STREAM READINGS

SCIENCE, TECHNOLOGY AND EXPERTISE IN POLICY

INSTITUTE FOR GLOBAL LAW & POLICY
HARVARD LAW SCHOOL

THAILAND INSTITUTE OF JUSTICE

IGLP SCHOLARS WORKSHOP | BANGKOK, THAILAND | JANUARY 7 - 11, 2018

Science, Technology and Expertise in Policy

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Description

This team will focus on the relationships among science, technology, and political power in contemporary policy making. The modern state's capacity to produce and use scientific knowledge is significant both in the production and maintenance of political order and in shaping or justifying the choices faced by policy elites. We will focus on the role of scientific knowledge in policy-making oriented to environmental "sustainability."

TABLE OF CONTENTS

Science, Technology and Expertise in Policy

Science and Technology Studies

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In the late twentieth century, science acquired unprecedented power to guide human affairs; yet this was also a period when knowledge became its own chief adversary. Our capacity for generating scientific knowledge about complex phenomena exploded, but so did our capacity to understand the limits of scientific knowledge. Climate science and its role in climate governance reflect these countervailing forces. Scientists played a defining role in placing climate change on the global policy agenda, particularly through the work of the Intergovernmental Panel on Climate Change (IPCC). Their findings, however, encountered and generated uncertainty on many levels. Climate science makes predictions across vast spaces and timescales but constantly bumps up against local signals that appear to confound global claims. Significantly, too, climate science rose in prominence at a time when research on knowledge-making practices and their social and political implications—a branch of the new field of science and technology studies (STS)—was also growing in sophistication and significance. As an emergent knowledge domain and a topic of high political salience, climate science quickly attracted the attention of STS scholars, with results that illuminate but also complicate the challenges of consensus-building and rational governance.

Climate change universalizes the future of humanity (Jasanoff 2010). Never in the history of our species has a single story about the fate of the planet been told with so much conviction and expert authority; nor has any such story commanded attention from so many people positioned to understand and act upon its message. Climate science, in these respects, fulfills the promise of the Enlightenment, bringing the light of scientific knowledge to a global populace mature enough comprehend it and govern itself accordingly. In successive reports following its creation in 1988, the IPCC strengthened the claim that climate change today is anthropogenic in origin, caused by human activities that release greenhouse gases into the atmosphere. These reports also predict increasingly dire consequences for human and ecological survival. According to the Fifth Synthesis Report (IPCC 2014), unequivocal warming of the global climate is already producing impacts on human and natural systems, and these are likely to be ‘severe, pervasive and irreversible’ unless emissions are curbed and reduced.

Climate science, however, is also a postmodern phenomenon that arrived in a world attuned to ambiguity and multiple interpretive standpoints. The very word ‘science’ serves today as an umbrella for many different methods of looking at the world. Further, science increasingly serves as a tool for problem-solving in virtually all areas of human activity, prominently including environmental protection. Climate science responds in part to troubling signals from nature, such as the famous rise in atmospheric CO_2 concentrations recorded at Hawaii’s Mauna Loa observatory, but it also corresponds well to changes in scientific production that some have described as ‘Mode 2’ (Gibbons et al. 1994). Such science is characterized by its interdisciplinarity, distributed production, strong links to policy, and openness to public questioning. Moreover, climate science processes massive amounts of data, integrates hugely disparate variables, uses metaapproaches that go beyond conventional disciplinary methods, and bridges longstanding conceptual divisions between the social and natural sciences (Jasanoff and Wynne 1998, Rayner and Malone 1998). In all these respects climate science is 'postnormal' (Funtowicz and Ravetz 1992), that is, marked by high degrees of uncertainty while high-stake decisions depend on its predictions being correct and reliable.

Climate science has served STS researchers as both a site and an instrument of theoretical investigation (for example, see Beck and Grundmann this volume). This chapter reviews the resulting body of scholarship and traces its implications for governance. One broad stream of STS research focuses on explicating how climate-relevant knowledge is constructed, contested, and achieves or fails to achieve credibility. This line of work is grounded in STS's longstanding preoccupation with the construction of facts and the settlement of scientific controversies (Latour and Woolgar 1979, Latour 1987). Another stream examines the debates on climate change in order to refine STS understandings of the relations between knowledge-making and other social and political phenomena, particularly in an era of globalization. That strand of work is more closely attuned to scholarship in the STS framework of co-production exploring the joint creation of natural and social orders (Jasanoff 2004). This chapter groups pertinent contributions from both STS literatures under four themes, one pair related to controversy studies and the other pair to co-production: (a) making climate a topic for science; (b) uncertainty and ignorance; (c) relations between scientific knowledge and politics; and (d) climate science as a vehicle for world-making. Overall, this chapter argues that intellectual exchanges between those who produce facts about climate change and those who study the making of those facts has not been as mutually supportive as it might have been. That mismatch partially explains the lag between humanity's knowledge of climate change and political leaders' willingness to do more about it.

Making the climate

Scientific facts do not acquire the status of public knowledge in and of themselves, whether they are esoteric like those of high-energy physics or relatively familiar like those of public health and infectious diseases. Facts are products of painstaking social activity, based on negotiated understandings within communities of scientists about the right ways to observe nature, to represent those observations, and to make persuasive sense of what has been observed (Shapin and Schaffer 1985, Latour 1987). Until closure is achieved on a claim or set of claims—until they are, in effect, black-boxed—science remains in a zone of 'interpretive flexibility' where observations are subject to multiple competing readings and consensus remains tantalizingly out of reach (Bijker et al. 1987, Latour 1987).

Individual observations, moreover, do not add up to science. To review, assess, and validate claims, one needs what the German physician and microbiologist Ludwik Fleck (1979) called a 'thought collective'. Such a like-minded community not only authorizes members' claims and findings but also attests to the rest of the world that its ways of looking at things must be taken seriously (Shapin and Schaffer 1985). A central feature of all significant scientific work, therefore, is the determination who belongs within the relevant expert collective, and hence is entitled to speak for it, as well as who does not belong and hence lacks such authority. That partitioning process is known as boundary work (Gieryn 1999). In public decisionmaking, expert advisory committees representing varieties of stakeholders and disciplines carry out the boundary work differentiating reliable from unreliable knowledge (Jasanoff 1990). Bodies whose work involves assessing science for policy purposes have accordingly been described as ‘boundary organizations’ (Guston 2001).

In everyday or ‘normal’ science (Kuhn 1962), boundary work is relatively unproblematic: the paradigm within which a group of scientists works defines who belongs inside and who does not. Sophisticated instruments, for example, demand skills that must be acquired through training. Someone unfamiliar with x-ray crystallography cannot work a machine that bombards crystals with x-rays or correctly read the diffraction patterns produced by that technique. Someone unfamiliar with the basic principles of molecular biology cannot extract DNA from a crime scene sample and produce images that establish a match with an actual human suspect. Climate science, however, is not paradigm-driven or ‘normal’ in the sense of being grounded in one underlying theory or a specific set of instruments and techniques. Nor was it historically the product of a single community of scientists. It is a composite of many different forms of observing and recording, each with its distinctive criteria of what constitutes good or bad work. Hence, much of the boundary drawing between legitimate and illegitimate climate science has occurred through the very processes of producing integrated climate assessments, above all within the IPCC, which functions as a global ‘thought collective’ for climate science. This is also why, as the historian Spencer Weart (2008) observes, global warming could be ‘discovered’ in several different times and places before the world community generally agreed that it was happening.

Both historical and contemporary studies shed light on the emergence of ‘climate’ as a focus of scientific contestation and ultimately consensus. Historians have noted the lengthy process by which observations of local-level changes became linked to new theoretical insights and, eventually, to more systematic studies of patterned climatic and ecological behaviors. It took nearly a hundred years to get from the Swedish physical chemist Svante Arrhenius’ pioneering 1895 claim about the heating effects of carbon dioxide on the Earth’s atmosphere to NASA scientist James Hansen’s 1988 testimony to the US Senate that the ‘greenhouse effect’, caused by human activity, was occurring with 99% certainty. During that time findings from many different research fields and institutions had to coalesce into a recognizable new field called climate science or climatology. New measurement and modeling techniques also came on line, from the historical study of ice cores and tree rings to computer modeling of atmospheric and oceanic circulation under diverse assumptions about global warming.

To be sure, today’s climate science did not spring from nowhere. It rests on older local and regional traditions and infrastructures for studying the weather and other natural phenomena. In effect, our knowledge about the climate today rests on structural supports that look like any large technical system (Edwards 2010). National weather services, for example, began standardizing and consolidating their data collection and forecasting methods by the late nineteenth century, eventually working under the aegis of the

International (later World) Meteorological Organization (IMO/WMO). Regionally, in the same period, the Bergen school of weather forecasting, working under Vilhelm Bjerknes, laid foundations for modern atmospheric science through its investigations of polar events (Friedman 1989). Advances in instrumentation enabled observers to enlarge the scales at which environmental problems were understood, eventually shifting upward to a planetary frame. Satellites, computers, and other aggregating technologies were at the forefront of generating global perspectives, although they were not necessarily most adept at providing early warnings of change. Thus, the British Antarctic Survey's monitoring station at Halley Bay was the first to detect and publish large local drops in stratospheric ozone (Farman et al. 1985). By contrast, NASA's satellites were programmed to provide more comprehensive global coverage but were less sensitive to local and regional variations, and they initially did not detect the localized ozone losses (Zehr 1994).

Airborne technologies affected scientific thinking not only through data collection but by physically positioning scientists and engineers to see Earth from above. Buckminster Fuller, the pioneering US inventor and engineer, coined the term Spaceship Earth to emphasize the planet's isolation and vulnerability as a self-contained system reliant entirely on its own resources (Anker 2007). The Apollo voyages to the moon sent back images of the Earth that further underlined the need to think of the human environment holistically, yet on a global scale (Miller and Edwards 2001, Edwards 2010). The World Commission on Environment and Development predicted in *Our Common Future*, that historians might eventually conclude 'this vision had a greater impact on thought than did the Copernican revolution of the 16th century' (WCED 1987, p. 308).

If seeing the climate as a unitary, global-scale phenomenon was the result of protracted, friction-laden processes, then so too were decisions about how to represent for others what climate scientists had found. One bitter and prolonged controversy concerned the 'hockey stick graph' (Mann et al. 1999), a data representation showing a sharp increase in global mean temperatures in the past hundred years (the blade) as compared with a relatively flat average for the preceding thousand (the shaft). Easily understandable to both media and lay observers, that image became one of the most contested artifacts ever produced by climate science. Arguments about the graph's validity engaged not only the scientific community but also the mainstream press, the digital media, and leading political actors. These exchanges vividly illustrated the interpretive flexibility of non-paradigmatic science and the near impossibility of forging closure on claims when underlying interests and values remain unbridged.

The hockey stick graph gained iconic status as alarming evidence of anthropogenic climate change. Almost as quickly, however, the conservative George C. Marshall Institute and prominent industry-funded scientists swung into action, attacking Mann et al.'s methods of aggregating and representing data. The hockey stick, they argued, impermissibly flattened noisy data supporting a far less clear warming trend than claimed by the graph's creators. Not all the criticism, moreover, came from interest-tainted scientists or marginal journals (von Storch et al. 2004). In response to fierce criticism, the

IPCC and its supporters were forced to seek external validation, such as a review by the National Research Council at the request of the US Congress. Those efforts confirmed the basic observation of a significantly elevated temperature record in the last century, but it also led to changes in the IPCC's representation of the aggregate model data. The Fourth Assessment Report displayed a range of millennial reconstructions instead of highlighting Mann et al.'s graph, as the Third Report had done at considerable cost to the IPCC's credibility.

Interpretive flexibility continued to surface around many aspects of climate prediction. One such issue was the observation that, since 1998, global mean surface temperatures had not risen at rates consistent with the warming potential of the increasing amounts of greenhouse gases discharged into the environment. What caused this slowdown or hiatus (Tollefson 2014)? Skeptics charged that scientists had mistaken extreme short-term variability as a signal of much worse to come, whereas IPCC scientists countered that reliably predicted long-term trends could not be undone by short-term fluctuations. The debate revealed a deep normative gulf between those within and those outside the climate science collective. For the scientists inside, professionally committed to their field, the slowdown in temperature rise was an anomaly to be investigated, using the same techniques of data collection, simulation, and recalibration (i.e., their 'normal science') that had revealed the phenomenon in the first place. Commitment worked the opposite way for skeptics, who took the hiatus as evidence of a non-problem, warranting rejection of the entire body of knowledge generated in support of the global warming claim.

Uncertainty and ignorance

With all that science has learned about climate change, the zone of what is not known has also grown in scope and political salience. STS research on the methods by which science seeks to bound the areas of non-knowledge is particularly relevant to issues of governance. When scientific claims are politically contested, a favored way to forestall burdensome action is to suggest that we do not know enough and need more research. Therefore, science's power to compel action frequently depends on scientists' success in rendering uncertainties irrelevant, invisible, or manageable. Put differently, black-boxing knowledge claims is equivalent to reducing or erasing the uncertainties around them. By the same token, opponents of a consensus position can destabilize it by getting experts to present counter-narratives and manufacture doubt (Oreskes and Conway 2010, Grundmann this volume).

STS studies have documented a number of methods by which science manages and contains uncertainty. One powerful technique is to express results in numerical form. The precision of numbers conveys an aura of definiteness, belying the inevitable choices and judgments involved in translating complex phenomena into mathematical terms. Numbers can provide more information in some respects than ordinary language, enabling comparison with a baseline or between discrete events. To say that an earthquake is severe tells us less than to say that an earthquake, such as the one that hit Fukushima in 2011, measures 6.6 M_w on the moment magnitude scale that seismologists use to measure earthquake strength. Lay people may not understand how such a number was calculated but they can easily understand relative degrees of severity when expressed on a numerical scale. Numbers in short are deemed trustworthy in ways that naked human judgment is not, even when the judgment is that of experts (Porter 1995).

Numbers can also function as ‘anchoring devices’ that offer apparent certainty in the face of shifting knowledge. One such device, the measure of ‘equilibrium climate sensitivity’, or average temperature rise from concentrations of atmospheric greenhouse gases, offers an instructive example. Van der Sluijs et al. (1998) showed that the estimate of 1.5°C-4.5°C increase in warming for a doubling of CO_2 remained constant over a roughly twenty-year period, until the IPCC’s Third Assessment Report, even though the underlying ideas and measurement techniques changed significantly. Moreover, participants in the IPCC process acknowledged that this was not an ordinary probability distribution, with a most likely peak and less likely tails. Indeed, as one participant observed, climate modelers were unable to offer probability limits as their colleagues would have liked, with the result that, ‘The range is nothing to do with probability—it is not a normal distribution or a skewed distribution. Who knows what it is?’ (Jasanoff and Wynne 1998, 70). Only with the Fourth Assessment Report did the IPCC introduce a slight modification in its estimate of climate sensitivity, raising the lower limit of the likely range to 2°C.

Models are ubiquitous in environmental policy—as instruments for simplifying complex systems, exploring causal hypotheses, and simulating future events. As such, they played a crucial role in representing climate change and managing the uncertainties associated with climate predictions. Most significant are the General Circulation Models (GCMs), computer programs that enable the aggregation of vast amounts of data about the Earth’s atmosphere and simulation of responses under different assumptions about the dynamics of the system. Much has been written about the imperfect relationship between models and the realities they purport to mimic, perhaps most dramatically summed up in the philosopher Nancy Cartwright’s provocative remark that models are ‘a work of fiction’ (Cartwright 1983). Nonetheless, as STS scholars have argued, models offer assurance in a variety of ways that are highly relevant to crafting policy.

On the plus side, models allow for constant refinement, or validation (Oreskes et al. 1994), to improve their consistency through comparison with actual observations about the world. In this respect, models operate as a theater of action in which scientists can closely approximate the real-world phenomena whose decoding is essential for human well-being and survival. On the less benign side, models may engender a false confidence that all of what needs to be known is contained within the inner workings of the model itself. Models operate in this sense almost as promises: that truth can be approximated ever more certainly simply by learning more about the parameters of the model (Jasanoff and Wynne 1998). Even when modelers themselves are keenly aware of uncertainties in their models, humility tends to be washed out in representations to outsiders, such as politicians who have a stake in using scientific knowledge for action (Lahsen 2005). This observation led the sociologist of science Donald Mackenzie (1990, p. 372) to propose a ‘certainty trough’, in which those at a middle distance from the origins of models are more certain about their conclusions than those closest in to the technical complexities of modeling and those least knowledgeable and thus alienated from the centers of expertise.

As part of the knowledge infrastructure for policy, climate models moreover are not merely technical but *socio*technical systems (Edwards 2010). STS scholars have stressed the social element because it helps explain the dilemmas that climate predictions raise for policy. Modelers, to begin, are not merely credentialed experts, garbed in priestly authority, but people with strong beliefs and commitments of their own. The human dimension of climate modeling forcefully emerged into public view during 'climategate', the controversy resulting from the 2009 disclosure of hacked e-mails from the Climatic Research Unit (CRU) at the University of East Anglia (Beck this volume). Climate modelers' intimate doubts were publicly aired, as in a statement by Phil Jones, then CRU director, 'The scientific community would come down on me in no uncertain terms if I said the world had cooled from 1998.' Jones legitimately downplayed his concern by questioning the statistical significance of a few years of cooling data (Ridley 2014), but the disclosures proved politically corrosive.

Knowledge and politics

In the modern world, knowledge is doubly political: as a resource in political battles as well as a site for performing politics (Baert and Rubio 2011, Jasanoff 2004). Given its significance for policies of worldwide dimensions, climate science was bound to attract both kinds of political attention, and so it did. Much of the attention focused on the IPCC, whose Working Group I had given a political voice to climatology. STS research sheds light on the sources and limits of the IPCC's epistemic authority; that research also raises questions about STS's own role in shaping how science influences politics and policy.

In STS terms, the IPCC sees itself as a 'boundary organization' (Guston 2001) whose task is to 'provide rigorous and balanced scientific information to decision makers.'[1] Yet, from the IPCC's inception the scientific assessment of climate change has never been distant from the epicenters of climate politics. As a joint creation of the UN Environment Program and the World Meteorological Organization, the IPCC was born a hybrid. Its establishment reflects in part the advances in climate science and assessment that a number of largely Northern scientific communities wished to carry forward with governmental support. At the same time, the IPCC enhanced the UN's status as a transnational voice for global environment and development policies. Assessment and policy were tightly coupled in the founding documents describing the IPCC's raison d'être and mission. Thus, while stressing the need for better knowledge, the WMO resolution supporting the IPCC's creation also noted a 'growing international concern about the possible socio-economic consequences' of increasing greenhouse gas concentrations.[2] The General Assembly, too, picked up the theme of 'potentially severe economic and social consequences' in its 1988 resolution endorsing the IPCC.

STS research has established that scientific advisory committees are forced to make policy judgments even when their formal charge is to assess science (Jasanoff 1990, Lentsch and Weingart 2011). Under these conditions, seeking legitimacy in science alone may prove counterproductive. Some have argued that advisory organizations may serve policymakers better by blurring boundaries between science and politics than by insisting

[1] Quoted from IPCC Home Page (Organization).
[2] WMO Resolution on Intergovernmental Panel on Climate Change (1988).

on a rigid separation (Guston 2001). Others see it as more important to clarify the adviser's role as an 'honest broker' of available knowledge (Pielke 2007). These analyses invite scientific advisory committees to be more aware, indeed self-aware, with respect to the complex relationship between facts, values, and expert judgment in policy-relevant science. Nevertheless, the IPCC sought from the start to base its authority primarily on scientific rigor, claiming that 'The work of the organization is […] policy-relevant and yet policy-neutral, never policy-prescriptive'[3] (see Beck this volume).

Over time, the IPCC changed its procedures, broadened its reviewer base, sought both technically and politically accountable experts, and ensured more participation by developing countries (Agrawala 1998). This evolution illustrates the phenomenon of co-production (Jasanoff 2004), whereby a new state of knowledge (global climate change) was certified as authoritative along with the social order (norms of global inclusion) needed to sustain that new way of seeing the world. Yet, when the IPCC comes under challenge, as in the controversies over hacked e-mail and errors such as assessing the rate of Himalayan glacier melting, the organization's tendency has been to retreat into traditional modes of scientific authorization: tighter conflict of interest guidelines, better means of expressing uncertainty, stricter peer review, and renewed calls for transparency (InterAcademy Council 2010).

Testimony before the InterAcademy Council convened to review the IPCC process illustrates the imperfect uptake of STS scholarship and its inconsistent application to climate assessment. Hans von Storch, a respected German meteorologist and occasional critic of the IPCC, quoted Silvio Funtowicz and Jerome Ravetz, arguing that climate science has entered a postnormal state: 'When *facts are uncertain, values in dispute, stakes high and decisions urgent,* **science is not done for reasons for curiosity but is asked for as support for preconceived value-based agendas**' (emphasis in von Storch presentation).[4] He concluded, however, that this bending of science toward politics must be countered through a separation of scientific and political functions within the IPCC and a stricter demarcation between 'scientifically constructed' and 'culturally constructed' knowledge. That recommendation perpetuates the presumption of a given-in-advance boundary between science and culture, contrary to basic STS observations that such boundaries are the results, not the precursors, of collective fact-making (Gieryn 1999, Jasanoff 1990). It also misses Funtowicz and Ravetz's (1992) key recommendation that postnormal science demands 'extended peer review', enlarging the community of critics to include interested and affected parties—a prescription long enshrined in US administrative law (Jasanoff 1990).

The InterAcademy Council's analysis of the right way to fit science and politics resonates well with a strand of research that attributes the IPCC's credibility problems to the corruption of science by political interests. In the United States, in particular, documented ties between the fossil fuel industry and dissident scientists on a range of environmental issues has led some to conclude that scientific consensus would carry the day were it not for the willful corruption of knowledge by politics (Oreskes and Conway 2010). Here, the

[3] IPCC Home Page (Organization).

[4] Hans von Storch, Presentation to IAC Review Committee, Montreal, 15 June 2010, PowerPoint available at http://reviewipcc.interacademycouncil.net/.

distorting influence is money, not 'culture' as in von Storch's analysis, but the conclusion is similar: what the IPCC needs to do in order to regain authority is to weed out corruption, whether inside its own house or outside the assessment process, in society.

That analysis may be comforting for the IPCC, but it dangerously simplifies a more symbiotic relationship between the production of policy-relevant knowledge and its public uptake and acceptance. STS research emphasizes that the persuasiveness of scientific knowledge depends not only on the circumstances of its production but also on the context of its uptake and spread in society (Shapin 1995, Shapin and Schaffer 1985). This is especially true of science that serves policy and hence is more than usually subject to the deconstructive forces of public scrutiny (Jasanoff 1990, 2012). To achieve credibility, then, climate science like any other policy-oriented science needs to pay attention to the cultural circumstances that aid or impede public acceptance of its claims. These conditions include diverse 'civic epistemologies'—or public ways of knowing (Jasanoff 2005)—that vary even across modern Western liberal democracies. These interdependencies between the context and content of scientific production help explain why an event such as the disclosure of CRU's hacked e-mails led to more consternation and policy skepticism in some countries than others, affirming different national narratives about climate change, the IPCC, and the need for collective action (Jasanoff 2011).

Climate science and world-making

The IPCC emerged in the late twentieth century as an agent of political as well as epistemic globalization, an actor that imagined and represented the Earth as a unitary construct needing integrated governance rather than as a space of competing sovereignties ruled by agreements among nation states (Miller and Edwards 2001). In part, as seen above, this relocation of the locus of envisioning and power was achieved through the infrastructural moves that created climate and climate science in the first place (Edwards 2010). Space-based technologies played their part. As the World Commission on Environment and Development (1987, p. 308) stated in *Our Common Future*, 'From space, we see a small and fragile ball dominated not by human activity and edifice but by a pattern of clouds, oceans, greenery, and soils.' This declaration represented the planet not only as a unified whole but also as a composite of interacting physical and biological 'systems' whose functions and futures could, in theory, be modeled without deference to 'human activity'. Science, in short, was henceforth to be the primary tool for knowing the Earth; political consequences would follow from what science discovered and dictated. That presumption was built into the IPCC's organizational structure: Working Group I, the chief focus of attention to date, would assess the science; Working Groups II and III would follow with their impact studies and mitigation options.

Any radical displacement of the standpoint for knowing a major social problem, however, entails a corresponding displacement of politics—by reshaping the discourses, institutions, and identities associated with the shifts in knowledge (Jasanoff 2004). STS scholarship, broadly conceived, provides several different angles on the political implications of the epistemic move embraced in *Our Common Future*. As early as the 1970s, when technologies of earth-system modeling were first taking off (Meadows et al. 1972), thoughtful critics noted their ideological dimensions. Models, as STS analysts have repeatedly observed, cannot in their nature be policy-neutral (Jasanoff and Wynne 1998). Specifically, seeing Earth whole and in systemic terms implied both the capacity and will to engage in such grand panoptic exercises (Ashley 1983).

The emergence of climate change as a universal, impersonal, and apolitical imaginary also carries profound ethical significance. Seen as a collective phenomenon, aggregated at the global level, climate change reduces the possibility of attributing responsibility to agents at lesser scales, such as specific nations or forms of consumption. Yet, resistance to that leveling of responsibility has plagued climate negotiations from Kyoto in 1997 to Lima in 2014. Developing countries continue to contest the (in their view) spurious egalitarianism that sets lower per capita emissions from populous poor nations on a par with higher per capita emissions from nations with smaller populations but more profligate consumption habits. Bruno Latour (1993) has argued that the separation of nature from culture, in this case the dissociation of atmospheric carbon from the activities that produce it, is a constitutional move of modernity, and it needs to be undone with greater respect for the actual hybridity of nature-culture networks (Neimanis et al., this volume). But the idea floated by Indian environmentalists Anil Agarwal and Sunita Narain (1991) to do just that, to classify, price, and tax carbon differentially in accordance with its human purposes—subsistence versus luxury—never gained traction in climate negotiations.

More subtly, climate science tends to undermine people's age-old attempts to make sense of their circumstances in local terms, based on close-to-home understandings of space, time, community, and rightful governance (Jasanoff 2010). To be sure, climate change urges all people on the planet to think globally (Edwards 2010). Yet, one must ask what forms of agency and autonomy can be taken away from people in the name of science, and which philosophical foundations (e.g., utilitarian or deontological) to adopt in answering those questions. What, for example, are the ethical and political implications of requiring people to shoulder burdens now for the sake of as yet unborn future generations when their families are suffering from hunger and need for shelter or fuel? Such questions loom even larger when mature scientific disciplines cannot decide how to relate present needs to future demands. That dilemma gained the spotlight in a debate among prominent environmental economists over the right discount rate for estimating the long-term impacts of climate change (Jasanoff 2010). The American economist William Nordhaus dismissed as too 'prescriptive', and hence presumably not scientific enough, the assumptions in the influential Stern Report on the economics of climate change commissioned by the UK government (Stern 2006).

A comparable debate has opened up around geoengineering. The difficulty of obtaining political agreement in climate negotiations has led some to argue that technological means must be found to counter extreme warming (Keith 2013). Two major types of geoengineering are most frequently discussed: solar radiation management and carbon dioxide capture, followed by storage (see Hansson et al. this volume). Both carry risks, and both raise large and as yet unresolved questions of ethics and governance. Going beyond the usual barrage of factual claims and counterclaims, scholars trained in STS ways of thinking have called attention to the world-making assumptions latent in proposals to engineer the Earth (Hulme 2014, Stilgoe 2015). In this debate, one may find hopeful signs of an integration of STS insights into discussions of how to move forward in the face of intractable uncertainty and ignorance.

Conclusion

The evolution of climate science and its increasingly significant role in climate governance reads in many ways like a playbook for STS: it illustrates almost every phenomenon that decades of STS research have identified as key characteristics of modern scientific production and use. First, it took more than a century of work to build the edifice known today as climate science; even now that edifice consists of a series of more or less tightly connected sub-structures occupied by communities living to some degree under rules and conditions that do not apply to the entire thought collective. Second, as with all attempts to shift paradigms, the emergence of climate change (displacing the slightly older construct of global warming) was deeply contested, generating epistemic uncertainties and fractures that still remain unhealed. Models played a crucial role in both the recognition of a global phenomenon and prediction of its consequences, but the results display the strengths and weaknesses of modeling as an instrument for making sense of the world. Third, the production of climate science cannot be teased apart from the dynamics of climate politics, a point that the IPCC and its defenders seem not to have fully accepted but that is influencing debates on geoengineering. Fourth, and most significant for governance, predicting climate change is but one face of a process of co-production that has remade people's normative expectations about how to live in a world in which climate is a major driver of change.

The most surprising feature of climate change from an STS perspective concerns what is called reflexivity: the capacity of a society or its members to reflect and act upon knowledge of their role as agents in a larger whole. STS has many stories to tell about climate science. The fossil fuel industry's efforts to manufacture debate, even on issues the great majority of climate scientists consider closed, is one but it is not the only one. That account of industry-fueled deconstruction does not do justice to the legitimate doubts and uncertainties that surround climate impact predictions, nor to the culturally heterogeneous ways in which societies come to grips with polarizing interest group politics. In elevating the corruption story above others, climate science risks ghettoizing itself as a community unwilling to accept deeper criticism of its methods of consensus-building. In reverse, the tale of science for hire, uncomplicated by other strands of STS research, tends to shore up tendencies within STS to be seduced into intervening in policy debates instead of maintaining critical distance as a source of reflective insight and clarification.

Decades ago, the renowned German sociologist Ulrich Beck (1992 [1986]) called for contemporary societies to engage in a process of reflexive modernization to take responsibility for the risks and uncertainties created through the global spread of advanced technologies and the dissolution of traditional institutions of governance.

Climate change, more than nuclear power and other preoccupations of the 1980s, raises most of the dilemmas that Beck articulated in his conception of the 'risk society'. STS studies offer illuminating perspectives on the nature and consequences of knowledge and non-knowledge of the risks of climate change, stressing the need for joint resolution of metaphysical and ethical concerns. A crying question for climate governance is whether ruling institutions will absorb and act on STS analyses of the contingency of knowledge and its normative implications—or whether answers placing an undue abundance of faith in science and technology to solve the climate problem will preclude our taking full ethical responsibility for our common future.

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Critical Policy Studies
Vol. 5, No. 2, July 2011, 187–200

Making climate change governable: accounting for carbon as sinks, credits and personal budgets

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This article explores how climate governance is accomplished in practical terms. To that end we develop an 'analytics of carbon accounting' that draws attention to the calculative practices that turn stocks and flows of carbon into objects of governance. Carbon accounting as a rationality of government is primarily concerned with the ways in which carbon can be measured, quantified, demarcated and statistically aggregated; but the concept also alludes to questions about (political) accountability in relation to emissions of greenhouse gases. The paper outlines three different regimes of carbon accounting – 'the national carbon sink', 'the carbon credit' and 'the personal carbon budget' – to illustrate how stocks and flows of carbon are constructed as administrative domains amenable to certain forms of political and economic rationality, such as government regulation, market exchanges and self-governance by responsible individual subjects.

Keywords: carbon accounting; climate policy; governmentality; sinks; credits; budgets

Introduction

How is climate governance accomplished? Or put differently, how can we conceptualize the processes by which climate change is governed? While such questions draw attention to the practical aspects of steering, they are often neglected in contemporary scholarship on, say, climate diplomacy and treaty-making, comparative climate policy and non-state governance. Concerned with 'who gets what, when, how' (Lasswell 1958) within and beyond the interstate negotiations, the contemporary study of climate politics has given surprisingly little attention to the practices that, in Oels' (2005, p. 185) words, 'render climate change governable'. This paper, by contrast, stems from an effort to understand *how* climate governance is accomplished in practical and technical terms. Rather than asking whose interests dominate the making and implementation of climate policy, or which governance arrangement is more effective or just, we are interested in the regimes of practices that make it possible for different actors to govern the climate in the first place. In particular we examine the techniques, tools and methods that have turned carbon into a coherent object of governance.

Against this backdrop, the paper outlines an 'analytics of carbon accounting' that explores how the climate domain is constituted as governable and administrable. In our view, contemporary climate governance hinges on the ability to account for stocks and

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ISSN 1946-0171 print/ISSN 1946-018X online

DOI: 10.1080/19460171.2011.576531
http://www.informaworld.com

flows of carbon. During the past century extensive natural science research has gone into the making of precise estimations of the global cycling of carbon between the atmosphere, the terrestrial biosphere and the oceans. As we will argue, these accounting practices do not take place outside politics. Rather, we approach carbon accounting as a governmental rationality that turns stocks and flows of carbon into objects of governance. This constitutive process requires that the global cycling of carbon can be translated from the realm of nature into the realm of the social and the political. Carbon stocks and flows are not 'pre-given, lying there waiting to be revealed. They have to be constructed and made visible' to use Miller and Rose (2008, p.14) formulation. The cycling of carbon has to be 'stabilized', i.e. located in spaces (e.g. national territories) and in objects (e.g. carbon credits) that make sense within a political discourse.

Inspired by Foucauldian governmentality studies (cf. Miller and Rose 2008), an 'analytics of carbon accounting' asks us to look beyond grand political schemata or economic ambitions and instead draw attention to the seemingly humble and mundane mechanisms (e.g. techniques of notation, accounting, auditing) that have turned carbon into a governable reality. It is an analytical approach that investigates how the every-day work of UN officials, scientific experts, auditors, verifiers, consultants and brokers give carbon emissions, produced by different people in different geographical sites, a certain degree of stability and comparability, and, at the same time, translate stocks and flows of carbon into artifacts (e.g. sinks, tradable credits, footprints, benchmarks) amenable to political intervention. In contrast to the burgeoning literature on climate governance (Biermann *et al*. 2010), the approach advanced here does not seek value the legitimacy or effectiveness of different carbon accounting schemes. Neither does it represent an outright critique of the managerial expectations tied to the human ability to monitor, administer and contain 'the wild, unknown powers of Nature' (Luke 1997, p. 90). The value of an analytics of carbon accounting is rather its emphasis on the processes of governing. By asking how the climate is rendered thinkable and governable, we may get a sense of the contingent and fragile nature of contemporary climate governance arrangements and hereby make critique of the seemingly self-evident or necessary possible.

In the following, we approach carbon accounting as a rationality of government that insists on the 'counting of carbon', and sets out ways in which carbon can be measured, quantified, demarcated and statistically aggregated. Hence, carbon accounting is more than a technical term. It refers to a form of rule that has given rise to particular ways of 'seeing' and 'knowing' the climate. In line with Boyd (2010), we suggest that it is necessary to attend to the actual manner in which particular scientific and technological 'ways of seeing' render problems comprehensible for political regulation. Only when investigating the intrinsic links between ways of knowing a phenomenon and ways of acting upon it, is it possible to understand how certain forms of governance become possible, and why they sometimes fall apart.

The paper is organized as follows. The first section outlines our 'analytics of carbon accounting' based on general insights from the literature on governmentality (e.g. Dean 1999, Miller and Rose 2008) as well as inspired by other examples (agriculture, geology and forestry) of *how* governing is made possible through representation and accounting procedures. We then exemplify our argument by outlining three different regimes of carbon accounting – 'the carbon sink', 'the carbon credit' and 'the personal carbon budget'. These three examples illustrate how carbon is constructed as administrative domains amenable to certain forms of political and economic rationality, such as government regulation, market exchanges and self-governance by responsible individual subjects. The concluding section brings these seemingly disparate empirical realms together and reflects on what they imply for our understanding of 'the political' in an increasingly carbon-constrained world.

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An analytics of carbon accounting

The theoretical departure for this paper is broadly the literature on governmentality. Since first sketched out by Michel Foucault in the 1970s (see Foucault's lectures from Collège de France in Burchell *et al*. 1991), the governmentality concept has been used and developed across numerous disciplines such as critical sociology, history, cultural studies and political geography (Rose *et al*. 2006, Rose-Redwood 2006). As indicated by the semantic linking of the words governing and mentality, Foucault's neologism draws attention to how we *think* about governing. Central to this analytical approach is the assumption that the ways in which we *represent* reality are intimately linked to the ways in which it is *acted* upon and governed. From this vantage point, the art of governing extends well beyond the practices of governments. Although states and their political apparatuses remain important, they are not approached as the only locus of power. Studies of governmentality are more often focused on the dispersed practices, techniques, calculations, methods and instruments that render various aspects of reality amendable to government intervention (Rose-Redwood 2006). Originating from the every-day work of, for instance, psychiatrists, social workers, accountants, economists, and spatial planners, such regimes of practices are often regarded as something that exist outside of politics. However, governmentality studies remind us that government does not only operate in relation to spaces defined and demarcated by geographical or territorial boundaries. Practices of government are just as much confined to zones formed through the circulation of artifacts, technical practices and devices (Barry 2001, p. 3).

Our analytics of carbon accounting builds upon this broad notion of politics and government. It is an approach that asks *how* climate governance is accomplished by examining the calculative practices that constitute carbon as a stable object of governance. In an essay on economic markets as calculative collective devices, Callon and Muniesa (2005) propose a three-step definition of calculation. Crucially, at the end of an accomplished calculation, a new entity will be produced. The entity could be a sum, an ordered list or an evaluation that corresponds to what has been carried out in the calculative space and that links and summarizes the entities taken into account. The resulting entity is not new in the sense of springing from nowhere, but it 'has to be able to leave the calculative space and circulate elsewhere in an acceptable way (without taking along all the calculative apparatus)' (Callon and Muniesa 2005, p. 1231). Further, in a formulation that speaks to students of climate governance, 'the most appropriate dividing line is no longer between judgement and calculation, but between arrangements that allow calculation (either quantitative or qualitative) and those that make it impossible' (Callon and Muniesa 2005, p. 1232). As will be clear in the next section, the calculative production of 'carbon artifacts' (like sinks, credits and carbon footprints) is crucial for the ways in which it today is possible to govern the climate.

Our analytics of carbon accounting draws inspiration from a range of studies (particularly in political geography) that have sought to understand how nature is constructed as a domain for political and economic calculation. Following Michel Foucault's rethinking of government and writings on the rise of biopolitics in eighteenth-century Europe, Murdoch and Ward (1997) have, for instance, examined the importance of statistics as a technology of government that makes visible domains of life that were once invisible. In a study of British agricultural reform during the twentieth century, they show how the use of statistical representations and accounting procedures brought agriculture into being as a formal economic sector that, in all its diversity, could be conceptualized as a 'national farm' open for coordinated state intervention (Murdoch and Ward 1997). In a similar manner Braun (2000) has illustrated how the introduction of geological surveys in nineteenth-century Canada ordered and classified the Canadian landscape in ways that allowed the imagining of the nation as a single geological specimen. Through the circulation of maps, reports and specimens, Canada was reinvented as a 'mineral nation' and hereby drawn into global circuits of extractive capital (Braun 2000, pp. 24–25).

This linkage between the making of 'knowledge spaces' and 'economic spaces' is further illustrated in Agarwal's (2005) study of forest management in colonial India. He argues that when modern statistics, surveys and inventories were introduced in the nineteenth century, forested lands were constructed as a domain fit for modern government. The statistical representation of forests (e.g. volume, area, value, percentage of tree cover) allowed foresters to establish commensurability in their results and thus imagine Indian forest land as an economic resource managed by performance indicators such as yields and revenues (Agarwal 2005). Rose-Redwood (2006) refers to geographical knowledge practices of this kind as 'geo-coding'. Through means of inscription (e.g. maps, statistics, surveys), geographical knowledge codes or orders abstract space and hereby constructs the very objects of government as something 'knowable'.

Although Foucault's work on biopolitics drew attention to the means by which *the population* became visible as a problem of government through the development of statistical techniques, geographers have taught us how the same kind of mechanisms are used to understand and construct nature and territory as new domains of political and economic calculation. Just as the population is represented as an aggregated whole with certain regularities (e.g. rates of birth, death and illness) in the modern European state, Elden (2007) notes that the land it inhabits also is something that is understood in terms of its geometric, rational properties or 'qualities'. From this vantage point, territory is more than land. According to Elden (2007, p. 578) it must be viewed as 'a political category; owned, distributed, mapped, calculated, bordered, and controlled'. Hence, what counts as territory does not precede its construction (Braun 2000, p. 28).

Whereas it may be tempting to ascribe this ordering of territory to a central government, Miller and Rose (2008) warn us not to overestimate the unity of such calculative practices. Following Foucault's open definition of government (i.e. the conduct of conduct), they urge us to look beyond the state as the single point of origin or locus of power and instead start the analysis from the practices of governing themselves. By focusing on the heterogeneous assemblage of mechanisms, techniques and knowledges by which the natural and social world is represented, categorized and ordered, it is possible to map out the multiple centers of calculation and authority that shape the conduct of individuals in modern society (Miller and Rose 2008, p. 20). Although these knowledge practices may seem disparate and weakly linked, they establish shared vocabularies, theories and explanations among agents across time and space. When doing so these technologies of government construct fields of visibility that shape and normalize the thought, aspirations and conduct of others. Hence, by paying attention to the actual mechanisms that make it possible to govern, an analytics of carbon accounting helps us to analyze how 'the technical itself has a politics' (Rose-Redwood 2006, p. 482).

Even though the history of carbon government is very brief, it illustrates the constitutional role of technical practices and devices. Paraphrasing Andrew Barry (2001, p. 10), we argue that any analysis of climate governance that does not consider 'carbon accounting' – i.e. the technical practices and devices that order and stabilize stocks and flows of carbon – runs the risk of missing half the picture. In the following section we illustrate how carbon accounting, as a rationality of government, operates through three examples from the climate governance landscape. We examine how techniques for calculating, reporting and verifying flows of carbon 1) within national borders, 2) in the carbon marketplace, and 3) at the level of the individual human body have made it possible to imagine the national

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sink, the universal carbon credit and the personal carbon budget as coherent objects of governance.

Regimes of carbon accounting: sinks, credits and personal budgets

To most observers it may seem natural to talk about climate change as a global phenomenon in need of global solutions. This 'way of seeing' the climate problem has a long history that dates back to early twentieth-century efforts to represent the global-scale cycling of elements such as carbon (Lotka [1924] 1956), and the rise of post-World War II carbon cycle science (cf. Boyd 2010). During the International Geophysical Year (IGY), jointly sponsored by the World Meteorological Organisation (WMO) and the International Council for Scientific Unions (ICSU) from 1 July 1957 to 31 December 1958, a systematic series of geophysical studies spanning the globe from North to South fed empirical data into emerging efforts to model the global carbon budget. Among the more famous measurements introduced during the IGY was the first permanent monitoring station for CO_2 installed on the Hawaiian volcano Mauna Loa. The Mauna Loa station measures atmospheric concentrations of carbon dioxide and the resulting graph is an iconic representation of *global* climate change. The graph displays a steep upward trend of atmospheric concentrations (measured as parts per million, ppm) of carbon dioxide. This metrics is one of many practical efforts to know and represent the Earth as one homogenous, natural, unit of account and is representative of a wide range of scientific knowledge practices that have structured the contemporary climate policy discourse.

The understanding of the climate as a global system affected by human greenhouse gas emissions was advanced by the United Nations in the early 1990s, and is today manifested by a long series of UN agreements such as the United Nations Framework Convention on Climate Change (UNFCCC), the Kyoto Protocol and the Copenhagen Accord. We argue, though, that there is nothing fixed or given about the climate as a social category. Far from constituting a field of readily intelligible objects, Braun (2000, p. 15) reminds us that nature 'enters into history' partly through its cultural legibility. And indeed, a study of the brief political history of the climate suggests that it can be read in many different ways. In parallel to political efforts to establish the climate as a global concern, we have during the past decades seen a range of alternative spatial representations of the climate as an arena for local (Bulkeley and Betsill 2003), regional (McGee 2006) and transnational (Bulkeley 2005, Andonova *et al*. 2009) action. Although these attempts to rethink the climate as political space have raised questions about the rationality of interstate arrangements, we argue that they have gained authority only to the extent that they have been underpinned by credible carbon accounting techniques that have stabilized this new spatial grammar as something knowable and operable. 'The national carbon sink', 'the carbon credit' and 'the personal carbon budget' represent three examples of such accounting.

The national carbon sink

In conventional political analysis the space of government is typically conceived of in terms of a relation between a national population and a national territory. The inside of the nation-state is the proper home of politics and the citizenry, and this is the space where democratic government is possible. Outside the borders of the nation-state is the international domain and the site for theories on regimes, common pool resources and inter-state diplomacy. Whether conceived of in terms of anarchy or hegemony, the international domain is typically understood as a political space where democratic government is not possible (Lövbrand and Stripple 2006, Barry 2001, p. 2). Although this distinction between the inside and outside of the nation-state has been subject to extensive scholarly debate and critique (Walker 1993, 2010), it still works as the central epistemological principle through which world politics is understood and ordered. From this vantage point the spatial understanding of carbon as a complex global cycling appears both theoretically appealing and politically challenging.

For scholars of international relations, the imagining of the climate as global space emerges as a vantage point from which the territorial organization of world politics can be analyzed. Practitioners of climate diplomacy have, however, been faced with the practical challenge of molding global flows of carbon onto territorial ground. In order to govern the climate in an effective manner, a range of climate experts have since the adoption of the UNFCCC been engaged in a complex methodological process to adjust the climate to the territorial borders of the signatory states. According to Article 4.1 of the UNFCCC (UN 1992), all parties to the convention are required to develop national inventories of their sources and sinks of greenhouse gases and to report the results on a regular basis to the UNFCCC secretariat in Bonn. Although this national greenhouse gas (GHG) accounting made little sense to carbon cycle science at the time, it was the direct result of the interstate negotiations in the early 1990s. In order to allocate responsibility for climate mitigation efforts among the negotiating states, it was necessary to first know how much carbon is emitted and sequestered within respective state borders. Hence, the global cycling of carbon between the atmosphere, oceans and land – long a preoccupation for climate scientists – had to be broken down into the conventional geopolitical grammar of the nation-state.

In order to make these GHG inventories comparable across national borders, the Intergovernmental Panel on Climate Change (IPCC) has, since the early 1990s, been engaged in an effort to develop guidelines for national GHG reporting. As clarified in the introduction to the revised 1996 IPCC guidelines, common reporting instructions are needed in order to accommodate inventories that have been developed at different levels of detail and with different methods. As a consequence all states are asked to account for their emissions and removals according to a standardized set of definitions, units and time intervals (see IPCC 1996). While these standardized reporting procedures were designed to keep track of national emission trajectories and thereby to facilitate the political negotiations leading up to the Kyoto meeting in 1997, these carbon accounting practices also held great promise for large emitters with substantial forest areas. Drawing upon results from atmospheric transportation models and biomass inventories in high to mid-latitude forests, a number of states in the Northern hemisphere such as the USA, Canada and Russia saw great potential in a net accounting and reporting system that would allow them to subtract the amount of carbon stored in biomass and soils from their annual GHG emissions. Although this net accounting system turned into a central part of the compromise deal in Kyoto, it became the subject of intense negotiations in the years that followed the Kyoto meeting (for an overview, see Lövbrand 2009, Boyd 2010).

When the negotiating parties reconvened in the convention's Subsidiary Body of Scientific and Technological Advice (SBSTA) in June 1998, a number of questions of a technical kind were raised. Which land use categories should be included in a net accounting system? How should a forest be defined? From which base year should land-based carbon removals be calculated? How should states best factor out carbon uptake resulting from natural processes rather than direct human-induced land use activities? While the answers to these questions may seem highly technical and thus outside the

domain of the political, we should not underestimate their political effect. As we have argued elsewhere (Lövbrand and Stripple 2006, Lövbrand 2007), the very idea to monitor and report *net* emissions of GHG on a national basis not only redirected the spatial and methodological focus of the carbon cycle science community. The development of standardized definitions and accounting methods for changes in terrestrial carbon stocks also made it possible to compare very different kinds of carbon measurements across time and space, and thus establish 'the national carbon sink' as a credible object of governance.

Hence, rather than challenging the territorial grammar of the nation-state, much of the techno-scientific infrastructure of the UN climate regime has worked to reinforce it. Or, as expressed by Paterson and Stripple (2007, p. 149), the politics of climate change is not transnational or 'beyond the state' to the extent that is often assumed in scholarly debates. Instead, a dominant element in the social construction of climate change has been a discourse of territory and territorialization that is 'singing climate politics into existence'. By this expression, Paterson and Stripple allude to an aboriginal tradition of 'singing the world into existence' (Smith 2004), which illustrates how the world that we take for granted is dependent on social categories. Territoriality as a social category has legitimized climate politics by rendering it intelligible to state elites, while, simultaneously, circumscribing the range of possible responses.

The carbon credit

Carbon markets have emerged as the major response to climate change. Since early proposals for international emissions trading schemes in the late 1980s (Grubb 1989, Barrett *et al*. 1992), global carbon transactions have become more than social imagining. As a result of the Kyoto Protocol's Clean Development Mechanism (CDM), the EU Emission Trading Scheme (EU ETS), and the proliferation of regional carbon markets in North America and Japan, as much as 8,700 million tons of carbon dioxide equivalents were, in 2009, traded by public and private actors to a total value of US$143,735 million (Kossoy and Ambrosi 2010, p. 1). While carbon markets are rapidly being entrenched around the world, the disciplines of political science and international relations have yet to develop a conceptual understanding how the worldwide commodification of carbon 'hangs together in the international sense', to paraphrase Ruggie (1998, p. 855).

Many studies have been occupied with understanding *particular* carbon markets. There are vast research agendas on the EU ETS (Skjaerseth and Wettestad 2008), the CDM (Paulsson 2009), and emerging carbon trading schemes in the United States and elsewhere. The particularities of the voluntary carbon market have gained increasing interest (Lovell 2010), as the possible designs of a new mechanism for forest carbon commodification (Boyd 2010). But, most contemporary work tends to conceptualize carbon markets as individual species, as specific policy instruments, and if they are researched in a comprehensive way, this is usually done with the ambitions to outline how they can be formally linked, while their 'family resemblance' is seldom acknowledged (for important exceptions, see Newell and Paterson 2010, Lohman 2005). An analytics of carbon accounting, by contrast, offers a way to capture the carbon economy in wider terms without into losing sight of individual markets. Drawing upon Foucauldian governmentality studies, this approach insists on conceiving power and politics without the state as the necessary locus, origin and outcome. The analysis of power in the carbon economy instead starts from the practices of governing themselves (e.g. forms of calculation, ways of categorizing projects, the emergence of standards).

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The growth of carbon markets has implied the establishment of a range of new carbon units. The European Union Allowance (EUA), the Certified Emission Reduction (CER) and the Verified Emission Reduction (VER) are just some of the many labels currently used to conceptualize the transfer of one ton of avoided or sequestered carbon dioxide emissions from one part of the world to another. Central to the imagining of such carbon transactions is the idea that reductions of greenhouse gas emissions (translated into standardized and comparable carbon dioxide equivalents) have the same atmospheric effect wherever they are carried out. Although the activities underpinning the avoided emissions may involve different people under very different circumstances, climate science tells us that a ton of carbon dioxide equivalents (1 tCO_2e) has the same climatic effect regardless of its location on Earth (Stripple and Lövbrand 2010). This imagining of an atmospheric mixing of carbon can be traced back to a long series of developments within meteorology and biogeochemistry during the past 100 years (for an overview, see Weart 2003). However, the invention of the fictional and interchangeable single ton of carbon, the 'tCO_2e', is also the result of the many calculative practices performed by UN officials, auditors, verifiers, consultants and brokers in the carbon marketplace. Through their every-day efforts to make carbon transactions operational, the 'tCO_2e' is today known as a 'thing', a basic unit of account, often understood to be a commodity, but increasingly also conceptualized as a currency.

Paterson and Stripple (2010a) have mapped out five crucial moments in the commodification of carbon. The *first* moment is the invention of the 'tCO_2e', the basic unit of account, which has become adopted in almost all carbon markets to date. The *second* is the proliferation of this unit into several 'asset classes'. The *third* moment is one of commensuration, the making of measurement devices and methods of calculation that specify how any specific ton of carbon should be accounted for across markets. The *fourth* moment is the conceptualization of what might be called the 'Boutique' carbon commodity in reference to over-the-counter markets where specific products find their niche and where direct buyer-seller relationships are important. By contrast, the *fifth* moment is that of what can be called the 'Wallmart' carbon commodity, which enters into fully commodified markets that involve much more abstract relationships between buyers and sellers, and that deploy a full range of financial instruments such as arbitrage and derivatives (Paterson and Stripple 2010a).

According to Callon (1998, p. 19) transforming something into a commodity requires it to be decontextualized, dissociated and detached. So where did the 'tCO_2e' come from? Contrary to what a functionalist argument would hold, the unit was not simply defined by regulators to have something to trade in the carbon economy. The unit was prefigured through the development of the Global Warming Potential (GWP), which enables different greenhouse gases to be compared within single metrics. The GWP unit emerged through the attempts, in the aftermath of Kyoto negotiations, to make states' obligations to reduce greenhouse gas emissions comparable and accountable. Post-Kyoto negotiations had to come up with measures that could level the playing field and make it possible to achieve the same thing (climate mitigation) through very different national strategies (for a fuller account, see Paterson and Stripple 2010a, McKenzie 2009). The Marrakesh Accord from 2001 codified 'certified emission reductions', 'assigned amount units', and 'emission removal units' in legal terms and, for the first time, these were named and known with characteristic three letter acronyms (CER, AAU, RMU), a practice that further underlined their thing-like quality. The 'tCO_2e' was hence invented as a fictional unit, an Archimedean point of reference that enabled commensurability and exchangeability with other units.

What we see now is that the 'tCO_2e' proliferates into new forms. It leaves particular calculative spaces (factories, projects, kitchens, cap-and-trade markets, bodies etc.) and

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Table 1. Compliance and voluntary carbon markets.

Carbon markets	Compliance market	Voluntary market
Cap and trade	Kyoto Emissions Trading (IET),	Chicago Climate Exchange (CCX)
	EU ETS, New Zealand ETS, Australian ETS, Regional greenhouse gas initiative (RGGI), California Climate Registry (CCAR),	Japanese Voluntary ETS
	Personal carbon allowances (PCA),	Sector no-lose targets (SNLTs)
	Tradable energy quotas (TEQ), Cap and share (C&S)	Carbon reduction action croups (CRAGs)
Baseline and credit	Clean development mechanism (CDM), Joint implementation (JI)	Voluntary carbon offsetting

circulates around the world as an abstract unit, a commodity. Table 1 below illustrates how carbon markets proliferate through the replication of calculative techniques and rules that aim to measure, report and verify flows of carbon throughout the global economy. Sometimes these flows are measured vis-à-vis a baseline (e.g. in the CDM of the Kyoto Protocol) and other times vis-à-vis an absolute level, a 'cap' (as in the EU ETS).

The personal carbon budget

In recent years, there has been a veritable explosion of projects designed to enable individuals to 'do their bit' in the struggle to limit climate change. Previously, the focus of action had been on states and firms, but in the early 2000s attention turned towards individual practice. This brief section will review *five* different ways in which flows of carbon have been articulated as 'personal carbon budgets' that can be, for example, reduced, compensated or traded. Although carbon accounting technologies that operate on the level of the individual are different from the ones earlier presented, the imagination of a 'personal carbon budget' rests on a similar calculative capability that assumes that one can account for the carbon footprints of individuals in relation to a totality of a country, a region, or the world.

Paterson and Stripple (2010b) outline and compare five different practices that aim at calculating, measuring and accounting for emissions of greenhouse gases at the level of the individual (footprinting, offsetting, dieting, rationing and trading with carbon rationing action groups or through a system of personal carbon allowances). These five sets of practices are *problematizations* of individuals' emissions of carbon dioxide. According to Miller and Rose (2008, p. 4), the term 'problematization' draws attention to the process by which things are rendered problematic. Rather than approaching problems as pre-given, issues and concerns have to be made to appear problematic in order to be governable. The problematization concept thus implies that there are intrinsic links between ways of representing and knowing a phenomenon, on the one hand, and ways of acting upon it as to transform it, on the other (Miller and Rose 2008, p. 15). Problems have to be rendered thinkable in order to be governable. The common denominator in the five problematizations outlined by Paterson and Stripple (2010b) is the focus on individual practice in relation to climate change. Through various accounting practices, individual carbon emissions are rendered problematic and are hereby possible to act upon.

As a regime of carbon accounting, personal carbon budgets are principally interesting because they shape individual subjects through exhorting them to manage their climate-related practices themselves. The core argument in Paterson and Stripple (2010b) is that there is an emergent government of carbon that molds and mobilizes a certain subjectivity (the individual as carbon emitter). Online carbon calculators or voluntary carbon dieting schemes compel individuals to govern their own emissions in various ways – as counters, displacers, dieters, communitarians, or citizens. Such carbon governmentality is enabled through calculative practices that simultaneously totalize (aggregating social practices, overall greenhouse gas emissions) and individualize (producing reflexive subjects actively managing their greenhouse gas practices). Paterson and Stripple (2010b) call this biopolitical carbon governmentality 'My Space', and the metaphor is suggestive of how the forms of individualization in these projects operate through the sorts of communicative practices involved in 'Web 2.0' technologies, such as My Space, Facebook, Twitter, Jaiku, Tagged and Flickr. At the same time, the phrase implies the appropriation of climate change for an individual subject, who thinks of 'her/his emissions' and responsibilities regarding them, but also is forced to account for her/his carbon space in relation to others through practices involving peer-pressure, comparison, and communication.

It is striking how the modern account of citizenship affects the problematization of the individual carbon emitter. Paterson and Stripple (2007) suggest that carbon consumers over the world often are territorialized rather than individualized. Individual CO_2 contributions are routinely calculated on the basis of national emissions, and then divided by the number of people living in that particular state. Rice (2010) points to a similar process in her study of greenhouse gas mitigation practices in Seattle. In this urban setting, local governments engage individuals in their climate policies by appealing to 'the good carbon citizen' (Rice 2010, p. 935). Rice (2010, p. 930) illustrates how carbon accounting practices enable 'carbon territories', which she defines as the 'active creation and quantification of bounded and ordered spaces of carbon-producing activities and simultaneous reproduction of local government jurisdictional capacities'. A relationship between the production of GHG emissions and specific urban activities is established through the use of GHG inventories and emissions monitoring. Rutland and Aylett (2008) argue that these territorial practices are at the heart of contemporary governmentality. When individuals internalize the carbon metrics of the state, and 'base their actions on these metrics, they become part of a network of self-regulating actors' (Rutland and Aylett 2008, p. 631).

Miller and Rose's (1990) term 'government at a distance' (inspired by Latour's (1987) 'action at a distance') captures how calculative practices of this kind operate on a distance and affect actions in places and by people who are not subject to any direct control. By making individual contributions to anthropogenic climate change visible, and hereby rendering individual greenhouse gas emissions problematic, personal carbon budgets constitute responsible subjects who come to think and act in new ways in relation to the climate. In line with Miller and Rose (2008), Dowling (2010) usefully cautions against reading too much inevitability into these subject-formation processes. The fully formed neoliberal (calculating, self-focused, rational) subject also 'enters into history' through its cultural legibility (Braun 2000, p. 15).

Conclusion

While much of the contemporary studies of climate politics focus on whose interests dominate the making and implementation of climate policy, or new forms agency and sources of legitimacy in climate governance, the approach outlined in this article is slightly different. We have raised questions about the *how* of climate governance; how climate governance is accomplished in practical and technical terms, how stocks and flows of carbon are turned into stable and comparable objects of governance, and how individuals govern their own emissions through the adoption of certain subjectivities. The advantage of our approach is that the analysis does not start from an *a priori* assumption about the distribution of power in world politics, a certain location of power (the state) or a certain understanding of the location (local, national, international) of the political with regard to climate change. Rather, the analysis starts from the constitutive practices of governing themselves (e.g. forms of calculation, ways of categorizing, the emergence of standards).

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We have outlined an analytics of carbon accounting to explore one key means through which climate governance is accomplished. Carbon accounting as a governmental rationality insist on the 'counting of carbon' and allows stocks and flows to be measured, quantified, demarcated and statistically aggregated. We have argued that these calculative practices enable certain ways of seeing and knowing the climate, and hereby turn carbon into an object of governance. Carbon accounting, here understood as the technical capability to give carbon flows, produced by different people in different geographical sites, a certain degree of uniformity and comparability, is thus a necessary step in order to make climate change governable. However, the concept also alludes to larger questions of accountability in relation to emissions of greenhouse gases. How do we act upon the emissions that we measure? What kind of politics is enabled? The latter questions have been implied, though not directly addressed, in our examination of three different regimes of carbon accounting – 'the national carbon sink', 'the carbon credit' and 'the personal carbon budget'. Through these examples we have illustrated how stocks and flows of carbon are transformed into administrative domains amenable to different forms of political and economic rationality, such as government regulation, market exchange and self-governance by responsible individual subjects.

It is fascinating how fast innovations in climate governance have occurred. Since the Mauna Loa measurements started in 1957, and climate change was established as a global phenomenon, new ways of seeing and knowing the climate have gained ground. Artifacts such as sinks, credits, benchmarks and personal budgets have in a few years become new objects of government through which political interventions emerge. Forests and soils, industry installations, and even human bodies are now established as sites of climate governance in ways that were very difficult to imagine just 15 years ago. How effectively these new governance arrangements respond to the challenge of climate change will most likely be a central matter of debate in the years to come. As a result of the Mauna Loa measurements of atmospheric carbon, we now understand the climate problem in terms of parts per million: 270 ppm marked the end of the pre-industrial era, and 377 ppm is where we are today. Four hundred and fifty ppm is estimated to be the level below which we need to stay in order to avoid (with reasonable assurance) a global temperature increase of more than two degrees Celsius, though 350 ppm might be what is really needed to avoid dangerous interference with the climate system (van Vuuren *et al*. 2011).

It is striking that the rather abstract and detached '350' was the name of a large campaign and organizing theme of social movements in the run-up to the Copenhagen climate negotiations in December 2009. While abstract and technical, the carbon accounting practices initiated in Hawaii in 1957 currently seem to determine the realm of the possible in climate governance. The kind of political analysis advanced here is not designed to value the legitimacy, nor the effectiveness, of carbon accounting as governmental rationality (although we agree that such analysis is important). As argued by Gordon (1991, p. 46), Foucauldian governmentality studies are ill equipped to transform the current agendas of political debate, or to generate new plans for the organization of society. The aim of our analytics of carbon accounting is, more modestly, to offer scholars and practitioners of climate governance a practical basis for political debate and imagination in the post-2012 era. When drawing attention to the mundane accounting practices that currently make the climate governable, we find that they are more contingent, recent and modifiable than most of us may think.

Acknowledgements

The authors would like to thank Frank Fischer, Matthew Paterson and two anonymous referees for their thoughtful comments on earlier versions of this paper. We are also grateful for comments from the participants at the 5th Interpretive Policy Analysis Conference in Grenoble, June 2010, and the Transnational Climate Governance workshop at Durham University, September 2010. The study has been made possible through financial support from BECC, the Swedish government's strategic focus on climate change hosted by the Faculty of Science at Lund University; the Low-Carbon Energy and Transport Systems (LETS) project, financed by Swedish Environmental Protection Agency (among others); and the Linköping University LiU FoAss programme.

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