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Unpacking the Concept of Bioeconomy: Problems of Definition, Measurement, and the Attribution of 'Value'

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Abstract

In this paper, we critically explore the evolution and impact of the concept 'bioeconomy' as a descriptor and driver of different scientific, technological, and policy initiatives in the life sciences. We unpack the different ways bioeconomy has been framed – as an emergent, present, or sometimes promissory economic regime underpinned by particular socio-technical practices - by tracing how its use has evolved in different disciplinary field and sectors. We also critically analyse three key reports that attempt to measure the size and contribution of the bioeconomy at regional levels. Our overarching questions are: What is the bioeconomy, how has it been used in different fields, and how might it be best understood and valued both economically and politically? In answering these questions, we build on and contribute to critical scholarship in science and technology studies, particularly theoretical work on biovalue, commodification, and assetisation; using this in conjunction with our empirical concept search and document analysis to contribute new knowledge and understanding of the bioeconomy's past, present, and future.

Keywords: bioeconomy, measurement, value, practices, promissory expectations, neoliberal

Introduction

In this paper we explore the evolution and impact of the concept 'bioeconomy', as a descriptor of various scientific, technological, and policy initiatives in the life sciences. We unpack the different framings of bioeconomy, or more accurately 'bioeconomies' (Pavone and Goven, 2017), which are driving different and often incompatible concep-

tions of value and benefit. Our overarching questions are: what is the bioeconomy, how has it been used in different fields, and how might it be best understood and valued? This is not straightforward given the ephemeral and speculative nature of the bioeconomy; the diverse disciplines within which the concept has acquired salience, and the

lack of consistency in the definition and categorization of its objects. The latter issue becomes critical when policymakers try to measure the size and overall contribution of the bioeconomy at national or regional levels. There has so far been no comprehensive and systematic attempt to trace the emergence of bioeconomy as a concept in different disciplinary fields, and link this to emerging theories of value and valuation practices. This paper therefore makes an important contribution to the social study of bioeconomy by using empirical evidence from a broad literature analysis to critically reflect on bioeconomy's different framings, and address the policy implications for measurement and the attribution of value.

Bioeconomy appears to be an emergent, present, but also promissory economic regime built on the exploitation of old and new biological resources. What we mean by promissory is that much of its value is speculative; based on estimations of future potential rather than current reality. Some even describe it as a 'neoliberal' political project (Goven and Pavone, 2015). The concept is frequently cited within academic and policy literatures, yet it remains ambiguous and contested. The definition of bioeconomy, which depends on how its material objects and practices are included or excluded within classificatory regimes (Bowker and Star, 2000), also has socio-political and economic consequences. Classification systems and the standards they embody are usually adopted to create order and stability in an uncertain world. However, we will show in the case of bioeconomy that decisions about how to order and classify different sectors and activities may obfuscate as much as they reveal. A certain ambiguity may be intentional, as policymakers must justify public investments in biotechnology and make good on powerful narratives of future promise. The bioeconomy might be considered 'performative' in the parlance of economic sociology (Callon et al., 2002). For example, governments and industry embrace life science innovation as a driver of economic and social prosperity, and this shapes the organisational structure and R&D options available to actors in the sector (Mitra, 2016).

There are nevertheless different framings of the bioeconomy, and competing narratives about

the contributions of the underlying science, technology, and material products. There is also recognition that multiple value(s) and valuation practices, beyond simply the economic, underpin the bioeconomy (Helgesson and Kjellberg, 2013; Lamont, 2012; Mitra, 2016). We suggest these multiple framings generate, within science/innovation communities and amongst critical social scientists, both promissory (Borup et al., 2006) and more cautious narratives around value and benefit.

In this paper, we unpack the concept of bioeconomy and reveal the different narratives of value, benefit, and worth that underpin it. We begin by presenting findings of a broad literature analysis we concluded in July 2018. Our aim was to trace the origins and use of the concept bioeconomy in the academic literature over time (from its first use until the end of 2017) in the sectors of health/medicine (red biotechnology), agriculture/food (green biotechnology), and energy/environment (white biotechnology). This gave us a sense of the concept's provenance and evolution, and revealed salient differences in its definition and use.

We then explore in depth different framings of bioeconomy. We discuss the bioeconomy as simultaneously a neoliberal political project to improve national competitiveness, and a scientific/technological project to meet global challenges such as climate change, food security, and health. The desire to generate new types of value from the monetisation of both old and new biological processes and technologies, in the context of these global challenges, illustrates the socio-political and economic issues at stake. Next, we critique three key reports (examples from the UK, US, and Europe) that attempt to measure the size and overall contribution of the bioeconomy using conventional metrics of value. We focus on these advanced economies because they have been at the forefront of innovation in life sciences and have most fully embraced the concept of bioeconomy in policy and practice. Given ambiguities around the bioeconomy concept, and its impact on different industrial and policy sectors, in the final section we consider the normative question of whether embracing a broader definition of value (beyond the economic) would help us better assess the bioeconomy's future.

In reflecting on our empirical data, we draw critically on a range of theories that have emerged around biovalue, commodification, and assetisation that we consider opens up possibilities for a more nuanced and broader approach to thinking about value and valuation processes. By opening up the concept of value to include the social practices of valuation, we suggest the bioeconomy can be explored in a more sophisticated and interesting way. So on the one hand, we identify the tensions between framing and theorising the bioeconomy as a political, neoliberal project, or alternatively a strictly scientific/technological project. On the other hand, we try to understand how different theories of value and valuation ('commodity' versus 'asset' for instance), might help us gain purchase on the techniques of measurement that are being used in policy contexts to promote a particular ideal of bioeconomy. Given so much of the value ascribed to the bioeconomy is speculative, we also draw on the sociology of expectations and socio-technical imaginaries, where appropriate, to illuminate and reflect on our data.

Methods

We conducted a systematic literature search and concept analysis, which was completed in July 2018, with the primary aim of identifying published material that explicitly used the term 'bioeconomy' and its close variants. In addition to the main search term 'bioeconomy/bio-economy', we also searched 'biobased/bio-based economy' up until the end of 2017 to ensure we had data for a complete set of years. Many authors treat bio-based economy and bioeconomy as synonymous, although Hausknost et al (2017) suggest technically bioeconomy refers to methods of converting raw material into bio-products, whilst bio-based economy refers to the raw material itself. We do not draw such a strict distinction in this paper. The published material covered peer-reviewed journal articles, some books and book chapters; and 'grey' literature, such as conference proceedings and abstracts, meeting reports, working papers, presentations, technical notes, annual reports, bulletin articles, and governmental and non-governmental reports.

Our search was conducted using 16 databases: AMED; ASSIA (Applied Social Science Index and Abstracts); BioMed Central; BIOSIS Citation Index; Business Source Complete; CAB Abstracts; CINAHL Plus- Cumulative Index to Nursing and Allied Health Literature; Cochrane Library; Congressional Record; Department of Health; Econlit; EMBASE; MEDLINE; IBSS (Social Science Premium Collection); Web of Science; and PubMed. The total number of hits across all databases, before we undertook a selection process and removed duplicates, was 5,313. Web of Science and IBSS generated the most hits with 1,780 and 1,352 respectively. The initial search was applied to the full texts of the unsorted articles in each database, with the main inclusion criteria being that the documents include a discussion, or at least mention, of the primary search terms. The titles, publication dates, URLs, and, where applicable or possible, the specific research fields and abstracts of the selected documents were then copied into an Excel spreadsheet file.

A total of 1,064 papers in the English language, published between 1992 (the first time an article that met our search criteria appeared) until the end of 2017, were then selected on the basis of perceived relevance. All included the search term in either the title or abstract, indicating the importance attached to the concept. The academic papers, which constitute the majority of our selected material, covered research areas from the natural, social, and applied sciences; and academic disciplines and interdisciplinary fields such as biology, chemistry, economics, law, innovation studies, geography, sociology, science and technology studies; education, medical sciences, materials science, environmental sciences, and agricultural sciences. Non peer-reviewed and more generalist documents, including policy-oriented documents and reports were also identified and categorized separately from the academic papers. Our final categorization sought to differentiate peer-reviewed academic papers from the natural sciences and the social sciences (our primary focus) and this broader gray literature, where we prioritized official governmental and non-governmental reports.

The purpose of the search was to reveal and sensitise us to how the concept of bioeconomy

had been used over time, in different academic fields, to complement our subsequent investigation of how the concept has been framed by different constituencies and stakeholders. Following the creation of the spreadsheet, Mittra (Lead Author) read through the abstracts of all articles, and scanned the full texts in some cases, to categorize the papers into the broad fields of white (industrial biotechnology/sustainable energy), red (health/pharmaceuticals), green (agriculture and food), and blue biotechnology. Blue refers to cases where it was not clear that the paper contributed entirely or mainly to one field. Blue biotechnology conventionally refers to marine biotechnology/aquaculture, but given we found so few articles in this specific field, we classified them alongside green biotechnology, reserving the blue category for those articles lacking specificity. In subsequently categorizing the papers according to whether they were from the social sciences, natural sciences, or 'other', we were able to identify salient patterns over time. This exercise was sufficient for our purpose of providing an overview of how the concept evolved in the literature over the given time period. We could have categorized the papers further into multiple sub-disciplines, but it is not clear how useful or accurate this would have been. Others have provided more detailed and comprehensive systematic reviews using citation data at the disciplinary level (Bugge et al., 2016; Golembiewski et al., 2015), and we refer to this work and its data to complement our own analysis.

Certain caveats are necessary to clarify the limitations of our method and the knowledge claims we can make. First, we note that there is an inherent subjective element to the choice of search criteria and the categorization of the papers. In many cases, the distinction between social science and natural science is blurred, e.g. environmental science, which embraces both natural and social scientific approaches. The same is true for the distinction between white and green biotechnology. For instance, where biotechnology is used to improve crop development for biofuels, this could reasonably be classed as both green and white biotechnology. There will always be some overlap at the boundaries of disciplines and fields, so some of our category decisions were

inevitably subjective. Alternative classificatory decisions could have been justified. In those cases where a paper contributed to more than one field, a decision was made to choose what we judged to be the predominant field. If the paper was contributing equally to more than one field, or where a decision on predominant field could not be ascertained, we categorized the paper as 'blue'. The latter were mainly policy-oriented documents or reports, as well as broader review pieces.

Second, the range of databases chosen, and the search terms used, may not have captured all articles addressing salient themes relevant to the bioeconomy. Many more articles would have been captured if we had included 'biotechnology', 'life sciences', or 'genomics' in our search (all of which discuss similar themes). However, given our primary interest was in the evolution and use of a new term called 'bioeconomy' or 'bio-based economy', as a signifier of novel activities and practices, limiting the search criteria was justified. Our results are broadly consistent with the findings of those who have conducted bibliometric/citation research on bioeconomy. In the following section, we summarise the key findings from our literature analysis, before unpacking and critically exploring the concept and its framing in more detail.

Tracking use of the term bioeconomy over time: Key findings from literature analysis

Our findings reveal that the use of the term bioeconomy, or biobased economy, has increased over time, particularly from 2006 onwards, as illustrated in Figure 1. Before 2004, only 15 articles met our final inclusion criteria. Since then there has been a steady increase in the total number of articles that explicitly reference the term in the title or abstract, with a particularly high number in the period 2014-2017. We surmise that the Organisation for Economic Cooperation and Development's (OECD) 2006 report *The Bioeconomy to 2030: Designing a Policy Agenda* (OECD, 2006), which we discuss later, became a key document that helped drive the salience of the concept and played an important role in popularising the term in a variety of academic disciplines.

Figures 2 and 3 show the number of publications by broad disciplinary area (social science, science, and policy/non peer-reviewed grey literature) and by field/sector respectively. Figure 4 displays the publications by field in

each disciplinary category to show differences in how social science and natural sciences, in particular, have prioritised certain approaches to bioeconomy.

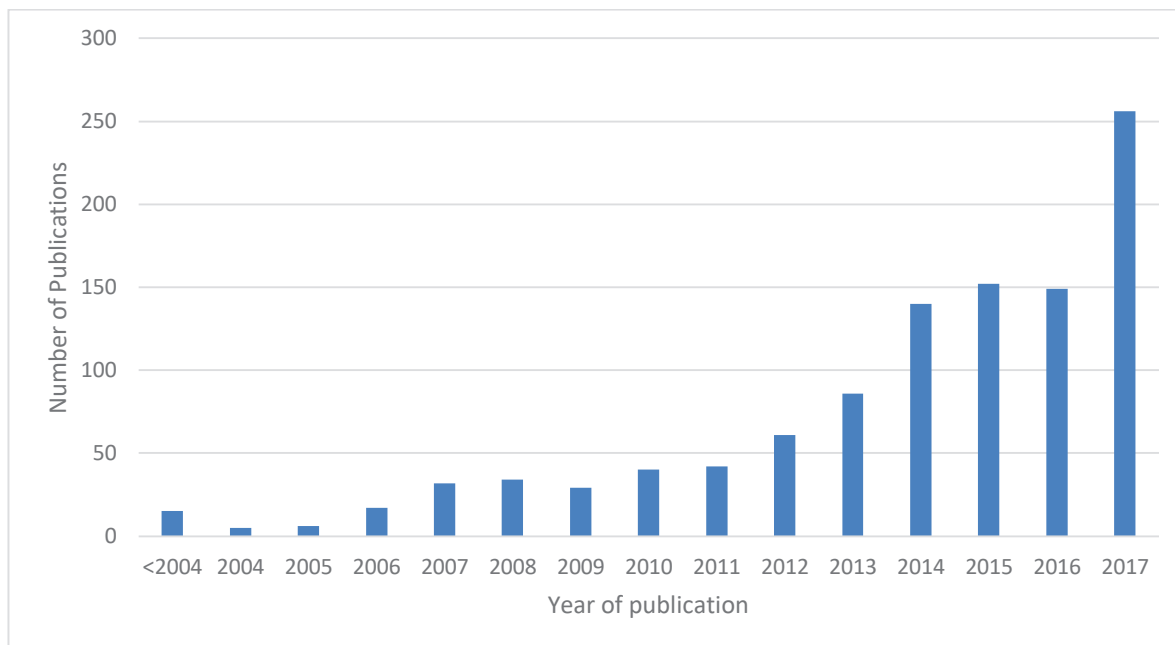


Figure 1. Total Number of Publications by Year Using the Term Bioeconomy or its Variants.

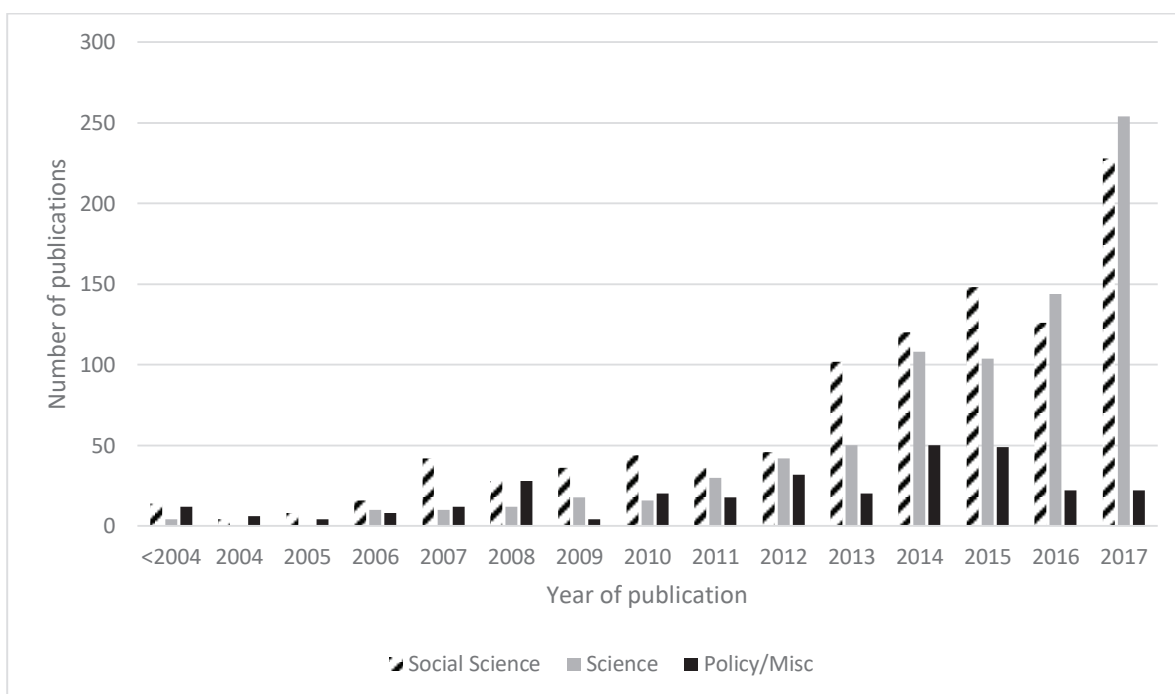


Figure 2. Publications by Broad Disciplinary Area.

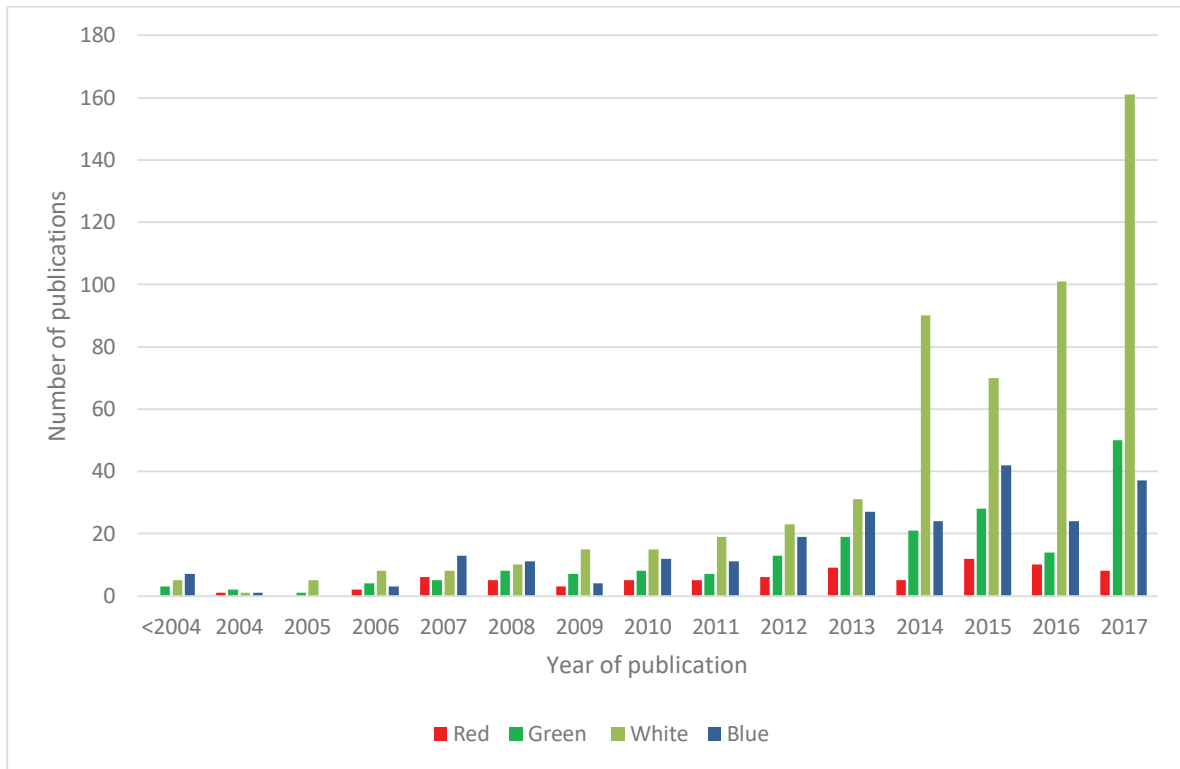


Figure 3. Publications by Field/Sector.

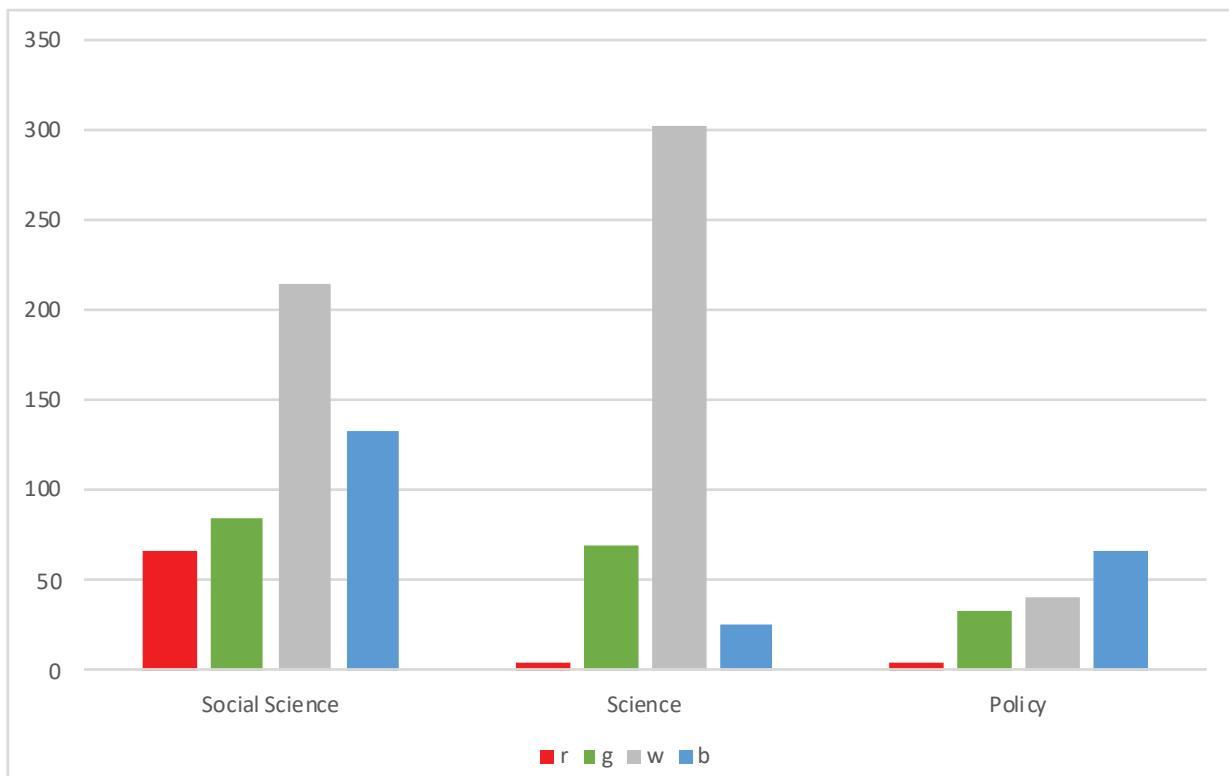


Figure 4. Publications by Field in Each Category.

In terms of broad disciplinary area (Figure 2) we can see that, apart from 2016 and 2017, slightly more peer-reviewed articles in our final selection came from the social sciences, rather than the natural sciences. However, we note our earlier caveat that the boundaries can be blurred in some cases. Nevertheless, the patterns of growth in the social science articles do not neatly follow those of the policy and science-based articles, which suggests that the disciplines have their own momentum. We did not attempt to classify the sub-disciplines within each general field, but Bugge et al. (2016) have in their comprehensive citation analysis. They found that amongst the broad diversity of disciplines in the sciences that have engaged with the term bioeconomy, the natural and engineering sciences have taken a predominant role, with the Web of Science categories 'Biotechnology and Applied Microbiology' and 'Energy and Fuels' constituting a 25% share of the total papers that the authors identified. This confirms our own search results from Web of Science.

However, the publications by general field/sector data (Figure 3) is more revealing. From 2006, we can see that in each year most of the publications were within the category white biotechnology, followed by blue (non-specific), then green biotechnology, and finally red biotechnology. So where it was possible to clearly identify a lead sector, white biotechnology was by some margin the one most likely to generate articles explicitly referencing bioeconomy. If we then look at publications by sector in each disciplinary category (Figure 4), we see that for natural sciences, white biotechnology is a clear leader with 301 papers, followed by green biotechnology (69), then blue (26), and finally red (5). For social sciences, white was still predominant (214 papers), but blue (133), green (85), and red (67) biotechnology were also far more likely to be represented than for the scientific disciplines. For our Policy/Misc field, white and blue biotechnology tended to be most common, with green biotechnology not far behind, but red biotechnology was very low with only 5 documents. We do note that the Policy/Misc category is not as comprehensive as the social and natural sciences categories. This is because we had to be far stricter on inclusion

criteria (official and significant reports) as this category could have included press releases, news items, conference posters etc that would have created an unmanageable and not particularly useful dataset. As such, the total number of documents in this category was small in comparison to the other categories, which are our main focus.

Of those papers that were in the field of red biotechnology, or the non-specific blue category (Figure 4), it is a significant finding that these were predominantly social science papers, which suggests that social scientists' understanding of, and intellectual interest in, the bioeconomy does not align with that of the natural scientists. To be sure, there is still high engagement with white biotechnology, as there is in the natural sciences. We should clarify here that most of the social science papers discussing white biotechnology were generally environment focused (risk assessment, economic analyses, survey research etc) in the context of biofuel development or sustainable agriculture/forestry. This was an area where the boundary between the social and natural sciences is often blurred, as we explained earlier.

Our data suggests, as we elaborate in the following section, that when scientists, and to some extent policymakers, mention bioeconomy, they are mainly talking about using biological processes in new ways to drive sustainable energy production, or contribute to environmental protection. It is this that is seen to constitute a new economic regime. Again, this finding is supported by the work of Bugge et al. In their list of science journals with papers citing bioeconomy, the top four were: 'Biofuels, Bioproducts & Biorefining-biofpr' (27 papers); 'Journal of the American Oil Chemists Society' (15 papers); 'Biomass and Bioenergy' (18 papers); and 'Journal of Cleaner Production' (12 papers). The journal 'Green Chemistry', despite only having 3 papers that used the concept, also generated the highest number of citations at 1056.

What we see in our data, and that of Bugge et al, is a complex picture in which a broad range of disciplines and fields are using the concept bioeconomy, but the peer-reviewed scientific literature tend to limit its definition to the use of industrial biotechnology to meet growing energy needs

in a more sustainable way. This, as we discuss in more detail later, mirrors many of the early policy approaches to the bioeconomy (such as the OECDs), where new economies of the future based on sustainable bio-based products have become part of the collective policy imagination, which we can describe as sociotechnical imaginaries (Jasanoff and Kim, 2009). This is interesting given many social science articles, particularly those critical of the commodification processes and neoliberal assumptions that prefigure an expectant bioeconomy, tend to reference examples from red or green biotechnology to support their claims. Social scientists' understanding and interest in the bioeconomy does not therefore align with that of natural scientists. So there are multiple framings and meanings attached to the concept of bioeconomy, which have material consequences for the ways in which R&D policy is structured, shaped, and understood. It is to these that we now turn.

Multiple 'framings' and theories of bioeconomy and their material consequences

Our analysis revealed that the concept of bioeconomy has been defined multiple ways in different contexts. Although in use before 2004, bioeconomy only gained traction and political salience from 2006, specifically as a term to describe emerging or nascent economic activities and opportunities from 'new biology'; that is the advances in molecular biology that accelerated in the 1990s and promised to revolutionize the industrial sectors of health, food, and environment (Wield, 2013; Wield et al., 2013). In an important 2006 report, *The Bioeconomy to 2030: Designing a Policy Agenda*, the OECD formally defined the bioeconomy as:

... the aggregate set of economic operations in a society that use the latent value incumbent in biological products and processes to capture new growth and welfare benefits for citizens and nations. These benefits are manifest in product markets through productivity gains (agriculture, health), enhancement effects (health, nutrition) and substitution effects (environmental and industrial uses as well as energy); additional

benefits derive more eco-efficient and sustainable uses of natural resources to provide goods and services to an ever growing population. (OECD, 2006: 1)

In an updated 2009 report, the OECD stated:

...the bioeconomy can be thought of as a world where biotechnology contributes to a significant share of economic output. The emerging bioeconomy is likely to be global and guided by principles of sustainable development and environmental sustainability ... A bioeconomy involves three elements: biotechnological knowledge, renewable biomass, and integration across applications. (OECD, 2009: 22)

These quotations provide a broad definition of bioeconomy, where new technological practices and economic regimes will extract latent value from natural biological processes to both meet sustainability goals and promote national competitiveness. The idea of latent value, which assumes biological objects and processes have both inherent and ascribed value, is shared by a set of scholars who talk about 'bio-value' and new processes of 'commodification' (Cooper, 2008; Novas and Rose, 2000; Parry, 2007; Sunder Rajan, 2006). These authors focus on new and emergent forms of 'biovalue', and are interested in how objects and practices that we might intuitively consider to be outside the conventional capitalist economy (e.g. natural resources) become monetized and seen as a source of different forms of economic value. In his review of the concept 'neoliberalism', Harvey (2006) also talks about how a fundamental feature of neoliberalism is that it opens up new fields for capitalist accumulation in areas previously seen in terms of a public goods framework, such as population genetic resources. Brown's (2013) work on the contradictions in use and exchange value in the cord-blood economy also highlights some of the challenges of these different conceptions of value.

The uneasy alignment of capitalism and biotechnology research, and the different business models and value systems that are coming to define contemporary life science-based industrialisation (Wield et al., 2015), has been critiqued by many Science and Technology Studies (STS)

scholars and bioethicists. The commodification aspects of the bioeconomy, and the co-production of so-called 'biovalue' (Cooper, 2008; Rose, 2001; Sunder Rajan, 2006; Waldby, 2002) is one approach. Others have contemplated the broader technical processes of accounting and assetisation that underlie the virtual bioeconomy and its valuation practices (Birch, 2007; Birch, 2017; Birch and Tyfield, 2013). These authors have unpacked the underlying assumptions of both practitioners within the bioeconomy, however defined, and critics who have sought to exceptionalise novel forms of biological material and ascribe it inherent value. Yet others have questioned the basis of what they suggest are promissory commercial narratives about a 'biotechnology revolution' (Hopkins et al., 2007), which become aligned with an imagined techno-future where current global challenges are ameliorated. Of course, some authors note that firms often consider more pessimistic scenarios, alongside their promissory claims, when, for instance, conducting foresight studies (Tutton, 2011).

The theory of bio-value itself has also been critiqued by some scholars (Birch and Tyfield, 2013; Birch, 2017) for not addressing the 'asset-based' aspects of the bioeconomy, and instead valorizing what are considered to be highly novel commodity aspects, which we discuss in more detail in the final section. Talk of 'latent value', which sees untapped potential in both conventional and new biological material, also tends to prioritize the sustainable, natural resource management aspects of the bioeconomy (white biotechnology), which we showed is predominant in the science and policy literatures.

The second quotation from the OECD more explicitly frames the bioeconomy as a vision of how advances in biotechnology can contribute to economic output and growth. Here, there is a clear alignment of investments in biotechnology research, capital, and perceived national competitiveness. This framing is also evident in the European Commission's approach to the bioeconomy, which has sought to make substantial investments in research addressing topics relevant to the sustainable production of new products based on biomass. This was a key component of the European Commission's 2012

Bioeconomy Strategy (European Commission, 2012), which we discuss later.

The accounts of policy-oriented organisations, captured in our literature search, tend to focus on the sustainable food and energy sectors and emphasise the need to respond to climate change and food security. As Hausknost et al confirm in a recent paper (Hausknost et al., 2017), 'green growth' through the industrial application of biotechnology has emerged as an important bioeconomy vision, or perhaps a socio-technical imaginary. So a predominant narrative is about creating new markets for industrial biotechnology, which recognizes opportunities to capture latent value in natural biological processes and accelerate the transition from a fossil-fuel economy. There is additional interest in the potential economic benefits of sustainable manufacturing and processing industries. Some regard this definition, which is rooted in the concept of 'biovalue' discussed above, as most meaningful and practical from a policy perspective (Brunori, 2013). Proponents claim multiple benefits, including the creation of high value jobs, lower emissions, energy security, reduction of dependence on subsidies, a growing agricultural sector, and even in some cases the stabilization of rural communities. This promissory and expectant discourse is part of the future-oriented vision of the European Commission as well as organisations like the OECD. We focus on these powerful policy actors precisely because they have played a significant role in the performative aspects of bioeconomy; shaping the nature of R&D practices and the metrics used to ascribe different forms of economic and non-economic value.

There is a strong neoliberal flavor to some of these framings of bioeconomy (linking global problems, science, and economic growth, and monetizing what might be considered public resources, for instance). This was perspicuous in President Obama's 2012 *National Bioeconomy Blueprint*, when it stated: 'Technological innovation is a significant driver of economic growth, and the U.S. bioeconomy represents a growing sector of this technology-fueled economy' (The White House, 2012: 1). We do not take a strong normative stance on what many social scientists pejoratively claim are the neoliberal underpinnings of the

bioeconomy. We are not, for example, seeking to criticize policy organisations that link bioeconomy, sustainability and economic growth. Nevertheless, we do find it interesting that the notion of the bioeconomy as a driver of sustainable growth, and as having unlimited potential to deliver economic and societal benefits, has been the subject of such criticism and debate. While many social scientists suggest that a neoliberal philosophy is driving policy, perhaps more importantly they argue this is ultimately based upon often unjustified speculative value propositions and ideologies. So there is a credibility gap between an imagined future and current reality. Cooper (2008), for instance, argues that the emergent biotechnology industries cannot be differentiated from neoliberalism's rise as a dominant political philosophy:

The biotech revolution ... is the result of a whole series of legislative and regulatory measures designed to relocate economic production at the genetic, microbial, and cellular level, so that life becomes, literally, annexed within capitalist processes of accumulation. (Cooper, 2008: 19)

Styhre and Sundgren (2011) describe the bioeconomy as the 'economic regime of accumulation where technoscientific know-how developed in the life sciences is capable of making the lived body a principal surface of economic value creation' (Styhre and Sundgren, 2011: 3) For these authors, bioeconomy and neoliberalism are intimately aligned, with the utility and vitality of life itself subject to the vagaries of speculative commodification (Sunder Rajan, 2006). Birch (2007) goes further in describing the bioeconomy as a 'virtual abstraction' of economic practices in which benefit and potential '...are intertwined concepts ... repeated numerous times throughout this policy literature, which essentialises and naturalises the claims made about its innovative potential' (Birch, 2007: 89). In an earlier article, Birch (2006) suggested that economic representations and practices are legitimisation devices for policy, which generate self-fulfilling prophecies. This is particularly evident in the context of claims about the bioeconomy's importance for national competitiveness.

In all these policy examples, and their critiques, the bioeconomy is framed mainly as a political

and economic project to support new forms of capitalism, rather than a scientific or technological endeavor. But what does it mean to say the bioeconomy is a political project? What does this framing tell us about the nature of the scientific practices that are both driving and being driven by the machinations of policy, government, and industry? These arguments need further unpacking.

The bioeconomy as a political project

Peterson and Krisjansen draw on the sociology of science and economic sociology to examine the sociopolitical significance of what they argue are promissory discourses enveloping discussions of the bioeconomy (Petersen and Krisjansen, 2015). They suggest these discourses have an important performative role in modern biopolitics. Activities that in the past might have been treated separately in policy, such as the different biotechnology sectors and industries around health, agriculture, and energy/environment, are now viewed under the general rubric of bioeconomy. The authors question the validity of some of the assumptions underlying these promissory discourses, as well as the logic of lumping disparate scientific, technological, and industrial activities and sectors within an all-embracing category.

However, it is the political nature of the bioeconomy that is implicit in their analysis, which is shared by Goven and Pavone who, in their Polanyian analysis, describe it as a promissory construct to "...induce and facilitate some actions while deterring others; most explicitly it is meant to bring about a particular set of political-institutional changes that will shape the parameters of possible future action" (Goven and Pavone, 2015: 1). Although not doubting the science and policy communities' noble intent to use biotechnology to solve global challenges; the authors describe the world in which the bioeconomy operates as imagined; one where "... human and environmental disasters are averted because a particular political-institutional configuration facilitated the development of profitable technological solutions" (Goven and Pavone, 2015: 4). In a more recent paper, the authors argue: "Bioeconomy strategies position the bioeconomy as key to 'global competitiveness', while the need for 'global

competitiveness' is taken for granted" (Pavone and Goven 2017: 7). They suggest this framing displaces alternative approaches that seek to address structural and endemic aspects of the global challenges facing society, and ultimately sustains the status quo. This view is consistent with Harvey's (2006) account of neoliberalism's damaging 'creative destruction', which emerges from the process of commodification and privatization, and an obsession with econometrics.

Similarly, Doezema and Hurlbut (2017) suggest dominant visions of the bioeconomy – i.e. as a political, neoliberal project in which the market is valorized above all else – reflect an 'imaginary of governance'. That is, they "...construct technoscience as the agent capable of enhancing social well-being, and outline the corollary political commitments that are prerequisite for desirable technological futures" (Doezema and Hurlbut, 2017: 50). Again, the argument here is that a promissory vision of a successful bioeconomy is suffused with assumptions and expectations about biotechnology's transformative potential. These authors see the OECD's Bioeconomy to 2030 Report and the US Bioeconomy Blueprint, for example, as exemplifying the aspirational political vision of technoscience as the ultimate solution to society's problems. In so doing, such reports 'draw upon and crystalize widely shared notions of the rights, roles, and responsibilities of political subjects in relation to both science and the state' (Doezema and Hurlbut, 2017: 50).

Hilgartner uses the term 'anticipatory enterprises' to describe organisations like the OECD and the European Commission. Such organisations are engaged in technological foresight, in which future-oriented expectations and imaginaries of technoscience are central. However, Hilgartner suggests that they are not simply seeking to anticipate the future. They are also seeking to shape or transform it. (Hilgartner 2007: 382.)

These powerful policy drivers to build a sustainable bioeconomy, whether or not their promissory visions are realistic, have an impact on research strategy and organizational practices, which is why we describe them as having a performative function. It is also why we consider them important objects of study. The hopes and expectations that are embedded within the reports of

national and international policy institutions, governments, and commercial organisations, are not simply rhetoric. They have a material impact on what areas of science get funded and what kind of research is valued.

The bioeconomy, we suggest, is both a political and a scientific/technological project, in that old and new science and technology is being exploited to transform society and economy. When a particular conceptualization of bioeconomy becomes attached to innovation policy and strategy, this shapes behaviour in the communities that are responsible for developing and applying biotechnology research. Although the scientific community may see its activities and practices through the prism of basic science and technology, innovation policy is shaped by social and political exigencies.

As our analysis revealed, most of the scientific papers used bioeconomy to frame a set of scientific and technological challenges. Moreover, this literature reflected a vision of the bioeconomy as a facilitator of white biotechnology; using microorganisms or enzymes to create new biological-based products to meet sustainability objectives or to improve global agricultural production systems for food security. This mirrors the policy approaches to bioeconomy over the past decade. As McCormick and Kautto (2013: 2594) argue, "The principal products of the bio-economy are bio-based products and bioenergy", so this is where the primary focus has been, as evidenced by Golembiewski et al (2015) in their bibliometric analysis of the bioeconomy landscape (Golembiewski et al., 2015: 309). A large portion of our selected articles from the science and policy fields emphasized this specific challenge. So what is the impact of these framings in terms of the policy agendas that are actually shaping the contribution of life science-based research to the economy? There are important questions about the size of the bioeconomy and where it is heading. To address these, we now discuss attempts to measure the activities and practices constituted within the bioeconomy, and critically analyse this in the context of the theories and concepts of biovalue and promissory discourses outlined.

Value(s), valuation metrics and practices in the bioeconomy

The way the bioeconomy concept is driving policy agendas and shaping industrial strategy raises questions about promissory value and valuation practices. This becomes salient when we look at attempts by policymakers and innovators to measure the size and growth potential of national and regional bioeconomies. As Hilgartner (2007) argues, realising the OECD's policy vision of an international bioeconomy requires a means to align the formal definition of bioeconomy (aggregate set of economic operations built on biological products etc.) with the everyday activities and practices that this abstract definition is used to represent. This:

... is not simply a matter of one-way reification, in the sense of treating an abstraction as if it had concrete existence; it is a process of iterative alignment that also involves making the abstraction more concrete by constructing techniques and institutional machinery capable of persuasively representing the activities (Hilgartner, 2007: 385).

Importantly, estimates of the economic contribution of activities and practices constitutive of the bioeconomy depend on the use of these calculative devices and techniques, which have political and commercial implications. Here, we look at three case examples; one from the UK, one from the US, and another at a pan-European level.

Measuring the UK's bioeconomy

A recent report by Capital Economics, TBR, and E4tech, on behalf of the UK's Biotechnology and Biological Sciences Research Council (BBSRC) and the Department for Business, Innovation and Skills (Bauen et al., 2016), presents a sophisticated evidence-based review of the contribution of the bioeconomy to UK growth and competitiveness. Like the OECD, this report defines the bioeconomy as encompassing "all economic activity derived from bio-based products and processes", and suggests that: "These contribute to sustainable and resource-efficient solutions to the challenges we face in food, chemicals, materials, energy production, health and environmental protection"

(Bauen et al., 2016: 3). Interestingly, the report clarifies that the bioeconomy builds on activities that involve 'transformative processes' -as well as their related upstream and downstream activities - around biological resources. This includes both conventional activities like growing crops and rearing livestock, as well as advanced bio-based products.

So the report is interested in both new, advanced biological innovations, as well as any activity or process that involves manipulation or conversion of biological resources into products that contribute to the economy. This broad definition increases the scale and potential value of the UK bioeconomy. The report states:

The transformational bioeconomy comprising agriculture and fishing, forestry and logging, water and remediation activities, food products and beverages and industrial biotechnology and bioenergy accounts for 3.5 per cent of gross value added in the United Kingdom (£56.0 billion in 2014), which is a little more than the wholesale trade and more than double the figure for the crude petroleum and natural gas extraction and mining industries (Bauen et al., 2016: 5)

When adding upstream and downstream activities related to this bioeconomy, the report states that £220 billion is generated in gross value added, supporting 5.2 million jobs. Furthermore, it suggests the UK bioeconomy plays a major role in attracting inward investment. The report states that in recent years the bioeconomy has performed much better than the economy as a whole, having previously lagged behind. In terms of European competitiveness, the report argues that the UK bioeconomy is smaller than in some other major European countries, in terms of gross value added, but that if contributions from agricultural activities were removed from the analysis, the UK bioeconomy is larger than Italy and Spain, and comparable to France. So here we see how measurements of growth potential (the report estimates that output could grow by 13% in the coming years) and international comparisons, which are important in policy contexts to align innovation, investment, and wealth creation; can significantly shift depending on the inclusion and exclusion criteria.

Overall, this is a sophisticated report in that it provides sector-by-sector data on jobs and economic activity, and does not limit the analysis to white biotechnology, so it is adopting a broad definition of bioeconomy. However, it does not enable us to estimate the specific contribution of the newer and advanced biotechnological innovations, which begs the question of whether by being so inclusive, such measurements and estimations render the bioeconomy concept meaningless. Nevertheless, as a political project, the bioeconomy concept is clearly successful in appropriating economic activities and generating the promise of future value – albeit comparative – and the creation of jobs.

Contribution of the US bioeconomy

In the US, a report by the Bioindustry Association (BIO), a trade body, and Battelle, a not-for profit R&D organisation, assessed the contributions made by five broad bioscience-based sectors to the US economy (Battelle et al., 2014). This report attempts to measure the contribution of certain bio-based sectors to the US economy, using data on sectoral employment and wages, R&D expenditures, patents, and various kinds of conventional performance metrics. Like the BBSRC report, the most revealing aspect is what is included and excluded in the analysis. The five sectors analysed were: 'Agricultural Feedstock and Chemicals'; 'Drugs and Pharmaceuticals'; 'Medical Devices and Equipment'; 'Research, Testing and Medical Laboratories'; and 'Biosciences-Related Distribution'. Overall, the report presents a sanguine picture of the success of the bio-industries, stating "... bioscience in the 21st Century has been a consistent producer of innovation-driven economic growth – generating jobs, income and output growth for those regional economies with key bioscience assets" (Battelle et al. 2014: 2).

The data presented show, like the BBSRC report, that the bioscience industries have responded better to the financial crisis of 2007/2008 than private industry as a whole. The sector has continued to grow in terms of job creation. Furthermore, in terms of gross economic output, the report reveals that in all five sectors nominal output continued to expand significantly from 2001-2012. The report also shows that, apart

from R&D funding, which had been relatively flat until 2014, most other metrics of value (employment, patents, venture funding etc.) had risen. However, it is important to note that job growth had declined in the drug development and agrobiotechnology sectors. Nevertheless, we again return to the critical issue of what is included and excluded in the selection of activities, practices, and material objects that are presented as constitutive of the bioeconomy. For example, in the 'Drugs and Pharmaceuticals category', no distinction is made between advanced bio-based R&D and conventional small-molecule drug development, so the specific contribution of biology to the health-related bioeconomy cannot be extracted from the analysis. One might legitimately ask if this aspect of drug innovation is more or less valuable as a driver of employment, economic growth, and indeed patient health and wellbeing, than conventional drugs? However, this question cannot be answered by the data provided in the report.

An editorial in the journal *Nature Biotechnology* (Nature Biotechnology, 2014), provided a nice critique of this report on the grounds that the size of the bioeconomy is a constantly moving target precisely because analysts are too inclusive in some cases, and not inclusive enough in others. It is therefore impossible to make accurate and meaningful judgements of its scale and scope. For example, the report includes firms that manufacture fertilizer in its 'agricultural, feedstock and chemicals' sector, when it might have been more justifiable to categorise this as part of the chemicals rather than biotech industry. This is similar to our earlier argument about the lack of a clear distinction between chemical and bio-based drug development. In terms of the "medical devices sector", the editorial argues the report accepts the US Department of Labor's definition, which includes "... manufacturers of clamps, canulae and bone drills as well as syringes, knives and medical thermometers" (Nature Biotechnology 2014: 598). These are not activities and products one would naturally associate with innovative life sciences, yet they are being captured in analyses of the economic contribution of the bioeconomy.

The Nature editorial reserves the greatest criticism for the categories excluded from the

analysis, and the employment data is particularly interesting. "...the report tallies up the number of bioscience patents but does not enumerate bioscience patent lawyers. It notes the gradual increase in venture capital spending, but does not count up venture investors" (Nature Biotechnology, 2014: 598). Furthermore, the report does not factor the increase in number of jobs within regulatory agencies and reimbursement agencies, as well as those in health insurance companies and reimbursement agencies, which are more relevant to the bioeconomy than jobs associated with conventional medical device development, or manufacture of chemicals for the agricultural sectors. Indeed, the size of the bioeconomy could turn out to be much larger than the report suggests, if all these additional jobs and activities were included, and others excluded.

Scepticism of many conventional attempts to capture the economic contribution of the bioeconomy is shared by Carlson (2016). Summarising the problem, he states:

Current understanding of the biotech sector is hampered by inconsistencies in usage and definition of 'biotechnology' and 'bioeconomy' ... These words may be used in reference only to pharmaceuticals (or biopharmaceuticals, or biologics, depending on one's definition), genetically modified (GM) crops, or public companies whose primary revenues rely on biological technologies, thereby muddling an integrated description of the industry ... Beyond linguistic imprecision, a lack of data resulting from inadequate characterization of the economy hampers any assessment of the economic size and scope of biotech. (Carlson, 2016: 247).

Carlson proceeds to point out that even in the US, which dominates global biotech, there is no official means to distinguish biological from non-biological technologies and products. For example, a chemical manufactured using biologics is treated similarly to one produced from fossil petroleum. The former may displace the latter "on the basis of price or preference, yet revenues now accrue to a category that includes petrochemicals." (Carlson, 2016: 247) So under the present system of classification, revenue accruing from a novel biomole-

cule could, according to Carlson, be misattributed to fossil fuels.

The value of the European bioeconomy

As a key region promoting the bioeconomy, the European Union's 2012 'Bioeconomy Strategy' and its 2017 review (European Commission, 2017) touts the importance of a market estimated in 2009 to be worth over 2 trillion euros and responsible for 20 million jobs (M'Barek et al., 2014). The key objectives outlined in the 2012 strategy are; 1) ensuring food security; 2) managing natural resources sustainably; 3) reducing dependence on non-renewables; 4) climate change mitigation and adaptation; and 5) creating jobs and ensuring EU competitiveness (European Commission, 2012). In a recent review of this strategy (European Commission, 2017), the Commission suggested the policy context within which the bioeconomy operates has significantly changed since the 2012 strategy was developed (particularly around sustainability goals). This may require a refocus on key elements. However, it noted there had been success on some of the deliverables of the original strategy, particularly around the mobilization of funding for research and innovation, under Horizon 2020, and the development of standards for bio-based products, as well as key contributions to European employment and income generation.

A recent paper takes the Commission's strategy and definition of bioeconomy and attempts to define a methodology to quantify two bioeconomy indicators - turnover and employment - using Eurostat data (Ronzon et al., 2017). This work was conducted in collaboration with the European Commission's Joint Research Centre (JRC). The authors conclude that:

The bioeconomy employed approximately 18.6 million people in the EU-28 in 2014, generating turnover around EUR 2.2 trillion. Between 2008 and 2014, employment in the European bioeconomy contracted, with the loss of nearly 2 million people employed. Agriculture and the manufacture of food, beverages and tobacco constituted three quarters of the jobs and two thirds of the turnover of the European Bioeconomy (Ronzon et al., 2017: 7).

More detail on the numbers and metrics can be found in a report by Piotrowski et al (2018). The authors discovered that the biomass sectors were the most labour-intensive, particularly agriculture and fishing. In terms of overall turnover, half of the 2 trillion EUROS is accounted for by the food and beverage sector, a quarter from agriculture and forestry, and the remainder from what are defined as 'biobased industries' (which included plastics and chemicals, pharmaceuticals, paper products, forest-based industries, textiles, biofuels and bio-energy). Again, we see how a very expansive and inclusive definition of bioeconomy can be used to make claims about current and future value. Disentangling from these figures the specific contributions of, say, advanced life sciences, and discounting what might be categorised as old or conventional biological activities or processes is not possible. The bioeconomy therefore becomes a catch-all term for an array of practices, activities and economic sectors that, together, are shown to generate value, support national competitiveness, and solve grand global challenges.

Discussion and conclusions: new approaches to measurement and value

What all these national and regional reports and strategies exemplify is how measurement, and the application of different tools and metrics, can be used to drive different narratives about the scale, scope, and value of the bioeconomy and its constitutive activities and practices. Most advanced nations attempt to measure their bioeconomies and evaluate their national competitiveness. So we have Dutch estimates of the size of its Bio-business (Heijman, 2016), and German attempts to measure the bioeconomy within the general economy (Efken et al., 2016). The idea of a vibrant bioeconomy is of strategic importance for nations and regions as they justify public investments in life sciences and industrial biotechnology.

What is interesting in all these reports, which have a performative role in shaping industrial strategy, is that they operate with different metrics for evaluation, making cross-country comparisons difficult. Also, they adopt a very narrow definition of value; one linked inextricably to crude

and conventional economic metrics, like profitability, employment, GDP etc. If we take some of these crude economic metrics at face value, they suggest that the supposed biotechnology revolution is not perhaps as revolutionary and profitable as has been assumed; instead being based on unfulfilled expectations driven by promissory discourses. As Birch argues, despite the global biotechnology industry increasing its market capitalization over time,

... in 2014 the life sciences sector was neither producing proportionally more products and services nor proportionally higher revenues than four or five years earlier ... [This illustrates] how uncertain and volatile value *and* valuations are in the bio-economy, and how disassociated they can often seem to be from the development of new products and services (Birch, 2017: 2)

Birch is interested in this contradiction between the high financial valuations placed on the biotechnology sector - partly sustained by reports suggesting the size and contribution of the bioeconomy is growing - and the failure of this to engender the products that public investments in biotechnology continually promise are imminent. One answer is that current value is simply based on the promissory visions and expectations of future economic returns from products, and this is what interests many scholars focused on bio-value and the commodification processes underlying the neoliberal bioeconomy. However, Birch's argument is that we need to look beyond this to the 'assetisation' processes; that is the financial technologies, knowledges, and practices that enable things to be transformed into assets and generate value. This leads him to consider value and valuation beyond the intrinsic or latent properties of the tangible biological objects themselves, or their related intangible products such as IP, which would be consistent with a commodity-based analysis. Instead, he looks at the financial valuation of the firms themselves, and their assets, arguing this is ultimately where the value is realised (Birch, 2017: 3). The outcome of this analysis is that "... value is constituted primarily by the *social practices* of the political-economic actors who *configure* the financial value and valuation of firms" (Birch, 2017: 3).

While this approach is still focused primarily on value in a commercial/economic sense, opening up value to include the social practices of valuation enables us to think about the bioeconomy in a more interesting and sophisticated way. This approach begs the question of whether the value allocated to the bioeconomy by different actors, and the transformative activities and ways of organising research that have been precipitated by governments, policymakers, and industry, should be evaluated primarily through crude economic metrics, whether that be commodity or asset value. The field of valuation studies (Helgesson and Muniesa, 2013) shows we can capture both the objective and subjective elements of value and make better sense of the economic and noneconomic evaluation practices that frame different accounts of benefit and worth (Lamont, 2012). A broader, inclusive approach to value forces us to consider the multiple ways in which economic and non-economic value is enacted and performed in different professional and social contexts (Mittra, 2016; Stark, 2009).

In the context of the bioeconomy, this approach to value enables us to illuminate the transformational changes that political projects, driven by advances in science and technology, have had on numerous industrial sectors and the ways in which their R&D is organised. It moves beyond narrow questions about whether the life sciences are meeting their early promise and satisfying expectations of delivering new products and economic returns, to looking at how interdisciplinary and collaborative practices are emerging alongside new business models and value systems in an attempt to make advanced biology work to solve global problems.

Policymakers, industrialists, scientists, publics, and a whole range of other stakeholders are concerned about the value and worth of innovation in the health, agriculture, and environmental sectors, as our literature analysis and critical review of official reports has shown. Nevertheless, measurement does guide behaviour, and attempts to talk about the bioeconomy as if its objects and practices were simple to define and measure can obscure as much as they reveal. As we have shown, the concept can appear meaningless given the diverse inclusion and exclusion criteria,

which can affect estimations of value and worth. Of course, it is important to note that this strategy has been very successful as a political project, and ensured resources have been allocated to sectors and organisations that have sought to enact these promises, hopes, and expectations. The trends in the science and social science literatures that we identified, particularly the ways in which different disciplines have focused on very different sectors and application areas, further highlights the complexity and diversity of framing. The scientific papers tend to mirror policy accounts that see the bioeconomy rooted in issues of sustainability, with the social sciences more critical of bioeconomy and likely to reference green and red biotechnology as their key examples of commodification and assetisation processes.

To conclude, we have attempted in this paper to trace the emergence and evolution of the concept of bioeconomy and show how it has been framed and used strategically by various constituencies as a political, scientific/technological, and economic project to meet regional and global challenges. Our starting point was to ask: what is the bioeconomy, how has it been used in different fields, and how might it be best understood and valued? It turned out that the answer to the last part, which is a normative question, is dependent on the answers to the first part. How the bioeconomy is defined, both formally and informally, and what activities and practices are considered to be its immanent features, determines its scale, scope, and ultimately the value that different stakeholders place on it. Nevertheless, by critiquing the concept of bioeconomy and the valuation tools and calculative devices used to measure it, we have shown that a broader conceptualisation of value that takes seriously underlying social practices, would perhaps better inform our understanding of the contributions made by the different sectors within the bioeconomy.

While it might be meaningless as a broad and highly inclusive concept, the bioeconomy, as a distinct economic regime that captures the new activities and practices of advanced biotechnology, can be studied in a meaningful and useful way. However, to do so, we need far more precision in the measurement tools we use; be highly cautious of reports that use inappropriate

inclusion or exclusion criteria that often artificially inflate the economic contributions of the bioeconomy; and we perhaps need to stop prioritising white biotechnology as the key driver. We have shown that doing so obfuscates or downplays the

important contributions of red and green biotechnology, and also elides the fact that benefits and limitations, including accounts of value, may vary between the different categories.

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The Shaping of Urban Public Transport: Two Cases of Alternative Leading Objects

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Abstract

This paper investigates the shaping of urban public transport by comparing 'alternative leading objects' to the car in the Norwegian cities Trondheim and Bergen. These have chosen different transport technologies, bus and light rail respectively. I draw on the concept of technological frames and illustrate how interpretations and expectations of sustainable urban mobility guide transport planning. The paper contributes to discussions in STS by exploring technological frames as ongoing practices instead of as outcomes, and as performed by what I identify as two framing coalitions. Both coalitions emphasised that Trondheim and Bergen represented different city identities and topographies. The paper demonstrates the importance of making such identities and representations of public transport systems in particular urban contexts in order to replace a car-dominated transport system. The paper draws on an observational study in two transport offices, interviews with transport planners and politicians and document studies.

Keywords: sustainable urban mobility, alternative leading object, technological frames, public transport

Alternative leading objects of urban mobility

Urban transport systems are multi-modal in the sense that they combine cars, buses, trams, light rails and more; presently, cars dominate nearly all such systems. Lefebvre (1971: 100) calls the car 'the leading object' due to its outstanding ability to shape the physical structure and performance of social life, and to the way in which it functions as a symbol of modern capitalism. However, global climate change discourses challenge its dominant position, particularly with respect to planning urban transport. During the last decade, many actors have positioned cities as promising sites to

reduce climate gas emissions (Bulkeley et al., 2015), with transport expected to play an important role in this regard. A major focus and challenge for cities has been to achieve a modal shift from car use to the use of public transport. What kinds of technologies are called for to achieve this shift, and what is the underlying argument for choosing one particular technology above another?

The paper pursues this question by investigating the shaping of public transport in two of Norway's largest cities, Trondheim and Bergen. In Trondheim, buses are the primary focus as the

development of public transport in the city has been and still is an issue of designing and building an attractive and effective bus system. In Bergen, the focus is on the construction of a light rail system, which has gained a hegemonic symbolic position in spite of the quantitative dominance of buses in Bergen's public transport system. The paper analyses the arguments forwarded by what I call the framing coalitions in the two cities, their arguments regarding the technological options and their navigation through these options when trying to increase the use of public transport. Inspired by Lefebvre's (1971) description of the car as a 'leading object' I use the notion of 'alternative leading object' to designate the technology that dominates discussions and investments in public transport.

There is an increasing focus on sustainable transport in Norway, and a main goal of Norwegian transport policy is so-called zero growth. It states that car-based mobility should not increase even though Norwegian cities are growing. Instead, increasing transport needs should be met by public transport, walking and bicycling (White Paper 26, 2012-2013). To this end, the National Transport Plan for 2014-2023 (White Paper 26, 2012-2013) proposes densification of the cities as a means to foster sustainable mobility. However, Berger et al. (2014) point out that there is no accepted definition of a compact city (see also Organisation for Economic Co-operation and Development, 2012) although 'compact cities' are often seen as a solution to problems created by urban sprawl and processes of suburbanisation (Neuman, 2005; Burton, 2000). The lack of a clear and universally accepted definition of the 'compact' city suggests a potentially important relationship between the choice of public transport and of the physical structure of a city, which I also explore in this paper.

Schwanen et al. (2011) reviewed leading transport journals in the 2000s and found that most research on sustainable mobility has addressed the effect of technology on carbon emissions, physical infrastructure provision and behavioral change. The focus on attitudes and personal norms emphasises consumer responsibility, which according to Schwanen et al. (2012) neglect the role of other stakeholders such as

the transport lobby, politicians and the media (see Buchmann et al., 2017 for a review of social science and humanities research in transport decarbonisation). Hodson et al. (2017) claim that previous research on sustainable mobility has focused on efforts to reduce the need to travel, the re-designing of roads for non-car transport and the shifts to other modes of mobility such as walking, cycling, tram and light rail (see also Banister, 2008; Parkhurst et al., 2012).

There is also a growing literature on innovations in sustainable mobility (see Schwanen, 2015 for a review). For instance, Pineda and Jørgensen (2008; 2015) discuss the development of urban transport systems in two cities – the metro in Copenhagen and the Transmilenio in Bogotá (bus rapid transit) – in a sustainability transition perspective. They use the so-called arenas of development approach to highlight the composition of discourses, claims, materiality and visions, arguing that when an arena matures (automobile-based transportation for example) it often materialises in institutions (Pineda and Jørgensen, 2015: 203). This paper is also concerned with how ideas and interpretations 'mature' in the shaping of sustainable transport in two different city contexts, but my paper adopts a somewhat different theoretical perspective (to be discussed in the following section).

A transport system may seem radical in one city and represents the norm in another due to the process of *embedding* an artefact into a local context that comprises various dimensions such as existing transport systems, governance, politics and funding (Hodson et al., 2017: 9, my emphasis, see also Schwanen, 2015). Thus, there is a need for empirical comparative studies of the embedding of transport artefacts in different urban contexts (Hodson et al., 2017). In this paper, I study how particular public transport technologies become 'the norm' in a specific city context by exploring how stakeholders in urban transport develop ideas concerning an alternative leading object in a local context of improving sustainable mobility.

To this end, I draw on concepts from Science and Technology Studies (STS). By contrast to perspectives focusing solely on technological fixes such as the making of low-emission vehicles or facilitating infrastructures for sustainable mobility (see Schwanen et al., 2011 for a review of such

perspectives), STS concepts are particularly suited to explore the introduction and the role of technologies in societies. This includes, among others, how various actors are important in the construction of new technologies (see for instance Pinch and Bijker, 2012[1987]), how some technologies 'win' over others (for instance Latour, 1987) or how technologies become co-produced with identities, discourses, institutions and representations in societies (Jasanoff, 2004). In this paper, I will focus on the concept of technological frames, which is part of the Social Construction of Technology framework.

The rest of the paper is structured as follows: first, I will briefly describe and explain why the concept of technological frames is useful in exploring the shaping of urban public transport. Second, I will give an account for the choice of case studies, the data sources I have used and how I analysed the material. Third, I dedicate the main part of the paper to the exploration of the two cases: the shaping of a (metro) bus system in Trondheim followed by the shaping of a light rail system in Bergen. I conclude by comparing the two frames, and suggest how to develop the concept of technological frames.

Technological frames and framing coalitions

The car remains the leading object in the Norwegian cities of Trondheim and Bergen. However, this domination is increasingly challenged by more sustainable modes of mobility such as public transport. Insights from Social Construction of Technology (SCOT) and particularly the concept of technological frames represent a promising avenue to explore the emergence and stabilisation of technological artefacts. While the original SCOT framework was concerned with how artefacts may be interpreted differently by relevant social groups, a process referred to as 'interpretative flexibility' (Pinch and Bijker, 2012[1987]), Bijker (1995) introduced the concept of technological frames to explain how certain interpretations stabilise over time.

According to Bijker (1995), technological frames consist of goals, ideas and tools that guide a relevant social group's thinking and interaction

with a certain phenomenon – in this case with respect to sustainable urban mobility. Technological frames emerge when interactions 'around' an artefact begin, meaning that the frames are not characteristics of actors but developed in interactions between actors and artefacts (Bijker, 1995). His argument is that technological frames thus contribute in structuring interactions because they constrain freedom of choice in the designing of an artefact. It is important to note that a technological frame is not merely an interpretation of an artefact (such as a public transport technology), because the artefact itself contribute to structure these actions and thereby also constitutes the frame (Bijker, 1995).

The concept is most conducive to the analysis of situations of instability and change (Bijker, 1995: 124) – where there is leeway to destabilise common interpretations. For instance, though the car is presently the leading object of urban mobility in Norway, there is an ongoing destabilisation of the car's leading role towards more sustainable mobility systems. Aibar and Bijker (1997) used technological frames to illustrate how three relevant social groups, defined as architects, engineers and the working class, competed to shape the extension of Barcelona city based on their ideas and interpretations of the city and the extension plans. Here, the relevant social groups had competing interpretations, and the Barcelona case ended with what the authors describe as a compromise between the architect and engineer frame.

The notion of relevant social group has mainly been used to illustrate differences between groups' interpretations and interests and how they may reconcile with respect to a given design of an artefact, like the bicycle. This paper is more concerned with the choice of transport technology and how this choice is framed to make it attractive. For this reason, I use the notion of 'framing coalition' to describe the actors that engage in the framing processes. A framing coalition is a group of people with shared ideas and interpretations of sustainable urban mobility in a particular city context, which through political channels and new media in particular actively promote a particular technology to establish a technological frame in the local context. Though the alterna-

tive leading objects are indeed challenging the car's leading role in the urban transport system, the paper is concerned with the relation between the alternative leading objects and their respective urban contexts. I focus on the content and the effects of the technological frames, rather than how the frames were initially developed. We should expect relevant social groups to be made part of a technological frame in the sense that a successful transport technology needs users or customers, but this gives them a lesser role than in Bijker's (1995) account. Following this, I see technological frames not merely interesting as outcomes – describing why artefacts look the way they do – but also as ongoing practices of generating interpretations and ideas, in this case of sustainable urban mobility. Hence, I use the concept to explore contemporary and future-oriented shaping of urban mobility.

The frames in the Barcelona case (Aibar and Bijker, 1997) included two types of closely intertwined artefacts: the Cerdà plan for the extension of Barcelona and the city itself. This two-fold inclusion suggests that technological frames may implicate actors' design choices and leeway not only with the exemplary artefact itself, in my case public transport technologies but also the local context in which it operates – the city. Pineda and Jørgensen (2015: 202) also point out that in order to nurture new initiatives (such as a transport system) there is a need to understand how the new initiative relates to the context in which it is expected to perform. This point is of highly relevance to this paper, focusing on technological frames in two different city contexts.

With these insights, the paper pursues the following research question: How are alternative leading objects decided upon, what frames do they become part of, and what are the effects of these frames in particular urban contexts? I will explore this by investigating the arguments forwarded by framing coalitions concerning alternative leading objects in Trondheim and Bergen. Before that, I will give a brief account of my methodological choices.

Methods

Bergen and Trondheim are the second and third largest cities in Norway, with approximately

280,000 and 190,000 inhabitants, respectively. Both cities have organised their work with urban transport in a three-party public sector collaboration between the state, county and municipality. In Trondheim, the programme is called Greener Trondheim, and in Bergen, the Bergen Programme for Transport. I chose these cities because they have invested in different alternative leading objects: bus and light rail. The paper focuses on the ideas and arguments forwarded by the main framing coalition in each city concerning this choice. I will identify the coalitions by means of visible actors' shared set of ideas and interpretations of alternative leading objects and the local context where these are expected to operate. The coalitions may include different types of actors with various interests of urban transport, for instance politicians, urban planners and the public in general.

I needed a qualitative research design to identify and to gain in-depth accounts of the framing coalitions' ideas and interpretations of both the public transport systems and their respective city contexts. This design consists of several sources, namely (1) observations in two planning agencies (Bergen and Trondheim), (2) interviews with transport stakeholders in these cities, (3) review of newspaper articles and (4) review of official documents from national and local authorities. I will briefly describe each of these datasets.

The primary source of data is an observational study inspired by Czarniawska's (2007) shadowing technique, carried out over a one-month period in two planning agencies (Bergen and Trondheim). Shadowing as a method lies somewhere between doing observation and participant observation. It is a 'fieldwork on the move' because the researcher carefully follows those being shadowed around throughout their working day (Czarniawska, 2007). During the fieldwork, I participated in and observed internal and public meetings, discussed with the planners and participated in on-site inspections, all of which allowed me to explore how urban planners interpret and negotiate sustainable urban mobility. I recorded the fieldwork in a written diary, on an audio recorder and with a go-pro camera.

The second source is interviews with urban planners working in the planning agencies I shadowed and with regional transport stakeholders and politicians. I conducted twelve interviews in total between May 2015 and January 2016. I selected interviewees partly due to their different areas of responsibility and partly due to their accessibility. Since regional governments in Norway are responsible for operating public transport, I also sought insights from regional transport actors including politicians. Each interview was recorded and transcribed and I have anonymised the interviewees. The combination of shadowing and interviewing in close succession gave me the opportunity to learn more about practices, controversies, ideas and interpretations involved in urban mobility planning.

The third source of data is newspaper articles collected from the online media base Retriever. Newspapers have a wide circulation and large readership in Norway (Østbye, 2008), and they represent an important arena of information and public debate. I used the transport programmes Greener Trondheim and Bergen Programme for Transport as points of entry. My aim was to identify how sustainable transport, in particular the new bus project in Trondheim and the light rail in Bergen, were debated in these cities' regional newspapers (*Adresseavisen* and *Bergens Tidende*). The newspaper articles comprised reportages, chronicles and letters to the editor. I did not explicate these differences because I was more interested in the content rather than potential intentions of the newspaper texts. In this way, I see the material from this source as to reflect the arguments of those involved in the public transport debates in Trondheim and Bergen.

The fourth source is official documents from national and local authorities such as the National Transport Plan for 2014-2023 and the websites of Greener Trondheim and The Bergen Programme for Transport. I reviewed these documents to search for national aims and goals of urban public transport and additional information including financials concerning the metro bus project and the light rail.

I analysed the data in a systematic coding procedure inspired by grounded theory methods as introduced by Charmaz (2006). I made open

analytic codes of pieces of text, which I further grouped into categories that I compared and explored.

The following analysis focuses on the framing coalitions' arguments in favour of their preferred choice of public transport in Trondheim and Bergen.

Two cases of alternative leading objects

The technological frames in Trondheim and Bergen relate as they both intend to replace the car frame. However, they pursue their objectives with diverging strategies and alternative leading objects. I will to some extent focus on the stabilisation of the frames but, as stated, the paper is more concerned with the content and the *effect* of the frames. My aim is to investigate the elements of the frames and by this how the frames may contribute in the further shaping of urban mobility in these two cities.

Emerging technological frames in Trondheim

The car as leading object of personal transport has been manifest in Trondheim for a long time. In the 1960s, there were even more private cars in Trondheim than the national average car registration per capita in Norway (Thomassen, 1991). The fact that the car is the current and traditionally dominant leading object suggests that there is a strong car frame in Trondheim. The car has remained the answer to most questions concerning urban mobility for a long time and thus obtained a sort of obduracy (Bijker, 1995; Hommels, 2005). However, the car frame is increasingly being challenged. According to a regional politician in Trondheim, matters of land use and congestion will force the car to be replaced by other means of transport in the future:

Facilitating public transport in cities is a matter of land use. There is not enough land to solve transport issues posed by cars because this boils down to how many people you can transport from point a to b within a city. People have to walk, cycle and/or use public transport. Otherwise, cities will choke in congestion.

Technological frames emerge through interactions with technological artefacts, for instance by publicly performed ideas and arguments. There have been lengthy debates between professionals and policymakers in Trondheim concerning the choice of an alternative leading object. These debates (recorded in Trondheim's regional newspaper) initially concerned the choice of tramlines, a light rail or a bus system. One debate concerned ideas and possibilities for constructing a tramline loop ('Midtbyløyfen') through the city center. The tram in Trondheim started operating from 1901 and occupied an important position in the city from the 1920s to the late 1980s but financial problems led to a shutdown of all except from one line in 1988 (Kjenstad, 2004). Several of Trondheim's local politicians in the Labour Party were part of this emerging coalition advocating the tram option. This coalition also included inhabitants in Trondheim hoping for a new golden age for the tram – celebrating its hundred-year anniversary in 2001 (see Kjenstad, 2004).

The coalition supporting the tram option ('the tram coalition') lacked financial and sufficient political support. For instance, the Minister of Transport refused to allocate the necessary 15 million NOK (today approximately €2.9 million) to build the tram loop (Leirset and Gisnås, 2001). The tram coalition had similarities to another emerging coalition advocating a light rail option in Trondheim. The similarities concerned financial challenges, but also how a rail based transport system invoked issues of localisation and enabled long-term urban development. For instance, the national rail company suggested a light rail for Trondheim in 2001 (NRK, 14.08.2001) and light rail became part of the public debate. Moreover, the Green Party in Trondheim pointed to possibilities of combining a light rail system with Trondheim's railway system (Hegvold, 2007).

The discussion that followed in the newspaper addressed whether Trondheim should create a tramline, construct a separate light rail system or expand the bus network. I understand this as three technological frames of sustainable urban mobility, posing different ideas of alternative leading objects to the car. The frames were constructed by frame coalitions consisting of politicians, planners and the public. However, the

coalitions were not equally strong. The coalition that advocated buses as the alternative leading object consisted of several members from the local Labour Party and the professional planning community in Trondheim. During the last decade, Trondheim has put great effort into developing a public transport system in which buses play the predominant role. Therefore, the next section will focus on how the bus coalition performed what I call the bus frame in Trondheim.

Performing a bus frame in Trondheim

The bus coalition interpreted buses as the alternative leading object of person transport in Trondheim. They developed the bus frame simultaneously alongside efforts to destabilise the tram and the light rail frame. In so doing, they argued that a tram and light rail were unsuitable by pointing to topographical and demographical aspects. An urban planner in Trondheim summarised the bus coalition's view in a local newspaper:

The choice of public transport technology relates to size and settlement. A light rail is conducive to transporting many people over long distances, like in Bergen, but Trondheim is a circle-shaped and small city. The bus gives greater flexibility because Trondheim does not yet have clear axes of settlement like Bergen. A light rail may be an option in the future, and some politicians are very determined that Trondheim should have a light rail, but I think this depends on the city's development (Kringstad, 2016).

The quote reflects an interpretation of Trondheim that emphasises topographical and demographical elements, and this interpretation was central in constructing the bus frame. Several interviewees in both Trondheim and Bergen claimed that Trondheim's population was clustered in semi-dense areas and needed buses because they could operate in several directions. The urban planner quoted above also pointed to flexibility as an important motivation for choosing a bus system. This relied on an expectation that a bus system would be more adaptable to shifting future settlement, compared to what was considered as a non-flexible light rail or tram solution. The bus coalition interpreted this flexibility as an advantage in terms of replacing the car as leading object in Trondheim.

Moreover, the bus coalition also stressed that due to relatively low costs, a bus system was more likely to give expedient results than a light rail, which would require construction from scratch. A representative from the county authority explained that it was challenging to get financial support in the absence of any convincing results: "if we had started planning for a light rail in 2008, we would not have had any results to show by now". It was seen as beneficial to document immediately how the public transport system contributed to replace the car as leading object in order to procure further trust and financial support from the national government. In addition, according to an urban planner: 'a bus system gives a lot more transport for the money than a light rail'.

The bus coalition found it necessary to make the bus appear as a desirable alternative to the car and was especially interested in recruiting car drivers as bus passengers. To do so they needed to frame the bus as a viable choice while at the same time restricting car use. A regional politician explained:

The first keyword for a better bus system is 'frequent departures'. This is related to the second keyword, namely 'predictability'. Further, we agreed that the buses had to be 'cleaner' in terms of fewer emissions. If buses are going to compete [with cars], you have to make the bus users feel that they are making an environmentally sound choice. Thus, we invested in buses running on natural gas when we upgraded the system.

The regional politician stressed frequency and predictability but also the fact that bus users needed to feel that they contributed to urban sustainability by taking the bus. In the bus coalition's view, all inhabitants in Trondheim were potential bus users and thus part of all-encompassing social group, even those who normally travelled by car. They saw the bus as a socially inclusive technology that in principle should serve the transport needs of all inhabitants. A representative from the county authority argued that a bus system appealed to all inhabitants in Trondheim: "A light rail only benefits those living close to it. The bus, by contrast, is for everyone, no matter where they live". Users, however, needed to be convinced and pushed to change their travel behaviour. Put

differently, the bus coalition tried to configure potential bus users by "...defining the identity of putative users and setting constraints upon their likely future actions" (Woolgar, 1990: 59). The bus coalition put much effort into the configuration of potential users by considering what measures would cause them to start using the bus.

The bus coalition contributed to 'ordering' urban mobility in their concurrent framing of the city of Trondheim and the bus system. They ordered the elements based on their ideas of topography and demography, the city's transport history and existing transport infrastructure, the importance of flexibility in urban planning to obtain quick results, economic concerns, and not least their user configuration. I understand this ordering of elements as a way of simultaneously producing a city identity for Trondheim and developing the bus frame. By this, they could argue that a bus system was the most legitimate choice of alternative leading object considering the city's unique identity.

With a bus frame also grounded in the city identity, bus technology appeared as the solution to the most pressing transport problems in Trondheim. Working with a bus frame (as opposed to a light rail or tram frame) indeed also resulted in some of the quick results that this coalition considered very important in political terms. For instance, planners and politicians in Trondheim transformed a mixed-use driving lane into a bus lane in the city centre in 2008. This was crucial according to a local urban planner in securing Trondheim the national Sustainability City Prize in 2008. This was also the same year as the establishment of Greener Trondheim, which prioritises and finances work with sustainable transport. Greener Trondheim has made the bus system their main priority in the matter of public transport. A regional transport actor applauded what he considered great success of these efforts:

What Greener Trondheim achieved in restructuring the bus system was unique. No other city in the Nordic region has made a similar achievement in such short timeframe. Greener Trondheim contributed to an increase in the share of bus travel up 60% between 2008 and 2015. This was an extreme improvement.

Despite the success, the increase of buses began creating new problems of bus congestion during rush hour periods. The planners also expected population growth and by this a correlative increase in bus travel. Thus, their main concern shifted from promotion to the difficulties involved in a further expansion of the bus capacity. A regional transport stakeholder interpreted the situation as follows at a public meeting in Trondheim:

Our bus success from 2008 is now stifling us. During rush hours, it is almost impossible to get through the city centre by bus. We will now introduce a new technology to solve this problem: the metro bus. The metro bus will be 'the light rail' of Trondheim.

The metro bus was intended to solve congestion problems by introducing vehicles with a significantly larger passenger capacity than regular buses (metro buses would be up to 24 meters long). However, when the alternative leading object, the bus, needed to accommodate technological change it seemed to re-open a debate, in which some again started advocating for a tram and/or light rail solution. When this occurred in 2015, articles in the regional newspaper in Trondheim referred to the metro bus as a 'monster bus' because of its size. There were also letters to the editor written by citizens and politicians that attempted to rekindle a public debate concerning why Trondheim did not invest in a 'real' light rail instead of a metro bus. The bus coalition's reaction to this claim was frequently to repeat the financial reality. For instance, the website of Greener Trondheim (2018) compared the metro bus and the light rail in Bergen, showing that the metro bus was estimated to cost 2.8 billion NOK (approximately €300 million) while the next line for the Bergen light rail alone was estimated to over 6 billion NOK (approximately €630 million).

Despite resistance towards the metro bus, the bus frame had grown obdurate (see Hommels, 2005) in the sense that it was challenging to think of topography, planning flexibility, results, economic concerns and user configurations without considering the bus as the alternative leading object. The bus, including the metro bus,

still appeared to be the answer to all problems of public transport in Trondheim.

Though the bus coalition enrolled the metro bus into the bus frame, they considered it an advantage if the metro bus was capable of evoking a light rail system for passengers, admitting that such system appeared more desirable. Actually, the website of Greener Trondheim (2017) described the metro bus as a hybrid technology with similarities to a light rail in terms of accessibility and reliability, design and frequent departures. The website even called the metro bus "a light rail on wheels". However, this did not destabilise or compromise the bus frame. On the contrary, it contributed to strengthening the position of this frame by including some important aspects of public transport planning, namely frequency, predictability and not least urban densification. An urban planner in Trondheim claimed that the light rail in Bergen had stimulated a densification of settlement along the rail lines and therefore expected that the three main metro bus lines would have a similar effect in Trondheim. As such, the metro bus did not only fit the contemporary city but was argued to be a forward-looking alternative leading object, which would transform Trondheim in the future. Ultimately, the developed bus frame meant that Trondheim should not need to engage in any more debate concerning alternatives like trams and light rail.

In this section, I have shown how the bus coalition in Trondheim performed a bus frame. They used topography and demography to argue why a bus system was a suitable option for Trondheim but they also pointed to the flexibility and how economically sound the bus was compared to the construction of a light rail. Moreover, they made the bus appear as an inclusive technology in the sense that bus travel was meant for everybody – everyone was considered a part of the relevant social group of the bus system. At the same time, it was also an exclusive transport system because the bus coalition did not plan for any other public transport alternatives. Importantly, this coalition stressed how the proposed metro bus technology would help densify the settlement along the bus lines, making this a far-sighted alternative leading object.

Next, I will turn to Bergen, which has a light rail system. With respect to the flexibility and relatively low costs of a bus system, it is somewhat surprising that Bergen chose this technology. First, I will give a brief account of how the light rail evolved as the alternative leading object in Bergen.

Emerging technological frames in Bergen

The city of Bergen is located on the west coast of Norway in a valley surrounded by mountains. Bergen faces severe challenges with respect to local air pollution, particularly during cold winters. This is due to so-called inversion in which polluted air (such as smog) stagnate close to the ground. In addition, there has been a strong car frame in Bergen for a long time, and this car dominance was according to a regional politician among the reasons why it was urgent that Bergen succeed in the matter of public transport:

Twenty years ago, the city centre in Bergen looked like one huge parking spot. The transport situation was a disaster, and the city kept growing. Bergen would have collapsed if the politicians had not started to make a plan for public transport.

Bergen has a long history of rail transport and the city had a tram system in operation from 1897. However, this system was limited to the inner parts of the city and did not reach the suburbs. Due to high operating costs, the tram was gradually replaced with bus and trolleybus lines and the tramlines were shut down in 1965 (and the tramcars were dumped in the fjord!) (Hodne et al., 1997). The deregulation of the car in Norway in the 1960s paved the way for the establishment of suburbs around Bergen followed by several discussions of alternative leading objects for transport in the city. For instance, in 1973, the city council discussed to introduce a rapid transit system inspired by the successful Oslo metro (opened in 1966) but they did not land on any decision (Meulman, 2000). Bjørn Gullachsen (then Communist Party member, later Left Socialist Party) advocated for a light rail option in the early 1970s and some first planning drafts for a light rail was introduced in this decade (see Vollset, 2007). However, these drafts met resistance from an emerging coalition

aiming to develop highways and bus infrastructure. A prominent actor here was Hordaland Road Department. They initiated the establishment of a toll ring around Bergen in the early 1980s to finance a massive investment in highways and got support from representatives from the municipality and politicians from the local Labour Party, the Conservative Party and the Christian Democratic Party (Lian, 2005: 66). This development was criticised by some local journalists, for instance Rødland (03.05.1993) who argued that this indicated a shift from focusing on public transport towards paving the way for an increase in private car use.

The next possibility for realizing a light rail in Bergen came with a decision from the Ministry of Environment to make Bergen a so-called prioritised environmental city ('Miljøby') in 1993 (Bergens Tidende Morgen, 1992). This status came with 10 million NOK (today approximately €1.6 million) dedicated to environmental projects in the city, in which a study of a city light rail would be a main priority. Articles published in the regional newspaper illustrate that there were disagreement on how to spend the money. There were in particular two coalitions with a different technological focus. One coalition, strongly represented by the bus company Bergen Sporvei AS (former tram company), was especially interested in investing in a new trolley bus system (electric bus system) arguing that trolley buses were a more viable alternative than a light rail system in terms of costs, time and environmental impact (Kristoffersen, 1992). The other coalition argued that a light rail was the most suitable alternative leading object for Bergen. This coalition consisted mainly of the professional planning community and actors from several local political parties, in particular the ruling local Labour Party. Labour Party Municipal Commissioner Anna Elisa Tryti (often referred to as one of the 'Bergen light rail mothers') emphasised that a light rail was highly necessary in order to develop a well-functioning transport system and also suitable considering Bergen's topography and demography (Lindebotten, 1992).

The light rail went through a study phase from 1993, but financial aspects caused conflicts between the political parties as well as Bergen's citizens. However, the light rail secured invest-

ment costs from the state, the county, the municipality and the toll ring when it became a project within the Bergen Programme for Transport established in 2000. Finally yet importantly, all local political parties in Bergen except the Progress Party and the Pensioners' Party voted in favour of the light rail alternative. In March 2000, the City Council decided to go for the construction of a light rail transit line between the city centre and the airport. The construction officially started in January 2008 and the Queen of Norway inaugurated the first line for passengers in June 2010. Even if this enactment was important in developing the light rail frame the further process was not easy according to a regional politician:

There was a never-ending debate regarding passenger capacity, and I used to say jokingly 'one more passenger and the light rail project will fall apart'. The [city's] politicians really did a good job avoiding this.

The quote points to how apparently settled technology projects still may need to be nurtured in order not to fall apart. In the next section, I will elaborate how the coalition supporting the light rail ('the light rail coalition') did this – or how they performed a light rail frame.

Performing a light rail frame in Bergen

The technological frames discussed in this paper reflect the focus on an alternative leading object; they are not statistical representations. A regional transport actor recounted in an interview that despite the introduction of the light rail in 2010 they still had to consider the existing bus system when planning public transport. Thus, the light rail coalition concurrently upgraded the bus system in 2010 because the light rail could not serve the transport needs of all inhabitants. In fact, 80% of all travels conducted by public transport in 2013/2014 were by bus and only 18% by the light rail (Bentzrød, 2018). Nevertheless, the light rail coalition used a representation of the light rail as the centrepiece of their public transport planning. In so doing, they had to construct a persuasive light rail frame to legitimise this technology's hegemonic role and make the project equally practical and symbolic. The light rail coalition

first pointed to topographical and demographical aspects and a regional transport actor made a comparison with Trondheim:

The short version of this story [the light rail initiative] is that Bergen has a linear city shape where the inhabitants are mainly concentrated in the Bergen valley, so it is easier to cover our transport needs with a light rail running through this valley. Trondheim, by contrast, does not have a concentrated population and a bus system is a better way to cover their transport needs.

Further, they stressed that the light rail was an inevitable choice due to Bergen's space scarcity:

It is impossible to travel through the Bergen valley by bus alone. We would need too many buses. There is not enough space and this was an important reason why we chose to build a light rail [regional politician in Bergen].

The light rail coalition emphasised the light rail's potential to help densify the settlement in Bergen because it would become attractive to live close to the line. In this regard, they framed the light rail as an efficient tool to reduce urban sprawl. Topography, demography and densification were all central aspects of their proposed city identity for Bergen in which a light rail was a very desirable element. In addition, they promoted the light rail itself as an identity marker for Bergen signifying a particular urban quality. For instance, the light rail coalition argued that other cities looked with great interest at Bergen's success with the light rail. Accordingly, they framed the light rail as a device that made Bergen appear as a modern and internationally oriented city and claimed that it strengthened the possibilities for Bergen to be included in international networks working towards increased urban sustainability.

Another important framing practice was the repetitive focus on the light rail's attractive components. A regional transport actor put it like this:

Inhabitants in Bergen are all familiar with the light rail and it has become a visible and important part of the city. People choose the light rail because it has frequent departures, it is very predictable and it is comfortable to use. People even prefer to use the

light rail during rush hours when it is very crowded instead of taking the bus, which runs close by.

The light rail coalition often used buses as a means to compare and demonstrate how attractive the light rail was. An architect involved in the light rail planning stressed that the light rail due to its attractiveness had changed the inhabitants' travel habits as well as their preferences of where to live and where to work – namely close to the light rail. However, the light rail was only in theory an option for everyone. In practice, its relevant social group consisted primarily of those living close to the lines and was less inclusive with respect to passengers living in the parts of the city not served by the system. Accordingly, the light rail as alternative leading object involved a more exclusive user configuration (Woolgar, 1990) than the bus system in Trondheim, which aimed at providing 'public transport for everybody'. The bus frame was exclusive with respect to other technological options since it did not allow for alternatives such as light rail or tramcars. The light rail frame was different by means that it needed to allow for the inclusion of other transport technologies – in this case buses.

The light rail coalition framed the light rail as a non-flexible system. This was overall preferred because it facilitated a long-term planning strategy. Quite the opposite of the bus system in Trondheim, the localisation of the rail gave clear guidance for future city planning and required extensive information about plans for the area under construction. Thus, the light rail raised controversies concerning the localisation of its lines. A proposal to construct a line crossing the cultural heritage site 'Bryggen' provoked significant political disunity in Bergen and even led the Commissioner for City Development to resign. Bryggen is a UNESCO heritage from year 1070 and is an important part of the identity of Bergen's inhabitants. The political disunity indicates a limitation of the light rail frame. While the need to construct a new line was acknowledged, the frame could not prevent the conflict that was generated by strong disagreement between and within the political parties. Still, the outcome confirmed the strength of the frame. The controversial plan to build in the Bryggen area was postponed in

favor of a less politically challenging route to the University hospital. The light rail frame remained effective in guiding transport planning. A regional politician stated:

A light rail is modern; it is a foresighted public transport system. I am absolutely sure that the number one job in public transport planning in Bergen will concern an extension of the light rail to all the city areas.

This indicates the success of the light rail coalition to embed the light rail as the alternative leading object of Bergen in the future. As with the bus frame in Trondheim, expectations concerning Bergen's future development were an important aspect as well as an effect of the light rail frame. In practice, buses would remain important but the light rail had achieved a symbolic hegemony with considerable consequences for the economic priorities of sustainable transport planning in Bergen.

In this section, I have pointed to how the choice of a light rail system as the alternative leading object in Bergen led to financial concerns and several public and political debates. Despite these issues, the light rail was promoted as in line with but also contributing to the symbolic identity of Bergen as a modern city, and recognised as successful by other cities by means of public transport planning. The light rail frame appeared as more exclusive than the bus frame due to its spatially selective user configuration – main users would live close to the lines. The frame was however less exclusive with respect to other transport alternatives because it needed buses as a complementary transport system. Still, the light rail was the alternative leading object because it attracted the most resources and attention, and because it represented ideas and expectations of an ideal public transport system in Bergen.

Conclusion: Shaping public transport systems through technological frames

In the introduction, I referred to Lefebvre's (1971) description of the car as the 'leading object' of present-day culture due to its outstanding ability to shape the physical structure and performance

of social life. This paper has demonstrated how two public transport systems, the (metro) bus in Trondheim and the light rail in Bergen, gradually have come to inhabit similar practical and symbolic properties as the car within a multi-modal transport system. As alternative leading objects, they contribute to shape the physical place in which they are part and they serve as symbols of a growing environmentally concerned urban planning practice. I was interested in how alternative leading objects were decided upon, what frames they become part of and the effects of these frames in particular urban contexts.

To investigate this, I drew on the concept of technological frames and explored what I called the bus frame in Trondheim and the light rail frame in Bergen. To study the framing processes, I introduced the concept of ‘framing coalition’ as an addition to Bijker’s theory of technological frames. A framing coalition is a set of actors that participate in the construction of a technological frame in a local, use-oriented context. As we saw, the framing coalitions in both cities developed similar problem definitions of urban mobility emphasising issues of topography, demography, space scarcity and local air pollution (especially in Bergen). Despite similar problems, both coalitions emphasised that Trondheim and Bergen represented different city identities and topographies. Trondheim was interpreted as a relatively small and circle-shaped city in which a bus system was suitable, while Bergen was seen as a rectilinear-shaped city in which a light rail was a better choice. Furthermore, this study has shown that the framing coalitions developed their reasoning of an alternative leading object simultaneously alongside an *interpretation* of their respective city identities – presently as well as preferred in the future. These interpretations guided the choice of alternative leading objects and laid the foundation for urban transport planning. Thus, the frames constrained the coalitions’ leeway to act in urban mobility planning.

The analysis in this paper has shown that the concept of technological frames may help us understand how ideas about a technology and its potential achievements may guide the development of urban public transport. Furthermore, the empirical observations demonstrate the impor-

tance of making identities and representations of public transport systems in particular urban contexts in order gradually to replace car-dominated transport into more sustainable mobility systems. I have also found the concept of technological frames useful for doing empirical comparisons of urban transport planning in different cities as called for by Hodson et al. (2017).

Still, I have observed the need for further development of the concept. First, I have pointed to the importance of the physical properties of the space in which a technological frame is unfolding. Both the bus frame and the light rail frame emerged from topographical considerations that had strong argumentative effects. Second, the analysis of technological frames needs to consider quantitative properties of the intended users like in the case of a growing population. Third, the stability of technological frames is always precarious. For example, the proposal of the metro bus in Trondheim led to the rekindling of the debate about and the suggestion of a reframing to include some light rail elements. Fourth, technological frames may need to be co-produced (Jasanoff, 2004) with a shared identity among the intended users. In particular, the light rail frame in Bergen became robust because it was made to resonate with the urban identity of Bergen’s inhabitants. Fifth, as already mentioned, I have added the concept of framing coalition to identify the framing efforts of actors engaged in the process. This does not replace a concern for relevant social groups as Bijker (1995) pursues, but it suggests that such groups may not always play a front-stage role.

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The Power of Place: How Local Engagement with Geological Disposal of Radioactive Waste Re-situated Technoscience and Re-assembled the Public

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Abstract

Intrigued by the role of geographical location in public engagement with science we examine the West Cumbria Managing Radioactive Waste Safely (MRWS) Partnership's undertaking of one of the most extensive local public engagements with environmental risk science in the UK. The case study highlights this three-year long local engagement as a process that changed both science and the public. Differently from other invited public engagements controlled by scientists in spaces set aside from the everyday, the Partnership's lay members led a process unfolding in the place that was potentially at risk. In contrast to public participation as experiments staged by experts the Partnership had the authority to demand that scientists addressed issues of local importance. The analysis uses the framing notions 're-situating technoscience' and 're-assembling the public', to capture how scientific knowledge claims were modified and a new local public emerged, at the intersection of public engagement with science and public participation in environmental risk governance in a specific place.

Keywords: public engagement, radioactive waste, place-making

Introduction

The discussion of public engagement with science and technology in STS has recently approached time and space in ways drawing attention to new issues. Case studies show how time limitations and spatial arrangements can prevent public influence on science and technology governance in engagement events arranged to facilitate it (Felt and Fochler, 2010). Standard time-space configurations of public engagement with science have been conceptualised as experiments,

highlighting that events are staged outside the realm of everyday experience and carefully controlled by scientists (Bogner, 2012; Laurent, 2016).

The spatial configuration of public engagement with science is also a dimension of environmental risk governance (Bulkeley and Mol, 2003). Case studies in this field show how scientists and technical experts retain control of events organised as rational debates, privileging formal

scientific representations of local environmental processes, risks and mitigation options (Aitken, 2009; Davies et al., 2011).

This paper brings these two discussions together to examine the role of geographical location in public engagement with science in the context of environmental risk governance. The analysis is developed in a case study of geological disposal of radioactive waste in the UK. Although geological disposal is the long-term solution preferred by most scientists, technical experts and policy makers, it has been politically impossible to site facilities in many countries (Shelley et al., 1988). After decades of public protest blocking the siting of geological disposal facilities in the 1990s many governments turned towards more collaborative approaches (Bergmans et al., 2015). The UK embarked on a new strategy of voluntary local involvement in the 2000s (Mackerron and Berkhout, 2009). The Managing Radioactive Waste Safely (MRWS) strategy, centred on local democratic decision-making, led to a public engagement programme in Cumbria (Chilvers, 2007).

The West Cumbria MRWS Partnership (the Partnership) was created to involve the local community and it undertook one of the most extensive public engagements with environmental risk science in the UK when examining the potential consequences of siting a facility for geological disposal of radioactive wastes in the area (West Cumbria MRWS Partnership, 2012). Underpinned by a formal delegation of decision-making power from national Government to local Councils, this organisation could summon scientists and technical experts to attend events conveniently located for members of the public. The Partnership also decided how much time the local public needed for their interrogation of the scientific case for geological disposal and to understand the potential consequences for the local community. The authority granted to this local, lay, organisation distinguishes the Partnership's work from engagement activities organised and led by scientists to address issues in science and technology policy, and from participation in environmental risk governance, in which scientists and experts decide where and for how long to interact with lay publics.

This difference is significant enough to warrant the introduction of two new terms – 're-situating technoscience' and 're-assembling the public' – to capture the dynamics of public engagement with science in a place at risk.

In the following we first overview literatures on time-space relationships in public engagement with science, technology and environmental risk, we finish this section with explaining the conceptual tools 're-situating technoscience' and 're-assembling the public'. Next, we outline the methodological approach and overview the materials analysed. After this we introduce the Partnership and undertake detailed discussion of the process of engagement it carried out and consider the changes brought about in the science and the public. In the concluding discussion we clarify the significance of the analysis of this case for the understanding of public engagement with environmental science generally.

Time and place in public engagement with science

The issue of how time and place shape public engagement with science and technology has been brought to light in discussions about the construction of participating publics. For example, examining the participatory governance of genetic testing Braun and Schultz (2010: 407) argue that public participation in science and technology governance has become "synonymous with discrete, formal, government-sponsored arrangement". They understand the temporal discreteness and the well-defined sites of 'invited' participation as the opposite of 'uninvited' participation which is diffuse in time and space. This difference between the time and place dynamics of invited and uninvited participation is further elaborated in Bogner's (2012) argument that public participation in technology policy function as laboratory experiments. He explains that invited participation experiments are "organised by professional participation specialists, taking place under controlled conditions and largely without reference to public controversies, political participation demands, or individual concerns" (Bogner, 2012: 510). The defining feature of participation as laboratory

experiment is the “isolation from political and life-world contexts, and its methodologically controlled design” (Bogner, 2012: 512).

Viewing public engagement with science and technology as laboratory experiment draws attention to the ways in which their spatio-temporal configurations are controlled by scientists and decision makers. Felt and Fochler (2010: 220) discuss how such public engagement experiments function as “political machineries” that “frame or pre-scribe particular kinds of roles and identities for the participating publics”. Their case study clarifies the relationship between the time allocated and the quality of the engagement, and they found that the overall duration of activities influenced the “degree of reflexive deliberation possible” (Felt and Fochler, 2010: 220).

Addressing the geographical location of engagement experiments specifically Felt et al. (2016: 7) argue that “[I]nsufficient attention is given to the importance of concrete ‘localities’, where knowledge is produced and distributed”. In their view “[P]laces always express the (power) relations of the people inhabiting them; they are open to some while difficult to access for others; they allow for engagement but also for distancing; and they spawn or restrain specific types of collective action” (Felt et al., 2016: 7). Understanding all localities as permeated with historically evolving culture they insist that “[I]n acknowledging place, we must also develop greater sensitivity to objects and scientific knowledge as carriers and expressions of certain cultural arrangements, values, and power constellations” (Felt et al., 2016: 7).

The critique of invited public participation, and its isolation from decision-making captured by the simile laboratory experiments, highlights the ways in which these activities are set apart from everyday activities and controlled by scientists and governments. Looking in a different direction Callon et al. (2009) focus on the uncontrolled space of the ‘wild’, where publics participate in processes with fuzzy time-space boundaries. To conceptualise this ‘uncertain world’ further the notion of ‘place-making’ suggested by Pierce et al. (2011) is useful. They argue, similarly to Felt et al. (2016), that localities in which people live are constituted in complex historical nature-culture

relationships. According to Pierce et al. (2011) places are continuously made through “social, political, and material processes by which people iteratively create and recreate the experienced geographies in which they live” (Pierce et al., 2011: 54). Informed by this notion we argue that scientists engaging with the world must recognise “the flexible, multi-scalar and always developing meanings of place; meanings that are produced via socially, politically and economically interconnected interactions among people, institutions and systems” (Pierce et al., 2011: 59). Environmental science that becomes involved with local risk governance has to engage with place-making.

Place-making involves many processes other than public engagement with science and technology. There are other politics of participation in operation. Of particular relevance to this paper is the right of affected publics to participate in local environmental risk governance, mandated in national and international environmental policy (French and Bayley, 2011). Critics note that such engagements often involve a bare minimum of consultation, arranged in ways that preserve the privilege of science-based experts who normally advise decision-making (Wesselink et al., 2011).

Despite the many barriers to lay people’s influence on science and expertise, in the context of environmental risk management, public engagement has the potential to change the knowledge produced and the way in which research is done. In some cases local public engagement have resulted in the co-production of new knowledge (Tsouvalis and Waterton, 2012).² The requirement to include publics in environmental decision-making has also prompted new scientific approaches, such as participatory modelling (Hare, 2011). Case studies show that publics can successfully engage science in place-making that address environmental risk, but that engagement activities “seeking to enhance citizen capacities need to be citizen-led, in terms of both the substantive content explored and the process deployed” (Selin et al., 2016: 6). Such engagement processes benefit from local residents’ “ability to reimagine local environments and chart a sense of responsibility for action”, and their interest to “act with regard to potential

futures, based on contemporary observations, buttressed by past experiences” (Selin et al., 2016:10). When science participates in local place-making it can support local publics and efforts to address local environmental problems (see Whatmore and Landström (2011) for a case study of re-distribution of expertise in flood risk management).

To increase the understanding of the involvement of science in place-making, and public engagement with science in the ‘wild’, we examine the work of the West Cumbria MRWS Partnership. In this case a local, lay organisation, had the authority to decide the time and place for activities that brought scientists and local publics together to consider the possible consequences of siting a facility for geological disposal of radioactive waste in the locality. This well-documented process enables examination of what long-term public engagement with science can mean for both science and the public when they are brought together in a place that is also the matter of concern.

The ability of the Partnership to demand that the technoscience³ experts answered the questions raised by local people in ways that satisfied the engagement process designed to build trust in the community brings to light themes not previously discussed in the literature. To address them we introduce two notions intended to capture distinct aspects of the changes brought about in this public engagement process. One – ‘re-situating technoscience’ – concerns the impact of local engagement on science, and the other – ‘re-assembling the public’ – addresses the transformation of ‘the public’ in a specific place. The two notions draw on well-known concepts introduced by Donna Haraway (1988) and Bruno Latour (2005), respectively.

‘Re-situating technoscience’ is a notion that allows us to consider the impacts engagement with publics can have on scientific and expert practices. It builds on Haraway’s notion of ‘situated knowledges’ that, among other things, insists that scientific knowledge is shaped by the context in which it is created (Haraway, 1988). The technical devices, scientific debates, social, political and economic relationships through which new scientific knowledge emerges imprint

it with a specific perspective. Since none of these circumstances can be general, or universal, all scientific knowledge originates in concrete discursive and historical locations that enable it to ‘discover’ some things while it cannot ‘see’ others.

We connect to Haraway’s notion as we try to capture the changes occurring in technoscience when it becomes involved with local place-making. That science and technology can change in encounters with local publics is demonstrated by the emergence of environmental participatory modelling (Whitman et al., 2015). This resonates with Cohen and Ottinger (2011) criticising the assumption in many studies of public participation that scientific knowledge is “relatively stable, its shortcomings predictable and enduring”, instead they urge us to realise that science is “flexible, contingent, and continuously under revision”, changing through interaction with publics (Cohen and Ottinger, 2011: 8). Re-situating technoscience is a notion that “directs attention to the ways in which scientific experts are prompted to do things differently when they become involved with local publics in environmental risk governance” (Landström et al., 2011).

The concept ‘re-assembling the public’ is inspired by Latour’s (2005) discussion of the constitution of particular publics in specific networks. Rejecting the idea of an always ‘already there’ general public, that provides a context for science and technology, Latour argues that publics emerge together with their matters of concern. The discussion of constituted publics has also highlighted how things, material and abstract, can bring new publics into being (Marres, 2012). In the present paper the notion re-assembling the public captures change, while paying attention to what has come before. It adds to the concept of place-making discussed above by also drawing attention to the past, indicating that there could already be publics relating to technoscience in a locality. Environmental risk management has been a societal activity since the 1960s, relying upon science and technology to address hazards (Beck, 1992). The governance of environmental risks has often sparked controversy, particularly when involving physical interventions in localities, processes constitutive of publics critical of technoscience (Wynne, 2014).

Public engagement with science in such places involves re-assembling the public, constituting a different public from those historically established in opposition to technoscience proposals relating to local environmental risks.

We insist that successful re-assembling of publics must originate locally. The institutions involved with previous failures cannot play a lead role (Whatmore and Landström, 2011). We also argue that re-assembling a local public takes time, as illustrated by Papazu's (2016) study of how the inhabitants of the Danish island of Samsø reconstructed the local economy around renewable energy. Confronted with a failure of national decision making to secure a future for the island to remain populated, a few local people developed a vision of a new energy future that could reinvigorate the local economy and secure the future of the island community. Working towards the new vision the local public was re-assembled, over time, in a way that enabled the development of new local expertise and the construction of new energy systems on the island.

The concepts of re-situating technoscience and re-assembling the public highlight two distinct (possible) effects of local public engagement – changing science and changing the public – both occurring in the process of place-making. Both notions are prefixed 're-', to indicate the importance of time. We are interested in how long-term engagement with science in specific localities with the local public impacts on both parties.

Historical interpretation of the recent past

Considering that the issue of geological disposal remains unresolved and controversial in the UK, we decided to rely on documentation of the activities of the West Cumbria MRWS Partnership produced at the time, by the actors involved.⁴ This approach differs from more common social science use of archival materials as complementary (Welch, 2000), but we wanted to study the recent past as the past, not primarily as a backdrop for the present.

The actors involved with the MRWS policy and the Partnership generated extensive docu-

mentation, made publicly available in on-line repositories that were created at the time to provide the local public access to the process and today preserved as historical record. That we could 'follow the actors' through digital archives dedicated to the MRWS process saved us from having to devise on-line search strategies to locate widely dispersed documents (Huistra and Mellink, 2016). The key electronic archive for this study was created by the West Cumbria MRWS Partnership at the time as part of the commitment to transparency, it is left for posterity and public access at <http://www.westcumbriamrws.org.uk/>. This archive holds all electronic documents relevant to the work of the Partnership and the documents produced by other actors involved with the MRWS process in west Cumbria. Materials from the Nuclear Decommissioning Authority and the Committee on Radioactive Waste Management are of particular interest to the present paper.⁵

The electronically stored documentary materials in the archive comprise policy documents, reports, meeting records, news publications, letters, information leaflets and more. We subjected these documents to qualitative interpretation. Informed by critical hermeneutics as developed by historians, we read the texts from the archive as traces of past actions (Ricoeur, 1973). Tamboukou (2014: 618) explains that when using this interpretive approach "the researcher's questions, interpretations, theoretical insights and analytical tropes emerge as intra-actions between space/time/matter relations and forces within the archive".

In addition to the study of archived documents, the case study was informed by the extensive academic literature on radioactive waste management in different national contexts, published from the 1980s to the present. The disposal of radioactive waste has been controversial since such waste was first produced and the issue has prompted a rich social science literature that we use to contextualise the discussions reported in the archived documents. Adding to the understanding of context and process was the experience of one of the authors of being a member of the MRWS partnership, thus having access to more detailed information about the local context

referred to, but not explained, in the primary documents.⁶

Managing Radioactive Waste Safely: the UK policy for geological disposal 2009-2014

The West Cumbria MRWS Partnership, in operation from 2009 to 2012, came into existence through a Government strategy initiated in 2001 and articulated in a 2008 White Paper. The White Paper was based on the 2006 report of the Committee on Radioactive Waste Management (CoRWM), set up in 2003 to advise the Government on the long-term management of higher activity radioactive waste in the UK.

The MRWS strategy can be understood as part of a wider international trend to involve local actors, such as elected councils, businesses and publics, with environmental risk governance. The notion of governance indicates a shift from top-down government driving decision-making and implementation, to multi-sited, multi-level networks (Meadowcroft, 2002). Processes referred to as governance have been defined as “a continuum of systems governing, in which state and non-state actors play a variety of roles” (Bulkeley, 2005: 877). The new, less top-down, environmental risk governance offered the UK government the opportunity to try a different approach after decades of failure to implement geological disposal of higher activity radioactive wastes. The policy reorientation was designed by CoRWM, in a comprehensive review (CoRWM, 2009).

Setting an example for involving a broader range of actors CoRWM's own work included public engagement as laboratory experiments (Bogner, 2012). They organised several events to which lay people were invited to deliberate on the challenges of radioactive waste (Burgess et al., 2007). CoRWM's approach to public engagement slowed down the reasoning in a way that is necessary for public engagement to have effect according to Felt and Fochler (2010). Slowing down reasoning in extensive public engagement has become a feature of radioactive waste programmes internationally in recent decades, by necessity as in the Swedish

KBS process (Sundqvist and Elam, 2010) or by choice in the case of the Canadian Nuclear Waste Management Organisation (NWMO, 2005). Following extensive public engagement and analysis of scientific and technical knowledge CoRWM produced a final report that provided the foundation for the MRWS strategy, emphasising voluntary local participation, transparency and self-determination (Chilvers, 2007).

Adopted in several countries in the 1990s and 2000s so called ‘voluntaristic’ siting policies for geological disposal of radioactive wastes have been subjected to social science scrutiny (Blowers and Sundqvist, 2010; Durant and Fuji Johnson, 2009). Some critics argue that voluntarism is another attempt to manipulate the public (Fuji Johnson, 2009). Others point out that the scientific belief (not tested in practice) that geological disposal will actually provide safety over the very long term has not been opened up to challenge in public deliberations (Durant and Stanley, 2009). It has also been argued that the invitation to the public to participate is a purely instrumental move to deal with the failure to site geological disposal facilities (Blowers, 2010).

The voluntaristic process in the UK started with the White Paper, published by the UK Government in 2008, extending an invitation to local authorities, as representatives of communities, to submit Expressions of Interest (Eoi) to take part in the MRWS process and explore the possibility of siting a geological disposal facility (Defra et al., 2008). Cumbria County Council, Copeland Borough Council and Allerdale Borough Council separately submitted such Eois. Moving to coordinate their actions the three councils formed a joint body in 2009 – the West Cumbria MRWS Partnership – to examine the implications of hosting a Geological Disposal Facility (GDF) in the area and to engage with local publics.

Historically entwined – geological disposal of radioactive waste and west Cumbria

Radioactive waste has been part of the history of west Cumbria for a generation and the local memory of controversies about GDF siting did influence local publics' views on the MRWS

strategy, regardless of the UK government presenting it as new and voluntary (Bickerstaff, 2012; Blowers, 2017). It was the controversy erupting around the previous GD programme that prompted the policy rethink resulting in the MRWS strategy. Against this backdrop it was critical for the Partnership to work in a way that engendered trust and legitimacy. However, it was not a neutral conduit. By not accepting the outcome of previous controversy as having settled the issue, the Partnership demonstrated an ambition to intervene in this aspect of local place-making, albeit not pushing for any particular decision.

The Partnership drew on CoRWM's way of working, they scrutinised expert knowledge claims and deliberated with publics. Like CoRWM, the Partnership used social science-based expertise to undertake a variety of public engagement activities. The consultant firm, 3KQ⁷, was the lead, guaranteeing that the local programme was expertly devised, managed and documented (PSE Sub-group, 2009). Differently from CoRWM the Partnership members were lay people with regard to the technoscience specialisms involved, but they had the mandate to question scientists and technical experts until they were satisfied with the answers. The many Partnership activities brought experts and local residents together in a concerted effort to make scientific knowledge about geological disposal of radioactive waste in principle address questions about what was likely to occur in the specific locality, should a GDF be sited there.

The Partnership arranged events, talked to people and communicated in different media, in a process that went on for three years. Their work programme aimed, on the one hand, to examine existing technoscientific knowledge. This meant learning about geological disposal (GD) and about what scientific experts knew of the potential impacts on the locality of constructing and operating a disposal facility, as well as about long-term safety. Whilst on the other hand, also find out what local residents thought about participating in the siting process and of the possibility of such a process leading to a proposal for constructing a repository in their area. While integrated in the actual process these two activities were reported as separate

streams, which corresponds with our interest in illuminating the two distinct aspects of change – in technoscience and the local public. In the next section we focus on how technoscience was re-situated with regard to two specific questions – inventory and geology.

Re-situating technoscience in west Cumbria

To examine technoscientific knowledge about GD the Partnership devised a systematic investigation process with sections focussing upon, in turn: the inventory; geology; design and engineering, and safety, security, environment and planning (West Cumbria MRWS Partnership, 2012). The inventory and the geology are both complex issues, historically embroiled in controversy and particularly interesting for the present study as they concern core scientific knowledge about the issues.

The inventory is a key feature of a GDF because it describes the type and amount of radioactive waste that is to be disposed of. It has potential for controversy when linked to the building of new nuclear power plants because types and volumes of wastes would then remain open-ended (Blowers, 2010). However, the MRWS strategy explicitly excluded discussion of future waste from new nuclear power stations, limiting investigation to existing waste and projected waste from existing operations.

Examining the inventory the Partnership asked the technoscience experts: "(i) what might go into a facility; (ii) what level of influence the community would have over changes, e.g. increases or decreases in the amount or kinds of waste, and (iii) principles for how the inventory might be changed" (West Cumbria MRWS Partnership, 2012: 68). Given the legal requirement to keep close tabs on radioactive waste we would expect that the experts had the answers to these questions readily at hand, but that was not always the case.

The Partnership's eleventh meeting in August 2010, with 37 attendees (including thirteen observing members of the public), aimed to 'develop an understanding of the inventory, the process for altering it and how the community might influence it' (3KQ, 2010: 3). At the meeting the technoscientific experts from the Nuclear

Decommissioning Authority (NDA), and the Department for Energy and Climate Change (DECC), the government branch responsible at the time, did a joint presentation and an independent expert addressed the issue from a different perspective. The session brought to light several uncertainties and the meeting report explains that:

Clarification was sought regarding the percentage of waste that is currently held at Sellafield⁸. The responses that were given made it apparent that there is no clear figure because it depends on what wastes are included, and how they are calculated/measured (e.g. by volume or activity). Concerns were raised that the Partnership has been operating to date on the basis that around 70% of existing waste that is earmarked for geological disposal is already held in West Cumbria. The Partnership asked for this to be confirmed or clarified as a matter of urgency. The NDA agreed that they would confirm the proportions currently held at Sellafield by volume, activity and types of waste. (3KQ, 2010: 19)

The NDA (2010) produced a technical note responding to the Partnership's questions in November 2010. That it took nearly three months to provide seemingly basic information about the existing radioactive waste shows that NDA and DECC were unprepared to engage with issues of concern to the local community. Standard technoscientific representation of radioactive waste treated the UK as a whole, reflecting requirements to report to national government and international oversight agencies. Information about the geographical distribution of the waste was not readily available even though CoRWM (2006) had explained that questions about where waste was stored would need to be answered when engaging with local communities. Still, it was not until actually encountering local residents – who knew that waste was stored in a facility in the area and requested more exact detail – that the experts could be convinced to address the issue. We understand this encounter as re-situating technoscience to include geographical specificity in the waste inventory.

The geology of west Cumbria was an issue of historical contention that could have sparked

public controversy. The MRWS process started with a geological unsuitability screening by the British Geological Survey (BGS), and they submitted a draft report to the Partnership for review in June 2010 and a revised, final report in September (Steering group, 2010; BGS, 2010). The Partnership had commissioned two technical expert reviews of the draft and held a meeting to discuss the draft and the reviews (Walker, 2010). The commissioned experts questioned some of the BGS's representations of distinctions between different elements (e.g. fresh water versus brine aquifers and the explicit inclusion of shale gas in 'oil and gas resources'). Partnership members raised questions that brought the societal context into the discussion, asking for example for a "plain English summary version" (Walker, 2010: 2-3) as they found the text difficult to understand. Another request concerned the provenance of the geological knowledge claims, as there was a need to be "clear about the Nirex⁹ information and how it has been dealt with" (Walker, 2010: 2-3). Local residents referred to the past controversy wondering about the links to the failed siting process by Nirex and the Partnership emphasised the need to make sure that the use of knowledge produced in that process was transparent. The BGS map was also found to be insufficiently clear as "the partial exclusion zone is going to be difficult to explain to the public" (Walker, 2010: 2-3). Partnership members found that "there is a danger that this map will be reproduced by journalists in a simpler format showing areas 'in' and 'out' which may lead to misconceptions that we are in the site selection stage, and also misinterpretations if they don't summarise it accurately" (Walker, 2010: 2-3).

In the examination of the geology the Partnership demonstrated an acute awareness of the local history of controversy over the siting of a GDF. In contrast the BGS again appears unprepared to engage with lay people in this place with its unique history regarding this issue. The technoscience experts lacked linguistic and visual vocabularies to communicate with audiences who did not share their disciplinary background. The BGS revised their report and brought it back to the Partnership for discussion at a meeting in November 2010 (Willis, 2010). The overall conclusion was that knowledge about the geology was limited at the

time, but that not all of west Cumbria had been proved unsuitable. The Partnership would decide whether they agreed that there was sufficient volume of rock within west Cumbria that could potentially be found suitable to enable further participation in the MRWS process, subject to satisfaction with other outcomes in other strands of inquiry, public consultation and local authority decisions. The BGS had managed to re-situate their knowledge claims in a way that allowed them to represent claims about the local geology in a manner comprehensible to local residents and sensitive to historical context. However, this was not the end of the matter.

The examination of the knowledge about the geology in west Cumbria was reported in the Partnership's regular newsletter. They presented a report of the BGS unsuitability screening opposite an account of the view of Dr David Smythe, that all of west Cumbria had been found unsuitable in the 1990s (West Cumbria MRWS Partnership, 2011). Now retired, Smythe had been deeply involved in the earlier controversy that ended with the rejection of Nirex's application for planning permission for a Rock Characterisation Facility, the first stage in GD (Smythe, 2011). Smythe's claim prompted CoRWM¹⁰ to write a letter to the Partnership highlighting the uncertainty of knowledge about the suitability or unsuitability of most of west Cumbria's geology (CoRWM, 2011). Alerted to the issue NDA held an informal meeting at their offices in Oxfordshire, with a former planning inspector who had worked with the Nirex inquiry in the 1990s, to clarify the knowledge about the geology of west Cumbria (NDA, 2011). Two experts from the Nirex inquiry also presented at a meeting with the Partnership Steering Group to clarify the implications of the knowledge generated by the former inquiry (3KQ, 2012). The opposing views on the potential suitability of the west Cumbria geology were discussed at a seminar on the 20th June 2011, arranged by the Partnership and attended by 100 people (3KQ: 2011). An independent expert commissioned by the Partnership to scrutinise the BGS report, presented a critique of Smythe's claims (Dearlove 2011). This critique was challenged by a letter from Smythe's former collaborator Stuart Haszeldine (2012).

This episode illustrates how the past can be brought into the present in a place-making process that involves long-standing matters of concern. Geological disposal has a long and contentious history in west Cumbria, and while national government and technoscience experts can regard past controversy over the issue as closed this is not the case in the local community. Past controversy over the siting of a GDF in a locality can be re-opened in response to new developments of the unresolved issue of radioactive waste disposal (Bickerstaff, 2012). However, in this case the disagreement did not escalate into public controversy. A Partnership meeting on June 23, after the public seminar, concluded that it was not possible to reach agreement on the question of geology and that the 'PSE Sub-Group should discuss the options further and come up with a recommendation for the way forward' (3KQ, 2011a). Thus disagreement was contained without being forcefully closed down, or allowed to disrupt the Partnership's programme.

As demonstrated by these two examples, the Partnership's critical scrutiny of technoscientific knowledge about GD impacted on the experts because it concerned the circumstances at hand in the locality. Engaging with the specific place challenged the technoscience experts to explain how their knowledge applied there and address the questions the Partnership considered important, not the questions the scientists viewed as relevant. The dispute over geology demonstrates the authority of the Partnership. Instead of allowing scientists with opposing views to lead the process into public controversy the issue was moved to a sub-forum where the experts could continue to disagree in the absence of new evidence.

Re-assembling local publics

The events arranged by the Partnership to examine the scientific and technical knowledge about GD were undertaken within the same overall local engagement process as a series of activities aiming to find out about how local publics viewed whether the councils should participate in the search for a GDF site. These activities were components in a Public and Stakeholder Engagement (PSE) programme with three 'rounds'

addressing all aspects of GD, underpinned by the principle “that it was important not to engage with people for the sake of engaging, or as a ‘tick box’ exercise” (West Cumbria MRWS Partnership, 2012: 43). Organising a wide range of face-to-face engagement activities the Partnership’s PSE programme differed significantly from the one-off events common to public participation in science and environmental management (Felt and Fochler, 2010; French and Bayley, 2011; Newig et al., 2016). The Partnership commissioned expert consultants to conduct different activities, using both qualitative and quantitative social science methods, as well as deliberative techniques. The PSE programme was comprehensively recorded, with reports presenting and summarising each stage, each activity and each meeting. Because communication of the Partnership’s work was an integral part of PSE, some of the archived materials, such as the newsletter discussed in the previous section, provided a running commentary at the time.

The first round of engagement – PSE1 – running from November 2009 to March 2010, had among its key objectives to “Build the understanding of stakeholder organisations and the public” and to “Seek input from stakeholder organisations on the Partnership’s work programme, Terms of Reference, Criteria and PSE Plan” (West Cumbria MRWS Partnership, 2010: 5). In posing this question the Partnership took a similar path to the NWMO (Nuclear Waste Management Organization) in Canada that was tasked with formulating a new policy (NWMO, 2005). However, the NWMO asked a national public about the principal issue of how to approach nuclear waste disposal, in contrast the Partnership asked the local communities about their views on undertaking a GDF siting process in their area. That this fundamental question was posed sets this engagement process apart from the type of events described in the literature, that invites a representative sample of the general public to participate in deliberative experiments controlled by scientists and experts (Bogner, 2012; Braun and Schultz, 2010; Felt and Fochler 2010).

Another PSE activity shows the Partnership visiting already established local public spaces to give presentations to Neighbourhood Forums (NF). In these evening meetings Partnership

members gave a standardised slide presentation that explained GD, the role of the Partnership and the PSE programme. Representatives from NDA, CoRWM and the Environment Agency for England and Wales (EA)¹¹ also attended many NFs. In total over 500 local residents attended these events (3KQ, 2010b). Presenting at NFs would in Callon et al’s (2009) terminology amount to going into the ‘wild’, we view it as scientists and experts involving with place-making.

Quotes in the NF minutes show the range of views expressed by members of the local community. For example, there was suspicion of the government’s commitment to voluntarism: “You’ve read and you’ll know section 6.5 of the (MRWS) White Paper; it says if an agreement can’t be reached Government will do whatever they think is necessary” (3KQ, 2010b: 9). Questions were raised about the process: “Who will make a decision on behalf of the community?” (3KQ, 2010b: 10) and about the current situation: “70% of the country’s waste is already stored at Sellafield – how long can it continue to be stored there until space runs out?” (3KQ, 2010b: 14). Memories of previous attempts to site a facility in the area lingered: “We went through surveys years ago; I don’t know the exact findings but there were flaws. That was 15 years ago. This area was identified as a potential site; it was not suitable so is this now the political place to put the waste?” (3KQ, 2010b: 11). There were also voices in support for siting a facility in the locality: “I haven’t got a problem with it to be honest. Sellafield do a good job. West Cumbrians know what they’re doing and we’ve all pulled together to make it work. I do think Sellafield has been managed really really well. I’d hate to see what West Cumbria would be like without Sellafield. I would like to see one stipulation to be that a lot/the majority of jobs go to local people?” (3KQ, 2010b: 13).

The different views among local people attending NF meetings show that there was not one united public in the locality. In addition to the diversity of publics showing in the Partnership’s accounts there was a historically established public opposed to GD that did not get involved. Local campaigners – including some environmental NGOs rejecting GD in principle – declined invitations to formally engage with the Partner-

ship (West Cumbria MRWS Partnership, 2010). This can be understood as a rejection of the Partnership's rationale of opening up the question that opponents of GD regarded as closed.

Sensitivity to the diversity of local publics is visible in the quantitative attitude surveys conducted by the polling organisation Ipsos Mori that complemented face-to-face activities. The first survey, carried out in November 2009, covered what in any other context would have been described as a representative sample of the population in Copeland and Allerdale. However, reminding us of how contentious the issue of determining the community's views was, the report cautions that: "It should be remembered at all times that a sample and not the entire population of Cumbria residents took part in the survey. Consequently, all results are subject to sampling tolerances, which means that not all differences are statistically significant" (Ipsos Mori, 2010: 11). Ipsos Mori found that 82% of the people surveyed thought that GD was the best option for higher activity wastes. 52% knew that the Partnership was talking to government about possibly looking for a site in West Cumbria and 50% were in favour of this. 47% were positive about siting a GDF in West Cumbria while 26% were opposed.

Concluding PSE1 the Partnership found that challenges had been brought to light, two of particular interest to this paper. The first was the insight that people in the locality had not forgotten the bad experience with Nirex (this was particularly important in relation to the debate about the local geology as noted above). The second finding was about the need to clarify decision making. It was considered critical to make clear who would be mandated to decide about what, and when. This points to a general problem with the shift from government to governance, with more actors getting involved in decision-making, responsibility and accountability can become unclear (Swyngedouw, 2014). This also resonates with the difference of this process from participation as experiment (Bogner, 2012) where the objective is to gauge public opinion on a set question without considering wider issues, such as future decision-making processes.

The second PSE round (PSE2), running from November 2010 to February 2011, focused on

enhancing public awareness. Although it would be possible to argue that a majority of the people surveyed supported the work of the Partnership and even the siting of a GD facility in the area, it was not clear how people understood the issue. The Ipsos Mori survey had found that only 27% of respondents knew that the government was looking for a community to volunteer to host a GDF and only 20% were aware that talking to the government did not mean committing to host a repository. Featured in the Partnership's newsletter (West Cumbria MRWS Partnership, 2010a) these figures indicated that public understanding was limited, implying that the support for GD expressed in the survey may not be stable and that views could change in response to any argument, correct or incorrect, relevant or not.

Again a wide range of local activities were organised, for example, 10 one-day events organised by 3KQ, the consultant firm commissioned by the Partnership to facilitate the process and support it throughout. Each such one-day event had four main elements: i) an explanatory exhibition; ii) specialists from DECC, NDA, BGS and the EA responding to questions from the attendees; iii) presentations with discussion and iv) written interaction that made it possible to record views and ideas expressed for further consideration (3KQ, 2010c). Another face-to-face format was Stakeholder Organisations Workshops with objectives including "to demonstrate how public input to date has led to real changes" (3KQ, 2011b: 3). A third interactive method, Residents' Panels, organised by consultants Vision Twentyone in February 2011, had aims including to "establish what would give local people confidence that The Partnership presents information in an open and transparent manner" (Vision Twentyone, 2011: 2). The question of what it would take for local people to trust the Partnership matters for how local community support for the Partnership's recommendations could be assessed and how much support is needed for a recommendation to be made.¹² The second opinion survey by Ipsos Mori showed that although awareness had increased, confidence in the Partnership was unchanged, but support for locating a GDF in West Cumbria had slightly decreased (Ipsos Mori, 2010a).

In the process of re-assembling the public PSE2 stabilised a local public, by ensuring that people were well informed and confident to voice consistent views on the issues. PSE1 had shown that while there was potential for a public that would be positive to the locality taking part in a siting process, this attitude was not necessarily based in a clear understanding of the issue, the process or the potential local consequences. Educating the local residents could facilitate the emergence of a potentially self-aware public constituted through a specific matter of concern (cf. Callon et al., 2009).

In PSE3 the re-assembling of the local public was tested in formal public consultation. A draft of the Partnership's final report was published and discussed in a variety of forums ranging from group deliberations, to written submissions from individual members of the public and a third survey by Ipsos Mori. Gauging people's views on whether the three councils should opt to participate in the search for a GD site the survey found that:

In Copeland, 68% thought the search should continue, and this was significantly higher than both Allerdale (51%) and the rest of Cumbria (50%). Conversely, the proportion in Copeland who thought that the search should not go ahead was lower than in the other areas (23% vs 37% in Allerdale and 35% in the rest of Cumbria). (West Cumbria MRWS Partnership, 2012a: 151)

Controversy about these findings threatened when a local resident submitted a critical letter that questioned the statistical representativity and the sampling methods. Ipsos Mori (2011) answered this letter in detail. The cautious language used in the survey and reports indicate the importance of transparency regarding how the local community's views were identified, interpreted and represented. It was made clear that it would always be impossible to achieve consensus on a community-wide scale.

Operationalising the White Paper's requirement of a 'credible' level of support in a local community deciding to participate in the MRWS process the Partnership used the notion of 'net support', enabling the process to progress when favourable survey responses outweighed the unfavour-

able. The Partnership were not trying to construct a singular opinion supporting a siting process in the area that would replace the historically established local public opposing GD, but to find out if local residents, who were not already committed to opposition, could be in favour of a decision to participate in such a process. In the end, the views remained diverse even within the Partnership itself:

Overall, most Partnership members are satisfied that the opinions and advice given in our Final Report reflect the public and stakeholder views we have received. However, some members feel this is not the case on some topics and this has been noted in the relevant chapters. (West Cumbria MRWS Partnership, 2012: 10)

The divergence of views noted in this quote is discussed in detail in the sections of the report addressing the topics on which consensus did not arise.

The long-term engagement with local residents undertaken by the Partnership did not invent new public engagement methods, but combined established techniques iteratively in a programme that also made the local community visible to itself via the on-going publication of activities and findings. At the end of the Partnership's work programme the visible public in west Cumbria was not the same in terms of knowledge and views as it was before it commenced. Although opposition to siting a repository in the area remained, the local public had re-assembled in a way where those in favour of exploring the possibility of participating in a siting process had become visible.

Concluding discussion

This paper has highlighted the role of place, in the sense of geographical location, for public engagement with scientific expertise in relation to environmental risk. We introduced the notions of re-situating technoscience and re-assembling the public to discuss two aspects of the West Cumbria MRWS Partnership's three-year examination of the possibility of participating in siting a facility for geological disposal of radioactive waste. We argued that this involved technoscience in local place-making, in a way not discussed in the

literature. Previous research has critiqued invited participation for leaving scientific ways of working unchanged (Felt and Fochler, 2011; Laurent, 2016). In contrast, uninvited participation has been found to prompt changes in research practice through public controversy (Wynne, 1996; Callon et al., 2009; Cohen and Ottinger, 2011). The analysis of the Partnership adds nuance to the binary of invited and uninvited participation.

Focussing, first, on re-situating technoscience the case study showed that the local history of public controversy over geological disposal prompted critical debate about issues usually defined as 'technical'. This time public controversy did not ensue, instead technoscience experts changed to accommodate interaction about local matters of concern. We contend that this pivoted on the Partnership's authority to demand that scientific experts engaged with the issues that mattered to the local community and communicated in ways that could be understood by non-scientists. When scientists disagreed about issues beyond the empirical evidence they were relegated to the margin of the engagement process. Technoscience was re-situated, from reflecting scientific practice, discourse and interests, to taking the place at risk, with its unique history, seriously. The re-situated knowledge claims were continuous with existing technoscience knowledge, but articulated with consideration to the specific place-making dynamics of west Cumbria.

Previous research has highlighted the ways in which public engagement with science and expertise is usually set apart from everyday life and local concerns, captured in the simile made with laboratory experiments (Bogner, 2010). In contrast, Partnership members brought science and technical experts to the places people visit every day – schools, village halls, libraries – to find out about community members' views. The understanding of the local community gained in face-to-face interaction was supplemented, not displaced, by social science methods adapted for the specific local programme by experts on public engagement (Chilvers, 2013).

Focussing on re-assembling the public brought to light how the long-term engagement process

changed 'the local public'. The Partnership worked in a place where historical controversies had constituted a public opposed to exploration for siting a GDF. To simply gauge this public's views would immediately have excluded further involvement with the MRWS process. Instead, the Partnership addressed people who might not otherwise have had time to get involved, or who did not believe that their views would matter. Opponents of a GDF in the area did not disappear, but other viewpoints emerged. Adding to the understanding of constituted publics the analysis recognises local history and specificity, insisting on there already being publics in places where concerns about environmental risk arise. This aspect of public engagement may be specific for environmental risk governance in which place matters in a different way than in many other processes involving technoscience futures.

The concepts re-situating technoscience and re-assembling the public were used to analyse different aspects of the same process. One targets change in the conduct of scientists and technical experts, the other illuminates change in the local social order. The case study demonstrated how these concepts can facilitate examination of the relationship between science and publics in environmental risk governance. Often public engagement with science and technology in this area follow the format of experiments controlled by experts (Felt et al., 2016), but this case shows that democratic delegation enabling local communities to lead is possible. This issue deserves more STS attention, as current trends in environmental policy involve delegation of risk management to local authorities who have to reconcile science-based expert knowledge with local public engagement.

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Notes

- 1 Former Executive Co-director, Nuclear Legacy Advisory Forum (NuLEAF)
- 2 'Co-production' is here used with reference to the discussion of lay people in scientific research by Callon (1999).
- 3 In this case we use the term 'technoscience' because the scientific experts involved in the process were presenting knowledge claims regarding an imagined technical construct and its possible impacts on the environment. The science involved produced knowledge about a technology.
- 4 In this study we do not inquire about the activities of opponents of geological disposal, as such or in the locality, because there are numerous, incisive academic studies of anti-geological disposal activism in the UK and elsewhere, see for example Blowers (2017).
- 5 The other organisations involved in the MRWS process maintained their own websites in that period, but have now removed them or changed their content. The version of CoRWM discussed in this paper has left a faint trail at http://webarchive.nationalarchives.gov.uk/*/http://www.corwm.org.uk/. Some of the documents published by NDA in the MRWS process can be accessed from <https://www.gov.uk/government/organisations/nuclear-decommissioning-authority>.
- 6 The co-author's work with the Partnership was not social science related and the Partnership completed its work before the research on which this paper is based commenced.
- 7 Chilvers (2013) discusses how social science methodological innovations for public engagement are taken up by expert consultants and provided on a commercial basis. The archive testifies to the critical role of 3QK in facilitating the Partnership's work. In addition to organising events, identify technical experts and make sure information flowed among the people involved, they also documented every detail of the programme.
- 8 Sellafield in west Cumbria is a nuclear fuel management and decommissioning site owned by the NDA, most of the higher activity waste from nuclear power production in the UK is currently stored in this facility operated by Sellafield Ltd.
- 9 Nirex was a body set up by the UK nuclear industry in 1982 to examine geological disposal, it became embroiled in a major public controversy in west Cumbria.
- 10 After the launch of the MRWS strategy CoRWM was re-formed to provide independent advice to government and scrutiny of the MRWS process.
- 11 The EA was at the time lead regulatory authority with regard to GD in England and Wales.
- 12 It is to be noted that after extensive consideration the Partnership decided against making recommendations and chose instead to present *findings*.

Comparing Forms and Degrees of Critique: Ontologies of Vaccine Criticism

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Abstract

This paper presents an analytical tool: a coding scheme designed to evaluate the degree and type of divergence between a dominant orthodox discourse and the discourse of heterodox actors who criticize this dominant position. The author draws inspiration from Boltanski's (2011) conception of critique and analytical sociologists' decomposition of social reality to shed light on actors' ontology. By summarizing the differences between orthodox and heterodox accounts of reality in simple tables, this method makes it possible to compare the discourses of a wide variety of actors. To show the heuristic nature of this tool, the author uses it to analyse the controversy that emerged in France in 2009-2010 over the safety of the pandemic flu vaccine. The author presents the social and medical ontologies on which these various critiques were grounded and their varying degrees of radicalism.

Keywords: vaccination, qualitative methods, controversies, critique

Introduction

Today, with the Internet, rumours and conspiracy theories regarding technology and risk are the object of much public attention. With just a couple of clicks, anyone can find pamphlets detailing how the government spreads chemical trails in the air, microchips through the water and poison via vaccines. The most exotic ones get shared like funny jokes via social networks, mailing lists and conversations around the coffee machine. They are discussed in detail in media pieces to illustrate the purported contemporary crisis of trust in Science and pervasive lack of political literacy (Harambam and Aupers, 2015). Public authorities and manufacturers draw on them to delegitimize more legitimate forms of critique by equating them with these symbols of the irrationality of the

public. In an opposite move, anthropologists have underlined their crucial social significance. They have shown that rumours and conspiracy theories are both products of and responses to the fundamental tensions that exist in any given society, and in capitalist and globalized ones in particular (Atlani-Duault and Kendall, 2009; West and Sanders, 2003). Conspiracy theories constitute a specific political repertoire that enables people who lack social resources to voice their discontent with a social and economic system that leaves them politically powerless (Fassin, 2011; Harambam and Aupers, 2015; Atlani-Duault et al., 2015).

But, for researchers interested in socio-technical controversies, the categories of 'rumour' and 'conspiracy theory' are problematic in themselves.

We cannot help but notice that not all actors who produce discourse on genetically modified organisms, nuclear waste or vaccination comply with legitimate forms of political and scientific argumentation. This must be taken into account to understand their position in these controversies. At the same time, the question of when critique becomes labelled as a conspiracy theory or a rumour constitutes an object of empirical enquiry rather than of theoretical debate. These labels and labelling practices point to two crucial issues 1) Under what practical and symbolic conditions may discourses that deviate from a norm or an orthodox position emerge? 2) What are the practices that maintain some cultural repertoires at the margins of a given society?

This paper contributes to this research agenda in two ways.

Firstly, I propose an analytical tool which helps to evaluate, on a given subject, the degree and type of divergence between a dominant discourse and that of heterodox actors who criticize this orthodoxy. This tool can be described as a method for content analysis which consists in breaking down the natural and social ontologies in which these discourses are grounded. Ontologies constitute a point of entry into the way actors involved in sociotechnical controversies build their trajectory (for a review, see van Heur et al., 2013). Accurate analysis of these ontologies is a crucial step in the process of shedding light on such controversies. Social scientists have built a wide variety of typologies designed to analyse the multiple discourses dedicated to a given subject. However, most of them are specifically tailored for a circumscribed subject and very few can be adapted to other contentious subjects (for an exception, see Douglas and Wildavsky, 1983). Most researchers have to resort to building their own typology when they approach a new research object. The lack of such tools discourages attempts at systematic comparison. The coding scheme presented here helps to underline the degree of 'radicalism' of critiques addressed to a dominant discourse on a controversial subject. Also, by summarizing the different positions held by critical actors in simple tables, it facilitates comparisons of the discourses of a great variety of actors.

Applying this analytical tool to the subject of vaccine criticism constitutes the second contribution of this paper and a demonstration of the heuristic power of this coding scheme. I will focus on the controversy that emerged in France in 2009-2010 on the safety of the pandemic flu vaccination campaign. I will then analyse the discourse of the main actors who voiced their concern about the safety of this vaccine. I will present the social and medical ontologies on which these various critiques are grounded and the varying degrees of radicalism of these critiques.

This analytical tool is not without its limitations and challenges. I will develop on these issues in the conclusion but it is necessary to mention them at this stage to facilitate understanding of this case study. This tool's focus on discourses and their ontological foundations means setting aside crucial non-discursive forms of action in controversies. Discourses relying heavily on irony or rhetorical questions, favouring a polemical tone or implicit assumptions constitute serious challenges for the coder. More importantly, by comparing all positions to that of one orthodox actor or set of actors, the analyst runs the risk of approaching a controversy as the opposition between two camps (one being homogenous and the other, heterogeneous). These limitations are the price to pay for a clear statement of the ontological diversity in a given controversy. Some of these challenges can be resolved by developing several coding schemes or by combining this tool with other tools of controversy analysis.

Mapping forms and degrees of criticism

Boltanski's approach to critique

Luc Boltanski's approach to critique derives directly from his understanding of the power of institutions as partly symbolic. Institutions such as the State can exercise power on a large number of individuals and groups insofar as they are able to impose their own representation of reality (Boltanski, 2011). Because representations of the social, physical and supernatural world circumscribe the goals and expectations people set for their lives, political tensions necessarily revolve around the issue of correctly describing

the world. This approach has contributed to the understanding of conspiracy theories. In *Mysteries and Conspiracies* (Boltanski, 2014), Boltanski sets the not-so-new public fascination for conspiracies against the backdrop of the historical unification of power around the State. He argues that this unification has been built on the production of a relatively unified discourse on both the social and the physical world with Science and the Law being cornerstones of this process. However, gaps between this discourse and reality are inevitable. They stem both from the uncertainties that remain even when scientific knowledge exists and from the limits of the power of the State to uphold legality for all. Conspiracy theories are therefore a specific type of critique of the gap between official discourse and real life. They reveal the tensions underlying the relationship between the State and citizens.

Degrees of critique

The analytical tool I present here is grounded in Boltanski's (2011, 2014) definition of critique as the act of unveiling a gap between reality as presented by a dominant actor and reality as represented by the author of the critique. But I also take further inspiration from Boltanski's work. Indeed, while his description of the various forms of critique is very rich and cannot be summarized in a simple typology, this is precisely what I have done to build my analytical tool. The following is therefore a personal selection and interpretation of his tremendous oeuvre. Boltanski's work helps identify several degrees of radicalism of critique, which forms the first dimension of the tool presented¹.

Doubt. Firstly, one of the main themes in Boltanski's analysis of critique is the pervasiveness of uncertainty which gives actors a 'grip' to express their dissatisfaction. Underlining uncertainty in an opponent's claims to factuality is a form of critique. It is not exactly exposing the gap between what is said to be and what is, but it consists in suggesting the possibility of such a gap. This constitutes the first degree of radicalism in criticism.

Re-prioritizing. Secondly, Boltanski underlines the fact that in contentious events (controversies, trials, etc.) actors refer to a multiplicity of values to make their argument. Divergence often lies in the prioritizing of these different values. For instance,

one's decision can be based on the priority given to economic development over social justice and its critique can consist in explaining why the reverse should be favoured. Changing the hierarchy of values constitutes the second degree of radicalism. It belies a stronger divergence since this form of critique underlines an error in the understanding of reality. This does not only apply to references to overarching values such as equity, progress, charity, etc. In Boltanski's work, critique applies to all forms of descriptions or judgments on reality: factual statements, self-descriptions, moral values, etc. This 're-prioritizing' can be seen whenever an actor proposes a different evaluation of the importance of the statements on reality in their opponent's discourse.

Side-stepping. The third degree of radicalism consists in pointing out an important element that is not taken into consideration by the actor who is criticized. Contrary to the previous case, the critique does not only re-evaluate the importance of one or several aspects of reality as they are presented in the discourse of the criticized. She or he points to elements of reality which are not included. For instance, in a dispute over the care given to sick patients in a hospital, nurses can invoke the necessity to provide psychological support, while the administration and surgeons can deem this completely outside the realm of medicine and the hospital's mission. This testifies to a stronger difference in how these actors see the world since they not only disagree on the importance of selected aspects of reality on a given subject, but also on the selection itself.

Revealing the unknown. The fourth and final form of critique consists in a stronger form of side-stepping. The difference with the third step lies in the fact that the actor whose discourse is being criticized doesn't recognize (implicitly or explicitly) the element put forward by the critique as existing, as real. There is therefore a fundamental divergence on what constitutes the world rather than on the evaluation of the importance of elements of the world which are mutually recognized as real. An example of such a divergence would be when, at a trial for murder, the defender claims to have been commanded by a ghost to explain and excuse his or her actions while the

justice system does not recognize the existence of ghosts.

Types of critique

At this point, it is important to remember that the realms of science and of politics are never completely separated (Jasanoff and Kim, 2015). Because knowledge production is inseparable from the way it is used by actors to transform the world, most critical discourses articulate a critique of opponents' vision of the world, of their mode of producing knowledge, and of their legitimacy to take action in the name of the collective. Cultural differences among actors are therefore not only about how they describe the world outside them, but also how they view each other as commonly involved in transforming it.

A second dimension must therefore be added to our tool. In addition to evaluating the degree of divergence between actors, one must take into consideration the different aspects of this divergence. Do actors only disagree on how molecules interact? Or do they also disagree on the best way to improve human life by using molecular technology? In addition to a classification of degrees of radicalism of critique, we need the impossible: a typology of the aspects of reality that can be the objects of critique. Social scientists of all creeds have been fighting on this subject. One could argue that this is precisely the object of social sciences and that the constant evolution of the names of the various specialized forms of sociology, for instance (sociology of work, of culture, of inequalities, of gender, of beliefs, etc.) testifies to the impossibility to reach a common agreement on this issue. One could also argue that the heuristic power of such a hypothetical typology would depend upon the actors who are studied (some actors' vision of the social world might be closer to that of Pierre Bourdieu's than to that of James Coleman's for instance). Indeed, approaching actors' ontology of the social world with social science as a reference for comparison, one is immediately confronted with the fragmentation of research in the social sciences and the multiplicity of theories of what constitutes society.

However, fuelled by dissatisfaction with this fragmentation and the proliferation of social ontologies in academia, a group of sociologists

have proposed a simplified ontology of social reality. The project of Analytical Sociology consists in breaking down complex social phenomena into smaller parts and rebuilding them as mechanisms produced by the articulations of these social 'cogs and wheels' (Hedström, 2005; Hedström and Bearman, 2009). Analytical sociologists claim that by using their own classification of a limited set of fundamental social elements they can explain the emergence of any social phenomenon. Analytical sociology is a form of Methodological Individualism. Whether or not analytical sociologists are able to do what they claim is not my object of concern. I use analytical sociologists' intuitions very differently from them: as a method for thematic analysis rather than as a method for producing actual knowledge on the social world. This means that analysts can use this coding scheme without adhering to the claims put forward by analytical sociologists such as that the use of collective entities to explain social phenomena is un-scientific, that multi-agent modelling is the future of sociology, that individual rationality is the cornerstone of the social sciences or that ideology undermines current discourses on modernity. This coding tool is not an application of analytical sociology to sociotechnical controversies. It just recognizes the fact that analytical sociologists' decompositions of the social world are convenient ways of coding public discourses. The second dimension of our coding scheme is thus a simplified version of analytical sociology's ontology. Differences in ontologies can be approached by focusing on four elements that compose the description of social reality that is being contested: the actors involved, their beliefs, their intentions and the actions they undertake. This means that there are four main ways to criticize an actor's discourse and these ways are often combined:

Beliefs. One can criticize another's beliefs. This is typically the ideal form of intellectual debate. Arguments pertain to descriptions of the world independently of the actors who produce them. Discussions on whether the principle of Archimedes is true or false, or whether it is right or wrong to kill someone to save three others, fall into this category. Following Boltanski, critique

consists in showing the (more or less large) gap between the opponent's belief and reality.

Actions. Most of the time, controversies arise because something has been done or is going to be done. Because many arenas where actions are taken are not very public, there is always the possibility that someone says he has done something when he has not. A second form of critique therefore consists in exposing a gap between the actions which are claimed to have been taken and the reality of these actions.

Intentions. A third form of critique pertains to the intentions of the actor whose discourse is the object of critique. Indeed, people often claim to only have the common good in mind when they are actually defending their own self-interest. A third form of critique therefore focuses on the motivations underlying the involvement of an actor in a given issue and showing a gap between their moral self-presentation and their actual morality.

Actors. Knowledge production and political action are collective enterprises which involve many different actors who have different roles in these processes. This division of labor in complex institutional settings is crucial in establishing trust and justifying a given action. However, there are often cases when a decision which is supposed to be taken by one actor actually reflects the influence of another. This is the case when public officials accept bribes to pass a law. A fourth form of critique consists in unveiling the gap between

the actors actually involved in a given action and the ones claiming these actions as their own.

While I drew inspiration from analytical sociology to invent this coding scheme, researchers using it should not restrict their analysis to the part of their actors' discourses that corresponds to what analytical sociologists consider to be 'proper' sociological concepts. For instance, Actors do not have to be individuals in the discourses under scrutiny. A person can be criticized for being the puppet of larger collectives, ghosts, or of obscure forces. Analysts should be neutral regarding what the people whose discourse they analyse consider to be relevant actors. This coding scheme therefore also applies to non-analytical lay sociologies.

By intersecting the two dimensions outlined, the critique a given actor addresses to another one can be summarized in a simple table with 16 forms of critique:

The lowest four slots constitute the most radical forms of criticism with slot 13 corresponding to very esoteric descriptions of the physical world and slots 14, 15 and 16 corresponding to very esoteric descriptions of the social world. Before applying this analytical tool to the subject of vaccine criticism, it is important to remember that these categories are relative. Indeed, when analysing the discourse of a given actor, analysts fill these slots by comparing its content to that of the actor who is criticized. This is important since the degree of radicalism of a conspiracy theory

Table 1. Forms and degrees of criticism.

	Beliefs	Actions	Intentions	Actors
Doubt	1	2	3	4
Re-prioritizing	5	6	7	8
Side-stepping	9	10	11	12
Revealing the Unknown	13	14	15	16

becomes highly dependent on the dominant discourse at a given time. The tool does not evaluate in any way the actual legitimacy of the discourses it is applied to.

Context and method

Context

I will now use this framework to analyse a specific vaccine-related controversy: the one surrounding the safety of the 2009 pandemic flu vaccine distributed in France.

In April 2009, the detection of a H1N1 strain of the flu triggered an unprecedented mobilization by international public health institutions and national governments which had been intensely preparing for a lethal pandemic since the beginning of the 2000s (Zylberman, 2013). In France, public authorities purchased 94 million doses of the vaccine and aimed to vaccinate 80% of the population. But after the announcement of the details of this campaign at the end of the month of August, a number of critiques were voiced against what was perceived as an over-reaction in the face of a minor illness (Sherlaw and Raude, 2013). The controversy over the vaccine's safety emerged in the media at the beginning of the month of September 2009, a couple of months before the launch of the vaccination campaign (November 2009). It lasted until the end of the 'swine flu' news cycle (January 2010). During this period, French public officials and a number of public health experts presented a common and coherent set of arguments defending the safety of this vaccine. The actors whose arguments I analyse here (nonprofits, unions, political parties, individual activists, bloggers, who I will call "actors") attacked these arguments on a variety of grounds. They tried to demonstrate that this vaccination campaign represented a risk for public health.

The case of vaccine-related controversies is perfectly suited for the research agenda mentioned at the beginning of this article. Firstly, there exists a hegemonic discourse on the subject. Public health authorities, both national and international, deliver marketing authorizations and recommendations for each vaccine. Secondly, these recommendations are transformed into a more general norm. Non-compliers

are publicly delegitimized and vaccine critics are publicly denounced as 'cult adherents', 'irrational' and 'obscurantists' (Leach and Fairhead, 2007; Blume, 2017)2007; Blume, 2017. Public health officials and experts tend to assimilate all forms of vaccine criticism to its most radical forms ('anti-vaccinationism' and 'conspiracy theories') and to use the term 'antivaccine' in a polemical manner (Blume, 2006; Colgrove, 2006; Hobson-West, 2007; Johnston, 2004; Leach and Fairhead, 2007). These public discourses on vaccine criticism gloss over the variety of meanings that can be attributed to this medical intervention (Atlani-Duault et al., 2015; Leach and Fairhead, 2007; Nichter, 1995; Streefland, 2001; Ward, 2016). This inability to distinguish between the various forms of vaccine criticism has greatly hindered the understanding of vaccine related controversies and the social tensions at their roots (Blume, 2006; Leach and Fairhead, 2007; Ward, 2016).

Method

The sample of actors was selected in the following way. First, I analysed the coverage of the issue of vaccine safety produced by 21 of the main French news media between April 1, 2009 and January 31, 2010. I looked for identifiable actors who criticized the safety of this vaccine. I did not discriminate between the types of actors (individuals, collectives, bloggers, politicians, etc.) and chose to let the people involved in this controversy determine authorship for themselves either by choosing to speak in their own name or as representatives of collectives or even aliases (see Callon et al., 2011). I then conducted interviews with representatives of these collectives who were asked to name other important actors involved in this controversy. I identified a total of 19 individuals or groups (for more details on the actors and methodology, see Ward, 2016).

The tool I presented in the previous section was used as a coding scheme and applied to the public discourse of these actors during this period which comprised: 1) the contents presented in the media gathered through the analysis of 21 media sources but also through nominative keywords searches in two general media databases (Euro-presse and INAthèque), 2) their website(s), and 3) the documents mentioned during interviews

and/or given to me directly. I restricted analysis to the documents pertaining explicitly to the 2009 pandemic flu vaccine.

Results

Using this analytical tool, I will now break down the various forms of critique of the safety of the 2009 pandemic flu vaccine, thus revealing the ontological disagreements at the core of this controversy.

The orthodox position

Regarding the handling of the flu pandemic, some issues were hotly debated among public health officials: who should be vaccinated first? Should people be vaccinated in ad hoc locations or at their local GP's? Even the lethality of the flu was controversial among public health experts and deciders. However, safety of this vaccine was considered to be a 'solved issue' and both public health officials engaged in the handling of the flu and public health experts speaking in the media completely rejected the claims that this vaccine could be unsafe. So much so that officials did not mention the safety of the vaccine before the issue made front-page news at the beginning of September 2009. This means that the discourse presented by the defenders of this vaccine was produced in reaction to the critique made public by the media. This was the case throughout the whole period. Defenders of the safety of this vaccine, despite their diversity (ministries, public health organizations, experts integrated in the ministries' task force, experts loosely connected to this task force...), presented a very coherent discourse which I will call in the rest of the paper the 'orthodoxy'. Contrary to most controversies, the discourse presented by these defenders of the vaccine did not evolve much as they regarded the arguments presented by vaccine critics as completely null and void. New arguments were occasionally added later in response to specific criticism. I will present these more marginal arguments later with the critiques that elicited them. Here are the main aspects of this orthodox discourse.

Firstly, behind the idea that this vaccine was safe, was a general trust in the efficiency of the

procedures deployed to identify and measure its effects. For orthodox actors, the fact that the vaccine had to go through a marketing authorization process guaranteed its safety. Secondly, public health authorities recognized that some uncertainties remained. For instance, they were not sure whether it was safe enough to use adjuvants, substances such as aluminium or shark oil which increase the immune system's reaction to the vaccine, for children aged 6 months or less. But for them, the risks associated with unforeseen adverse effects were limited in two ways: 1) they recommended non-adjuvanted vaccines for those subgroups and 2) pharmacovigilance was intensified to allow for a potential re-assessment of these recommendations.

Interestingly, these arguments were presented relatively independently of the issue of the lethality of the pandemic flu virus. Even though the question of the danger of this virus was never quite solved during this period, these actors all presented the vaccine as safe regardless of these uncertainties. Their reasoning was twofold. Firstly, if the virus mutated into a version similar to the much feared Spanish flu of 1918-1919 (also an H1N1 strain), then the vaccine would definitely be less dangerous than the flu. Secondly, results from early clinical trials suggested that even if the virus was "only" as dangerous as the seasonal flu, the vaccine would still have a positive benefit/risk ratio.

A critique of vaccines and vaccination

A first set of arguments presented by critical actors pertained to what makes vaccines effective and what can make them have a negative effect on people's body. These arguments relate to how the physical world can be described which corresponds to the first column in our table: beliefs.

Doubt.

Many actors in our sample underlined the uncertainty regarding the safety of this vaccine but also regarding the danger of the flu. For instance, the non-profit *Health, Nature and Medicine* makes the following demand in their press release published in September 2009:

(Health, Nature and Medicine) demands scientific proof demonstrating that this vaccination is necessary and without danger, especially for pregnant women and young children, since hindsight on the side effect of this new hastily prepared vaccine will be almost inexistent.

As we can see, this form of critique is grounded in the same type of rationality as the one applied by public health organizations in their decision making process: risk assessment. Actors presenting this type of argument conform to the dominant form of apprehension of dangers as 'risks' and the associated focus on a posteriori computation of events in order to produce probabilities seen as predictors of the occurrence of such events (Douglas, 1990). This type of argument constitutes an insider's critique. Indeed, in the paradigm of risk assessment, the limit to a given judgment on the danger of a phenomenon is defined by the amount of data available concerning previous events involving this phenomenon. Here, actors such as *Health, Nature and Medicine* suggest that the risk assessment provided by public health officials does not translate the high uncertainty left by the gaps within their dataset. The same applies to arguments regarding the "real danger" of the virus. For instance, *Pharmacologist X* insists upon the lack of reliability of data regarding the deaths caused by this flu.

Re-prioritizing.

Most actors within our sample went further than simply raising doubts concerning public health officials' risk assessment. They inverted the hierarchy between the competing risks (virus vs vaccine). This was done by simultaneous presenting claims that the flu was not very dangerous ("as dangerous as seasonal flu" or "less dangerous than the seasonal flu") and claims that the vaccine was more dangerous than expected. In an interview broadcast in September 2009, *Pharmacologist X* develops on this commonly held view:

This use of the precautionary principle is appalling. It is used just in one way! Why don't we apply it to a vaccine that's been developed so hastily? Yet, it's easy to estimate the risk of a vaccine given to a great number of people (...). I calculated it. 20 million people will catch the flu with a death

rate of 1%: we get 20 000 deaths. We develop a vaccine in amateurish conditions that I've never seen before! Everyone knows that we don't detect serious side effects among 1000 patients during clinical trials. So, let's take the pessimistic hypothesis, as public health authorities do: we have 1 death for 1000 people. This gives us 60 000 deaths.

Side-stepping.

The core of the argument presented by public health officials consists in comparing quantitative measures of the risks of the flu and of the vaccine. In the two previous forms of critique, heterodox actors worked within this frame. However, most actors involved in this controversy did not stick to countering the assessments of public health authorities point by point. Most also mentioned an element that was not explicitly present in the orthodox discourse at the time: adjuvants. The main element of any vaccine is the antigen, a liquid containing the attenuated form of the virus meant to stimulate the immune system to create antibodies. Adjuvants are oil-like substances added in the vaccine which increase the body's reaction to the antigen. They allow using less antigen in each vaccine and increase its efficiency. For public health authorities, the use of adjuvants in the pandemic vaccine was not problematic and did not warrant a specific debate. On the contrary, most of the actors in our sample disagreed on this point defined adjuvants as a real problem and they concentrated a significant part of their discourse on their alleged dangers. According to them, the use of adjuvants increases uncertainties, arguing that their long term effects are not well known. Also, representatives of *Ecology and Health* - among others - insist that many adjuvants contain products known to have effects on the development of babies. According to them, adjuvants pose the same types of problems as endocrine disruptors whose effects are significant but difficult to measure because of multiple exposures.

Many commentators on vaccine criticism tend to analyse heterodox views of vaccines as grounded in age-old alternative visions of health such as homeopathy, chiropractic and naturopathy (Poland and Jacobson, 2011; Wolfe and Sharp, 2002). In doing so, they suggest that alternative and allopathic medicines are cast in stone.

This focus on adjuvants must be set against the backdrop of major transformations and tensions which have emerged partly within the institutional realm of allopathic medicine. One crucial trend has been the increasing focus of researchers on the effects of environmental pollution on health. As Francis Chateauraynaud, Josquin Debaz and Matthieu Fintz have shown, the emergence of this strand of research at the frontier between the political and academic spheres has renewed the understanding of the effects of the environment on the human body and challenged existing regulations of these risks (Chateauraynaud et al., 2011, 2014).

While this focus on adjuvants constitutes a significant departure from the orthodox position, it still denotes an important proximity. Indeed, in their responses, public health authorities recognized the fact that adjuvants exist and are used in these vaccines. They also recognized the fact that the various mechanisms linking environmental pollutions and bad health described by these actors exist or are plausible. They simply denied that they applied here or were sufficiently important to warrant a separate debate and a re-assessment of the risk/benefit ratio of this vaccine.

Health, Nature and Medicine presented another form of side-stepping. Their main spokesperson during the period gives the following advice in a document published online in October 2009:

Now that the science of immunology is better known, we know that the immune response is conditioned by the HLA system which is unique to each human being. We're discovering that it is ridiculous to build large-scale vaccination systems for individuals that are so different. (...) One piece of advice, remember to do a blood test before each vaccination to check if you already have the antibodies or if you are already incubating the disease!

This concern for the differing effects of drugs and diseases on people's health is part of a growing trend in contemporary medicine towards 'individualized' or 'personalized' medicine. While these differences in reactions to vaccines are admitted to be real by public health authorities, which led

them to prescribe a non-adjuvanted vaccine for specific subgroups such as pregnant mothers; 'individualized' medicine is not recognized as relevant by them when it comes to wide-scale vaccination campaigns. This is shown in the fact that despite worldwide recognition by public health authorities that a blood test can adequately tell whether the patient has the antibodies associated to the vaccine, they do not recognize pre-vaccine tests as part of vaccination campaigns.

Revealing the unknown.

All the previous arguments targeted the 2009 pandemic flu vaccine specifically. They respected the principle of judging each vaccine and each of its components separately. A small portion of our sample of actors went further in their critique and broke with this fundamental principle of public health ontology. These actors questioned the safety of vaccination in general. Among these typical 'antivaccine' arguments were claims that vaccines in general tend to weaken the immune system, to generate the infection rather than safeguard against it and more generally that they are poisons. These arguments were often grounded in neo-vitalist ontologies which present immunity as a form of equilibrium between the various fluids within the body (Johnston, 2004). While not all of the actors in this subgroup explicitly refer to homeopathy or naturopathy, they all emphasized the importance of the "terrain", the individual physical capacity to fight off any exterior aggression, and downplay the role of viruses in bad health (for more detail about these arguments, see Dubé et al., 2015; Kata, 2010; Streefland, 2001; Wiese, 1996).

It is important to note that these actors propose an alternative definition of immunity, one that is not recognized as relevant or even worthy of discussion by public health authorities and mainstream biomedicine in general. Indeed, while public health authorities and experts have tried to counter the arguments presented in the previous sections, they made no effort to answer the arguments relating to vaccination in general, apart from general declarations on "the importance of vaccines" and the usual delegitimation of obscurantist "antivaccinationists". This is not surprising since the invention of

vaccines was crucial in the emergence of the main paradigm in contemporary biomedicine: microbiology (Moulin, 1991). These forms of critique are part of a long tradition of resistance towards the paradigm of microbiology which started to dominate in medical academia at the end of the 19th century. These forms of critique are grounded in the then legitimate medical theories that were being supplanted by microbiology. These medical theories did not die with Pasteur and the fight on the issue of what constitutes good medical science has continued ever since, even if resources available for each side have been increasingly unequal.

But actors in our sample did not restrict their demonstration to medical considerations. Indeed, most of the arguments I just presented, to be true, imply institutional failings in the organization of this vaccination campaign.

A critique of those who make and recommend vaccines

Critical discourse was also directed to the reality of the claims made by public health authorities to have done everything in their power to guarantee this vaccine's safety. I will now analyse the social ontologies underlying this more classically political form of critique which correspond to the three remaining columns in my synthetic table (actions, intentions and actors). For convenience, I will present them together.

Doubt.

A first form of critique simply consisted in questioning whether the orthodox description of the decision making process that led to this vaccination campaign was accurate.

Many actors denounced the lack of "transparency" on a number of crucial subjects: which adjuvants will be used? What are the side effects identified during clinical trials? Will pharmaceutical companies be held responsible when adverse events occur? This was the core of the message of an important petition signed by the *Far Left Party* demanding that "the debate be open" on this campaign. This was often linked to the ethical issue of providing the public with enough information for them to make an informed decision. These doubts regarding the actions undertaken were

often combined with a similar attitude toward public officials' claims that the best interest of the population was their main concern. Such claims were pervasive in the discourse of public health authorities from the beginning of the pandemic to well after the last vaccination site closed in February 2010. This was especially the case once the French news media started debating on the alleged conflicts of interests of special advisors to the World Health Organisation and to the French Minister for health at the beginning of the month of November. Public health officials admitted that financial motives were part of public health decisions since on the one hand pharmaceutical companies' *raison d'être* was to make profit and, on the other, a large vaccination campaign could not take place without pharmaceutical companies producing these vaccines. At the same time, officials claimed that the well-designed institutional processes for the distribution of these vaccines were effective in restricting the influence of these financial interests. These considerations were part of their answer to the doubts expressed by most of the actors in our sample.

These doubts regarding actions and intentions were completely intertwined with doubts regarding who really made these decisions. Public health officials claimed to have been the sole actors in charge of deciding to recommend the vaccine. According to them, pharmaceutical companies were not integrated in the process apart from consultations on practical issues such as pricing and production.

As Anthony Giddens has showed, uncertainty is a fundamental feature of 'late-modern' societies (Giddens, 1991a, 1991b). Because these societies feature intricate institutional 'abstract systems', people's experiences of danger and risk become delocalized and trust becomes a central issue. While public authorities have the tendency to suppress these uncertainties in their public communications, social movements of all kinds have participated in diffusing a consciousness of these uncertainties, especially on health related subjects. These critiques of opacity in this vaccination campaign are therefore in direct line with the intensification of mobilizations against paternalism in medicine and, more generally, consumer rights, since the 1960s (O'Neill, 2002).

Re-prioritizing.

All of our actors but one went further than simply raising doubts.

They claimed that the authorities did not take the actions they claimed to have taken. This took the form of claims that the vaccine was “not sufficiently tested” and that public health authorities did not gather enough information to buttress their claims regarding the severity of the flu. Some also challenged the claim that the public was given all the information required to make an informed decision. This took the form of a denunciation of the bias in the presentation of information. For instance, during the month of November, *Nurses’ Union X* regularly denounced the focus in public health authorities’ communication on benign adverse effects of vaccines and its alarming tone regarding the virus. Some used harsher terms, such as “propaganda”, to present a similar argument.

They also judged that public health authorities undermined the actual influence pharmaceutical companies and their financial interest. The mechanism through which the control by pharmaceutical companies was exerted on public health officials was presented with varying degrees of precision. Some accused experts in the advisory committees of national and international public health organizations (such as the World Health Organisation, the European Council, the European Medicine Agency...) of having conflicts of interests. Some spoke more bluntly of a “control of pharmaceutical companies over the studies that evaluate vaccines” (*Journalist X*) or, more generally, of a control over public health representatives and of “experts paid by labs” (*Far Left Party*).

This form of critique can appear extreme in some of its expressions, with for instance the wide use of the term “corruption”. But it is important to note that it is targeted on actors who are recognized by public health authorities as part of the institutional decision-making process of this vaccination campaign. The same goes for the part of this argument pertaining to the motives behind these decisions. Claims that pharmaceutical companies’ financial interests were the main motive behind this vaccination campaign were occasionally formulated in a brutal manner. But the intentions supposed to have guided this vacci-

nation campaign remain those commonly recognized – even by public health officials - as those of pharmaceutical companies: profit.

Denunciation of conflicts of interests has also become a classical repertoire of critique in the domain of health since the emergence of consumer rights and ecological social movements (Chateauraynaud et al., 2014; Conis, 2014; O’Neill, 2002). Such mobilizations have led to major transformations in national legal systems, with laws pertaining to conflicts of interests being enacted, major scandals arising in the mainstream media, etc.

Side-stepping.

The previous arguments focused on the actions public health officials claimed to have taken, and on actors and intentions recognized by public health officials to be part of normal institutional decision-making processes. I will now turn to the actors who suggested that other groups or people were involved in this campaign, that deciders took other measures and/or had ulterior motives.

One of these alleged secret actions was that the French government used its institutional resources to put pressure on nurses and medical professionals to vaccinate and get vaccinated and on the media to spread positive information about this vaccine. Some also claimed that the government guaranteed that pharmaceutical companies would not face charges in case of adverse events and denounced this “impunity”.

These forms of critique depart from the discourse of public health authorities not only by negating the existence of the actions claimed to have been taken, but also by suggesting the existence of a different set of actions. These hidden actions nevertheless stay within the boundaries of a social ontology shared with orthodox actors. Indeed, the existence of the kind of biases and strategic communicating mentioned in the previous section, and the kind of institutional pressure and bargaining I just mentioned are part of contemporary political common sense. The existence of such actions in the world of policy making and sociotechnical controversies is admitted and they appear as plausible a minima. Indeed, public health officials and experts accuse “antivaccinationists” of such acts. Another piece of

evidence of the inclusion of such hidden actions in the ontology of the social world underlying the orthodox discourse is the fact that public health authorities publicly responded to these accusations with lengthy arguments detailing exactly what they had done.

A minority of critical actors also attributed another set of intentions more grounded in traditional political cultures. They claimed that the intention behind public health authorities' decision to organize this large-scale vaccination campaign was to cover themselves in case the flu was really dangerous. Their intentions were therefore political self-interest based on a distorted use of the precautionary principle. They accused the government of wanting to "appear to be active" and to score political points. Others claimed that the underlying impetus behind this campaign was ideological. *Far Left Party*, for instance, used this argument in the opening line of their September "dossier" on the pandemic:

Fear is a market, and a policy. The flu, after foreigners and urban youths, allows the government all kinds of wrongdoings that reveal its secret desires: free market and a strong State.

Other actors denounced the focus of the government on the cost of sick leave for the economy. These arguments targeted the right-wing political orientation of government at the time of this pandemic.

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These forms of critique constitute a significant side-step compared to the discourse of public health authorities. Orthodox actors framed the pandemic as an a-political issue, a very common frame for health and risk-related policies, especially in France (Borraz et al., 2007). While the existence of political bias and political self-interest are commonly accepted by all politicians, experts and bureaucrats, orthodox actors did not accept that this was an issue in this particular case. This form of critique constitutes a very classical repertoire of critique. However, the critique consisting in pointing to politicians' self-interest has gained unprecedented popular appeal in the past decades with a general decline in trust in public servants since the end of the 1970s, especially in France (Inglehart and Welzel, 2005). It constitutes a form of resistance towards the professionalization of a political and administrative class and its

social consequences (see for instance: (Bourdieu, 1998)).

Among the crucial points my analytical tool revealed is that almost all critical actors restrained this side-stepping to the actions and intentions of public health authorities. Only two of them suggested that some hidden actors played a role in this process.

The leader of the Party of Life, in an address at a convention of an “anti-Zionist” political movement, suggested that “militant Zionists” and “financial and military elites” were behind this campaign. Justice For All is the other actor. This non-profit filed a lawsuit in July 2009 for “preparation of a crime of genocide” (sic). In their brief, they pointed to another set of actors: Barack Obama, the United Nations, bankers (David de Rothschild, David Rockefeller and George Soros in particular) and, in other documents, towards the Federal Bureau of Investigation, the Federal Reserve and the Bilderberg Group. The activist behind this non-profit also mentions the crucial role played by Freemasons in unifying the actions of these different groups.

No-one among the French political elite denies that Barack Obama or the FBI exist and even if they are probably wary of the term “elite” and probably define it in slightly different ways. Their decisions are premised on the fact that some actors are more important than others and should therefore be included in discussions and negotiations relative to policies. The existence of Freemasons is also widely recognized as real. However, nowhere in the public health authorities’ multiple public discourses is there a reference to this specific choice of actors (except for Barack Obama but in a very different way: as important in decisions pertaining to vaccination in the US only). The idea that they matter in the process that led to the organization of the French vaccination campaign is very exotic compared to how this process was presented by orthodox actors: institutional negotiations between national and international public health agencies and political organizations (such as those that compose the European Union), governments, representatives of public health professionals, public health experts and pharmaceutical companies. This choice of actors to include as relevant does not respect the premise

of public health authorities’ own description of the institutional world of contemporary nation states and international coordination as characterized by: 1) thematic specialization, 2) a social division of labour (in this case the institutionalization of the specific professional and economic domain of health and medicine), and 3) a political unification guaranteed by the institutions that compose national states and international cooperation structures.

With this form of critique - side-stepping applied to actors - we enter into the realm of conspiracy theories as they have been approached by contemporary anthropology. This form of critique consists at least partly in denouncing the secret actions of enemies within (Goldberg, 2008). They point to traditional scapegoats antedating the emergence of the French State and the intensifying globalization of the 20th century - the Jews (Pipes, 1999). This illustrates Harry West and Todd Sanders’s point that reactions to globalization are embedded in the past and in local cultures (West and Sanders, 2003; see also Dingwall et al., 2013). The reference to Freemasons is a more recent form of critique of power. It is grounded in the emergence of national states and of the type of political elites associated with this new form of organization of power. It seems that one of the major transformations of this social ontology with globalization has been its internationalization and a greater importance given to private companies. But another important evolution in the discourse on Freemasonry has been its hybridization with emerging discourses on Unidentified Flying Objects (UFOs) and aliens as we will see now.

Revealing the unknown.

Justice For All is the only actor to go even further and suggest that the most important actors are ones that are not recognized as existing by all actors from the French mainstream politics: the Illuminati-Reptilians. According to the activist behind this non-profit, the illuminati are the “elites of freemasonry” and their goal is to establish a “New World Order”. They control all important organizations, such as the ones mentioned in the previous section. Documents of Justice for all suggest that they are actually extra-terrestrial

beings who came to earth to exploit the planet and the human race. According to them, because of the work of the illuminati, data concerning the existence and sightings of UFOs is not released to the public. This prevents the world from recognizing the truth, which was what John F. Kennedy wanted to do and the reason he was assassinated.

Such descriptions of the social world have a long and complicated history linked to the emergence of occultism in European salons at the end of the 18th century, the emergence of theosophy at the end of the 19th century, and, more recently, the tales of UFO sightings and the popular success of Erich von Daniken's tales of "the ancient astronauts" who founded all major civilisations (Stoczkowski, 1999). It is unclear exactly what kind of power relations are targeted through this form of social aetiology except for the kinds mentioned in the previous sections. Wiktor Stoczkowski (1999) argues that occultism

and, more importantly, theosophism constituted forms of protest against the claim by Christian institutions to the monopoly on discourses on the fundamental texture of the world. The increase of cultural exchanges with Asia and South America during the second half of the 19th century enabled to frame this discontent around the issue of European ethnocentrism. Following Jodi Dean, Ufology can be interpreted as a similar type of protest but applied to Science as the new central institution in charge of stating what is real but also as a political project inseparable from the expansion of the realm of nation-States during and after the Second World War (Dean, 1998). Recent studies devoted to forms of esotericism that share traits with the discourse of Justice For All have also analysed them as critiques of how scientific materialism is presented as a tool to orient the life of the people toward economic activities (Asprem and Granholm, 2012). The influence and nature of

Table 2. Types and degrees of critique of the safety of the French pandemic flu vaccine.

	Beliefs	Actions	Intentions	Actors
Doubt	Is the flu so dangerous?	Lack of transparency	Doubt that the public's interest prevailed	Doubt that public health authorities were the main actors
	Is the vaccine safe?			
Re-prioritization	The vaccine is more dangerous than the flu	The authorities did not do everything in their power	Financial interests prevailed over the public's interest	Conflicts of interests
		Authorities only give part of existing information		Pharmaceutical companies control the process
Side-stepping	Adjuvants are unsafe	Behind the scene pressure to vaccinate more	Politicians and public servants' interests prevailed	Other actors: Zionists, freemasons, Bildenberg Group...
	Personalized medicine	Big pharma is protected	Ideological motives prevailed	
Revealing the Unknown	Rejection of all vaccines	Vaccines were poisoned	Instauring a New World Order	Secret actors: the illuminati
	Alternative conceptions of immunity		Mass genocide	

traditional scapegoats seem to be reinterpreted through this lens.

While *Justice for All* was the only one to talk about secret beings, several other actors presented radical revelations either on the intentions behind this pandemic or on the actions that really took place. They most often did so without really specifying who was responsible for these actions, for instance by using the pronoun “they”. Indeed, a small minority of actors claimed that public health authorities (or whoever is in charge) added substances known to cause more harm than good in order to poison the population (see for instance the lawsuit I mentioned before). Also, the non-profit *Justice For All* claimed that authorities put microchips in these vaccines in order to set up a general surveillance of the population. This minority of actors also added a repertoire of motives that went much further than the arguments presented in the previous section and denied the possibility of benevolence or positive actions on the part of public health officials.

Indeed, for actors such as *Life’s political party*, the real motive behind this vaccination campaign was a will to impose a “New World Order” characterized by the oppression of the masses. In this type of argument, self-interest becomes wilful wrongdoing. This actor and *Justice For All* added the theme of eugenics by affirming that the vaccination campaign is actually a Malthusian policy meant to reduce the population of developed countries in order to maintain this New World Order.

Discussion and conclusion

Using the coding scheme presented in table 2, I summarized the positions of vaccine critics in simple tables (see Appendix 1). In this particular case, one table per actor was enough to summarize their critique because there was very little evolution in their discourse during this short controversy. But it is also possible to use this analytical tool to show the evolution of the position of

Table 3. Health Nature and Medicine’s discourse in the media.

Health, Nature and Medicine

	Beliefs	Actions	Intentions	Actors
Doubt				
Re-prioritizing				
Side-stepping				
Revealing the Unknown				

actors across time or their choices of repertoires of critique depending on where they voice it (the media, administrative arenas, academic journals, etc.). This can be simply done by producing several tables. For instance, the *Health Nature and Medicine's* website presented contents that departed significantly from the very tame critique they made in their media appearances and in their letter to the European Medicines Agency (see Appendix 1). References to individualized medicine, to alternative conceptions of immunity and to the New World Order disappear in the latter.

This shows both a will to appear publicly as moderate but also dissension within the group on the subject of what constitutes a legitimate form of criticism.

Also, because this analysis approaches critique in relation to a dominant discourse of reference, it helps avoid reifying radicalism. Critical discourses are not radical in themselves. They are radical in relation to another presentation of reality. For instance, the table would be very different in a context where anti-Semitism is widespread or where homeopathy is the norm. This coding scheme is a flexible tool which needs to be adapted to the specific context and controversy under scrutiny.

The analytical tool presented here helps shed light on the diversity of actors involved in a particular controversy but also the way repertoires of critique are shared between them. This is particularly crucial when studying vaccine-related controversies. There is a general tendency in the public health literature to lump all forms of vaccine criticism together and to treat as equivalent arguments pertaining to side effects, conflicts of interests, natural immunity and plans to poison the world (Hobson-West, 2007; Johnston, 2004; Ward, 2016). The tables presented here paint a very different picture. Some arguments do tend to be presented together and these bundles mix medical and social aetiologies. But clear delimitations also appear, suggesting the diversity of social movements involved in vaccine criticism as well as processes of boundary-making and tensions within these mobilisations (see Ward, 2016). As we can see, almost all of our actors presented arguments pertaining to the balance between the risks and benefits of this vaccine

and to the risks of adjuvants. These arguments were even presented by actors who developed much more general theories of how vaccination necessarily has a degrading effect on health even though these theories render conditional forms of critique redundant. The simultaneous presentation of these arguments should appear surprising. Indeed, the medical ontology behind the idea that adjuvants can cause long-term damages is based on a form of mainstream microbiology. It is incompatible with the alternative theories of immunity that ground the rejection of the principle of vaccination, as we have seen in the first part of the results section. The ontological pluralism of radical critiques is not limited to medical aetiology. For instance, *Life's political party* and *Informed Freedom in Health* both combine denunciation of the influence of hidden actors and the language of conflicts of interest.

This ontological pluralism must be set against the backdrop of the public stigmatisation of the "antivaccine movement" and of "conspiracy theorists". Its correlate is that the actors whose form of critique is labelled in such a way are marginalised and cannot have access to central arenas of debate and decision-making. For instance, in our case study, the media coverage of critics was almost entirely focused on the actors who restricted their critique to the pandemic vaccine and to the role of pharmaceutical companies in the campaign. Indeed, these differences in forms of critique do not appear out of thin air. They are closely linked to the trajectory that led these actors to take an interest in this vaccine. Those who only produced a conditional critique of this vaccine have a variety of backgrounds (environmental health movement, patients' rights movement, political parties, a nurses' union, an epidemiologist...). But they all have in common the fact that they are part of what Pierre Bourdieu would call the dominant political and medical fields (Bourdieu, 1977). They are all at least somewhat integrated to the arenas of debate and decisions around health related issues. For instance, one of them is a member of the prestigious Academy of Medicine. *Ecology and Health* comprises several researchers from French public research institutions and has been able to successfully lobby the European Union on the issue of

BPA. *Far left party* and the *Green party* have many elected representatives at various levels of the French administration. To use Bourdieu's vocabulary, these actors can be seen as involved in the political and/or medical "games". They are vying for the resources these two fields have to offer. Their form of critique translates the fact that they are playing this game, and that they recognize a minima the legitimacy of the institutions they wish to be integrated to - the first and foremost being the State in its different forms. The contrast is striking with the actors who presented more radical forms of critique. The fact that they deny any legitimacy to official and scientific institutions is inseparable from the fact that they are not involved in these arenas of debates. These medical and scientific ontologies are closely connected to the way these various actors find the resources for their mobilisation in relationship with political and scientific institutions.

This analytical tool is not without its limitations and challenges. Its focus on discourse and ontology has several consequences. It does not directly apply to many crucial forms of actions pertaining to the political treatment of science and technology (regulations, political influence, financial transactions...). Its heuristic power and ease of use depends on whether the discourses under scrutiny are elaborate, explicit and engage with the actor's opponent's arguments. In my case study, the main coding difficulties came from texts which adopted very polemical tones and made heavy use of irony and rhetorical questions. This often made it difficult to distinguish between Doubt and Re-prioritizing, especially on issues of transparency and corporate influence. For instance, this was the case of a long speech written and read by the leader of Life's political party. In this speech addressed to the Minister of health, each paragraph started with a bold explicit or implicit accusation such as: "you lie", "you have put your talent (...) at the service of the industry of on-prescription poison", "Why do you think 60% of doctors and medical professionals (...) refuse vaccination for others even more than for themselves?". However, the following sentences

were always much more nuanced, questioning whether the Minister's actions were voluntary or even suggesting that the decisions she took were not really the product of the industry's interference but that of her personal "naïve" beliefs. In this case as in others, I chose to code conservatively, treating rhetorical questions as Doubts and focusing on the more explicit claims. Because in all problematic cases my actors had made more explicit statements in other documents, this conservative approach did not raise particular issues for the analysis. But taking all of the actor's production together also means that there can be a risk of assigning the actor to its most radical statements (or spokesperson) as could have been the case for Health, Nature and Medicine as I discussed at the beginning of this section. This rather intellectualistic bias also means that this tool sets aside the various genres and styles of intervention specific to each platform and arena. Finally, the choice of actor of reference (the "orthodoxy" in my case study for instance) constitutes a crucial issue and should depend on what the analysts' research questions are. It might also be that in many controversies such a coding scheme only applies to some aspects of the controversy or that it is necessary to develop two or more separate coding schemes.

The analytical tool presented in this paper has enabled me to break down the ontological disagreements underlying the controversy over the 2009 pandemic flu vaccine's safety. It has also enabled me to underline the ontological pluralism present in some critical actors' discourse. I believe its combination of a simple definition of critique and an adaptable decomposition of the social world makes it applicable to a great variety of issues by a variety of analysts. I also believe that it constitutes an addition to the portfolio of tools developed in the field of STS. It could especially be fruitful when combined with digital methods developed recently to "map" controversies as they leave an important space to qualitative coding schemes (Marres, 2015). Future explorations should help judge whether or not this is the case.

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Notes

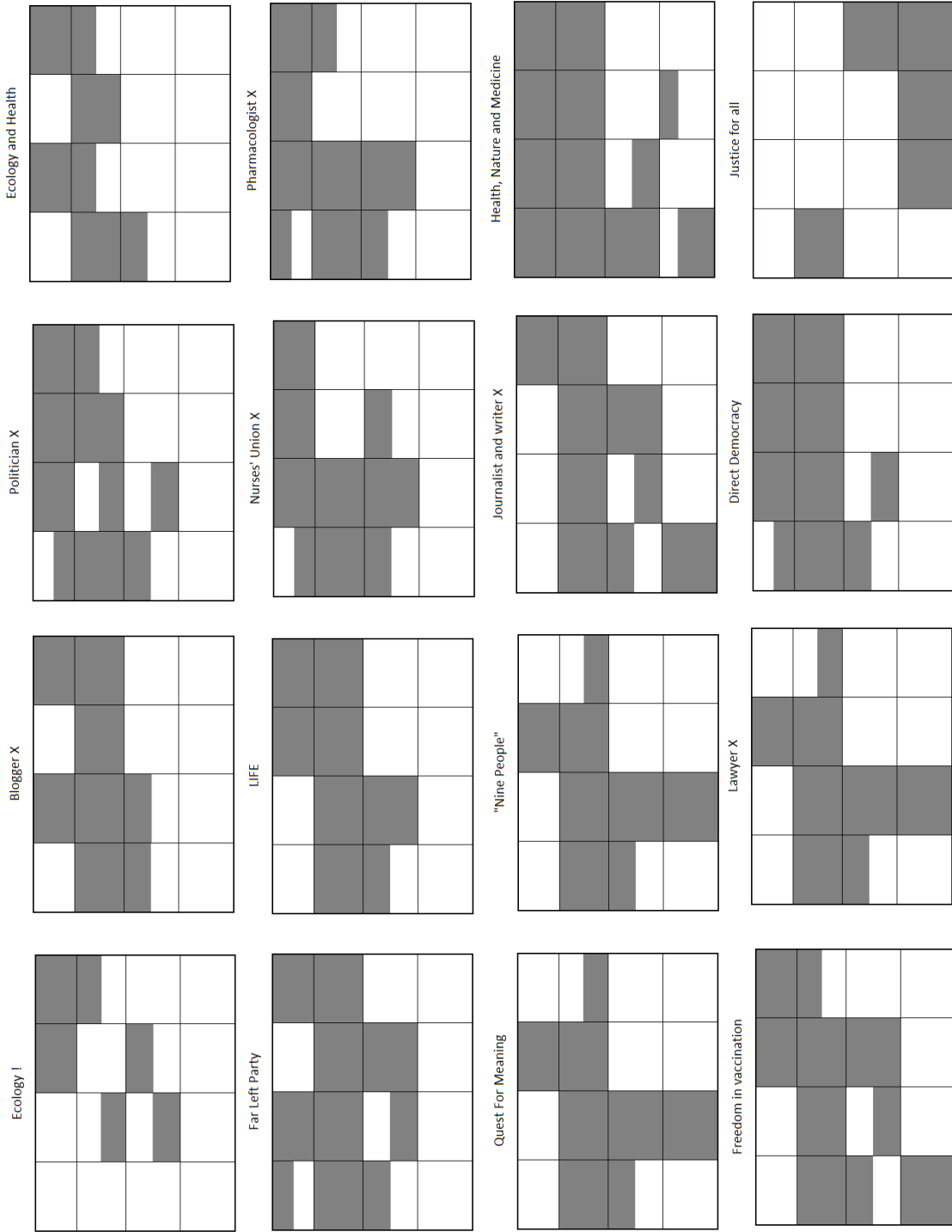
- 1 While he does not provide an explicit definition of what discourse is, Boltanski (2011) uses the term to describe a variety of enunciations, written or oral, produced in any social setting. While he tends to focus on what is explicitly stated by the actor, his analysis also applies to the often implicit ontological premises of these statements.

Appendix 1. Arguments presented by the 19 main actors who criticized the French pandemic flu vaccine.

Each table presents a summary of an actor's critique of the pandemic flu vaccine. The contents of the columns and lines are presented in the table below. By intersecting the two dimensions of the typology presented in this paper, these tables allow assessing the degree and type of each actor's critique.

Infectious Diseases Expert X

	Beliefs	Actions	Intentions	Actors
Doubt	Shaded	Shaded	Shaded	
Re-prioritizing	Shaded	Shaded		
Side-stepping				
Revealing the Unknown				



Eric B. Winsberg (2018) *Philosophy and Climate Science*. New York: Cambridge University Press. 270 pages. ISBN 978-1-316-64692-2

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During the last two decades, numerous books have been written from philosophy in relation to climate change. Most of them concern ethical, social, and/or political issues. However, this book by Eric Winsberg provides a general approach to Climate Science from an eminently epistemological perspective. Following the publication of his earlier work, *Science in the Age of Computer Simulation* (2010), Winsberg offers an introduction to the Philosophy of Climate Science that aims to contribute—as the author himself states—to a deeper understanding of the general public to the scientific practices that currently influence environmental policy. Although the book is aimed at philosophers of science in other areas, I believe that this book could be especially valuable for scientists and technologists researching in fields where philosophy is apparently far away. For climatologists, oceanographers, atmospheric physicists, or any scientist directly or indirectly involved in the study of climate change, reading this book can provide a deeper insight into the kind of knowledge applied in everyday scientific research. And, conversely, the philosophers of science who deal with classical questions will see how old problems are revived in these sciences whose practices are remarkably new.

The philosophy of climate science is interested in understanding the logic, methodology, and conceptual underpinning of these sciences within a broad and consistent epistemological framework. Some of the philosophical questions that Winsberg addresses throughout the fourteen

chapters that structure the book are: the nature of scientific data and its relation to theory, the role of computational models and simulations, the character of probabilities in science and decision-making, statistical inferences, the influence of ethical and social values in scientific practice, the social processes of knowledge construction, etc. Most of these contain a compendium of the research that Winsberg has published throughout the last decade, so it can also function as an introductory manual to one of the most fruitful researchers in the philosophy of climate science. In what follows, I will explore the contents of the book which are, arguably, the most illuminating for the scientific community and philosophers of science in general.

Winsberg begins the second chapter by addressing the observational data—collected through weather stations and satellites—that we already know about the climate. It also addresses the hypotheses that have been generated based on this information, stating that, indeed, the climate has already changed significantly over the last century. He first warns that these hypotheses are inferred from what Patrick Suppes (1969) called *Models of Data*; a reconstruction of the raw data collected by thousands of thermometers, sensors, weather balloons, and a series of instruments distributed around the planet, which reexamines the Dunham/Quine problem and the need to use ‘auxiliary hypotheses’ when making scientific predictions. The central question defended by Winsberg is the epistemic validity of these models

against critics who try to invalidate techniques that actually require great scientific sophistication and the cooperation of a plurality of experts. A case of what, in philosophical literature, is called ‘confirmational holism’ which is not exclusive to the sciences of climate change, but present in well-established physical theories (Dunhem, 1991), and even in logic and mathematics (Quine, 1953).

Chapters three and four deal with climate modeling, with an emphasis on *Energy Balance Models* (EBMs), but also on *Models of Mediation*. Likewise, he reviews the epistemology of scientific simulations, which is the main theme of his previous book (Winsberg, 2010). Chapter five is dedicated to the chaotic nature of atmospheric dynamics and its scientific implications. In particular, he explains the difference between making *predictions* in meteorology and making *projections* in climatology, providing a rigorous conceptual clarity to what is an otherwise chaotic system, and by demarcating the role of the *Butterfly Effect* phenomenon in each case. Through the example of two kinds of simple chaotic models—Lorentz’s model and Robert May’s logistic application—he illustrates several features which are relevant when philosophically studying climate systems. Winsberg emphasizes that, even in a chaotic system, the degree of predictability depends largely on the initial conditions introduced and, once again, on the type of prediction scientists want to make. Through examining the strategies with which they try to mitigate the butterfly effect—such as the PICEF, a type of forecast in which a point prediction for the state of the system in the future is replaced by a distribution over possible future states—and by drawing a comparison with the *Hawkmoth Effect*, Winsberg concludes that there is no analogous model close to the structure of the butterfly effect model, and even if there were, it would not affect climate projections. Precisely because they are not predictions, but ‘forced experiments’, in which we change the initial conditions to study one or another aspect of the system.

The second part of the book deals with the role of probability and *Uncertainty Models*. Chapter six focuses on the role of Uncertainty Models in the communication of (dis)knowledge from experts

to politicians, being the method with the least subjective bias available. Unlike other sciences, climate sciences have a significant social and political influence, and although scientists are well-suited to talk about how the climate will behave, they do not represent the values and interests of society. Thus causing Winsberg, in the next chapter, to question the *confidence* placed in these models. He assembles in seven categories the sources of uncertainty that influence the allocation of probabilities in each of the possible scenarios proposed by the IPCC. Winsberg explains that these probabilities are a representation of *beliefs*, not an exact mechanistic quantification. They are estimates that include unquantifiable factors, such as the experience of scientists, and represent the consensus of a group of experts, which is one more objective that scientists must satisfy.

Chapter eight deals with statistical inference—focusing on the Bayesian paradigm and the frequentist—and decision-making under uncertainty. It also includes a discussion on *Integrated Assessment Models* (IAMs), in which Winsberg warns that they should not be presented as a ‘scientific alternative’ to political decision-making based on ideology. To use them responsibly, they need to take into account basic elements such as *Equilibrium Climate Sensitivity* (ECS) and *Damage Function*, which could significantly influence their results. Following this thread, chapter nine begins by asking to what extent scientific research can—and should—reflect the social and ethical values that surround it. For its part, it seeks to clarify what role these play in the case of climate science, distinguishing between the traditional context of discovery and the context of justification. Winsberg evokes the famous debate between Richard Rudner and Richard Jeffrey on the argument of *inductive risk*, in order to demonstrate how climate modeling advocates ought to accept the inevitable role of values in science.

In chapter ten, Winsberg focuses on the *skill* of models; a quality that identifies it with the capacity of models to obtain adequate results with respect to the purposes for which they have been built. Discussions are included about the verification and validation of these models, and it is concluded that these processes are

rarely useful in the case of climate modeling. Rather than following a set of normative rules, the skill of these models concerns small *ad-hoc* modeling, so Winsberg advocates leaving aside such rules. However, when dealing with the reliability of inferences derived from a tuned simulation, a general pragmatic criterion should still be observed: if a simulation is capable of successfully predicting new data, then it is reliable. In this way, it assigns the value of consequences before the way in which the causative modeling of results is configured, which may depend on the epistemic positioning of the evaluator. This leads him to consider, in chapters eleven and twelve, the role of robustness analysis; that is, on the epistemological value of hypotheses arising from the integration of a set of models, which can be supported by a greater or lesser amount of evidence. For example, if several different models demonstrate that we should expect the ice caps to melt at this or that speed, is there more evidence if additional models accumulate, indicating the same? To this end, Winsberg reviews the properties that models should have so that there is sufficient diversity to obtain epistemologically robust hypotheses.

Chapter thirteen introduces a theme that, in my opinion, is one of the most revealing of the whole book: the social epistemology in climate science. Specifically, he examines the three areas that Goldman and Blanchard (2018) include in their social epistemology: (i) the social interaction of agents and the locus of justification, (ii) the study of groups as the possessors of opinion and knowledge, and (iii) the knowledge-producing consequences of social arrangements and institutions. Winsberg develops interesting questions in all three branches, such as the possible deductions that non-experts can make before a consensus of specialists, the value of dissidence in research, or the nature of epistemic authority in such a plural and distributed science. Maybe it is not the field where Winsberg is a specialist, but he tackles

questions of great projection, especially taking into account the external context particularities which permeate the current climate sciences.

To sum up, the work outlined here is a compendium of the problems, discussions, and positions that Winsberg himself has carried out in recent years. It may not be a complete introduction for expert readers, but I think it may be a collection of solidly grounded notions and explanations to begin with in the philosophical study of climate science. If the reader is looking for a rigorous and cutting-edge study, it is possible that some chapters will be presented with little depth for him, with brief descriptions of the problem and little developed arguments. However, it may be useful for researchers who wish to approach for the first time the philosophy of a particular science that is socially very relevant today. For the latter case, there are chapters that can be difficult to understand without having a minimum knowledge-base on the subject, so it is advisable to have a base on general questions of the philosophy of science. For this reason, I believe that, in summary, this book can serve as a good initiation to the epistemology of the climate sciences for the reader who knows classical questions of the philosophy of science, but perhaps not at all recommendable for someone who does not already possess a basic understanding of such themes. If the reader is not an expert in this sub-field of the philosophy of science, I think it is a highly recommended book. As Winsberg himself states, this is a philosophy of a particular science, which emerged a few years ago and is now experiencing a very rapid growth. An area where epistemologists can offer valuable insight to society, as well as to other disciplines involved in elucidating and clarifying complex and novel concepts. Winsberg invites the rest of the philosophers of science who deal with adjacent subjects, advocating the need to present the fundamentals of these sciences in the light of the perennial approaches they have traditionally dealt with in our discipline.

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**Kean Birch (2018) Neoliberal Bio-Economies?
The Co-Construction of Markets and Natures. London:
Palgrave MacMillan. 208 pages. ISBN 978-3-319-91424-4**

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We can define this work of Kean Birch in two dimensions. On the one hand, it provides a discussion on one of the emerging issues in the STS field: the nature-culture relationship, and more specifically the nature-market relationship. On the other hand, it represents the synthesis of a large work from the author on the subject.

In a first moment, according to Kean Birch, we need to rethink markets and natures in order to understand the trajectories of public policies on bioeconomy in Canada. Through the co-construction between natures and economies we can understand how each process is related to the other. Thus, the question that runs through the book is: can we truly think of nature separate from the economy?

Through eight chapters, the author seeks to answer this question. However, this inquiry is more than a broad, theoretical concern, aiming at understanding the role of the bioeconomy in mitigation processes against climate change. Canada, with a strong matrix based on natural resources, is currently one of the countries making the greatest efforts to advance a sustainable future.

The author initially outlines and discusses these efforts and the related trajectory in the subject. However, based on the pieces of evidence and the complexity of this topic, he decides to suggest an innovative theoretical approach. Subsequently, the author introduces the reader to a study of political-economic materialities as an approach to socio-technical transitions and environmental

economic geography. This approach constitutes, according to the author, the basis for showing how natures and markets are co-constructed.

As a result, the author helps the reader to abandon the dichotomous visions of how the economic system “affects” nature. Neoliberalism, as the current hegemonic economic approach, also needs to be thought in spatial and temporal terms. Truly, to advance in understanding how bioeconomy ideas are placed on the agenda, Birch warns the reader that we have to think about how a “neoliberal” nature exists. Only from this vantage point, we can understand Canadian trajectory on bioeconomy. However, Birch also involves the reader in a specific story. As climate change assumes various material forms, the bioeconomy appears as a narrative, as a way of understanding a sustainable future. The author, then, gently nudges the reader into a convincing reconstruction of how this narrative is materialized. But, mainly how this materialization must be understood from a perspective based on the co-construction between natures and economies.

Birch clarifies that this is a process based on the need to think about a future, which begins from a material base and dialogues with actors and public policies. Subsequently, this process transforms the materiality and derives in a dispute of meanings. Thus, the bioeconomy (in this case in Canada) is a way to respond to these disputes, which inevitably contribute to this co-construction. Different actors put their vision at stake, either as bio-based

products, in response to substitution for fossil fuels or as a socio-technical transition. The bioeconomy, thus, is foremost a dispute of imaginaries, a search for the construction of meanings and a material basis that may complement them.

However, such a material basis is not a static concept. Different waves of materiality complement, enable or constrain future decisions (Gordillo, 2014). In the Canadian Bioeconomy, the development of R&D activities, public policies, and technological advances all proceed from the existence of materiality, which in turn legitimizes these speeches.

Previous aspects of materiality, in fact, limit this legitimating process. The consolidation of neoliberalism not only gave rise to previous materialities, such as those associated with fossil fuels. It also gave rise, to a specific extent, to a neoliberal nature. To use Birch's words, "there is no neoliberalism without nature and no nature without neoliberalism" (p.107): when politics expresses wishes, only materiality and nature allow them to take place.

This is how public policy enters the game of co-construction. As with the previous material basis, there also existed legislation that accompanied these processes, which constituted the reality of the current bioeconomy. However, this process ends up advancing in questioning sustainability in the future. When politics does take into account previous experiences, the policies designed end up possibly generating new problems, to the point that they may end up not working at all.

In this journey, which explains very clearly the role of materiality, neoliberal nature and public policy in the co-construction of the bioeconomy, the author raises the unavoidable issue of how to think about a process of transition towards sustainability. Understanding the existence of these previous elements is central since a 'neoliberal nature' enables a transition.

In the process of elaborating transitions, imaginaries come to occupy a central place. The Canadian policy, without defining major national lines, however, relies on specific imaginaries that permeate all levels of government. These imaginaries of sustainability and bioeconomy come from a global narrative but end up materializing at the local level. Therefore, a central task of the actor

is to understand these 'politicized' materialities. Understanding them makes it possible to think about the design of (alternative) sustainability policies.

Through this theoretical journey, the reader finally understands the role of advanced biofuels in the bioeconomy approach to transitions. Whilst originally biofuels came to represent the way forward now it becomes necessary to think about the value chains associated with these and see how they open a model of greater sustainability. These new technologies require, Birch warns us, the construction of new natures, neoliberal natures.

Neoliberal natures and the related policy measures that seek a transition to sustainability should be compatible with the financial system. However, Birch states: "The political-economic materialities of advanced biofuels may militate against specific forms of private investment, necessitating more direct involvement of the state in support in their expansion" (p. 183).

By the end of the book, it finally appears clear how this co-construction between markets and nature works. Thanks to the successful functioning, the petroleum-based system continues to be predominant, and also due to a matter of socio-technical and political configuration Kean Birch considers, though, that it is necessary to work on real alternatives to this production system. Since the natures and markets cannot be conceived independently from each other, any viable alternative needs to reconfigure the market as a materialized process to enable the emergence of real alternatives.

These alternatives, which we could call 'new bioeconomies', have to start from understanding this process of co-construction and move on to subvert the principles that engender current neoliberal natures. Drawing from the cases of organic agriculture and eco-economy, Birch shows how some real alternatives exist and are there to rethink these relationships and enable control of the market. Changing our perspective on what is a market can be central building alternatives.

Finally, this book reminds us of the bioeconomy as a subject within the STS field and about studies on materiality gaining momentum. Kean Birch has done a very remarkable job not only in showing

a novel and empirically relevant approach but also in presenting how materiality is a gateway to expose STS studies to a dialogic process, which complements and improves the existing debates. Last but not least, this book makes a compel-

ling argument to re-think the socio-technical approaches of STS in extended ways, where materiality will be likely to occupy an important part of the future agenda of our field of studies.

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