus free to pick the study that fits their purpose.

Examples from public discourse includes the Dutch PVC-debate of the early 1990s. Bras-Klapwijk (1998) discusses the role of LCA therein, and identifies three problematic aspects with this role.

The first issue concerns their “pre-environmentalist frame” (i.e., nonadherence to the precautionary principle). The methodology by which LCA is calculated, he argues, precludes them from accommodating “uncertain effects that cannot be proven in a formal, quantitative way, such as the effects of additives, bio-accumulation and hormonal disrupting effects” (Bras-Klapwijk, 1998: 339). Incidentally, these were precisely the effects that environmental organizations were most concerned about. From their vantagepoint, “all organochlorines should be considered to be toxic, persistent and biomagnifying substances until evidence to the contrary is provided” (p. 337).

The second issue concerns their nonconductiveness towards “dialogue about different conceptualizations of the environmental burden of PVC” (p. 340). For most policymakers they constituted black boxes whose policy prescriptions were presented in technocratic, formal ways without justifications aimed at laypeople.

The third issue concerns their lack of reliability. While some studies “concluded that PVC had a higher environmental burden than other products”, others “indicated the opposite” (p. 337). The results were opportunistic cherry picking and a polarized debate climate. Political actors “suppressed or denied [uncertainties about the results] when the results were in line with their view” (p. 340-341), while acting as critics “when references were made to LCAs that were not in line with their ideas”, pointing to “the methodological shortcomings and the lack of knowledge, using this tactic to undermine the authority of the [studies]” (p. 337).

5 The role of LCA in sustainability discourses

This section addresses the role of LCA in two Norwegian sustainability debates. It consists of two subsections. The first (5.1) addresses the 2021 debate about a managed decline of petroleum production. The second (5.2) addresses the 2007 – 2019 debate about a managed transition from plastic bags to paper bags.

5.1 A managed decline of petroleum production

The carbon footprint of Norwegian petroleum exports has long been a bone of contention in Norwegian sustainability discourse. Due to its outsized proportions relative to domestic emissions, environmentalists have long decried demands-side policies (i.e., those targeting domestic consumption) as insufficient; calling instead for supply-side policies (i.e., those targeting petroleum production). Opponents have dismissed theses calls as ill-informed; arguing that unilateral production cuts would just be offset by increased production elsewhere (i.e., carbon leakage). In fact, since the impact factor of Norwegian petroleum production ranks among the lowest in the world – so the argument goes – unilateral production cuts might even backfire and cause global emissions to rise (Sandvik, 2019).

The debate reached a crescendo in the wake of the 2013 general election, in which the Norwegian Green Party (MDG) became the first party, represented on the Norwegian parliamentary, to openly endorse supply-side policies. By 2019, this stance had been echoed by the Socialist Party (Rødt), the youth organizations of the Liberal Party (Unge Venstre), the Labor Party (Arbeidernes Ungdomsfylking), and the Christian Conservative Party (Kristelig folkepartis ungdom) (Mullis, 2019; Wasberg, 2019); as well as 40 000 striking schoolchildren who demanded, among other things, a managed decline of petroleum production through an end to new drilling licenses (Sandvik, 2019).

Proponents of supply-side policies often framed their stance as evidence-based by citing the 2013 SSB paper "Climate policies in a fossil fuel producing country"; republished in 2017 in 'The Energy Journal' (Fahn et al., 2013/2017[15]). The stated purpose of this paper was to find the optimal balance of demand to supply side policies for a given abatement target. The authors constructed a CLCA model which combined a "computable general equilibrium (CGE) model for Norway" with historic data for "representative, marginal cuts in Norwegian oil production (..) based on for the period 2009–2011". (p. 84), and found the optimal balance of demand-to-supply side policies to be roughly 2 to 1.

One example of its invocation was during a 2019 debate between Karl Eirik Schøt-Pedersen, then-CEO of the petroleum advocacy group 'Norsk Olje og Gass' (Norog), and Theodor Brun, a spokesperson for MDG. Schøtt-Pedersen presented Norog's usual argument against unilateral production cuts: since other oil-producing countries were ready to replace Norwegian oil with dirtier alternatives, unilateral production cuts would likely result in increased global emissions. Brun dismissed this claim by informing the audience that "SSB has recently published a report which unequivocally concludes that reducing Norwegian oil production is the most effective thing we can do to reduce global carbon emissions (..) because only about half of the reductions will be offset by increased production elsewhere"

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[15] This thesis will only cite page numbers from the 2017 edition.

(Sandvik, 2019). Schøtt-Pedersen responded by referencing another LCA which had found the total life cycle emissions of Norwegian petroleum, including emissions from combustion, to be the lowest in the world. No sources were provided, and it remains unclear which study he referred to[16].

Two years later, during the runup to the 2021 national election, Norog commissioned a new LCA on the same topic, from the consultant firm Rystad Energy. In contrast to the SSB assessment, which considered production cuts for marginal oil fields, this one considered production cuts spread across all Norwegian oil and gas fields. The authors constructed a CLCA model which combined a partial equilibrium model of the petroleum market with data from "relevant scientific literature, combined with our own considerations, market insights and data" (Rystad Energy, 2021: 10). It found unilateral reductions in Norwegian petroleum production to "most likely result in increased global GHG emissions" (p. 5).

The public was informed about the assessment on August 16th, two weeks prior to its publication, when it was invoked during a televised political debate. Une Bastholm of MDG had just cited the SSB paper as supporting evidence for supply side policies, when the moderator informed her that "Rystad Energy is about to release a report which comes to the opposite conclusion; that cuts in Norwegian petroleum production will probably lead to increased global GHG emissions". A spokesman for Norog later told an interviewer that they had personally informed the network about the study (Myrset and Vikingstad, 2021).

The reactions came in three partly overlapping waves. The first wave centered on the credibility of the report. Since it remained unpublished for another two weeks, none of the claim-makers involved were actually familiar with its content. Instead it was largely dismissed out of hand by proponents of supply-side policies, and embraced matter-of-factly by opponents. The second wave began with the August 31st publication of the report, and took the form of an expert debate about its validity, assumptions, and methodological choices. The third wave took the form of a boundary dispute, in which Rystad and its academic adversaries vied for epistemic authority. What follows is a small sample of each wave, intended to give a taste of their respective flavors.

5.1.1 First wave: Initial reactions

Following the August 16th debate, MDG immediately began to challenge the credibility of the report. One party member dismissed its conclusions as "crazy", and drew a comparison between Norog and the tobacco lobby, which "also leveraged its financial and political power to sabotage healthcare policies (..) by commissioning its own contrarian research" (Hansson, 2021). Another party member diagnosed it as "propaganda" with "zero credibility", and urged readers to keep in mind that "this is not peer reviewed research, but a commissioned report, bought and paid for by the petroleum lobby in an attempt to derail the climate debate in the runup to the election" (Myrset and Vikingstad, 2021). A third party member, described the event as a "terrifying example of the power of the oil lobby and of the media's lack of critical judgment" (Trædal, 2021).

Several environmental NGOs echoed these sentiments. WWF Norway described the assessment as a political ploy, and criticized NRK for bringing it up during the debate. "It was

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[16] I emailed Norog 18.02.2022 and have not yet received a response

not appropriate of NRK to mention this report. This was a distasteful way to conduct journalism" (Myrset and Vikingstad, 2021). Greenpeace Norway, encouraged politicians to base their policies on the peer-reviewed research, rather than "a report commissioned by Norog" (ibid). Naturvernforbundet described the report as "out of touch with reality" (Due, 2021).

Across the aisle meanwhile, several opponents of supply-side policies cited the report matter-of-factly as supportive evidence for their stance. Hjelmeng (2021), a law professor at the University of Oslo, informed his readers that "a fresh report from Rystad Energy shows that reductions in Norwegian oil and gas production would most likely result in increased global CO2 emissions" and consequently that supply-side policies were "crazy and symbolic". The Progress Party (Fremskrittspartiet, 2021) published a blogpost, stating "it is obvious that Norway should continue its oil and gas production after Rystad's report showed that global emissions will increase if the Norwegian petroleum sector is phased out". For Ketil Solvik-Olsen, a member of The Progress Party, the report demonstrated why "Norway should be the last country in the world to phase out its petroleum sector" (Myrset and Vikingstad, 2021). For Terje Søviknes, a former minister of petroleum and energy, "the Rystad report published last week shows us that reductions in Norwegian petroleum production would increase global carbon emissions. That makes it pointless for us to reduce our production" (Søviknes, 2021).

5.1.2 Second wave: Expert debate

On August 31st the report was publicized. The following day Rystad published an op-ed in the newspaper Aftenposten, outlining its assumptions and main conclusions (Rystad et al, 2021a). This marked the onset of a second, more technical, phase of the debate, in which two rival epistemic communities vied to deconstruct each other's truth claims, and foreground the methodological limitations and biases on which these purportedly rested.

Within two days of its publication, three of the four authors of the original SSB paper had published an op-ed criticizing Rystad's report on four grounds (Fahn et al., 2021a). Firstly, they questioned the assumption that production cuts would be spread across the entire petroleum sector, rather than concentrated to marginal oil fields. Realistically, they argued, supply-side policies would entail production cuts only to the least profitable oil fields – which also happened to be the ones with the highest impact factors. Secondly, they criticized Rystad's decision to estimate price elasticities (i.e., how suppliers and customers would react to price changes), based on a combination of statistical market data and guesstimates. They described this as "to put it mildly, a strange approach", given the tendency of supply to always match demand in the long term. Thirdly, they criticized Rystad's reliance on old and non-peer-reviewed sources. Finally, they criticized the apparent neglect of OPEC's market power which they described as modelling them as "just another producer which produces all its oil with a production cost lower than the market price".

A representative of the right-wing think tank Civitas – traditionally an ally of the petroleum sector – challenged the study on three grounds (Nordbakken, 2021). Firstly, he questioned the assumption that marginal cuts in Norwegian gas production would be replaced with energy with the same impact factor as the European energy mix. Instead, he argued, Rystad should have used the impact factor of a marginal supply increase (ref section 4.2.2). Secondly, he questioned the choice to estimate price elasticities from historical records for the period 1973 - 2020, in light of "major adjustments in relative prices, throughout the economy, resulting from the rising price of carbon" and "the ongoing price reduction of low carbon energy". Thirdly, he challenged Rystad to clarify its assumptions regarding "future carbon taxes and quota prices in Norway and the EU", which they had failed to make explicit.

Rystad et al. (2021b) responded to the criticism. Regarding the elasticity of demand, they argued that what truly mattered was future, not historical, figures – and that these were trending downwards. Over the coming decade, they predicted the most price-sensitive applications of petroleum (e.g., power plants, boilers, and vehicles) to be gradually phased out; prompting the elasticity of demand to continue its downward trend. Regarding the elasticity of supply, they predicted a looming oversupply of petroleum which would push it downwards. Regarding OPEC, they expected its marked power to decline as a function of aggregate global demand. "OPEC has a short-term relevance, but not a long-term one" (ibid).

In an interview with Morgenbladet, Jarand Rystad, the founder and CEO of Rystad Energy, turned the tables on SSB by disparaging the method they had used to estimate price elasticities. "If the SSB report was correct, then a doubling of the oil price – like we saw from 2000 to 2012 – would have cut demand in half. That obviously did not happen since the infrastructure that uses oil cannot change that quickly. It is illogical and has no support in the scientific literature" (Velo, 2021).

The authors of the SSB paper wrote a response in which they accused Rystad of misrepresenting their assessment (Fahn et al., 2021b). Based on their assumptions, they argued, a doubling of the oil price would cause demand to fall by 30 % – not 50 %, as Rystad had claimed. They furthermore ascribed the 2000 - 2012 price hike to rising demand, particularly from China. To use the observation that price and demand grew in tandem as evidence for a weak price elasticity, they therefore dismissed as circular reasoning. Finally, they defended their paper as focused on long term impacts, i.e., a period sufficiently long for technology and infrastructure to adjust.

5.1.3 Third wave: Boundary dispute

Throughout the ensuing debates, Rystad and its critics engaged in ceaseless boundary disputes. Rystad, for instance, responded to the first wave of criticism by rhetorically drawing a boundary between their critics: politically motivated laypeople; and themselves: technical experts. For certain commodities like furs, they allowed, supply-side policies might indeed make sense. Oil markets, however, were different "even though many people imagine that production cuts in Norway would result in an equivalent cut in global production. If that was true, MDG's way of thinking would have made sense" (Velo, 2021).

To the second wave of criticism, from SSB and academia, Rystad responded by framing themselves as the true experts, and their critics as pseudo-experts.

> "Many research institutions are customers of our data, and we work with most energy companies. So we know the degree to which informed actors see academic research as useful input or not. I can therefor say that academia does not play a particularly important role in shaping our understanding of oil markets. It is the companies, who invest hundreds of millions of dollars, who truly understand the market. And they rely on consultants like us, not academics at some college" (Jarand Rystad as quoted by Velo, 2021).

Asked about their assumptions about the behavior of OPEC, they replied with further exclusionary boundary work, again presenting themselves as better informed than their critics. “These are things we work with. OPEC is an important customer of us. To summarize: we are insiders when it comes to the workings of OPEC” (ibid). Asked about an alleged conflict between their conclusion and those of the IEA, they likewise responded by framing themselves as informed insiders. “No, our conclusions are in complete alignment with those of the IEA. We are in constant dialogue with them. They agree with us that only demand-side policies work” (Solli, 2021).

These statements drew immediate fire from academia. Partaking in the firing squad was Curt Rice, the principal of the Norwegian University of Life Sciences (NMBU), who wrote an op-ed decrying Rystad’s boundary work as “contempt for academics” (Rice, 2021). He went on to flip their exclusionary boundary work on its head by reframing the industry experience, on which their claim to epistemic authority rested, as anecdotal. “Such anecdotes are obviously important and worth understanding, but what is essential is the use of principled models based on knowledge. Industry anecdotes can per definition not provide us with an ‘understanding of the oil marked’. They can only confer subjective experiences” (ibid). The exclusionary assertion about academia not having an important role to play in shaping our understanding of oil markets, he further dismissed as “not just strange, but outright false”.

Much of the subsequent boundary work directed at Rystad emphasized the Mertonian norms of disinterestedness and organized skepticism. This is an academic boundary-defining tactic that is widely discussed in STS scholarship (e.g., Gieryn, 1983; Jasanoff, 1987; Jasonoff, 1990). Although Merton’s picture of the normative structure of science arguably does a poor job of describing the day-to-day behavior of most scientists – so the argument goes – it nonetheless plays a central role in their efforts to demarcate their work from that of other knowledge-producers, enhance the social standing of their profession, and assert epistemic superiority.

In the words of one critic, pointing out Rystad’s presumed lack of disinterestedness, “it doesn’t require much understanding about source criticism to see the difference between the SSB and Rystad studies. The former is an independent study, founded by the public for the public. The latter is bought and paid for by [a group] with clear interests in its conclusions” (Torgersen, 2021). According to another critic, Rystad seemed to be “more concerned with oil production than with knowledge production” (Rice, 2021).

Remarks about Rystad’s lack of peer review began to crop up during the first wave of responses, e.g., the aforementioned MDG member who urged readers to keep in mind that “this is not peer reviewed research” (Myrset and Vikingstad, 2021). Yet in the third wave, entire op-eds were dedicated to presenting peer review as a key demarcation criteria of ‘epistemically authoritative publications’, and Rystad’s report as falling short of this bar.

Several of these responded to an attempt by Rystad to expand the boundary around ‘epistemically authoritative publications’ to include their own assessment, by presenting their approach as analogous to peer review. “Any expert who so chooses may check what we have written [and] our assumptions and conclusions” (Jarand Rystad, as quoted by Velo, 2021).

For Rice (2021), this was a false equivalence. Results had to be checked *before* they were presented to the public as truth claims, he argued, not afterwards. He cited the debates about price elasticities as an example of something that might have been highlighted and rendered more nuanced if the report had undergone peer-review. In its absence, “it becomes the responsibility of the readers to evaluate the validity of the arguments. And just like that, it loses its claim to be suitable for informing decision makers” (ibid).

Tveit (2021) echoed this sentiment by praising the quality of the journal in which the SSB article had been published, and outlining a hierarchy of sources in which peer-reviewed papers stood at the pinnacle. Despite individual cases of low-quality peer-reviewed research, and individual cases of high-quality consulting reports, he described peer-reviewed research as, on average, “much more reliable than consulting reports”. The burden of proof consequently “rests with those who base their views on the latter”.

5.2 A managed transition from plastic to paper bags

The managed transition from plastic to paper bags has been a recurrent theme in Norwegian sustainability discourse for the past 15 years. Its origins can be traced to a local 2007 debate in Stavanger, that begun when its major, Leif Johan Sevland, announced his ambition to implement a citywide ban on plastic bags.

The supermarket and grocery store industry pushed back against the proposal, arguing that the ban would cost them customers. Bjørn Kløvstad, the director of information at the supermarket cooperative COOP, informed an interviewer that he “didn’t see the realism in the proposal”. Thomas Angell, a representative of the industry organization ‘Handels- og servicenæringens hovedorganisasjon’ (HSH), expressed concerns that “the audience would experience this as an untimely intrusion into their personal lives”, (Hovland, 2007). In the end, nothing came of the proposal.

5.2.1 First Round of Debate: 2008 - 2009

The debate entered the national stage in 2008, when the minister of environment, Erik Solhem, echoed Sevland’s proposal. In an interview with the national broadcast network (NRK) he argued “China has already banned them, Irleand has taxed them heavily, and Australia is contemplating a ban. Norway shouldn’t be worse than these countries”. The Christian Conservative party applauded Solheim, demanding that he made good on his proposal. “There are more environmentally friendly alternatives, like paper bags made of recycled milk cartons”, one party member suggested (Elsebutangen, 2008).

In a bid to frame his proposal as evidence-based, Solheim commissioned a report from the Norwegian Environmental Agency (then known as ‘*Statens forurensningstilsyn’* or SFT), on the environmental benefits of banning plastic bags. “In order to justify the ban, we had to show that it would entail environmental benefits”, one spokesperson for the Ministry of the Environment later expressed, “otherwise it would have been difficult to gain popular support for it” (Næss, 2014).

SFT decided to outsource the task to the consultancy group Norconsult, which solved it by conducting a literature review of foreign LCAs on the topic. Most of these turned out to favor plastic bags, and the review thus concluded by diagnosing the proposed transition as environmentally unsustainable (Bakke, 2008). This counterintuitive conclusion was picked up by a number of national media outlets. Several journalists (e.g., Kongsnes, 2008) presented the review as if it was conducted by STF. Lunner (2011) explicitly described it as "life cycle assessment" of different grocery bags, which took into account "processes like production, transportation, and more". Others (e.g., Nilsen, 2008), accurately described it as a literary review of foreign studies conducted by consultants. In the end, Solheim had little choice but to drop the proposal (Olsen, 2008). The debate then laid dormant for the next three years.

The Norconsult review was later criticized for relying on foreign studies with questionable external validity (Kvitrud, 2019a). According to critics, most of the studies surveyed concerned bags made of different types of plastic (HDPE) than what is typically found in Norwegian bags (LDPE); and drew on outdated data that did not reflect present-day value chains and production methods. Yet the validity of the report does not seem to have been questioned in the media's initial coverage. Instead, it was presented to the public as a scientific exposition of the ignorance upon which the established knowledge rested.

5.2.2 Second Round of Debate: 2011 - 2012

The debate reemerged in 2011, when the EU proposed a unionwide ban on plastic bags. At this point a number of grocery stores had begun to offer paper bags as an alternative to plastic. Despite the 2008 debate, these were marketed as a sustainable alternative to plastic bags. This seems to have matched the established knowledge at the time. According to one survey, cited by Lunner (2011), 80 % of respondents regarded paper bags as more sustainable than plastic bags.

Environmental NGOs like Fremtiden i våre hender also supported the ban. According to their leader, Arild Hermstad, the ban would "make us change our [unsustainable] consumption habits" and "help raise awareness about climate change" (Næss, 2014). He decried policymakers who opposed the ban as "afraid to implement environmental policies that forces people to change their habits (..) as this might cost them votes". Finally, he charged the "mixed messaging" of these politicians with masking the seriousness of the predicament. "On the one hand, they describe climate change as the greatest challenge of our times. On the other hand, they tell people to go on living as before, with no need to change one's habits." (Næss, 2014).

The media soon began to challenge this stance (e.g. Lunner, 2011), once again presenting the conclusions of the 2008 Norconsult report as having busted this myth. Haugland (2011) described a ban on plastic bags as "a blunder if we want to do something good for the environment", informing proponents that "it is important to ask whether this would be good for the environment, before implementing policies that drastically interferes with people's lives". This question, he continued "has already been asked in Norway [by] governmental experts at STF. Their answer: plastic bags should not be banned"

The report was also cited by Erik Solheim, in response to a question by Line Henriette Holten – a member of the Norwegian parliament – as to why Norway would not follow in the footsteps of Italy, which had recently banned plastic bags. Solheim responded by referring to the review as "evidence" that "plastic bags, in a life-cycle perspective, have lower environmental impacts than paper bags" – and consequently that "we do not consider paper bags to be an environmentally preferable alternative to plastic bags" (Solheim, 2011).

5.2.3 Third Round of Debate: 2017 - 2019

The debate reemerged in the summer of 2017, when a goose-beaked whale was found stranded on the shores of Sotra with 30 plastic bags in its stomach (Mehren, 2017). Pictures of the whale's plastic-stuffed stomach made the rounds in Norwegian media, and drew a range of reactions.

The Labour Party of Tromsø, for instance, reacted by proposing a local ban on plastic bags "as a minimum, for shops in the city center" (Mehren, 2017). Kristoffer Joner, a movie star and member of the Labor party of Stavanger, diagnosed the use of plastic bags as "ridiculous" and asked "why don't we just ban these plastic bags? It may not be what saves the world, but it is a strong symbolic thing. If we cannot manage to do even this, we have a big problem" (Østbø, 2017a).

These proposals soon got dismissed by various claim makers, who again cited the – by now a decade old – Norconsult report. "I think it's good that people are getting involved in reducing our consumption of plastic bags", an assistant manager of recycling at IVAR informed the media. "But it's a myth that paper is more environmentally sustainable than plastic. Most life cycle assessments conclude with the following: increased consumption of paper bags would entail more environmental impacts than our present-day consumption of plastic bags" (Østbø, 2017b). "Kristoffer [Joner] is a good boy", expressed Leif Arne Moi Nilsen, a member of the Progress Party, "but I think he overlooks a lot when he comes out with such a simple solution" (ibid).

The following year, a new LCA on the topic, commissioned by the Danish Environmental Protection Agency, was published (Bisinella et al., 2018). This was the first major Scandinavian LCA to compare plastic and paper bags. It found that – for most end-of-life scenarios – paper bags would contribute less to climate change, but more to most other environmental problems (e.g., air and water pollution) than plastic bags. In particular, it found the production of paper bags to entail an order of magnitude more ozone depletion (p. 55).

This study was widely covered by the Norwegian media. Rema 1000, the second largest grocery store chain in Norway[3], even cited it as their reason not to offer paper bags[4]. As with the 2008 review, the conclusions were largely presented to the Norwegian public as a matter of scientific fact (e.g. Arntzen & Egeland, 2018; Blaker, 2018; Molnes, 2018). Few questioned its validity in light of its reliance on databases that were several decades old and, among other things, associated the production of paper bags with significant CFC emissions; or the decision to compare one plastic bag with two paper bags, thus skewing the results in favor of the former (Kvitrud, 2019a).

Several media outlets presented its main conclusion as stating 'paper bags have to be reused 43 times in order to be as sustainable as plastic bags'(e.g., Arntzen & Egelenad, 2018; Molnes, 2018). In actuality, '43' was the number of reuses prescribed for a pair of paper bags to outperform a single plastic bags with respect to every single impact category. By this point, the former would, for instance, entail two orders of magnitude less carbon emissions than the latter. And if the functional units were adjusted to one paper bag vs. one plastic bag – which was how the media presented the comparison – each impact factor, for the former, would be cut in half.

This round of the debate culminated in an inquiry by faktisk.no – the leading fact-checking organization in Norway, run by its leading newspapers (Dagbladed and VG) and television network (NRK) (Molnes, 2018). Their assessment began by citing the 2007 Norconsult report matter-of-factly as supportive evidence of the sustainability of plastic bags, quoting its main conclusion with no questions asked. “Most life cycle assessments conclude that a transition to increased use of paper bags would be bad for the environment over the long term”. It went on to reference the 2018 Danish report, again quoting its main conclusion matter-of-factly without engaging with its underlying assumptions or data. “An important reason for why plastic bags comes out ahead”, the fact-checkers explained, “is because the production of plastic bags entails less environmental impact than those of other carrier bags”.

Their article then briefly cited two other LCAs on the topic: a 2009 exploratory study by researchers at The Hong Kong Polytechnic University (Muthu, 2009); and a 2011 whitepaper by the British Environmental Agency (Edwards, 2011).

The former (Muthu, 2009) was an ALCA which combined secondary data from a 2004 assessment of the energy required to produce plastic and paper bags, with up-to-date emission factors for petroleum and coal-fired power plants. It found plastic bags “to be little better in terms of environmental impacts compared to paper bags”, while warning readers that “this stage of conclusion solely depends upon the secondary data and the LCA software employed for the study” (p. 317). As critics later pointed out, if one retained all other data and assumptions, but replaced the impact factor for Chinese coal-fired power with that of Norwegian hydropower, paper bags would come out ahead (Kvitrud, 2019a). Consequently, the whitepaper could be read as supportive evidence for the sustainability of paper bags in the Norwegian context. Yet once again, the external validity of the paper went unaddressed by the fact checkers. Its conclusion was simply presented as a timeless, non-contextualized matter of scientific fact.

The latter (Edwards, 2011) was an LCA which combined primary data from 2006 for “material types and weights to produce carrier bags and primary packaging, the production of carrier bags, transport modes and distances and waste management operations” with secondary data about “the production of raw materials and waste process emissions (..), electricity generation, fuel production, vehicle emissions and other more minor processes” (p. 23). The study may be described as a limited CLCA since it accounted for end-of-life impacts beyond the supply-chain of the product (e.g., “the avoided production of primary materials when HDPE based materials, LDPE, PP, cardboard and paper are recycled” and “the avoided production of any energy produced from incinerating or landfilling any of the carrier bags” (p. 22)), but not for marked reactions to changes in demand. Again, the age and external validity of its data and assumptions (e.g., that electrical energy was supplied by gas-fired power plants) went unaddressed.

One of the key narratives that emerged in the wake of this inquiry was one of popular demand – founded on a lack of scientific understanding – pushing commercial actors in an unsustainable direction. As Arntzen & Egeland (2018) put it “paper bags are less environmentally sustainable than plastic bags (..) but now, producers of plastic bags may have to produce paper bags in order to survive”. According to a representative for the plastic bag manufacturer Serviteur, “people simply do not understand that paper is worse for the environment, and it is incredibly difficult to get this message across to people”. And consequently, “if customers do not want plastic bags anymore, we have no choice but to switch to paper even though it is an environmentally inferior solution”.

Asked about the decision to sell paper bags “even though they are not good for the environment” (ibid), Knut Lutnøs, the sustainability manager of COOP, defended the choice as “important symbolically”, and a way to “give customers the choice”, instead of challenging the emerging construction of plastic bags as more sustainable than paper bags.

At this point, even Fremtiden i våre hender crossed the aisle. “This might be surprising to most people, but paper bags release twice as much CO2 during production as does plastic bags”, a representative expressed, citing – among other studies – the one commissioned by the Danish Environmental Protection Agency (Arntzen & Egeland, 2018). This is an interesting turn of events. Not only because it clashes with the actual conclusion of the cited study (which found the production of paper bags to entail less GHG emissions, but more emissions of most other pollutants). More significantly however; because it contrasts with the accusations that environmentalists on other counties have raised against LCAs that come to counterintuitive conclusions, for being “a justification for products, rather than an objective analysis” (Jensen et al., 1997: 18), or for violating the precautionary principle by excluding “uncertain effects that cannot be proven in a formal, quantitative way” (Bras-Klapwijk, 1998: 339).

A rival NGO, Naturvernforbundet, did however maintain its support for paper bags. In an early-2018 press release – praising the decision of Kiwi, a major grocery chain, to begin offering paper bags – they described paper bags as “superior to plastic bags, both because plastic is a fossil product which requires oil for production, and because of the damage done by plastic bags when they end up astray” (Molnes, 2018).

By late-2018, in the wake of the inquiry by Fakta.no, even Naturvernforbundet had acknowledged what by then seems to have become the new established knowledge; that the production of paper bags entailed more environmental impacts than that of plastic bags. They nonetheless maintained their support for the former, due to concerns about plastic pollution (Naturvernforbundet, 2018). If only a fraction of a percentage of the one billion plastic bags that were sold in Norway each year ended up in nature, they reasoned, this would soon add up to millions of displaced bags. And due to the scientific uncertainty surrounding microplastic, the precautionary principle prescribed a ban.

6 The role of LCA in decision making

This section addresses the use of LCA for environmental decision making in public administrations. It consists of 5 subsections. The first (6.1) addresses Stavanger kommune. The second (6.2) addresses Sandnes kommune. The third (6.3) addresses Haugesund kommune. The fourth (6.4) addresses small and medium sized municipalities. Finally, the fifth (6.5) addresses Rogaland Fylkeskommune (Rogaland County Municipality).

6.1 Stavanger kommune

The 2018 "Climate and Environmental plan 2018 – 2030" established a goal of reducing municipal carbon emissions by 80 % within 2030 (Vareide et al, 2018). The accompanying "Action Plan 2018-2022" stipulated 146 policy initiatives for setting the ball rolling. Among these were initiative E12 "Include environmental impact and life cycle costs (LCC) as award criteria for procurements" (p. 17); K1: "Develop a climate budget for the plan period and present annual climate accounts" (p. 36) and K9: "Provide as complete as possible assessments of how Stavanger is performing in relation to the established objectives for GHG cuts" (p. 37). Each of these required carbon emissions to be quantified. Three representatives were interviewed for these thesis, each providing a slightly different perspective on these efforts.

According to one interviewee, the administration applies a three-step process for actively steering towards the mandated reduction target. First, by constantly keeping their business-as-usual and climate-plan-aligned emission trajectories up to date. Second, by using these trajectories to establish annual carbon budgets. And third, by suggesting initiatives for closing the gap between budgeted and targeted emission numbers. By their account, "the process is very politically managed", and members of the city council are briefed on a quarterly basis. "[The politicians] might not understand the numbers, but they can see that a graph is trending upwards when it should be trending downwards", they explained. These quarterly updates pose some methodological issues, however, as most of the requisite input data is only provided by national authorities on an annual basis. As such, quarterly climate budgets are "estimated based on whatever data is available to us, such as toll payments, the number of ships docked at the harbor, etc."

Asked about the downsides of this approach, they listed several. Chief among these were the resources it draws away from actually implementing climate policies. "If [the calculations] are not detailed enough, we will be criticized for that", they related. But as the level of detail increased, so did the resources it drew resources from other activities – as well as the marginal costs of further increases. "We have now reached a point where it takes a lot of time to increase the quality of these numbers just a little bit. But it's hard to know where to draw the line (..) We cannot calculate everything. Sometimes we have to stop and use common sense". The interviewee maintained, however, that the environmental section probably would not have received as much funding as it does, were it not for the efforts put into these calculation. "This ensures that carbon emissions remain on the agenda. We keep the politicians engaged. It stays fresh in their mind".

Another downside that was brought up might be described as a manifestation of metric fixation. According to the national standard for municipal carbon accounting, municipalities are only accountable for direct emissions (i.e. from sources that are physically located within their boundaries). This not only excludes indirect emissions from imported goods and services. In the case of Stavanger, it also excludes many local emissions that intuitively seem like they should be included in the municipal carbon account. The local waste management and district heating plants, for instance, lie just south of the border to Sandnes. The local airport, just west of the border to Sola. The local sewage treatment plant, just north of the border to Randaberg. All of these point emission sources are thus excluded from the carbon account of Stavanger. Politicians, as the interviewee put it, "care about measurable accomplishments. Some of them even campaigned on promises to help realize the 80 % reduction target". Their incentives may thus be skewed towards reducing local, rather than global (or even regional!), emissions.

This predicament was brought up during a November 2020 city council meeting, by Leif Arne Moi Nilsen – a representative from the Progress Party – who challenged Stavanger kommune to accept its fair share of the responsibility for these emissions (Stavanger kommune, 2020). According to one interviewee, this set in motion an intermunicipal collaboration to redistribute these responsibilities; culminating in a revised climate budget for the greater Nord-Jæren area. These exogenous emissions were, however, not included in the climate budgets or emission pathways of Stavanger kommune. The interviewee admitted that no one seems to know for sure whether these are now included in the 80 % reduction target. "The revised climate budget [which includes our fraction of the shared emission sources] was devised after the 80 % reduction target was established. But the target might now include these emissions. We are not really sure. No one has really answered this".

Another interviewee described a lack of holistic approaches for distributing the mandated emission cuts among sectors and projects. "The responsibility can easily fall into the cracks between different sectors". At the project level, they explicitly described the implementation of climate policies as "hoping for the best". "We implement initiatives based on what we believe will make a difference. Practically and professionally speaking, this probably should be done in a more rational way (..) The administration generally wants to use tools like LCA and climate budgeting more, but lacks a framework for doing so".

According to the third interviewee, municipal construction projects are now required to calculate the life cycle costs and environmental impacts of 12-13 different components (two or more different products per component). They described this requirement as "very general", however, and not accompanied by any instructions for "how different concerns are supposed to be weighed against one another". In lieu of such instructions, the administration has prioritized costs. "If we compare two products – one that is preferable in terms of costs and one that is preferable in terms of emissions – we choose the former. Our priority is to minimize costs".

The administration has been looking into ways of using LCA in procurements. They have some experience in asking contractors – who are bidding on construction or infrastructure projects – to include Environmental Product Declarations (EPD) in their bids. These are third-party certified LCAs, conducted in accordance with product-specific PCRs[17]; which, in principle, can be used as award criteria. In practice, however, the administration has not yet leveraged this possibility. "If we were to [use climate impacts as reward criteria], then someone in our organization would have to follow it up, participate in project meetings, and so on. We have this expertise inhouse, but there are lots of other important things going on (..) they cannot take on extra workloads".

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[17] Product category rules (ref. section 4.2)

Change might be on the horizon, however, with an upcoming framework agreement on procurements of certain products (e.g., gravel), which will set climate impacts as an award criterion alongside cost and quality. The winner, the interviewee explained, will then be legally obliged to deliver products, that are at least as sustainable as the one offered, for all deliveries throughout the contract period.

Among the three interviewees, several other barriers and pitfalls were described. Some were political, such as: “communicating complicated concepts like reference pathways and scenarios to politicians”; “politicians struggle to understand why they can’t get perfect numbers for everything”; “there is too much focus on that which can be quantified. Those who work on other environmental issues, like recycling and local pollution, feel like their issues ‘disappear’”.

Others were methodological. These included the sensitivity of LCAs to more-or-less arbitrary choices and assumptions. “The choice of emission factor for e.g. electrical power can sometimes decide whether or not an investment is ‘sustainable’”. Another concern was the “extremely data sensitive” nature of LCA. For LCAs to be useful, as one interviewee put it, “one cannot simply pick data from databases. Such assessments are too generic. We need to invest time and money in collecting and assessing primary data about concrete alternatives”. Smaller municipalities, they reasoned, might purchase these services from consultants, but it is hard to apply the numbers for anything useful, without sufficiently qualified staff. For many municipalities, it is probably better to spend the money on implementing initiatives rather than on calculating their effects.

Other concerns were related to difficulties in evaluating the data, and uncertainty about the choice of standards, software, and baselines. “it’s nice to reduce emissions, and it’s nice to document emission reductions”, as one interviewee put it, “but I’m not sure what we would use the data for”.

6.2 Sandnes kommune

The “Climate and Environmental plan for Sandnes, 2020-2025” established the target of reducing carbon emissions by 40 % within 2030 relative to 1990 (Kommunestyret i Sandnes, 2020). At the time of its adoption, this target mirrored the intended nationally determined contribution (INDC) of Norway. Yet, as one interviewee explained, now that national authorities have revised their target to 55 % relative to 2015, Sandnes has de facto, though not officially, followed suite. The climate and environmental plan stipulates 8 policy initiatives; only one of which calls for climate impacts to be quantified: “we will assess the consequences of the ‘area section’ of the municipal sector plan with regard to carbon emissions”. The two interviewees from Sandnes kommune asked to be interviewed together, and were thus able to elaborate on each other’s answers.

“We are starting to find out what has happened with our emissions since [2015]. That is, how much they have changed since then, and what is required to achieve the new goal” one of them explained. “We in the administration can calculate this. Once this is done, we can use the calculations to propose a set of initiatives that puts us on course for achieving our reduction target. We have already given our input to the policymakers.” The result, so far, has been the establishment of a working group responsible for climate budgeting and for staking out a path to 55 % reduced emissions. These efforts have been coordinated by an administrative manager, while the day-to-day efforts of implementation have largely been left to individual project managers.

Both interviewees expressed difficulties in translating the macro-level reduction targets into concrete project-level initiatives. “We have to figure out what to do in the individual projects in order to achieve these goals”, one of them explained. “Then we need to figure out how we are going to report on this. It is easy to set quantitative goals. But if you look at our action plans, you’ll find few initiatives”. “The goal is there, but we don’t always see the path leading to the goal” the other one chipped in. Notwithstanding, they described ongoing efforts to ascertain what it would take for Sandnes to meet its abatement target.

Decisions about whether – and how – to implement climate action at the project level, they described as predominantly made on an ad hoc basis, with little or no connection to the macro-level reduction targets. These decisions have furthermore been based “not on calculated climate gas emissions, but on what we know to work well” as one interviewee put it.

When asked about the barriers to using LCA, both cited a lack of interest among local policymakers. “The politicians do not request numbers for carbon emissions. That colors the way we work”. At the project-level, the priority has been to limit investments, and to some extent life cycle costs. “We don’t build any ‘climate stuff’ because that costs money”, as one of them put it. “Today, cost generally trumps environmental concerns. I think this is true for most municipalities (..) We can put forth as many numbers as we like, and suggest as many initiatives as we like; but if they raise costs, they will not be implemented”. The tool they use to calculate the cost of construction projects – ISY Calculus – does provides rudimentary climate gas estimates, but the administration has not yet used these estimates, neither for decision making, nor for reporting.

According to one interviewee, the hesitation of many project managers to incorporate LCA into their projects, is exacerbated by the fragmentation of responsibilities that beset municipal organizations. The project managers – who are responsible for costs and emissions from construction projects – tend, for instance, to work in separate departments from those who are responsible for these during the use-phase of the building. This sets up incentive structures in which life cycle approaches are hard to implement.

They nonetheless described growing interest within the administration to work more systematically towards the 55 % reduction target. “We see a need to start pushing politicians to make decisions that we feel are correct”. In this context, they mentioned a freshly minted investment instruction, which mandates the use of environmental impacts as decision criteria for certain kinds of procurements. This includes the calculation of climate impacts for construction projects above a given threshold. Yet as one interviewee explained, the instruction does not specify how environmental impacts are to be weighed against e.g., costs.

Other barriers that were mentioned, were a lack of inhouse expertise and doubts about the validity of LCA models. “It’s hard to look deeply enough into the crystal ball to see the entire life cycle. There is always the possibility that such studies turn out to be ‘garbage in – garbage out’ assessments. I’m not convinced that those who produce them are skilled enough to do it appropriately”. As an example, they mentioned LCAs that present biogas and district heating as more sustainable than electrical energy. They found this unconvincing. “Intuitively, nothing is more sustainable than hydropower. I understand the arguments in favor of e.g. district heating and biogas, but it’s hard to imagine these as more sustainable. It doesn’t seem right”.

The interviewees nonetheless saw a potential in LCAs for converting macro-level reduction targets into day-to-day activities. “It forces us to think through the choices we make” as one of them put it. “I think it’s smart to include carbon calculations in the decision basis. It makes us think twice”, the other agreed. The key to acquiring useful, trustworthy numbers, they described as “involving the right people as early as possible and giving them sufficient time to deliver reliable numbers that give us more certainty about the choices we make”.

6.3 Haugesund kommune

The «Klima- og energiplan 2021-2030» of Haugesund kommune established the target of reducing carbon emissions by 55 % within 2030, relative to 1990 (Haugesund Bystyre, 2021a). Uniquely among the municipal climate plans reviewed for this thesis, this one explicitly expresses the associated emission and abatement figures. “In 2019, Haugesund emitted 90,4 kt CO_2e. In 1990, Haugesund emitted 73,6 kt CO_2e. In order to reduce our emissions by 55 % relative to 1990, Haugesund may thus emit at most 33,12 kt CO_2e in 2030. By then, we must therefore reduce our emissions by 57,28 kt CO_2e” (p. 2). The plan furthermore states an “expectation” that the municipality also reduces the climate footprint of its own organization by 55 % (p. 16). For 2019 these emissions were estimates as 30,1 kt CO_2e, and explicit reference and target emission pathways are drawn up.

The associated action plan includes a range of initiatives explicitly calling for carbon emissions to be quantified (Haugesund Bystyre, 2021b). These include “establish climate budgets and accounts for all companies owned by the municipality” (p. 9); “request climate budgets for all construction projects” (p. 4), and “ask suppliers to document the climate footprint of their products and initiatives to reduce these” (p. 9). It also includes a range of initiatives that implicitly calls for quantification, such as “strive to make Haugesund a climate-neutral municipality” (p. 10), “reduce climate emissions from road traffic by 50 %” (p. 5), and “purchase climate-friendly products by attaching high weight to climate-friendliness when choosing suppliers and products” (p. 9).

Two representatives from Haugesund kommune were interviewed for this thesis. Just like the ones from Sandnes kommune, they asked to be interviewed together.

The new climate plan had gone into effect just four months prior to our interview (December 2021). The interviewees thus conceded that none of the initiatives had yet been implemented, and that no systematic efforts had been made to stake out a course to the 55 % reduction target. They both agreed that the ideal path forward would be to use the emissions trajectory, mandated by the reduction target, to deduce annual carbon budgets, and allocate these budgets among different sectors (e.g. traffic, industry, etc.). The main barrier to doing so in practice, they described as the significant fraction of municipal emissions that lied outside of their jurisdiction. “Shipping is hands down the largest source of carbon emissions for Haugesund”, one made clear. “And the emission trajectory of this sector will depend on technological progress and national policies that are outside of our control”. As such, allocating annual carbon budgets among different sectors, they reasoned, might just be a time-consuming armchair exercise without any practical significance.

“The carbon emissions that are within our control are by and large associated with road construction, traffic, buildings and procurements. These are therefore the primary focus points of both the new climate plan and the associated action plan. In order to meet the reduction targets, many initiatives must be completed. We need to use all tools at our disposal and cooperate with other parties, including in the private sector" one explained. They also shared their interpretation of the aforementioned initiative "request climate budgets for all construction projects" from the action plan, to mean that LCA should be used to identify low hanging fruits for reducing carbon emissions, "but I am not entirely sure". "We have discussed how [climate impacts] should be weighted in procurements – how to include it as a requirement for contracts" the other shared, "there is a lot of pieces that have to fall into place eventually".

They described some prior experience with quantifying carbon emissions. "We did our climate budget and projected emission pathways based on data from the Environmental Agency (..) We are planning to continually update [these] to track our progress". This, they hoped, would prove useful – not only for planning purposes – but also for "'show and tell sessions' with politicians. It might help us secure more resources for climate initiatives".

They moreover shared their experience with using simple excel-based LCA tools – published by the Environmental Agency – to compare and rank competing climate initiatives and allocate funds. One interviewees described attempts to encourage colleagues to adopt these, only to find them too short on time "both for learning how to use the tools, and for conducting thorough assessments". This, they described as the chief barrier to using even these comparatively simple tools more widely. "It truly boils down to capacity". They also described a lack of inhouse expertise in project-level LCAs, and the need to purchase this from consultants.

Finally, they mentioned some experience with organizational carbon accounting. So far, these had been produced with the web-based tool Klimakost, with data supplied through their membership in the climate action network Klimapartnere Rogaland. They expressed doubt about the longevity of these efforts, however. "It takes a lot of time and effort, and we have so far never used the numbers for anything. No one is asking for them (..) We might well discontinue our membership in Klimapartnere. The politicians are simply not interested".

6.4 Small municipalities

None of the interviewees from the small municipalities had much experience with LCA. One had been involved in a few construction projects in which LCC had been used. A second had been involved in procurements in which bidders had been asked to calculate the life cycle emissions of their deliverables, but which did not use these numbers for anything. A third knew about a project that had applied for funding from *Klimasats*; a national climate fund that asks applicants to quantify the climate impacts of their proposals.

One interviewee described having just handed the final draft for a new municipal climate plan over to political review. The previous climate plan, which this one was set to replace, included a goal of reducing carbon emissions by 10 % between 1991 and 2022. By their account, no systematic efforts had been made to meet this target, but it somehow ended up being met anyway. This, they attributed more to a revision of the national standard for municipal carbon accounts – which just so happened to favor them – than to any reduction of physical emissions.

Like most of the climate plans reviewed for this thesis, this new draft suggested a reduction target corresponding to the national target of 55 %. Yet, the interviewee conceded, the draft did not come with a roadmap for how to reach this target. “The plan doesn’t include anything akin to ‘initiative A will reduce municipal carbon emissions by X tons”, they explained. Climate budgeting and emission trajectories, they reasoned, would be beyond the ambitions of their municipality. Instead, the aims of the new plan were to get the ball rolling, attain buy-in from the powers that be, and gain insights into municipal climate action. “The plan will be revised every four years” they explained. “Our strategy has been to tread lightly this time around, so as to get everyone on board. Stricter initiatives, and more professional tools, can be implemented in time”.

In discussing reduction targets, one interviewee from a small municipality pointed out that two thirds of their reported emissions stemmed from agriculture. Even if they somehow managed to reduce all other emissions to net zero, this would barely put them north of halfway to complying with the national 55 % target. “These emissions cannot be reduced unless we reduce the number of livestock, and we cannot reduce these due to national policies about food security”. As a consequence, they had opted to leave agricultural emissions out of their carbon calculations, to ensure “more encouraging numbers”.

Since these agricultural emissions would come on top of all ‘ordinary’ emissions, they reasoned that their total carbon emissions would be far greater than those of most comparable municipalities. As a consequence, the emission reductions that could be achieved by any given climate initiative – calculated as a fraction of total municipal emissions – would be far smaller than they would have been elsewhere. This, the interviewer worried, might discourage administrators and politicians from taking climate action. “In the current calculation regime, any given climate initiative would barely move the needle”. If agricultural emissions were kept out of the equation, on the other hand, the impacts – calculated as a fraction of total emissions – would be far greater. Ignoring agricultural emissions, they reasoned, might thus make it easier to get people enthusiastic about climate action, as any particular initiative would then be made to make a meaningful difference.

One interviewee described LCA, at the municipal level, as mostly just relevant for procurements. “Procurements take up a lot of room in our space of possible climate actions”. Consequently, they had been trying to implement this for a while, but had found it challenging. “It takes a lot of time and capacity to conduct high quality LCAs. We simply cannot do it for most procurements (..) In principle, we could conduct an LCA whenever we were going to purchase, say, 100 new pens. There are probably some pen-manufacturers who have more sustainable supply chains than others. But we simply do not have the capacity to do so”. They did, however, describe ongoing efforts to implement LCA in some of their largest procurements, particularly for building and infrastructure projects. “LCA is a branch on the tree of climate and environmental policies, that we would very much like to explore”.

When asked about the barriers to using LCA more systematically, the interviewees more or less unanimously echoed the same handful of issues. These comprised concerns about costs, doubts about benefits, wanting inhouse capacity and expertise, and weak political mandates. “We already know that most of our emissions stem from transportation and industry”, one interviewee explained, expressing doubt about the usefulness of LCA. “It is better to spend our money on reducing, rather than calculating, these emissions”. In theory, they reflected, “LCA might be used to find the largest emission sources, and then find ways to reduce these”. Yet there was no demand, neither politically nor administratively, for doing so. “No one cares. This has to come from the politicians. And there has to be a plan for how to use the data. Otherwise this will only impose costs on projects without adding anything of value”.

“I feel that climate accounts are mostly used as ornaments. What truly matters, when it comes to making decisions, are costs”, one relayed, using as an example a recent decision to demolish and rebuild an old school building instead of renovating it. Although this entailed more environmental impacts, it also entailed more “economic safety” by lowering the risk of unforeseen costs.

One interviewee cited methodological concerns. “It is hard to know which stages to include in the calculations, especially whether to include some indirect emissions, or limit the scope to direct emissions”. “We prefer things that are more concrete. We can estimate climate emissions any which way. The results partially depend on what one choses to include, and how one choses to estimate things. We don’t really know what we would have done with the data we would have received. It would be difficult to use the data for anything sensible. We are a small municipality without dedicated staff to work on things like this”.

6.5 Rogaland Fylkeskommune

Rogaland Fylkeskommune is a relative newcomer to the quantification of carbon emissions. According to the representative interviewed for this thesis, the administration published its first climate budget in the fall of 2021 and plans to follow this up with a carbon account at the end of 2022. It has also just begun to apply LCA in infrastructure projects. To ensure its usefulness as a management tool, “it will be accompanied by processes for identifying efficient initiatives, securing financing and following up on implementation”. Since these efforts have only just begun, they see it as “still a bit too early to say anything about its usefulness as a decision-making tool”.

The interviewee described the methodology used to calculate the climate budget as a “work in progress”. They furthermore expressed expectations for it to remain so for the foreseeable future. As such, they admitted, the numbers produced will not be commensurable over time, and cannot be used to track progress. As an example, they mentioned plans to incorporate emissions from a greater fraction of the county’s vehicle fleet into next year’s climate budget. The administration has identified two types of projects for which LCA seem useful: infrastructure projects and construction projects.

With regard to the former, “the calculation tool VegLCA, which was developed for the Norwegian Public Roads Administration (Norwegian: ‘Statens Vegvesen’), will be used for some upcoming road construction projects. This will hopefully provide us with the experience we need to evaluate whether this is an appropriate tool to use on a larger scale, and to gradually improve our understanding of greenhouse gas emissions from such projects”.

With regard to the latter, “we are still evaluating different approaches, with the goal of eventually being able to compare the carbon impacts of different design choices – for example of different material choices – and compare these with their respective costs before making decisions. (..) Once we get to the point where we can calculate the emission reductions of different climate initiatives, we can compare these and select the most efficient ones”.
When asked about downsides, the interviewee replied, “the fact that there can be major emission sources that are not quantifiable. We risk overlooking initiatives aimed at these [non-quantifiable] emission sources, and the significant emission cuts they might have entailed”. They nonetheless stressed that “this is not something that could have been solved by dropping the climate budget as a management tool, so it is hardly a ‘barrier’ in that sense.

It is more of a factor that one must be aware of, and which points to the importance of mapping out as many emission sources as feasible, so as to ensure that LCAs paint the most accurate pictures possible”.

7 Discussion

Let us begin our discussion by returning to the opening statement of this thesis: "Sustainability transitions can be said to have three prerequisites: the will to pursue them; the means to pursue them; and the expertise to distinguish sustainable from unsustainable transition pathways". The third prerequisite has been the focal point of the foregoing sections; with a special emphasis on the expertise needed to assess environmental impacts in a life cycle perspective. Due to the complexity of modern economies, this expertise is often regarded as essential for sound environmental decision making. Yet expertise is a double-edged sword. It can be mobilized as a tool of rationality (as in evidence-based policymaking); or as a tool of rationalization (as in policy-based evidence making).

Insofar as quantitative truth claims are allowed to construct the concepts they espouse to measure, the experts who produce them have the power to define and redefine reality. In 2013, SSB defined a managed decline of petroleum production as sustainable. And every time this got repeated in the media, by politicians, and over the lunch table; it became a bit more real. In 2019, Rystad redefined this transition as one of disputed sustainability. And once again; every time this got repeated, it became a bit more real. In 2008, Norconsult defined a managed transition away from plastic bags as unsustainable. And ever since, proponents of this transition have – as a matter of socially constructed fact – been in the wrong. Throughout the private and public sectors, bureaucrats and consultants define and redefine transition pathways as sustainable or unsustainable on a daily basis. Often in good faith to identify optimal transition pathways. Other times opportunistically, to promote vested or ideological interests.

Let us next contrast the following pair of sentences:

(1) Methane is a 25 times more potent greenhouse gas than CO_2.

(2) In 2007, IPCC Working Group I revised its estimate of the GWP_{100} of methane from 23 to 25, to account for some recently discovered second-order effects.

These sentences paint the number '25' in rather different lights. Sentence (1) depicts a ready-made-number[18]; a black box; a matter of fact. There is no trace of its origins or construction. No trace of the scientific, political, and moral debates from which it emerged victorious. It might as well have been handed down to Moses. Sentence (2), on the other hand, depicts a number-in-the-making; an open box; a work-in-progress. It shows us that sentence (1) has not always been a matter of fact, but that it is, on the contrary, a tentative convention; agreed upon by a particular group of actors situated at a particular point in space and time. Sentence (2) speaks of a number that has changed in the past, and will continue to change in the future. This is the CO_2-equivalency of methane as it appears at the head of the knowledge stream; from the vantagepoint of the climate scientists from section 4.1.

As we move downstream, we soon encounter the LCA practitioners from section 4.2; toiling away under tight budgets and looming deadlines to estimate the climate impacts of their respective projects. From their vantagepoint, sentence (1) is a black box. '25' is simply the constant by which cells, tagged with 'tons of CH_4' in their spreadsheets, needs to be multiplied, before they can be added together with other numbers. This ready-made-number

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[18] Derived from the distinction Latour (1987) draws between 'ready-made-science' and 'science-in-the-making'

is, to borrow a description from Latour (1987), "just sitting there in the background, [its] scientific or technical contents neatly distinct from the mess that [the practitioner] is immersed in" (p. 4). Individual LCA practitioners may intellectually question the validity of this number, but such doubts are of no practical significance. GWP is the blackest of all black boxes. Meticulously constructed by some of the most prestigious climate scientists in the world. Pieced together from hundreds of peer reviewed papers. Stamped with the insignia of the IPCC. Its authority is absolute[19].

The climate impacts of the particular projects for which these practitioners work, on the other hand, are numbers-in-the-making. Their exact magnitudes will depend on the myriad little methodological choices and assumptions that remains to be made. There are system boundaries to be drawn. Missing data to be replaced with proxies. Impact factors to be culled from various databases. End-of-life scenarios to be chosen. In the words of Merry (2018), the job description of these practitioners amounts to confronting "challenges of missing data and unmeasurable phenomena, but through pragmatic compromises, [manage] to produce quantitative knowledge that shapes public attitudes and policy decisions and responds to the human desire to know the complicated and often unknowable world" (p. 25).

Downstream of the LCA practitioners, we enter the realms of the policymakers, project managers, and administrators from section 6. Here, the climate impacts of the particular projects have become black boxes. From this vantagepoint, these are ready-made-numbers; datapoints among other datapoints on which evidence-based decisions must be made. Individual decisionmakers may intellectually question some of these numbers, but have – in want of the prerequisite expertise – no social license to discard them. Doing so might leave them on the hook if their projects somehow end up as politically contentious.

All along the stream, we also find the journalists and commentators from section 5, who distribute the end-products – the freshly baked facts – to the general public. These distributers are not passive entities; mere mediums through which new facts disseminate. Instead they are active agents who shape, and are shaped by, these facts. One pundit might transform a literary review by a consultant into a life cycle assessment by the Environmental Agency. Another one might revise her previous stance on supply side policies in light of new facts. A litany of partially overlapping truth claims, derived from those assembled by upstream experts, may eventually circulate in the public sphere.

Some of these will be qualitative; others will be quantitative. The latter – due to their intuitive associations of rigor and objectivity – will disproportionately tip the scale of public opinion. No qualitative argument against unilateral production cuts could stand its ground against a quantitative assessment that spoke against it. Two quantitative assessments that contradict each other, on the other hand, can fight head to head.

Now, before we focus our conceptual lenses more sharply onto these activities, let us return once more to the head of the knowledge stream; and work our way downstream.

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[19] Were we instead to move upstream from the climate scientists, we would of course similarly find the black boxes on which they rely – like the Planck and Stefan-Boltzmann constants – opening up into number-in-the-making under perpetual refinement by physicists.

7.1 Discussion on the validity of LCA

The validity of LCA can be described as a function of three variables: (1) the validity of GWP_{100} as a metric of contribution to climate change; (2) the empirical accuracy of particular GWP_{100} estimates (3) the correspondence between calculated and physical GHG emissions.

Since the appropriateness of a given climate metric depends on a combination of scientific, political, and moral deliberations, the validity of GWP_{100} is not straightforward to assess (Forster et al., 2021). The more appropriate question might be 'under what conditions is GWP_{100} a valid climate metric?'

From a scientific perspective, GWP has been criticized for constructing as 'equal' emissions that result in unequal temperature responses (Allen et al., 2018). This is particularly the case for SLCPs (e.g., methane), for which GWP overstates the impacts of sustained emissions and understates the impact of new emissions (Forster et al., 2021). The scientific validity of GWP, in any particular LCA, may thus be described as inversely proportional to the fraction of SLCPs in the basket of GHGs under assessment. As an example, GWP might be fairly valid in a comparison of alternative vehicles; but less so in a comparison of alternative diets.

From a political perspective, GWP may be conceptualized as a compromise between the contradictory ideals of policy relevance and empirical accuracy (Forster et al., 2021). Any alternative metric – in either direction on the causal chain described in section 4.1 – would have entailed less of one or the other. One troubling aspect of this actually existing compromise, however, is that any global carbon budget – expressed in terms of GWP – can result in a range of different temperature responses, depending on "the composition of the basket of gases whose emissions are reduced" (Skovin, 1999: 15). As such, "we do not know the actual climatic effect, for instance of the Kyoto target, until after it has been effectively implemented" and this composition is known (ibid).

From a moral perspective, GWP has been criticized for equating the 'survival emissions' of the poor with the 'luxury emissions' of the rich (Agarwal and Narain, 1991). This is both symptomatic of, and conductive to, the overarching construction of climate change as a problem that is both caused by, and confronts, an undifferentiated, global 'us'; rather than one that is caused by people in the Global North and confronts people in the Global South.

There seems to be strong support in the scientific literature for describing newer climate metrics, such as GTP and GWP*, as more scientifically valid than GWP (e.g., Allen, 2018). Yet these have hitherto been roundly defeated in what Merry (2016) terms the "competitive marketplace of indicators". Climate scientific laypeople – and this includes most LCA practitioners – simply do not have the expertise required to assess competing climate metrics. Outside of the confines of a narrow specialist community, these are all black boxes. A free-for-all with regard to metric selection would only mean that providers of e.g. methane-intensive products could cherry-pick GTP as their metric-of-choice, while providers of CO_2-intensive products could stick to GWP. This would solve nothing, and leave us with a mismatch of incommensurable truth claims. Seeing as all major LCA standards (e.g. ISO 14040, ILCD, PCRs etc.) are based on GWP, moreover, individual LCA practitioners have little choice but to follow the crowd.

As argued by Porter (1995), however, the commensurability of numbers is often of more important than their validities. If some particular country or organization unilaterally decided to calculate its carbon emissions by assigning methane a GWP_{100} of e.g. 30; this might improve the validity of their calculations. But it would also render them incommensurable with all other such calculations. Sacrificing some validity for some commensurability would – in most cases – be a better option. The price to pay for devaluing validity, however, is the risk of sub-optimal – if not counter-productive – climate action; optimized for reducing ‘paper emissions’ instead of physical ones.

A coordinated transition to a new climate metric does not appear to be on the horizon either. The entire edifice of international climate cooperation, ranging from the UNFCCC, to Intended Nationally Determined Contributions (INDC), to emissions trading systems (e.g., EU-ETS), would have to be revised. At the same time, all actually existing climate budgets, trajectories and LCAs would be rendered obsolete; and the hands of climate sceptics, seeking to undermine the epistemic authority of climate scientists, might well be strengthened. For better or worse, GWP_{100} seems to be locked in.

As discussed in section 4, particular GWP_{100} estimates are under perpetual refinement by climate scientists. Due to space limitation, this thesis only covered the evolution of GWP_{100} for methane; which rose by roughly 50 % over the past three decades. In retrospect, therefore, early GWP estimates do not seem to have corresponded all that well to the phenomena they were supposed to represent. Instead the only thing to which they may be described as having corresponded, was the epistemic authority-weighted average opinion of the members of IPCC Working Group I; which turned out to be fairly off base.

Unlike the two aforementioned variables – which are more or less common to all LCAs – the correspondence between calculated and physical emissions varies as a function of e.g. the complexity of the system under assessment, the skills of the practitioner, and the time and money invested in data collection.

Numerous sources of poor correspondence are described in the LCA literature. Some models have poor construct validity in the sense of “using inputs or methods that imperfectly capture the characteristics of the product system“ (Matthews et al., 2014: 193). Some are subject to data inertia in the sense of relying on data from outdated databases (Matthews et al., 2014). Some encourage metric fixation by leaving out impacts that are hard to quantify (Bras-Klapwijk, 1998). Some rest on assumptions that are only valid within narrow spatial or temporal confines (e.g., that electrical power is supplied from coal-fired power plants), and becomes invalid when extrapolated elsewhere (Kassatly, 2020). Finally, some are conducted as ALCA when they should have been conducted as CLCA, or vice versa (Plevin, 2013).

I principle, the only appropriate use of ALCA is for allocating environmental responsibilities in an accounting sense. Only in “extremely unlikely cases” in which all market-mediated effects are negligible, can ALCA – even in principle – achieve complete correspondence between calculated and physical emissions (Plevin et al., 2014). More generally, this correspondence can be described as proportional to the ratio of first-order impacts (which are accounted for) to higher-order impacts (which are not accounted for).

When applied as an accounting tool, however, any particular ALCA may be described as valid in so far as it complies with the rules of the particular accounting scheme for which it is being conducted. This does entail some hard-to-stomach results, though. Recall, for instance, the rapeseed-to-bio-electricity chain – described in section 4.2.3.1 – whose carbon footprint was drastically reduced when assessed under the US’ “Renewable Fuel Standard” instead of the European “Renewable Energy Directive” (Wardenaar et. al., 2004). In principle, such discrepancies should not be cause for concern. Decisions about how to allocate responsibilities must be grounded in moral, political, and legal deliberations – and might reasonably be expected to vary from country to country. In practice, however, LCA practitioners have a tendency of presenting ALCAs “in a way that suggests that policy decisions based on these results will yield the quantitative benefits estimated” (Plevin et. al, 2013: 73). And decisionmakers have a tendency of being convinced by these presentations.

The validity of any particular CLCA, meanwhile, depends on how well it predicts the environmental impacts of the decisions under assessment. This validity is generally hard to assess. Even the most impeccable CLCA may end up invalidated by unforeseeable shocks down the line. The practitioner may, for instance, perfectly estimate the amount of energy consumed over the life cycle of a product; only to have the assessment invalidated by technological or political disruptions to the forecasted pace of the energy transition (and thus the impact factor of energy consumption). Or perfectly estimate the amount of waste generated at the end of a life cycle; only to have the assessment invalidated by disruptions to waste management technology (and thus the impact factor of disposal).

In principle, the validity of a CLCA model should be expected to grow as a function of the fraction of all consequences that are accounted for. In practice, alas, there is no guarantee of convergence to a progressively more correct answer as the number of modelled consequences grows. In extreme cases, the results may even alternate between positive and negative with each additional consequence (Ekvall, 2020: 16). And, as discussed in section 4.2.2, this leaves a lot of room for mathiness and Texas sharpshooters.

Each additional consequence, added to a CLCA, moreover adds to its completion time. And since LCAs generally have to be ready in time for the decisions they are meant to influence, lines have to be drawn somewhere. Recall, as an example of failures to do so, the mid-1990s LCA of the U.S. auto industry – discussed in section 4.2.4 – which was rendered outdated and irrelevant by technological changes, before it was even published (Matthews et al., 2014: 21).

7.2 Discussion on a managed decline of petroleum production

On the eve of August 16th, 2021, the sustainability of a managed decline of petroleum production was a blackboxed fact, backed by the epistemic authority of SSB. It was something one could reference matter-of-factly in a debate, to leave ones adversary fumbling for a retort. Virtually overnight, this fact had been reduced to a contested claim; an open box full of speculative assumptions about price elasticities, the behavior of OPEC, and average vs. marginal values. Proponents of supply side policies – who had attached the credibility of their stance to this now-contested paper – scrambled to its defense.

On a surface level, the ensuing debate may be described as an ordinary case of two epistemic communities speaking past one another. Strictly speaking, the two research papers that formed the backbone of the debate, did not even contradict each other. The first one concluded that production cuts in marginal oil fields would likely be a cost-efficient way to reduce carbon emissions. The second one concluded that a general scaling down of petroleum production, spread across all oil and gas fields, would likely result in increased global emissions. Both conclusions seem both plausible and mutually compatible. Taken as a whole, representing ‘what science tells us about the climate impacts of unilateral production cuts’, they blandly inform us that ‘production cuts in marginal oil fields (e.g. Veslefrikk) would likely be a cost-efficient way to reduce carbon emissions, while production cuts in highly productive fields (e.g. Ekofisk) would not’.

There is a very real sense, however, in which this description seems to miss the point. From a micro-sociological perspective, it would no doubt be interesting to analyze the debate in terms of ingroup-outgroup dynamics, status economics and motivated reasoning. From the more macro oriented perspective of this thesis, however, the debate is better conceptualized as a power struggle over the authority to construct the petroleum sector, on behalf of the Norwegian public, as ‘sustainable’ or ‘unsustainable’. In principle, this distinction is, of course, a spectrum, not a dichotomy. In practice, however, behaviors and technologies tend to get dichotomously coded as one or the other. And consumers, political parties, funds, and anyone else who want to present themselves as ‘green’ or ‘sustainable’ have to adapt or risk charges of hypocrisy or greenwashing.

The second wave of the debate, in particular, brings to mind Bras-Klapwijk’s (1998) description of the Dutch PVC-debate of the early 1990s. Claim makers from both camps “suppressed or denied [uncertainties about the results] when the results were in line with their view” (p. 340-341), while acting as critical peer-reviewers “when references were made to LCAs that were not in line with their ideas” (p. 337). Neither camp seemed particularly concerned about the aptness of CLCA for the task at hand. Instead they both homed in on the perceived flaws of the model that vindicated the stance of their adversaries.

In the wake of the debate, it is hard to gauge the effect it may have had on public opinion. Given the polarized nature of supply-side policies, both camps may have plausibly seen the events as confirmatory evidence of their own preconceptions. From the environmentalist point of view, they may have served as confirmatory evidence of the corrosive power of the petroleum sector. From the pro-petroleum point of view, they might have served as confirmatory evidence of the irrationality of environmentalists.

From the environmentalist point of view, the events may be further conceptualized as Gresham’s Law meets Merchants of Doubt. The metric used to evaluate the sustainability of the Norwegian petroleum sector had been established – not so much by SSB as by the environmentalists who leaned on its epistemic authority to construct their policy stance as evidence-based – as the impact factor of unilateral production cuts. By purchasing a custom-order LCA based on a scenario that was prone to paint such cuts in a non-flattering light (a general scaling down of petroleum production, spread across all oil and gas fields), the petroleum industry may be described as having gamed this metric.

The events can also be seen as confirmatory evidence for Seidel’s (2006) assertion, cited in section 4.2.4, that “LCA results have tended to support the interests of the study sponsor” (p. 340). Sponsors who, as discussed in section 2.2, control “the framing of the question, the design of the study, the conduct of the study, how data are analyzed, selective reporting of favorable results, and spin in reporting conclusions” (Lundt et al., 2017: 5). Once the research question “are unilateral production cuts sustainable?” got operationalized as “are unilateral production cuts spread across all oil and gas fields (with no regard for differences in productivity) sustainable?”; the answer was already given.

The debate moreover raises some important questions about the power to decide who gets to decide on the evidence. NMBU professor Knut Einar Rosendahl, for instance, later informed a journalist that he had twice applied for grants from the Research Council of Norway ('Forskningsrådet') to research this exact question; only to have his applications denied (Schei and Vartdal, 2021). He attributed this outcome to the current set of grant programs, in which power-critical climate-related research "falls between two chairs" – not fitting into any of the predefined categories. Lars Gulbrandsen, of the Fridtjof Nansens Institutt, seconded this account. "Forskningsrådet tends to favor grant applicants who incorporate 'user cooperation'; and users tend to only be interested in research that is immediately beneficial for them" (ibid).

In short; publicly-funded researchers were barred from producing up-to-date knowledge on this topic, whereas vested interests like Norog had the financial muscles and intellectual freedom to fund whatever research they saw fit.

The new truth claim, they commissioned, thus only had to contend with a single, decade-old, research paper of questionable validity. The evidence for and against the proposition under debate was literally 50/50. In an alternate reality of research funding regimes, in which Rystad's claim had to contend with a handful – if not dozens – of other up-to-date papers on the topic, it might have found itself outnumbered and outgunned. The claim 'dozens of research papers contradict this finding' seems to bear at least an order of magnitude more weight than 'one research paper contradicts this finding'. In the actually existing reality, however, the score was 1-1, and everyone turned to whichever paper they preferred.

According to an online poll, hosted by the national newspaper Nettavisen, 89 % of respondents agreed with the statement 'global GHG emissions would likely decrease if Norway stopped producing oil and gas' (Solli, 2021). As of 17.02.2022, the poll has 23 184 respondents. In order to gauge how the debate influenced popular opinion, however, such post-debate results would have to be compared with a counterfactual. The prior distribution could, in principle, have served this purpose, as ceteris paribus it would have been unlikely to change much over such a short period.

During a 2019 debate, Karl Eirik Schjøtt-Pedersen, then CEO of Norsk Olje og Gass, claimed that "we have research showing that three quarters of the Norwegian population thinks that reducing oil and gas production is unlikely to impact global climate emissions" (Sandvik, 2019). Yet he does not provide his source[20], and as such the commensurability of these two polls cannot be assessed. As the Nettavisen poll remains active, it is furthermore not possible to distinguish those who voted during the debate from those who voted in its aftermath[21].

Regardless; the debate has, perhaps irreversibly, transformed the discourse from one in which 'the research shows that supply-side policies are efficient' to one in which 'the research is divided'. By leveraging what Jasanoff (1987) refers to as "the strategy of highlighting the indeterminacy of science" (p. 225), Norog may have successfully barred its adversaries from matter-of-factly citing the SSB paper as supportive evidence. The ready-made retort to those who *do* cite it, would now be that 'other studies have come to the opposite conclusion', and by extension 'you are just cherry picking the study that fits your purposes'.

From this perspective, the debate resembled, less a boxing match, than a tournament game of chess, in which the player controlling the white pieces (environmentalists) had to play for the win, while the player controlling the black pieces (Norog) could gladly settle for remis. In the end, the sustainability of unilateral production cuts was left in limbo; an intermediate state

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[20] I emailed Norog 18.02.2022, and again 26.05.2022, but have not received a response

[21] I emailed Nettavisen 25.02.2022, and again 26.05.2022, but have not received a response

between fact and fiction; science and speculation. From the vantage point of third party observers “the whole topic is simply a mess from which no credible fact emerges” (Latour, 1987: 86). Demand-side policies were, in short, rendered less evidence-based – and thus harder to justify – than they had been prior to the debate.

7.3 Discussion on the proposed transition from plastic to paper bags

In the spring of 2008, the will and means to peruse a managed transition from plastic bags to paper bags seemed to have come into alignment in the person of Erik Solheim; The Norwegian Minister of Climate and the Environment. This transition was essentially vetoed, however, by the sole consultant[22] who was hired to produce the expert knowledge needed to transform it from an ‘ideologically-based’ policy into an ‘evidence-based’ one. The decision of this consultant to treat a series of old, foreign LCA models as black boxes; whose outputs could be transposed to the contemporary Norwegian context, not only blocked the transition, but also framed its proponents as misguided.

The actual report did stress the uncertainties inherent to LCA. But by the time its conclusions entered the public sphere, they had been stripped of such concerns. Now the report itself had become a black box; ‘research by SFT that showed plastic bags to be more sustainable than paper bags’ – and whose content was rarely discussed. Even when journalists, on the odd occasion, did open the box, its contents were merely presented as more black boxes; i.e., ‘SFT surveyed a number of life cycle assessments’. Barely ever were these internal boxes opened or their contents examined.

The case provides a vivid illustration of the social nature of the construction of facts. Had this budding fact-in-the-making not been picked up and embraced by the media, it might have remained buried in obscure consultant reports and academic journals. Instead it got repeated ad nauseum by all major media outlets for more than a decade. And the more it was repeated, the truer it became. Over the years, an imposing set of actors would come to lend it their epistemic authorities: the Minister of Climate and Environment, Faktisk.no, Fremtiden i våre hender, etc. Dissenting now meant confronting the combined authority of this “community of believers", to borrow a term from Merry (2016).

As this community grew, so did the marginalization of remining skeptics. Although less pronounced than in the first debate, an element of boundary work can be seen at play here. Dissenters from the emerging consensus were judged against the epistemic authority of those against which they dissented – and were found wanting. Isolated skeptics, ranging from Kristoffer Joner to the faceless consumers who “simply do not understand that paper is worse for the environment” – as the spokesperson for Serviteur, quoted in section 5.2.3, put it – were lightheartedly patronized for a while and then gently escorted to the margins of the discourse.

The case moreover illustrates the trust contemporary societies afford scientific, and in particular quantitative, truth claims. To repeat an observation made in section 3; arguments presented during this debate often boiled down to “a research paper has concluded X, therefore X is true”. Yet, like the macroeconomic models of section 2.3, LCA models cannot, by their very nature, incorporate the totality of our knowledge. The LCAs invoked during the debate, for instance, all assumed end-of-life scenarios in which the plastic bags would either

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[22] Or “pair of consultants” if you count the colleague who signed off on the quality control

be recycled or incinerated. Yet, as some dissenting environmentalists (e.g. Naturforbundet) pointed out; if even a fraction of a percentage of the one billion plastic bags that are sold in Norway each year ends up in nature, this soon adds up to millions of displaced bags. This exemplifies what Bras-Klapwijk (1998) refers to as the “pre-environmentalist frame” of LCA, which – as discussed in section 4.2.4 – precludes it from accounting for “uncertain effects that cannot be proven in a formal, quantitative way” (p. 339). In this case; the effects of plastic pollution and micro plastic on humans and their environment.

The debate also underscored the difficulties in operationalizing and evaluating sustainability. Most of the studies referenced by its participants concluded in favor of paper bags with respect to some environmental impacts, and in favor of plastic bags with respect to others. Consequently, even a perfect LCA might not have been able to provide a straightforward call to action. Weighing different impacts against one another would have required moral and political – not technical or scientific – deliberations.

The 2018 study, commissioned by the Danish Environmental Protection, for instance, found that – for most end-of-life scenarios – a pair of paper bags would contribute less to climate change, but more to most other environmental problems (e.g., air pollution and ozone depletion) than a single plastic bag. Since plastic bags were used as a reference, the conclusion listed the number of times other bags would have to be reused before they outperformed plastic bags with regard to every single impact category. For a pair of paper bags, 43 reuses were required. By then, a pair of paper bags would of course have outperformed a single plastic bag with regard to every single impact category. For some impacts, including climate impact, they would have done so by two orders of magnitude.

Nonetheless, one narrative that gained a lot of traction held that paper bags would have to be reused 43 times before they were as environmentally benign as plastic bags. The subjective weighting factors, that would have been required to actually rank these products, were rarely discussed. Instead the number ‘43’ was treated as a technical matter-of-fact; a ready-made-number that expressed the relative sustainabilities of the two technologies.

In the wake of the third round of the debate, several questions remain open. Why, for instance, did suppliers of paper bag fail to commission contrarian research to cast doubt on this fact-in-the-making; despite the apparent threats it posed to their vested interest? It might be that suppliers of grocery bags by and large resemble Serviteur, who supply both paper and plastic bags; and thus presumably do not consider the distribution of demand among these two products as all that important. A closer look at the grocery bag industry was beyond the scope of this thesis, but might be an interesting avenue of follow-up research.

And was Solheim’s decision to commission the report, that launched the national debate, a successful case of evidence-based policymaking, or a failed attempt at policy-based evidence making? If this truly *was* a case of evidence-based policymaking, then his decision to drop the proposal, when the evidence spoke against it, needs no explanation. If, on the other hand, this was a failed attempt at policy-based evidence making, this begs the question of why Solheim did not follow in the footsteps of his colleagues – mentioned in section 2.2 – who ignored the recommendation of ‘Lavutslipp-sutvalget’ and ‘Barnefamilieutvalget’ and instead went through with their preferred policies.

The most straightforward explanation would be that Solheim simply found the expert advice convincing and change his mind. Another explanation would be that the political feasibility of his proposal rested – as suggested by the spokesperson quoted in section 5.2.1 – on his ability to demonstrate its environmental benefits. Or the difference between this case and those discussed in section 2.2, might boil down to the expected omission bias of voters; i.e. the tendency to condemn more harshly sins of commission than sins of omission (Ritov and Baron, 1992). The decision to ignore the expert recommendation to launch a national information campaign about climate change was a sin of omission. A decision to ignore the expert recommendation *not* to ban plastic bags would have been a sin of commission, and as such; perhaps harder to justify.

As with the debate about a managed decline of petroleum production, it is hard to assess the impact this debate had on popular opinion. One 2017 poll hosted by Stavanger Aftenblad, found 83 % (332/490) of respondents to support a ban on plastic bags. (Østbø, 2017a). Seeing as this was an online poll hosted by a local newspaper, however, it might be considered as tainted by self-selection bias and of questionable external validity as an indicator of national public opinion. There furthermore does not seem to be any prior survey results against which this one may be compared. The 2011 survey, mentioned in section 5.2.2, did find 80 % of respondents to agree with the statement ‘paper bags are more sustainable than plastic bags’. But there are no grounds for assessing how “regard paper bags as more sustainable than plastic bags” maps onto “support a ban on plastic bags”, and as such this survey has no validity as a control for the 2017 poll.

An alternative indicator of impact is the set of actors who initially supported the transition – including policymakers (e.g. Solheim) and NGOs (e.g. Fremtiden i våre hender) – but eventually withdrew their support. Given the epistemic authority these actors command with regard to environmental issues, one might expect their turnabouts to have influenced some non-trivial fraction of their audiences. Yet barring access to e.g. sales data or survey results, the magnitude of such impacts would be hard to assess.

Regardless of any hypothetical changes in consumer behavior, however, the debate seems to have had tangible political and commercial implications. These range from its role in constructing the continued legality of plastic bags as an evidence-based policy. Through the reason (or rationalization) it provided commercial actors like Rema 1000 not to offer paper bags. To the way it shielded the legality of plastic bags from a united front of environmentalists, who might otherwise have rallied against it.

7.4 Discussion on the use of LCA in decision making

One striking finding from this part of the research, was the range of attitudes and applications that could be found within such a small sample of organizations. Some interviewees had embraced LCA as an essential tool for staking out emission trajectories, benchmarking, and communicating progress to policymakers. Others viewed it with suspicion; as a potential sink for money and efforts that would have been better spent elsewhere.

The most frequently cited application of LCA was for procurements. Most interviewees had some experience in using LCA for this purpose. Some had even entertained the idea of using carbon emissions as award criteria. Yet none of them had any experience in actually doing so.

Some expressed misgivings about this application, though; grounded in concerns that might be described as Goodhart's law. Asking contractors to calculate the climate impacts of their deliverables, and then using these calculations as award criteria, they reasoned, might incentivize contractors to game their emission figures. This might entail cherry picking software or databases that assigned the lowest possible emission numbers to their proposals. Or it might entail mathiness through tweaking their models in ways that would be hard for non-experts to detect. In extreme cases, it might even entail fabricating numbers. Examples of the latter include the ventilation shafts delivered by Ventistål to the new National Museum in Oslo, whose "third-party verified LCA documentation" (i.e. Environmental Product Declaration) was later exposed as falsifications (Mathisen, 2019).

One refrain, repeated with surprising frequency, was efforts to produce emission figures that were never actually used for anything. This not only included procurements in which bidders were asked to calculate the climate impacts of their deliverables, without actually being evaluated based on these numbers. It also extended to inhouse efforts, such as those of Haugesund, whose representative admitted spending "a lot of time and effort" on quantifying their own emissions, but had "so far never used the numbers for anything".

Some applications seemed like premeditated efforts to leverage the seductive qualities of numbers. Although, as one interviewee put it, policymakers may not understand the particular numbers they are presented, they can see that numbers are trending upwards when they should be trending downwards. The claim 'our emissions grew by 12 000 tons of CO_2e last year' simply has an oomph that 'our emissions grew by quite a lot' does not. As discussed in section 4.2.1, once decision makers begin to disclose their emission figures, this may even create a "sense of urgency" to improve these figures (Freidberg, 2014). This seems reflected in the reported willingness of policymakers to fund additional initiatives, when presented numbers that were tending in the wrong direction.

Other applications had an air of mathiness to them (ref. Romer, 2015). These include the efforts of Stavanger kommune to update their carbon budgets on a quarterly basis, despite not actually having the requisite data for doing so – instead relying on proxy data of questionable validity. This, as one interviewee explained, was deemed necessary to ensure the constant flow of new numbers needed to "keep policymakers engaged". These efforts, admittedly, drew resources away from actually implementing climate initiatives, but had – by their account – helped secure funding for initiatives that might otherwise not have been funded.

Some applications even verged on policy-based evidence making (ref. Christensen and Holst, 2020). These include LCA models that seem optimized more for political impact than for construct validity. One case in point was the decision, described by one interviewee, to keep agricultural emissions out of their model, so as to increase the percentagewise emission reductions that could be achieved by climate initiatives in other sectors. They explicitly defended this approach by arguing that smaller percentagewise reductions might feel discouraging for those involved.

The trust and expectations contemporary societies put in numbers, may furthermore be seen reflected in the confusion of local policymakers as to "why they can't get perfect numbers for everything", as one interviewee put it. The implications seem to be that such numbers ought to exist, and any actually existing numbers, produced by certified experts, ought to approximate this ideal.

In practice, alas, the seemingly straightforward question 'how many tons of CO_2e will this initiative abate?' often turns out to exemplify Jasanoff's (1990) observation that "questions regulators need to ask of science cannot in many instances be adequately answered by science" and consequently that "decisions have to be made on the basis of available facts supplemented by a large measure of judgement" (p.7). Yet such judgement calls are precisely what decisionmakers often seek to avoid. Having some ready-made-number to which decisions may be delegated, relieves them from having to justify, and stand accountable for, subjective judgment calls (ref. Porter, 1995).

The LCAs that were mentioned by the interviewees seem exclusively to have been ALCAs. As repeated ad nauseum throughout this thesis, ALCA models are – in principle – only meant for assessing environmental footprints in an accounting sense; not for predicting the consequences of decisions. Yet given the difficulties and reservations expressed towards even comparatively simple ALCAs, CLCA might be out of the question for most municipalities. In particular, it would seem unwise to use CLCA for politically contentious issues, or to ask contractors to conduct CLCAs of their own deliverables. CLCA simply offers too many degrees of freedom, and thus too much room for mathiness and controversy

A number of barriers to more widespread use of LCA were brought up during the interviews. These ranged from a lack of inhouse expertise, to a lack of political interest, to a lack of coherent frameworks for integrating LCA with other considerations.

A number of interviewees expressed concerns about metric fixation. A single-minded focus on carbon emissions, they reasoned, might crowd out other environmental concerns, such as air and water pollution. Although the LCA literature describes the method as one that covers "all attributes or aspects of natural environment, human health and resources" (ISO, 2006, 7); in practice, these interviewees knew it as a tool for calculating carbon emissions. Far from illuminating all environmental impacts so that these could be weighed against one another; LCA – in their experience – put a spotlight on climate impacts; while shrouding all else in shadows.

As discussed in the context of Stavanger (see section 6.1), the national standard for carbon accounting may even in and of itself constitute a source of metric fixation. Politicians who campaigned on promises to help reduce municipal carbon emissions, may find themselves incentivized to optimize for 'paper abatements' rather than physical abatements. Stavanger kommune might be an extreme case due to the myriad point emission sources that are located right outside of its borders. But to some extent, one might expect this to apply generally.

In a worst case scenario, this national accounting standard might even trigger Goodhart's law. If environmentally concerned citizens were to evaluate policymakers – or policymakers were to evaluate bureaucrats – based on official emission statistics, those subjected to said evaluation might be incentivized to game the system, e.g., by outsourcing point emissions sources. From then on, downwards-trending carbon accounts would cease to be a valid indicator of successful climate policies.

Finally, several interviewees expressed a lack of political interest in LCA. Some saw this as problematic; others as a rational choice about allocating scarce resources – earmarked for climate action – to practical initiatives. Some, additionally, hinted at a deeper lack of political interest in even implementing initiatives. Although this falls slightly outside of the scope of this thesis, it does raise some thorny questions – in light of the need to distribute the emission reductions mandated by the Norwegian INDC[23] – about free-riding and the autonomy of local democracies (analogous to the questions free-riding in international climate change mitigation efforts raise about the autonomy of nation states).

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[23] Intended Nationally Determined Contribution (ref. section 6.2)

8 Conclusion

"*Thus is it written: 'It's easy to lie with statistics, but it's easier to lie without them.'*"
– Scott Alexander Siskind

This section concludes the thesis. It consists of 5 subsections. Sections 8.1 through 8.3 respond to the three research questions posed in section 1. Section 8.4 suggests further avenues of research. Finally, section 8.5 offers some final reflections.

8.1 How valid is LCA as a mechanism of sustainability metrication?

The validity of LCA as a mechanism of sustainability metrication has been discussed as a function of three variables: (1) the validity of GWP_{100} as a metric of contribution to climate change; (2) the empirical accuracy of particular GWP_{100} estimates (3) the correspondence between calculated and physical GHG emissions.

The validity of GWP_{100} has been challenged on scientific, political, and moral grounds. According to critics, it overestimates the climate impact of sustained methane emissions; underestimates the climate impact of new methane emissions; fails to map a unique temperature response onto a given carbon budget; and treats 'luxury emissions' as equivalent to 'survival emissions'.

The perpetual evolution of GWP_{100} estimates – combined with the poorly understood relationship between emission rates and changes in atmospheric concentration for e.g. methane – also puts in question the empirical accuracy of the estimates currently in use. In retrospect, earlier GWP_{100} estimates do not seem to have corresponded all that well to the phenomena they were supposed to represent. This empirical accuracy has presumably increased as climate science progressed. But since aggregated radiative forcing can only be calculated, never measured; we have no way to actually verify that newer estimates are indeed more accurate than older ones. And if history is any guide, we should expect our present-day estimates to deviate, at least to some extent, from those of tomorrow.

Which is not to say that GWP_{100} has not been useful, or even essential. Only that its usefulness has been grounded – less in its correspondence to that which it purports to indicate – than in its role in facilitating a shared sense of a reality in which collective climate action could be coordinated. Actors ranging from mom-and-pop shops to supranational organizations – united in their awareness that the perceived sustainability of their activities hinge on the numbers assigned to them by this metric – have submitted to its authority. Defending an environmental record – that gets a rough treatment by GWP_{100} – by appealing to alternative metrics, would come across as bad faith. And perhaps rightly so, given the systemic cherry picking and mathiness a free-for-all with regard to metric selection would encourage.

There seems, nonetheless, to be strong support in the scientific literature for describing newer climate metrics, such as GTP and GWP*, as more scientifically valid than GWP. Due to lock-in effects like data inertia and institutional inertia, however, a coordinated transition to one of these does not seem to be in the cards. And from the perspective of individual actors, whatever improvements in validity might be purchased by adopting other metrics, would come at the cost of incompatibility with all actually existing LCA standards and benchmarks.

As an accounting tool, any particular ALCA may be described as valid in so far as it complies with the particular accounting scheme for which it is being conducted. As a mechanism for evaluating the environmental impacts of decisions, on the other hand, its validity may be described as proportional to the ratio of first-order impacts (which are accounted for) to higher-order impacts (which are not accounted for). In cases where first-order impacts are expected to dwarf higher-order ones – ALCA may be sufficiently valid to outperform its plausible alternatives (e.g., expert intuition) as a mechanism for evaluating – at least certain aspects of – sustainability.

For CLCA, the correspondence between calculated and physical emissions is proportional to the ratio of modelled to real-life higher-order impacts. This correspondence is subject to scenario uncertainty, vulnerable to unforeseen political or technological disruptions, and generally not possible to assess objectively. In cases where higher-order impacts are assumed to be – at least – of the same order of magnitude as first-order ones, one may nonetheless expect CLCA to outperform ALCA as a mechanism for evaluating sustainability.

Due to its “pre-environmentalist frame” (i.e., failure to account for uncertain or unquantifiable consequences), however, the validity of any particular LCA, as a mechanism of sustainability metrication, may at best be described as partial. The information it provides (e.g. climate impacts) needs to be weighed against the information it does not provide (e.g. mixture toxicity). Its proper role might thus best be described as a tool of *decision-support* rather than *decision-making.*

8.2 How are LCAs used in sustainability discourses?

One must – of course – tread lightly when seeking to generalize from two datapoints (i.e. the two debates discussed). More comprehensive research would be needed before definite answers can be drawn. This exploratory study may, nonetheless, provide some preliminary insight.

Firstly; the two cases may be conceptualized as representing two poles on a spectrum of possible roles LCA might play in sustainability discourses. In general, one might thus expect to find its roles, in other debates, either clustered around these poles, or spread along the spectrum.

During the debate about a managed decline of petroleum production, LCA was mobilized as a tool of rationalization; for constructing a predetermined stance as evidence-based. Here, its function was to polarize the debate and collapse all nuance into binary oppositions like "supply-side policies are evidence-based” vs. “supply-side policies are not evidence-based" or "this study is solid” vs. “this study is weak".

During the debate about a managed transition from plastic to paper bags, LCA appears to have been mobilized as a tool of rationality; for ranking alternative policy decisions in terms of sustainability for the sake of selecting the most favorable one. With the exception of some snarky remarks from a representative of Serviteur (see section 5.2.3), vested interests appear to have been all but absent from the debate. Alas, the function of LCA largely boiled down to prematurely closing the debate; rendering impacts that were excluded from the assessments (e.g. plastic pollution) invincible; and marginalizing dissenters.

Secondly; the debates highlighted what might be the three most troubling aspects LCA:
(1) reification; (2) co-option; and (3) technocratic depolitization.

Vulnerability (1) refers to the act of mistaking the map for the territory (i.e. a mathematical model for that which is being modelled). This vulnerability was highlighted by the debate about a managed transition from plastic to paper bags. As predicted by earlier findings in STS and the ethics and sociology of quantification (e.g., Latour, 1987; Merry, 2016); LCA models – that within the confines of a specialist community had been open boxes full of questionable assumptions and methodological choices – entered the public sphere as blackboxed matters-of-fact. Their verisimilitudes were simply taken for granted. And through years of repetition, their conclusions solidified into socially sanctioned facts. Metric fixation can be seen as a corollary of this vulnerability. Plastic pollution, for instance, – which was not accounted for by the LCAs – was rendered invisible. And those who cared about such issues were marginalized.

Vulnerability (2) refers to tactical appropriation by vested interests, e.g. for greenwashing, manufacturing doubt, or shutting down criticism. This vulnerability was at vivid display during the debate about a managed decline of petroleum production. For nearly a decade, the 2013 SSB paper on supply-side policies had been a linchpin of a growing movement calling for such policies. By purchasing a custom-order LCA – based on a scenario that was prone to reach a favorable conclusion – Norog may be described as having co-opted LCA as a tool for advancing the commercial interests of its member organizations. In this particular case, the doors for co-option had been left conspicuously wide-open by a regime of research funding in which private interests were the only actors able to produce new knowledge claims about this topic. Advocates of supply-side policies thus found themselves bereft any supportive evidence save a sole decade-old paper.

Vulnerability (3) refers to the metamorphosis of moral or political decisions into technical ones; and the associated transfer of power from elected officials to technical experts. This vulnerability came into play during both debates. During the one about a managed decline of petroleum production, it did so in two stages. Initially; through environmentalist policymakers who leveraged the 2013 SSB paper as an instrument for presenting their highly controversial policy stance as if it was all but dictated by science. Eventually; through pro-petroleum policymakers who leveraged the 2021 Rystad paper in much the same manner. During the debate about a managed transition from plastic to paper bags, it was brought into play by the policymakers – e.g., Erik Solheim and Leif Arne Moi Nilsen – who allowed a consulting report to dictate the sustainment of the status quo. This unabashedly technocratic view of policymaking went on to echo through the media landscape, more or less free from pushback.

8.3 How are LCAs used in decision-making processes?

We must – once again – generalize with caution. The decision to limit the sample of municipalities to those in Rogaland, might have reduced the external validity of this discussion relative to what could have been achieved by random sampling. As a region, tightly intertwined with its petroleum sector, the climate action of its municipalities might differ systematically from those of other regions. One upside of this actually chosen sample, however, is that it allows for a higher-resolution picture to be drawn of how LCA is used in this one region; and lays the groundwork for longitudinal or comparative studies to be carried out down the road.

Three out of the ten organizations that were initially contacted, declined their invitations for interviews, citing a lack of experience with LCA. Among the seven organizations that accepted their invitations, few had used LCA in any systematic fashion.

Some saw it as a potential tool for mapping the abatement targets of political climate plans onto the day-to-day activities of public administration. A few had even begun, or were planning to begin, such efforts. This often boiled down to calculating business-as-usual and climate-plan-aligned emission trajectories; calculating the emission reductions of potential initiatives; and then assembling bundles of initiatives for closing the gap between projected and targeted emissions.

More commonly, however, LCA was used in an ad hoc fashion, without any explicit link to overarching climate goals. Its most commonly cited application was in construction projects. Some interviewees described experience in conducting their own LCAs. One even described a mandate to compare the life cycle impacts of two or more products – for a dozen different components – for every construction project.

For many interviewees, however, experience with LCA was limited to asking contractors, who were bidding on municipal procurements, to calculate the climate impacts of their deliverables. Some had contemplated using these numbers as award criteria, but none had actually done so. Several expressed reservations about this approach. Successful use of LCA as an award criteria seemed to hinge on hitting the sweet spot between mandating calculation rules that are too stringent (and thus breed metric fixation by limiting the set of initiatives rewarded); and ones that are too lenient, (and thus breed mathiness by allowing bidders to tweak their models until favorable numbers pop out). For certain procurements – notably, construction and infrastructure projects – this balancing act was partially handled by national LCA standards and calculation tools. For other procurements, they seemed more problematic.

Several interviewees, particularly from the smaller municipalities, expressed reservations about LCA in general. These were grounded in such concerns as the resources it would draw away from other efforts; the substantial fraction of municipal emissions that were outside of their jurisdiction; and the lack of holistic frameworks for – or political interest in – balancing emission reductions against costs. Some furthermore reasoned that their lack of in-house expertise would mean that all LCAs would have to be outsourced to consultancies. This would drive up costs, and leave the administration without a sense of ‘ownership’ over the resulting numbers, nor an understanding of how to apply them.

8.4 Suggestions for further research

The research problems, outlined in section 1, may be expanded in a number of directions

The research on the role of LCA in sustainability discourses could, for instance, easily be extended to the rest of the debates mentioned in section 3. This might allow more patterns to be discovered, and more general conclusions to be drawn. Possible hypotheses to test might include: (1) debates involving powerful vested interest will be more contentious (as more evidence may be commissioned and signal-boosted) than others; (2) debates centered on CLCA will be more contentious than those centered on ALCA (as CLCA requires more subjective judgements that might be challenged).

It might also be interesting to expand this research into a country-level comparative analysis. This might entail assessing the correlation between national levels of trust in expertise and scientific authorities, and how LCA is used in sustainability discourses.

Several of the municipalities that were included in this thesis, had either just begun to use LCA or were planning to begin soon. This opens the possibility of expanding this part of the thesis into a longitudinal study of how applications of – and attitudes towards – LCA evolve over time. Alternatively, one might conduct comparative studies to see if the findings of this thesis generalize for other municipalities of comparable sizes. It might particularly be interesting to compare successful applications of LCA with less successful ones, and try to distill some common denominators of the two. A number of interviewees cited Trondheim and Oslo kommune as actors that were ahead of the pack in their application of LCA. These might thus make for interesting subjects of further research.

Based on this limited sample of subjects, enthusiasm for LCA seemed to correlate inversely with the population size of the municipality. This might be an interesting hypothesis to test statistically. If affirmed, this correlation might have policy implications for national efforts to encourage and incentivize life cycle thinking.

It might be interesting to recalculate municipal carbon accounts into different climate metrics (e.g. GWP* or GTP); and assess how this affects their sectorial distributions and temporal trendlines. Since the Environmental Directorate publishes annual GHG estimates segmented into municipalities, economic sectors, and type of climate gas; this would be fairly straightforward. Using GWP* as an example, one would simply have to multiply cells – tagged with GHG_i in their spreadsheets – by the ratio $[GWP^*(GHG_i) / GWP(GHG_i)]$.

It might also be interesting to research how private companies use LCA for branding and marketing. This might entail assessing the validity of these LCAs, the reactions of audiences, and whether (and if so, how) these figures get challenged. In particular, it might be interesting to take a cue from the NVE investigation – mentioned in section 2.2.1 – which found independent ecologists to report, on average, more than twelve times as many red-listed species as those employed directly by windfarm developers. Independent LCA practitioners might, in this case, repeat existing LCAs that were commissioned by companies, in order to check for systematic biases.

Finally, it might be interesting to research the potential expert inertia among Norwegian LCA practitioners. Those who were interviewed for this thesis, or wrote the Norwegian studies that were surveyed, were mostly alumni of the Industrial Ecology program at the Norwegian University of Science and Technology (NTNU). How does this concentration of 'expertise certification' affect our current pool of LCA experts, and the professional values and assumptions these bring to their work? Might there be any discernable differences between the LCAs produces by this group and those produced by other practitioners?

8.5 Final reflections

The foregoing discussion seems to leave us at an impasse. Reducing sustainability discourses and decision making to LCAs is problematic. Not only because of the resources and attention it diverts away from the big picture, onto details, numbers, and disagreements about which experts and reports to trust. But also because sustainability transitions are about much more than just the tons of CO_2 we abate. They also touch upon such fundamental questions as what kind of society we want to build, how we ought to allocate responsibilities, and what we are going to live off in the future. These are through and through political, not technical, questions.

Yet reducing sustainability discourses and decision making to sociotechnical imaginaries – detached from the mundane realities of supply-chains and displacement effects – can be equally problematic. As illustrated by the string of examples outlined in Section 1, failures to account for such effects can lead to policies that intuitively *seem* sustainable, yet nonetheless lead to increased global emissions. Against this backdrop, LCA – while by no means a silver bullet – may nonetheless pass 'Churchill's razor' in the sense of being less bad than any of its plausible alternatives. Or to riff off the quote by Siskind (2013) that served as the epigraph of this section: it is easy for sustainability transitions to go astray when LCAs are invoked; but it might be even easier for them to go astray when LCAs are not invoked.

To elaborate on this point, a sharper distinction must be drawn between legislative policy decisions subjected to public debate (i.e., should Norway unilaterally reduce its petroleum production?); and the mundane decision making of public administrations (i.e., should the new school building use vinyl or linoleum flooring?). In the former case, LCA has the potential to shut down debate, get co-opted by vested interests, marginalize dissenters, and depoliticize policymaking. In the latter case, the public is unlikely to ever know – much less care – about the outcome of the decision. From a pure 'problem-solving' perspective; administrators – who want to limit the environmental footprints of their projects, but lack environmental expertise – may reasonably expect the heuristic "trust the LCA" to outperform "trust my intuition" by a wide margin.

Siskind (2013) argues tongue-in-cheek that "if [something is] worth doing, it's worth doing with made-up statistics". Consider e.g., the research of Tetlock and Gardner (2015) on 'Superforecasters' who used Bayesian updating with more or less "made up" probability figures, to outperform those who did not. Riffing off Siskind once again, we might argue that if climate impacts are worth talking about, they are worth talking about with "made-up" emission figures (i.e. ones of questionable validity). There are a number of reasons for suggesting so.

Firstly; as a culture that "counts what counts", the very act of "counting" carbon emissions is a way of affirming that these do in fact "count". From a political perspective, this amounts to accepting the actually existing reality in which quantitative assertions crowd out qualitative ones. The costs of environmental policies most certainly "count" and are thus "counted". If the benefits are to compete on equal footing, they better be "counted" as well. When contractors are asked to calculate the carbon footprints of their deliverables, for example, they are implicitly, but unambiguously, told that these matter. And as exemplified by Walker's – the chip manufacturer mentioned in section 4.2.1 – once a company begins to quantify its climate footprint – while being told by a major customer that this number matters – it might even feel "a sense of urgency" to improve said number (i.e., initiate climate action).

Secondly; even highly uncertain LCA results may provide actionable information. Consider, as an example, the impact factor of nuclear energy, which was found in section 4.2.4 to lie somewhere between 7,6 and 337 g CO_2e per kWh. Despite the gaping width of this interval, it nonetheless allows us to locate this impact factor roughly an order of magnitude below that of coal; somewhat lower than – but perhaps of the same order of magnitude as – that of natural gas; somewhat higher than – but perhaps of the same order of magnitude as – that of solar energy; etc.

Or consider the debate about a managed decline of petroleum production. The two LCAs that formed the backbone of this debate, collectively suggest that this policy would reduce global carbon emissions (perhaps even cost-efficiently) if production cuts were concentrated to marginal oil fields (e.g. Veslefrikk) – but not (indeed, might even increase global emissions) if production cuts were spread among productive fields (e.g., Ekofisk).

Or the debate about a managed transition from plastic to paper bags. If one discards all the oldest papers cited in the Norconsult report (due to changes in technology and supply chains), and substitutes locally invalid impact factors with locally valid ones (e.g., that of hydropower for that of coal-fired power plants) – then the bulk of the evidence suggests that this transition would decrease carbon and plastic pollution, but increase most other environmental impacts. The task of weighing of these impacts against one another would then come down to consumer (and/or voter) preferences.

Although far removed from the ideal of using LCA to draw scientifically objective boundaries between ‘sustainable’ and ‘unsustainable’ activities; such insights may nonetheless help inform decision making.

Thirdly; Although LCA *can* encourage greenwashing (e.g. mathiness) or counter-productive initiatives (e.g. metric fixation); more generally, it encourages climate action that otherwise would not have occurred. Consider carbon benchmarking in construction projects as an example. In the absence of such benchmarking, actors seeking to portray their projects as ‘green’ may optimize for the spectacle of sustainability (e.g. slapping some PV panels on the roofs and wrapping the facades in wood panels). Actors seeking to meet quantitative benchmarks (e.g. 40 % lower carbon emissions than the industry standard), by contrast, have to consider climate impacts across the board (can we reduce the amount of virgin steel in this beam? Is there a ‘greener’ concrete we might use in the foundation?). Regardless of the validity of the calculations, the net outcome of these efforts is likely to be more sustainable cities. Another example is the policymakers who agreed to fund additional climate initiatives after seeing “the numbers trending upwards when they should be trending upwards”. Regardless of the validity of these numbers, they reportedly instigated purposeful climate action.

From the standpoint of the health of our democracy, by contrast, this stance is less than satisfactory. Not only because of the epistemic power that gets outsourced to private consultancies. Or the technocratic overtones of letting mathematical models dictate public decision making. But also because decisions that begin as mundane, may at any point morph into political controversies. And if the relative sustainability of these decisions has already been framed in terms of LCA results, vested interests may now co-opt this tool as an instrument for greenwashing, manufacturing doubt, or shutting down critique.

These and related issues are the subjects of much contemporary scholarship in STS and the ethics of quantification. How should democracies debate and enact policy decisions that rest on uncertain knowledge? How should they balance technical and participatory concerns? Although a fuller discussion of this literature is beyond the scope of this thesis, notable examples include “technologies of humility” for “systematically assessing the unknown and the uncertain” (Jasanoff, 2003: 223); and “sensitivity auditing” for “ensuring transparency and balance in the use of models, (Saltelli and Funtowicz, 2015: 151).

So where does this leave us? The impetus of this thesis – as sketched in section 1 – was the hope that a fuller understanding of the uses and abuses of LCA might allow us to better realize its potential as a tool for optimizing sustainability transitions; incentivizing climate action; and mapping political climate targets onto the day-to-day activities of public administration. And to do so while simultaneously mitigating the risks associated with reification, co-option, and technocratic governance.

In the end, I have no silver bullets to offer. Like the metrics that predictably fail to capture the messiness of real-life decision making contexts, so any verbal prescription I might offer here would undoubtedly fall short. As tends to be the case, balancing such contradictory goals as those sketched above (not to mention those not mentioned, such as accountability, legitimacy, and budgetary constraints) inevitably involves some amount of ‘muddling through’. Yet my hope remains, that with a greater understanding, may come a greater scope for integrating and unifying these goals. And although more research is required, this thesis has sought to lay a foundation for such an understanding.

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