WHO AUTHORS FUTURE ENVIRONMENTS?
PUBLIC ENGAGEMENT WITH EMERGING ENVIRONMENTAL TECHNOLOGIES IN THE ANTHROPOCENE

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The Anthropocene, the geological epoch where human activity is visible in geologic strata, is often framed with a coming-of-age story: Society must use its new knowledge about earth systems to play an active role in earth stewardship. In some versions, this extends to taking responsibility for designing or managing ecological processes. However, designing or managing ecosystems increasingly involves using emerging technologies for environmental modification that may require specialist expertise or high capital, provoking questions of who has the ability to choose, use, or design these technologies. This dissertation explores four "ecotechnical imaginaries" on varying scales: (1) "negative emissions technologies" such as bioenergy with carbon capture, which are included in climate models; (2) the "blue revolution", or new forms of ocean-based food and energy production; (3) restoration or management of California's Salton Sea; and (4) solar geoengineering in the Arctic.

The key question addressed in this dissertation is: By what means or processes can citizens have more agency in intentional environment-making? Fifty-five extended interviews were conducted, primarily in Finnish Lapland and California's Imperial Valley, to explore citizen and stakeholder perceptions of opportunities for public participation in environmental decisions and design.

From looking at these four imaginaries together, three major themes emerge. First, public engagement with environmental futures often takes the form of rationally selecting between ready-made options. This "selectability" fits with familiar forms of participation in contemporary life, such as shopping, clicking, and representative democracy. Agency construed as an ability to choose is a very limited form of agency, and actors are generally constrained from shaping environmental technologies themselves. However, civil society actors do work on generating compelling narratives and metrics to improve the selectability of particular futures. Following on work by STS scholars, sociologists, anthropologists and human geographers, who have observed that anticipations of the future are made through practices of quantifying, performing, and imagining, I trace how selectable environmental futures are produced by multiple actors through mutually constitutive combinations of metrics and narrative in these four imaginaries.

When citizens are able to shape which options are selectable, there is greater room for other important processes of ecological future-shaping, such as making and taking responsibility. The second key theme involves how the narrative of responsibility in the Anthropocene should be modified to deal with entanglements like burden and agency, and to emphasize response. Selection between futures in a moment of decision cultivates a type of one-off responsibility that curbs agency in the long run. I join other sociologists of the Anthropocene in calling for a continual notion of responsibility, which focuses on responsibility as not a moment of taking the right decision among predetermined options, but as responsibility as a continual process of care and maintenance that recognizes labor and agency.

The third major theme is that the imaginaries are serving purposes other than their stated purpose. In this case, rather than deploy climate engineering, restore the Salton Sea, or harness ocean life and energy, the work done by these ecotechnical imaginaries serves other ends besides material transformation: legitimating business as usual or states, performing responsibility without taking it, haunting the climate policy discussion and strengthening the case for other climate pathways, providing jobs for professional calculators, and creating speculative investment in the moment, among others. Social science that looks at imaginaries across scales can help illustrate the work these imaginaries do, which can help citizens shape them towards different ends. The conclusion argues that the selectable and calculable nature of these ecotechnical imaginaries belies the fact that certain disciplines have more privilege in constructing the future, and that an interdisciplinary field of "future studies" grounded in empirical work from fields like sociology, anthropology, and human geography is much needed to better make and take continual responsibility for ecological flourishing.

BIOGRAPHICAL SKETCH

Holly Jean Buck grew up in the designed community of Columbia, Maryland, and graduated from the University of Maryland, Baltimore County with a Bachelor of Arts in English. She holds a Master of Science in Human Ecology: Culture, Power, and Sustainability from Lund University in Lund, Sweden. Prior to her graduate study at Cornell, she worked as a foreign affairs analyst in the US Department of State's Office of the Geographer, a surveyor and radar operator for a remote sensing company, and a Writing Fellow at Naropa University in Boulder, Colorado. She and her partner have one daughter, River Jean.

Dedicated to the New River

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List of Abbreviations

BECCS	Bioenergy with carbon capture and sequestration
CDR	Carbon dioxide removal
DAC	Direct air capture
EEZ	Exclusive Economic Zone
IPCC	Intergovernmental Panel on Climate Change
NETs	Negative emissions technologies
RCP	Representative concentration pathways
SRM	Solar radiation management
SSMP	Salton Sea Management Program

Introduction

1. Research questions and rationale

The Anthropocene, an epoch defined by human activity in the geologic record, is seen by some as a moment where humans have entered responsibility for nature. As Bruno Latour writes, modern people thought "the future was one of greater and greater detachment from all sorts of contingencies and cumbersome ties. Free at last!" Yet with our attachments to the biosphere becoming explicit, we now face "the weaving of careful attachments with an ever greater and greater list of explicitated beings ... Attached at last! Dependent! Responsible! " (2007: 3).

Now that humans are self-aware about the Anthropocene, global society may decide to move to a more sustainable pathway, suggest some earth system scientists. "We are the first generation with the knowledge of how our activities influence the Earth System, and thus the first generation with the power and the responsibility to change our relationship with the planet," write Steffen et al (2011)— notably, the responsibility here is to change a relationship, implying social change. This responsibility for social change derives, at least in part, from the new scientific knowledge, not simply from a moral source. Given what is known, directing the future towards a kind of planetary stewardship is no longer a mere possibility, but an imperative. On the other hand, post-Cartesian social science critics often express skepticism about this need for design— and about the whole Anthropocene narrative. It has instrumentalist tendencies, and it folds everyone together, obscuring inequality and the environment-shaping done by capital (Malm and Hornborg, 2014; Moore, 2014). Meanwhile, other social scientists — such as myself — are intrigued by the idea and what responsibilities it could open up, even while recognizing the limitations.

The Anthropocene as blurring, time-warping, dramatic rupture of a "thought-event" (Colebrook, 2013) is riddled with questions of agency. Capacity for directing social (environmental) change is up for dispute. Latour exclaims that "Suddenly, agency and historicity are in the glacier!" Ironically, agency in terms of intentional individual action on global situations, such as climate change, is stripped away or made irrelevant at the very time "we" are realizing geologic agency. Shaping the sort of Anthropocene we are in is possible, I argue, through making and taking of collective responsibility and agency — but the ability to engage in these collective processes is not a given. Rather, it is constrained by social structures, vested interests, and inherent scalar tensions, as these chapters illustrate.

My thinking in this dissertation is broadly aligned with Robbins and Moore, who suggest an all-of-the-above approach to the question of agency, writing that novel Anthropocene ecologies are "simultaneously 1) *gardens* of our own crafting albeit, in the words of Emma Marris, wholly unruly and rambunctious ones, 2) *monsters* born of our tinkering albeit, in the words of Bruno Latour, ones deserving of our love, and 3) as sites of *struggle*, albeit in the words of Neil Smith, ones of production and accumulation."

(2013: 12). That is, modified or engineered landscapes are all of these things at once, and I look at how citizens are addressing landscapes, climates, and even oceans as gardens, monsters, and sites of struggle.

Because so much of the emergent capacity to shape environments faster, more dramatically, and with different labor inputs than ever before relies on new technologies, this dissertation considers agency in ecological modification through the language of "emerging technologies", while simultaneously pointing out that the focus on "technologies" has its limitations. In this dissertation, I explore ecological sociotechnical imaginaries related to climate engineering, lake restoration, and ocean management. Many of these are better construed as practices rather than technologies or artifacts. But while the technics are available, the social, cultural, and political ability to take on new responsible and responsive roles or practices is less certain.

A major premise of this work is: If we are indeed at a unique moment of responsibility and caretaking, we need to understand much more about the social aspects of building future environments. Failing to do can result most mildly in unrealized, ineffective, or failed designs, and more gravely in the use of environmental technologies that are blind to environmental justice and exacerbate harms to people.

Hence, the key question in this dissertation is: By what means or processes can citizens have more agency in intentional environment-making? Citizens can (1) participate in developing the technologies that enable environment-making, or (2) directly participate in the selection process between different futures through formal deliberative processes. Opportunities for these two forms of participation, however, are often limited, and the examples in this dissertation showcase several limiting factors. I explain that there is a third important avenue for citizen participation in environmental future-making: to participate in generating compelling narratives or metrics to make particular futures "selectable", i.e. to do storytelling work to influence which options get on the table.

These five chapters share a similar storyline: the Anthropocene is characterized by a technocratic, or top-down, or metrics-heavy vision of future environmental action, and also a bottom-up or participatory alternative (which is typically conducive to or promotional of procedural and recognitive environmental justice). The tension between these two visions is not just one found in environmental governance literature in the wake of neoliberalism, or in science and technology studies — foundational threads of this binary, such as rationality or calculability, have been a central theme in sociology through the Frankfurt School back to the days of Weber and Simmel. The idea in this dissertation, however, is expressly not to simply set up and recite a familiar and formulaic binary in several different contexts. Neither do I want to absolutely privilege the bottom-up over the technocratic. While my sympathies lie in some regards with Thomas's "futurology from below" (2015), even "below" publics and citizens are constructed. Arguments that some of the ecological challenges we face could be better managed by experts or technocrats are also considered.

Instead, I explore: In which ways do these formalized or bureaucratic or rational visions and structures *interact with* human beings or grassroots organizations — or even lively nonhumans or climates? Where are those interactions surprising or productive, and where do they run aground? I explore this through four examples of ecological sociotechnical imaginaries: the engineered landscape of California's Salton Sea, imaginaries of solar geoengineering, the idea of the "Blue Revolution" in ocean commodity production, and the rise of "negative emissions technologies" in climate models. Each of the chapters weaves in new insights about these different "ecotechnical imaginaries", and the selection process between them.

Below this inquiry, at a foundational level, are sub-questions: How are expectations of the future made, and how do futures become "selectable"? What actors are driving some imaginations and possibilities and precluding others? How might these particular imaginaries shape Anthropocene ecologies in specific places? I argue that "selectable" environmental futures are produced through combinations of metrics and narrative. This follows on work by STS scholars, sociologists, anthropologists and human geographers who have observed that anticipations of the future are made through, as Anderson observes, practices of performing, calculating, and imagining (Anderson, 2010). I focus on the interplay of calculation and narrative, and in particular, the notion of "options" and option-making.

This dissertation works with several big concepts: agency, responsibility, participation, selectability, citizenship, environmental justice, design, scale, metrics, narrative, and umbrella categories of "emerging technologies." They are not all treated with equal attention. In general, the concepts which relate most closely to environmental sociology are given more weight, and concepts from neighboring fields like geography (scale, landscape), science and technology studies (emerging technologies), design, or the humanities (narrative) are given somewhat less attention than agency, collective responsibility, and participation. This disciplines the dissertation in a way that I hope is helpful. The choice of emphasis is not because these concepts are more important than the others; rather, it is a matter of audience and contributing to specific sub-fields. In the following section, I contextualize the contributions of this dissertation within the specific bodies of literature it is in conversation with, introducing some distinct concepts from the literature that will be used as flexible tools throughout the dissertation. The third section reflects on the methods used, and the fourth section introduces the five chapters by means of explaining what insights they bring to the research questions.

2. Contributions of this dissertation to scholarly literature

Social science on climate engineering

This dissertation makes specific contributions to two bodies of literature, and draws from and is in conversation with a third.

The most specific contribution of this work is to the social science literature on climate engineering. It joins the empirical social science literature — a small body of sociological work which is often conflated with the larger climate engineering governance literature. Much literature on climate engineering governance is implicitly or explicitly based upon the image of the self-interested rational actor, which appears as a specific kind of citizen (e.g Barrett, 2014; Victor, 2008; Bodansky, 2013; see review by Harding and Moreno-Cruz, 2016). Moreover, even the empirical work on climate engineering often asks respondents to compare the technologies as essentialized artifacts without any social context — a legacy perhaps of the foundational 2009 report on climate engineering by the UK's Royal Society, which set out a taxonomy of climate engineering methods and attempted to comparatively assess them. Much of the literature on climate engineering governance is speculative and not based upon empirical research; of the empirical social science research that exists (about 30 studies), around half use deliberative methods (Burns et al, 2016)[1]. Only one other study (Carr, 2015) uses semi-structured interviews. I argue that qualitative and deliberative methods potentially have a lot more to contribute to how climate engineering is conceptualized, researched, and governed than the present body of literature indicates. This is not a novel suggestion —

[1] About fifteen deliberative studies have been done with regards to solar geoengineering in the last 8 years; see Bellamy and Lezaun (2015) for an excellent review. They have characterized these deliberative investigations into two "waves." The first wave was encompassed in the 2010 *Experiment Earth?* dialogue, which formed geoengineering as a discrete object of deliberation. A second wave of public engagements aimed to "unframe" geoengineering: to unsettle assumptions, and allow for a diversity of approaches and framings of climate engineering to avoid "locking in" geoengineering as a concept— as Bellamy and Lezaun explain, this was a "a deliberate response to the perceived role that public engagement was beginning to play in reifying geoengineering as a tangible technological future" (2015). Strategies for "unframing" included asking respondents to consider geoengineering alongside mitigation and adaptation, or other broader considerations about climate and social and political systems (Bellamy et al, 2014, Macnaghten and Szerszynski, 2013). The method of semi-structured interviews used in chapter five allowed respondents to essentially unframe geoengineering themselves, by allowing respondents to guide the conversations along the lines of other preferred strategies for coping with or combatting climate change.

others have called for more deliberative social science research or upstream public engagement (Carr et al, 2014; Burns and Flegal, 2015; Burns et al, 2016). However, this work is another attempt to fulfill that call in practice.

Three of the chapters in this dissertation bring new insights to this small but growing body of literature. The first chapter reviews the social science literature on negative emissions and calls for existing work on biofuels, afforestation, CCS, and energy transitions to be applied to the topic: this is not a particularly radical argument, but it was the first review of the social science on carbon removal technologies. The fourth chapter looks at negative emissions in a particular context, as embedded in a landscape, which was a new thought-experiment in imagining particular ways ecotechnical imaginaries may manifest — it builds on the first chapter to highlight issues around environmental justice and participation through a concrete case.

Both chapters four and five explore on the relationship between place and perceptions of climate engineering, which no other studies have looked at. This focus encourages exploring the social context in which climate engineering might be used. Chapter five is a genuine addition to the literature in two ways: it is the first work to explore how place is related to perceptions of solar geoengineering, and it brings up the issue of how citizens perceive geoengineering differently than state or other elite interests do. In sum, the three chapters in this dissertation help fill gaps in the climate engineering literature related to the social context in which climate engineering might be used, how citizen views can diverge from expert or elite views, and how these global imaginaries are seen through local lenses.

Sociology of the Anthropocene

This dissertation's second contribution is to the growing interdisciplinary body of literature on the Anthropocene, a concept which has intrigued human-nature geographers, anthropologists, earth system scientists, political theorists, humanities scholars, and also sociologists. As Lorimer describes it, the Anthropocene is "a wider intellectual event: a flurry of activity with far-reaching ontological, epistemic, political and aesthetic consequences"; this event-space has been termed the "Anthropo-scene," and it serves as both a boundary object and "charismatic meta-category" (2017: 118).[2] This wave of interest has produced a crop of new titles on how to make sense of, inhabit, or shorten this epoch (Haraway, 2016; Tsing, 2015; Alaimo. 2016). The concept has also garnered popular attention (see titles by Vince, 2014; Ackerman, 2015; Biello, 2016; Grinspoon, 2016): as Lorimer notes, it has "captured an *intellectual zeitgeist*, providing a plastic and catchy label for a common curiosity and anxiety about the state and future of Earth after the 'end of Nature'" (2017: 121).

In this dissertation, I am broadly interested in social questions of design. There are many vocabularies for discussing the role of design — with regards to

[2] Lorimer's 2017 review in *Social Studies of Science*, "The Anthropo-scene: A guide for the perplexed", is a helpful review which puts forth a typology of five ways the concept has been mobilized: as scientific question, intellectual zeitgeist, ideological provocation, new ontologies and science fiction.

geoengineering, we have seen a shift from climate engineering to climate intervention. However, I prefer design over engineering or intervention because I believe it is more aspirational than engineering, more personal than intervention, and more adaptive than planning. As Ross et al write, in terms of ecosystem design,

> Design is the broader plan where goals are set, actions are taken to achieve goals, and failures and success are studied and incorporated into the next iteration. In this framework, architecture is design and construction is management; in essence, design is strategy and management is tactics. As such, we consider adaptive management and related approaches as design processes. (2015)

In this view, design encompasses a visioning process, and that is what the chapters of this dissertation are interested in: whose visions for future environments are on the table, and how are they executed? Part of this discussion involves questions of expertise, and here I draw from Appadurai's comments on design in social worlds. Appadurai notes that "Most ordinary people do not experience their social worlds as either planned or designed. They experience these worlds as given, as external to them, as relatively fixed, and as largely indifferent to their own preferences or desires" (2013: 253). Yet daily life is produced through effort, imagination, and deliberate investment; so "from this point of view, design is only partly a specialist activity, confined to an artisanal or digital class, and is better seen as a fundamental human capacity and a primary source of social order" (254). Appadurai is writing about both design of objects and of social order, but in the Anthropocene, this broad thinking could be extended to ecologies as well. Industrial capitalism, he observes, brings a double gap — a gap between professional design and the quotidian design of daily life, and "a growing gap between design, as substantially confined to the realm of the marketed commodity, and *planning*, an activity connected with cities, states and empires" (256). I am interested in how to lessen these gaps, and in particular, how technologies can be designed to lessen them. Appadurai emphasizes that design is something that everyday people do: "ordinary people are already involved in both planning and design as part of their efforts to achieve dignity and equity in their lives" (267). This is largely the sensibility I take through my work, while discussing the various factors, from institutions to technologies, that might inhibit people to express this inherent capacity for design in their environments.

One specific contribution this dissertation makes to the sociology of the Anthropocene literature is on the theme of responsibility for designing environments. While the Anthropocene narrative has been critiqued for the ways it universalizes the agency of the "human" species, occluding how particular actors created the Anthropocene(e.g. Malm and Hornborg, 2014), the narrative that the Anthropocene is a time for taking responsibility has some appeal to both critics and promoters of the concept. As Arora writes, "Within this debate, however, there seems to be substantial agreement that humans must urgently bear the responsibility to address climate change and to reduce their geological impact" (2017). However, there is some slippage between the forwards and backwards dimensions compressed into "responsibility." Backward-looking responsibility includes accounting for past harms, which many seem to be on board with in theory. Earth system scientists have articulated a backwards-and-forwards type of stewardship: as explained by Steffen et al, it "entails emulating nature in terms of resource use and waste transformation and recycling, and the transformation of agricultural, energy and transport systems" (ibid). For Palsson et al, responsibility is one part of "a 'radical' change in perspective and action in terms of human awareness of and responsibility for a vulnerable earth – a 'new human condition,' to paraphrase Arendt (1958)" (2013). But when it comes to taking responsibility for ecological functioning, in terms of modifying nature or control-driven formulations of stewardship (Arora, 2017), "responsibility" becomes a controversial claiming of something.

Indeed, the Anthropocene literature is replete with ways of looking at responsibility. One is entanglement, as brought up by Latour. Donna Haraway writes about kinship and making-kin. More broadly, in terms of future responsibilities, Adam and Groves write that "responsibility requires that we involve ourselves in *tending* to a relationship by providing what is needed by another person or persons." This form of non-reciprocal responsibility is associated with care: "Care is therefore both future directed and, in the first instance, always attached to specific individuals. It is thereby specifically directed toward their futures, and is therefore tied to futures which are embedded in distinct contexts of concern. Consequently, it constructs lived and living futures" (2011). Karen Barad writes of relationship as well, explaining that "Responsibility is not an obligation that the subject chooses but rather an incarnate relation that precedes the intentionality of consciousness"; not a "calculation to be performed" but an "iterative (re)opening up to, an enabling of responsiveness" (2010).

Yet responsibility is not the same thing as being able to respond — an entity might have responsibility for some socio-environmental situation, but not be able to mount a response. Conversely, not all responses are responsible. Responsiveness brings up questions both of capacity and of agency. As Gibson-Graham and Roelvink write, references to millions of years "now endow us with gargantuan agency and an almost unbearable level of responsibility—intuitively beyond our capacities for rational or concerted action" (2009; see also Lidskog & Waterton, 2016).

While I also look at responsibility in these terms of care, tending, and relationship, building on the work of these theorists with some concrete examples, I'm primarily interested here in how responsibility interacts with agency. I define agency as the ability for action, focused here upon action that shapes one's future — not to *select* it, or to choose a particular option, but to engage in material or discursive practices which create its substance. It can be produced by social structures and enabled by technology; it can also be constrained by them. When it comes to shaping future environments, in some cases, a lack of power precludes actors from taking responsibility for shaping their environments, and also for having agency in their environmental futures (agency and responsibility in this case are roughly equivalent). In other cases, power allows actors to avoid responsibility for ecosystem management (agency enables irresponsibility). There's also a way in which taking responsibility might look like "appropriation of planetary agency for humans", bringing into question of the agency of nature (Arora, 2017). Indeed, I see nature as having agency — much as Mitchell writes about how "nonhuman agencies enter into human partnership not just as passive elements to be costed and arranged, but as dynamic and mobile forces with their own powers and logics" (2002: 299). But while the literature features rich multi-faceted discussions of responsibility and agency, it rarely looks at these as entwined social processes.

Responsibility as a social process: Where is the sociology of responsibility?

While responsibility is a concept elaborated in jurisprudence or ethics, when it comes to responsibility as a social process — how it is made or taken — there is surprisingly little writing. Responsibility is a stowaway within the Anthropocene literature, but rarely is it a focus of sociological work, though there are some exceptions through the years. Strydom (1999) reviews the history of responsibility, tracing it to a postwar crisis of consciousness among scientists. He describes how in the 1960s a new sense of responsibility emerged gradually, in tandem with new environmental and social movements. Strydom suggests that "a shift has occurred from traditional emphasis on individual responsibility, which sociologists like Durkheim, Weber, Parsons and even Habermas took for granted, to a new conception of collective or co-responsibility"; he treats responsibility as a new master frame (ibid.). Whether this has actually happened, or if this is Strydom's longing, is unclear. But the concept of co-responsibility, which brings a public level of responsibility without disburdening individuals of their individual responsibilities, is a useful one for our discussions.

Giddens also engages with responsibility, writing of responsibility as a multi-layered term which only seems to have come into English in the late eighteenth century; he names it “a notion associated originally with the rise of modernity” (1999). He writes about it mostly in conjunction with risk, explaining that risks only exist when there are decisions to be taken, and the idea of responsibility presumes decisions: “What brings into play the notion of responsibility is that someone takes a decision having discernable consequences” (Giddens, 1999). The transition from external to manufactured risk is bringing about a crisis of responsibility, because the connections between risk, responsibility and decisions are rearranged.

Beck, too, engages with responsibility in a limited way, writing about organized irresponsibility, describing a system where social processes and institutions collaborate to create risks without being held responsible for the consequences or damages from their actions (Curran, 2016). Climate change is often held up as a prime example (see Beck, 2015). Responsibility has also been touched on in conjunction with neoliberal environmental governance. Pellizzoni (2004) writes about four dimensions of responsibility — care, liability, accountability and responsiveness — in terms of environmental governance, illustrating how the caring state has been replaced by new arrangements focused on liability and accountability, and largely fails at responsiveness.

Even though these writers have engaged with responsibility, it has not emerged as a coherent and sustained theme for sociologists, particularly with regards to responsibility as a social process. There are several possible reasons why: (1) Responsibility has been considered in other domains: philosophy for the moral dimensions; law, and science and technology studies / responsible innovation in future-oriented policymaking. “Responsibility” writ large is perhaps too vast and abstract to study. (2) Responsibility was eclipsed by other concepts, such as risk (see Strydom, 1999). (3) Environmental sociologists have focused more on notions of personal or individual environmental responsibility, rather than collective ones, in studies of consumption throughout the 1980s – 2000s – trending, perhaps unwittingly, along with a neoliberal ethos that transferred responsibility onto individuals. (4) Responsibility, when it came to the environment, was a relatively empty signifier compared with its potential – there was much rhetoric around it in the early 1990s, but not much ecological responsibility has actually been taken, making it a difficult process to study.

However, the Anthropocene storyline points out that this is an interesting time to take another look at responsibility as a social process. The chapters – chapter three in particular, but also five – explore: What are the social processes by which responsibility for ecological flourishing is made, and what are the processes by which it is taken? Moreover, in what ways does having the responsibility for an ecosystem differ from having the agency to participate in shaping its ecological future?

I argue that making and taking responsibility is one part of how futures are made. I discuss how ecosystem responsibility making and taking are complementary or interrelated processes, but not exactly the same. My contribution to the discussion in this dissertation is to suggest how the narrative of responsibility in the Anthropocene should be modified to deal with entanglements like burden and agency, and to emphasize response. This emphasis on response is similar to the approach of theorists like Barad (2010) or Haraway (2016), but I connect it with the ways my study participants approach action or intervention in landscapes, both materially and discursively. There is a component of responsibility, etymologically, which is connected to responding, and to answering; it connotes the ability to speak in response, and also to author. There is a relationship between design and authorship, and narrative as well, which my title (Who authors future environments?) alludes to. Taking responsibility for ecological design is a burden, but is also a way to capture the ability to author.

Sociology of the Future, Sociology of Expectations, and Public Engagement with Emerging Technologies

Thirdly, this work is in conversation with work on the sociology of expectations (e.g. Brown, Rappert, and Webster, 2000), methods for studying imagined futures, and the "sociology of the future" broadly. As Selin explains, "sociologic tools readily equip scholars to look at the future in terms of how various people today talk about tomorrow; but they do not enable taking the social reality of futures seriously", and "conducting inquiries *at* the future confronts social scientists with not only problems of methods and methodology, but also problems of developing theories that move and can account for change processes" (2008). Nevertheless, sociologists study "things (prototypes, strategic plans, design sketches); deeds (investment decisions, educational programs, chemical processes; like pollution); or words (science fiction, after dinner speeches, political promises) to get at the future" (ibid.), and this dissertation considers archival and textual material (public speech) as well as private interviews from respondents on how they see the future.

I use two key concepts from this literature: socio-technical imaginaries (Jasanoff and Kim, 2009; 2015) and embodied futures (Adam and Groves, 2007, 2011). Jasanoff and Kim defined socio-technical imaginaries as “collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology” (2015: 322). They explain that “only when the originator’s “vanguard vision” (Hilgartner 2015) comes to be communally adopted” do these rise to the status of an imaginary, and it often is institutions like law or the media that accord imaginaries a dominant position for policy purposes (2015: 4).

The term "sociotechnical imaginaries" was elaborated as a way of foregrounding how advances in science and technology have shaped collective visions of desirable futures (Jasanoff and Kim, 2015). Their work often looks at science and technology policy at the national level to see how these imaginaries are formed and implemented. I’m looking at something a bit different — imagined forms of social life that center on the fulfillment of environmental projects, but ones that involve innovative technologies. Here, I am interested in ecological sociotechnical imaginaries — collective visions of desirable ecological futures, shaped by science and technology. “Ecological sociotechnical imaginaries" is a clumsy phrase, so I have shortened it to "ecotechnical imaginaries", though at the risk of eliding the thing I want to emphasize (the social). I see solar geoengineering and negative emissions and blue growth as ecotechnical imaginaries. I wouldn't say that specific visions for the Salton Sea are ecotechnical imaginaries, as they would be projects or plans, but more general concepts like a managed Salton Sea or a restored Salton Sea might be. These types of imaginaries have relationships with spatial and environmental imaginaries, which can be found throughout the writing of geographers, but the role of technical systems is key to this work. A key observation made by Sovacool and Brossman in their study of future energy systems is that the interactions between imagination and technology are mutually constitutive (2013). In this dissertation, I look at how the narrative content of the imaginaries helps constitute environments, but it's also important to keep in mind that the environments help constitute the imaginaries.

This mutual constitution relates to Adam and Groves's concept of embodied or embedded futures (2011). Their observation is that the way institutions construct futures institutionalize irresponsibility, through constructing empty futures and economic practices that discount the future. To generalize broadly, previous societies often had seasonal or cyclical patterns linked with social practices that provided structural security. Modernity brought the fiction of an empty future. When the future is decontextualized future and emptied of content, Adam and Groves argue, it's open to exploration and exploitation, calculation and control. It can be traded, exchanged, and discounted. As they write, "We can forget that our future is the present of others and pretend that it is ours to do with as we please, with our imagination, creative skills and technological prowess the only boundaries to our activities" (2011).

The alternative to this fiction of an empty future is what they call an embodied, or embedded, or contextualized future. Some of the ways in which my work seeks to counter that emptying of the future is to embed these imaginaries of the future in both spatial and historical context, and also to address responsibility directly. These two conceptual tools — ecological sociotechnical imaginaries and embodied futures — are just two that I've borrowed from this rich body of literature on the sociology of the future.

This dissertation is also in dialogue with the literature on public engagement with emerging technologies. Interestingly, in the case of the Salton Sea as well as stratospheric aerosol geoengineering, what's imagined is a fusion of "emerging" technologies as well as very old or crude engineering. While none of the chapters in this dissertation includes much about formal "public engagement", some of my past and forthcoming writing goes into this space — chapter five is part of a larger project which aimed to incorporate publics into the scientific research process. The way I think about public engagement is largely consonant with what Chilvers and Kearns (2016) set out. They explain that there is a dominant or residual "realist conception of participation and the public", which entails publics as external to participation; they are an aggregation of autonomous individuals. Participation is a technologized procedure separate from science and democracy. It happens in discrete and ephemeral events, with a linear model of participation and engagement and with debates around extending it and scaling it up; inclusion is a key quality of success. In contrast, they put forth a version of participation which sees publics as mediated and emergent collectives, and participation as nonlinear with experimental practices "in the making", with key qualities of reflexivity and humility; participation is constitutive of science and democracy. In this work, I have aspired to the latter view, as well as reflected with respondents on how it could be strengthened.

3. Methods and study design

Study populations

This multi-sited dissertation involved work with "publics" as well as "studying up", a term that's been used in anthropology to describe focusing on elite groups (Nader, 1969). Some of my fieldwork attempted to discuss environmental decision-making with professionals who are involved with politics or with producing the knowledge that policy-makers use. But I also made an attempt to talk with "lay people", though this is a blurry divide. I would not claim the label of ethnography for this work, but it does have an ethnographic spirit, in that I attempted to enter the lifeworlds of the people I spoke to and understand the issues from their perspectives, as well as conducted participant-observation. The Anthropocene calls for this kind of research, argues McGregor, who writes that creative cross-scale multi-sited research that studies how decisions are made and how industrial innovations are facilitated or presented can link responsibility for earth systems change with those negatively affected by it (2017). This style of research, McGregor writes, can help dispel the "species thinking" haunting Anthropocene debates.

Like other multi-sited studies, this work has various audiences. Hine describes the tensions in this kind of work:

> Multi-sited ethnographers craft field sites with an eye to producing appropriate accounts for heterogeneous audiences comprising diverse sets of peers, policymakers, funders, bosses and research contacts. Rather than a pre-existing territory in the middle, there is instead an embodiment of tensions, in the ethnographer attempting to sustain a sense of meaning in the project out of diverse responses and accountabilities. From this perspective a study is therefore not, in some abstract sense, adequate or not. Instead, the ethnographer seeks out resonances, finding audiences for whom the study will be recognized as having an adequacy to connect with their concerns. (Hine, 2007)

I hope that this work can influence varying audiences in solar geoengineering research as well as Salton Sea restoration, not to mention the scholarly debates around responsibilities for design in the Anthropocene that span these two rather particular topics.

Study sites and methods

In terms of the foregrounded methods — the empirical fieldwork — this dissertation included semi-structured interviews in two sites. The work in Finnish Lapland (August- Sept. 2016) was conducted after several months of searching for a collaborator in an Arctic site, which was very challenging. The field season there is short, and research institutes based in the Arctic are swamped with requests from people studying the climate changes actually unfolding; it is a difficult ask to request people's time for a more speculative project, particularly one focusing on such an unappealing prospect as solar geoengineering. I was fortunate to meet a fantastic collaborator in Ilona Mettiäinen at the Arctic Centre at the University of Lapland, who facilitated and translated our focus groups. (The results of the focus groups are discussed in a co-authored manuscript which is not part of this dissertation; see Buck and Mettiänen, 2017) We chose the Arctic as a region of study because of the discussions around regionally using stratospheric aerosols to cool the Arctic (see chapter five for more discussion). There has only been one study of Arctic people's thoughts on climate engineering, which is Carr (2015), who spoke with indigenous peoples in Shishmaref, Alaska. Carr is also the only other social scientist to use semi-structured interviews as a method, and part of my interview guide is modeled upon his so that we may consider doing a comparative analysis in the future. I found this method to be particularly rich compared to the focus groups, as it allowed people to be more forthcoming about emotions as well as individual biographies.

My work in the Coachella-Imperial valleys (Oct. – Dec. 2016, with pilot visits in July 2014 and January 2016) consisted of semi-structured interviews, as well as visits to museums and archives, visits to sites of production (farms, geothermal plant, algae production facility), an informal tour of factories and energy production sites outside Mexicali, and attendance of formal meetings (e.g. Imperial Irrigation District Water Conservation Board, Salton Sea Authority), training workshops for farmers, and community events around environmental justice and the Salton Sea. The interview guide used had some similar questions to the Lapland project in terms of whose responsibility the situation was, and who had the agency to change things. I chose to work here because it was already such an engineered landscape, and I was interested in how perceptions of this would figure into attitudes about climate change or Salton Sea management. (This turned out to be a difficult thing to measure, though my impression is that people who live there are not as struck by the degree of intervention as someone from outside would be.) More specifically, I chose the Salton Sea as my object of focus because it turned out to be a defined object that a wide range of people were concerned about.

The dissertation also draws from the well of what I'm calling "background methods"— knowledge-gathering which I did not document in a formal, standardized way. I repeatedly engaged with a specific community of climate engineering researchers over seven years. This includes speaking at and attending meetings on geoengineering research and governance over the past several years, including a two-week research residency at Harvard (2016); two week-long summer schools at Harvard (2013) and Heidelberg (2010); work with the Solar Radiation Management Governance Initiative, including a stakeholder engagement in Jamaica; speaking at the SRM Science conference at Cambridge, UK; a workshop on the ethics of solar radiation management in Missoula, Montana; consulting with the Carnegie Council on Geoengineering Governance initiative in New York City; speaking at the US Forum on Solar Geoengineering Governance in Washington, DC; participating in a metrics workshop in Hamburg, etc. I held a position as a project scientist at the Institute for Advanced Sustainability Studies in Potsdam, working on an effort to incorporate ethical criteria into assessment of climate engineering technologies, and served on the steering committee for climate engineering conferences in Berlin in 2014 and 2017— making eight trips to meetings in Potsdam over the course of writing this dissertation, during which I learned much about integrated assessment modeling. I also held a position as a Faculty Fellow with the Forum for Climate Engineering Assessment at American University, and consulted with their Academic Working Group.

These activities are part of the normal course of building a policy-oriented academic career, but at the same time, they gave me insight into knowledge production in climate science generally and climate engineering in particular, and shaped this dissertation as much as the formal fieldwork did. In particular, I was a participant in numerous discussions about how publics are constructed. The disjunct between some of the ways publics were spoken about (as unknown forces, broadly put, who were seen to have a power or stake in the technology development, but in an abstract way, without specific mechanisms for participating) highlighted a need to understand both ideas that publics might hold about their agency as well as the role of researchers (including myself) in constructing publics.

The aim was not to compare two field sites, or any of the ecotechnical imaginaries studied, in a formal way. To do so would be like comparing four bricks in a building, or four paving stones on a path. The aim is more additive: by considering these together, it is easier to see insights about things like responsibility in the Anthropocene, how global imaginaries live or are perceived in particular places, or how people can have agency in designing future environments. In the rest of this introduction, as well as the conclusion, we will step back and consider the themes that emerge from looking at the ecotechnical imaginaries together.

4. How the chapters address the research questions

These chapters are organized by scale, from the planetary to the individual. We will begin with an ecotechnical imaginary that began in global integrated assessment modeling, negative emissions. Then, we will look at how the imaginaries of the "Blue Revolution" and the ocean economy play out on the national scale. The third and fourth chapters are sited in the landscape and community scales. The fifth chapter is the most personal: even though it is focused on the global or regional imaginary of solar geoengineering, people discuss what climate change and climate engineering means to them through language of loss, security, and hope for change.

In what follows, I'll introduce the chapters in greater detail with respect to what insights they add to the research questions, (1) By what means or processes can citizens have more agency in intentional environment-making? (2) How are expectations of the future and "selectable futures" made?

Chapter one, "Rapid scale-up of negative emissions: social barriers and social implications," is a review paper of the social science literature on negative emissions, and its central argument is that empirical work on topics like land use change, agricultural and energy system change, and technology adoption can help us understand the social implications of scaling up negative emissions technologies. It does not address citizen agency explicitly, but implies that social science might play a role in making these the social implications of these technologies visible — participatory social science research on the ground could be a first step in increasing citizen agency. What this paper does not address, but what I will point out here, is that negative emissions can be seen as a way of depriving future citizens of agency — a responsibility-deferring device, if you will. James Hansen et al point this out in a paper entitled "Young People's Burden: Requirement of Negative CO_2 Emissions," stating that if negative emissions is a way to continue fossil fuel use, this "unarguably sentences young people to either a massive, possibly implausible cleanup or growing deleterious climate impacts or both" (2016). If the future is not empty but embodied, populated with these people, negative emissions is a weighty trajectory to model, and selecting this pathways out of the others that have been graphed commits them to heavy infrastructure and labor.

Negative emissions make a fascinating case study in how expectations of the future are made, because in this case the vision of negative emissions was created by modelers trying to show plausible pathways to keep global mean temperatures below 2°C. Anderson and Peters explain that "the allure of BECCS and other negative-emission technologies stems from their promise of much-reduced political and economic challenges today, compensated by anticipated technological advances tomorrow"; part of this is embedded in the integrated assessment models, which assume perfect knowledge of technologies and give less weight to future costs (2016). It is by no means certain that anyone actually expects these technologies to be scaled up to the levels required to remove emissions — not even the modelers themselves, who were in a sense simply doing their job to figure out what would be required for that particular temperature trajectory. At the same time, it's possible that now that the concept exists, it has become part of climate policy discourse to some degree — Jeffrey Sachs has mentioned this as part of presentations on deep decarbonization; Shell referenced it in a recent scenario report (2016); and Saudi Arabia called for it to be part of upcoming IPCC special reports (IISD, 2017). We may be witnessing a concept that was imagined by modelers as a theoretical calculation becoming part of and shaping material reality; it is too soon to tell if a discourse coalition will emerge in favor of negative emissions (more on this in Chapter four).

Chapter one also looks at expectations of the future by means of analogue to the 2008-2010 biofuel boom, which illustrated the gap between the promise of the technology and the reality on the ground when it is "deployed", as well as what happens on local scales – how new relations of production were inflexible, how speculative activity and "phantom crops" emerged, and how marginal land designated for biofuel deployment was not really all that marginal. By looking at analogies from the biofuel boom and also forest carbon projects, it argues that both scientists and policymakers thinking about scaling up NETs should be attentive to their roles in creating or curbing speculative investments — investments which may or may not materialize, but which can have real changes for people on the ground regardless.

The second chapter, "Calculating the potential for "Blue Growth": how imaginaries of ocean futures are built upon numbers," focuses upon the particular narrative of "Blue Growth" – how the oceans can be mobilized to meet Anthropocene-era demands for food, fuel, raw materials, and carbon services – and analyzes the quantification practices which buttress this narrative. The paper traces how scientific and political trends converged to boost ideas of new ocean wealth, including high commodity prices, rapid scientific advances in biotech and robotics, and contemporary references to the blue economy in ocean development discourse. The chapter focuses on four states, explaining that they have varying motivations for creating expectations of blue growth.

In particular, the paper illustrates how stories and numerical practices work together to drive a socio-environmental imaginary. Twin narratives of the ocean's importance and fragility are propped up by numbers, numbers derived through three practices of calculability: geographical measurements are combined with biophysical monitoring to enable economic calculations of "ocean wealth." Ocean wealth is hidden;

it rests on practices of quantification to make it recognizable. Grim numbers also help drive the blue economy, as it is an imaginary built around sustainability and even repair – the worse things get, the more we need the blue economy. This is a logic of necessity that works in all four imaginaries addressed in the dissertation. Assessments of ocean wealth can be a performative tool for states to engage promissory capital; on the other hand, conservation organizations also try to use them to make a case for saving ocean wealth. Calculating the blue economy goes beyond the aims of driving policy and investment to complex political and cultural concerns: from geostrategic aims to economic diversification to valuing cultural heritages which were undervalued during colonialism. The chapter questions the assumption that quantification of the ocean economy enables management of it — these are lively and fluid ecologies, with biophysical factors that confound methods of calculation and social factors that are underappreciated. The quantification does, however, make a future based on the ocean economy more selectable.

Like the concept of "negative emissions technologies", this is largely a top-down imaginary designed to solve a global problem, without much purchase on the ground from people who would be doing the labor of creating the blue economy. The first two chapters share a similar mandate, in terms of using social science to highlight how these global imaginaries are not merely technical but also social. Similar to chapter one, chapter two suggests that social science could play a role in citizen agency — observing that some measurement of ocean life is done to further conservation and restoration goals, and suggesting that deliberative or anticipatory governance with communities about what they want to measure, and how.

The third chapter, “Choosing a future for California's Salton Sea: Making / taking responsibility in the Anthropocene”, moves to the landscape scale, and is the first of the three involving new data collection. It looks at how options for the Salton Sea have been formed, chosen, or rejected. The chapter provides a history of the process of selecting the sea’s future, and looks at how, in the wake of previous failures, the state of California has come up with a limited and incremental plan of action for the sea. Responsibility was legally taken by the state through a 2003 water transfer agreement, but expectations of the future have somewhat stalled. From the state’s point of view, the only possible path of action was to try and mitigate dust from the sea’s shrinking through constructing shallow habitat, which is still unfunded, and review the situation in ten years (a type of incrementalism and dependence on future action which is also built into the Paris Agreement). In both the instances of Salton Sea restoration and climate engineering, the assumptions seems to be that future people will be richer, more capable, and more committed than we are to addressing these issues.

From the citizen point of view, however, the future is still open, people are actively making a vision of sea-to-sea water import or alternatives, using tools of visualization and design. They are producing both a narrative of water import, as well as metrics to support the idea: they need the numbers to win the battle for who is being “realistic.” The alternative vision refers strongly to engineering and technologies, such as desalination, advances in algae cultivation and saltwater agriculture, and renewable energy. The chapter shows how citizens are using formal processes, citizen science, and social movements to make and take responsibility for their future landscape. Citizen organizations can (1) visualize alternatives, (2) educate people and policymakers about the sea, (3) help locals participate in formal processes; they can engage in media production as well as reframe the problem in terms of environmental or social justice. However, citizen science is not the same as citizen engineering, and citizens are in a bind trying to address a problem of this material scale, which requires incredibly high initial capital to move earth and water. While citizens don't yet have the capacity to make up for the absence of state action, they can use the tools at their disposal to shift conceptions of what's most "realistic" or selectable, or push alternative expectations of the future.

Chapter four, "Climate change technologies in California's Imperial Valley: Prospective challenges for negative emissions at the landscape scale," remains in the Salton Sea region. It turns back to the issue of climate engineering, arguing that looking from the landscape scale can illuminate frictions and tensions in instituting a global imaginary like negative emissions. The landscape scale is useful for seeing the landscape holistically; it invites human habitation and allows one to imagine negative emissions technologies not as artifacts but as part of a socio-technical landscape, placed not just in spatial context but also temporal context, history and future.

The empirical fieldwork points to a disconnect between how the Imperial Valley under climate change is seen from outside and within it — a disconnect also taken up in the next chapter, where imaginaries of climate change from inside and outside the Arctic are in tension. From a wide-zoom standpoint, the Imperial Valley is filled with empty land for solar, and will face increasing water stress as the southwest continues to heat and dry. From inside, the myth of empty land for solar evaporates; the water shortages are not threatening because of strong water rights; the heat is already extreme to the point where a few more degrees might not matter; and anthropogenic global warming is a matter of debate. The chapter argues that attitudes about climate change are germane to the possibilities of scaling up negative emissions — and that it's not just the attitudes, but the disconnect between them and the global imaginaries that matters, because these stances affect adoption of and participation in the NETs regime.

The chapter argues that one can see NETs as part of the broader renewable energy transition, and that both existing efforts at climate-smart land management and the rapid scale-up of renewables allow some foresight into what scaling up NETs in the landscape would entail. In particular, negative emissions are likely to face five types of challenges: financing, technical barriers, landholder adoption, broader social acceptance issues of the technologies, and environmental justice concerns. From looking at the renewable energy landscape, we can see how there are different versions of what it might look like. In particular, the chapter hears from citizens and activists who are resisting energy development for various reasons. Resistance and promotion of particular technologies don't always map onto familiar narratives. Some of the resistance is easily coded as not-in-my-backyardism, but much of it is in fact related to environmental justice — people in the valley have to bear harms from particular forms of development, and the benefits flow elsewhere. So opposition is not inherent to the technology itself, but to the place-blind ways it is being implemented.

In the imaginary of negative emissions technologies, a portfolio concept is taken for granted, where the best options will be selected and combined. This case study illustrates how there might in fact be tensions between different technologies and their actor-interest groups. The chapter also illustrates that while some issues with renewable energy or carbon removal are "local", it would be a mistake to simply consign them to a box of "local issues." Some concerns that are evident when examining the local are only *addressable* on larger scales. Finally, the chapter illustrates one key issue with the imaginary of NETs — it is largely based upon metrics and lacks a compelling narrative, and a NETs future will likely not be selectable on metrics alone.

In the fifth chapter, "Perspectives on albedo modification from Finnish Lapland: Viewing a global imaginary from a regional context," we look again at how people in a specific place experience a global imaginary — that of albedo modification, or solar geoengineering, as seen by people in Finnish Lapland. With a similar inquiry to chapter four, chapter five asks: How do they imagine themselves shaping solar geoengineering? What agency might they have in determining its research trajectory or use, and what experience can they bring to bear? What does placing albedo modification in a local context help us see regarding the prospects of governing this kind of global intervention?

The results from this set of semi-structured interviews challenge the global socio-environmental imaginary of solar geoengineering as it appears in the geoengineering governance literature in several important ways. Firstly, the chapter challenges the tacit assumption that people's climate preferences are obvious or quantifiable. When it came to climate change, respondents were concerned with changes to wintertime, and worried about it becoming unfamiliar or uncanny while also planning how to adapt to the new long, dark autumn.

Secondly, this chapter challenges the tacit assumption that people will look at climate change and climate intervention through the prism of local concerns, through an individual utilitarian lens or like a state would. The literature seems to assume competition between self-interested actors, but the respondents here seemed to share ideas about cooperative governance (and in fact had a similar set of concerns to respondents in other qualitative studies). Shorter and stranger winters were the most frequently cited effect of global warming, but often not the primary concern – the primary or urgent concern with climate change was global suffering in far-flung places, which people believed would affect them eventually. When it came to climate intervention, people viewed the earth as a complex system and were concerned about unforeseen consequences. Participants had a more sophisticated, nuanced view of benefit and detriment than a "winners and losers" discourse on climate change would suggest; rarely was the Arctic seen as an ultimate "winner". While their concerns were global and abstract, and touched on how people in other places would be affected, these concerns were still informed by particular contextual histories of the north and Europe – Cold War tensions and living on the border with Russia, local contaminants making their way to the Arctic, and European colonialism and racial integration. These types of concerns are not readily found in the geoengineering governance lit, which bounds such topics off from environmental governance.

Thirdly, the chapter challenges the tacit assumption that states act in the interests of their citizens. There may be a divergence between citizen ideas about solar geoengineering and nation-state or elite, decision-maker imaginaries of it. Participants found that a history of non-participatory decisions made it difficult to imagine citizen participation in something so vast — no one directly imagined themselves shaping the trajectory of geoengineering research or deployment, even though they thought at a minimum consent should be given. At the same time, people felt a strong case for considering local perspectives. They uniformly suggested international governance, while questioning if it would work. Residents wanted to talk about broader issues such as loss, insecurity, and worries about the current zeitgeist – their worries were not simply about solar geoengineering as a technology, but solar geoengineering in the context of global instability; it was perceived to be a chaotic, non-secular time where "national interests are back." That is, it was not an empty future, but an embodied one, and there was not a widespread faith that people in the future would be better human beings than present people are. People vacillated between democratic liberal ideas of what should be and pessimism about how things were trending, evidencing the fluidity of positions about what is realistic or possible: the same person could in a matter of minutes express both optimism and pessimism about human nature and human values. Geoengineering was seen as something which deserved research, but not as a source of hope. In general, many respondents wanted to broaden the horizons of the problem and solutions – they found hope in talk of relocalization and new rural livelihoods, as well as dematerialization of the economy, new values, and education.

The ambiguity about solar geoengineering in the fifth chapter can be seen as a breakdown of the master narrative about scientific, economic, and cultural progress. People are remarkably unenthused about the idea, and this shows up in other studies of climate engineering as well: they largely accept a rationale for *research* into the idea, but this is not the same as being supportive of it as an exciting pursuit. The other Anthropocene-era socio-environmental imaginaries studied here are met with the same lack of real enthusiasm. Negative emissions are met with the vigor of someone being excited about cleaning up a huge mess — the state of California has the same general attitude about the Salton Sea. The Blue Revolution has the most potential out of the four imaginaries for genuine enthusiasm, but it's inextricably twinned with observations about the ocean's decline. Technology in an era of obligatory repair means something different than the previous analogues of these technologies (referents: weather modification technologies of the 1950s, or aquaculture and ocean energy enthusiasm of the 1970s).

How connected are these two narrative events: modernity's failure to be credible — at least to those in the West and perhaps elsewhere — and the Anthropocene, the self-awareness of environmental impact and commensurate responsibility? They are clearly related, but the decline of one does not follow neatly upon the rise of the other. For some critical scholars, the Anthropocene represents totally technical rationality; disillusionment; ecological management and control — modernity at its final end. In other words, it is an extension of modernity, not a replacement narrative for it. This is a reasonable viewpoint in light of the history of the Imperial Valley, which reflects a century of control of both nature and racialized labor (Andrés, 2015), or in light of early ecological modernization efforts. As the Brundtland Commission report, "Our Common Future", declared, "This new reality, from which there is no escape, must be recognized – and managed" (WCED, 1987). After so many decades of histories and framings of control, it is very easy to see the Anthropocene narratives of responsibility as managerialism in new clothes — especially since the Anthropocene is grounded in scientific observation and the metrification favored by earth system scientists, e.g. discussions of planetary boundaries.

Yet the evidence suggests that ecological modernization— the notion that eco-friendly innovation would benefit both environments and economies — has not transpired; a more rapacious and kleptocratic neoliberalism happened instead, dashing hopes of carbon markets or weak sustainability. Ecomodernism seems like an ever-more-elusive dream in the face of modern irrationality: the empirical fieldwork from my dissertation indicated this as well. Hence, I do not see the Anthropocene as an extension of modernity, but rather as a new story which comes after it— messily overlapping with it's tail end and thus being influenced by it, but whose contours and storyline are up for authorship. Haraway brings up no less than eight objections to the "Anthropcoene as a tool, story, or epoch to think with", some of them in this vein: it relies too much on bounded utilitarian individualism, it tends to be top-heavy and bureaucracy-prone; it's most easily meaningful and usable by elite intellectuals (2016). Most of her objections are noteworthy; yet the Anthropocene still seems to be doing useful work as a shorthand and provocation to think through possible stories before it becomes clear what comes next. An underlying theme in the very constitution of the four imaginaries discussed in this dissertation is what kinds of narratives around ecotechnical imaginaries are possible once modernity is exhausted as a master frame, and this discussion will be returned to in the conclusion.

Together, the chapters illustrate the difficulties of citizen participation in these global ecotechnical imaginaries — and illustrate paradoxical thinking on the part of their promoters, since these imaginaries might not travel far without citizen involvement. How do promoters imagine that the imaginaries would be taken up, deployed, adopted, or created? There are several possible explanations. One is that the people generating and propagating these imaginaries are amazingly technocratic and managerial even in the face of a paradigm that has shifted away from this view of science and technology's controllability, in which case they are able to cope with a remarkable level of cognitive dissonance. A second possibility is that the imaginaries arise from disparate discourse coalitions of multiple and disconnected actors, and no one is charged with assessing the imaginaries' overall viability. A third possibility is that the people proposing the imaginaries are not hopeful or invested in them being materialized, but are doing so out of a lack of knowing what else to do, with the added bonus that developing them offers gainful employment. It seems likely that the point of these imaginaries is not that they are actually ever realized (in which case, critical scholars should not be taking them at face value). What, then, *is* the point of them? The conclusion addresses the varied work these ecotechnical imaginaries are actually doing, and further synthesizes what these chapters bring to the question of how citizens can have more agency in the design and decisions around environment-shaping technologies.

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Chapter 1

Rapid scale-up of negative emissions technologies: social barriers and social implications

Abstract

Negative emissions technologies have garnered increasing attention in the wake of the Paris target to curb global warming to 1.5°C. However, much of the literature on carbon dioxide removal focuses on technical feasibility, and several significant social barriers to scale-up of these technologies have been glossed over. This paper reviews the existing literature on the social implications of rapidly ramping up carbon dioxide removal. It also explores the applicability of previous empirical social science research on intersecting topics, with examples drawn from research on first- and second-generation biofuels and forest carbon projects. Social science fieldwork and case studies of land use change, agricultural and energy system change, and technology adoption and diffusion can help in both anticipating the social implications of emerging negative emissions technologies and understanding the factors that shape trajectories of technological development. By integrating empirical research on public and producer perceptions, barriers to adoption, conditions driving new technologies, and social impacts, projections about negative emissions technologies can become more realistic and more useful to climate change policymaking.

1. Introduction

Scenarios in the fifth Intergovernmental Panel on Climate Change (IPCC) report rely upon the use of "negative emissions" technologies to maintain less than 2°C of warming; in particular, they anticipate widespread deployment of bioenergy with carbon capture and sequestration (BECCS) (IPCC, 2014; Fuss et al, 2014; Gasser et al, 2015). Negative emissions technologies (NETs) are in varying, speculative stages of development. Yet they are implied in meeting the ambitious 1.5°C target set in Paris. This critical role of negative emissions has alarmed scientists, provoking commentaries on the feasibility of these scenarios and calls for climate researchers to be candid to policymakers about the tight carbon budget (Anderson, 2015; Geden, 2015; Peters, 2016; Williamson, 2016).

What would a rapid scale-up of NETs entail? How would a successful scale-up transform society? There are few integrated analyses of the "technological, economic, social, and cultural pathways to get to 1.5°C, or about the implications of a massive expansion of negative emissions technologies", observed Mike Hulme (2016). Of those few analyses, the social and cultural analysis is particularly limited (work in the special issue of this journal edited by Tavoni and Socolow, 2013, is a notable exception). Many factors contribute to this lack of analysis: there are inherent uncertainties in the technologies and in the future that make declarative "results" difficult, and methods in the social sciences lend themselves to the study of currently-existing phenomena rather than future prospects. Social implications like changes in food security, concentration of land ownership, or resource access dynamics at community or household levels require difficult or expensive-to-gather data to understand in the present, and are even more challenging to anticipate in the future.

Thus far, the primary aim of studies on carbon dioxide removal is typically to calculate the potential that these methods can offer. Lines of inquiry begin from that starting point, bringing in social implications as difficult-to-quantify side issues later in the conclusion or discussion sections of the work. This work generates crucial insights and cautions about material issues that *will* have social implications, like fertilizer use and bioenergy crop yields (e.g. Creutzig, 2015, Smith et al, 2015). Yet a focused discussion of both social barriers and implications of the rapid scale-up of carbon dioxide removal is notably absent.

If the claims that NETs will be necessary to reduce climate damages are credible, the lack of social research is remarkable, since understanding the social dynamics is key to making these futures actually happen. A genuine evaluation of the social feasibility of large-scale carbon dioxide removal needs to be made if society is serious about comparing these technologies with other large-scale mitigation approaches, in order to make public and private decisions about what to invest in and design policy accordingly. On one hand, the research community could simply continue to acknowledge the vast social and political uncertainty around NETs. However, this may lead to "analysis paralysis", which risks "losing valuable time and helping to self-fulfill the prophecy that GGR cannot be realized at scale", as Lomax et al (2015a) point out. Another course could be to use the already-existing body of empirical social science studies on related topics to understand the social implications and challenges to scaling up NETs. "Empirical" here simply means evidence-based: evidence from analogue case studies, from discourse, from commodity chain analysis, from the conventional suite of social science methods like interviews, surveys, focus groups, and other means of gathering social data. Evidence from the ground can indicate factors which biophysical and large-scale economic models may not be able to include, such as corruption, landowner preferences, not-in-my-backyard-ism, household and inter-community inequalities in land or food access, to name just a few. This chapter aims to lay the groundwork for such an analysis by first reviewing the existing literature on the social implications of NETs. Then, selected examples from fields like environmental sociology, agricultural development, and science and technology studies are reviewed, to further understanding of what a rapid scale-up of NETs would entail. The contemporary, real-world examples of what happens when communities are left out of environment-shaping illustrate what is at stake when imagining a scale-up of NETs. If negative emissions are going to be more than a discursive tactic for (temporarily) evading responsibility for climate action, the social challenges discussed below will have to be met head-on.

2. Roles for social science research on NETs

Social science can contribute to discussing (1) public understanding and acceptability of NETs, including how NETs come to be understood and defined by society, (2) barriers to deploying or scaling up NETs, including what factors are shaping the technology as it develops, and (3) the social implications of a rapid scale-up of NETs, including changes in social relations. Within "social science", there are a range of relevant fields and sub-fields— environmental sociology, communications, anthropology, human geography, political ecology, science and technology studies, international development, to name a few, each with a range of methods. Some methods, like scenario and foresight exercises, are better for understanding implications of the more speculative emerging technologies.

Can social implications emerging technologies be anticipated? "Typically it is only as a technology is rolled out into society that one can get a firm grip on the timing and strength of side effects, the operation of countervailing forces, and the mobilization of direct opposition", writes Meadowcroft (2013), who cites biofuels and wind energy as examples. This is mainly true, yet there are numerous case studies of precedents and analogues to draw upon, and because most NETs have known component technologies, it should be feasible to get a handle on some "side effects". Because technologies are not simply forces that are rolled out— rather, they are shaped by human choices throughout their (often non-linear) development— doing such social inquiry at all stages of development is useful. Moreover, technologies develop along with societies: Meadowcroft helpfully points out that CDR approaches should not just be assessed from the perspective of their mitigation potential (tons removed over time), but also by "asking what sort of societal development trajectory they imply", noting that "a civilization that employed large scale afforestation and reforestation, for example, would look very different from one that declined this option; widespread BECCS implies an extensive bio-energy economy, and so on" (2013). Taking account of social contexts is crucial in anticipating technological development.

What social science research on NETs already exists, and how comprehensive is it? There is virtually no social science literature on the non-biological technologies (direct air capture, enhanced mineral weathering). This may be because non-biological methods are seen as distinct technologies to be rolled out, compared to biological carbon dioxide removal, which is more obviously embedded in socio-technical systems. However, the scale-up of an entirely new infrastructure or industry with either direct air capture (DAC) or enhanced weathering (EW) would warrant serious social research. Drawing down 50 ppm of atmospheric CO2 with enhanced weathering could cost \$50-500 trillion for mining, grinding, and transporting rock, with further similar costs for distributing it (Taylor et al, 2016). A global enhanced weathering industry that sequesters 1Gt Co2e per year may have an energy demand equivalent to 0.7-19.4% of global energy consumption (Hartmann et al, 2013). The governance and implementation barriers to distributing these amounts of rock are massive— some of the tropical lands signaled by models as geologically suitable for enhanced weathering are in places like the Democratic Republic of the Congo (Moosdorf et al, 2014), where institutional infrastructure for promoting adoption of new land use practices is limited. Direct air capture would also have high costs and substantial energy requirements (McLaren, 2014); in some analyses, powering

DAC with gas or coal would be pointless as more emissions would be generated than captured. The direct land footprint of DAC is low, but optimally emissions-free DAC implies large renewable energy resources, which may have been used for other purposes, and which may require large amounts of land. For example, for the U.S. to sequester ~13GtCO2/yr, roughly 100,000,000 acres of land in the Southwest would be required for the solar energy to make it emissions-free (NAS, 2015). Moreover, much of the current industrial infrastructure society enjoys was built in a time where infrastructure was valued as a source of national pride; today, in a fuller world, infrastructure has a new politics and is much more contestable. In sum, new industries of air capture or enhanced weathering would indeed be shaped by society, with opportunities but also considerable challenges. However, because literature on the social barriers, implications, or perception of DAC and EW has not yet emerged, we will turn to examining social research on the other technologies.

2.1 Research on biological NETs

Modeling studies on biological NETs (terrestrial or marine carbon sequestration) often point to the need for more social research. There is virtually no social science literature about microalgae biofuels or macroalgae sequestration, and just a few studies of "blue carbon" sequestration in coastal ecosystems (e.g. Wylie et al, 2016). Much attention has gone to terrestrial sequestration, particularly BECCS. Concerns identified with BECCS include land requirements, input requirements, freshwater requirements, and tradeoffs for food and fiber production (see e.g. Cruetzig et al, 2015; Geisler and Currens, 2017). For example, using dedicated high-energy crops (willow and poplar short rotation coppice and *Miscanthus*), Smith et al found that achieving 3.3 Gt Ceq yr^{-1} of negative emissions would require a land area of approximately 380–700 Mha in 2100, which represents 7–25% of agricultural land, and 25–46% of arable plus permanent crop area (2015). Both BECCS and afforestation and reforestation would have land demands 2-4 times larger than land identified as abandoned or marginal, and thus the use of these techniques on productive land would impact the amount available for food production and other ecosystem services (ibid). BECCS could increase groundwater reserve tapping, reduce access to clean water, and divert water from ecosystems. Moreover, BECCS would consume a significant portion of the world's fertilizer supply: an estimated 17–79 Tg N y−1 applied per sequestered Pg C y−1 could represent up to 75 % of global annual nitrogen fertilizer production (Smith and Torn, 2013). Phosphorous availability is another consideration, as this resource is limited and subject to price spikes, with reserves concentrated in just a few nations.

How do these biophysical projections "translate" into social impacts? Writing about bioenergy broadly, Creutzig et al (2013) point out that modeling studies of bioenergy potential are deficient in two ways: firstly, social impacts are measured in terms of economic efficiency, economic growth, and occasionally food prices, which leaves out important dimensions of human wellbeing like change in socio-economic and health conditions; secondly, the high level of spatial aggregation makes place-specific drivers and distribution of impacts among social groups and regions invisible (2013).

The translation from model results to social impacts is not straightforward, which is where empirical social science research could be helpful. A handful of studies address expert and public perceptions of BECCS. Lomax et al (2015b) conducted twelve semi-structured interviews with experts, who caution about systemic technology "lock-out" due to reasons of technology choice, infrastructure development, resource supply (for biomass and biochar), and capacity and skills. Vaughan and Gough reported on a deliberative workshop about BECCS feasibility, finding that social acceptability was likely to be a barrier, though there was little consensus on the magnitude (2015). Dowd et al (2015) review the public opinion research on bioCCS and discuss social license to operate, with the key question of whether or not the public opinion challenges of CCS will apply to BECCS, noting that BECCS might receive more public support than its component technologies do individually. While social research on BECCS is limited, CCS has been well investigated.

2.2 CCS research

Underpinning both BECCS and DAC is carbon capture and storage, which has been the focus of a relatively large body of social science research on CCS since 2005; see for example the edited collection *The Social Dynamics of Carbon Capture and Storage* by Markusson et al (2012a), or the special issue on the politics and policy of CCS in *Global Environmental Change* edited by Bäckstrand et al (2011). Two foci in this literature are 1) public perception and acceptance and 2) economic modeling of deployment options (Markusson et al, 2012b). This is largely still the case at the time of writing this article. Markusson et al also point to a small literature on CCS innovation and technology development, such as learning curve analysis, which tends to borrow from cost trends in other technologies (2012b).

Why has carbon capture and storage, a technology considered necessary in climate assessments, had so much difficulty in getting off the ground? Barriers include the lack of government action, public concerns about storage, low carbon prices and advances in alternative renewable technologies (De Coninck and Benson, 2014). Other key questions revolve around whether CCS will be an "add-on" technology, or a broader part of a hydrogen economy (Shackley and Thompson, 2012), or whether it creates fossil fuel "lock-in" (Vergragt et al, 2011). These types of questions are relevant to the scale up of DAC and BECCS as well. Areas for further research identified by Bäckstrand et al (2011) were the synergies and tensions between CCS and renewable options; public dialogue and choice; and work in developing countries, including technology transfer and risks in the context of fragile political institutions. These are all crucial areas for further inquiry within the contexts of DAC and BECCS.

3. Bringing in insights from empirical studies of intersecting topics

This chapter will examine two cases of relevant literature from other fields: empirical studies of the recent biofuel boom, and studies of forest carbon projects. These are clearly more relevant to biological NETs, and were chosen to illustrate the depth and breadth of work already being done on environment-shaping in the Anthropocene. Equally interesting to bring in would be studies of biochar projects (Leach et al, 2012) and agricultural sequestration efforts (e.g. Swallow and Goddard, 2013). There are also case studies of energy system transitions and infrastructure scale-ups that could help analysts understand a scale-up of a DAC industry. For example, with regards to the CCS part of DAC, Rai et al (2010) studied analogue technologies of nuclear power, SO2 scrubbing, and global liquefied natural gas, observing the decisive role of government, the credibility of incentives for investment in commercial-scale projects, and the weakness of the truism that experience with technologies inevitably reduces cost. Literature on the scale-up of renewables would also be particularly useful: for example, Iyer et al (2015) examine constraints on diffusion of low-carbon technologies and review the historical diffusion rates of energy technologies. Here, though, the focus is on bioenergy and forest carbon, in order to illuminate: What social factors identified in the existing literature on bioenergy and forest carbon could shed light on the social dynamics of a rapid NET scale-up?

3.1 Biofuel booms and busts

Most, if not all, projections regarding BECCS assume second-generation biofuels: switchgrass, *Miscanthus*, poplar, crop or forestry residues, etc. Advanced biofuels would theoretically be free of the social concerns that first-generation biofuels came under fire for. Nevertheless, empirical studies of the most recent first-generation biofuel crop boom (late 1990s ~ 2010) are useful to understand future biofuel scale-up for two reasons. Firstly, the *speed* of land use change and infrastructure and policy development is an object of study. This wave of interest in ethanol and biodiesel produced from sugar, starch, and oilseed crops mirrors earlier waves of interest in the late nineteenth century and in the 1970s; however, the twenty-first century boom was also driven by concerns about agricultural stagnation and climate change (Kuchler, 2014). Secondly, the failure of this earlier biofuel boom is still affecting prospects for a second. Advanced biofuels still have not received the breakthroughs they would need to be competitive, and while part of this is technological— cell walls in woody biomass evolved to be difficult to break down— part is certainly economical. Despite the cleanly demarcated terminology of "first" and "second", these are interrelated technologies.

There is no shortage of high-level assessment of first-generation biofuels. Much of this is framed in terms of sustainability and addresses various aspects: e.g. the UK's Gallagher Review of the indirect effects of biofuel production (2008); there are also numerous studies of livelihood impacts. Because this literature is vast, I want to do two things here: (1) point out some factors identified in this first-generation literature that have not been mentioned with regards to NETs, but may be quite relevant, and then (2) mention a few studies that are specifically interesting in terms of their focus on second-generation biofuels.

Empirical research on the first-generation biofuel boom reveals three related concerns: (1) the inflexibility of new relations of production, (2) speculative activity and "phantom crops", and (3) the actual status of "marginal" land. Biofuels for domestic use or export can represent employment opportunities, but income effects for growers depend on the model of feedstock cultivation: typical modes include plantations, contract farming or outgrower schemes, independent smallholder farming, and subsistence farming (Creutzig et al, 2013). The switch to cash crops and paid jobs may not be a net gain for rural peoples, since cash crops bring new vulnerabilities like dependency on world markets. For example, Van der Horst and Vermeylen cite the plight of Kenyan commercial rose farmers during the Icelandic ash cloud of 2010, who were stuck with a product that had no local demand (2011). They argue that "simplistic proxies" like the number of jobs or the average pay per worker cannot adequately measure the involvement of rural communities in producing liquid biofuels (ibid). In a six-country study of biofuel projects, German et al report that most of the production models, "whether industrial-scale plantations or outgrower schemes, lock land and labor into relatively inflexible arrangements that hinder the potential to adapt to changing socioeconomic and market conditions" (2011). In one example, a jatropha outgrower scheme in Zambia, focus groups and household surveys revealed one-sided contractual obligations that were signed by farmers but not the company, as well as provisions requiring farmers to keep land under jatropha for 30 years and sell only to the company—the risks were borne by the smallholders who could least afford them, instead of the behind-the-scenes investors promoting the scheme (German et al, 2011). Numerous examples of changing relations of production point to concerns not just about income and flexibility, but about repercussions on food security, gender equity, health, etc. To be clear, effects of new relations are not always negative: for example, Riera and Swinnen studied a case of castor biofuel contract farming in Ethiopia where positive spillover effects on food production occurred, perhaps due to better fertilizer access, improved soil quality from the castor, or technical assistance from extension agents (2016).

A second concern involves what Niemark et al have dubbed the "phantom commodity", or a commodity existing in a "parallel economy of expectations and appearances", which is "used in company rhetoric and policy and development discourse, but does not materialize into any real market exchange or deliver on promised environmental and social benefits" (2016). Their case involves jatropha in Madagascar, where in 2011, the total amount of land intended for biofuels was roughly 800,000 to 1 million ha— but only about 60,000 ha were "reportedly" producing biofuels, and much land was classified in either preparation or temporary suspension phases of production (2016). A similar situation developed in Ethiopia, where government ministries offered investment licenses to 83 parties to produce biodiesel feedstock, but 3-5 years later, only 7.2% had started production, and that on a limited scale; notably, state enterprises are producing much more (Shete and Rutten, 2014). The concern is that speculative investments in "phantom production" is driving land prices upwards (2016). While modelers calculated impressive production potentials, some companies were merely interested in financial, speculative profits rather than the complicated work of producing new feedstocks in areas without advanced processing infrastructure and proximity to markets. Expectations and hype giving way to phantom commodities is a cautionary tale for development of NETs.

Without "ground-truthing" these investments and projects, it would be difficult to know about changing relations of production, livelihood impacts, or the phenomenon of phantom production. Similarly, it would be hard to assess the true uses of "marginal land", which is often categorized using remote sensing methods. Fieldwork has shown that (1) much land classed as marginal is actually used in various ways (Nalepa and Bauer, 2012), (2) the designation of "marginal" or "degraded" often is done for political reasons (Lyons and Westoby, 2014), and (3) though biofuel crops can theoretically be grown in marginal land, or using rain-fed irrigation, growers may decide to use non-marginal land if crops do better there and profits will be higher. This is all highly relevant for second-generation biomass production, as it is projected to use marginal land. Notably, BECCS is imagined to use significant amounts of crop and forest residues, in which case the first-generation biofuel analogy would be less applicable.

The literature on second-generation biofuels is much smaller and more recent. It focuses less on impacts, and more on anticipatory issues of social acceptance and interest. Creutzig et al suggest that for rural livelihoods, second-generation plantations would provide higher income and land rent compared to first-generation biofuels, but would again marginalize local people with informal land tenure, though they note that residues are promising for energy and livelihood improvement (2013). However, very little research has been done on advanced biofuels and rural livelihoods in the developing world. Most research has focused on high-income countries and involves gathering social data from various groups: the public, experts, and producers. For example, Longstaff et al (2015) reported on a deliberative democracy event about advanced biofuels in Canada, which discussed biotechnology and citizen participation in government policy. Also in Canada, Rollins et al (2015) used a choice experiment to examine public opinion on planting genetically improved poplars on public lands, with the majority allowing it if the fiber is used for biofuels. Raman et al (2015) employed stakeholder and expert interviews to assess the assumptions, values, and future visions around lignocellulosic biofuels in the UK, while Ribiero and Quintanilla used the Delphi method to survey experts from several countries on the potential social impacts of cellulosic ethanol (2015). Producer decision-making is also considered: Brunner et al (2015) found that among 505 forest decision-makers surveyed in northern Michigan, 47% would be willing to harvest trees for cellulosic ethanol feedstock, with most having non-market factors such as recreation, conservation, and "other worthwhile goals" part of their decision-making. Caldas et al surveyed 1984 Kansas famers about their willingness to grow cellulosic biomass, and found differences between Eastern and Western Kansas, with farmers' perceptions about risk and profits as a key factor in decision-making, compared to biophysical factors (2014). These studies— all from high-income nations— indicate that social factors play a large role in both public and producer decision-making. These results warrant more attention when thinking about a scale-up of terrestrial CDR, particularly when considering genetically modified feedstocks, given that genetically modified crops have already faced contestation in the global north.

These three aspects of the first-generation scale-up — new relations of production, phantom commodities, and alternative uses of marginal land — were examined here because they are aspects not easily teased out from modeling studies. There are certainly other social implications of scaling up advanced biofuels, and perhaps more relevant ones. But these three offer an example of why the literature on first-generation biofuels is useful to bring in: it illustrates the gap between the promise of the technology and the reality on the ground when it is deployed, as well as what can happen on local scales. These results may darken the promise of projections regarding BECCS. Yet ideally, the three observations point to how policymakers could be smarter in designing incentives or devoting R&D funding for this new generation of biofuels, when the imperative is not just greener fuel but greenhouse gas removal.

3.2 Forest carbon projects

Afforestation is a way of enhancing the carbon sink, and there is a robust literature about how existing programs and projects attempt this. For example, Thomson Reuters Web of Science article citations in the Social Science database for "REDD" number 325; there are 114 articles for "forest carbon" + "social". Many if not most of these are field-base case studies; some aggregate monitoring and evaluation information about REDD+ program effectiveness (e.g. Caplow et al, 2011). Impacts data is of varying quality, with indicators like employment more common than health or literacy (Caplow et al, 2011). Fieldwork can illustrate several social issues around afforestation, and how choices about future environments are made. Here, two will be explored: changes in forest ownership and forest access, and concerns about who benefits from afforestation projects.

Crucially, people who currently use forests (for food, fuel, grazing, etc.) may not be the ones making the decision to afforest for carbon projects. They may not even be the owners, since nation-states own much forestland. In the world's 36 most forested countries, representing 85% of the world's forest estate, national governments have statutory ownership of 60% of lands— a legacy of state appropriation in many countries (Sunderlin et al, 2013). State ownership varies regionally: governments have official control of about a third of Latin American forests, about two-thirds in Asia, and virtually the entire area in Africa (ibid.). This matters because people with communal or unclear land tenure may be displaced if governments launch forest carbon sequestration efforts. Some studies report limitations to access, which takes various forms. For example, Lyons and Westoby studied the largest plantation forestry operator in Africa, in Uganda, and describe restrictions on crop cultivation, grazing, bee keeping, and collection of firewood; the confiscation of animals that strayed into the plantation area, with expensive payments required to collect them; fines and jail time for "trespassing"; and destruction of burial sites (2014). Another broad governance problem with scaling up terrestrial carbon sequestration is that nation-states are not equally strong, cohesive, or efficacious. Recommendations in carbon-woody biomass literature may work using assumptions that a developing country government actually controls all the lands within its borders, while in reality its influence might meet resistance rather than compliance (Unruh, 2011).

Unruh’s blunt assessment: “In reality the derivation and implementation of improved policies, laws, and ‘will’ in the developing world, particularly over large multicountry areas needed for carbon storage to be a mitigation option, are unrealistic within the needed time frame” (2011). These disjoints between imagined forest projects where nation-states guarantee smooth operations and conditions on the ground can lead to both conflict in particular places and disappointment for remote policymakers.

Who benefits from existing forest carbon projects? In the Ugandan case study, foreign investors were the primary beneficiaries, as well as domestic power elites, company staff, and “local elites with ‘special’ access rights to graze animals and grow food crops within the license areas" (Lyons and Westoby, 2014). Cases like this can be found elsewhere. For example, Niemark et al studied a REDD readiness site in Laos, where higher status families were able to organize themselves and capture initial benefits, and chiefs and their families became local knowledge brokers on REDD+ and carbon trading (2016). Unruh identifies two complications regarding benefits: first, the benefits earned from forest carbon projects have to be compared with the counterfactual; second, people often interact with forest resources for immediate needs, while carbon storage is theoretically long-term, so there is a temporal mismatch (2011).

What of social safeguards? Protections for forest people designed to deal with the above issues may have limited efficacy. Within the REDD+ framework, social safeguards for REDD-readiness mandate tenure clarification. The Climate, Community, and Biodiversity Alliance has established certification schemes to ensure biodiversity and community livelihood goals are met through REDD+ projects (e.g. standards) to ensure that biodiversity and community livelihood goals are met through just means while also reaching carbon mitigation goals; however, these standards are not always met (Suiseeya and Caplow, 2013). As in the biofuel example, the disjunct between idealized reality and actual reality was recognized, experts attempted to intervene (in the biofuel case, by developing sustainable biofuel standards); then a literature evaluating the effectiveness of that intervention emerged. This literature offers a wealth of information for thinking about how the scale-up of carbon dioxide removal would deal with the issues of natural resource ownership and access and distribution of benefits.

The above examples draw largely from the developing world, but there are also helpful studies addressing forest carbon in countries where land ownership is clear. For example, in a survey of Australian landholders, relevant factors in their willingness to adopt afforestation for carbon sequestration included the design and social acceptability of afforestation, as well as the socio-demographic attributes, knowledge, skills, and experience of landholders (Schirmer and Bull, 2014). Empirical research can suggest not just barriers to scaling-up carbon dioxide removal activities, but information to help target new projects.

4. Thinking beyond negative emission technologies towards carbon practices

With a carbon budget as tight as 590-1240 $GtCO_2$ from 2015 onward to have a likely chance of keeping global mean temperature below 2°C (Rogelj et al, 2016), the stakes for understanding how society can scale-up carbon dioxide removal are quite high. The previous section identified several social aspects that would need to be confronted for a successful scale-up: (1) new arrangements of production of advanced biofuels or carbon commodities for biological sequestration; (2) the phenomena of speculation and phantom commodities as investment is scaled up, including the role of science and policy in creating or curbing speculative investment; (3) issues of informal land tenure and "marginal" land; and (4) the question of who accesses the benefits of new technologies. The existing empirical work on these factors in previous biofuel and carbon policy suggests a few recommendations for scientists, entrepreneurs, and policymakers hoping to scale up NETs.

Firstly, researchers and policymakers should examine intermediate scales. While modeling can illustrate global processes, strategies for scaling up CDR are going to be extremely context-specific, with local challenges. The regional level is a promising place to start bridging these scales. Few regional or national models have looked at NETs, with Sanchez et al's (2015) study of BECCS for power generation on the west coast of the US being an exception, and a blueprint for other studies (Bauer, 2015). Another useful scale is the landscape level, as it can spur holistic thinking about ecological and social feedbacks (see Hunsberger et al, 2015). Regional and landscape-level expertise from environmental sociologists, anthropologists, and human geographers can illuminate challenges particular to local cultural dynamics. In regards to bioenergy, Creutzig et al

(2013) called for a comprehensive assessment by human geographers and agricultural economists to think about distributional livelihood effects and the particulars of biofuel deployment schemes, from crops to institutional arrangements and tenure schemes; they noted an "ample opportunity to soft-couple integrated assessment models with local livelihood analyses and CGE and partial equilibrium sector models". This kind of work will be essential in transcending scalar disconnects between coarse models and local impacts for CDR.

Secondly, previous research on analogous and related technologies and projects suggests governments worldwide will need to employ a stronger hand in many aspects of the process of scaling up NETs — the market is not going to deliver outcomes that are good for broad swathes of societies without copious support and guidance. The research on the existing "social safeguards" for REDD+ and safeguards for allocating land to large-scale biofuel feedstock should be extended, as the current body of work suggests that voluntary guidelines are not sufficient to curb adverse effects of new land uses. Governments will need to provide clearer definitions of "marginal land" and revisit productive use requirements (Cotula et al, 2008)— both in terms of tenure security and avoiding phantom commodities. This stronger role of government involves, obviously, setting up a carbon price and revisiting energy subsidies. It also involves support for technologies to cross the valley of death from pilot-stage to implementation, training the workforce for new opportunities, as well as agricultural extension support and incentives for new land use practices. Moreover, this greater state involvement goes beyond what may immediately seem to be related to negative emissions technologies. Proceeding towards a greater economic valuation of carbon will not work without institutions that support livelihoods, good governance, and land tenure security in developing countries; current efforts from rich countries to provide aid to these goals must be expanded. In short, actually scaling up NETs will require policies that are out of line with hands-off, market-led approaches to environmental management and technology development. It is better to reckon with this now, rather than separating the technology out from the social changes necessary to scale it up, and imagining that it can develop on its own.

Finally, all of this suggests that "technologies" being "deployed" is not the most helpful way to think about these practices. In regards to "negative emissions technologies", the focus on "technologies" is misplaced to the degree that it treats technologies as objects or artifacts — what Corry has called the "contraption fallacy" (2014). Rather, it matters how the forest or crop is grown, how the infrastructure is built, and who is changing their soil management practices to sequester carbon. It matters where the profits go, where the commodity chains lead, who is in the social groups that experience differential opportunities or constraints, etc. An alternative framing might be useful in emphasizing these features, such as a holistic discipline of "carbon management", though "management" implies a precision and control that is lacking at present. Within agriculture, "carbon farming" is a useful approach to emphasize the activity of farming. Perhaps "carbon production" will become a concept, in terms of storing carbon in long-lasting wood products or plastics. In any case, a focus on the activities (negative emissions practices, emphasizing the verb and action, rather than the noun or technological object) keeps the social dimensions of people and place in the picture. Empirical social science can work towards understanding the contexts, changing social relations, and barriers to these activities on the ground in ways that are crucial to bringing carbon dioxide removal from pilot-scale theory to scaled-up practice. It also illustrates ways in which previous imaginaries of large-scale land transformation for climate policy have fallen short. For policymakers and modelers to continue to include assumptions about negative emissions in climate pathway projections constitutes, as Geden (2016) points out, the continued co-production of irresponsibility.

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Chapter 2

Calculating the Potential for "Blue Growth": Building Stories of Ocean Futures with Numbers

Abstract

The "blue economy" or "blue growth" narrative suggests that to feed and fuel nine billion people, humans will tap the oceans' potential to provide protein, energy, genetic resources, and ecosystem services. Twin narratives of the ocean's importance and fragility are buoyed by a litany of numbers cataloging dwindling fish stocks, seabed resources, carbon storage potential, and so on, measuring both the potential for responsible development and irresponsibility. Emerging technologies and methods of quantification drive the blue economy's ambitious story about the future human relationship with the ocean. Quantification operates in three overlapping ways: geographical measurements are combined with biophysical monitoring to enable economic calculations of ocean wealth. Four case studies of national interest in creating ocean economy metrics (the United States, China, Mauritius, and Ireland) illuminate how this number-based narrative and operates in policy, noting how assessments of ocean wealth can be a performative tool for states to engage promissory capital, and questioning underlying assumptions about how to manage lively oceans in the Anthropocene.

1. Introduction

Ocean acidification, dead zones, diminishing biodiversity: this is a perilous moment for the planet's oceans. While data about ocean decline is flowing in, the ocean is simultaneously being constructed as a terrain of abundance, a “knowable space” loaded with “marine resources” or “bioresources.” Varied terms are given to this vision of growth based upon ocean resources: "blue growth", "the blue economy", "the ocean economy", and "ocean wealth" are the most common. What counts as part of the blue economy? Assets like seafood, genetic resources, and mineral resources; new forms of energy like wave, current, tidal, ocean thermal, and offshore wind; and services like carbon sequestration are commonly counted. Shipping and trade, cable telecommunications, and tourism are sometimes counted: though sectors like tourism can be at odds with extractive sectors.

The blue economy is commonly introduced with a litany of facts and figures supporting the ocean's relevance to economic life, as well as life in general. The ocean produces half the oxygen we breathe. It provides 4.3 billion people with more than 15 percent of their annual animal protein consumption, and global ocean economic activity is estimated to be USD 3–5 trillion (FAO 2014). Ninety percent of trade moves by maritime transport; 95% of global telecommunications are carried by submarine cables; and 13 of the world's 20 megacities are coastal (Cicin-Sain 2015). Looking beyond the numbers, it is not clear that these are figures directly linked to the promise of the blue economy: how does "three-quarters of the earth's surface is water" directly link to economic potential? These statistics do, however, provoke a sense of wonder for this often-overlooked realm the planet. The ritual repetition of them reminds the reader that the ocean is there, vaster and older than us.

Importantly, the referent for ocean imaginations is often terra firma. It is land's relative scarcity which encourages the ocean to be constructed as a contrasting terrain of abundance. The ocean is posited as the solution for various land-originating crises: food, energy, material scarcity. The plain language found in an OECD assessment of the ocean economy is typical: "By mid-century enough food, jobs, energy, raw materials and economic growth will be required to sustain a likely population level of between 9 and 10 billion people. The potential of the ocean to help meet those requirements is huge" (2016). In short, the sea is the next frontier where all these needs will be pushed towards.

Ocean wealth, unlike many forms of land-based abundance, is hidden below the waves. It rests on practices of quantification to make it recognizable. Once it is countable, the results can promote attention and investment. There is also a mostly-unquestioned assumption that quantification of the oceans enables management. In the past decade, states and supranational organizations have incorporated the blue economy / blue growth vision into policy, relying on a myriad of measurements and metrics in order to do so. The past few years have seen a modest literature spring up to question the blue economy discourse and the specific measurement practices that enact it, and this article reviews this literature. There are a number of critical literatures that intersect with the blue economy — those on ecosystem services, for example, as well as fisheries and aquaculture production. Selected examples from these have been included in this review when their focus is on measurement and metrics, but in general, this review is limited to articles that either (1) engage the blue economy discourse directly, or (2) discuss its quantification practices. The review embarks with a brief discursive history of the blue economy. The second part examines the drive by nation-states to measure the oceans' wealth with economic tools. The third section looks at the measurement practices from biology and geography that these economic valuations depend upon, and explores the overlapping currents of literature from political ecology, geography, and science and technology studies that critically analyze these practices.

2. Where Did the "Blue Economy" Come From — and Why Does It Emerge Now?

Scientific measurements are indicating that the ocean is warming and rising in salinity, forcing changes in stratification and ocean overturning. It is acidic: ocean acidification is the "sleeper issue" of climate change, where about 30% of the carbon dioxide emitted into the atmosphere is now in the ocean, decreasing the average pH from about 8.2 to 8.1 since the beginning of the industrial revolution (NRC 2010). The rate of this change exceeds any known change in ocean chemistry for at least 800,000 years (ibid.). The ocean has 400+ dead zones, driven by eutrophication from agriculture (Diaz

2008). Notably, this dark facet of the Anthropocene ocean also rests upon quantification practices that enable us to know with greater and more painful accuracy what is occurring. While the statistics on the new ocean might seem to shatter any notions about the oceans as a space of new potential, the grim numbers in fact help drive the blue economy, as it is an imaginary built around sustainability and even repair. The worse climate change gets, the more we need alternative energy and food sources. The more challenges to biodiversity, the more ocean research is needed to address them: such is the logic of the blue economy. It is not just potentials and assets which count, but losses. As Achim Steiner wrote in a forward to the UN-agency collaborative report *Green Economy in a Blue World*, "through a better understanding of the enormous economic losses being sustained and the enormous opportunities from investing and re-investing in marine ecosystems, perhaps the balance can be tipped away from degradation and destruction to sustainable management for this generation and the ones to come" (2012). The hope lingers on that valuing ecosystems monetarily will result in valuing them spiritually and culturally enough to stop destroying them.

While this picture of the troubled ocean became increasingly detailed, economic, scientific, and political trends were converging to boost ideas of new ocean wealth. Firstly, high commodity prices (e.g. for food) and the land rush of 2008-2010 provoked a new wave of anxiety about the limits of terrestrial food and energy production. Promoters of new ocean industries, particularly aquaculture, but also marine renewables, seized upon this anxiety.

Secondly, rapid scientific advances in biotechnology and chemistry fed the search for new organisms that thrive in novel environments and encouraged excitement about new processing techniques for ocean biomass, like the marine biorefinery. Other technological advances in working offshore (e.g. robotics), telecommunications, and mapping are also opening new opportunities.

Thirdly, contemporary references to the blue economy in international development discourse began welling up in the run-up to the 2012 Rio+20 summit. This is well detailed in Silver et al's collaborative event ethnography, which examines the articulations of the term within four competing discourses about human-ocean relations: oceans as natural capital, oceans as good business, oceans as integral to Pacific SIDS, and oceans as small-scale fisheries livelihoods (2015). Oceans are now marked by their own Sustainable Development Goal: "Conserve and sustainably use the oceans, seas and marine resources for sustainable development". This SDG was pushed for by the Pacific SIDS (Visbeck et al 2014), and has the sub-target: "By 2030, increase the economic benefits to Small Island developing States and least developed countries from the sustainable use of marine resources, including through sustainable management of fisheries, aquaculture and tourism" (Cicin-Sain 2015). Metrics— i.e., quantitative indicators that make the previously unknown measurable— are key to this sustainable management, and to knowing if progress towards the goal has been achieved.

While the transnational notion of the global blue economy is often traced to the Rio+20 moment, many national ocean strategies attempted to quantify ocean wealth in the early 2000s, as will be discussed below. There was also an earlier ripple of literature about ocean wealth in the early 1970s and 1980s, with some similar drivers as today. Firstly, the Limits to Growth era sparked an initial interest in ocean cultivation for food and fuel — manifesting in projects like the US Navy's Ocean Food and Energy Farm project between 1972 and 1977, which constructed ocean farms for cultivating giant kelp (Wilcox 1982). Deep-sea mining was also of interest in this time, though it has yet to prove lucrative. Policy developments envisioned a more managed sea: for example, in the US, marine policy went forward with the Marine Mammal Protection Act of 1972, which explicitly required commercial fleets to change how they fished, and the Magnuson-Stevens Fishery Conservation and Management act in 1976. Before these, federal management of marine fisheries was virtually nonexistent (Myers and Worm 2003). Further enabling the sea to be managed terrain was the landmark 1982 UN Convention on Law of the Sea, a bottom-up agreement which enabled responsibility-taking, but which also made it possible to make definitive claims to resources. Scientific advances like the deep-sea research of the Alvin submersible also factored into excitement about the potential of the seas. While this earlier literature will generally not be reviewed here, it is important to note that today's wave of interest in ocean wealth has an earlier precedent.

3. Calculating the Blue Economy: State Attempts

Why spend time making these calculations, and for whom? It is not intuitive that it is necessary to measure the wealth of the ocean — in fact, through one lens it can seem quixotic, creating an information system for measuring the activity in a territory which is vast, fluid, and materially challenging to work in. While industry benefits from ocean economy enthusiasm, industry does not seem interested in creating collective ocean economy statistics. Sustainability, as mentioned, is a justification for measuring the oceans, and some NGOs are entering the discussion. The World Wildlife Fund's report *Reviving the Ocean Economy* put forth an annual gross marine product of $2.5 trillion and an oceanic asset base of $24 trillion: "Putting it into an international context, if the ocean were a country it would have the seventh largest economy in the world" (Hoegh-Guldberg 2015). The report is clear about what it hopes to achieve with its quantification-based revisioning: "We believe this new economic analysis, coupled with the scientific evidence, makes an undeniable case to move urgently beyond rhetoric to action" (ibid.).

For the most part, though, national ocean accounting is a state-led, or at least state-influenced, project. States need to measure to (1) manage their resources, and (2) be sustainable and make sure ocean health is protected. In general, there is an unquestioned assumption that links data with the capacity to manage. As Zhao et al write, in regards to China, "the availability of a wide range of accessible data on ocean economic activities is necessary for achieving the efficient management of the marine economy" (2014). Less oft-articulated reasons for measuring ocean wealth include (3) creating excitement to attract investors, and (4) creating jobs for the people doing the measuring.

States have varying, specific motivations for incorporating blue growth as a strategy. Small island states, with their 200-mile EEZs around each island, can revision themselves as "large ocean states" (Acharya 2014). Single-resource dependent countries like Oman, whose government income depends on oil and gas, could diversify their economies by expanding into blue biotech (Al-Belushi et al 2015). China, for example, has some geostrategic interest in expanding its ocean territory. The Irish strategy for harnessing ocean wealth hearkens towards valuing a part of its heritage which was undervalued under colonialism. Calculating the blue economy, then, goes beyond the aims of driving policy and driving investment to complex political and cultural concerns. In what follows, we will look at four examples from states who have been attempting to calculate ocean wealth, in order to ground discussion of these quantification practices and illuminate how they tie into management and responsibility-taking.

The United States: Quantification for planning and protection

Because of its academic strengths, work from the US has had a prominent role in measuring ocean wealth, though the US does not have a strong maritime identity compared to other nations. While in other states the drive to measure the ocean economy has been a top-down, ministerial-driven process, in the US academic entrepreneurship seems to have played a strong role. In the US, the National Ocean Economics Program began in 1999, and is headquartered at the Middlebury Institute of International Studies at

Monterey. Early studies estimated the GDP derived from ocean-related economic activities; more recent work looks at employment, wages, and different scales of analysis (Colgan 2013). Recently, the definition of the ocean economy has moved from a focus on economic activity rather than economic value (Colgan 2013). The four concepts comprising "activity" are establishments (a place where employees work), employment, wages, and gross domestic product-state.

These national efforts also include cross-national dialogue on ocean economy topics. For example, the newly developed Center for the Blue Economy has been holding workshops like the 2015 "The Oceans in National Income Accounts: Seeking Consensus on Definitions and Standards," in which representatives from 10 nations worked upon finding mutually agreed criteria for ocean wealth measurement (Spalding 2016). The work of scholars from the NOEP has been influential in other national programs, judging by citations, and so the values expressed in their techniques may also have been exported. The work in the US indicates a dual purpose for measuring ocean activity: planning and protection. In a 2010 article, Kildow and McIlgorm lay out the rationale for estimating the contribution to the oceans to national economies: oceans comprise a large part of national economies, and so marine trade and resource trends can have national-level impact. At the same time, ocean data is helpful to address challenges of moving away from a carbon-based economy, a decline in fish stocks, and land-based food shortages (ibid).

China: Quantification for industrial and geostrategic development

China is one of the few nations where the government collects and disseminates ocean economy data. China's marine economy plays a larger role in its national economy than in most nations — 9.7% of GDP, compared to the ranges of 1-3% calculated elsewhere (Song et al 2013). Its calculation efforts began in earnest in 1989, when the State Oceanic Administration was ordered to take responsibility for collecting and organizing marine statistics (ibid). The SOA has been responsible since the early 1980s for things like surveying and monitoring the marine environment, scientific research, and environmental management; the agency now also organizes how marine territory is used (Takeda 2014).

In 1990, the SOA drew up the Index System of National Marine Statistics. Interestingly, two of the eight categories it was initially comprised of did not yet have any data — marine medicine and seawater utilization— indicating a forward-thinking direction. These two domains received special five-year plans for their development in 2012 and 2013, giving them investment support (Zhao et al 2014). This was the first of many publications in marine statistics, the history of which is detailed in Song et al (2013). The field became increasingly relevant with the 2006 Outline of 11th Five Year Plan for National Economic and Social Development, which "emphasized that ''we must strengthen ocean awareness, safeguard ocean rights and interests, protect ocean biology, exploit ocean resources, implement marine integrated management and promote marine economic development'" (ibid). At this time, 12 categories were solidified, from offshore oil and gas to sea salt and marine engineering and architecture. It seems that a great emphasis is placed upon taxonomy. For example, the 2006 "Industrial classification for Ocean industries and their related activities" laid out core, supportive, and outer layers of the marine economy, and divided them into 28 first classes, 107 second and 380 third classes (ibid).

Currently, work is in progress on accounting for marine permanent capital, environment, and non-market valuation (Song et al 2013); see Zhao et al (2014) for details. The 12th Five Year Plan (2011-2015) goes into greater depth about the ocean economy, calling for the nation to “develop and implement a marine development strategy based on unified sea and land planning, and improve marine development and control capabilities" (Takeda 2014). Three new areas of emphasis in this plan are renewable energy from the oceans, deep-seabed mineral exploration (e.g. methane hydrates), and polar exploration, as China seeks to make its mark in the Arctic (ibid). The government also plans to develop 11 ocean economic development zones (Zhao et al 2014). However, some of this emphasis on emerging industries— which contribute just a small fraction of growth— is concurrent with neglect of traditional industries like aquaculture (Ding et al 2014). Ding et al note that the marine economy is not developing exactly as planned: instead of coastal reclamation, large scale sea reclamation is done because it is cheaper. According to one government report, more than half of China's 18,000 km of coastline has been artificially modified (ibid). Rather than developing "marine resources", industrial coastal development has occurred, such as port construction, real estate, shipbuilding, etc. (ibid). This disjunct between the policy vision and outcomes, even in a state which emphasizes planning, may indicate the limits of state control over investment flows.

In China, the marine economy is wrapped up with state power. In a 2012 address to the National Congress of the Communist Party of China, General Secretary Hu Jintao declared, “We should enhance our capacity for exploiting marine resources, develop the marine economy, protect the marine ecological environment, resolutely safeguard China’s maritime rights and interests, and build China into a maritime power" (Takeda 2014). Scarcity plays a role in this. Productive land resources are near the limits of exploitation in some areas of China— the nation imports the majority of the oil it uses, has limited supplies of fresh water, and has limits to cultivation— all of which has led national strategy towards the seas, and towards asserting its rights to their resources (Zhao et al 2014; Takeda 2014). In 2013, the SOA director gave a speech in which he stressed safeguarding the maritime rights of the state: "We will move further ahead with comprehensive administration, and we will strike a ‘combination blow,’ the main elements of which will be legal, administrative, and maritime activities and public opinion propaganda. We will undertake systematic deepening of research and external propaganda on hot issues of maritime rights and interests.” (Takeda 2014). Quantification practices are set to underlie the legal and administrative aspects of this "combination blow."

Ireland: Quantification for economic recovery and cultural awareness

Ireland's "Harnessing Our Ocean Wealth" strategy was launched in 2011, after roughly a decade of work on ocean economies by academics and government researchers at the state's Marine Institute and NUI Galway's Socio-Economic Marine Research Unit. It has two numerical targets: to reach €6.4 billion a year in turnover from our maritime sectors by 2020, and doubling their contribution to GDP to 2.4% a year by 2030 (2012). The strategy emerged in the wake of the 2008 downturn— and the government's emphasis on "balanced" economic recovery, which means recovery for regions and rural areas. At the same time, the ocean strategy is a part of a broader economic thrust towards a knowledge-based high-value added economy. One of the aims is to "strengthen the collation of marine socio-economic data to ensure the timely availability of marine socio-economic statistics, providing an evidence-base for policy and decision- making, economic forecasting and scenario planning." The academic efforts to quantify ocean wealth (Morrissey et al 2011) draw upon Colgan and the US NOEP; and academic work has also looked at regional disparities (Morrissey and O'Donoghue 2012), illustrating the power of a geographical analysis. Morrissey and O'Donoghue (2013) extend their work to an input-output analysis, which looks at inter-industry linkage effects, production-inducing effects and employment multipliers. Marine mapping has also been a part of the strategy broadly.

The strategy's three goals (based on the three pillars of sustainability) are to have a thriving maritime economy, to maintain healthy ecosystems, and to increase engagement with the sea. This goal of strengthening maritime identity and increasing awareness of the value (market and non-market) of the sea might seem out of character with this kind of report, but it relates to the history of cultivation and land appropriation under British rule, in which land was the focus of struggle. The state's narrative in the strategy alludes to this: "We have embraced the land as the primary provider of food and fuel; often overlooking our ocean wealth. We often hear that we tend to have a blind spot in relation to Ireland's marine resource." The document is in essence a reframing document, beginning with a map captioned: "The 'Real' Map of Ireland with 220 Million Acres Under the Sea" ("Harnessing" 2012).

The example of Ireland is notable for its emphasis on public buy-in. It was shaped by stakeholder consultation, with 192 submissions, and it continues to seek to engage the public. For example, the third annual Our Ocean Wealth conference in 2016 at the National University of Ireland, Galway, is being held concurrently with an industry conference (Global Insights: Irish Opportunity, by Bord Iascaigh Mhara), and a public festival: SeaFest, with a giant paper boat, tours of marine survey and research vessels, and remote controlled boats to play with. It will be interesting to track if the goal of public engagement with the sea translates into success with other aspects of the strategy.

Mauritius: Quantification for a developmental state

Mauritius, an island nation 2000 km off the coast of East Africa with a population of 1.3 million, is not the smallest of island states, with more people and economic capability than many of the small island developing states. Mauritius considers itself to be a "large ocean state". It has an "economic ocean space" of 2.3 million square kilometers, "equivalent to the combined land mass of Spain, Italy, France and the UK" (Roadmap 2013). That is, its ocean space is more than 1100 times that of its land mass (ibid.).

As the Mauritius Government Programme 2012-2015 states, the recognition of Mauritius's economic rights over the EEZ "will transform our sense of our own geography and constraints", and hence "government will invite the nation to embark on a major rethink of the potential beyond our existing land mass and consider opportunities as an Ocean State" ("Government" 2012). On one hand, this is clearly an exercise in actively re-imagining one's brand, and Mauritius is highly invested in its brand of being an "economic miracle in the Indian Ocean". However, Mauritius has gone further than many nations in claiming an "ocean economy" as a pillar of its economy. With one of the highest median incomes in Africa, Mauritius occupies a space where it can plausibly imagine a technology-driven development strategy— and it has a history of guiding its own development and standing up new industries. While the colonial economy was driven by sugar, the government took on a program of industrialization post-independence, building industries in export processing / textiles and then finance. The ocean economy is considered to be the latest new strategic direction. The government has proceeded in an organized matter. As part of the "Government Programme 2012-

2015", Mauritius created a National Dialogue on the Ocean Economy, and from this process set out the 2013 Roadmap for the Ocean Economy. The seven main clusters identified in the Roadmap are (1) seabed exploration for hydrocarbon & minerals; (2) fishing, seafood processing, and aquaculture; (3) Deep Ocean Water Applications (DOWA); (4) marine services, including biotech, tourism, finance, ICT, and ship registration; (5) seaport-related activities; (6) marine renewable energies; and (7) ocean knowledge ("Government" 2012). The position of Minister of the Ocean Economy was created, and in 2014, Mauritius opened the Faculty of Ocean Studies, which strategically feeds into the ocean knowledge cluster.

Developing the Ocean Economy is envisioned to take time. In speech made by the former Prime Minister Ramgoolam, he stated, "It has taken us some 50 years to be where we are from a monocrop economy. It will take Mauritius longer to develop its Ocean Economy. This task is not for our generation only – it is a task for many more generations – and it is a task that we need to accomplish. The Ocean Economy is the bridge to the future of our country" (2013). This narrative continues the story of Mauritius rising from its colonial past to a diverse, postmodern economy. Though the administration changed in 2014, the new government seems to still be committed to the ocean economy idea. The Ocean Economy, in this case, is a program of nation-building and future-building for a post-colonial state.

These four cases show the varying rationales that can drive the blue economy. While to some degree the answer to "Who authors future environments?" is in fact "technocrats" or "economists", working in some coalition of state-sponsored research and academia, they are responding to different demands. The sensitivity to the environment evidenced in the US efforts probably reflects the influence of a strong environmental NGO presence in ocean discussions; the focus on education in Mauritius shows its drive to be a development-oriented state and build local capacity in a strategic area. The processes by which Ireland sought to do stakeholder engagement in its ocean strategy, and the inclusive title of "Harnessing our ocean wealth", show efforts to cast the ocean as a collective resource. How well these positions translate into citizen involvement in environment-shaping is an empirical question beyond the scope of this chapter, but the four cases offer interesting insights into how national interests can influence the terms, tenor, and grounds for citizen engagement in environment-shaping imaginaries.

4. Quantification Processes: How Geographic, Biological, and Economic Forms of Measurement Work Together

The above four cases illustrate a variety of motivations for quantifying ocean economies: integrated management, geostrategic expansion, cultural identity-building, national economic development. These cases also illustrate the patchwork nature of ocean economy measurement. There are two main challenges to coherent metrics: (1) official national statistics are not designed to measure the economic contribution of the oceans, and (2) "the results obtained in these studies are not comparable because the selection of maritime activities, classification systems, data collection methodology, time periods or geographical scale, that is, the very definition of what it is considered maritime economy varies from country to country" (Fernandez-Macho et al 2016). Perhaps in an era of big data, some of this data-matching will become easier, but it may require a much stronger force to lobby for it to be better funded.

There is not a widespread literature about the practice of ocean accounting, or about the blue economy comprehensively. Why? Perhaps because the notions are relatively new, perhaps because of disciplinary boundaries; perhaps because some of the technologies are emergent, or because the blue economy is a largely discursive phenomenon, encompassing some sociotechnical imaginaries that may not yet have great impacts on the ground (compared to other phenomena that catch the attention of social scientists). However, there are sub-literatures that address facets of ocean economy measurement. That is, while scholarly attention is not focused directly upon measuring ocean wealth as in the four examples mentioned above, scholars have scrutinized component practices: measuring ocean space and measuring ocean life.

Geography: measuring space and place-bound resources

The drive to measure ocean space, and what it contains, has roots in navigation and maritime charting. For a historical perspective, Anne-Flore Laloë's 2016 book examines the scientific and cultural paradigms leading to the production of knowledge about ocean-space over the last four centuries. She examines the role of technologies like sounding-devices, ships, and measuring buoys. The link between these historical practices of charting and the blue economy can be seen in the US National Ocean Policy's Ocean Economy section, which aims to "Advance our mapping and charting capabilities and products to support a range of economic activities."

To sustain the flow of the trillions of dollars and goods that pass through our ports and the many business that rely on the ocean, our coasts, and Great Lakes, agencies will coordinate to produce better mapping and charting products, which serve to preserve, protect, and expand our Nation's maritime economic activities. Improved mapping, charting, and associated products will enhance the efficiency of maritime commerce through safer navigation and better accident-avoidance, and updated hydrographic charts and seafloor maps will support marine industries such as offshore energy. These products will also provide coastal communities with better elevation and bathymetric data to plan for and mitigate economic impacts of disasters.

The rationale here is that mapping brings (1) efficiency, (2) knowledge for extractive industries, and (3) security, in terms of disaster response. Beyond cartography, the policy also advocates ocean-observing systems for real-time information on marine conditions, to support commerce.

From a nation-state perspective, quantifying the maritime domain through geographic practices is useful for both military aims, and for making claims on ocean space. Under the UN Convention on the Law of the Sea, maritime claims are based upon underwater geology, as coastal states have sovereignty over their continental shelf. Each nation's exclusive economic zone (EEZ) extends 200 miles from the shore, but in some cases the continental shelf extends beyond 200 nautical miles, thus enabling claims based upon the "extended continental shelf." Improvements in undersea charting technology have enabled many such claims in recent decades.

Quantifying ocean space is of interest to other actors, however; conservationists, for example, argue for marine protected areas. In the past decade, marine spatial planning (MSP) has been proffered as a multi-stakeholder approach to addressing multiple uses of marine space. This can be seen as an attempt to extend the logic of urban planning into rationalized global sea-space, regulating not the materiality of the sea but the relations between users (Ryan 2015). Ryan points out that "zoning is profitably understood as a taxonomical process: as technological capability increases and scientific knowledge of the ocean expands, the global maritime is being systematically sub- divided into ever smaller administrative units" (2015). With multiple stakeholders and multiple uses, there are tensions inherent in marine spatial planning, as the logics of production and conservation are at odds (ibid.).

Marine spatial planning and other mapping practices have given rise to three key scholarly responses. Firstly, there are calls to better incorporate social data into marine spatial planning, and make it truly more participatory or interdisciplinary (e.g. Kittinger et al 2014; see also Gruby et al's 2015 review article on a social science research agenda large marine protected areas). Secondly, there is literature expressing concerns about how maritime protection zones and MSP contribute to new enclosures and "green grabbing" for conservation, or "blue grabbing". Thirdly, and relatedly, there is an emerging geographical current of literature encouraging thinking beyond Euclidean space (Ryan 2015). Steinberg and Peters propose "a wet ontology not merely to endorse the perspective of a world of flows, connections, liquidities, and becomings, but also to propose a means by which the sea's material and phenomenological distinctiveness can facilitate the reimagining and reenlivening of a world ever on the move" (2015). They highlight dimensions of volume, motion, and animation, as opposed to state ontologies of defined lines, suggesting that "In various frames, then, the sea is a fruitful space for revisioning volume and subsequent geopolitical order, offering a lens through which to study space and power from different angles. It is also a useful space for reconceptualising and ungrounding notions of time" (ibid.). This is a very different approach to ocean space from quantifying it with GIS tools. Empirical case studies like Van der Horst and Vermeylen's look at wind farm zoning procedures and top-down spatial planning for flow resources illustrate the difficulties of counting on fluid assets (2010).

One result of these geographic practices, as Ryan points out, is to create value: "By being able to scientifically analyse, plan and predict the usage of space it acquires an economic worth. A hierarchy of value is constructed – some spaces are deemed to be more productive than other spaces and a market comes into being" (2015). The economic calculations of ocean wealth rely on these geographic practices to contain their value; they also rely on practices which count what is inside the containers.

Biophysical science: measuring life

Measuring ocean life has a long history in fisheries management. One primary current of literature stems from this, critiquing new enclosures and aquaculture as well as conventional fisheries management. A second current of literature focuses upon measuring of ecosystem services, such as climate regulation. In this we can include carbon, with "blue carbon" (carbon stored in mangroves and seagrass, for example) as a field of increasing interest (see Silver et al 2015). A third, narrower current of literature links with science and technology studies, and looks at marine bioprospecting — which involves finding new forms of life, with the aim of quantifying their genetic material. All of these concerns are included within a growing field of literature on "ocean grabbing"; below, these three currents of literature will be reviewed in turn.

Fisheries governance, aquaculture, and the "Blue Revolution"

The measurement practices in sea fishery management have been interrogated from various angles. Single-species biomass forecasting is used by governments to set the total allowable catch (TAC), and the UNCLOS mandates its signatories to use

Maximum Sustainable Yield to set catch yields (Cardwell and Thornton, 2015). Cardwell and Thornton review the history of three approaches to sea management — market-based fisheries management, based in bioeconomics; area-based conservation, based upon conservation biology; and community-based management, based upon anthropology. They also helpfully review the small literature in human geography work on the sea, and call for more of it. Geography can offer new ways of thinking about governing ocean space; as mentioned in the previous section. Scholarship on more-than-human geographies can highlight how the liveliness and mobility of sea life complicates rational management practices, as Bear (2013) does in an exploration of the Welsh Cardigan Bay scallop fishery.

Alongside an ecological or sustainability critique of sea fishery practices is a producer-oriented critique. Mansfield authored a series of articles about neoliberalism in the oceans (2004), examining topics like property rights and the role of the state. The processes of rationalization she analyses are obviously linked with measurement practices. Later, a special issue of The Journal of Agrarian Change edited by Campling (2012) demonstrated the "historical and socio-ecological complexity of capture fisheries", and critiqued how technical practices designed to capture "maximum sustainable yield" are in fact political processes bound up with capitalist accumulation. Multilateral agencies like the Food and Agriculture Organization (FAO) have some sensitivity to this. After Rio+20, the FAO headed up the Blue Growth Initiative, which seeks to help countries implement the blue economy. This has nevertheless provoked some critical response for its quantification practices and “technocratic understanding” they represent (Doerr 2016).

This critique of the Blue Growth Initiative is more understandable in the context of the recent land rush (Bennett et al 2015). Some scholars and NGOs focusing on how land grabbing affects smallholder farmers have turned their attention to fisherfolk, or ocean grabbing, with a landmark report being the Transnational Institute (TNI) 2014 primer on *The Global Ocean Grab.* As Oliver de Schutter, UN special rapporteur on the right to food, said: “Ocean-grabbing’ – in the shape of shady access agreements that harm small-scale fishers, unreported catch, incursions into protected waters, and the diversion of resources away from local populations – can be as serious a threat as ‘land-grabbing”. Bennett et al (2015) caution about misapplying the term, and offer a method of determining whether an intervention is "ocean grabbing," which they define:

> Ocean grabbing refers to dispossession or appropriation of use, control or access to ocean space or resources from prior resource users, rights holders or inhabitants. Ocean grabbing occurs through inappropriate governance processes and might employ acts that undermine human security or livelihoods or produce impacts that impair social–ecological well-being. Ocean grabbing can be perpetrated by public institutions or private interests.

Ocean grabbing can refer to appropriation of spaces or resources, living or non-living (ibid). While at first ocean grabbing was used to refer to fish stocks, it could also refer to the taking of habitats, sand or minerals, etc., through various means of reallocation: single or multiple-use enclosures, changing property regimes, and changing resource allocation or resource use regimes, all of which are helpfully explored in Bennett et al's (2015) framework. The drivers, according to TNI, are the emergence of a corporate seafood regime rearranging production chains and concentrating power and control; the privatization of sea-scapes; and the financialization of natural resources (2014).

In response to these concerns about new enclosures, some have posited the marine counterpart to food sovereignty: seafood sovereignty. "Blue Growth is an extension of the sustainability discourse that does not promise substantial change to capitalism's environmentally and socially destructive practices, whereas Seafood Sovereignty advocates environmentally friendly and labor intensive practices which should receive recognition and protection as traditional or acquired fishing rights" (Doerr 2016). In this discourse, blue growth is a cover for continued exploitation, and some technologies even decrease seafood sovereignty. As Harris writes, "Seafood sovereignty is threatened and challenged by the introduction of exotic species, inshore aquaculture, inshore harvesting by non-traditional technologies, allocation of access to offshore fisheries to foreign interests with non-traditional technologies, the tendency for foreign interests to deplete and depart, the creation of marine protected areas, the introduction of frankenfish and supersalmon, habitat destruction, and exploitation for exportation"(Harris 2013).

To understand this basket of threats, it's helpful to understand the contemporary moment in terms of another "blue" catchphrase: the Blue Revolution. It imagines the counterpart to the Green Revolution. “Within the next fifty years fish farming may change us from hunters and gatherers on the seas into ‘marine pastoralists’—just as a similar innovation some 10,000 years ago changed our ancestors from hunters and gatherers on the land into agriculturists and pastoralists”, writes oft-quoted management guru Peter Drucker (1999). This idea also featured in groups like the Seasteading Institute: “We’ve pushed agriculture and the Green Revolution to its limits on land, but remained hunter-gatherers on the ocean. A Blue Revolution in ocean farming technology would launch seasteads to center stage” (SI n.d.). And, of course, aquaculture companies would also be on stage: “by 2050 the human population is projected to be at 9.6 billion ... We currently stand astride an historic moment when aquaculture is finally overtaking capture fisheries as the largest source of protein from the sea, just as in our distant past, animal husbandry eventually overtook hunting as our primary source of meat,” states Henry Clifford, the VP at Aquabounty Technologies, who makes AquAdvantage GMO salmon (BioMarine 2013: 15).

The rise of aquaculture takes place upon the backdrop of the decline of capture fisheries, which have faced falling catches since the 1990s. So far, aquaculture has been able to make up the shortfall. There are numerous potential problems with industrial-scale aquaculture: feces and waste feed falling to sediments can create sterile zones, nutrients can fertilize the water and create noxious algae blooms, waste from culture ponds can cause algae blooms, cultured organisms could transmit disease to wild organisms, cultured fish could escape, genetic diversity can change, etc. (Stickney, 30). One key problem is that 1/3 of the wild fish caught on earth end up as fish meal, and of that 81% goes to feed farmed fish (Myers and Worm 2003). A chief critique of the aquaculture industry is that instead of raising smaller fish, it's raising carnivorous ones, which is nonsensical from a sustainability standpoint. Yet carnivorous fish are just 7.1% of aquacultural production, with omnivores and hervibores at 34.4%, filter feeders (like mussels) at 35%, and photosynthetic plants at 22.9% (World Bank 2007). So there really is a diversity of animals and plants being domesticated in the water beyond the press-grabbing carnivorous fish. Moreover, 90% of global ocean-cultivated tonnage is from ecologically friendly crops like seaweeds, herbivores, omnivores and detritivores (Neori 2007: 117).

But it's clear that there are all kinds of quantification practices necessary to enact a Blue Revolution — the scientific application of extending domestication and control into the seas requires measuring the species under cultivation, examining their growth rates, examining their impact, and so on. This is a highly regulated sector in many countries. Aquaculture broadly has generated a wealth of empirical social science studies, and the work on this new form of production is beyond the scope of this article to review. Political ecologists have looked at ecological, boom-bust, and valuation dimensions of the transition to seafood farming (e.g. Hall 2003; Martinez-Alier 2009).

Few people, though, have looked at the Blue Revolution discourse more broadly — perhaps because it rings as hubristic and unrealistic, or perhaps because empirical scientists are often grounded at local scales.

Blue carbon and blue infrastructure

Many of the key concerns in the literature inspired by studying effects on fisherfolk — such as the degradation of the global commons and unjust resource allocation — also crop up in the literature about measuring not just the stocks, but the flows, of marine life. New science offers new ways of conceiving, and measuring, the flows. One prime example is the concept of blue carbon, which was first introduce by UNEP and other organizations in a 2009 report, *Blue Carbon: The Role of Healthy Oceans in Binding Carbon* (Nellemann et al 2009). Blue carbon is the carbon dioxide stored in coastal ecosystems like mangroves, marshes, and seagrass meadows. However, the current push to value blue carbon needs to be seen in the context of a broader push for valuation and commodification of nature, argues Barbesgaard (2016). As of now, there is very little literature on it, save for Wylie et al's review of four case studies (2016).

A related concept is that of "blue infrastructure", defined by Edwards et al as "the coastal and near shore habitats that provide the physical matrix for ecological functions, which in-turn provide important services and ecological benefits to society" (2014). These authors measured the economic impact of restoring blue habitats, finding that habitat restoration projects funded through the 2009 American Recovery and Reinvestment Act created 17 jobs per million dollars spent — a similar number to other conservation industries such as parks and land conservation, and much more than industries like coal, gas, and nuclear energy generation (ibid). This case points towards how efforts to value habitat and services that occur within it can have outcomes that are not necessarily just marketization for capital's sake: rather than the state valuing the ecosystem to create new markets for capital, it valued the ecosystem in order to justify restoring it.

Marine bioresources and bioprospecting

Marine biotechnology products are a multibillion dollar industry, with marine genetic products found in pharmaceuticals, cosmetics, nutrition supplements, and more. Marine bioprospecting, or the discovery of new genetic resources in marine life forms, has yielded several thousand novel molecules in recent years (Leal et al 2012). Bioprospecting is occasionally cited in reports as a countable, and exciting, part of the blue economy. Leary et al (2009) reviewed the literature about bioprospecting in marine areas. There has been a push for international policymaking in recent years, with the issue negotiated in five different international institutions and mechanisms (ibid). What does this have to do with measurement? The Ad Hoc Open-ended Informal Working Group— one part of the UN process— noted the "socio-economic value of marine biological diversity in areas beyond national jurisdiction" among knowledge gaps that need to be filled for policymaking (Leary et al 2009).

There is an implicit link between counting something and conserving it — and between counting marine genetic resources and recognizing their value. Many marine invertebrates are "undervalued", but hold great potential for new drugs, and exploring these organisms could offer great revenues for countries holding legal rights over the EEZs where bioprospecting happens, provided that countries conserve these resources (Leal et al 2012). The hidden potential in lifeforms is a call to value life. Biotechnology also creates value across sectors: deep-sea discoveries affect the development of applications from biotechnology, which can be quite diverse (Leary et al 2009). For example, the company Verenium has developed an enzyme for cellulosic ethanol production on the basis of samples collected by the deep sea submersible Alvin (ibid.). The ways in which the search for genetic material is regulated can have far-reaching impacts on multiple non-marine sectors.

One of the only critical analyses of marine genetic biotechnology was done by Stefan Helmreich (2007), who develops the concept of "blue-green capital" in his ethnographic study of a marine biotech research center in Hawaii. In his analysis, "blue stands for (a particularly American vision of) the freedom of the open ocean and for speculative sky-high promise, and green for belief in ecological sustainability as well as biological fecundity" (2007: 289). Helmreich describes how marine biotech was imagined as biocapital, which has a promissory character: the resources are expected to replicate wealth through their biological processes. Given the promissory excitement around marine bioresources, it is interesting that there is not more scholarly work on the underlying assumptions. Perhaps this is simply because these organisms are some of the most remote on earth, and because this arena of measuring life or "ocean grabbing" is the least accessible to social scientists and critical scholars.

5. Conclusion: Quantification Between Extractivism and Protection

This exploration has delved into how geographical and biological methods of counting collaborate to inform economic valuations of ocean space and ocean life. Underlying these calculations are questionable assumptions about the importance of calculation and data in managing the oceans — and the ability to manage the lively, fluid seas itself. At a time when cultures and organizations are obsessed with data, and when technology has made massive datasets possible, a focus on data as the key to management is understandable. However, this can obscure other factors key to management: the wellbeing of labor forces, stable climatic conditions, freedom from corruption, cross-sector cooperation, etc. Moreover, underlying the quantification practices and the discourse around them is also a deep, and yet predictable, tension between generating wealth and conserving ecology. All of this leads to two key questions. Firstly, *can* there be measurement-informed management of these lively spaces? Secondly, can there be management that is not simply extractive? Subquestions emerge: Where does data-driven managerialism work? Why does it fail? What actors are involved, who bears the risks and wins the profits of these endeavors, and what do they mean for local, regional, and global ecologies?

Empirical research may be able to partially answer these questions in the future. The empirical research done thus far, which in some aspects is quite minimal, does not give cause for optimism about a data-driven managerial approach. Many of the studies mentioned above have drawn a picture of an ocean relentlessly monitored to turn lifeforms into profit. Analyzing attempts to calculate ocean wealth also illuminate how the state works for capitalism, in creating these ocean wealth fantasies for investors. Ocean calculations are performed in a dual sense: they are also a performative tool for engaging promissory capital. Performing the calculations is one stage in the process of state facilitation of the enclosure of marine resources, as described by TNI, where the state acts as "the ultimate broker in allocating how, for what purposes and by whom, fish water and land can be used" (2014). Looking from the perspective of the state, one can see an example of how states envision their role in Ireland's strategy, which lucidly sketches out an integrated marine plan with a strong focus on private investment. It states that the government cannot dictate market demand, but it "can facilitate economic growth by delivering a business-friendly and robust governance, policy and planning environment, which is supportive of private investment and entrepreneurship. In other words, governments can create the right conditions for growth" (“Harnessing” 2012).

On one hand, there is cause to fear that states have been co-opted into facilitating private extraction of ocean biopower and natural wealth, in many cases also impacting people who derive livelihoods from the sea. On the other hand, the measurement practices attempted by states may be useful tools in some cases: they are packaged with a mandate to consider conservation, and within the sustainable development discourse, this is a large part of the rationale for enacting these practices. Some measurement of ocean life is done to further conservation goals, and restoration goals. The US ocean strategy, for example, points out that one needs planning to restore an ecosystem, and monitoring to know if the restoration is going to plan (NOC 2013). It is hard to imagine the ecological healing this era demands without some types of quantification. The question is, what types of quantification can coexist with other types of valuation, awareness, and appreciation?

Insomuch as a risk of these quantification practices is that they omit the social, or make assumptions about how the social relations around future marine production will be arranged, social scientists can help fill these knowledge gaps. Further research is particularly warranted into three areas. First, more empirical studies of the changes in social relations already wrought by Blue Economy calculations and practices are needed, including ocean grabbing, new forms of cultivation, and new oceanic extraction: what have these initial attempts to contend with the Anthropocene ocean brought communities, ecosystems, and nation-states? A second area of research is alternative metrics, such as measurements of ocean health, though complementary indices will not be a strong synthetic solution to the tension between extraction and protection as long as they can practically be ignored. An important third line of inquiry could use deliberative and anticipatory methodologies from social science (2008; Guston 2013), in order to generate and record citizen's narratives of possible life with the Anthropocene ocean. Key questions might include: What do people want to measure? Who should perform these measurements, and how? Who can access and use the results? What would quantification, monitoring, and caretaking by local communities look like? What happens to those dimensions of living with the ocean that aren't easily measured? How do measurements support forms of responsibility like accountability? Together, research along these three streams can highlight how metrics might be used for responsibility-making on oceanic terrain, which has for so long been beyond the bounds of legal responsibility.

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Chapter 3

Choosing a future for California's Salton Sea:

Making and taking responsibility in the Anthropocene

Abstract

California's largest lake, the Salton Sea, is shrinking and becoming more saline. As part of a rural-to-urban water transfer agreement, its inflows will be lowered at the beginning of 2018, placing the sea at an ecological tipping point. Failing to intervene will allow an environmental and public health crisis due to fish and bird die-offs and exposed dust blowing off the receding shores. Based on site visits and 30 semi-structured interviews in the Coachella and Imperial Valleys, this paper analyzes how the options for the sea's management or care have been formed, chosen, and rejected. How do people legitimize or sell a limited, interim, or incremental "solution" to environmental crisis? How does a society come to accept ecological sacrifice, or generate other options? Though the State of California is attempting to take action with a new ten-year plan, it is possible that it is not even technically capable of dealing with the issue due to fiscal, political, legal, and regulatory constraints, and so responsibility for the sea has been made but not yet fully taken. In the absence of sufficient responsibility-taking by the state, other actors such as citizens, environmental startups, and farmer-led private sector initiatives are attempting to take responsibility, but they face systemic constraints. The paper explores how these

actors wrestle with and attempt to move around these constraints via approaches of reframing the issue in terms of social and environmental justice, media production, citizen science, and participating in formal processes. This study offers insight into how responsibility for ecological flourishing can be made and taken via collective social processes, and also reveals some of the limitations of the increasingly popular narrative that the Anthropocene represents a new era of ecological responsibility.

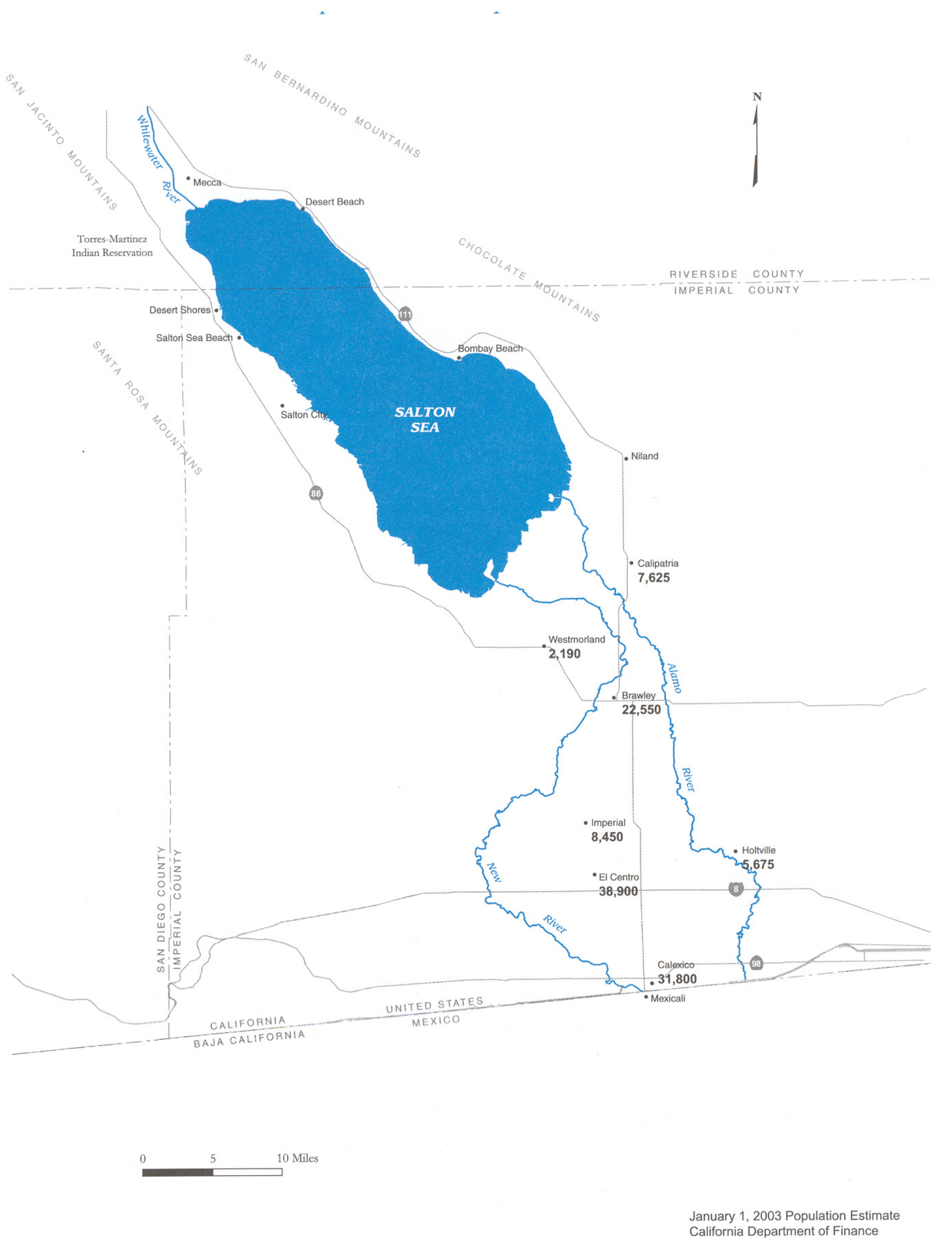
1. Introduction

I had drunk in a certain doctrine, whose sources are as obscurely ubiquitous and whose substance is as tainted as New River water, that only an "expert" has the right to judge the acceptability of the water of life. The Salton Sea is a ding sump or the Salton Sea is the most productive fishery in the world.

— William Vollman, Imperial

The Salton Sea in southeast California is an ecosystem whose days are numbered. On Dec. 31, 2017, provisions in an agreement to transfer Colorado River water from the Imperial Irrigation District to the sea expire. At this point the sea will contract more rapidly, exposing 48,000 acres of dust laden with farm chemicals over the next ten years.

Salinity will begin to rise more dramatically, tripling over the next thirty years. (SSMP, 2017)[3].



[3] Currently, the sea is about 59 ppt, with model estimates of 153.1 ppt by 2045 — ocean water is approximately 35 ppt (SSMP, 2017)

Figure 1. Map of Salton Sea and surrounding communities, California Department of Water Resources

In another sense, the Salton Sea's days are cyclical and eternal, as there has been an intermittent lake in this sink which has appeared and disappeared several times over the centuries. This most recent incarnation is commonly attributed to a human blunder: from 1905-1907, a cut in a canal made by the California Development Company changed the course of the Colorado River, creating what's been called the "lake by mistake." It has no outflow, and dwindling inflows, as it is fed by agricultural water — in fact, some farmers observe that it hadn't been created in 1905, it would still need to exist today in some form as an agricultural sump for the lush desert farms. An agreement to transfer water from this desert agricultural area to the thirsty urban coast means that less water goes into the sea.

For decades, technical committees and Salton Sea citizens across the Coachella and Imperial Valleys have been evaluating options for the approaching ecological and public health crisis. This paper explores the processes for selecting environmental futures, particularly recent efforts, and examines how some options for the sea are viewed as realistic while others are rejected. In particular, we will look at the State of California's plans for a "smaller, sustainable sea" and dust suppression, the land management options put forth by farmers and private entities, and the hopes for importing ocean water into the sea. This paper then discusses these options and their promoters with regards to notions of responsibility and agency in environmental modification: Who is responsible for the sea's continued functioning as a viable place for human and nonhuman life? How is responsibility made and taken? Who must act, and who can act?

Part of the coming-of-age story of the Anthropocene — the idea that humans are in a new geological epoch due to human activity — involves recognizing a responsibility to care for the earth, either in terms of repairing past damages or actively helping to design and maintain novel ecosystems. While much Anthropocene literature looks at risk and responsibility on a global scale, it is illuminating to look at a landscape-scale process of making and taking responsibility. There are a number of reasons why the Salton Sea makes an interesting study for interrogating this responsibility-in-the-Anthropocene narrative more deeply. Firstly, the current incarnation of the sea was created by human error, and the idea that this is already not a natural ecosystem modifies perspectives about what kind of obligation we have for it. Secondly, the sea is within a heavily managed industrial agricultural landscape — in some ways, it could be seen as a byproduct of environmental irresponsibility by agribusiness. Thirdly, it is at a recognized ecological tipping point — almost every actor agrees that there is a mandate for increased human responsibility of some kind. Fourthly, the responsibility for the sea has been legally taken by the State of California as part of a water transfer agreement, which is a unique situation. In the rest of this introduction, we'll delve into the environmental history of the sea and explain its current situation.

The "lake by mistake": A creation story

The Imperial Valley is one of the harshest landscapes in North America, with three inches of rainfall a year and typical temperatures over 110 degrees Fahrenheit (43°C) in the summer months. It is also a socio-economically distressed landscape, with 25% unemployment and 1 in 5 residents living in poverty (LHC, 2015). It should not be taken as inevitable that this valley would boast 500,000 acres of irrigated farmland producing millions of dollars worth of melons and lettuce, not to mention sudangrass, Bermuda grass, and alfalfa for Chinese cattle and Saudi camels. But the inhospitability did not dissuade the dreams of "the pioneers", who materialized at a time when the frontier was closing elsewhere.

The two engineers who built the valley's irrigation system were George Chaffey, a self-taught maritime engineer who in the 1880s combined irrigation, electric light, and telephone lines to build foundational examples of the modern southern California lifestyle, and Charles Rockwood, a surveyor and engineering-school dropout who was determined to build a canal to bring Colorado River water downwards via gravity into the Salton Sink (Starr, 1990: 15). With partners, Rockwood created the California Development Company (CDC), an enterprise which by 1900 was desperately in debt. George Chaffey had just returned financially ruined from a decade of learning about irrigation in Australia, and took on the project of building the canal as a design challenge that could repair his reputation.

Chaffey renamed the Salton Sink the Imperial Valley, and the task of the next few years was to attract settlers to the desolate landscape through an imaginative marketing campaign. This was successful — cropland expanded at a remarkable rate. However, political discontent was swelling over how private entrepreneurs were abusing federal legislation designed to give land to homesteaders. In the desert, land was worthless without water, and settlers had to buy "water stock" from the CDC and its mutual water companies. So there was a conflict between the CDC's private model of development and the public-good model espoused by irrigationists such as William Ellsworth Smythe, who believed that California could be a culture "in which each square foot of the land would be cherished and crafted as either irrigated agriculture, landscaped garden, or fallow soil resting for future productivity" (Starr, 1990: 31). This crafted landscape, Smythe believed, should be developed by government, whose role it was to fairly distribute the water. Irrigation also implied other developments: education and "mental development", building homes, setting up permanent towns with post offices, and other endeavors which government might have a role in. In short, some of the early irrigationists imagined responsibility for ecological design as the foundation of a whole society.

However, this model of development lost out in southeast California — a water cooperative member who debated the head of the CDC on stage got tarred and feathered and ran to Mexico on a rail (Starr, 1990: 36). It was irresponsibility which ended up creating the Salton Sea. The hastily constructed canal system was silting up precisely when the CDC was under pressure to meet new demand. In a move to avoid US jurisdiction, the CDC negotiated with Mexico to make a cut in the canal and irrigate the valley with Mexican water. To work around the silting problem, in October of 1904, Rockwood made a cut into the western bank of the Colorado with a temporary headgate. The river flooded five times between February and March 1905, and Rockwood realized in March that this "temporary" cut in the river, with its inadequate headgate, needed to be closed. The engineers made a futile attempt to close it with piles, brush, and sandbags. Further attempts proved useless, and the river continued to flow northward instead of southward, flowing downhill into the Salton Sink. Desperate, the CDC turned to the Southern Pacific railroad, which assumed control of the rapidly-becoming-worthless company. The federal government declined to help out with this problem, which it saw as created by private enterprise. For nearly two years, the railroad labored to close the cut in the river. Finally, in February 1907, Southern Pacific engineer H.T. Cory and 1500 laborers— many from the Pima, Papago, Maricopa, Cocopah, Digueno, and Yuma tribes— closed the breech with 2500 rail carloads of rock, gravel, and clay comprising a 15-mile long, eight-foot-high levee (Starr, 1990: 40, DeBuys, 1999: 115). With damage claims piling up from a submerged salt mining company and the Mexican government, the CDC declared bankruptcy in 1909.

In these early days, people thought the sea would evaporate within a few years: they did not imagine that agricultural runoff would perpetuate the sea for decades. Yet the sea persisted and the Imperial Valley grew, weathering the Great Depression. The Salton Sea shared in the postwar boom, with visions of the California Riviera. But by the 1960s and 1970s, the collapse of speculative property deals and the foul-smelling algae blooms and fish die-offs had worn off the sea's luster. In 1988, the Salton Sea Task Force was formed, which dissolved for lack of funds; but the Salton Sea Authority was created in 1993 (LHC, 2015). They set numerical targets for the sea: salinity between 35,000 and 40,000 ppm, and an elevation of 230-235 feet (DeBuys, 1999: 247). A 1996 evaluation came up with a price tag of $100-200 million for constructing a dike in the shallow portion of the sea (ibid).

Perhaps this would have remained a technical or engineering issue, but in the late 1990s, thousands of pelicans began dying from botulism outbreaks. These charismatic and photogenic fauna sparked public attention and won a celebrity campaigner, Sonny Bono, who made the sea a key issue of it during his time in Congress. An imaginary of the sea as an engine for economic growth arose— with first-class resorts and casinos, perhaps a navigable lock-lift system, or an inland seaport (Morrison, 2014). While a grandiose plan failed to materialize, the interest fired up imaginations, and mainstreamed a new way of thinking about the sea: not just as a technocratic problem for environmental managers, and more of a space for economic or community development.

The "water transfer"

December 31, 2017 looms large for the sea. To understand how an ecosystem gets a definitive date where it will get worse, it is necessary to review the 2003 "Quantification Settlement Agreement" (QSA), commonly known as the "water transfer", as it creates the largest farm-to-city water transfer in US history. The QSA is actually a set of agreements between the State of California, the Department of the Interior, and state water agencies. Key to understanding the water transfer is the basic math of Colorado River allocations: the Imperial Irrigation District, through the doctrine of prior appropriation and beneficial use, gets 3.1 million acre-feet per year of the Colorado's water, or about 70% of California's 4.4 million acre-feet allotment. By comparison, Mexico receives 1.5 million acre-feet, Arizona 2.8 million, and Nevada 0.3 million. In short, Imperial County gets more than 20% of the entire Colorado River's average annual flow. Recall that the population of Imperial County is about 180,000, and that this water is used by about 500 farms. With an urbanized coast of 19 million customers and a drought, the massive allocation to the Imperial Valley may seem difficult to defend. On the other side, Imperial residents can look northward across the sea to the Coachella Valley, and see over a hundred lush golf courses for the nation's fly-in elite: certainly a flagrant use of water compared with the proud task of feeding the country fresh vegetables in winter.

Under the water transfer, 30 million acre-feet over 75 years are sent to San Diego and the Coachella Valley. The idea is that Imperial County farmers can make up for the water transferred away by implementing more efficient methods of production— lining canals to reduce seepage, installing advanced sprinklers, etc. For an initial 15-year period, the IID has been required to send "mitigation water" to the sea— water "saved" from fields they were paid to fallow. After 2018, the 15-year start-up phase ends, and the requirement to send any "mitigation water" to the Salton Sea expires. About 200,000 acre-feet less will be flowing into the Salton Sea per year. Ideally, the IID and farmers would also use this 15 year start-up period to ramp up water conserving methods and technologies, since new systems require an initial outlay of capital. The state, for its part, was supposed to use these 15 years to figure out what to do about restoring the sea. A crucial part of agreement is that local water agencies would pay the first $133 million towards mitigating the impacts of the transfer upon the Salton Sea, and then California would pay the rest. That "rest" was not well-estimated at the time of signing the agreement.

When the mitigation water stops flowing, the sea will start shrinking more rapidly. The receding shoreline leaves behind fine silt containing sodium sulfate and selenium, and desert windstorms blow it across surrounding communities. By 2045, the 150 square miles of exposed playa will be adding up to 100 tons of dust per day into the air (Cohen, 2014). In humans, selenium's effects include neurological problems and cirrhosis; sodium sulfate causes respiratory problems (Adee and Moore, 2010). Air quality already has surpassed federal standards for particulate matter less than 10 microns in diameter (PM10), and asthma hospitalization rates are twice that of California as a whole (LHC, 2015). Within fifteen years, salinity in the sea will triple (Cohen, 2014), making it unsuitable for most forms of life (besides algae, bacteria, and viruses). The ecological convulsions cause hydrogen sulfide events, as decaying algal blooms send up "burps". As one resident of the Coachella Valley told me, on high-odor days they say, "The Salton Sea's come to visit." Not just an aesthetic problem, the traveling stench has tremendous impacts upon property values and the resort economy to the north: the rotten-egg odor has previously made visits all the way to Los Angeles. The sea is also a critical habitat for over 400 species of resident and migratory birds, whose habitat along the coast and the Central Valley was consumed by development. In short, an impending tipping point in the sea's ecology brings economic and health impacts for a wide geographic area, as well as a number of species.

Finding a way forward

What is next for the sea? In the next section, I will discuss how citizens evaluate the available options for moving forward — namely, (1) the state's incremental plan for habitat construction and dust mitigation; (2) the idea of building a pipeline to import water from the ocean; (3) trees, tillage or alternative land management led by farmers and private citizens; (4) political options involving changing the QSA. The third section will look at how stakeholders view the responsibility and agency of various actors in developing and choosing between these options. The fourth section discusses the approaches citizens are using to make and take responsibility at the sea, and the concluding section draws from this case to suggest some modifications for the Anthropocene narrative of responsibility more broadly.

But first, a brief note on methods. This paper draws from fieldwork conducted in the landscape of the Coachella, Imperial, and Mexicali valleys during July 2014, January 2016, and Oct.-Dec. 2016. This involved site attending community activist meetings and official hearings about the Salton Sea, meetings about other environmental justice issues in the valleys, and visits to farms, water infrastructure, and existing and planned energy production sites. Thirty semi-structured interviews were conducted, as well as several other in-depth but informal conversations; 27 of these interviews were of appropriate recording quality to be transcribed and coded using NVivo 11. In Appendix A, the respondents are listed with brief descriptors of their role in the community — though this does not represent a fixed typology of respondents, since farmers could be entrepreneurs or work in environmental activist roles; community advocates could work with vulnerable people and yet act in entrepreneurial ways; and so on. Rather, it is more helpful to see all these people as having a valuable situated perspective, rather than playing one neat and discrete role in a social structure.

Through observing formal and informal participation in decision-shaping processes, and interviewing stakeholders in depth, I learned about how residents evaluated the possible options and how they felt about opportunities to participate in creating and deciding about these possible futures. Because many of the respondents were identified and selected through their participation in issues related to the sea, the sample is decidedly non-representative of the greater demographics of the Imperial and Coachella Valleys. For example, only about a quarter of my respondents were of Mexican-American descent, as many local officials who work on Salton Sea issues are white males. I attempted to address this by reaching out to advocates from the Latino community who work on environmental justice and other civic issues, and women in particular. While I did interview several respondents from this community, others declined to formally participate and mentioned past negative experiences with researchers and NGOs who had "partnered" with them in unequal or self-serving ways. Many people in this area generally question the helpfulness of academic study, given that the scientific studies conducted have not produced action or change at the sea. While I speak broadly about the concerns of this community based upon the interviews I did conduct, it remains a limitation of the study not to be able to include a wider range of people speaking in their own words.

2. Citizen views of the future landscape

Imperial is a dream without details. — William Vollman

If you don't dream, you can't set a target for the future. — Michael Clinton, consultant (Goolsby, 2016)

Phase I: The State's Current 10-Year Plan

In March 2017 the State of California announced its much-anticipated 10-year plan, the first phase of the incremental "Salton Sea Management Plan" (SSMP). "Phase I" calls for measures to expedite construction of habitat and dust suppression by 2028. This first step of the yet-to-be-written larger plan includes "shovel-ready" projects like habitat restoration and wetland construction, water backbone infrastructure, and saline impoundments to support fish and wildlife. As a local official put it, this is the most "common sense", "bang for the buck" plan of action.

However, there are some glaring issues. Phase I calls for $383 million, with only the aforementioned $80 million from a prior water bond currently in the bank — there is not a committed funding stream. Another is that this $383 million is still just a fraction of the billions needed, according to prior assessments; critics point out that it does not solve the underlying problem of the shrinking sea and its spiking salinity. Essentially, it is a stop-gap measure to cover up some dust and mitigate some air quality impacts while a long-term solution is devised.

To understand how this stop-gap plan emerged, it's useful to have some backstory about the state's previous attempt to create a more comprehensive plan. In 2007 the California Department of Water Resources produced a report detailing eight options, the cheapest of which cost $3.3 billion for a saline habitat complex of 75,000 acres. An ambitious $8.9 billion option featuring a marine sea was chosen as the "Preferred Alternative". It was influenced by criteria added from the 32-member Salton Sea Advisory Committee and members of the public, but was vague on how to pay for it all (LHC, 2015). The $8.9 billion number was enough to scare away anyone, and illustrates the potential perverse impacts of pinning a precise number on a problem. Moreover, people were concerned that suggesting interim or incremental ideas would give the state an excuse not to do more (Delfino, 2015). Some community members recalled the process as a stakeholder process, but not necessarily a democratic one. As one resident remembered it, "The state put all this money and effort into people's participation, getting their information, getting their feedback. They basically said, Excuse me, fuck you, we're going to come up with our plan. All of that time and effort and threw it in the trash can"

(C21). Or, as a local business owner who had been on the State Water Resources Committee in 2006 and 2007 recalled, the committee posed a $6 billion option, but "then the guy from the Department of Water Resources, he picked and choosed from all the different plans, just a little bit of everything in the basket, mixed it all up, for 8.9 billion with 150 million O&M [operation and maintenance] costs per year. I think it was done on purpose because they knew they couldn't afford it" (C18).

Another observer saw the plan as designed to fail, but not necessarily on purpose:

> They insisted that tourism be retained. They insisted that the fish be retained. There were certain criteria by which the various plans had to be reviewed and interpreted, and they were self-contradictory and utopian. As a result, they ended up with an enormously expensive monstrosity. The plan that they came up with was to divide the sea in half with a dam that runs across the middle. The middle of the sea is 50 feet deep. You're talking about a 50 foot dam that runs 30 miles across the sea, on a muddy substrate, immediately adjacent to the San Andreas fault. That was selected because it was the best of the alternatives. The process was clearly flawed. I think if you look at what the criteria were, I think it was flawed in the sense that they were insisting that everybody come out happy. (C12)

Since this comprehensive, multi-stakeholder effort stalled, the official vision is now a "smaller, sustainable sea", promoted by the Imperial Irrigation District, who launched the "Salton Sea Restoration and Renewable Energy Initiative" with Imperial County. As described by IID general manager Kevin Kelley, the sea would be two-thirds its current size — with the southern part featuring renewable energy projects with habitats areas interspersed, a kind of multifunctional renewable landscape (Than, 2014). This dovetails with the state plan. A local official describes it this way: "The Salton Sea will be smaller than it was in the 2000s, early 2000s, but it will be managed, there will be managed habitat at the Salton Sea for fish eating birds, and for the fish and for the wading birds .... The center of the sea will be a sink, a very salty area. Around the edges we will build this habitat and the air quality mitigation" (C7). This official acknowledged much uncertainty about the ecosystem's eventual transition:

> The other thing, from a climate change perspective and maybe just from a long range planning perspective, is over time even that habitat we've developed is going to become increasingly salty. At some point in time in the future we're going to have to transition from what we have now for an ecosystem to a Great Salt Lake ecosystem or Aral Sea type of ecosystem. ... That doesn't mean the wildlife goes away, it means a different kind of wildlife, to some extent the invertebrate population will change and so some of the bird populations will change. We don't quite understand the increase of the climate change or the increase in temperature well

> enough to predict exactly when we're going to get to that point. I'm talking even about the managed habitat getting more salty, we don't know exactly when we're going to get to that point. It's probably 30 or more years down the road, but it is something long term to look at. (C7)

Water import

The state's plans, in the eyes of many citizens, don't solve the underlying problem of reduced inflows to the sea. If the problem is a loss of water, the solution seems to be to put water in. Though some have proposed bringing in water from the Pacific via the California coast, I will focus here on the specific idea to import ocean water from the Sea of Cortez. This does not fix salinity, unless you either desalinate the water or pipe salty water out again. But as for the other problem, elevation, "Sea to Sea certainly fixes elevation. You could fill the lake back up to what it was in 2000 if you wanted to, and that's tantalizing to people. I get why people like that idea. If you look at that aerial photograph for instance, it's close. It's downhill most of the way," explained one official (C7). Another official pointed out that "it's extremely doable technologically speaking. In other words, it's not rocket science, it's not science at all, it's totally doable. And that's where people are getting hung up. Because just because it's technically feasible doesn't mean that there aren't other factors involved" (C24). These "other factors" include (1) the cost, (2) dealing with the excess salt, (3) an endangered porpoise, the vaquito, which lives in the sea of Cortez, and (4) having to negotiate the water import with Mexico. Another official had concerns about ecological unknowns (C11): "Say, what if shark and stingray eggs are imported to the Salton Sea? Are they going to be viable and reproduce here and create a whole new dynamic? All of a sudden ... it's a whole different Salton Sea than what the people that live along the shoreline remember- not this tranquil body of water, but maybe this shark-infested body of water and it's like 'Wait, wait, wait, we didn't plan for this.'"

Proponents suggest that desalination could deal with the salt, and that negotiating the water import through Mexico would be doable as Mexico would also have a stake in the issue. As for the cost, could a private entity construct the pipeline, and generate power and profit as a part of delivering the water? One entrepreneur has worked hard in partnership with the native Cocopah people in Mexico on a scheme that would benefit them through renting the land the pipeline would cross. The costs are a matter of debate, with varying estimates and a number of proposed funding mechanisms.

At the heart of the conversation about sea-to-sea is a debate about who is being more realistic. Everyone seems to agree that the plan is not technically sophisticated. People with government experience tend to find it politically or economically unfeasible. On the other hand, proponents of the sea-to-sea concept see the government as equally lacking a feasible plan for actually dealing with the real issue. They also see the state and water import plans as potentially compatible — and some officials have considered at least studying the concept. As one proponent explained:

The dust is the big issue. When you look at the numbers, I can put water on dry land for five thousand dollars an acre. The wetlands are 35,000 an acre. If you fill the lake up to the proper level, like 235, then that wipes out 100,000 acres of dust, potentially dusty land, because it's under water. Then, the wetlands people can go build enough of the material that they need to deal with their birds. And the two people can get along just fine. But the way they're doing it now, they need two or three billion dollars, which equates to like 200 million a year, and they have less than 20 million, like 18-19 million per year, and they need 200. And they only have money for 3 years and they need money for 20 years. They just can't get there. The legislature's not going to do it — they should do it, they just won't. So they'll fail at a very high level, because they just are horribly underfunded, and when you need 200 million and you get 20, that means you'll never get there. It's like showing up and paying rent when you have a quarter of the bill in your hand. It just doesn't work. ... We all pray ... that IID will put their foot down, and we all pray that the homeowners will file class action lawsuits against the state, and we all pray that the state people come back to the table with a sense of reality. Because today they're just not realistic about what it's going to take. (C19)

Farmer and citizen-led revegetation and land management

Farmers and other private citizens also have propositions for revegetating the sea. Farmers "want to raise their families here, they like it here and they're willing to put their work boots on and see what they can do to address these issues," in the words of one community member (C9). Propositions include planting local trees as windbreaks, or creating a ridge and till system. Six-foot wide furrows would break up the wind, and salt-loving plants could grow at the bottom of the furrows — salt cedars, iodide bush, etc. According to one farmer, this waterless dust mitigation could be done for 28.50 an acre, or a fraction of the cost of constructing wetland habitat (C18).

Another farmer developed a private-sector led approach to planting trees interspersed with wetland habitat, drawing on existing expertise with permanent crops, including planting half a million pistachio trees, "each one perfect in a certain way". "We've got a couple hundred acres of date palms we planted in the Imperial Valley, and a couple hundred acres of citrus. Those are exotic species. What about Colorado River species? Cottonwoods and willows? Shit, just give me a tree source, and I need to clean up some of the salts, just like I would for citrus of dates, and I know how to do that, and I'll grow original Colorado River woods" (C5).

Political solutions

While habitat construction, water import, and land management are all engineering solutions to a problem defined in terms of aspects of the environment, the crisis of the impending shrinkage on Dec. 31, 2017 is actually a political crisis. It follows that it may be easier to negotiate a social solution to a social problem, rather than engineer one. One expert suggested tying removal of water from the Imperial Valley to the state's ability to mitigate the dust, which could protect public health without taking away water rights.

> You're not just saying, "Oh, well I entered into a contract 15 years ago, so you guys all have to die. I'm sorry." I just think that's a completely irresponsible position for the state to take. They have to do something about it. What can they do? Well, they can start putting out their straw bales, or whatever it is else they're going to do, gravel and whatnot, and build marshes. The problem is they can't do it fast enough, and they don't have the money for it. Limiting the water transfers from the Imperial Valley is much cheaper. The estimates are that it might be $50 million a year to buy that water away from San Diego. They could do it for 10 years and still be cheaper than the straw bale idea. It protects the water rights of San Diego, but at the same time it protects the health of the people. It's a direct, inexpensive, immediate relief that meets all the criteria that you would want, except San Diego doesn't get its water next year. That criterion's not met, but they still have their water rights. (C12)

There is a precedent for this idea, as it was what happened at Mono Lake, where the water board tied the ability of Los Angeles to draw water to markers of elevation at the lake. However, this idea has not been discussed much. It is possible that the QSA was so difficult to negotiate that the stakeholders would rather consider the problem as an engineering one, or an environmental one, rather than revisit the political decision that is giving the problem its urgency.

3. Citizen views on responsibility and agency

We have been accused of gross negligence and criminal carelessness in making this cut, but I doubt as to whether any one should be accused of negligence or carelessness in failing to foresee that which had never happened before. — Charles Rockwood

Whose responsibility is it to do something about the sea? Collectively, farmers and the Imperial Irrigation District are key shapers of the already heavily-managed landscape. The QSA, however, assigns legal responsibility, and most respondents specified that the state of California is the responsible party. The QSA works as a responsibility-assigning device. Yet the codified responsibility of the state also occludes some of the other potentially responsible parties. In what follows, I will discuss stakeholder perspectives on potentially responsible actors. In doing so, I will also examine the constraints they face on action, including the relationship between responsibility and their agency.

The State of California

Before the water transfer, people couldn't decide whose problem the Salton Sea was; afterwards, the State of California had a contractual obligation to mitigate the transfer impact. In 2014, the Imperial Irrigation District petitioned the State Water Resources Control Board and threatened the whole water transfer deal, which made the state realize the problem must be dealt with. One might think that after a clear delineation of legal responsibility, a solution would unfold — but making responsibility doesn't mean the responsibility is fully taken up. The QSA, according to a few who have read it, is poorly written, because it doesn't specify the consequences for not carrying out the responsibility. A scientist explains that the state said they would take care of the Salton Sea in order to get the IID to go along with the water transfer, thinking that it wouldn't be too expensive — but then looked into it, and found that the plan would cost $8.9 billion. "At that point, they just went, 'Oh my god, we had no idea. Don't worry, it's the Schwarzenegger administration, and we'll be gone soon.' Sure enough, they were gone, and then the Brown administration came in and they didn't want to deal with it, and then it was 2008 and we had the financial crisis." (C12)

A businessperson's interpretation reflects some of the emotion in the community: "When they did that deal 15 years ago, no one really anticipated what that number was going to cost. But today they know exactly what it's going to cost. And this is a number the state just does not want to pay for any reason, ever. And it's wholly dishonest. I mean, they made an agreement, they have a contractual obligation, they're the owners, and they collect about a billion dollars in taxes from this region, and they're just being cheap. They're basically saying, we don't want to pay. There lies the problem. They're not honest about it" (C19).

Why has the state not acted, when the responsibility is so clear? Aside from the cost, respondents speculated upon three key reasons: (1) peripherality, (2) vested interests, and (3) systemic incapability. Firstly, there is geographic peripherality: it's in the "farthest corner of the state". Secondly, there is peripherality in terms of voter base, with a population of only 180,000; and thirdly, 80% of those people are Latino, many living in disadvantaged communities (to use the State of California terminology). Many respondents also speculated on types of vested interests — the Salton Sea crisis has been going on for so long the Salton Sea Authority, its board members, and related people are something of an institution. There is also a bevy of contractors who have been used for everything from dust mitigation to stakeholder consultation; dust mitigation is already a big industry in this area. It is difficult to assess how much influence vested interests have in the lack of action, but it is worth noting that some respondents were concerned about this.

Either the state is intentionally dragging its feet, either because of vested interests or because it's not paying enough attention to this peripheral area — or it is not intentionally dragging its feet, but it is simply unable mount a response. This is a frightening prospect, as it begs the question of whether governments more generally are capable of dealing with complex environmental challenges that require long-term vision and high-capital infrastructure. As one scientist put it, the state "is both financially and technically incapable of dealing with this issue":

> The reason that I say that ... is another major project in the state is to build two tunnels to take water from the Sacramento River and funnel it to the south. ... The state has been working on that for 10 or 15 years with federal help, and they have gotten nowhere. The state is also planning to build a high speed train from Los Angeles to San Francisco. They figure that is going to cost $64 billion, and they can't have made any progress on that either. When I see them trying to work on complex projects that are engineering projects and require a lot of funding, I don't see the state with the capabilities of actually completing those projects. Quite frankly, they don't have the capability of starting them, much less completing them. That makes me skeptical about what they would do with the Salton Sea. I am concerned that we are actually just on a treadmill to have this be an ecological disaster. Then the question is, was it intentional? Was there some clever person who thought, this is what we'll do, and we'll save $3 billion? I find that hard to believe. The amount of money that's going to be spent on trying to solve this problem after the fact will be huge, and unsuccessful. (C12)

Why, though, is the state systemically incapable of these large engineering projects now — given the history of successfully modifying this region's environment throughout the twentieth century? Firstly, California has budgetary issues, related in part to things like Proposition 13, the ballot initiative which limited property taxes in the state. Secondly, some suggest the state is just too large, compounding complexity as well as making regions far from the coast compete with other big projects like restoring the Sacramento Delta. Thirdly, the population explosion through the last century means that the landscape is already built out; there is existing infrastructure to contend with. Fourthly, it has a very intense regulatory system, and permitting and contracting for projects can take years.

The federal government

The federal government is not prominent in conversations about the Salton Sea. Like the state government, the federal government is seen to have a capability issue with large engineering projects. One official pointed out that people cite the Central Arizona Project and the Central Valley Water Projects as examples of people "dreaming big and getting it done," but "those days are as gone as the 1950s Salton Sea is." Another official mentioned that while agencies are committed to environmental protection, they are not designed to do something. "They're designed to stop some things from being done."

> That's very different than probably 1935 or 1955, where government agencies in this country did things like built Hoover Dam, or big freeways, or a big piece of infrastructure. Those served purposes and had major impacts, environmental impacts, cultural impacts and others. Well, the pendulum has certainly swung, and at the Salton Sea, there is no one agency and entity that can correct the Salton Sea, but there are 30 that could stop it. (C16)

Some argue that the federal government should have a stronger role because they have the funding to do something. However, a farmer suggested two reasons why the federal government is largely absent from the picture, aside from the responsibility being given to the state of California: first, that the Obama administration did not want to criticize Sacramento because Pelosi, Feinstein, and Boxer were influential politicians, and second, that the US government played a significant role in creating the air quality issues faced in the valley because military training activities in the late 1930s and 1960s out of the El Centro Naval Air Force base and surrounding areas basically ground up the desert vegetation (C5). This farmer expressed concern about the federal government getting involved, citing three big issues that would "put a hammer in the hands of people in Washington, DC": that the Salton Sea would cease being a viable ecosystem, that levels of Lake Mead would drop below the 1074 foot limit, and the dust. "Now the worry is that the EPA is gonna start declaring an air quality emergency at the same time the Bureau of Reclamation starts declaring a water emergency on the Colorado River," and expressed that "I've seen what's happened with water issues in the San Joaquin Valley, and they decided we've got a hammer and all we can do is take water away. We can't deal with exotic species, we can't deal with sewage treatment plants, we can't deal with delta islands that minimize habitat, all we can do is take farmer water away, so let's start swinging hammers, hammering farmers" (C5). This farmer wanted the government involved in some ways, but feared for the form it would take.

In short, while stakeholders here held the state government responsible, this also mingled with frustration about an incapable or broken federal government, which resonated much more wildly on both sides of the political spectrum. One expert on the sea commented that the 2016 election evidenced "a real feeling that the government has not addressed the problems of people, particularly people who are not well-to-do, urban entrepreneurs. I'm sorry to say that the Salton Sea strikes me as the prime example of this kind of neglect, and so does Flint. ... In both cases, you have unelected officials making decisions that profoundly affect minority populations, where decisions are made on the basis of money as opposed to public health. I'm afraid that that's a very common phenomenon across the country" (C12).

Farmers, the Imperial Irrigation District, and Imperial County

Imperial Valley farmers are key to the sea's health, because their irrigation provides its inflows. At the same time, they're also a source of pollutants in the sea. As one resident explained:

> This is anathema. If I were to say this publicly, I would probably be tarred and feathered, but the farmers have not taken any responsibility whatsoever for their problems with the Salton Sea. Part of those problems ... I know that there's a lot of selenium that comes into the sea naturally from the Colorado River. It's just the way Mother Nature is, but the fertilizers, the pesticides and all of the other parts to being a farmer down here that ultimately end up in the Salton Sea, they contribute to the problem. Don't ever think that a farmer is going to take any accountability or responsibility in any way, shape or form, particularly signing the front side a check to deal with that issue. They're just not. They pay 20 bucks an acre-foot for water. It's a pretty sweetheart deal. (C9)

One community advocate describes the historical responsibility of agribusiness, noting that agricultural runoff over 100 years sent the pesticides and selenium into the sea, and the Imperial Irrigation District had a role in allowing it to happen (C10). Farmers along with the IID have a history of strong leadership and power in this particular valley, and historically have played a large role in decision-making. On one hand, the IID and county leadership have been instrumental in pressing the state for action on the sea. On the other hand, the IID and county leadership are seen by some as an obstacle; one entrepreneur names "those 15 guys, 20 people, they're 99% guys, they're all 60 year old white guys no less" as "the reason nothing ever gets done" (C19).

Some farmers grew up here, and "they want to see it be beautiful and happy and booming again", as a local businessperson put it (C9). But others have moved to the coast and run their operations from afar, and now there are only about 435 farmers in the valley. The community advocate describes the transformed social structure: "Now you have agribusiness that can come in and bring their city, move their city now, an army of workers that migrate into Arizona, to California, into Northern California, Salinas Valley, and they just will bring in their army of workers. What's left for us is a lot of the residue, and that's what's created the Salton Sink. That's what's created that sea. Now, the ones who have created it, which is the farmers with the approval of the Imperial Irrigation District, somehow want the state to solve it" (C10).

At the turn of the century, big agribusiness served on the boards of the small cities, but today, they aren't concerned with running a small community because they have enough money to do what they want outside of the community. This community advocate describes not only an outflow of resources, but a deep disparity in what remains.

> For 100 years, they've benefited off of the cheap water. Even the rates today, $20 an acre foot. ... It's ... I can't find the right word. It's immoral. It's ... I don't know, but I just can't find the right word. How bad it is that this disparity exists in our neighborhoods and in our inner cities, because our streets are in such bad shape. Our homes and our gardens and our yards are drying and dead because we can't afford the high price of water to water our lawns. We're asked to make reductions when they're being

> paid not to grow, to make their reductions. It just doesn't seem moral to me, and definitely that the public utility controls the water that was made for the benefit of the agribusiness community, bends over backwards to give them whatever they want and however they want it. Because they have the economic wherewithal to mold their political agenda, and that's just the way it is. It's the people's problem, but agribusiness created it and why aren't they weighing in on the solution? Where are they in the conversation? Where are they? (C10)

Through one lens, the taxpayers of the state of California are responsible for cleaning up the mess where big agribusiness and a select group of people have run away with large profits. But from another perspective, some farmers are engaged and have ideas for remediating the situation at the sea (as well as expertise in local land management), and yet are not listened to by decision-makers.

> They don't want to listen to farmers. ... They have to listen to someone who is an expert, that they pay a lot of money to hire as a consultant. I see it happen so many times - they'll hire these people that come down and are brilliant. They don't have a lick of sense. They've never seen the Salton Sea - they get hired and come down here. I told [a state official], if you want to hire someone you ought to chain them down to the sea for a year. And then turn em loose, and if they still want to take the job, then OK. (C18)

Some farmers do have a deep tie to the land and have actively been stewarding it for decades. The term "farmers" can connote family farms in which the farmers are engaged in daily activities, to farms in which the farmer is a manager of a large enterprise — but it seems that both varieties of farmers feel disenfranchised from Salton Sea decisions. How do any of these farmers get a seat at the table? Is there an institutional structure that would enable responsibility-taking? There are a number of institutions, like IID's water conservation board, or the farm bureau, where cross-conversations occur. As the above farmer described, though, the decision-makers ultimately privilege outside expertise over local knowledge (C18). One respondent suggested a tax on agribusiness for Salton Sea cleanup (C10), which in essence would serve as a responsibility-taking device — the responsibility would be indirect and channeled through another entity. One issue with this is that farmers are already struggling to compete with cheaper produce from Mexico and South America: even though this discussion is focused on restoring a local site, it is deeply entangled with global flows.

The private sector

Right now, the private sector — agribusiness or otherwise — bears no responsibility for the Salton Sea. Could private sector actors take responsibility in improving it? People on various sides of the political spectrum say this is challenging due to regulations. One developer points out that to propose a project regarding habitat restoration, "you have to have deep pockets and sufficient money. You have to have a lot of folks that know and understand the business and what it takes" (C8). Another group wanting to start projects for remediation explained that "there's no real conduit for funding, and for testing and demonstrations" (C4); it's hard to cross from pilot-scale to commercial expansion, because the state hasn't made the sea's future clear. With grant funding, universities are better equipped to apply. The review process for different ideas, as this person described, sucks the life out of efforts: "Everyone that's in a position of power, they get paid to administer and review things, so that's why nothing ever happens, is they're just turning their wheels, and they're getting paid to turn their wheels, and they're getting handsomely paid to go to meetings that don't ever have an eventual endgame in mind" (C4).

Perhaps because of the QSA's assignment of responsibility to the state, or perhaps because of the nature of the problem, no one saw the private sector alone as the key agent of change. Rather, the private sector was hoped to be one part of the solution.

Whither citizens?

Do the people who live by the sea have a *responsibility* to make it better? A few people working in civil society and environmental organizations mentioned this as part of various conceptions of citizenship in general, or in terms of a "do your part" environmentalism, but because most of the residents neither caused the problem nor have means to solve it, they were not seen as responsible per se.

Do they have *agency* to make it better, or to choose or participate in its future? Here again the answer is a qualified no. One basic challenge is that very few living in the general area even know that it is there, much less in an impending crisis.[4] One Latina community advocate wondered why it is mostly visited by tourists. "I don't know if it's because of the smells and the perception that it's a contaminated lake and people don't want to go there. I grew up here and I probably only went there once" (C15). Another challenge is that the people who do live here have other responsibilities. One community advocate explained:

> There are so many immediate hazards or immediate threats to our health and our well-being in this area, that it's very difficult for people who have grown up here, people that live here, to see like broader, bigger-picture-type things. I don't mean because they're not able to, but just they don't have the time or the energy to look at those bigger issues, because they don't have potable water to drink, or they don't have a sewage system to treat their waste, so it's an interesting sort of dilemma, I guess, because it prevents us, sometimes, from reaching the bigger pictures. Or from even

4 In turn, the invisibility goes both ways: as discussed, the state doesn't seem to care that these people are there. In the Coachella Valley, there are a segment of citizens that are virtually invisible to the state, those who live in mobile home parks scattered among the agricultural fields — one nonprofit used satellite imagery to count 135 mobile home parks, ranging from a few homes to 300-400 homes per park. These are often informal or unpermitted, and their residents are undercounted in the census, sometimes including undocumented migrants or communities of indigenous Mexicans which do not speak Spanish or English.

> joining coalitions or making partnerships to address those bigger issues, because we're too focused on more immediate needs. (C13)

Another community advocate related that people aren't really asking questions about environmental futures: "When it comes to things like technology, or even where folks work, people don't ask questions about where they work, or about the technologies that have been implemented in their communities. People travel hundreds of miles. They immigrate here, sometimes under dangerous conditions, just to work. So they're not really asking questions about, 'Why is this the way it is? I'm just here to work and make money and send money back to my family.'" (C2)

There have been public meetings held about the Salton Sea, but they are often not well attended. One citizen reported that the audience was mostly investors or businesspeople. A constant gripe is that the meetings are not always held in convenient locations — often at water agency or institutional headquarters in Palm Desert or El Centro. Important state meetings are in Sacramento, and public testimony at all of these meetings is limited. One resident explained, "I don't have the money to be attending meetings. Oh, in Sacramento. Let's see, Sacramento's a six and half to eight hour drive one way. Gasoline's anything from 2.50 - 3.50 a gallon. Your motel's 80-150$ a night. You know, you're talking hundreds of dollars to attending a meeting.... By California law... you're allowed to speak for three minutes. It used to be five" (C21).

Not just individual residents, but entire groups, have been distanced from decision-making. While some tribes have seats at the Salton Sea Authority, such as the Torres Martinez Desert Cahuilla Indians who are landowners, others which are more remote have capacity challenges with officially engaging — which can be seen in the context of a long history of struggles to "engage in consistent intergovernmental relationships" over the past century, as well as efforts to join United Nations processes on climate decisions (C23). One person working with a Native American group explained that "it's burdensome to have us travel far distances to kind of quixotically scheduled meetings where the opportunity to present to the record are limited" (C23). There is a very strong normative and substantive rationale for greater inclusion from tribes in the area. As this respondent explained, their knowledge of species from close observation over thousands of years is important to the record, and reliable to journaled science that is "really fairly limited in review." The testimony on the record "lacks the depth of testimony from the peoples who have lived in that environment and understand its mechanisms and its fickleness, and how it changes to different effects and inputs that we've seen over time," and the respondent identified a need for "a more reliable platform, less burdensome to our resources, in order to provide [such] information." (C23)

In addition to lack of awareness about the sea, the presence of more pressing problems, and the practical challenges of engaging in official processes, active citizens are facing another challenge: burnout from dealing with this issue for decades without seeing meaningful progress.

> — When you've been at this at ten years and you've seen no progress whatsoever, you tend to get upset and not want to do anything anymore. I can't let that happen, because I don't want to leave here. I don't want the state of California and the federal government going, oh you have a toxic situation out here, you have to move. Oh, by the way, and we're going to buy up all your property at 80 cents on the dollar. No, you're not. I'll stick here until they absolutely have to drag my ass out of here.
>
> — Do people out here talk about moving?
>
> — No. The long-term residents? Over my dead body. And the problem is, as the sea dries up, our dead bodies get closer in time. (C21)

Burnout and the burdens of systemic constraints on action seem to mingle with a root sense of malaise about no longer being a nation of builders. The paralysis itself becomes another obstacle to overcome. A nonprofit worker describes the situation as one of fear of risk-taking:

> The Salton Sea we see today was in part due to people dreaming big and people daring to build communities for the betterment of the future of their livelihood. They were farmers, engineers, building canals from the Colorado River all the way out to the middle of the desert to produce food for their families. If that's not dreaming, if that's not ambition, if that's not going after something big, then I don't know what is. I think we have lost that, I think in our government especially, in our leaders. I'm not sure why.

> I think a lot of people nowadays are afraid to take risks and dream big because they're afraid of failing. (C14)

A farmer with very different political affiliations has thoughts rooted in the same narrative:

> In 1919 there was a group of pioneers in this valley. The aquifer was going down at that time because agriculture was pumping water out. Aquifer's going down. They made a trip to Washington, D.C. and said, "We want to get river water." They made a pact. We have what priorities we do have because of those guys in 1919. Can you imagine getting on a horse in 1919 and then going to a train station and going all the way across the country? The foresight. What's the foresight there? It's amazing. Yet here in California they haven't built a water project since Jerry Brown's dad did. When Jerry Brown came in, he canceled every water project. You go back, the last big reservoir was built like in 1964 when the population was 18 million people. It's doubled. It's 36 million, and there's been no new water projects. (C3)

"The Salton Sea confounds the region's and the nation's traditional confidence that physical problems must inevitably yield to engineered solutions", writes William DeBuys (1999: 246). Viewed through one lens, the basin holds the salty ruins of the American Dream. Importantly, these narratives about foresight and dreaming big omit key parts of the environmental history, such as the greed and incompetence of the California Development Company and the tension between private-sector and government-led irrigation development which at times resulted in physical violence. Yet in analysing how people who hold completely different sets of politics often view the problem in the same terms, we can see the roots of possible allegiances and opportunities.

4. Analysis: Future prospects for responsibility making and taking

Even at the Salton Sea, the face of death has its smile. In the morning the wind is still blowing but the sun is bright, and life is stirring. Even at the bottom of a well, there's life.

— Lawrence Ferlinghetti, Salton Sea Notes, 1961

There are three key avenues citizens are using to make and take responsibility and agency: formal processes, citizen science, and social movements. This section discusses their prospects.

Formal processes

Ulrich Beck, writing about global climate risk, describes "organized irresponsibility", which occurs when there is a fundamental distinction between those who produce the risk and those who are affected by it — those who take decisions are not accountable to the people affected, and those people who are affected cannot participate. This is a key way in which the Salton Sea differs from global risks: the situation is not one of organized irresponsibility, as decision-takers are accountable to the people, and the affected people do have structures for participating in decision-making. Those structures are imperfect and underused, but some people do try and use them. In my interview set, people described participation in other environmental decisions in myriad ways: advocating for procedural changes to the electoral system of the water district, organizing town hall meetings about hiking trail closures, enacting legislation to make sure impacts from a new power plant were offset into funds for community betterment. One nonprofit worker describes the value of formal participation at board meetings as being able to "kind of put the heart back into the equation, put the human element back into the equation," noting that hearing community voices "has been critical and crucial into changing the minds of the players" (C14).

Participating in these processes requires the education, time, money, and leisure to get organized, and confronting people who have much more of those resources. A community advocate describes how the "little guys" have "not a lot of recourse" when it comes to going up against the agribusiness lobby: "We could get elected into positions, but we can only push so hard and then we'll get stomped on big time" (C10). At the same time, this community member notes that for the first time, "we have a Latino State

Assembly member, a Latino State Senator, a Latino United States congressman, a Latino Speaker of the State assembly, a Latino Speaker of the Senate, a Latino Attorney General, a Latino Secretary of State. Now, these are now an evolution of Mexican-American community members that have lived in communities of color, that have suffered and now are in positions to cut the pie up a little bit more equitable, and that's all we want" (C10).

Responsibility is, in a sense, labor. At the moment, responsibility is professionalized, as the state hires consultants not only to mitigate the dust and create the habitat, but to facilitate stakeholder meetings and conduct public outreach. One can't fairly argue that volunteer labor should replace this: one option would be to pay community members and advocates to develop solutions for the sea, instead of hiring outside consultants to come in from the cities, but then there are questions of what kinds of knowledge and education are needed, and how that capacity can be built locally.

Citizen science

If the government is unwilling to fulfill its responsibilities in terms of environmental care, can citizen science fill the gap? One scientist comments on some of the opportunities and challenges, describing how citizens are putting up air quality monitors as well as using the monitors to fly colored flags at schools to advise students and teachers about air quality: "They're fulfilling a need there that the government is not fulfilling. On the other hand, only the government can really step in and do something about air quality not meeting standards. Citizens can't say, "Okay, you can't drive any trucks up and down the street today." That's managed by the government." (C12)

This academic scientist points to an important problem: even when citizens have data, they are often not equipped to fix the thing that is causing the phenomena they're observing. Secondly, citizen science is not the same as citizen engineering — some of the actions needed to mitigate dust at the sea are high-capital projects that citizens would be unable to fund. However, citizen science, particularly in the absence of government biological monitoring at the sea, can provide important insights as to the state of the ecosystem, and these insights can be shared on social media and used by social movements to create pressure. There is a remarkable lack of official biological monitoring at the sea. Citizen science could also generate baseline data that would be used in future legal proceedings, as pointed out by one resident, who wants to collect baseline health data now, before the mitigation water ceases and the lake becomes more exposed.

Social movements and media production

Social movements connected with environmental justice or community development have important strategies for making and taking responsibility for ecosystem restoration. The Salton Sea has not received the attention that places like Lake Tahoe or Mono Lake have garnered from green groups, perhaps due to its reputation for being unnatural or "man-made"; one activist also lamented a general failure to make the desert an iconic landscape (C22). However, small local organizations as well as local chapters of large NGOs like the Sierra Club are increasingly involved. NGOs focused upon saving or restoring the sea have been important in (1) producing visualizations of alternative proposals, (2) education about the sea, and (3) helping local people participate in formal processes. Media production, particularly social media, is key to this work. Another important part of the responsibility-making work these organizations do is reframing the problem definition.

One way a few respondents alluded that the problem could be reframed is in terms of geography, though this is a challenging prospect. Is the problem the Salton Sea, or water allocation on the Colorado River and the dessicated Colorado Delta? Or is the problem with water in the West, and Southern California's water needs? What about upriver at Lake Mead and being able to store more water at Hoover Dam? Experts tend to believe that this would get into too many other conversations, which is probably why relatively few people argue for a geographical reframing. Another respondent saw the problem definition in terms of food systems: "it's a socioeconomic issue, it's an environmental issue, it has to do with our food, it's a lot of our food production. This is 70 to 80% of our nation's winter vegetables grown right here" (C1). This reframing also gets into tough terrain fast, because it gets into questions of virtual water, what crops are grown, and water rights.

However, quite a few people argue for the problem definition to extend beyond the environmental box. Broadening the problem definition allows for a broader vision of ecosystem and community restoration, as well as economic development (in more familiar terms). As one local official stated, nobody's listened to the environmental pleas for 25 years, but making it an economic development issue would “get a lot more legs from everybody involved; state, feds;” the official noted that “there's a thousand reasons to fix it and there are no reasons not to fix it. It boggles my mind that it's not being done” (C17). The broader problem definition didn't work in 2007, when the $8.9 billion "Preferred Alternative" attempted to incorporate multiple goals and failed. But many are still raising the problem as an economic or social development issue, and actively attempting to reframe it as such, illustrating that this is still a tension to wrestle with. Efforts to combine framings of the Salton Sea problem with discussions of energy have been moderately successful, as the IID's Salton Sea Renewable Energy Initiative illustrates. The notion of the Anthropocene, and all its entanglements, may justify renewed attention to just how broad the problem definition should be.

There is one looming problem which is rarely discussed in regards to the Salton Sea: climate change. From a macro-scale, one reading of this case is that we are watching the process by which sacrifice zones are decided upon: not all will thrive in a new climate-change era, and how much will the broader society be willing to subsidize the failure of specific regions? As Donald Worster muses, "Will this place turn out to be one of the West's biggest ghost towns ever?" (2016, 136). Ironically, a world that is 4°C warmer, with 30 feet of sea level rise, could bring the ocean to the Salton Sea via the Sea of Cortez for free, without the need for multibillion-dollar pipelines (Mayton, 2016). Yet it seems that in the Imperial Valley, climate change is still largely outside the bounds of discussion. The river, as Polk points out, is expected to maintain a constant flow while the practices made possible by the river "are expected to increase without end" (2014, 15). Climate change, however, is upending what is constant.

5. Conclusion: Refining responsibility

The story of the future will be more like the story of the Salton Sea. It will concern society's efforts to live with and at times ameliorate the consequences of what was broken. We have entered an age of obligatory adjustment and repair. — William deBuys, Salt Dreams

Many writers on the Anthropocene have commented on the need to "take responsibility"; in the Anthropocene-as-bildungsroman, this is the moment of our growth; “humanity” steps up to the challenge. Responsibility crops up everywhere in the burgeoning Anthropocene literature — in environmental ethics, where duties and obligations to the future are explored; in jurisprudence, where responsibilities for environmental damage are challenged; in climate governance, in discussions of historical responsibility and loss and damage; in science policy, where innovation should be responsible; in business, where corporate social responsibility is taking hold. What's new and different in the Anthropocene, though, is (1) that humans are geological agents, and (2) we are aware of it. Earth system scientists have argued that new knowledge brings a responsibility for stewardship (Steffen et al, 2011). Sometimes, this responsibility is extended to a stronger role in managing ecosystems or natural processes, whether it be ecosystem restoration towards a prior baseline, or designer ecosystems optimized for some function (Ross et al, 2015, see also Mansfield & Doyle, 2017). However, many scholars critique "the new grand narrative in which Man becomes conscious of the fact that his activities transform the earth at the global scale of geology, and that he must therefore take responsibility for the future of the planet," as Stengers (2015) puts it, for the historical responsibility of particular actors that it occludes — the general responsibility erases particular responsibilities. Responsibility looks backward and forward. While the increased (general) acknowledgement of historical responsibility and accountability for environmental damage is welcomed, as is the idea of responsibility to future generations, many scholars do not extend this responsibility to ecological maintenance.

In short, the example of the Salton Sea has pointed to some refinements that need to be made in the narrative of humans taking responsibility in the Anthropocene. I will mention three. First, "responsibility" needs a stronger distinction between making actors accountable for past harms, and being responsible for future environmental decisions, which is something everyone should have a role in. The backwards-looking responsibility should enable the forwards-looking, and the discussions should acknowledge each other, but there should also be some analytic separation. Responsibility is not the same thing as being able to respond, as the Salton Sea example illustrates. The notion of "taking responsibility" is rife with questions of capacity, of responsiveness, of agency and power. In some cases, power allows for the avoidance of the responsibility to manage ecosystems, as is largely the case with the state of California in this instance as well as agribusiness. In other cases, the lack of power precludes citizen actors for taking responsibility for shaping their environments. A more systematic look at forward and backward-looking responsibility, as well as a separation of responsibility from capability, would be helpful.

Second refinement: responsibility is continual — not a decision or a moment of responsibility-taking, but a process. Kearnes and Van Dooren (forthcoming), following Derrida, argue that what responsibility is defined in part by is its continual nature; the fact that it unfolds amidst undecidability and is revisable in the face of an uncertain future. The fact that responsibility is an ongoing process highlights the labor involved. One doesn't want to place undue labor on those who did not create the problem, and place responsibility on the already burdened. This attention to the work demands of responsibility-taking — the actual physical work — brings up questions of professionalization of responsibility, of expertise, and of education in the Anthropocene. For example, "responsibility" looks a lot different depending on where you are standing: "taking responsibility" might mean something different to a woman working the second shift of childcare on top of her job. An understanding of responsibility as continual labor could help the burden be distributed more fairly. On the other hand, it's important not to simply see the caretaking as a burden, as this impedes one from taking the agency and benefitting from potential opportunities.

Third refinement: there is a type of responsibility which creates a space for ecosystem health which does not go so far as to complete control or design of ecosystems: call it co-responsibility with nature. Critique of the Anthropocene often is critique of a vision of controlling nature, but in this example, something more like co-responsibility would be more true to what various actors are proposing. Local officials describe management programs not as ecosystem control, but a kind of doing-ones-"best", offering up habitat — the rest is up to the other lifeforms. As one official put it, "I think the wildlife will adapt and they'll figure it out, all we can try to do is give them some kind of stable environment with a reasonably decent water quality, a reasonably decent salinity level over time and make that there is some kind of forage opportunities there for them, and we'll see how they evolve" (C7). Or, as a farmer explained, "We're suppressing the Colorado River delta riparian habitat, and if you put water on Imperial Valley, and stop farming it, it will come back. Mother Nature will come back on its own, and if you give it a little bit of a hand, by planting some trees and moving some dirt around so that you've always got wet spots, it'll come back quicker" (C5).

In fact, another farmer (C18) argued that the birds on the Pacific flyway would be better off without the sea; that they have become dependent and should be fending for themselves, opining that "they ought to let the birds find other sources." His experience with pelicans makes clear how complicated taking responsibility for an ecosystem is: perhaps one tries to create habitat and ends up making a death trap.

The pelicans - they can go to the Pacific Ocean, the coast. They go back and forth all the time to the Sea of Cortez. Matter of fact, the Salton Sea becomes a death trap in the summer when the juveniles have just got their wings, they're flying good, like all teenagers, you know, they're ready to try anything. They hang out in groups, just like teenagers do.

So their parents take them down the Sea of Cortez, they go down early in the morning - they leave when it's still dark, they go early and it only takes an hour and a half to fly down there. And so they spend the day down in Mexico, fishing and what-not, and the teenagers, they go off by themselves, they go, *Hey let's go back to the Salton Sea, maybe there's something going on there.*

So they start back at two in the afternoon. And there's sixty miles of desert, and the surface temperature of the desert is 160 degrees. And all those heat waves coming off it, they just run out of gas. We have pelicans crashing down all over here in the summertime. And they're all juveniles, trying to make it back to the sea. Pelicans don't drink water. They get all their moisture from the fish they eat. So if they're dehydrated, they lose muscle control and they can't fly. If they can't fly, they can't hunt, and if they can't hunt, they can't get fish, and if they can't get fish, they can't get moisture. That's the end of the pelican. You see them laying alongside of

> the road, crashing into powerlines, knocking up transformers, hitting buildings. So, you know, it's a death trap in that sense. (C18)

This firsthand experience of the sea's dual nature is why people talking about maintaining the sea here don't speak in idealistic terms about control or perfection. This is not "Imperial"; it's not a grand vision. Those days are over. This is about ecological design by doing just enough.

Even by modifying responsibility to include a distinction between forward-looking and backwards-looking forms, extending it to a continual process encompassing care and recognizing labor, and construing it as responsibility not for control but for co-responsibility, we still don't have a perfect language for what needs to be done. Speaking of making or taking responsibility makes it seem like the default state is neglect or absence, when really responsibility in this case is taken up somewhere, by some actor, either nature or other humans. In this case, responsibility will be taken up by citizens who will become responsible for managing the damages, in terms of their health care costs; like in neoliberal environmental governance more generally, the individuals bear the cost. We have not fully evolved the language or concepts for the task at hand. But for the context of the Imperial Valley, responsibility has some resonance, and it might be the best language for the job.

The stakes here are high, because they are not just about one ecosystem failing. The stakes involve the legitimacy of institutions, and what it means if the state is seen as willing to essentially declare an ecological sacrifice zone. Beck observes that the ecological crisis brings a crisis of basic rights "whose long-term effect in weakening society can scarcely be underestimated," where dangers "are being produced by industry, externalized by economics, individualized by the legal system, legitimized by the natural science and made to appear harmless by politics. That this is breaking down the power and credibility of institutions only becomes clear when the system is put on the spot" (1996: 18). In this case, the credibility and legitimacy of the state of California is being stretched to the breaking point; this was clear in nearly every interview. That the state is attempting to perform some responsibility with Phase I of the SSMP is either heartening, or a legitimacy-extending tactic. At a Salton Sea Authority board meeting I attended in late 2016, an Imperial County official and board member quipped that "the State is like me with finals in college, waiting to the last minute." He said that he woke up later in life to the realization that this is not the best way.

Perhaps these realizations are making waves. On June 1, 2017, SB 701: Salton Sea Obligations Act of 2018 was brought forth by Imperial County legislators and approved in the California State Senate. If approved in both houses, it will send a ballot proposal in Nov. 2018 to have voters authorize a $500 million bond. The director of the Salton Sea Authority, Phil Rosentrator, lays out the options: "A 'Do Nothing" scenario is the most costly of all options, predicted to cause $70 Billion in damages to human health, property values, environmental degradation and the connected economies of agriculture and tourism. Conversely, a YES vote for SB 701 provides a positive alternative and a realistic path forward." Initial financing, at least, is being made selectable; it now looks like the responsibility will be spread to the voters of California.

Financing the state's plan, and the responsibility-taking by the state implied, is not the same as giving Salton Sea residents the means to shape future there. Ongoing community consultations reflect the continued interest in water import, as well as continuing efforts by the environmental justice community to stop the exposure of playa dust in the long term. Metrics and economic calculations, and the ability to produce them, remain key to both these future goals. Community advocates do not have the resources to produce the engineering outcomes they seek, and their ability to collect the data they need to produce arguments is mixed. But they are successfully engaging with and deploying concepts of the "long-range" and seeking a more permanent vision and solution than the state's ten-year plan. The time horizon of present action has successfully been put up for debate, and with it, notions of responsibility have been extended beyond the short-term. This is not a minor victory, as it can pave the way for further deliberation of what long-range future is desired.

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Chapter 4

Climate change technologies in California's Imperial Valley:

Prospective challenges for negative emissions at the landscape scale

Abstract

Negative emission technologies have emerged in climate models as a global-scale solution to a planetary problem. If negative emissions technologies attempt to cross the fraught threshold from global imaginary to local carbon infrastructure, what social dynamics will they face? This paper looks at how carbon practices are evolving in one particular landscape: the Imperial Valley in southeast California, a desert landscape highly engineered for industrial agriculture. Local officials, community activists, and business ventures are re-imagining the valley as a renewable energy landscape, some with interest in carbon-negative technologies. At the same time, actors from farmers to desert environmentalists often contest aspects of this development framework: either for technical reasons, or for questions around how the vision is executed and for whose benefit. Based on semi-structured interviews and site visits, this paper examines how community actors have received, participated in, imagined, or contested solar, wind, geothermal, biofuels, and on-farm soil carbon sequestration. It also examines local understandings of climate change, which can vary from global perceptions — and these variances may shape the deployment of negative emissions technologies and practices.

Analyzing these social processes offers a concrete illustration of how local, particular dynamics around (1) landholder adoption, (2) contestation of how the technologies are scaled up, and (3) lack of policy for technology investment will confront the environmental politics of different negative emissions technologies if they are successfully scaled up.

1. Introduction: Viewing negative emissions on a landscape scale

The origin story of "negative emissions" is that the concept emerged in the early 2000s from the efforts of integrated assessment modelers to "solve" the problem of how society might achieve global mean temperature targets. Bioenergy with carbon capture and sequestration (BECCS) in particular was used as a "tool to allow for ambitious climate targets", according to one modeler, who in an interview said that the concept had been misused in regular emissions scenarios when it was intended to be a backstop (Hickman, 2016). Though the concept emerged in different places by different groups, it has its grounding in a global modeling perspective. The problem definition is global (global mean temperature), and the view of the climate solution is also global. "Negative emissions" is the object, but the process has also been termed "carbon removal", and also features as one half of the umbrella concept "climate engineering", meaning large-scale intentional interventions in the climate system, which emerged around the same time.

Fast-forward 10-15 years after this concept was created, and the majority of the scenarios for curbing temperature rise to 2°C now rely upon negative emissions, typically in the form of BECCS. The models are essentially pointing to the massive and widespread deployment of a technological system with heavy, capital-intensive infrastructure that has not been proven at scale. Some of the challenges are obvious and familiar, such as land use competition, competition for water and inputs, shocks to food prices (Boysen et al, 2017; Fuss et al, 2014; Heck et al, 2016). It is difficult to think through or even see potential challenges and friction points when governance discussions are on a global scale. Analysis on varying scales would help generate appropriate policy for negative emissions — either to support the growth of these technologies and nurture possible co-benefits, or to mitigate their impacts upon communities and in climate policy more generally, depending upon how people and policy-makers see them. While regional, nation-state, and community-level analyses would be valuable, this paper focuses on a landscape scale of analysis, smaller than a region but encompassing multiple communities. In this paper, the premise is that exploring the dynamics of nascent carbon sequestration practices as well as the scale-up of renewables can indicate potential challenges and opportunities for negative emissions. The research question addressed here is: in the landscape of the Imperial Valley, how have varying actors have received, participated in, imagined, or contested technologies related to negative emissions?

Why consider the landscape scale to illuminate a global practice like climate engineering? Holism is one reason to think in terms of landscapes: a landscape scale of analysis, smaller than a region, encompasses both ecological and political processes, as well as the *feeling* of the land. This unity forces us to think holistically about how and why land is altered, and what ecological and social feedbacks result from modifying it, as Hunsberger et al point out in their study of climate mitigation activities (2015). Though these authors are writing about climate mitigation, the same rationale extends to thinking about negative emission technologies on the landscape level. A landscape scale of analysis could also work counter to a logic of viewing landscapes in terms of their climatic attributes or carbon content, calling attention to what place means beyond the "green gaze" of carbon, nutrient, or hydrological flows (Fairhead et al, 2012). The landscape view invites human habitation. The value of this perspective here is to get away from seeing negative emissions "technologies" as objects or artifacts that are deployed, but part of the "socio-technical landscape" (see Rip and Kemp, 1998). Part of the value of this particular case is that we understand the deployment of landscape-altering technologies and practices not just in space, but also through time, as part of continuation of the landscape's history. The temporal dimension is important for carbon removal, as it is imagined to unfold in time-scales of centuries.

Why consider *this* landscape, the Coachella-Imperial Valley in southeast California, to illuminate how negative emissions might be scaled up? Firstly, it's the site of advanced agricultural production as well as a rapid transition to renewables, so there is data there to draw upon about how the landscape is already put to work for specific human goals. This chapter is necessarily speculative; it extrapolates from the current energy transition into the future, and in fact sees negative emissions as an extension of this decarbonization process. Secondly, this landscape is in California, which has some of the more advanced energy policies as well as environmental regulations, as well as a lot of technical innovation. We can imagine that if negative emissions technologies are going to gain a foothold somewhere in the United States, California might be an early adopter. I draw upon data from visits to biofuel and geothermal production sites, farms, laboratories, and community meetings, as well as ~30 extended interviews with community members, businesses, and scientists, conducted in July 2014, January 2016, and October – December 2016. Most were conducted in the Imperial Valley; some were conducted in the neighboring Coachella Valley and others in Mexicali (all are essentially part of the same geographical area, the Salton Sink). These interviews included questions about the future of the landscape in 2050, and touched upon many environmental and economic themes — some focused upon energy systems, and a few mentioned carbon removal explicitly, but most also discussed the future of agriculture, water rights, the restoration of the Salton Sea, and other topics that respondents felt germane to their vision of the future landscape.[5]

Climate change and imagined energy futures in the Imperial Valley

The Imperial Valley is one of the harshest landscapes in North America. It receives an average of three inches of rain a year, and summer temperatures routinely climb into the 110s. Water is drawn here through 80 miles of desert from the Colorado River via the All-American Canal, and so the valley is also a lush salad bowl, producing a

[5] Interviewees are referred to numerically, along with a descriptor of their choosing. See appendix for interviewee list.

significant portion of the nation's winter vegetables. Because climatic conditions are already so harsh and dry, an observer from afar might think it is especially vulnerable to climate change — and because it is relatively sparsely populated, that far-off observer might also think of it as an empty desert in which to place renewable energy.

There are disconnects between how the Imperial Valley under climate change might be viewed on a wide-zoom scale, and how the valley resident might perceives it. This variance may be fundamental to people's support for (or resistance towards) negative emissions practices, in that when it comes to rural landscapes in the United States, people may resist something that feels like it's mandated by outsiders. Firstly, from the local perspective, the idea of empty land for solar evaporates — as one desert activist put it, urban activists don't see what the desert is about. "It's easier for them to go, 'Well, that would be a good place' [for solar deployment]" (C22). Nor does the "high modernism" approach practiced by the Bureau of Land Management / Dept. of Energy see other ways of valuing the landscape, as Moore and Hackett describe in their analysis of public engagement with renewable energy siting in another California desert valley: the cartographic lens, they argue, should be ground-truthed to help maintain "a goldilocks principle between high modernism and narrowly constrained, intractable controversies about specific sites" (2016).

Secondly, and perhaps more surprisingly, some residents don't see water shortages as threatening the agricultural future of the valley. It might appear on the front lines of climate change in climate models, and yet the Imperial Irrigation District has senior water rights to a large portion of Colorado River Water — what one farmer emphasized as “the strongest water rights of the river” (C18). Despite general water security, due to the water politics of the area, some respondents were still worried about the impacts of climate change upstream, and the needs of the other seven basin states of the Colorado River. A few commented on how Lake Mead was approaching historic lows, and what conservation situations that could trigger. But in general, water is seen as a political battle and an allocation challenge, since the landscape is not dependent upon rain.

A third factor is the lukewarm concern about climate change is the already-extreme heat: “The heat is a real thing, but it's one of those things that people just think, ‘Okay, this is how it is in the valley’” (C2). On the other hand, people wondered about the ability of the body to actually tolerate such high temperatures. Farm workers are particularly vulnerable; employers provide minimal protections such as shaded resting places and water breaks. In short, people are already adapting to extreme conditions, so in a sense they must just pile on more adaptation.

In the Imperial Valley, as in many rural regions, many people are skeptical about anthropogenic global warming. Farmers in particular are attuned to variability, and some question whether climate observations just reflect natural variability. One farmer explained:

> I was born in this valley, and my grandfather was here in the '30s. …I've been around here for so long that the one thing you learn as a person who pays attention to weather ... For example, I can't prune unless I have enough dormancy. I have to watch heat spells coming in the summertime and so on and so forth, that the one thing you learn is that it's very unpredictable, and for the comments to be made that we're been continuously warming, or continuously cooling, however you want to do it, are just false. I mean, it's up and down, it's up and down. It's unpredictable. ... Normally everything averages out… There is no such thing as normal weather. There's average weather, and you will notice things average out. (C3)

Another farmer had a similar line of questioning: "The word climate change, or phrase, I'm not sure what people mean by it. Is it just a drought that we're in, a drought cycle? That certainly has changed the climate; that's for sure. Is it man-made? I don't know. There are a lot of different thoughts on that … You go to look at tree rings, back 2000 years, you see cycles that are very similar to what we have today" (C18). Moreover, it's not just a matter shaky science — some growers see the climate change discourse as politically motivated. "Lookit, they've raised a lot of money through carbon taxation, they changed the way people live, which was really the goal in the first place. It's all about money. They've done it" (C3).

Yet despite the mixed concern for climate impacts, and a fair amount of climate skepticism, visions of renewable energy in the Imperial Valley are thriving.[6] Local development officials celebrate the valley's natural blessing: 360 days of sunshine a year, a 1° slope on most lands, and the geothermal resources of the Salton Sink — geographical features which are buoyed by the state's renewable energy portfolio requirement of 50% by 2030. The potential is seen for both energy and jobs in a region with 25% unemployment: as one former county supervisor put it, "Renewable energy is going to give Imperial County a shot in the arm" (Li, 2013). Local agencies such as Imperial Irrigation District — a large landholder as well as an electricity provider — as well as the Imperial Valley Economic Development Corporation are actively promoting development of this "21st century gold" in the region, with fair success. The growth of renewables has exploded as utilities such as San Diego Gas & Electric buy from massive Imperial County solar and wind projects to fulfill their mandate. Even if not everyone buys into anthropogenic global warming, many see the benefits of participating in the boom.

While developers build mega-projects, citizen scientists have viewed the landscape as an area of experimentation. Both local entrepreneurs / activists and large, established institutions see the Imperial Valley as offering a global model for new energy futures, in different ways. One citizen trying to bring technology companies together in a scientific collective discussed a vision for

[6] This should not surprise, as support for renewable energy research in the US tends to be strong even when belief in anthropogenic global warming is low (Marlon et al, 2016).

> …incorporating renewable energy, like geothermal energy, solar energy, maybe solar gradient ponds, algae, biofuel technology, taking technologies that already exist and work to filter water and to create better water quality for wetland habitat, and even drinking water, like desalination. …
> Healthier people, healthier communities, cleaner air, cleaner water, cleaner food, cleaner habitat, it's all possible. Just got to see it and believe it, and then build a road map to get to that point. It's really that real to us. (C14)

The vision is for a demonstration area where a number of diverse companies can learn from each other: “"Where's the hydrogen?" It's over there. "Where's the solar testing area?" It's over there, and there's 20 different solar companies that are trying to be more efficient than the other one, and be more productive” (C4). Rather than being a strictly entrepreneurial vision, the idea is landscape transformation and changing the microclimate: “What would it do when you have an arid desert that now is lush green, and all the mangroves there are sequestering carbon on a regular basis, and all of the animals there are only there because you have created a new habitat for them?” (C4)

In short, there are a few different ways to imagine the future renewable energy landscape: large-scale mega-projects for energy export, a smaller, diverse sampling of pilot projects with community engagement, and things in-between. But these visions won’t come to materialize easily. In what follows, we will take a look at the challenges inherent in three major components of a carbon-removal landscape: biofuels, renewables, and on-farm sequestration.

2. Biofuels: Tough lignin in a tough investment climate

Bioenergy with carbon capture and sequestration has become a fundamental negative emissions strategy, and the Imperial Valley is considered an area favorable for biofuels due to its abundant sunlight and cheap water.[7] Sugarcane and algae are under development as biofuel feedstocks. Until now, there was no cane processing facility in the valley, though the warm climate is favorable to production. California Ethanol & Power's large processing facility is about to come online, which is projected to catapult sugarcane to Imperial County's third most valuable product (Rubenstein, 2017).

Whether it makes sense to use Colorado River water to grow bioenergy for export — or potentially for negative emissions — seems like an obvious question to an outsider concerned with climate change. But not everything that is contestable will be contested. Though the water footprint of biofuels, and cane in particular, has received attention when it comes to large-scale land acquisitions in the developing world (Borras et al, 2011; Johannsen et al, 2016; Tejada and Rist, 2017), it's likely this might not be contested here. For one, the main crop is alfalfa, which goes to China and the Arabian Peninsula, so there's already a large water export — one could argue that it might as well

[7] Whether there is local carbon sequestration potential in the underlying Salton Trough is unclear from the geological literature (Downey and Clinkenbeard, 2006), and no bioCCS plant is planned, so I don't mean to suggest that biofuels for BECCS would definitely be grown in this valley. It is beyond the scope of this paper to suggest how far the supply chain would stretch; research suggests that BECCS would exhibit diseconomies of scale in biomass transportation and supply costs (Sanchez and Callaway, 2016).

go to biofuels than to foreign cows. Farmers whom I asked about this virtual water trade countered with questions about the balance of trade and the embedded water content of electronics produced in China.[8] Secondly, one farmer pointed out that the Imperial Irrigation District is currently underusing its allotment, so the unused water could be used by new sugarcane production (C18). This virtual water discussion is a bit nuanced to get into here, but suffice it to say these are the kinds of questions that can come up when envisioning BECCS at scale. Yet they might not come up everywhere, or may be raised primarily by outsiders.

In order to avoid issues of competition with water, land for food, inputs, etc., BECCS is imagined to use cellulosic ethanol, e.g. from switchgrass grown on non-agricultural land or from farm residues. But the story of cellulosic ethanol has some important lessons of technical barriers and vested interests. In the words of one biofuel scientist:

> We started about 20-30 years ago to do cellulosic ethanol. We're going to take cellulose and melt it down and turn it into ethanol. Many of us thought, "Well, that's kind of a crazy idea because plants spent the last 500 million years evolving not to be turned into ethanol. In fact, there are plants in California that have sat outside for 6,000 years, a single tree, bristle cone pines, there's lots of them. They're four, five, 6,000 years old.

[8] Because of the abundance of empty containers in California which need to be sent back to China anyway, it's very affordable to fill them with alfalfa. However, farmers are a bit more skeptical when it comes to "Arab" firms making large-scale land purchases and then using the cheap water to grow grasses which get shipped away; this is seen more like land grabbing.

They've sat outside in the Sierras exposed to every bacteria and insect and animal and everything else for 6,000 years and they're still there. That's because evolution got cellulose not to turn in to something other than cellulose, and it had five million years to perfect that. Why we thought we could un-perfect that with our invention is beyond me but it became very clear to everybody in science four years ago, five years ago that cellulosic ethanol was going nowhere. That we had spent a billion dollars in research in the previous five years and got nowhere….

Four years ago, we all knew this was a bad idea. What happened? We put another billion dollars in, why? How on earth could this happen, right? It happened because people who had centers and people who worked on this went to Congress and told them, "We are almost there. I know we put a billion dollars in, in the last five years and we didn't make one discovery that changed it one bit but if you just give us a billion more," and Congress did, because these are the best scientists in the world.

One of the most influential guys … actually said, "Well, we're going to need an enormous breakthrough for this to work, something that I can't even imagine yet." This is after 10 years and $2 billion and that's not a trivial number. That is virtually 80% of what we spent on all renewable fuels.

> We knew it didn't work, still spent all of our money that way. Why, because it was 5,000 people and those 5,000 people are real people. There was a real postdoc in Berkeley who was going to get put out of a job. Now, it's true that somebody else in another university was going to get a job working on algae or working on jatropha or working on cyanobacteria or working on something else. They weren't going to get a chance to do that. Nope, those people didn't get a chance, they didn't get funded. All right.
>
> It's funny, people always say, "Aren't those big oil companies bad and they try to block you guys from doing something." … It actually turns out that scientists will be at least as self-serving as the worst oil company executive ever. (C28)

There are a few takeaways here, if you take this scientist's perspective to be accurate, which is supportable.[9] One is that vested interests in science, when committed to a certain research path, can keep going in the absence of evidence that it's a good path. Another is that being committed to one research trajectory can come at the expense of researching something else. Investing in the wrong idea can be costly. Furthermore, the underlying scientific conundrum described by this scientist is not yet to my knowledge solved; yet assumptions of BECCS potential seem to rely on it. I have called this a technical issue,

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[9] Dale (2017) writes about the slow scaling of cellulosics, writing of difficulties in pre-treatment at scale, but also pointing to upstream issues like biomass storage and the cost of setting up supply chains — while chemical engineers think about feedstock for their processing operations as a given, farmers have no commodity markets to participate in for residues, and think of supplying residues as a distraction from their work of growing food.

but it’s also a cost issue: it’s certainly possible to break down lignin when processing feedstock, but the enzymes required are expensive, and this is one key limitation to cheap biofuels (NRC, 2011: 267).

Another feedstock suffering from low cost-competitiveness is microalgae. Hopes were high in the Imperial Valley for algae: cheap water and land, abundant sunshine, and proximity to the blue biotech hub in San Diego made this an attractive place to develop algal biofuels. In the past decade, companies like Kent Bioenergy have garnered sizable grants from the DOE for utilizing microalgae for carbon sequestration and greenhouse gas abatement; companies like Carbon Capture sprouted up, with their algal ponds to be later sold or rented to Synthetic Genomics, General Atomics, etc.: there are now empty raceways among the desert scrub. In my analysis, microalgae biofuels have not had great success thus far because (1) oil prices dropped, and (2) there hasn’t been a coherent national-level energy policy. Algae companies have pivoted to other non-fuel products such as nutriceuticals and food dyes.

In theory, the valley could go beyond microalgae to macroalgae (seaweed), a favorite of some carbon removal visionaries. As one scientist pointed out, seaweed is almost an ideal biomass for making energy as it gets around the aforementioned lignin issue: “Any other kind of terrestrial biomass had to hold itself up against gravity and it does that with lignin and cellulose. Cellulose and lignin, right? Seaweed doesn't need any of that. It's neutrally buoyant” (C26). In one proposal, the excess CO_2 from a natural gas power plant would be eaten up by seaweed, which could be grown with a media of salts and sewage water sprayed on the seaweed. The biomass could be used to make food or fish feed, or with a hydrothermic liquefaction process to make more fuel (C26). While this isn't the same as negative emissions (as the carbon has to be reliably stored somewhere), it is another example of a new energy technology intervening with carbon that would need to be scaled up. It is hard to see these ideas prospering without national-level support sustained across several administrations and legislative sessions.

While the investment climate is rough and technical challenges are rife, in the Imperial Valley context, biofuels don't face some of the social acceptance issues that other technologies do — or that biofuels might elsewhere. For example, it seems likely to me that BECCS on a scale large enough to make a difference in global warming would involve genetically modified feedstock or genetically modified enzymes in production. Thus far, genetically modified organisms do not seem to have faced much social backlash in this valley.

In short, it's quite possible to see a massive scale-up of biofuels in this region, given the cheap water and lack of criticism about using that water for biofuels. While previous efforts in advanced biofuels have faltered, and questions arise about committing to the wrong technologies at the expense of others, it appears that the incentives offered by state and local entities are beginning to generate growth for sugarcane ethanol (perhaps at the expense of algae development). Production of biofuel feedstock, however, does not translate into BECCS here any more readily than it would elsewhere without incentives to remove carbon on a much wider scale. Renewable energy, on the other hand, is in a somewhat opposite situation — it has benefitted greatly from state-level policy, but faces various forms of social contestation, as the next section discusses.

3. "Choking on daytime electrons": Solar, geothermal, and wind as California's "21st century gold"

Why talk about renewables in a paper about negative emissions? Aside from it being a good analogy for developing a large-scale infrastructure, many negative emissions technologies are energy-intensive, and they would have to be powered by renewables to actually be net-negative. Hence any scale-up of negative emissions implies a significant expansion of renewables.

The Imperial Valley has been making use of the potential here for several decades. Geothermal first began in 1982, and there are now 21 plants in operation in the area, most of them operating on old technology. The Salton Sea field in particular has a potential of almost 3,000 megawatts; right now, only 380-390 have been developed. Geothermal is part of the vision for the shrinking Salton Sea, as it could take place on the soon-to-be exposed lakebed. An industry expert believes that this development will be concurrent with habitat building: "We're going to need roads and plant sites and well pads ... Transmission lines, everything that is part of a geothermal project. All of that can be developed in a manner that is consistent with the development of habitat. You can have a power plant right next to a duck pond, say, for example" (C9). At present, geothermal plants are interspersed with fields and solar farms. In theory, all of these renewables and other land uses would cohabitate and support each other.

However, there are ways in which these technologies compete. Some people are cynical about geothermal's future because it isn't cost-competitive with cheap solar, which benefits from tax credits. "It's a very, very unlevel playing field and anybody that has worked in this business would be able to tell you that. It's not a secret. Solar companies, perhaps you're aware, are exempt from property taxes, whereas our property tax bill is 20% of our annual O&M [operations and maintenance]" (C9). Utilities love solar, this expert explained, because transmission lies are used by solar for six hours a day.

> With gas prices at arguably historic low cost, utilities, they can say what they want, they can talk about it and spin it however they want, but they love it, because they have to have the spinning reserves, they have to fill up the other 18 hours in the day that solar is not producing with electricity that they can generate from their own generators with incredibly inexpensive fuel and still charge the same prices, so they make a lot of money. They pay their dividends on their peaking plants. (C9)

If you look at it from this standpoint, you could argue that solar was able to be scaled up so rapidly because of cheap fossil fuels — at the expense of other renewable options. A different policy design could have created a different scenario for geothermal: as one geothermal expert pointed out, a price could be put on the "greenhouse gas value for not burning a little bit of natural gas when the sun's not out", and geothermal could get a greenhouse gas offset credit to make it more competitive (C9). But at present, as pointed out by the solar developer: "The cost of geothermal hasn't changed in 20 years, whereas the cost of solar has dropped by 90%, and it's gonna continue to drop. Why would anybody want to sign up for expensive geothermal when you can get cheap solar?" (C5) Cheap solar sounds great, but there may be a case of oversupply in the works. "As a solar developer, there are so many sunny places in California where you could put solar, and California already has a lot of it, with another 15 gigawatts in the supply chain ready to be built, and when that 15 gigawatts is built, California will be choking on daytime electrons" (C5).

It's not that policymakers are unaware of the uneven situation and the challenges that a successful solar scale-up could bring— California Senate Bill 350, passed in 2015, requires utilities to take on "integrated resource planning" and figure out how to integrate their renewable portfolios. The point is that as an observer, it's not intuitive to look at these renewable technologies as competitors — we imagine they will all be used. Similarly, it's taken for granted that a portfolio approach to carbon removal technologies would be used. But the case of the renewable scale-up in California illustrates that there might be tensions between different technologies, and their actor-interest groups, as they mature.

The scale-up of renewables also points to lessons about the role of vested or entrenched interests in commercialization strategies as these technologies scale – in the renewable case, the role of the utilities with their access to cheap natural gas, and the regulatory role of the California Public Utilities Commission. When it comes to scaling up NETs, there may be a similar role for entrenched fossil fuels, at least when it comes to direct air capture — the main markets right now for the captured carbon are enhanced oil recovery. CO2 to fuel with lower carbon intensity (as required by California's Low Fuel Intensity standard) are the commercialization strategy of direct air capture startup Carbon Engineering, and would likely figure into markets for other firms as well. This of course does not meet the long-term objectives when it comes to net-negative emissions.

In the Imperial Valley in particular, the scale-up of solar looks like a success in terms of acreage, though the reception is not always warm. Solar in the valley is about 1,200 MW, but the economic development council claims a potential of 42,000 MW, enough to power 31 million homes (Miller, 2017). Both activists and farmers have issues with way solar has been rolled out here. In the words of one, "It's ridiculous to build solar projects 100 miles away [from San Diego, in the Imperial Valley], or 150 miles in the case of LA, to where the energy's going to be used, because then you have to destroy a whole bunch more desert with these high-power transmission lines, which are ugly and ruin the wildness of the desert. Absolutely crazy" (C22). What is the alternative to this style of scaling up renewables? "The best-case scenario is don't put up a single other large-scale, remote, renewable energy or other kind of energy project, and start covering the goddamned parking lots," this activist stated, explaining that "San Diego could be energy independent if we used all our parking lots and rooftops and public buildings and abandoned landfills, and right around the city, create the renewable energy in the microgrids right where people live" (C22).

Wind energy has faced similar types of resistance in the valley. "Those big, tall turbines, there's 112 of them on either side of Highway Eight there in an area that's considered part of a sacred Native American cultural landscape. Indeed, it's adjacent to a federally designated area of critical environmental concern for cultural use, the Yuha ACEC. It's essentially part of the Yuha ACEC" (C22). A conservation group filed a lawsuit against the federal government for doing this project.

> They did it anyway. They said, "We'll just remove ... We'll stay away from the cultural geoglyphs and what not, and everything will be fine," but you're destroying the landscape by breaking it up with wind turbines, which are hideous. You may have read in the paper and on everybody's Facebook last week, one of the wind turbines actually collapsed. The point is, we didn't need to do that, and also Ocotillo Wind Energy Facility is not producing the wind in the capacity that the developer had promised it would do. …. Yeah. We have solutions right here at home, if we would only get together and form community aggregations to create our own power. (C22)

Resistance and promotion does not always map onto familiar narratives. In this environmental conflict, one of the Native American groups in this area had been attempting to set up a wind installation on reservation land but faced resistance by both the Forest Service and by environmentalists .

> Even though the reservation has no utilities, no grid, no telephone or cell, radio or anything, we've made ourselves a part of a wind project, so there are 20 turbines intended for the southeast ridge of the reservation as part of a larger wind energy project. And that has been opposed at every point by the same environmentalists that we join in common cause with on the Salton Sea, that oppose even one take of a predatory bird - a golden eagle, in this case. We are protectors of the environment, the golden eagle is a spiritual entity for the tribe. It has great power with the tribe. And we would not engage in a project that would harm or intend to harm or would cause harm to the golden eagle population. We took golden eagles for ceremonies for thousands of years and choose not to do so now. But that we would be opposed by environmentalists, environmental organizations, for the potential take of even one golden eagle over a twenty year operating span of a wind project, which is a green energy project, which displaces carbon-based energy, which is a net positive and GHG reduction and supports climate change, is really difficult for us to understand. Development takes many forms. (C23)

In the view of this local official, non-tribal people tend to use tribal lands "as mitigation banks for their own adverse development" (C23). This appears as a case of a local group not being allowed to benefit from the renewables scale-up.

While some of the resistance to these projects can sound at times like aesthetic complains or not-in-my-backyard-ism, the resistance is shot through with environmental justice concerns, and to dismiss it as NIMBY-ism would obfuscate that. First, these people have to bear the harms from the development. Some contend that solar development creates particulates in an area suffering from low air quality: "They scrape the entire desert. In order to keep the desert sand from blowing, they use huge amounts of water to tamp it down, at least while they're putting in the solar project. Then they go away, and … there's been a couple of amazingly huge dust storms in the last year from the solar project … a huge, ugly thing, with not a thing growing underneath it. It takes 10 minutes to drive by it, it's so large" (C22).

Second, the benefits — both financial and energy — are flowing elsewhere. While the above quote was from someone working for a nearby environmental group, a Latino community advocate in the center of the valley reflected similar concerns :

> You've got Semper coming in here and putting 1,000 megawatts of power and it's all going out. Then you've got all these other 20 some solar facilities around us too, that have dug out the desert and then we have these episodes of wind now where all these dust is blowing. Now because

> of the water transfer, the Salton Sea is drying and more dust will be blowing. We see our hospitals with acute respiratory disorders in newborns and the elderly. Somehow, again, the word to me is immoral that this is happening and somehow our decision makers feel like they can't do what they need to do with this. (C10)

As a Latina environmental justice advocate put it: “Time and time again, in this community where, yeah, it's cool, technologies are proposed, but who do they really benefit? And who continues to suffer?” (C2). Farmers, too, have questions about who benefits and who loses from these megaprojects. Part of the objection is the economic impact: solar only brings a few jobs, and so the economy of the whole community can change. But part of it has to do with the loss of a way of life, and an identity; an ongoing loss that solar is seen as one part of.   In a video with 41,000 views, which garnered 692 tearful and angry emojis, a farmer shows up at an Imperial County Board of Supervisors meeting with several boxes of the last cantaloupes from what used to be known as the Bacon Ranch, and is now the Iris solar project: “The ground my family’s farmed for 50-60 years, which is some of the best farm ground … there was hundreds and hundreds of people working out there last winter; I’ve got a hundred people out there today – this is the last crop off that ground” (ICFB, 2016). There is also an urban/rural divide here; some in the agricultural community do not appreciate these lands being used for powering big cities.

The local contestation of renewables, which might on the surface seem like an unquestionable good — especially to those outside this place — is relevant to discussions about NETs which would use renewable energy, as well as to broader discussions of energy system change. Crucially, the opposition is not to the technologies, but in the occasionally place-blind ways they are being implemented. Some legislation at the state level attempts to address the issue of how disadvantaged communities can benefit from the renewable scale-up, such as the 2012 California Senate Bill 535, which requires that 25% of the revenue from CA's cap-and-trade system be spent on projects benefitting disadvantaged communities, and 10% of that be in projects actually in these communities. It will be interesting to evaluate the success of these measures in the coming decades.

4. On-farm carbon sequestration

Given that Imperial Valley has over 515,000 acres of agricultural land (USDA, 2012), it could theoretically sequester a lot of carbon in its soils. California has a Healthy Soils Initiative, a multiagency plan with multiple soil health goals, including sequestering and reducing greenhouse gases. However, there is often a disconnect between the legislators and the farmers in this area: as one agricultural expert noted, "the state of California makes all kinds of proclamations, and it's really out of touch with reality of whether that could ever work, and then when it doesn't work, there isn't real consequences there" (C20).

On-farm carbon sequestration is tricky because of issues of monitoring and verification. Beyond the technical challenges, incentives are required for landholder adoption — a new Healthy Soils incentive program funded through CA's Greenhouse Gas Reduction Fund is currently under development. Carbon farming is an idea talked about by smaller farmers in the Bay Area, noted one respondent, but many of those farmers only have a very small acreage and could be considered gardeners from the Imperial Valley scale. In the Valley, "there's some that are really into the whole idea of trying to defeat global warming, but that's a small portion. If it affects their bottom line, or their livelihood or whatever, then just like anybody else, it becomes more important" (C20). Another factor in adoption is that biochar was initially oversold, according to this respondent, which led to some disappointment.

Even though many farmers might be climate change skeptics, there are ways in which on-farm sequestration is still a promising strategy in this area. The region is deeply committed to farming as an identity, and to building good soil health.

> Farmers take a much more global, long-term view of things than any other business. And it's obvious, because farms stay in a family for generations, just having a farm means something to them. In CA, where most of them own their land, most of them would be better out if they just cashed out. But they don't. They really will take a longer term view. You just

> need to help them along enough so that they will do that; so that at least they aren't losing money doing it. (C20)

The valley has a lot of profitable, large farms who have the capacity to experiment with different growing techniques. Irrigated agriculture has also increased the soil carbon storage in the Imperial Valley in agricultural soils, due to organic matter decomposition and plant respiration over several decades (Wu et al, 2008). There are opportunities to deliberately build upon the work farmers are already doing with regards to soil carbon sequestration. On the other hand, non-farmed soils in the valley are vulnerable to losing carbon. Carbon is stored underneath California desert ecosystems as inorganic caliche (calcium carbonate), and when the land is disturbed, as can happen when building out large solar developments, the stored carbon can be released into the atmosphere; the desert is no longer sequestering that carbon. Scientists recommend revegetating solar developments with short-stature plants and building carbon in the underlying soil (Allen et al, 2013). In short, there is good room for improving soil carbon sequestration practices in both cultivated and non-cultivated soils.

5. Conclusion

Through examining the possibilities of biofuels for BECCS, on-farm carbon sequestration, and expanding renewables, we can picture a sociotechnical landscape of carbon sequestration practices overlapping in this valley in the latter half of this century. Whether this landscape is appealing to live in depends very much on how it evolves.

Evaluating the evolution of these practices in this particular place has made visible five types of challenges: financing challenges, technical barriers, landholder adoption, broader social acceptance issues of the underlying technologies, and environmental justice concerns. Some of these challenges can be addressed by smart policy design, but some are fundamentally cultural and will be more difficult to address through "governance", especially at macro scales.

An important point is that while some of these issues are "local", they can't simply be placed in a box of "local issues" that people working on the global or other scales can simply ignore or delegate to the local scale. Many of these concerns that are *evident* when examining the local are actually only *addressable* on state or national scales, such as the challenges to investing in new facilities and helping them cross the valley from demonstration-scale to commercial-scale, or properly incentivizing landowner adoption.

There are a couple of crosscutting issues beyond the ones mentioned above. One crosscutting issue is underlying climate denial, as perceptions of climate change are going to be important for attitudes towards negative emissions technologies — this is something that modelers and far-off policymakers are not well equipped to confront, but ignoring it is likely to result in policies that are distant from reality. From the Imperial Valley, one important lesson is that climate skeptics here are not anti-science. In fact, every skeptic I spoke to valued the scientific method. As one put it, "Science should be challenged. Then, if it stands up, then great, right? Then a bunch of these counter arguments are not true. You're still not sure whether anthropogenic global warming is true, but you know that certain counter arguments have been disproven, and I'd be much happier with that" (C5). When discussing research and development of technologies designed to address a problem that's based upon scientific understanding of the carbon cycle, policymakers and others should communicate the situation as one of managing risk rather than dealing with certainties — an approach that stakeholders like farmers may appreciate.

A second and perhaps underappreciated crosscutting issue is that NETs imply vast new infrastructure in a world that's already built out, and infrastructure is newly contestable. This is something to be celebrated in some respects — imagine if native peoples around the world had the ability to contest infrastructure and new production across their lands without being killed. But it also makes it more difficult to make sweeping transitions to new systems that require land or changes in land use, especially when many of the agencies dealing with land management have mandates that focus more on restricting activities. As one local official put it:

> In our world— and perhaps California is more pronounced than the rest of the country— we have a number of government agencies whose mission it is to protect the environment and other agencies who, increasingly, are focused on protecting the environment. But most of the agencies and organizations, at least the official ones, are designed to say, "No," and

> they're not designed to do something. They're designed to stop some things from being done. … That's very different than probably 1935 or 1955, where government agencies in this country did things like built Hoover Dam, or big freeways, or a big piece of infrastructure. Those served purposes and had major impacts, environmental impacts, cultural impacts and others. Well, the pendulum has certainly swung … These agencies that are designed to protect the environment or society or cultural resources are so geared toward stopping the bad thing from happening, they don't know how to make a good thing happen. (C16)

On a national level, there are a few agencies like ARPA-E (the Department of Energy's Advanced Research Projects Agency – Energy) which are designed to make something like negative emission technologies happen, but they are few and far between, and don't appear at all scales. So, if you combine the newly politicized world of infrastructure with the lack of agencies that have a strong mandate to build out new systems and deal with those politics — it doesn't seem like carbon removal has a bright future, at least not with the set of institutions we have. Something this large may require the design of new for-purpose institutions on varying scales.

But proposing new institutions brings up the issue of bottom-up support. A third challenge for something like negative emissions is the issue of narrative. Negative emissions are by definition some invisible thing; it can be difficult to get a widespread coalition of actors involved with a narrative about the benefits of negative something.

The "Global CO2 Initiative" has a philanthropic push towards carbon utilization, which might be more attractive – turning carbon into a usable commodity rather than a pollutant – but the scientific feasibility needs more work; a recent analysis by MacDowell et al (2017) in Nature Climate Change finds it to be a negligible contribution to the mitigation challenge and a risky narrative. At least with renewables, regular people have the potential to make money and see tangible benefits from them. Advanced monitoring technology might help make visible the invisible, especially if it could gamify the carbon removal somehow, and "governance" of negative emissions should focus a lot on monitoring and verification not just at the national level, but at the level of individual landowners.

In general, these three crosscutting issues of climate skepticism, the lack of institutions focused on new endeavors, and the lack of a strong citizen narrative around carbon removal — plus the other challenges mentioned — indicate that an attempt to raise "negative emissions" around a global goal like curbing global mean temperatures is not going to do very well. Success would entail clear social and economic benefits tailored for various landscapes, as well as some level of citizen interest. The curious thing about negative emissions, though, is that very few people are arguing for them — probably because they know it's a technocratic dream with all these underlying material and social challenges. The policy world is relatively silent. States like Saudi Arabia bring up carbon geoengineering in meetings of the IPCC (IISD, 2017), but there's very little communication about it elsewhere. Companies are similarly silent — Shell, for example, has a scenarios report on a net-zero world (Shell, 2016). Yet the vision of how one would get there is extremely vague. No one is making strident efforts to forge a path through the fog between the present moment and this imagined net-negative end-of-century: and yet the models say these phantom technologies will inhabit the landscapes. Given the lack of effort to date, it is questionable whether anyone will forge a path through the fog at all.

However, sketching out the picture of negative emissions in one particular landscape, it's almost possible to see biofuels, on-farm sequestration, and renewables as part of an agro-energy negative emissions system. If it will happen anywhere, here is one of the likelier places: and if it can't happen here in industrialized agricultural California, it's time to rethink what work "negative emissions" is actually doing. Geden (2016) describes how carbon removal technologies have had the effect of masking the "growing inconsistency between political talk, decisions, and actions". If this "co-production of irresponsibility" between policymakers and modelers has in fact become the point of negative emissions — which the available evidence suggests to be true — empirical social science research and speculative exercises such as this one can help point to the inconsistency, so we can be honest about the future. The examples here illustrate the tensions or failures that can arise when ecotechnical imaginaries are selected from afar — such as large-scale solar installations, investment in cellulosic biofuels, or incentives for soil carbon sequestration — without engagement from the people who will be living with these practices and infrastructure. In this case, it is not simply a disjunct between visions of ecotechnical imaginaries, but a disjunct between local and remote interpretations of what climate change means for a particular landscape. However, these disjuncts are not insurmountable: the ongoing work at the state level to reformulate policy around soil carbon incentives and renewables, as well as the engagement of the environmental justice community and green groups, indicate opportunities for various actors to shape the landscape through activism as well as participation in state and local processes.

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Chapter 5

Perspectives on albedo modification from Finnish Lapland: Viewing a global imaginary from a regional context

Abstract

While some scientists have proposed albedo modification[10] or "solar geoengineering" as a way to cool the Arctic and perhaps avoid some global tipping points — e.g. by injecting particles into the stratosphere — this concept has generally remained a global imaginary, an impersonal engineering technique based upon global models of coarse resolution. How do local people experience a global imaginary, and how do they imagine themselves shaping it? What agency might they have in determining its research trajectory or use, and what experience can they bring to bear? How can reading albedo modification through a local context help us see new things about the prospects of governing this kind of global intervention? This paper synthesizes perspectives from extended interviews with citizen stakeholders in Finnish Lapland. While citizens took a global perspective on geoengineering governance, and questioned their agency in influencing when, whether, or how solar geoengineering would be employed, they also used the topic of solar geoengineering to spark broader discussions of questions of how to live in the Anthropocene in ways which were quite unique to their northern / Arctic context,

[10] Albedo modification is the umbrella term for techniques that would modify the earth's albedo, potentially on the ground but also in the atmosphere or stratosphere.

including how to live with loss and unfamiliar climates, relocalization and new rural livelihoods in the north, and dematerialization of economies. The results challenge some key aspects of governance discussions: (1) that people's climate preferences are obvious or quantifiable; (2) that people will look at geoengineering as a local concern, or through an individual utilitarian lens, when in fact they might have much more of a cosmopolitan or interconnected systems-perspective; and (3) that states act in the interests of their citizens, when in fact they may act in the interests of elites.

1. Introduction and Rationale

It could be possible to cool the earth by placing particles into the stratosphere that would reflect a fraction of incoming sunlight. Whether these "solar geoengineering", albedo modification, or climate intervention ideas are even worthy of scientific research has been the matter of some debate. Moreover, "understanding of the ethical, political, and environmental consequences of an albedo modification action is relatively less advanced than the technical capacity to execute it", as noted in a recent National Academies of Sciences report (2015). A common question in the literature on solar geoengineering is: "Whose hand will be on the Earth's thermostat?"

Even though we understand that the earth doesn't have a thermostat, and there wouldn't be one hand making a choice, there are decisions about this technology that may need to be made, including whether to stop talking about it. These choices are manifest, and could only be done by a collective over a vast period of time due to their complexity: where to place the particles, what sort of particles they are, who will do it, how it will be paid for, how many to form, how to monitor their progress, when to adjust, and, most importantly, how to decarbonize the energy system into net-negative emissions and ensure we would be able to stop the particle deployment — since without lowering carbon dioxide concentrations, the level of solar geoengineering would need to be maintained indefinitely. One person would not have the knowledge to plan out something this complex. But perhaps fifty people could. Better, perhaps, a thousand people having input — or a million? Or ten billion? For we would all be clients of the engineers, with a stake in the project — even regional climate interventions would in many cases have global repercussions.

How to design a governance system for an intervention of this scale seems in some ways intractable, but a worthy first step is gathering multiple perspectives on it. Most of the literature on climate engineering has addressed the global scale, even though social science studies have happened in particular places. This paper aims to address regional and local dimensions of climate engineering, and examine how they interact with the global. In particular: How do local people experience a global imaginary, and how do they imagine themselves shaping it? What agency might they have in determining its research trajectory or use, and what experience can they bring to bear? What does placing albedo modification in a local context help us see regarding the prospects of governing this kind of global intervention?

A few studies have examined geoengineering “in place”, namely Carr (2015), who focused upon vulnerable populations in Kenya, the Solomon Islands, and indigenous Alaska. Wibeck et al (2015) studied public sense-making of geoengineering in Sweden, and Asayama et al (2017) studied views of citizens in Japan. Much deliberative and qualitative work also happened in the UK (reviewed by Bellamy and Lezaun, 2015), and there has also been survey work in the US, Canada, and Germany into attitudes about solar geoengineering (see Burns et al, 2016, for a review). Most of these studies, however, look at views from a broad scale, rather than analyze how cultural knowledge might have shaped perspectives on climate engineering.

It is interesting that in this small sample of 20-30 empirical studies, educated laypeople in developed countries had relatively similar views about geoengineering: ambivalence about geoengineering experimentation, and concerns about its controllability, but support for researching the idea in case it might be needed in a climate emergency. Carr also found strong commonalities among his three very geographically diverse study populations in Kenya, the Solomon Islands, and Alaska (2015: 43). These commonalities might indicate that placing geoengineering in a specific context would not affect people’s views — and, in fact, in this study, people had similar concerns to participants in the research mentioned above. The curious similarity of views on geoengineering may simply be that (1) this is a limited number of studies with participants with relatively similar milieus, or (2) that most of the studies were topic-blind recruitment with low familiarity of respondents going into them, so the participants were mainly hearing about climate engineering for the first time — there may be a similar set of "initial thoughts" between respondents that could change later. Another possibility is (3): that researchers saw the similarities because their analysis was more focused upon those, rather than asking questions about how local context figured into people's views on geoengineering.

This relatively coherent set of concerns is at odds with some prevalent ideas in the governance conversation: that people will necessarily want to set the thermostat at different levels, that they will rationally choose climate preferences based on their self-interests, and that they will hold widely divergent views on whether or how to embark upon geoengineering research (e.g Barrett, 2014; Victor, 2008; see review by Harding and Moreno-Cruz, 2016). Bodansky (2013) summarizes major governance challenges:

> Who should decide whether and how to engage in geoengineering? Should individual countries be allowed to weigh the potential benefits and risks on their own? Or should geoengineering require collective decisions and, if so, what international body should have this responsibility? What limitations, if any, should be placed on individuals to prevent them from undertaking geoengineering? And how should the international community address attempts by individual states to engage in geoengineering?

These questions are set in terms of competition between actors, and who holds power to permit or limit— while the empirical social science research thus far seems to indicate that citizens have remarkably similar views of the problem and how to address it (including approaching it with caution, conducting scientific research to learn more about the risks, and establishing international governance of it). Are the tensions between these worldviews simply because there is a difference between the geopolitical or economic understandings of climate engineering, and individual citizen understandings? If so, what does that mean for prospects for governing this technology in a way that people in civil society feel content with? Delving more deeply into the local context and how it affects people's understanding of climate engineering is one way to explore the tension between these two views. If people reveal concerns and questions that are specific to their place, culture, or history, the idea of a universal rational-economic or rational-nation-state response to climate engineering begins to disintegrate.

Looking at the far north

While it would be valuable to study local and scalar perspectives of geoengineering in multiple regions, this project took the Arctic as its object of study. The rapid and nonlinear changes in the Arctic have been brought up as reasons for researching albedo modification in the Arctic (Caldeira and Wood, 2008, MacCracken 2016, Moore et al 2014, Tilmes et al 2014), and there are also proposals to regionally modify the Arctic, e.g. to stop ice melt and other follow-on climate impacts (Tilmes et al, 2014, Jackson et al, 2015). Corry (forthcoming) has argued that "the Arctic has become a site of virtual geoengineering experimentation and intervention," tracing the history of this interest back to Cold War times. There are a few different strategies proposed for how regional albedo modification could be done — injecting aerosols into the stratosphere, brightening marine clouds, or even refreezing ice (Desch et al, 2016). However, no one except Carr (2015) has asked Arctic residents how they might feel about the concept. This study is essentially a first attempt to think through methods that might be used to help fill this void, though the Arctic is a heterogeneous region with a diversity of perspectives, and many inquiries would be needed in various places.

The specific study area, Finnish Lapland, has a complex relationship to “the Arctic”. Most interviews were done in the regional center of Rovaniemi, and nearby smaller municipalities to the north. Rovaniemi, with a population of about 50,000, sits on the Arctic Circle and is considered the “home of Santa Claus”. When respondents were asked if they felt themselves to be Arctic residents, the majority did, but with qualifications: many mentioned that they didn’t experience permafrost or Arctic fauna, and that the Arctic was a political concept that came more recently. People here have multiple, overlapping identities: Lappish, Finnish, Nordic, European, and “citizen of the world” all came up. While Finnish Lapland may not be definitively Arctic to all citizens, they did identify their region and identity as “northern”, with themes that may be familiar to northernness in other northern areas: sparse population, feeling themselves on the periphery, an interest in self-sufficiency, and feeling close to nature.

2. Methods

The material in this paper was gathered through twenty-two in-depth, semi-structured interviews, ranging in 30-120 minutes in duration and conducted in August and

September, 2016. The interview guide was loosely modeled after Carr (2015), but focused more upon the Arctic, and also asked respondents about ideas for further scientific research. I asked respondents about climate change and impacts they had already observed or expected. Respondents were then read a paragraph about albedo modification through stratospheric particle injections, and shown a diagram of the technique. They were asked for their concerns, ideas, or questions, and asked about Arctic perspectives on the issue as well as questions about how decisions about this approach should be made. Interviews were coded in NVivo to identify primary themes.

To date, most of the qualitative work on climate intervention has been through focus groups or deliberative workshops (notable exception Carr, 2015). Group public engagement methods may be well suited to a particular cultural context. As Pidgeon et al note, these methodologies have worked in Europe for over two decades, they were developed in the context of Danish civic culture and the "consensus conference", and may not always transfer to countries with different cultures of citizen participation (2013). The one-on-one conversation of the interview may be a more portable and versatile way of gathering qualitative, in-depth data, where citizens can speak freely without being judged by their peers (though of course, there is always the issue of the presence of the interviewer biasing responses).[11] In-depth interviews allow the

[11] Intensive interviewing is not a public engagement method in the sense that it develops a dialogue between science and non-scientists (see Corner et al, 2012), though these interviews were conducted alongside a project which aimed to incorporate public questions and ideas gathered from focus groups into the scientific process. To that end, part of the interview design asked participants if they had specific questions that they wished scientists would focus upon.

respondent to go into personal histories and contexts that have shaped their understanding of the phenomena in question.

The twelve men and ten women respondents ranged in age from mid-twenties to mid-sixties. Recruitment was by email, word-of-mouth contacts, or professional networking sites, and aimed to recruit persons with a variety of backgrounds who might have a stake in the issue, broadly construed. I strove to reach a balance of ages, and initially had difficulty recruiting women, so made an effort in the recruitment process to invite more women than men to assure near-equal numbers. Persons working in politics from major political parties were reached out to, with people affiliated with at least three of the most significant eight registered parties participating. While some participants had Sami heritage or had lived and worked in areas with more Sami residents, none of the participants officially represented Sami institutions.

The invitation letter was not topic-blind; it included mention of climate change and climate engineering, which means that participants were likely to be interested in climate issues. This does not necessarily make the sample less relevant, as the people who will be engaged with the issue and shape the initial politics around it will likely be those who are interested in climate and have the resources to engage. It does mean that the sample is likely more interested in climate change, and it is notably a well-educated, professional group: not strictly a "lay public" nor an "expert group." Several people brought their professional experience from sectors like wildlife research, tourism, or education to bear on the topic, but most spoke more generally from a personal or citizen standpoint—

climate intervention was sufficiently unfamiliar that people did not seem to feel they had authority to connect it to their expertise. Even though recruitment mentioned climate intervention, most people reported no familiarity with the topic. One issue of note is that interviews were conducted in the English language— while 85-90% of Finns can hold a conversation in it, not all might feel comfortable with it, and one invitee did turn down the invitation due to feelings of insufficient English.

3. Results

3.1 Thoughts about climate change

Uncanny winters

Every respondent interviewed was concerned with shorter winters. The changes to winter duration and quality — noted by most respondents as already in progress — have economic, cultural, and mental health impacts. Economically, Rovaniemi is the "home of Santa Claus", and scores of Christmas tourists come to visit him in Santa's Village. Now, snow is expected in the beginning or middle of December, while twenty-five years ago, the white season could be guaranteed to customers in November —"If there's no snow during December, it kind of loses the magic" (F8). Even respondents not connected with tourism noted the regional economic impacts of not having a white Christmas. But the impacts are also cultural — for example, people who traveled to school by skis in their childhood wondered if the coming generations would even learn to ski (F7).

Respondents were concerned about the distinguishability and predictability of seasons. Winter seems to be a season whose integrity was deteriorating, slipping away. One interviewee related an anecdote told by a longtime resident:

> When he was a child they used to play with snow, they used to make balls and used to throw, this ball could break a window as well. But now the snow becomes like that ... it is losing its cohesion or something. ... there's something changed, the quality of the snow is not strong like previous times. This is a practical example. (F2)

Many cited worries about an endless autumn, a "dark long season", and concerns that "in the end we won't have anything but autumn all the time" (F4). In other places in the northern hemisphere, autumn may have bright and pleasant connotations, but in Lapland, it is rainy and dark, a cloudy burden. The stretching autumn has mental health implications: in the words of one respondent, "in October it's already very dark here, it's not much daylight… and when the snow comes it changes everything, the light and people's minds, you get more energy because there is brisk air and white everywhere" (F20). To have a "real winter" or a "good winter" is a part of the identity here, and it's more than an aesthetic preference. Winters getting "worse" include changes in the quality of the snow, the amounts of it, and the integrity of it.

Two thirds of respondents cited the impacts of a deteriorating winter on reindeer — many mentioning that with warmer winters, the snow melts and refreezes, forming a layer of ice that reindeer cannot crack to get to the lichen below, which they need to eat. While only three or four respondents had actually worked with reindeer herding, this seemed to be common knowledge — as one respondent explained, "People here live very close to nature, and that's how they know it" (F6). In fact, the majority of reindeer in Finnish Lapland— perhaps three-quarters— are actually fed hay and other food over winter (F20). But the image of the reindeer digging with their sharp hooves into the ice, unable to reach food, was well-known, and resonant. A reindeer expert described the problems that reindeer have when spring comes too early – the streams are opening earlier, and they have problems crossing the rivers which they normally had crossed on ice (F20)– the image is of a fragmented landscape, perceived through the eyes of the reindeer, but resonant with some deeper sense of fragmentation.

I would summarize these images of fragmentation, indistinguishability, lack of cohesion, and lack of predictability as being "uncanny" — the sense is that the familiar is now strange; that the future climate is unknown. However, not everyone expressed a sense of the uncanny, especially when speaking from a professional standpoint. An expert in agriculture in Lapland also opined in a quite rational or matter-of-fact way about the challenges of finding new cultivation techniques for plants who would have to deal with thawing and dramatic refreezing (F3). Or, as a tourism security expert put it,

> From industry point of view I don't see any drastic damages right now … Industry is going to adapt to circumstances and the environment. New program services for tourism will be developed. Of course story or narrative of Santa Claus can change if we don't have snow in Rovaniemi for example, but global-wise or European-wise this is not a big issue or drastic issue. It's only economical thing now. (F17)

In summary, people were unanimously concerned with the changes to wintertime's duration and quality, and were both experiencing it as unfamiliar or uncanny as well as thinking about how to adapt to it.

Global turmoil

While shorter winters were the most frequently mentioned concern, it was not often the *primary* concern. Many people interpreted the primary, key, or most urgent concerns with climate change to be global suffering— for example, food and water security in the global south. In the big picture, Arctic concerns were not as important:

> The impacts in the Arctic - even though they are supposed to kind of be earlier, they are already visible in a way - they are sort of miniscule in comparison to droughts that could happen in the south that affects hundreds of millions of people…. I'm just imagining the sort of

> instability we will have in the next generations ... If you look at history, this kind of big migration always causes huge upheavals, huge problems, social problems and economic issues. I'm not sure if Europeans are capable of economically, socially, politically accepting these kind of flows of people who will have nothing else to do. They will have no other choice. They will simply have no water, no food, not enough kind of wellbeing on a very very low level. So, I guess this is my main concern for the future. I don't think Arctic will be such a big deal when things go further. (F1)

This was perhaps altruistic or empathetic, but also rational, as many believed that changes abroad would eventually affect them via migration and economic impacts. In the words of one politician:

> Of course, my biggest worry is the not so direct impact, but what happens to the global economy and how third world countries can cope with the uncertainty with the climate. How the food security and all kinds of issues related to health and then extreme, severe weather causing lots of problems for people. How that affects the globe and mankind, because of course that has a global effect to us as well. (F8)

Though many cited potential benefits from climate change, such as agricultural benefits, none seemed to believe that their region would be an overall "winner." Participants had a more sophisticated, nuanced view of benefit and detriment than a "winners and losers" discourse would suggest. "If the losers are big areas, tiny areas who are winners cannot compensate it. We are in the same boat," explained one respondent (F12). Participants were also cognizant of a temporal dimension to winning and losing. As one entrepreneur put it, "in business we here in north are in short term winners, but in longer term difficulties reach also us" (F21) Or as a grandmother put it,

> Sometimes I close my eyes and ears, because it hurts to think about the future, because there will be refugees because of the southern Europe drying and the storms will be very hard and there will be many kinds of problems coming along with climate change. I don't see any profits and any good things. Coming in three years, there will be some good things. Or some five years. But if we think of tens of years, the changes will be very difficult and dangerous. (F16)

3.2 Thoughts about climate intervention

After respondents had answered questions about expected climatic changes, I read a brief paragraph explaining albedo modification through stratospheric particle injection, and asked for initial thoughts, followed by eliciting people's key concerns. Interestingly, even though the interview guide had in some ways primed them to think from a local or regional context, most people generally didn't express concerns or questions about how climate intervention would affect their region in particular. When specifically asked what "people in the Arctic" would think about climate intervention – not themselves, but other Arctic residents – the impressions ranged widely, and many people remarked that it was difficult to know, or that it would depend upon the framing. On one hand, some remarked that Arctic people might feel like a "test laboratory" and be very skeptical or afraid (F17). Others commented along the lines that since people in traditional lifestyles were concerned about the effects of climate change, "people could be quite open if we had new solutions that would actually affect quite fast" (F15). Some thought that other Arctic residents would be approving, and invoked what's been called as the "moral hazard" of avoidance of change: "I suppose that some of them would be very delighted. 'Okay, wonderful. Now we've got a technical solution. So we don't have to do anything.' That may be. Perhaps that's also the risk in that kind of thing. 'Wonderful. We can just continue as before and we don't have to change anything'" (F16).

Across the board, people were concerned about unforeseen ecological consequences. They viewed the earth as a complex system — "there is not a mechanical system" but a "very very chaotic system" (F5). It is difficult to say whether this systems perspective is part of the generally well-educated Finnish society, or if this study population was perhaps even more socialized into systems thinking because of their professions. As one political scientist commented,

> As much as I want to trust the science behind it, I've heard so many times from climate scientists and from people dealing with weather modeling and with climate modeling there's so many factors that it's simply impossible to predict everything, to take into account everything. There's always some wild cards in the climate system that we still don't understand very well.   (F1)

Because of ecosystem complexity, many participants viewed it as difficult or impossible to accurately predict the outcomes of engineering the climate.   They were concerned about unknown interactions once the particles were released into nature— this was an environmental concern, but not limited to "nature" or "the environment." As one tourism researcher commented, "if the environment is harmed, then human systems are harmed as well" (F10). This concern about unknowable effects has been frequently noted in other studies (Wibeck et al, 2015).

The difficulties in climate intervention were explained not simply via understanding earth systems as complex; they were seen to be linked with history. "We have quite a bad history as humankind, of doing things that shouldn't be done or taking risks," noted one respondent, mentioning nuclear weapons, chemicals with unknown impacts, and an ocean full of plastic (F4). Another explained:

> I have seen that the humankind has thought before that when we do this A operation, then it creates the consequence B and C, and they have never figured it out in time that there has been consequences D, E, and F also - which are a pain in our ass today in our ecological net. And this is the master scale of manipulation which should be done … and the scale that it's global wide, it could never work in the way that it could be useful. (F14)

Most of the concerns that emerged about climate intervention's impacts were global or abstract, and often touched upon effects of climate intervention about people in other places. However, their concerns were still *informed by* particular contextual histories. For example, a few mentioned how residue from Chernobyl affected Sami reindeer herders, or the recognition that persistent organic pollutants were in the Arctic food chain. The Arctic appears as a place where contaminants end up: "anything people are doing somewhere, it affects them although they don't get any use, or they don't benefit" (F4). As one explained,

> You have the pollution coming from the outside, the persistent organic pollutants, climate change is being triggered from outside, mercury is coming from outside, black carbon is coming from Asia and from Europe and from the central northern America. So... so I guess that maybe, and this is just a guess, I think maybe when people start thinking about climate

> intervention, they also think as this kind of something that south is doing, is impacting somehow Arctic. I guess this could be also the feeling that one shares with all peripheral regions, peripheral in any sense, economically peripheral - so developing states, the least developed states, or people also away from these centers of governance. (F1)

People read the idea of climate engineering not just through northern or Arctic histories, but European ones — including dark histories of barbarism and colonialism. One respondent discussed the relationship between recent terrorist attacks in France and turmoil with French colonies in the 1950s and 1960s, and the difficulty of integration, commenting on the relationship to nature during colonialism, which questions of climate engineering brought up: "If our attitudes towards nature and attitude towards the globe and human race is the same as it was 150 years ago — at the moment, I think that it's very close to that — what will happen?" (F3) Another referred to the history of Europe before nation-states:

> My concern is that the climate is going to change so quickly and rapidly that it's going to cause these kind of international consequences, like the people has to leave in a big masses from another area to go to some other area. If we go back to the history when the nations were born in Europe, that you know the Huns and the Germans, Barbarians go to one area, they went to Rome - they were, if the climate is going to change, it's going to change the way of the nations that we are used to. You know the raw

> materials, first water is going to run out, whatever it is, whatever it is, it's going to be violence of the last resources who is going to get them. That's what I see if the climate is going to change quite quickly. (F14)

These types of concerns are not found as commonly in the geoengineering governance literature, which tends to steer away from prospects like neocolonialism and the breakdown of nation-states, and also bounds topics like racial integration off from environmental governance. This is not to say that the references to European, Nordic, and northern histories are entirely pessimistic — some discussed, for example, previous referendums on nuclear energy as evidence of people's ability to choose a technological future. Similarly, Wibeck et al (2015) found that Swedish laypeople often referenced the 1980 referendum on nuclear power in Sweden.

3.3 Beyond climate intervention – Questions of how to live in the Anthropocene

Living with loss, insecurity, and the uncanny

These conversations were about climate change and climate intervention, but the evoked broader and deeper issues that people wanted to talk about. Loss was a major theme: loss of climatic conditions, species loss, and a more general cultural loss or disruption in memory that had to do with modernity more generally. Some of these losses were spoken of broadly, e.g. "I'm worried about the future of my children because

I know that the world is changing so rapidly. Perhaps their life won't be anything like what we have" (F4). People also brought up very specific examples, like whether and how to relocate a population of 400 Saimaa ringed seals, who only inhabit lakes in southern Finland (F4). Or "small things", as evidenced in one artist's example about the willow grouse — it changes color to be while in the winter, but ten years ago, the grouse changed color two or three weeks before the snow, and the population declined. Now, it is protected and not hunted, while in the respondent's youth the willow grouse was hunted by the hundreds (F19). The loss affects the very color of the landscape: "If you go and walk in the forest, this kind of white, pine tree forest with this lichen …. They have vanished away and now they are these kind of blueberry fields. Nature is changing. The color of the nature is changing and the animals are changing a little bit. It's obvious." However, this respondent also reflected, "I think that it's not very often only about the climate changes, because there are a lot of changes like tourist business, mining industry, those mixed together with these and we never know what are the effects or the reasons in reality" (F19).

Many spoke of the permanence of extinction — "when you lose some species or parts of your nature we will never have it back"(F15) — but also related extinction to human loss. "Loss of biodiversity is terrible and of course loss of livelihood for people as well," commented a cultural worker; who put it as part of an active process and a struggle: "I think we are losing" (F18). Another interviewee focused on northern societies, and warned that "this invaluable unique culture could change and vanish away immediately" (F19).

The stories and comments about loss, and the sense of the uncanny and unfamiliar, relates to climate insecurity in its many facets, and a sense of vulnerability. Even in the global north, and with a strong welfare state, there were ways in which the human systems here were vulnerable. A few spoke in terms of the climate security discourse “in the north, exploration of raw material can become more intensive and it might have safety and security impacts on state relations, relations between great powers in circumpolar regions for example” (F17). But others saw the vulnerability in more everyday terms:

> So, for the whole region, to live here - now the snowplow is driving three times a week, we get more snow the snowplow is driving every day, someone has to pay for it. Is the state ready to pay for something like this? This is the thing - it influences everything; we have to pay even more taxes to pay for this infrastructure that works. We can't live over here if the snowplow is not running; we can't drive. I even can't get to work. It's interesting, if you start to think which influence is possible ... it's endless. (F6)

Context is about time as much as place, and many respondents brought up worries about the current zeitgeist. Climate insecurity was just one component of a greater malaise. A tourism operator noted that customers who used to ski in the Alps are coming to Lapland not just because of poor snow in the Alps, but because of terrorism: “they feel the loved ones is still safe" (F7). These sentiments about rising insecurity or global instability were absolutely relevant to perceptions about climate change or climate engineering, and how they could be governed.

> I think we must do something [about climate change] quite soon, probably in the next 20 years or something like that, but we don't have enough time to have all those negotiations and deliberations … because in a political level, the world is now more chaotic. Those crazy people are going into power like the president of the Phillippines, the Turkish Erdogan, Donald Trump, Putin. Rationality is going away. The people in the UK voted to exit from the EU even though some of them didn't even know what is the EU. … China is trying to govern natural resources everywhere in the world. In Africa, in Iceland. … National interests are back. I think it would be very difficult to have those kind of consensus which you need. (F5)

In many cases, participants vacillated between democratic liberal ideals of what *should* be, and pessimism about how things seemed to be trending. One, who had been quite optimistic about positive change, ventured into worries about migration:

> And ... what about if we have here, in this tiny area called Finland, good conditions, but we have very strong border, and there is people who are suffering, and they decide, let's go to Finland, it is nice place to

> live! There is water and good climate. What about if 50 million people from south of Europe decides so? We cannot do anything. It is always a stronger boy who takes the candy from a small boy's hands. (F12)

Another echoed that human history is "a game for the fittest, strongest," stating that there wasn't a democratic way of making decisions about climate engineering because of the "pure power politics behind everything which are not shown to us normal people," elaborating that "they show it to us after 30 years in the memoirs of Hillary Clinton, and even not then" (F14)

> I think if somebody hits the nail on the head and figures out a way that we manipulate in this way, the climate, whatever it is, he or she will be the master of the universe. He will use this kind of information to have the rest of the humankind to be his or her slave. It's the role of the god, then, if someone figures it out that we have the powerful system to suck carbon dioxide from the atmosphere and put that into the ocean or into the space, whatever it is. When they have their research, when they have their possibility, and the life gets hotter and hotter on the globe, then they will announce that you have to pay us and we will take 3 centigrades off the warming, and that's the system. (F14)

In some of the interviews, respondents alternated between perspectives of pessimism, and liberal hope about democratic decisions, evidencing the fluidity of positions about what is realistic or possible. The war about what is realistic or possible is waged in people's minds. While expressing pessimism about human nature and human values, the same person could moments later express optimism about it.

> We have the wrong kind of values. Total wrong kind of values. This generation. And as I told you, this year I have been visiting a good lecture .. how the identity of here, a Lappish person, is developing, and how it is changing every 4th or 5th generation, and then we have everything what people believed in 1850 is now gone. And if we think 4 or 5 generations in the future, they don't have that kind of values what we have. And then I think about it.. actually, it's good that they have different values. And it is changing automatically. It is like skin. People have new values, and they think about different way. That time, 1850 we have believed in king, or priest, and nowadays not. We don't believe anyone. [laughs] And we ... believe in decision-makers, or we think ourselves. But we want a lot of property and use natural resources. But in the future, I believe they are different. I believe the future is better that way. (F12)

Some spoke about a loss of faith in progress — which helps to make sense of the ambiguity about geoengineering, which can be seen as a breakdown of the master narrative about scientific, economic, and cultural progress. One respondent even stated that "I don't believe in this paradigm of scientific and technological progress anymore," and saw geoengineering as connected with American optimism, juxtaposed perhaps with Finnish reflectiveness or questioning.

> I think that in Finland ... people in north, they're more suspicious, they think more than the people down in south in rat race, and if you go to see the reindeer farmers and herders in Lapland, local people, they keep on thinking. All of them they are thinkers. … So I think that many people possibly think very positively about that maybe they do something, but I think we still could have a really big pessimistic part of the population thinking, oh well, that's another Russian invention, and that's another Yankees invention, and oh, whatever, this kind of a normal Finnish pessimism … I hope in Lapland that in the middle of the forest, we still have these open-minded people who will tell what we should have done when they invented the first steam engine, James Watt invented that in 1700 in England, that it should be broke down. It should be broke down.… and since then we have lost the game. (F14)

Could albedo modification be a remedy, a salve, for insecurity? Notably, climate intervention was not really seen as something that would relieve these concerns about security. At this stage, solar geoengineering just seems to add to the insecurity, or to compound it, rather than being something that "saves" people from loss or instability. Several people brought up being afraid of geoengineering, though this may have been associated with gender – seven women mentioned fear, but only two men. One of the men qualified “scary” with “a little bit” (F1), and another spoke about not fear of geoengineering, but fear of a post-secular society (F5). While it is possible that women are more afraid of climate intervention than men, it is also possible that gender is one factor of many that conditions how free people feel about expressing their emotions. But in short, no one at present indicated that climate engineering was something that made them feel more confident or comfortable about any perceived global trends.

Responsibility and agency in decision-making

Respondents were asked both whose responsibility it is to do something about climate engineering, and who should make decisions on climate engineering. Some noted the responsibility of big polluters like the US and China to act. Climate change itself had multiple realms of responsibility and solutions, from the individual or regional to corporate, nation-state and international levels. But across the board, they believed that climate engineering would need to be governed by some international process or body. People were able to visualize different scales of climate solutions with more familiar methods of mitigation; no one mentioned smaller scales or areas of responsibility in terms of climate intervention, though in one case regional geoengineering was brought up: the idea that reindeer modify albedo through their grazing habits (F14).

There was a disjunct between ideas of responsibility and agency: who should be responsible for solving climate change differs from who has the power to do so.

Geoengineering was seen to complicate this: “It’s like transferring the responsibility from myself to somebody else in tacking climate change,” commented one respondent (F17). Climate engineering was also seen as something that would be hard to have a say in; hard for citizens to shape. There were at least three reasons: complexity, peripherality, and history. Firstly, as one respondent explained, the climate regime “now looks like a crazy web of different provisions and measures,” only some of which are implemented. “I think that the problem with climate intervention is that this would develop a similar network or similar framework, a patchwork of different measures and different ideas, so it would be very complex” (F1).

Secondly, in many instances, there was a sense of being on the periphery despite being in the “global north”— people did not see Lapland or even the Arctic as very powerful. Moreover, no one who was asked thought it was very plausible that potential Arctic interests in a warming climate would figure into decisions about climate engineering. First, there was a sense of being on the periphery even of Finland: that for southern Finland, Lapland “does not exist. They don't need Lapland. There's nothing. There are only trees” (F6). Another elaborated,

> Decisions are kind of made in the south, and then the north is this kind of colony, or periphery, that is being used, extracted, controlled, protected. So there is this kind of resistance by many people to this southern environmentalist - Helsinki, Stockholm, Washington-based environmentalist who come to the north and tell people that they are not

> doing, that they are not protecting their environment. And then you have the big companies that are in the south trying to get at the resources. (F1)

Thirdly, citizen participation in a geoengineering regime was hard to imagine due to the history of non-participatory decisions around the world. One participant who had migrated from Bangladesh explained that normatively, there should be collective decision-making, it would be difficult to actualize:

> [The decision to do climate engineering] should be made actually together. Because nobody, not even the developed or rich countries, they are not the owner of this planet. So I think all the countries, they are the stakeholder and owner. So I think it should be taken in open forum, it could be - at the beginning it could happen with meetings, and then they can make some committees in order to introduce this idea, and then they can take opinion country-wise, but before the countries are participating in this forum, each and every country, they need to know this and they need to discuss with stakeholders inside the country, kind of clusters, like political groups, researchers, civil society members.. and then actually, then they can consider if this is going to work or not, or what is better. Because nobody can take this decision by themselves. (F2)

This respondent saw mitigation as something that a developing country could take part in, but participation in climate engineering was more difficult both in terms of capacity and in terms of a history of unequal global relations.

Despite the challenges, when it comes to regional geoengineering, people felt that local perspectives should be considered. One respondent pointed out that the idea means something for "Russians, northern Scandinavians, maybe Iceland, for Greenland people, Canada, northern part of that. Most of the people in the world believe that this empty area, there's nothing harmed. Yeah, in that case, I just really hope that these people who are living there, they have some rights to say something" (F19). Some people brought up the agency of indigenous groups and the need to speak with them, and a few also discussed how women might be marginalized from decision-making. One noted:

> [Women] are anyway the minority in decision-making in this area … they are not so interested in the new technology. They are not so much involved in it. They don't believe so much in the new technology as men. Technology and economics, they are very much in the hands of men. Women also fear that we don't understand. That it's a men's business. That kind of segregation is even bigger in this Arctic and Lappish area than in other parts of Finland, for example. I suppose they leave it, in a sense, in the hands of men. That's a problem. (F16)

People began to think of methods of representative participation in decision-making, such as voting schemes, though these interviews were carried out in the wake of Brexit, which provoked a few critical reflections on the idea of voting. For example, one respondent mentioned that some months ago, she would have suggested a referendum.

> But what happened now in England, this is an example how it shouldn't work. So the older people went to vote, and they had still the old United Kingdom in mind, what was existing many, many years, and they didn't like the influence of whole Europe, and they voted not to belong to the EU anymore. But the younger people, they even didn't go to vote. So now they are out. And I think that this kind of thing is dangerous as well. It's hard to decide if the politicians should be able to say what we should do - this is as well dangerous. Maybe we should be [doing] independent research. (F6)

Sources of hope

Many participants expressed a desire for scientists to research other topics, which would be preferable to climate engineering: into new energy sources, for example, or into the question of why political will to act on climate change is so low given everything we know about climate science. Other studies have also found that in discussing geoengineering, people broaden the horizons of the problem and solutions. As Wibeck et al (2015: 29) put it: "The focus group participants repeatedly criticized the growth ethos while articulating far-reaching demands for renewable technology, lifestyle change and societal transformation." Corner et al (2013) also noted that "while the link between mitigation (via lifestyle change) and materialism is clear, what was more surprising was the extent to which deliberating about geoengineering also triggered many comments about the wasteful nature of society;" they remark that for some participants, considering geoengineering triggers "a rejection of the idea that consumption rates can continue to grow indefinitely, facilitated by a geoengineered climate." In this study, a few people mentioned the concern that geoengineering would be used to continue economic growth, but surprisingly few discussed this. Many mentioned the need for societal transformation, however.

What form did hope for the future take? Not geoengineering, by and large — it was rarely seen as a source of hope. People did cite familiar green strategies, but without particular effusiveness or passion about them (decreasing flying and driving, taking "individual actions", reducing waste, electric cars and windmills). However, there were areas in which people did imagine the future in positive terms.

Relocalization and new rural livelihoods

Lapland is a rural region experiencing structural change — as one respondent pointed out, thirty years ago there were 10,000 farms; now there are 1,500; while there were 3,500 dairy farms, there are now 300. When speaking about the future, "the challenge for this area is how the people can work here; what kind of job they have" (F9). It was observed that children want to "escape the countryside" (F18). Another asked, "Why are we not doing anything against urbanization? That also people can live in the country" (F5).

Some approached this question around future rural livelihoods in conjunction with questions around climate futures: "we have to find basic living there [in rural areas], and the climate change could bring new possibilities." One cited opportunities in local energy production for villages, and making small villages more self-sufficient in energy and food (F3). The changes wrought by climate change could be opportunities for restructuring, from centralized systems into dispersed systems; to change to a system of processing materials near where the resources are. Another respondent saw the power of place as providing possible new livelihoods in terms of nature tourism offering therapy or healing: that "ecosystem services" are both mental, cultural, and spiritual; that the ecosystem offers a good place to work with troubled youth or people struggling with addition, a kind of nature tourism beyond beauty or wildlife to a deeper healing experience (F19).

Dematerialization, education, and new values

Related to this question of new rural livelihoods is the idea of dematerialization — that perhaps the economies don't need to be based on material goods as much anymore. While some ideas around relocalization or new livelihoods might sound romantic, part of the discussion is linked to the failure of new economic opportunities from climate change to materialize. One researcher describes discovering

> maybe one year or two years ago, that because people are discouraged with the speed or nonexistence of this large-scale development ... there were so many hopes for oil and gas extraction, and mining, and shipping, ships going back and forth all over the Arctic, but that is not happening, or is happening very slowly, people notice that there are so many constraints, including environmental constraints. Climate change is not actually the main factor in triggering these developments. (F1)

Instead, people are thinking about industries like the bioeconomy, data centers, cold climate testing and technologies, and "how sparsely populated remote regions can benefit and - not only benefit but somehow create, create jobs, create economic growth inside the regions based upon knowledge based economy, communication technology, or digitalization" (F1). Other respondents commented on the prospects of this not from the policy side, but from observing what younger people are interested in:

> In rich countries, of course, there are poor people living in rich countries but people have already everything they need. There are not so many things you want now. Too many things or surprises, surprises are more here like you can see those Pokémon Go. You couldn't imagine

something like that some months ago. It's a real surprise. … Probably it's part of economic growth and not consuming so much. Ecological damages not such a big part … Of course, people who can probably travel more are lucky to find those Pokémons. … If economic growth will happen in the virtual world, it's not damaging so much the global ecology. (F5)

Another respondent commented that new generations "have different values, and they don't appreciate so much in this area, I have seen signs of it – they don't appreciate so much about new things in my cupboard, or buy new things, new clothes, maybe that is the future" (F12). Of course, there is a question of capacity to buy new things — the same respondent, an educator, warns young people "that maybe they are the first generation ever that will be poorer than their parents. And they get big problems, environmental problems, and less resources, we have been eating their cake, part of their cake." The educator sees hope in that this generation "has better education than any generation before" (F12).

4. Discussion and conclusion

How can reading climate intervention through a local context help us with governance efforts? Out of the two widespread concerns about climate change — shorter, uncanny winters and global turmoil — only the latter was really discussed in relationship to climate intervention. People did not emphasize how climate intervention would impact them locally, and many believed it would only be tried in times of global crisis, e.g. if food production in the global south was failing. Contrary to discourse that suggest people will be out to maximize their own climatic interests, the cosmopolitan perspectives voiced actually point towards more hope for cooperative global governance of climate engineering — if governance was up to citizens.

It might seem inconsequential to talk about what a few dozen Lappish people think about albedo modification, but in fact, these conversations bring up challenges to three tacit assumptions in the geoengineering discourse to date.

The first is that people's climate preferences are obvious or quantifiable. We in lower latitudes might assume that people up north might be okay with it a few degrees warmer, when in fact only one person mentioned that as a possible benefit (and not much of one, in the context of other changes). There aren't metrics which easily capture snow quality, the type of snow, or "real" winter. Even metrics like temperature are contextual. As one respondent explained:

> Over here, if you have minus 20 degrees, ... it's cold. You can go out, it's not possible anymore to do downhill skiing, your face is freezing and fingers, not nice. As well cross-country skiing is dangerous, you have to breathe a lot, it's ... but minus 20 doesn't feel that bad because it's so dry, over here. Minus twenty in Germany, you freeze to death, because it's humid. Over here it's dry. If I wash clothes and put it somewhere to dry,

> it takes an hour to dry, in wintertime - because it's so dry. And it feels different, totally. It does not feel so cold as in Middle Europe, when you have the same temperature. (F6)

At minimum, this suggests that people will need more information besides temperature metrics to understand what a climate under albedo modification might feel like. It also underscores the importance of going out and engaging with various populations to understand their climate preferences.

A second key assumption is that people will look at geoengineering as a local concern, or through an individual utilitarian lens. However, these respondents — in part because of their systems view, but perhaps for other reasons — understand the interconnectedness of the world's economies and peoples, even if politicians are speaking in terms of nation-states. (This might seem counterintuitive in a time which seems to be marked by rising nationalism, but these could be simply two sides of a coin.) The material in these interviews invites us to rethink the relationship between categories of "outside" and "inside"; what is external and what is local. People in societies like Finland may be open to democratic, collaborative processes for governing climate engineering. But there may be a serious disjunct between citizen imaginaries and the positions of states on this issue. People also did not claim a self-interested position themselves, but observed "power politics" in the behavior of states, now and throughout history. Several people brought this up— one in the context of China, where it might have been easier to see:

> Now even China has a stake on the Arctic and they are aggressive in so many terms, and the Arctic countries even, the Arctic Eight, they know about this and they have so many forums, and still they are doing what they want to do. They want to explore the Arctic for more resources; they are also not following the rules or they are not very ... aware to protect the situation, about the climate change issues. They are thinking about their own stake and their own profit. So they are making this cost-benefit analysis, so in that case I don't know how the citizen will react, whether they will agree. (F2)

Relatedly, a third tacit assumption is that states act in the interests of their citizens—when this has not been true in the case of climate change governance. What happens to ideas of governing climate engineering in situations where governments do not represent the will of the people? More research is needed into the possible tension in these perspectives.

Reading geoengineering through other local contexts would be useful in order to explore whether people's perspectives on geoengineering are indeed shaped by local or individual interests, and examine whether there is in fact tension between the perspectives of citizens and the states that purport to represent them. Similar studies could also offer insight into regional variations in conditions of acceptability, or whether people’s views are determined by climatic geography or other factors like equality and trust in institutions.

Finally, it is notable that an interview guide with questions rather narrowly focused about climate engineering could evoke such a wide array of thoughts about how to live in a new or unfamiliar world — including an uncanny climate, but with thoughts even beyond climate or “environmental” issues. This suggests that (1) perhaps the geoengineering discussion has a role in coming to grips with the changes needed, even if geoengineering is never conducted, and (2) people need more venues in which to think about the future they want — it’s rare that people have formal opportunities to discuss the future, and ideally there would be more forums for thinking about these questions of sustainable livelihood in the era of climate change over the medium-to-long term. This is something which goes beyond academia, and yet people working in the academy have a potentially important role to play in creating these spaces, both in terms of the students served in universities and the wider public.

Issues like geoengineering make clear the need for such deliberative forums: in a sense, it is curious why institutions for future-imagining and path-making do not exist already. Is it because representative democracy has delegated decision-making and future planning to professional representatives? Is it because activities like planning are so heavily bureaucratized? Is it a question of scale — meaning that people can be engaged with local planning issues, but not global ones? Probably a combination of these reasons and more; yet is the latter one that is most relevant for this example of solar geoengineering. These new global responsibilities demand a different sort of institution for participatory deliberation of possible futures, and it's possible that we may need to innovate one where none exists. Some creative work in the social sciences is being done in this direction. Szerszynski and colleagues conducted deliberative research where participants were asked to imagine the worlds that might be brought about by geoengineering (discussed in Szerszynski, 2017). Stilgoe (2016) has suggested geoengineering could be reframed as part of a regime of collective experimentation (rather than a regime of technoscientific promises), in which publics are part of an experimental system. It's not yet clear how these types of efforts work together, but this type of research could be considered "basic research" in a nascent field of interdisciplinary future studies.

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Conclusion

This dissertation has examined four ecotechnical imaginaries, and focusing attention on how these imaginaries are articulated, negotiated, and contested on varying scales has brought up three insights. Firstly, public engagement with environmental futures takes the form of selecting between options. Though many of these options are formed and promoted by experts, civil society actors do work on generating compelling narratives and metrics in order to improve the selectability of particular futures. Secondly, these imaginaries have illuminated some of the ways the narrative of responsibility in the Anthropocene is deficient and should be modified, i.e. to view responsibility in environmental future-making as not a moment of taking the right decision among predetermined options, but as a continual process of care and maintenance that recognizes labor and agency. Thirdly, this dissertation reveals how these imaginaries are doing work far beyond their stated purposes in material transformation (in some cases, perhaps in lieu of their stated purpose). In this conclusion, we will revisit and expand upon these three key takeaways, elaborating their implications for the key question of how citizens can have more agency in deciding about and designing emerging technologies of environmental future-making.

1. Considering selectability: From the Arab Spring to the First 100 Days

This work emerged in the shadow of its context. This context is not incidental, and not just background color to the chapters I have presented here. Two social transitions loom especially large: one has been on the front pages of our newspapers almost daily, and the other seems curiously forgotten in the US, by both the press and academia. Much of this fieldwork was done in August-December 2016, and the US presidential election was inescapable, both in the conversations I had with respondents and as general mood. More troubling, though, throughout the five years I worked on this, was the unraveling of the Arab Spring. When I was working as an analyst in the US Department of State in 2011, it seemed that it had actually begun as an African Spring. Events in Tunisia unfolded at the same time as the January 2011 referendum in South Sudan birthed a new country through a selection mechanism, the vote. There was much hand-wringing during in the following months about how the intelligence community had "missed" the Arab Spring, not unlike the postmortem of how political and social scientists “missed” the rise of Trump five years later. At the time, my interpretation was that Middle East – North Africa analysts had failed to see that citizens were able to mobilize as genuine actors; that the gaze of even the best analysts was trained to think other types of actors were the ones that mattered. One think tank looked at analysis across professional sectors from academic, other think tanks, journalism, business, and NGOs, assessing that “even those who focused their work on the bottom-up perspective would not have judged that civil society groups, labor movements, or informal networks would be the catalyst for real change in the time frame considered” (Laipson, 2011: 5). Perhaps citizens would have to count.

We now know how things seem in the countries we were watching: Tunisia, Libya, Syria, Yemen, Bahrain, Egypt, Morocco, and elsewhere, including South Sudan, with parts of the new country now in a state of famine, with the oil exports the people hoped to benefit from virtually nonexistent. People celebrated when South Sudan chose to be born. They celebrated when protestors across the MENA region saw democracy as selectable over autocracy. Six years on, those of us in the US witnessed the rise of a narcissist with autocratic tendencies in our own country, selected by popular minority. His first overseas trip involves selling $109 billion of arms to Saudi Arabia. We can imagine that some of these will be used to prolong and expand the suffering in Yemen: where just a few years ago people were celebrating the ousting of Saleh after a 33-year reign, and which is currently one of four countries at risk of famine. Meanwhile, global mean temperatures rise, with models predicting that parts of the region will cross the threshold of what heat stress the human body can bear (Pal and Eltahir, 2015); it is people in Yemen who will not have air conditioning to insulate them. Fossil fuels are transmuted into double-suffering of weapons and heat, via the United States and voters like those whom I spoke with in rural California.

What does it mean to talk about selecting futures when our main mechanisms for doing so are broken? Or when those with arms are willing to kill you for selecting something different? The strategy I am arguing for, and observing some instances of — that citizens can use narratives along with calculations to shape what options become selectable — seems absurd in the face of an AK-47, or in a place where a narrative of possibility and change did emerge and was quashed by violence. This is where the geopolitical realists are able to lay their claim to understanding the world.

However, crafting narratives and metrics to fight for selectability can still be a viable strategy for places like the US. For example, the Salton Sea, as discussed in chapters three and four, different civil society actors (1) are calling for action in terms of environmental justice, and holding the state accountable for additional air pollution, and (2) working to make alternative engineering projects for the sea selectable. They do so through strategies such as monitoring air pollution and wildlife, sharing data about it, and producing media designed for wider audiences, as well as attending formal meetings and using the traditional political structures on offer. These hearings are a form of what Chilvers and Kearnes (2016) have called participation as technologized procedure; at the same time, they allow participants a forum to articulate the calculations and narratives of their alternative visions.

In the case of solar geoengineering, actors such as the ETC group, a small civil society organization, were actually quite effective in laying out a case for climate engineering being non-selectable. They used the umbrella term "geoengineering" to bundle methods together and claim a moratorium on it using the UN's Convention on Biological Diversity. In general, they have used narrative tactics, but also buttress their narrative with metrics of their own — i.e., meticulously tracking patents issued on technologies (ETC, 2010). The option they would prefer is sustainable agriculture; the choice of climate engineering becomes defined as a choice of agricultural production systems (Buck, 2015). These groups have been relatively effective in reconfiguring the choices, given their limited resources. It is possible, though, that in other contexts the selectability of geoengineering would emerge quite differently, if the selectable alternative is extreme warming. A greater concern about climate change is correlated with willingness to consider solar geoengineering in several studies (Visschers et al, 2017; Merk et al, 2016; Mercer et al, 2011). Visschers et al (2017) found, for example, in China, public opinion of SRM is more welcoming; they muse that the "lack of adaptive and mitigative capacity in certain countries such as China may explain the more positive opinion of SRM held there."

Both solar geoengineering and negative emissions technologies are relatively unheard of by laypersons, which is a major issue, because there are limited opportunities to participate in shaping the imaginaries of these technologies. Even participation by organizations claiming to represent civil society tends to close down discussion rather than open it, potentially resulting in a situation where global public views are authoritatively authored and mapped out before the vast majority of people have even heard of these techniques. When the imaginaries are so unfamiliar to people, it remains largely speculative to write about how publics could do storytelling work to shape how they emerge— or counterfactual accounts that may be stories or actual histories. The "ocean economy", for example, is perhaps too wonkish and top-down to be a site of popular struggle (at least not until its construction results in material effects, should that come to pass). But there is a fascinating way in which the visions of some enterprises with roots in 1970s counterculture — e.g. in aquaponics or algae cultivation or ocean energy — is packaged up with other, more traditional "blue" sectors of growth, such as fishing and deep-sea extraction. Some of the sectors counted in the blue economy may be at odds with each other, and part of the debate around selectable futures involves deciding what goes into the package. Mauritius, for example, had a long process of creating its roadmap for an ocean economy, involving a National Dialogue with public consultation; yet it had already defined the ocean economy as building on the work of making Mauritius a petroleum hub (Ramgoolam, 2013). Part of the dilemma is the lack of forums for engaging in debates around the long future in more general terms, and deciding what even gets to be "roadmapped" — a theme we will return to shortly. But in summary, the storytelling and quantitative work done by civil society actors to make various options selectable is worthy of much more analysis, which could explore under which conditions these efforts are successful, what kinds of responses they face, and how the metrics and narratives used work together or against each other.

2. Revising Responsibility in the Anthropocene

Part of the Anthropocene theory quoted throughout this dissertation reiterates that the events in places like South Sudan are not distant tragedies, but connected to everyday life in the global north even more than ever during a time of carbon democracy (Mitchell, 2013) and climate change. For example, during the last two meetings of the IPCC, Saudi Arabia pressed for carbon geoengineering and negative emissions to be included in various IPCC special reports (IISD, 2016; IISD, 2017). Not a single scientist working on solar geoengineering or negative emissions that I have met is interested in developing these technologies so that the Saudis can pump more oil — and, in fact, would likely find that irresponsible— but it's very possible that this becomes the reality despite our best efforts and intentions. A critical rendering of the Anthropocene involves recognizing these entanglements, and what responsibilities they might bring. It also involves reframing our choices to select climate repair over war. In my eyes, the brilliant innovation in a recent paper by Desch et al (2016) about artificially refreezing Arctic ice is not its calculations for winter ice thickening as a form of "geodesign" (the authors' preferred term over geoengineering). The innovation I appreciate is the framing: that the price tag of $500 billion per year to deploy freezing devices over the entire Arctic "is an enterprise comparable in scope to the U.S. automotive industry, or the execution of the Iraq War, which is to say that it is expensive but is economically achievable" (2016: 14). In those terms, refreezing the Arctic is more selectable. It is also appears as a more responsible choice than the Iraq war. There is immense work to be done in rehearsing possible imaginaries and the responsibilities they highlight.

This dissertation is about the search for a new story, after the master narrative about modernity and progress is wearing out; the breakdown of this narrative is another entanglement between this work and its temporal context. This is a time when the old stories are not working — the campaign slogan of Donald Trump reflects this, and in some ways the rise and failure of the Arab Spring might as well. Modernity under neoliberalism did not deliver; neither has digital democracy as of yet. What new stories are taking hold, as narrated by my respondents? Who populates these Anthropocene stories? The antagonists I am concerned with in this dissertation are characterized by their lack of response, their stagnation. Haraway writes of the thoughtlessness of decision-makers in this time; of "refusing to know and to cultivate the capacity of response-ability; of refusing to be present in and to onrushing catastrophe in time; of unprecedented looking away" (2016: 35). This seems to be something more like the story: the antagonists are antagonizing in their slowness, their non-reactiveness. And what of the protagonists? They have the same characteristics: they are like Hamlet in their indecision and melancholy. If the content of the story is repair — of how the world can be repaired — this is a classic story, and could perhaps do the job, if it is transformative. Henke, writing about industrial agriculture as an ecology of power, draws a distinction between repair strategies of maintenance and transformation, writing that repair as maintenance tends to be the default strategy (2008: 11). Dust mitigation at the Salton Sea as well as solar geoengineering could be seen as maintenance-repair strategies. If repair-as-transformation prevails against that default, this could be a compelling story worth telling, with plenty of archetypical narratives about Eden, greening, restoration, or even springtime to draw from.

What I heard from some ecologists in the Imperial Valley was that they were attempting their best to build boring-looking, least-cost ponds to keep some fish and birds alive. It wasn't a grand design, and there was no hubris there, either. It's not an interesting story. The same thing goes for people in Finnish Lapland, who were dreaming of new livelihoods in rural, depopulating areas or ways of educating children to have less material values. People were in some sense living the new ecological paradigm, but in the face of long odds and difficult global challenges: trying to do their best. These stories lack the heroics of modernity's order, progress, and rationality; they are harder to see and not as clickworthy as disaster. They are stories which are very hard to produce in this media ecology. If turned into headlines, they would read as if from the satirical publication *The Onion* in their quotidian aspirations and lack of heroic ambition.

Is this a problem? In the Anthropocene, where we are all actors now, perhaps it's a relief to be liberated from these big heroic narratives of progress; we can have and be smaller heroes. Still, Sovacool and Brossman (2013) analyze visions for new energy technologies such as automobiles, hydroelectric dams, and nuclear reactors, finding that the optimistic fantasies around their widespread use had some commonalities. They were positive, and responded to some challenge facing society; motivating "people to become enrolled in the fantasy together"; they were flexible in their open-endedness and vagueness; they gave people a story about how the future would be positively different from now (ibid.). Today's audiences may be different readers, but it seems likely that this still applies — at least the people I spoke with seemed to want stories about how the future will be positively different.

Responsibility is a part of narratives of resistance against certain ecotechnical imaginaries. Part of the ETC Group's argument against solar geoengineering involves shirking responsibility: "the major private sector players in geoengineering will likely be the same energy, chemical, forestry and agribusiness companies that bear a large responsibility for creating our current climate predicament – in effect, the same folks who geoengineered us into this mess in the first place" (ETC, 2010). Similarly, with regards to negative emissions, Actionaid argues that "the "net-zero emissions" approach shift the climate burden onto southern countries who have done the least to cause it (Anderson and Stone, 2015). In short, negative emissions are seen as an avoidance of responsibility in the global north resulting in transference of burden, and the responsible, selectable future has to do with food security.

These are important responsibilities to bring up, and elucidating historical responsibility is an important part of environmental justice. But what of stories of how the future can be positively different? One way to include responsibility in these stories is to bring up the forward-looking dimension, which is coupled with agency. This is discussed in some narratives of land-based negative emissions technologies, such as soil carbon sequestration's restorative dimension where growers can take agency in climate-smart agriculture, or in plans for restoring the Salton Sea.

A final point on new conceptions of Anthropocene responsibility: it is not just the text with its content, setting, and actors in these responsibility stories that will be important, but the forms in which they are told. Ulrike Felt, for example, writes about the narrative of Austria as being free from GMOs as an "imaginary of the absent"; an imaginary that entered the "repertoire of the possible" through successful rehearsals in varying forms, from storytelling to mapmaking (2015). She writes that "this imaginary was the outcome of a gradual, long-term, bottom-up formation, always in need of rehearsal and (re)stabilization" (2015: 119). Haraway writes that stories strengthen response-abilities: "The details link actual beings to actual responsibilities. … Each time a story helps me remember what I thought I knew, or introduces me to new knowledge, a muscle critical for caring about flourishing gets some aerobic exercise. Such exercise enhances collective thinking and movement in complexity" (2016: 29).

3. The multiple functions of ecotechnical imaginaries

The third key observation throughout these chapters is that these ecotechnical imaginaries are serving purposes other than their stated purpose. Part of the storytelling work that can be done around these imaginaries is not just in shaping them as if they were going to exist, but for these other ends. This becomes a bit clearer when we look at the specifics, as all these imaginaries have alternative purposes. The instances actually differ quite a bit.

In the case of negative emissions, I refer to an excellent piece by Oliver Geden, where he discusses the work climate targets do. "A decision on a certain climate target is presented and perceived as an act of deliberate choice between different possible end states, to be accompanied by assessments of proper sub-targets and instruments and followed up with the deployment of appropriate measures," he explains, clarifying that "Policymakers do not specialize in solving problems but merely in dealing with them. They view talk, decisions, and actions as independent organizational products, and do not see decisions as necessarily requiring appropriate action" (2016). The goals of 2°C or

1.5°C are products of the work of the policymakers doing their jobs, and also generate jobs for modelers. With Paris, though, the goals are not top-down mandates for what's environmentally desirable, but bottom-up goals for what's politically feasible, and "the only way to alleviate the inherent contradiction between top-down and bottom-up is to create a narrative in which voluntary bottom-up actions are able to deliver top-down climate stabilization targets" (ibid.). This narrative hinges on the innovation of negative emissions into carbon budgets in the IPCC's AR5, which makes it possible to mask the growing inconsistencies between political talk and action (ibid.).

At the same time, the Paris Agreement doesn't refer to negative emissions, because it is known that the amount of CDR needed to meet the temperature targets is unfeasible due to land competition and other issues — i.e. the issues in scaling up NETs discussed in chapters one and four in this dissertation are tacitly apprehended to some degree. But if NETs were magical thinking, and policymakers knew it, then why set these temperature targets so low? Geden identifies four other functions of these targets: "(1) creating legitimacy for policymakers and the negotiation process; (2) claiming responsibility for saving the planet; (3) mobilizing short-term action within the negotiation process; and (4) creating a potential benchmark for loss and damage claims." Crucially, he observes, target implementation is not necessary for the targets to fulfill these functions (ibid). Negative emissions are an innovation in calculation that accomplishes these other functions: it doesn't mean that they will actually come to pass. The tricky thing is that now that NETs exist in calculations, they may in fact be taken at face value as a selectable option. As Beck and Mahoney ask, “does the significant presence of BECCS in RCP2.6, and the political significance of RCP2.6, make a BECCS-inflected future more likely?" They argue that the IPCC should take responsibility for a future-making role, and do work in solution-oriented assessment, as one way to facilitate policy alternatives (2017).

It is hard to know if NETs and BECCS are impossible or inevitable. Van Lente notes that "one of the striking things about technological futures is that they often appear in the imperative mode. That is, once defined as promise, action is required" (2000: 43). Negative emissions certainly appear in the imperative mode, but because of the aforementioned challenges as well as lack of a profit rationale, action will probably be forestalled. The imperative is not as strong as the inertia in this case. At the same time, this technology would be incredibly useful if done in a socially just way, which is part of why I have bothered to write about its feasibility in chapters one and four. I believe that examining the social aspects of carbon practices on a landscape level can provide a dual function of disrupting the alternative work that negative emissions does as masking political action and imagining what a better version of NETs could look like.

What work do these other ecotechnical imaginaries do? In the case of blue growth / the ocean economy, the state motivations are covered in chapter two: the objectives of the imaginary vary from geostrategic to economic, but one key aim is to garner investment in blue biotech as well as other sectors (including offshore fossil fuel extraction). The arguments for the blue economy, as calculated in the United States, collect the importance of all these sectors as a unified unit. In Mauritius, the idea of blue growth is important to identity as not just a small island state but a “large ocean state”; in China, the ocean economy involves sovereignty as well as claiming territory. The calculations work to support some grand ideas, in theory — it is an empirical question how many people are paying attention to blue economy calculations, and how far the associated ideas travel.

In the case of solar geoengineering, which is frequently met with allegations of being a way to avoid responsibility and allow continued fossil fuel pollution, I believe its few advocates genuinely believe that it could be one way of averting a climate emergency. They do not see the climate system as controllable; they know it doesn’t have a “thermostat.” Solar geoengineering still seems worth researching given the alternate scenarios. But one alternative end it could serve is haunting the climate policy discussion. Some social science evidence suggests that it galvanizes action for mitigation for some groups (Corner and Pidgeon, 2014), concern about climate risks (Kahan et al, 2015), or, for political conservatives in the UK, actually increases trust in climate science (Fairbrother, 2016).

In the case of the Salton Sea, I believe that the state has come up with smaller, sustainable sea and the habitat creation projects because it legally had to do something — the Imperial Irrigation District delivered a significant threat to pull out of the water transfer if the state did not act. Performance of small actions is necessary to maintain legitimacy. However, the citizen-led development of alternative ecotechnical, engineering-heavy imaginaries, is interesting as it seems to be an exception to the norm.

Why would people here articulate different ecotechnical futures? Part of it may be desperation: they have nothing left to lose; property owners can't afford to go elsewhere. Part of it may be that the state has defined responsibility and a contractual obligation, and the state is part of the people, so there is both a clear mandate and a means of participating. Part of it also may be the advent and penetration of the Internet, which makes it much easier for citizens from geographically disparate communities all around the sea to document and discuss the sea's decline. Communication about the sea is serving a communal function for some people, who have made it their daily work and passion.

The future of future studies

An overarching idea in this dissertation is that social science can do much more to address how people do and can make environmental futures. The study of how futures are made falls into a disciplinary void. The chapters of this dissertation aim to fill the gap in small ways, but they are drops into a vast field. To further understand why this is the case, I turn to Appadurai's discussion of the "anthropology of the future", which he imagines would examine things that shape the "future as a cultural fact": imagination, anticipation, and aspiration (2013). Appadurai explains that anthropology's core concepts such as culture, diversity, and custom pull scholars towards concerns like persistence, stability and fixity in various societies; culture has been viewed as a matter of pastness while development is seen in terms of the future. "This opposition is an artifact of our definitions and has been crippling," he observes, explaining that economics has become the science of the future, "and when human beings are seen as having a future, the keywords such as wants, needs, expectations, calculations have become hardwired into the discourse of economics. In a word, the cultural actor is a person of and from the past, and the economic actor a person of the future" (2013: 180). Sociology, he argues, took as its central problem the shift of societies of sentiment to societies of contract; anthropology chose to look at societies of the past and societies that remained outside of Western modernity (2013: 285). This left the systematic study of future-making to other fields: neoclassical economics and its derivative policy fields like decision analysis or operations research; environment sciences and planning; disaster management; and when it comes to the material environment, design and architecture (2013: 286).

Rational choice is an artifact of how the future has been disciplined by this disciplinary hegemony. Stirling, writing about energy sustainability, discusses how politics has been conceived as a process of "rational choice" by these disciplines, the effect being that much social science work on energy has drawn upon these rational choice framings towards "tranquil, neatly segregated and formally orchestrated procedures of 'polycentric governance' – for instance in 'global assessments' with narrow topical remits driven primarily by experts," where qualitative form merely reflects the closure committed in quantitative expert analysis (2014). The same processes can be seen in environmental future-making more broadly. However, as Appadurai emphasizes, imagination is not a professional or expert capacity, but a "vital resource in all social processes and projects, and needs to be seen as a quotidian energy, not visible only in dreams, fantasies, and sequestered moments of euphoria and creativity" (2013: 287). Imagination is a workday thing, as is the capacity to aspire; the future must be deprofessionalized terrain.

What is needed, then, is not just a sociology or anthropology of the future, but an interdisciplinary field of future studies where these can be not competitors to rational-choice ways of seeing, but in conversation. I'm also quite sympathetic to Thomas's call for a parallel "futurology from below", including case studies, deliberative processes, and fieldwork "from below" for a people's assessment of new technologies (2015); in my view, this would go beyond assessment to involvement in development of new technologies. Fields such as political ecology and science and technology studies have already done the work of explaining how (eco)sociotechnical orders are constructed: as Appadurai notes, social construction of the future is by now too well established to need belaboring; but he comments that “the corollary that other worlds are always there for the making is less well understood and still less acted upon” (2013: 339). I hope that this dissertation has shown some glimmers of other worlds there for the making, and am grateful to everyone who shared their fragments of alternative futures with me: from the man who served me a test dish of reindeer casserole as part of a plan to introduce Lappish schoolchildren to local, sustainable meat, to the farmer who took me to a restored marsh habitat he had built at the shores of the Salton Sea. The future is not empty; it is populated with other humans and nonhumans.

The conclusions here could read as grim: many of these chapters have showcased severe obstacles to citizens having more agency in shaping environmental futures. It seems impossible, or at least a conundrum with a yet-unresolved solution, to reconcile a global imaginary like solar geoengineering with ideas about citizen participation in research and design. It seems unlikely that citizens near the Salton Sea will see a full restoration or maintenance of the sea in the near-term; many of these imaginaries, like negative emissions or ocean cultivation, seem technically feasible but sociopolitcally very distant in time. Part of environmental justice, though, is recognitive — recognizing and grappling with failures of responsibility, action, and judgment. It seems impossible to move forward without going through this process, and while taking responsibility can seem like (and legitimately be) a burden, it is also part of the way to agency.

Loving our monsters, tending unruly gardens, and doing our best with continued struggles is the only way to reclaim agency. The willingness of people to love something as monstrous as the Salton Sea, care for its marshland habitats, and show up at meetings with power-points full of alternative plans is a testament to how continued responsibility-taking can mount a response to inaction. While this dissertation has been replete with big-picture concepts and grand coming-of-age, restoration, or responsibility narratives, it is also the everyday actions of ordinary people which are interesting and additive in terms of creating greater agency for environment-shaping in the Anthropocene.

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Appendix A. Respondent key

Respondents in California — Chapters 3 and 4

C1 Community organizer
C2 Community advocate
C3 Farmer
C4 Entrepreneur
C5 Farmer
C6 Architect
C7 Official
C8 Developer
C9 Businessperson
C10 Community advocate
C10 Environmental official
C12 Academic scientist
C13 Community advocate
C14 Environmental advocate
C15 Community advocate
C16 Official
C17 Official
C18 Farmer
C19 Entrepreneur
C20 Agricultural specialist
C21 Community member
C22 Activist
C23 Community advocate
C24 Official (national)
C25 Agricultural executive
C26 Researcher
C27 Former teacher
C28 Scientist
C29 Activist
C30 Facilitator

Respondents in Finnish Lapland — Chapter 5

F1 Political scientist
F2 Social researcher
F3 Agricultural scientist
F4 Forest expert
F5 Environmental policy expert
F6 Expert in winter testing for automotive industry
F7 Tourism entrepreneur
F8 Politician
F9 Regional planner
F10 Tourism researcher
F11 Engineer
F12 Educator
F13 Politician
F14 Environmentalist from the northern part of Finland who knows reindeer in the Arctic area
F15 Politician working on youth issues
F16 Gender studies expert
F17 Tourism security expert
F18 Cultural worker
F19 Artist
F20 Wildlife expert
F21 Entrepreneur and business leader
F22 Reindeer expert

Appendix B. Interview Guides

Interview guide

California's Imperial and Coachella Valleys in 2050: The future of the land, agriculture, and new technologies

Preliminary Questions: *I would like to begin with some background questions about your community and your views on the future of the environment here.*

1. How long have you lived here? What is your role in this community?

[What products do you grow, and how?]

2. Describe the region in which you live. How has it changed over time?

[How has production changed over time?]

[Has the recent drought impacted your community? Your work? Your life? In what ways?]

3. In 30 years, what do you think the environment of this valley looks like?

[How do you think climate change will affect this area?]

4. What are your main concerns about the environment in the future?

5. Which of these concerns is the most important to you, and why?

6. What, if anything, do you think should be done about climate change? By whom?

7. How do you plan to cope with projected climate changes?

8. What do you think is the future of agriculture in this valley?

Salton Sea Questions: *In this second part of the interview, I'd like to hear your thoughts on the Salton Sea.*

9. How concerned are you about the situation at the Salton Sea?

[Do you expect the shrinking of Salton Sea to personally affect you in the future?]

10. What do you think the best option for the Salton Sea is?

11. Have you seen this option discussed? If not, why not?

12. Whose responsibility do you think it is to do something about the Salton Sea?

13. Why do you think the people responsible have been so slow to act?

14. Has this experience changed your opinion about our ability to solve environmental challenges, such as climate change?

Interview Guide

Climate intervention in the Arctic:
Integrating public engagement and climate model simulations

Background questions about your community and your views on climate change:

1. How long have you lived here? What is your role in this community?

2. How has the environment in this community changed over time?

3. How do you identify with the Arctic? Are you an Arctic resident?

4. How do you think climate change will affect the Arctic?

5. What are your main concerns about climate change? Which is most important to you?

6. What, if anything, do you think should be done about climate change? By whom?

Climate intervention questions:

7. Have you come across the topic of climate intervention, climate engineering, or geoengineering before?
If yes:

7a) Where have you heard about it?
7b) What do you think about it so far?

Even though you may have heard of climate intervention before, because many people might be unfamiliar with it, I'm going to back up and give a brief description about the type of climate intervention that I'd like to discuss today. This is so that everyone has the same information about it.

Some scientists have proposed using strategies to alter the climate on purpose, to counter climate change. They call these techniques "climate interventions." One type of intervention involves reducing the amount of sunlight that comes to the surface of the earth, so that the planet's surface is cooler. This is called "albedo modification". Other terms for it include "solar geoengineering" or "climate engineering". One example of albedo modification is injecting particles into the upper atmosphere using specially designed aircraft. These particles would block a small fraction of incoming sunlight. This would need to be done for several decades, perhaps indefinitely. Another example is using ships to create clouds at sea that would reflect incoming

sunlight. Today, we're going to focus on stratospheric particles. You can see this concept depicted in Figure 1.
Scientists researching these techniques have found that there is no substitute to reducing greenhouse gas emissions. All these climate interventions involve different types of risks. However, some scientists recommend increasing research into these techniques in case they might be helpful in the future.

I am not an advocate for or against these technologies. I am interested in learning what other people think about them.

8. What are your initial thoughts about climate intervention?

9. Do you think scientists should be researching climate intervention?

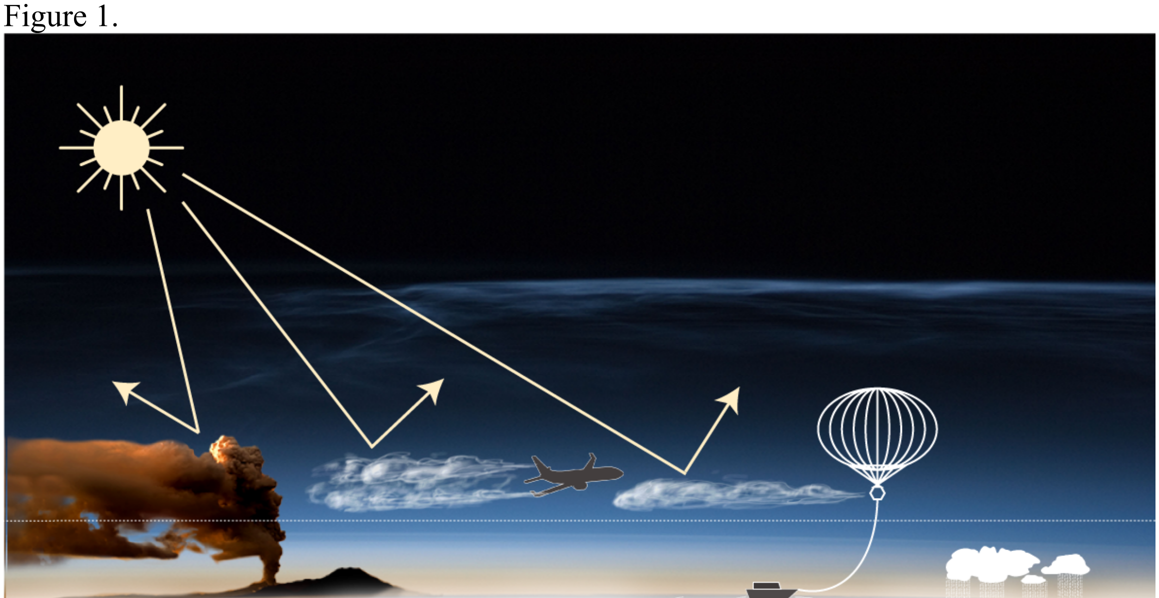
10. What are your main concerns about climate intervention?

11. Do you think climate intervention could change your community? If so, how?

12. How do you think citizens in the Arctic will feel about climate intervention? How do you think decision-makers in the Arctic will feel about climate intervention?

13. How should decisions about climate intervention be made?

Figure 1.



Particles in the upper atmosphere can block sunlight, which lowers the earth's temperature. Scientists learned this from studying volcanoes.

Some scientists suggest that humans could put particles there on purpose, using balloons or airplanes that can reach very high, in order to cool the planet.

Where would the particles go then?
They would remain high up in the stratosphere, above the rain clouds, and then fall to earth after a year or two.