Beyond Prediction: Climate Change Adaptation, Science & Technology Studies (STS), and Transformational Change

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Abstract

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Climate change adaptation is a priority for researchers, policymakers, and the public. Adaptation practices, however, have largely failed to keep pace with climate change risks and deliver the systemic changes required to reduce vulnerability. Critical scholarship has focused on conventional planning and decision-making processes to explain the inadequate and inequitable outcomes of adaptation. This thesis applies Science and Technology Studies (STS) theories as a complementary means of explaining such outcomes. Chapter 1 introduces the stakes of adaptation, the concerns brought by critical adaptation scholars, and the potential benefits of STS for advancing adaptation practice. Chapter 2 identifies four themes in STS through a literature review: representations, boundaries, politics and participation, and the future. These demonstrate how STS can enrich adaptation studies' explanations for why insufficient adaptation persists. Chapter 3 presents a case study that applies STS concepts to explain the structure and outcomes of a participatory adaptation planning initiative in Washington State's North Olympic Peninsula region. Key findings, drawn from twenty-six interviews with planning organizers and participants and an analysis of planning documents, illustrate how adaptation's meaning in practice was tied to its creation in broader social and institutional settings. The thesis synthesizes how STS can both benefit critical adaptation studies and advance the broader mission of effective adaptation.

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Chapter 1 - Introduction

The impacts of climate change have likely already introduced themselves to you but allow me to reiterate a current state of affairs. Floods and fires of unprecedented severity now strike with unsettling frequency (Corringham et al., 2022; Shi et al., 2022; Turco et al., 2023). Sea levels are ebbing higher (Graham et al., 2015; Tebaldi et al., 2021), air quality has declined across the U.S. (Schlanger, 2025), and the relief of cool nights in the summer is fleeting too (Denworth, 2025; Trent, 2022). These are the first glimpses of a new climatic regime, one in which even today's extremes will stand as the coolest years of the coming century (Hansen et al., 2025). While the biophysical signals of climate change are increasingly visible (IPCC, 2022), their meaning and consequences emerge through uneven interactions with social systems (Dahl et al., 2023; Ensor et al., 2019). This means that climate change impacts are not simply created or contained within the physical footprint of any disaster, nor is their level of harm measurable by the magnitude from which they deviate from climatic norms. Rather, climate impacts are equally products of existing vulnerabilities and uneven institutional responses (Ajibade, 2022; Nightingale et al., 2020; Ribot, 2011). Wildfires tear through regions already plagued by housing shortages, compounding displacement and prolonging recovery (Klein, 2007; Lambrou et al., 2025). Smoke and heat disproportionately burden those facing long-standing disparities in labor conditions, healthcare access, and environmental protection (Romanello et al., 2024). As a result, coping with and preparing for the impacts of climate change requires considering not only how to meet the risks created by a changing atmosphere, but how humanly-devised systems themselves *co-produce* climate risks (O'Brien et al., 2007; Webber, 2016).

Climate change adaptation describes actions taken to lessen the present and future impacts of climate change (Dahl et al., 2023; IPCC, 2023). Early climate change research and policy focused

on averting climate change through mitigation, as well as modeling how unmitigated climate change would unfold (Hulme, 2011; Pielke et al., 2007). While these remain paramount for responding to the climate crisis, adapting to the present and assured future impacts of climate change is now recognized as an equally vital response (U.S. Dept. of State 2024; UNEP, 2024). Amidst the ascendance of adaptation as a global concern and policy priority, what adaptation describes and requires is less certain. The diverse, inequitable, and emergent ways climate change is experienced are mirrored by the diverse ways adaptation transpires in practice (Orlove, 2022; Singh et al., 2022). In other words, while it is relatively easy to define adaptation as actions that mitigate climate risk and harm, a sweeping range of actions and policies could plausibly accomplish this aim (Berrang-Ford et al., 2021; Dupuis & Biesbroek, 2013). This is visible when comparing adaptation strategies that target hazard exposure and those that confront social systems and practices that themselves co-produce vulnerability to climate change.

Broadly, scholars distinguish between these two adaptation approaches as "incremental" and "transformational" adaptation (Dilling et al., 2023). Incremental interventions adjust, but ultimately preserve, existing socio-ecological systems through protective practices (Few et al., 2017; Leichenko & O'Brien, 2024). Common examples include hardened or protective infrastructure, early warning and forecast systems, and agricultural adjustments such as irrigation or crop selection (Pelling, 2010). Transformational adaptation is often defined as the fundamental changes to underlying social practices and socio-ecological systems that address the root causes of climate vulnerability (Pelling, 2010). These can include livelihood diversification, migration, improved social services, and changes to social practices and power relationships that govern rights and capabilities and engender uneven vulnerability (Few et al., 2017). These orientations

exist on a continuum, rather than a strict binary. Still, they reflect starkly different visions of what adaptation should achieve, how, and for whom (Leichenko & O'Brien, 2024; O'Brien et al., 2007).

Despite adaptation's potential interpretive flexibility, adaptation as practiced has leaned overwhelmingly towards incremental, hazard-focused interventions (Berrang-Ford et al., 2021; IPCC, 2023). Moreover, these prevalent forms of adaptation are frequently insufficient or ineffective in reducing vulnerabilities (Eriksen et al., 2021). Incremental interventions have been shown to be inequitable in their distribution of benefits and can overlook or even exacerbate social root causes of vulnerabilities (Shah et al., 2025). The emerging field of critical adaptation studies (Webber, 2016) interrogates how adaptation practices are shaped by historical, political, and social contexts and examines the omissions and consequences of predominantly incremental adaptation. Rather than taking adaptation as a self-evident good, critical adaptation studies interrogates how adaptation practices can reflect and reinforce durable social divisions and power relations in ways that both shape the resulting forms of adaptation in practice as well as stabilize social inequities (Klepp & Chavez-Rodriguez, 2018). Accordingly, work in the critical adaptation field often emphasizes transformational adaptation in response to both the scale of climatic disruptions and the interacting social and environmental causes of vulnerability (Taylor, 2014). This position is now widely accepted across mainstream climate research and policy (Dahl et al., 2023). The relative absence of transformational adaptation in spite of its acknowledged necessity raises critical questions for adaptation science and practice: *If transformational adaptation is crucial, why does adaptation so often take incremental forms?* And, *how can adaptation science and practice be amended to better serve transformations towards just and sustainable futures?*

This thesis explores these questions by drawing on insights from Science and Technology Studies (STS). STS is an interdisciplinary field concerned with the social construction of scientific

knowledge and the mutual shaping of science, technology, and society (Felt et al., 2016). STS provides analytical tools to examine how scientific practices and products, such as those of climate science and adaptation, are embedded within and take-up broader cultural, institutional, and political contexts—or as Jasanoff states "all the building blocks of what we term the *social*" (Jasanoff, 2004, pg. 3, italics original). Investigations in STS demonstrate how these social contexts go on to shape what emerges as authoritative knowledge and what questions science is motivated to ask (Law, 2023). However, in highlighting the social shaping of science and technology, STS does not discount the world-making potential of scientific or technological advances, nor does it reduce either's characteristics to being fully socially determined (Jasanoff, 2020; Livingston et al., 2024; Vervoort et al., 2015). Work in STS maintains a symmetrical approach: The epistemologies and ontologies of science shape and underwrite the social orders of our societies (Jasanoff, 2004). In sum, STS can be helpful in explaining *why* the practices and products of science manifest as they do, in part, by investigating science's co-emergence and evolution with the normative orders and expectations that structure society. This concept of social and scientific co-constitution is referred to as *co-production* (Jasanoff, 2004).

Work within STS has proven adept at explaining the co-production of climate change science and governance (Beck & Mahony, 2018; Jasanoff, 2010; Miller, 2004). Additionally, more recent works have used STS concepts to explain the formation and characteristics of adaptation as a creation between interwoven scientific and social principles (Beck et al., 2024; Beck & Forsyth, 2015). By bringing STS further into conversation with adaptation studies and extending this integration, this thesis demonstrates how the empirical and theoretical contributions of STS can advance explanations for the reproduction of inadequate adaptation regimes. I propose that STS, and specifically its description of science and society as *co-produced*, should be central to

investigating dominant adaptation practices. Such analysis can extend work in critical adaptation studies that assess the imprint of social contexts in the making of adaptation regimes.

STS: An Innovative Critical Lens for Adaptation

This thesis consists of two interrelated Chapters that bridge STS and adaptation studies. In Chapter 2, I introduce concepts in STS and review adaptation scholarship that has adopted them. Chapter 3 applies the analytical lens of co-production to an in-depth case study of adaptation planning in Washington State's Olympic Peninsula. Both Chapters 2 and 3 are informed by a foundational understanding of science and adaptation as deeply entangled in the political, institutional, and social structures of society (Beck et al., 2024; Jasanoff, 2015, 2016a, 2021a). This understanding is mirrored by the stance of critical adaptation studies, which itself documents how common forms of adaptation science, practice, and policymaking are liable to reproduce durable social orders and limit opportunities for transformational change (Chakraborty & Sherpa, 2021; Goldman et al., 2018). However, STS holds further potential through analyzing how contingent social frames and institutions become enrolled in the making of science and authoritative knowledge (Beck et al., 2017; Bremer & Meisch, 2017). In other words, assessing adaptation through the lens of co-production enables a more thorough accounting for the ways and means adaptation is constructed between epistemic and normative orders (Forsyth & McDermott, 2022; Haverkamp, 2021; Paprocki, 2018), whereas adaptation studies itself has largely focused on *the consequences* of particular resulting planning and decision-making arrangements (Bertana et al., 2022; Owen, 2020; Shah et al., 2025; Singh et al., 2022).

A co-productionist perspective on the emergence of a given adaptation arrangement reveals where adaptation's recurrent limitations—its technocratic style, incrementalism, and tendency to stabilize rather than transform—are not incidental failures or procedural missteps (Eriksen et al.,

2021; Ojha et al., 2016). Rather, they are symptomatic of how adaptation is constructed and produced as part of historically- and socially-specific sociotechnical arrangements (Nightingale et al., 2020). As such, STS does not simply add to the growing list of adaptation critiques. It offers frameworks to explain why dominant forms of adaptation are re-produced and persist, and points to sites and moments where leverage might be applied to interrupt and reconfigure these co-productive dynamics—a core focus of this thesis.

Thesis Structure and Chapter Overview

Chapter 2: *Four Heuristics from Science & Technology Studies to Deepen Critical Adaptation Studies*

Chapter 2 serves as a conceptual bridge between adaptation studies and STS. I identify four key themes relevant to both STS and adaptation research and practice: representations, scientific boundaries, politics and participation, and the future. For each, I discuss how STS and adaptation have engaged the topic, drawing on a literature review method. I close each subsection by discussing where the theories and analytical approaches of STS regarding each theme promise benefits to adaptation research.

Chapter 2 applies an interpretive approach common in STS to compare and synthesize topics of both STS and adaptation studies (Law, 2016; Schwartz-Shea & Yanow, 2013). Through close reading and synthesis of key theoretical contributions, I distill central positions and conceptions from each field regarding four topical domains to find separation between the two and to isolate where STS's positions may complement and contribute to those in adaptation studies. I draw from a broad base of literature from across STS and adaptation studies to make these contributions but did not employ any specific review inclusion or exclusion criteria. The method is not systematic

or empirical and instead represents an interpretive and synthetic account of the four themes from across the two fields.

In **representations,** I discuss the development of visuals, models, and "climate information services" (CIS) used to render climate futures legible and actionable for risk reduction efforts. Often positioned as neutral tools, STS approaches demonstrate how scientific representations encode particular assumptions, values, and political commitments (Coopmans et al., 2014). Adaptation scholarship can benefit from STS's approach to representations by understanding their constitutive functions in defining adaptation as particular arrangements, in addition to the descriptive roles they are more often conceived in. **Boundary work** covers how the definitions of adaptation practices and concepts are shaped by negotiations and strategic accommodations over the rightful boundaries of science and policy (Hulme, 2008; Jasanoff, 1987; Mahony, 2013). For example, concepts such as climate risk and vulnerability have shifted over time (Ford et al., 2018), evolving from earlier hazards-based framings to current, more contextual understandings. However, these conceptual shifts, and corresponding accommodations of the adaptation field, are argued to be limited by an enduring conception of nature and society as separate, which continues to privilege biophysical drivers of risk as predominant (Taylor, 2014; Thomas et al., 2019). **Politics and participation** engage with STS critiques of science's post-political and technocratic governance (Jasanoff, 2021b; Kenis & Mathijs, 2014; Swyngedouw, 2010). Participatory science is discussed as a key element in the co-production of a politics that sustain this post-political moment (Chilvers & Longhurst, 2016). While participation is often heralded as a democratizing force for adaptation, STS approaches reveal how it can operate within existing power structures that predefine *the who, what, and how* of engagement—allowing democratizing practices to serve dominant interests (Haverkamp, 2021; Mills-Novoa et al., 2020). Last, climate adaptation involves

creating more livable **futures** (Coulter et al., 2019; Leichenko & O'Brien, 2024). STS concepts and approaches support analyses of how dominant visions of the future are constructed, stabilized, and contested—complicating, but ultimately enriching, the adaptation field's drive to pursue transformation through alternative future visions (Beck & Mahony, 2017; Jasanoff & Kim, 2015).

STS is not presented as a prescriptive solution to treat the limitations of adaptation studies and practice. Further, I am not the first to draw connections between critical adaptation scholarship and STS (Baker et al., 2023; Beck et al., 2024; Haverkamp, 2021; Nightingale et al., 2020). This Chapter serves, instead, to provide motivation to take up the capabilities of STS in adaptation studies in service of exploring how and why incremental adaptation remains persistent.

Chapter 3: ***Beyond Prediction – A Case Study of the Olympic Peninsula***

Building on the theoretical foundations of Chapter 2, Chapter 3 applies the co-production concept as an analytical lens to a case study of a regional adaptation planning initiative in Washington State's Olympic Peninsula, U.S.A. Using a combination of document analysis and interviews, Chapter 3 investigates how a regional adaptation initiative's form and ambitions may be explained through the co-productive dynamics that pervade its conceptualization and methods.

Chapter 3 employs a single-site qualitative case study approach in examining regional adaptation planning on Washington's Olympic Peninsula (Yin, 2017). I incorporated data through analysis of two adaptation planning documents created in 2015 and 2022, along with twenty-six interviews conducted in July-November 2024. Interview subjects were all participants in the prior adaptation planning processes and included city and county staff, consultancy staff, and community stakeholders. I conducted a two-phase coding of my qualitative data, informed by the STS concepts

and approaches covered in Chapter 2, to trace the co-production of adaptation and ideas of achievable or desirable futures through the planning process (Saldaña, 2015).

Chapter 3 finds the regional adaptation initiative was constructed as a predictive and incremental exercise. I emphasize that this finding does not contend that this is an undesirable outcome, as the methods I employ were not designed to investigate the desirability or feasibility of the plan's outcomes or its alternatives. Instead, it describes the result of adaptation being co-produced through the normative social, political, and institutional contexts present in the case (Jasanoff, 2004). In other words, my aim is to explain why adaptation manifested as it did, given its many possible interpretations, using co-production as my primary analytical lens. I found that the planning process privileged governmental logics, apolitical interventions, and avoided confrontations with foundational social institutions. I describe the resulting adaptation arrangement as a "predictive" and incremental imaginary of adaptation, meaning that the conceptions of adaptation and adopted interventions observed in the case elect to preserve existing social arrangements into the future, rather than transform them. Specifically, this predictive imaginary was co-produced through three mechanisms. First, boundary work that excluded contentious topics like housing and migration. Second, the mainstreaming of adaptation within existing governmental routines. And third, the institutional shaping of adaptation knowledge and authority through legal regimes and other entrenched norms.

Chapter 3 moves to discussing a set of alternative sociotechnical imaginaries, shared future visions of connected social and technoscientific orders, that described some alternative adaptation pathways that were articulated by participants and adaptation planning documents (Sismondo, 2020). The alternative imaginaries each describe distinct forms and desires for adaptation and its role in delivering a desirable future. However, all three are alike in diverging from the prevailing

predictive imaginary that oriented the planning process and holds steady the social values, economic principles, and forms of community organization the alternative imaginaries describe as transformed. These include: an urbanizing vision emphasizing adaptation through affordable housing development, transportation, and a greater focus on equity and social vulnerability; an ecological vision centered on nature-based adaptation solutions and more-than-human values; and a regional resilience vision rooted in local food systems, energy independence, and communal forms of organization. Elements of the alternative imaginaries were raised in the planning process, in addition to emerging in my interviews, and are interwoven with broader regional narratives of change and desired futures. However, each was supplanted by the dominant predictive frame, a phenomenon I describe as the "closing down" of the future, drawing on previous scholarship (Andersson & Westholm, 2019; Muiderman et al., 2023; Stirling, 2008).

In detailing these dynamics, Chapter 3 demonstrates how the analytical tools and frames of STS like co-production and sociotechnical imaginaries, can be operationalized in empirical evaluations of adaptation planning. Moreover, using these tools uncovers critical contextual specificity as to how durable normative commitments and orders are actively enmeshed in adaptation and its sightlines for the future. The findings in Chapter 3 contribute to and advance a broader emerging literature in critical adaptation studies that shows how even well-intentioned and participatory adaptation initiatives are liable to reproduce dominant sociotechnical orders and incremental interventions, despite impulses for transformation (Andersson & Westholm, 2019; Forsyth & McDermott, 2022; Haverkamp, 2021; Shah et al., 2025). Further, the inclusion of alternative imaginaries within the Chapter's co-productionist analytical approach offers points of egress beyond critique for how future research and planning might surface and, critically, support more plural, just, and imaginative adaptation pathways (Latour, 2003).

Contributions and Implications

This thesis contributes to adaptation studies in several ways. First, it works to bring the explanatory insights of STS into adaptation studies scholarship more deliberately. A growing number of empirical and theoretical contributions in adaptation studies have drawn from STS through concepts such as co-production and imaginaries (Davoudi & Machen, 2022; de Jong et al., 2024; Kanarp et al., 2025; Lövbrand, 2011; Muñoz-Erickson et al., 2017). This thesis argues that further integration is warranted that expands on, diversifies, and deepens what crossover has occurred. In uniting STS and adaptation studies, the thesis moves beyond borrowing from STS as a new language for familiar critique to instead situate reviews of adaptation from the perspectives and commitments of STS and then demonstrates the potential value of doing so empirically. Second, I provide an empirical and contextually specific application of co-production as an analytical tool for evaluating adaptation initiatives. Co-production has been referenced elsewhere to describe the interactions of normative and epistemic cultures in the making of particular adaptation arrangements. However, the specific ways that co-production occurs and the elements of intertangled social and scientific life that instantiate co-production, are frequently "black-boxed," meaning studies often fixate on their consequences with less consideration for how co-production transpires (Eriksen et al., 2021; Mikulewicz, 2018a). Additionally, critical assessments of adaptation, such as those concerning its procedural or recognitional injustices, are often limited to the named practices of adaptation, despite the influence that broader epistemic and social orders exert on how adaptation is conceived and unfolds, a dynamic co-production is more adept at capturing (Jasanoff, 2004). By offering an accounting of co-production as a process, rather than solely as an outcome, Chapter 3 develops an approach to investigate just how the meaning of adaptation is made and negotiated in situ. Third, I triangulate between co-production,

sociotechnical imaginaries, and adaptation and climate futures work in my empirical analysis. Sociotechnical imaginaries have received increasingly scholarly attention and have spread across disciplines (Hendriks et al., 2025; Jasanoff & Simmet, 2021; Sovacool et al., 2020). However, this rapid adoption has resulted in some conceptual drift and a dissolution of the term's tight connections to co-production (Jasanoff & Simmet, 2021). In my analysis, I show how approaching imaginaries of adaptation through the co-production idiom can strengthen, rather than limit, the concept in applications to critical adaptation scholarship.

Looking forward, the integration of STS and adaptation studies of the kinds I describe and demonstrate points to new directions for research and practice across and between both disciplines. Adaptation poses a pressing, yet underdeveloped, area of study for STS scholars and their attention to the making of worlds between normative and epistemic orders. Similarly, adaptation science and practice will be asked to deliver desirable futures, beyond merely survivable ones, as climate impacts accelerate and emissions go unabated. The synthesis I push for demands and enables greater reflexivity by adaptation scholars and practitioners. This entails interrogating our own assumptions and practices, accounting for the performative and subjective dimensions of adaptation's favored methods, and work that fosters pluralistic, creative, and, where appropriate, contested engagements.

Chapter 2 - *Four Heuristics from Science & Technology Studies to Deepen Critical Adaptation Studies*

Introduction

Climate adaptation is now considered imperative across academic and public discourse (Wasley et al., 2023; Nalau & Verrall, 2021). At the same moment, adaptation sciences are at cross-roads, plagued by fundamental questions of adaptation's efficacy and a growing recognition for the field's inadequate successes (Berrang-Ford et al., 2021; Singh et al., 2022; UNEP, 2024). This juncture encourages more robust assessments of adaptation, their characteristics and their tendencies (Nightingale et al. 2020).

Critical scholars of adaptation detail the persistent shortcomings of formal adaptation practices, such as their inability to effect larger transformations, technocratic organization, and adaptation's often-inequitable and unjust outcomes (Cretney, 2014; Ensor et al., 2019; Mikulewicz, 2018b). The durability and distribution of these shortcomings begs for a renewed interrogation of adaptation to avert these same outcomes (Eriksen et al., 2021; Shah et al., 2025). Put differently, adaptation studies must ask: "*what is it about the technological, scientific, and social practices of adaptation, as it commonly occurs, that engenders and sustains insufficient or unjust forms of adaptation?"* This Chapter places recent research and critical perspectives in the adaptation field into conversation with Science and Technology Studies (STS) as a means of approaching such questions. It develops a case for STS as a promising reflexive frame for evaluations of adaptation and work towards its reimagination. This position amplifies that of a growing contingent of scholars arguing for critical reappraisals of adaptation as both a discipline and enterprise through the lens of STS (Goldman, 2013; Jasanoff 2010; O'Lear, 2016; Mikulewicz, 2019).

STS is an interdisciplinary field that examines the social nature and practices of science and technology, as well as how its endeavors yield knowledge and products that interact with and shape society (Felt et al., 2016; Hess & Sovacool, 2020; Jasanoff, 2016a). Considering science as a social process does not relegate science or facts to being fully relative, nor does it attempt to debase the importance of scientific work and institutions. Instead, by framing *science as social*, STS rejects the notion that science "done right" transcends the people, political systems, and places that produce it (Baker et al., 2023; Jasanoff, 2004). Stemming from this, STS does not work to undermine the phenomenon science describes but shows how means of knowing and describing occur through particular ways of measuring and representing (Konrad et al., 2016; Vertesi et al., 2019). Many empirical studies in STS do this in the context of particular cases, revealing the processes at work across the organization, production, and circulation of science and knowledge that enable or invite subjectivity into science's descriptions of the world (Klein et al., 2024; Loconto et al., 2024; Nost & Goldstein, 2022). Latour and Woolgar (1979) famously do this in their ethnographic study of a neuroscience lab, documenting the "social construction of scientific facts" as depicted in *Laboratory Life* (Latour et al., 1979). Such studies reveal that the methods and infrastructure which comprise scientific epistemologies are historically- and contextually-specific constructions, a central tenet of STS known as **constructivism** (Baker et al., 2023; Coulter, 2001; Latour, 2003; Lynch, 2016).

STS not only treats the forms and functions of science as socially produced; it also provides tools to explain *why* science manifests in particular practices, practitioners, and institutions. For example, the organization of Intergovernmental Panel on Climate Change (IPCC) and its role in shaping the subjects and issues of climate science and policy has received significant attention within STS (Jasanoff, 2010; Miller, 2004; Miller & Edwards, 2001; Wynne, 2010). STS scholars

have explored how the IPCC's design as an institution, its attempts to balance influence with perceived neutrality, and the composition of its contributors are historically and socially liable characteristics that result in a specific approach to climate change science and decision support (Miller, 2004, Miller & Edwards, 2001; Miguel et al., 2022). These characteristics are shown to influence what forms of knowledge the IPCC acknowledges and amplifies. For instance, the IPCC's historical privileging of modeled, global, and physical phenomenon in its assessments over lived experience or other forms of knowing socio-environmental change is explained as a byproduct of the institution's assemblage within and obligations to normative expectations regarding how climate change should be conceived and managed as an issue (Beck, 2011; O'Lear, 2016; Rubiano Rivadeneira & Carton, 2022).

Just as STS analyzes the creation and demarcation of scientific knowledge through its social practice, it also examines how the knowledge and material products of scientific and technological practice operate as powerful influences on broader societal structures. This includes exploring the ways scientific and technological endeavors can themselves produce or reify common conceptions of desirable arrangements for society (Jasanoff, 2004, 2016a; Laurent, 2024; Law, 2015). An example of this in STS scholarship traces the production of future visions in society. STS research describes how conceptions of technoscientific innovation and progress can underwrite and inform ideas of social progress, creating and strengthening narratives of what a promising future resembles (Beck & Forsyth, 2020; Jasanoff, 2020; Jasanoff & Kim, 2015; Landström & Soneryd, 2024; McNeil et al., 2015). While I single out these two broad lines of questioning—science and technology production and its interactions with society—to help introduce the STS field and its core concerns, they are deeply intertwined in practice. As I demonstrate, adaptation requires consideration of how the production of knowledge and its operation within broader society interact

and reinforce fundamental questions adaptation scientists are concerned with: Adaptation *to what* and *how*?

This Chapter's discussion of STS does not summarize the entire field. Instead, the many topics of STS are reduced to a core set that hold potential to contribute to research on the recurrent limitations of adaptation practices, such as its technocratic, de-politicized, and incremental manifestations (Eriksen et al., 2021; Eriksen et al., 2015). STS invites attention to the emergent arrangements of science and society to complement and extend these lines of questioning within adaptation studies. Borrowing and blending with STS's constructivist and reflexive capacities, as I do in my analysis, is not unwarranted. Indeed, STS is thoroughly "transdisciplinary" and has benefited other fields such as political ecology, environmental studies, and energy social sciences (Goldman et al., 2011; Hess & Sovacool, 2020; Sovacool et al., 2020). As Jasanoff (2016a) notes, reaping the benefits of STS only requires "the radical, critical move that asks, 'Why is it so, and must it be?'" (Jasanoff, 2016a, pg.236). I argue that turning this gaze on the common methods and debates of the climate adaptation field can help explain the persistence of deficient adaptation practices and inform more just and transformative alternatives.

This Chapter begins by introducing the constructivist perspective of STS and the central concept of **co-production** as a key lens for adaptation studies. Constructivism here means that scientific practices, such as prevalent forms of adaptation science and practice, owe their characteristics and tendencies to historical and social creation, rather than being inevitable or inherent traits. Co-production, in the STS sense, enables a deeper understanding for the ways resulting constructions of scientific knowledge parallels and mirrors the ordering of social life and the divisions of power in society. From there, I identify four salient themes where STS offers valuable insights for adaptation studies: (i) representations, (ii) boundaries, (iii) politics, depoliticization, and

participation, and (iv) the future. I use these themes to illustrate where and how STS can support reflexive evaluations and transformative futures for climate adaptation. I conclude by discussing methodological directions that link the insights of these themes.

Constructivism and Co-production

The co-production concept in STS is a powerful lens for exploring how contingent social and scientific orders are constructed together and become naturalized across science and society (Jasanoff, 2004). "Orders" refers to the combination of assumptions, preferences, institutions, and practices that give shape to scientific and social arrangements (Jasanoff, 2004; Laurent, 2024). Co-production emphasizes that science and technology influence social orders, just as social preferences reciprocally structure scientific knowledge and knowledge-making (Jasanoff & Kim, 2015). In this view, science and society are not just interrelated. They are mutually-constitutive, meaning that epistemic and normative representations of the world are produced together and are reinforcing (Miller & Wyborn, 2020; Simmet, 2025; Wyborn et al., 2019). This cyclical and symmetrical model for the construction of science and society echoes the broader position of STS: Science is neither fully relative and socially-determined, nor are the characteristics of science and its role in society "natural" or inherent (Jasanoff, 2004). Two key characteristics of co-production further enable its application to reflexive research in adaptation studies.

First, co-production is an "idiom," not a strict theory with rote methods (Jasanoff, 2004). Thus, co-production more serves as a general intellectual orientation for approaching the features of science and society as connected. In this spirit, co-production can serve as a flexible and more comprehensive foundation for examining and explaining adaptation regimes (Beck & Forsyth, 2015; Forsyth & McDermott, 2022; Nightingale et al., 2020). Co-productionist accounts can extend beyond the settings or topics of other evaluatory approaches, illuminating the role of

processes external to an adaptation initiative *per se* that nonetheless act on adaptation's interpretation and realization (Mahony, 2013; Mahony & Hulme, 2018). For example, the predominance of biophysical risk models informing early adaptation practices is linked to social preferences and habits for depicting and governing risk. Forsyth (2023) refers to this as the "constitutional role of risk," indicating that the operationalization of adaptation as a response to physical and globalized risks reinforces normative positions on what makes climate change impacts harmful, to who, and resulting proper forms of recourse (Beck et al., 2024; Forsyth, 2023). Specifically, STS research has shown how the attribution of climate risk to greenhouse gas emissions and resultant physical hazards both reflects and stabilizes the depiction of climate change as a global and atmospheric problem, aligning it with specific forms of expertise and institutional authority privileged to govern climate change (Beck, 2011; Beck & Oomen, 2021; Miller, 2004). Co-production's holistic and flexible coverage serves adaptation studies by opening a broader swath of venues, actors, and topics to consider as influential in the defining and making of adaptation in practice.

Second, co-production symmetrically assesses how social and scientific orders converge. This means that co-production not only accounts for the ways social elements are embedded in science, but how science's adoption and performance of normative frames help produce society (Bremer & Meisch, 2017; Honeybun-Arnolda et al., 2024). Fundamentally, co-production can serve the adaptation field by drawing attention to the ways normative assumptions and institutional structures shape what adaptation becomes and the ways adaptation, in turn, comes to advance these in the knowledge and products it produces.

The term co-production has also been taken up in adaptation and sustainability science, often in its instrumental meaning. In this usage, it describes a method of engaging stakeholders,

collaborating with users or decisionmakers, or increasing the relevance of scientific outputs (Wyborn et al., 2019). This "instrumental" co-production emphasizes participatory science to produce more usable and relevant information and scientific products (Dilling & Lemos, 2011; Norström et al., 2020). In contrast, the analytical co-production of STS is not a method for intentionally generating agreeable knowledge but a lens to *explain* how knowledge, power, and social recognition are made together (Jasanoff, 2004). Co-production serves as the theoretical backbone for the themes and topics spanning adaptation and STS in this Chapter. While I introduce additional STS concepts in each of the four topical sections of this piece, these should be seen as building upon the perspective of co-production and its advances for inquiries into adaptation.

Representations

Representations and visualizations are central to the science and practice of climate adaptation (Mahony & Hulme, 2016; Morseletto, 2017; O'Neill & Smith, 2014). Maps, models, and interactive platforms detailing future climate conditions are common products of research that inform adaptation practice (Davoudi & Machen, 2022; Porter & Demeritt, 2012). Moreover, representations in adaptation science are often intended to influence the behavior of information users beyond relaying a study's findings (Findlater et al., 2021; Nost, 2024; Palutikof et al., 2019). Products such as local sea level rise maps and seasonal agricultural forecasts reflect outputs from climate models and observational data curated to the geographies and timescales that enable them to inform adaptation decision-making (Donatti et al., 2017; Herring et al., 2017; Tall et al., 2018). As part of presenting information in this way, representations also adopt and serve normative interpretations. The informational products of adaptation science reflect subjective conceptions of what makes information relevant, credible, or useful, and critically, what problems, risks, or solution pathways warrant consideration (Addor & Melsen, 2019; Babel et al., 2019; McLaren &

Markusson, 2020; Rubiano Rivadeneira & Carton, 2022). To that effect, representations amplify particular interpretations of what adaptation itself is responding to, what it should provide, and to whom, through the phenomenon and users they target. These are not foreign concepts to the adaptation sciences—numerous studies have uncovered the heuristic and accommodating processes through which modeling products and visualizations are developed in line with particular normative frames (Findlater et al., 2021; Mahony, 2012, 2016; Wardekker & Lorenz, 2019). However, parallel approaches in STS that deconstruct scientific representations as a practice and product can contribute to this research and aid in critical reflections of adaptation science. STS complements existing research by exploring and explaining *how* and *why* particular normative frames become constituted within visuals, models and adaptation decision aids (Movik et al., 2021). Research on the development of climate information services (CIS) and models illustrate this and hint at the potential benefits of more sustained integration.

The adaptation field has increasingly sought to develop information that aids the public in weathering acute shocks as well as informs long-term adaptive decision making (IPCC, 2023; Johansson et al., 2017). CIS are a prominent form of user-oriented representations in the adaptation field made for this purpose (Palutikof et al., 2019; Wong-Parodi et al., 2020). CIS range widely in style, scope, and intended application, but share generally recognized traits—notably their decision- or context-specific and translational presentation of information, and their collaborative design (Boon et al., 2022; Carr, 2023). CIS contextualize climate information such as global temperature or hydrological models to make their insights more applicable to decision-making by presenting it scales and in formats relevant and accessible for decision-making (Bremer et al., 2019). Additionally, CIS commonly integrate information regarding the compounding and contextual factors that moderate or intensify climate impacts or motivate one set of interventions

over another (Carr, 2023; Carr et al., 2020). This commonly includes pairing biophysical data with other information like demographic data or critical infrastructure locations. Climate services are also commonly defined as being products of co-production (Vaughan & Dessai, 2014; Vincent et al., 2018). In this case, co-production refers to the instrumental strand of co-production. Intentionally co-producing CIS is seen as increasing the salience and credibility of these platforms by leveraging collaboration to guide the tailoring and presentation of information (Boon et al., 2022; Lempert et al., 2023).

Despite the democratic prospects of CIS, development and implementation of these tools is prone to tracking with existing power dynamics and conceptualizations of climate risk and response. In other words, platforms and procedures used to develop them are also inevitably products of normative-epistemic co-production that can stabilize existing societal biases and assumptions. The purpose and nature of adaptation in a given context is subjective and value-laden, making the particular framing of adaptation captured within a CIS platform, via the geographies, scenarios, interventions, or futures it reflects, prone to empowering specific perspectives at the expense of others (Webber, 2019; Mahony & Hulme, 2016). Gerlak and Greene (2019) provide a pointed example of this, finding that the Global Framework for Climate Service (GFCS) largely omits dynamic and relational understandings of vulnerability in its guidance, hewing instead to a spatially-coarse and exposure-related framing of vulnerability (Gerlak & Greene, 2019). The authors hypothesize that the predominance of meteorologists and physical scientists that lead the GFCS may have led to the observed presentation of vulnerability (Gerlak & Greene, 2019).

Climate services, and representations used in adaptation more broadly, are also susceptible to obscuring the presence of multiple or even conflicting framings of hazard and adaptation within the context they are developed and applied (Webber et al. 2017; Carr, 2023). In these cases, what

information is relayed could be factually accurate and relevant to a subset of stakeholders while remaining inapplicable to the adaptation interventions envisioned by or accessible to marginalized stakeholder groups (Biella et al., 2024; Tall et al., 2018). These limitations result in CIS that can fail to live up to their defining characteristics of decision relevance, context-specificity, and collaborative origins (Carr 2023; Boon et al. 2022; Herrick et al 2021).

The common pitfalls of CIS are considered by researchers and practitioners operating in this space (Boon et al., 2021; Carr, 2023). Mainstream critiques of CIS tend to treat these shortcomings as procedural deficits: failures to sufficiently involve users, accurately tailor information, or ensure a product's contextual relevance (Tall et al., 2018; Vaughan & Dessai, 2014; Wall et al., 2017). In essence, mainstream positions call for better processes of co-production in the instrumental sense while maintaining the value of CIS as a means of assembling and disseminating knowledge (Vincent et al., 2018). However, this risks treating CIS and its representations as neutral vessels of information. STS scholarship complicates this view by treating the creation and application of representations as socially and politically consequential acts (Klein et al., 2024; Mahony, 2012, 2016; Nabavi, 2025). From this vantage point, CIS are more than a means of information conveyance; they are artifacts that bear and stabilize particular conceptions of who adapts, to what, and how (Gerlak & Greene, 2019; Nost, 2019; Webber, 2019). STS theories on the constitutive and performative nature of representations thus offer a complementary perspective on the creation and function of CIS platforms that may serve the adaptation field in its mission of advancing adaptation and equitable vulnerability reduction (Coopmans et al., 2014; Lynch & Woolgar, 1990).

STS scholarship traces the performative role of representations, meaning that the act of curating and circulating representations does not simply describe phenomena but participates in creating them and solidifying their meaning. In this view, what is represented and how it is represented are

inseparable from the social, political, and epistemic orders that give those representations meaning and authority. For example, representations like circulation models and global emissions scenarios have helped render the climate as an object primarily visible, knowable, and governable at global scales. This scaling effect is a product of co-production with prevailing governmental and scientific practices that privileges a certain problem definition and governance approach to climate change over alternatives (Beck et al., 2017, 2024; Jasanoff, 2010; Miller, 2004). STS scholars argue that the global–physical framing of climate change, underwritten by global and physical representations, supports technical descriptions and solutions such as emissions accounting, and geoengineering, while marginalizing approaches centered on justice or contextual and relational vulnerability (Forsyth, 2023). In this way, representations are not simply tools of description or decision-making; they help constitute and define the problems they are meant to inform (Konrad et al., 2024; Matzner, 2016; Nabavi, 2025). Applied to CIS and modeling, this perspective invites us to scrutinize not only the procedural development and decision-relevance of user-oriented representations, but the ways in which these also co-produce and stabilize identities (such as users), modes of governance, and particular conceptions of adaptation and risk. STS's analytical perspective on representations problematizes the very questions and collaborations through which representations emerge, moving to ask why certain represented phenomena and questions have come to signify problems and adaptation options while others may exist off-screen. For example, Nost's (2019) case study of sea level rise and erosion modeling on the Gulf Coast of Louisiana showed how decision-oriented modeling efforts and a "data-first" approach to adaptation present an air of objectivity, yet invited political and social contestation as to whose data and whose future's get modeled and recognized (Nost, 2019; Nost & Goldstein, 2022). Nost draws on STS approaches to reveal how "data-driven" environmental governance presents representations as

objective windows into the future while masking the tuning of models and metrics and the selective nature of what data is even created in ways the yield "winners and losers" (Nost, 2022). In one example, Nost finds that sedimentation models used in Louisiana's coastal adaptation planning assume the continuity and protection of oil and gas production when ranking land restoration priorities and modeling potential future coastlines. Nost contends that this representational approach stabilizes existing economic and state priorities and relations in the co-produced models of environmental processes, closing down transformational adaptation pathways that may seek to move away from tenuous and extractive industries by leaving such possibilities unrepresented (Stirling 2008; Muiderman et al., 2023).

CIS are just one specific, albeit highly relevant, form of representation that appears in adaptation studies and practice. A broader swath of modeling tools used to describe and predict biophysical processes and future scenarios are put to work across the adaptation field. Accordingly, critical approaches to models and model-making that draw on STS approaches to scientific representation are another rich area of scholarship that can benefit adaptation studies (ter Horst et al., 2024). Much of this research delves into the ways inevitable interactions between science and normative social structures impacts the production of models, rather than dissecting the technical uncertainties of different modeled outputs (Melsen, 2022). To be sure, choices in methodology and subject matter have profound effects on the certainty or subject of modeled outcomes, but the role in applying an STS perspective here is more geared towards explaining *why* certain methodological modeling choices may get made (Addor & Melsen, 2019). For example, Melsen et al. (2019), show that seemingly technical modeling choices such as spatial resolution, calibration period, and performance metrics influence hydrological models simulated outcomes of floods. These choices, although often presented as technical parameters, are connected by the author to

the normative and heuristic preferences of modeling teams. The study calls attention to the modeler's role in shaping outcomes through subjective configuration, reinforcing STS positions that representations do not simply reveal "nature" but actively *produce* it (Khosrowi, 2023; Melsen et al., 2019).

STS approaches help in revealing where representations serve in the *production* of adaptation knowledge and practice beyond simply reflecting it. Moreover, the co-production of representations with society's normative foundations yields scientific products that uphold existing power and political structures by tacitly embedding and naturalizing their presence in representations. As the above examples begin to illustrate, the outcomes of this co-productive process should be expected to tilt unevenly towards prevailing conceptions of adaptation and the privileging of existing forms of organizing and governing the climate crisis. A central contribution of STS is thus revealing that what is represented of adaptation is a historically and socially specific outcome, and marks only one possible configuration and vantage point, recalling the constructivist orientation of the field introduced earlier (Haraway, 1988; Jasanoff, 2017). Further, STS is helpful in asking and explaining why possible alternatives go unrepresented and the political and social motivations that lead to the separation of these outcomes. Hess (2016) and Frickel et al. (2010) call this "undone science" (Frickel et al., 2010; Hess, 2016). Applying this to adaptation, representations risk "closing-down" transformational adaptation by way of representing and representations that hold steady prevailing normative commitments and expectations (Stirling, 2008). A reflexive orientation toward representing in adaptation prompts practitioners and scholars to interrogate the normative dimensions representations inherit and co-produce. For example, whose futures and what knowledge is mobilized when models or CIS are produced? As Nost demonstrates, even where a collaborative project is responsive to stakeholders and their

informational needs, such questions still raise important considerations regarding what is assumed and what is made operable. STS reorients the topics of efficacy for models or decision tools from those of accuracy and usability to questions of recognition and ontology.

Boundaries

What is adaptation? This may at first appear to be an innocuous question, if not purely semantic. But upon closer inspection, the boundaries of the adaptation field, and the forms of expertise and interventions that get included in it, are found to be contingent and contested (O'Brien et al., 2007). Pausing on this question begins to reveal the ways political, institutional, and epistemic orders converge to shape the meanings and the practices of adaptation. This means that what *is* and, importantly, *isn't* adaptation, hinges as much on the beliefs and commitments of those posing the question than on any natural qualities of certain information or actions, making the contours of adaptation itself a product of epistemic-normative co-production (Ribot, 2011). On this topic, the concepts of STS offer valuable tools for unpacking how concepts and fields are produced, stabilized, and contested, and the practical and material implications of adaptation being defined in particular ways. By approaching the definition and borders of adaptation and adaptation science as co-produced or emerging through interactions between scientific practice and social institutions and values, STS helps reveal why certain interpretations of adaptation take hold and how the setting of definitional boundaries influences the scope of adaptation's possibilities.

Raising the fluidity of adaptation in concept is not to say that specific acts and initiatives cannot be or are not labeled as adaptation, or that such initiatives are not credible or beneficial. Nevertheless, the adaptation field hosts multiple positions as to what should be included under its umbrella (O'Brien et al., 2007; Orlove, 2022). Different conceptual approaches to adaptation harbor distinct problem framings and objectives, resulting in diverging positions on what should

prompt adaptation and the proper resulting forms of response (Orlove, 2022; Popke et al., 2016; Ribot, 2011; Rodina, 2019). This is apparent when contrasting the demands of incremental and transformational approaches to adaptation and their material and practical manifestations. While the former focuses on understanding biophysical impacts and reducing exposures, the latter enrolls the diverse causes of inequitable vulnerability in society as adaptation's primary concern (Few et al., 2017; Shi & Moser, 2021; O'Brien et al., 2007). As a result, "adapting" to similar hazards could look radically different depending on the ways adaptation and vulnerability are bounded.

The question of boundaries in and of adaptation has not been neglected by mainstream adaptation research, nor have the potential contributions of STS in this space gone unrecognized (Cretney, 2014; Eriksen et al., 2015; Shockley, 2023). Still, the debates over what constitutes adaptation, and the tools to recognize different definitions in the making, remains a topic of continued relevance that stands to benefit from greater integration with STS. Where adaptation studies identifies and problematizes categories and concepts such as vulnerability, subjects, and relevant knowledge (Goldman, 2003; Mikulewicz, 2020; Mills-Novoa et al., 2020), STS provides language as to how and why these concepts emerge through the co-production of adaptation and adaptation science with society. The concept of boundary work in STS describes the subjective means by which the topics of science, and their separation from non-science, come to be defined and ordered as they are (Gieryn, 1983; Jasanoff, 1987; Lamont & Molnár, 2002). Demonstrated below, demarcations over the assigned meanings and assumed functions of adaptation reflect the "boundary work" processes that STS scholarship has proven adept at surfacing and explicating.

The concept of boundary work in STS originated to describe efforts to maintain science's distinct and privileged epistemology and hierarchical position in relation to policy creation (Beck & Mahony, 2018; Gieryn, 1983, 1999). Boundary work emphasizes the *efforts* to render science and

its practices as distinct and authoritative, finding that the distinctions between science and its authority from "non-science" only occur through cultural (re)negotiations (Mahony, 2013; Wiegleb & Bruns, 2023). STS scholarship considers the divisions between science and other epistemic practices as culturally produced and performative, shifting focus to how and why contingent divisions are drawn, defended, or modified (Gieryn, 1995; Lamont & Molnár, 2002). Distinctions of authoritative knowledge and knowledge-holders in epistemic practice are frequently covered. Such distinctions are shown to be important processes in the creation and stabilization of categories and identities, rather than simply recognizing them (Gieryn, 1999; Jasanoff et al., 1995; Maas et al., 2022). Gieryn (1999) uses "cultural cartography" to describe this process holistically. Boundary work carves out and solidifies the cultural space occupied by science and the features or objectives assigned to it, inverting the assumption of particular modes of knowledge production as inherently scientific.

Boundary work occurs through a number of explicit and implicit pathways, including formal rules of membership, as with an expert organization like the IPCC, as well as processes of assembling evidence and scientific review (Beck et al., 2017; Chilvers & Kearnes, 2020; Lövbrand et al., 2015; Miller, 2008). Boundary work is also visible in the behavioral and design tendencies of scientific practice, such as the durable gender and racial biases in science and the making of distinctions around expertise and Indigenous knowledge (Mar Pereira, 2019). For example, Wiegleb and Burns (2023) elucidate how boundary work influenced knowledge production by the IPBES, an international biodiversity body similar to the IPCC. The selection of participants and uneven geographic composition of member states solidified north-south and scientific-local divisions (Wiegleb & Bruns, 2023). The authors argue that despite explicit attempts to open up the epistemic

practices of the IPBES, boundary work tacitly reproduced status quo assumptions of what makes for authoritative knowledge (Wiegleb & Bruns, 2023).

The boundaries of and within science emerge from cultural and place-specific histories and through an alignment with other forms of social ordering and expectations. Stemming from this, while boundary work contends that prevailing perceptions of what science is, what makes knowledge authoritative, or who holds expertise are not innate categories, they are not infinitely or immediately pliable either (Irwin, 2008; Gieryn, 1999). These distinctions in science mirror durable social orders and systems of governance, recalling the co-production of science and society (Jasanoff, 2004, 1987). Accordingly, a boundary work approach can aid adaptation study's ability to see not only that different definitions are conceivable or desirable, but where the prevailing definitions that characterize the adaptation field result from their congruence with powerful normative structures, and thus why these contingent boundaries remain stable as a result despite impulses for change.

For the adaptation field, boundary work provides a reflexive lens to reconsider the inherited and assumed divisions that denote adaptation from other endeavors, as well as those that isolate topics of the field, such as risk and vulnerability, from the embodied ways they are experienced. Divisions over the meaning of vulnerability, and the resulting obligations of the adaptation field through its commitment to vulnerability reduction, are one such area. Vulnerability is a central concept within climate adaptation, generally describing a "susceptibility to harm" (Ford et al., 2018, pg. 190). Climate adaptation often seeks to reduce vulnerability, inextricably linking the two concepts (Adger, 2006; IPCC, 2023). Yet, what creates climate vulnerability, and consequently, what

adaptation might act on, is contested, with significant implications for the realization of adaptation in research, policy, and material interventions as indicated above.[1]

Early research in climate adaptation emphasized the role of exposure, a framing that continues in many current adaptation policies and practices (Beck, 2011; Berrang-Ford et al., 2021). This interpretation links climate vulnerability expressly to the risks posed by external hazards (Burton, 1993; Cutter, 2006; Dessai et al., 2009). STS scholarship on the construction and co-productive dynamics that shaped the IPCC's agenda link its early hazards-focused or "end-point" vulnerability framing to the predominate "definitional power" of the physical sciences in shaping climate change study (Mahony, 2013; O'Brien et al., 2007). In contrast, critical scholars and work in adjacent fields have long moved to define vulnerability as a structural and relational context in which social, economic, and political systems shape how and why communities experience climatic risks (Kehler & Birchall, 2021; Ribot, 2011; Taylor et al., 2025). Over time, mainstream positions, such as the definition provided in the IPCCs Assessment Reports (ARs), have incorporated social-contextual framings of vulnerability relative to earlier hazard-exposure based models (Ford et al., 2018). In doing so, the boundaries of what constitutes adaptation science expanded through new epistemological and ontological positions that were previously proscribed from formal scientific work. For example, O'Brien et al. (2007) notes how contextual framings of vulnerability "set much wider boundaries around the issue of climate change" by requiring a more holistic assessment of the factors and interactions that produce vulnerability (Beck, 2011; O'Brien et al., 2007, pg. 76). As such, the debates and shifting meanings of vulnerability consequentially

[1] Unpacking the literature on the uses of vulnerability in adaptation is beyond the scope of this Chapter. I instead focus on a single, central, distinction regarding the origins and predispositions of climate vulnerability to demonstrate how the broader contours of the adaptation field are subject to accommodation and remaking.

redraw the boundaries of adaptation science by broadening the scope of knowledge, phenomenon, and experiences it deems credible and relevant. One needs only to compare the methodologies, data points, and disciplines of studies adopting these diverging perspectives on vulnerability to appreciate how its shifting definition within adaptation have also entailed epistemic and ontological expansion and revision (Cretney et al., 2025; O'Brien et al., 2007). Implementation of these contextual framings of vulnerability is incomplete, in part because of the imprint of the durable boundaries in the current organization of climate science and policy (Kehler & Birchall, 2021; Mikulewicz, 2018a; Weatherill, 2025). Nevertheless, this ongoing shift serves as a salient example to show the boundaries of adaptation as contested, fluid, and an important subject of inquiry unto themselves. Where the example of vulnerability helps to establish the contingency of operating adaptation definitions, applying the concept of boundary work to the traits of adaptation that remain rigid and examining the reasons and repercussions of this may prove to be of even greater service to the adaptation field.

The adoption of contextual framings of vulnerability within the adaptation field exhibits the *potential* fluidity of science-nonscience and intra-field boundaries. Yet, revisions to the vulnerability framings that organize and motivate climate adaptation have not yielded broad transformations in enacted forms of adaptation, nor has this shift significantly altered the occurrence of inequitable vulnerability globally (Berrang-Ford et al., 2021; UNEP, 2024). Nightingale et al. (2020) note how the risk framings in planning and adaptation practices continue to support technical interventions, despite decades of research pointing to the critical role of contextual and political-economic factors in climate risk and vulnerability (Nightingale et al., 2020a; Steig & Oels, 2025). This is the case even where risk framings appeal to both biophysical and contextual drivers of vulnerability and risk (Taylor, 2014). Nightingale et al. (2020) among

other authors, contend that this is due to a more fundamental and durable division that maintains society and environments as separate entities (Latour, 1993). Scholars working across adaptation and STS have raised the ontological division of climate from society as a continued source of maladaptive practices, and one that is similarly reproduced through practices of boundary drawing and their defense (Goldman, 2021; Goldman et al., 2011; Taylor, 2014).

The nature-society divide is not unique to adaptation, having served as a central axis throughout Western cultural and scientific traditions (Latour, 1993; Cronon, 1995). The appearance of this dualism in adaptation echoes the mutual and cyclical making of science and society that co-production describes. Meaning, the treatment of separate cultural and natural domains in broader society is stabilized by the ways science orders the world and separates the two domains (Lahsen, 2023; Jasanoff, 2010, 2015). STS scholars have long problematized this bifurcation, arguing that nature and society are not separate interacting entities but are instead locally co-produced "socio-natures" (Haraway, 2013; Barad, 2007; Jasanoff, 2010; Latour, 1993; Nightingale et al., 2020). The development of a dualistic operationalization of climatic pressures as exogenous *natural* forces that impact vulnerable *social* systems is symptomatic of boundary work that produced climate and adaptation fields which consider climate as "average weather" rather than climate as experienced (Hulme, 2008, 2011; Law, 2023). This persistent framing of separate interacting systems is continuously reproduced through the organization and treatment of climate change research into durable categories that abstract from the origins and experiences of social vulnerabilities *and* hazards as locally and socially co-produced (Shah et al., 2024; Taylor, 2014). The result is the familiar depiction of unique environmental and social pressures influencing vulnerability in society (Blaikie, 1994), rather than an understanding of these as co-emergent (Nightingale et al., 2020; Taylor, 2014). This has substantial implications for the field's

conceptualization of how vulnerability manifests and adaptation's attendant solutions. Even where social vulnerability framings are adopted, interventions often revert to managing exposure to external hazards, rather than recognizing how socio-environmental processes co-produce both hazards and harm (Haverkamp, 2021; Nightingale et al., 2020).

Examples from scholarship at the intersection of STS and adaptation demonstrate the ramifications of this persistent boundary. Taylor (2021, 2023) provides an example from agriculturalists in India. Taylor notes how state-led resilience initiatives targeting socially vulnerable smallholder farmers maintained adaptation as a set of responses to external climate risks (Taylor, 2023; Taylor & Bhasme, 2021). The initiative recognized the importance of social vulnerability in the distribution of adaptation resources but failed to incorporate a grounded understanding for how vulnerabilities and hazards are *co-produced*. Taylor (2023) describes the interwoven social and natural production of vulnerability, stating:

> *"A withered crop manifests itself in increased indebtedness that results in an inability to upgrade irrigation infrastructures which in turn means that farmers must pay one third of their harvest to more affluent farmers who can pump in crop sustaining waters"* (Taylor, 2023, pg. 211).

Taylor's work demonstrates how the interactions of climate pressures with social dynamics and restricted capabilities co-produce hazards and uneven vulnerability. In other words, what these farmers experience as climate and climate hazards are co-productions of natural and social forces, making the interventions that cast vulnerability as a *quality* rather than a *creation* ill-equipped to deliver meaningful reductions in vulnerability. This echoes Ribot's (2011) call for vulnerability *before* adaptation, which brings to the fore the creation of hazards with vulnerability, rather than the presumed linear chain with climate hazards being the first domino (Ribot, 2011). Forsyth and

McDermott (2022) provide a similar example of insufficient and maladaptive outcomes resulting from dichotomous conceptualizations of natural and social spheres. The authors find that adaptation programs struggle to break free from a binary focus on the direct impacts of natural hazards that trickle down from rising atmospheric emissions and global scale processes of climatic change (Forsyth & McDermott, 2022). Adaptation was designed in accordance with this legacy of bracketing social and environmental processes and pressures, despite their co-constitutive nature on the ground. In both examples, the authors engage with STS to imagine forms of adaptation science and practice liberated from the "technical trap" that currently characterizes the adaptation field (Nightingale et al., 2020).

Ribot (2020, 2021) provides an additional example that demonstrates the melding of boundary drawing as an epistemic exercise with its political and socially constitutive powers. Ribot finds the categorization and popular conceptions of climate migrants exhibits the same natural-cultural divide commonly seen across adaptation policy and research (Cottier et al., 2022; Lahsen & Ribot, 2022; Ribot et al., 2020). This term is often used in a way that suggests there are discrete, climate-induced, causes for human mobility. However, as Ribot and co-authors emphasize, decisions to migrate emerge from complex entanglements of social, economic, political, and environmental factors. In an example of migration from the Sahel, the authors find that the dominant description of drought-driven migration hides the reality of drought as an emergent condition of social and natural origins. In other words, lack of rain and lack of political recognition, access to alternative livelihoods, and coping measures all coproduce water insecurity. The boundary-making that casts certain migrants as "climate migrants" isolates the environmental drivers from their culturally entangled production and effectively naturalizes the other drivers that push migrants to seek relocation such as poverty and persecution (Lahsen & Ribot, 2022). Critically, Ribot shows how

boundary-making focuses attention on narrow technocratic responses to the climatic drivers of migration and away from transformational interventions that address migration's interwoven social and environmental causes.

In short, these authors apply STS's close attention to epistemic boundary work to reveal the ways dominant adaptation practices respond to climate and society as separate entities, obscuring their mutual emergence and influencing adaptation responses as a result. Redressing this requires building adaptation practices up from the experiential, partial, and local ways climate is produced, simultaneously breaching a durable division in the conceptualization of the climate change problem (Haraway, 1988; Jasanoff, 2017, 2021a).

Boundary work invites reflexive examination within the adaptation field for how and why certain definitions of adaptation persist and what social arrangements they stabilize. In this light, the durability of the nature-society boundary is not merely a vestige, but a construct of historic and recurring power relations, epistemic practices, and institutional priorities at play in what counts as science and what adaptation should be accountable to (Gieryn, 1999; Hulme, 2008). Distinguishing the climate from the ways nature is experienced and enacted protects a bifurcation in the treatment of climate change and climate risk from engaging the *co-production of vulnerability in society.* This means that boundary work not only demarcates the domains of science and its conceptual territories, but it also underwrites the typical technocratic organization and political engagement of these same topics, recalling the cooperative functions of boundary work to legitimize political action (Beck & Mahony, 2018; Garud et al., 2014; Huitema & Turnhout, 2009). By stabilizing the notion of climate hazards as external natural phenomena, adaptation science is complicit in narrowing opportunities for political contestation, restricted to the ways in which hazards inflict disproportionate harms, rather than more transformative engagements that consider how current

social arrangements themselves co-produce harms and hazards (Nightingale et al., 2020; Pelling 2011; Taylor 2015). This reinvigorates the opening question of "what is adaptation" for the field, placing emphasis on how the boundaries that contain adaptation are actively drawn and stabilized to resist more holistic answers.

Politics and Participation

The previous section discussed the ways in which active processes of boundary work order, and in some cases, constrain, the concerns of adaptation science and practice. Yet, I only allude to the contested and consequential boundaries between politics and adaptation. There is a rich literature devoted to politics in STS, which is considered in this section. STS does not present one streamlined definition of politics, as I discuss below. For the purposes of this entry, I refer to *politics* as the formal and institutionalized social management practices through which prevailing normative orders and power relations are enacted and maintained (Mikulewicz, 2018a; Swyngedouw, 2011). Whereas *the political* encompasses the ever-present, yet more diffuse, articulations of antagonism and discontent that prohibit any stable state for society (Swyngedouw, 2013). This definition of politics covers only those more formal actions and arenas that produce societal orders, but it equally enables acknowledging the imprint of politics well beyond these arenas, particularly their extension to epistemic practices.

Politics appear throughout the adaptation literature and is regarded as key to the creation of adaptation policies and material interventions (Mikulewicz, 2018b; Nightingale, 2017; Nightingale et al., 2022; Turnhout et al., 2020). However, discussion of politics in adaptation science has often treated the two domains as essentially distinct, conveying the belief that good science yields good policy (Beck, 2011; Beck & Mahony, 2018; Maas et al., 2022). Even where more recent maneuvers within adaptation science have moved to acknowledge policy-making and

politics as essential to achieving adaptation, this is often achieved through attempts to make science more legible or readily applicable to policymakers, as with the use of instrumental co-production (Bandola-Gill et al., 2023; Dolšak & Prakash, 2018; Turnhout et al., 2020). Critical scholars have pushed back against this framing, which casts politics and policymakers as consumers of science downstream of the making of knowledge (Beck et al., 2017; Miller & Edwards, 2001; Muñoz-Erickson, 2014). Work in critical adaptation studies contends that the very making of adaptation's subjects and objects and the resulting distribution of capabilities in society are as much artifacts of politics over whose and what issues gain recognition as they are a consequence of biophysical phenomena (Jasanoff, 2012a; Kanarp et al., 2025; Mikulewicz, 2018a; Nightingale, 2017). Similarly, STS's co-productionist perspective maintains that the ways science describes and orders the world are inseparable from the ways society desires it to be, with politics being foundational to the construction of any desired social order. Bringing STS's analytical tools into adaptation studies' recognition of politics and political power enables a more fine-grained accounting of how politics and political debate operate within and mediate adaptation, and how adaptation science and practice then stabilize, reproduce, or contest the social orders and agendas politics advances (Eriksen et al., 2015). Surveying the breadth and depth of STS literature engaging the relationships of science and technology with politics is beyond the scope of this Chapter, but I allude to the diversity of this area of theory to clarify two points for adaptation scholarship seeking to integrate STS's political orientations.[2]

[2] Brown (2015) provides a typology of the diverse applications of politics in STS literature. These include positions that cast science as inherently political, science as politics by another means, and post-humanist perspectives that ascribe political agency to objects (in addition to people) (Brown, 2015). Others, including Latour (2007) and Jasanoff (2016), break down the STS field's collective conceptualizations of politics differently, underscoring the multiple avenues that science can be seen as both political, used in an adjective sense, and a site of politics, referring to science as a space hosting political action (Jasanoff, 2016b; Latour, 2007).

First, research in STS engages politics and the political in multiple ways. This is both through different operating definitions of both terms, which are no less contested in political theory, as well as by engaging diverse sites and scales through which politics and political power occur (Irwin, 2008; Ezrahi, 1990; Miller, 2004). While potentially confusing, this diversity enables flexibility for examining the co-production of politics and science. For example, discussions of politics in STS can be found in assessments of the embedded politics of scientific artifacts (Winner, 1980), such as the representations discussed in the opening section, in addition to investigations of more formal institutional science-policy arrangements like the IPCC. Second, across these diverse conceptualizations and engagements, STS treats politics, science, and technology as invariably intertwined (Jasanoff, 2012b; Maas et al., 2022). This stands in contrast to other disciplines which, while aware and typically weary of the *politicization* of science, often maintains that science is purifiable from politics, given proper attention and care (Latour, 1993; Simmet, 2025). Returning to the central premise of co-production, which holds that conceptions of what is and what ought to be in the world are mutually constitutive, this proposition has proven to be a powerful lens for understanding the interactions of science with politics as well (Bremer & Meisch, 2017; Goldman et al., 2011). Simply put, politics and dominant forms of political organization and power serve as powerful vehicles that capture society's prevailing normative commitments and desires and bring them into the making of science and technology. How this occurs is a primary question of constructivist STS scholars.

Participation is a particularly rich site for investigating the co-production of politics and science and is a topic of immense relevance for the adaptation field. Broadly, STS investigations of participation examine how normative modes of ordering society, citizenry, and the definitions of issues are enacted through the ways the science-politics interface is performed and policed in

participatory venues (Konrad et al., 2016; Matzner, 2016; Nost, 2024; Turnhout et al., 2010). In other words, participation as a licensed measure of political engagement is considered for the ways it serves to co-produce and solidify distinctions of authoritative actors and accepted problem framings in both the creation of scientific knowledge and its appraisals in a democratic society.

Outside of STS, participation has traditionally been presented as a democratizing force within scientific production and governance (Chilvers, 2016; Hügel & Davies, 2020; Klenk & Meehan, 2015). Work within STS does not relegate the importance of participation by any means, but problematizes the "residual realist" view of participation accessing a static "public" regarding a predefined problem through participatory formats that all exist *a priori* and without influence (Chilvers & Longhurst, 2016; Turnhout et al., 2010). In essence, public participation is seen in STS as an act that co-produces a problem frame for science as well as legitimizes the presented political means to engage and govern it. A key lesson for work in adaptation, then, is to recognize the performative and politically stabilizing functions of participation that go beyond questions of adequacy or representativeness (e.g., Haverkamp, 2021).

STS provokes moving beyond normative and instrumental views of participation. STS scholars contend that such perspectives lack critical consideration for the ways pervasive social orders like politics situate and condition participatory science and subtly work to define what problems, actors, or changes are considered (Chilvers, 2016; Macnaghten & Chilvers, 2014; Turnhout et al., 2010). Broadly, this arrangement is shown to underwrite existing forms of politics and problem frames through the institutions and experts privileged in participatory processes, which simultaneously limits participatory science as a space for deliberative, or political, debate. For example, Andersson and Westholm (2019) describe how a participatory process for eliciting and debating alternative visions of forest use winnowed possible futures to a consensus vision. This

occurred not by the deliberative work of participants, but through the assumptions, and priorities embedded in the processes by its industry-aligned and politically powerful organizers (Andersson & Westholm, 2019). The outcomes of the participatory process hewed to standing economic and political preferences and leveraged existing knowledge brokers, restricting the role of participation to the acceptance of a narrowed consensus future. This finding aligns with other empirical STS examinations on the co-productive effects of politics and participation, which find that the recognition and stabilization of certain identities and problem framings in participatory science trace existing political fault lines of recognition and power (Chilvers et al., 2018; Mills-Novoa et al., 2020; Turnhout et al., 2010).

In another example, Mills-Novoa et al. (2020) develop a case study of adaptation projects in Ecuador. While the adaptation projects frame participation as an initiative "cornerstone," the authors find participation was enrolled in the greater project through specific means that stem from the states preferred mode of ordering citizens, space, and adaptation's purpose. They show how the contingent design of the participatory processes created and stabilized new subjectivities of vulnerable adaptation project beneficiaries. These new subjectivities aligned with and authorized the interventions already promoted by the state and its top-down "hydro-social imaginary" (Mills-Novoa et al., 2020).

Stirling (2008) calls these dynamics the "closing down" of participatory science, in that they reduce the potential of participation to select outcomes that are homogenous with prevailing political and social orders (Stirling, 2008). Such critiques are not foreign to adaptation studies. However, the strength of STS is, again, to explain *how* a given manifestation or practice of participation and its outcomes emerges through co-production with prevailing political orders. In these cases, participation and its epistemic procedures and products reflect a specific history with

and deference to other social preferences and institutions. A key lesson from STS's approach to participation for adaptation scholarship is then to ask who and what motivates, frames, and delimits participatory practices in ways that reduce their potential to articulate alternative and possibly politically antagonistic adaptation pathways (Chilvers et al., 2018; Turnhout et al., 2020).

In their influential essay "Apocalypse Forever" Swyngedouw (2010) critiques current manifestations of climate governance as post-political, a condition they describe as "the predominance of a managerial logic in all aspects of life, the reduction of the political to administration where decision-making is increasingly considered to be a question of expert knowledge and not of political position" (Swyngedouw, 2010, pg. 225). Post- or de-political governance of climate change does not remove the political nature from the causes and impacts of the climate crisis, but institutes a post-democratic and techno-managerial approach to governing these concerns, such as how different drivers of risk and the forms and beneficiaries of adaptation in society are identified and formalized (Kenis & Mathijs, 2014; Mikulewicz, 2018b; Swyngedouw, 2013). Jasanoff has called this "evacuation" of the political (Swyngedouw, 2011, pg. 370) from public participation in the making and appraisal of science "the vanishing public square" (Jasanoff, 2021b). In diagnosing this post-political moment, Jasanoff, Swyngedouw, along with the broader STS field, contend that the predominant technocratic style of climate and adaptation governance and politics has stripped participatory venues of their political potential (Latour, 2018; Mikulewicz, 2024). Further, the preferred mode of social ordering and governance seen in prescriptive participatory adaptation helps co-produce scientific facts and projects congruent with this orientation to governing the climate. The examples above highlight the ways in which collaborative forms of adaptation that appeal to participatory processes as a form of democratization can, in fact, extend this depoliticization. Participatory adaptation operated as post-

democratic forums where the issues and needed solutions of interacting social and climate crises come prefigured. The authors whose work I cite above, as well as theorists like Stirling, Swyngedouw, and Jasanoff offer similar recourse to the current arrangements between adaptation and politics that blocks more robust political engagement and the entertainment of transformations to adaptation and social orders (Jasanoff, 2003; Stirling, 2008; Swyngedouw, 2010). Across these examples, the authors encourage a greater recognition of difference. Differences of adaptation needs, of political power, of future desires, and of ontologies are all flattened in participatory methods that presuppose the purpose of adaptation in accordance with its management through technocratic means (Beck & Forsyth, 2020; Haverkamp, 2021; Nightingale et al., 2020). STS's contribution, then, is to highlight the ways difference manifests and is negotiated out of deliberative adaptation so that it can be reengaged.

The Future

The future is central to adaptation. Major pillars of the field, including research that models biophysical and atmospheric changes and their relative impacts (van Beek et al., 2020), as well as common adaptation planning practices (Nalau & Cobb, 2022; Sheppard et al., 2011), are explicitly forward looking, as they attempt to predict and prepare for the climate conditions of the future. Under these frames, adaptation science typically casts the future as an inevitable destination constantly coming into view (Muiderman et al., 2023; Rickards et al., 2014). Each additional layer of modeling clarity brings the climate future further into focus, to which adaptation measures can be planned and scaled (Dessai et al., 2009). Critical perspectives in the adaptation field also engage the future, but do so from a less deterministic perspective (Bauriedl & Müller-Mahn, 2018). Just as the *predict-then-adapt* mantra of climate adaptation has been critiqued for its tendencies towards "climate reductionism" and reliance on technological interventions (Hulme, 2011), work in critical

adaptation has sought to resolve the shortcomings of mainstream adaptation's typical prediction-based engagements with the future (Goh, 2021; Lövbrand et al., 2015). Principally, this is done by identifying the aspects of society—technical, economic, political, and otherwise—that mediate adaptation and that could be transformed in future societies to yield more just and sufficient reductions in vulnerability (Pelling, 2010; Pelling et al., 2024). In this way, critical adaptation perspectives nudge the future from an object of prediction to become a site for critical transformation and creation. Leichenko and O'Brien (2024) subtitle their foundational book on the social dimensions of climate change "transforming the future", indicating the distinctly constructivist orientation critical social approaches bring to the future (Leichenko & O'Brien, 2024). These authors are not alone in framing adaptation as "future-making" (Broto et al., 2024; Comelli et al., 2024; Nalau & Cobb, 2022). This position has gained broader traction within the critical adaptation field as well as in adaptation planning practices centered around speculation, back-casting, and scenarios (Hoffman, 2022; Vervoort et al., 2015).

Discussing plural futures and future-making can come across as hollow academic flourish, but this perspective and its use in framing adaptation has increasingly gained traction within mainstream adaptation discourse (Dahl et al., 2023; IPCC, 2023). This mirrors a broader rejection of purely positivist logics across science in favor of framing knowledge as partial, subjective, and value-laden (Haraway, 1988; Konrad et al., 2017; Pacchetti et al., 2024). Futures pathways appear in the most recent IPCC assessment report, for example, and depict branching scenarios whose potential trajectories and foreclosed opportunities are molded by social decisions and desires in the past, present, and into the future (Schipper et al., 2023; Wardekker & Lorenz, 2019). Indeed, as the need for transformational adaptation to address widespread vulnerability and inequity has become more widely accepted, approaching adaptation as a practice of imagining transformations towards more

just and sustainable futures has similarly moved towards the mainstream. Yet, adaptation routinely proceeds in ways that "close the future", rather than opening it to alternative transformational pathways (Andersson & Westholm, 2019; Muiderman et al., 2023; Stirling, 2008). That is despite the growing recognition for pluralistic future perspectives in adaptation research and practice. As with the topics covered above, concepts and research in STS prove helpful in moving explorations of adaptations relationships to the future from purely descriptive to analytical.

The future is also a central concern of research in STS. Within STS, visions of the future are approached through the lens' of constructivism and interpretive flexibility, much like the co-productive making of the present (Miller, 2023). This draws attention to the reasons certain futures gain narrative strength and institutional backing, while other potential future trajectories go unexplored or unimagined (Jasanoff, 2020; Milkoreit, 2017). Returning to the axiom "it could be otherwise" that orients much of the STS field, this phrase holds true just as much for visions of the future of science, technology and society as it does for its current manifestations (Hendriks et al., 2025; Nowotny & Schot, 2018 n.p.). Like the topics covered in previous sections, the future has by no means been neglected by the adaptation field, but still stands to benefit from integrating the analytical approaches of STS into its own theorizations. Research and analysis within STS similarly recognizes the possibility for different futures but goes further in offering explanations for *how* and *why* particular future trajectories and visions diverge and win out (Jasanoff & Kim, 2015). I argue this is relevant to the adaptation field, should its calls to build a more just and resilient future society via transformational adaptation be realized. When posing the question "what is adaptation" I have explained where STS proves useful in explicating how and why the field's characteristic features and material practices owe their shape to historically and socially contingent processes. Turning this question to prominent ideas of the future's adaptation could

enable and create, and the ways these ideas structure decisions and actions in the present, is another key contribution of STS to adaptation.

Scholarship in STS as well as other critical social sciences use the term imaginaries to describe collectively held and persuasive visions of society (McNeil et al., 2016; Gregory, 1995; Taylor, 2004). While the term is applied flexibly across the social sciences, and not exclusively to describe future visions, it is frequently used within STS in reference to the more specific concept of sociotechnical imaginaries (STI). Jasanoff and Kim (2009) define sociotechnical 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" (Jasanoff & Kim, 2015, pg. 28)

STS uses sociotechnical imaginaries as a broad way of explaining why outcomes manifest and appear as they do. In this case, why do visions of the future hold their distinctive characteristics? The above definition touches on the social nature of imaginaries, distinguishing a collectively held and circulating imaginary from an individual's own imaginative capacity (Hendriks et al., 2025; Wakefield, 2025). Imaginaries gain their societal influence through their performance, meaning their appearance in public and policy discourse and their material and visual manifestations produce, shape, and stabilize their meaning (Davoudi, 2023; Konrad et al., 2016). Crucially, imaginaries are also politically salient, as they endorse forms of governance and its priorities in the present and future to bring about particular outcomes (Groves, 2017; Muiderman et al., 2020). Sociotechnical imaginaries are connected to a further concept in STS of anticipatory governance in this regard. Anticipatory governance refers to modes and efforts to govern uncertain futures in the present (Muiderman et al., 2020, 2023; Vervoort & Gupta, 2018). These governance practices

are integral in the realization of certain desired future imaginaries and averting or obscuring others (Beck & Mahony, 2017; DeLeo, 2017; Paprocki, 2022a).

Research applying the sociotechnical imaginaries concept has centered on illuminating the co-production of normative desires for the future with visions of scientific and technological progress (Cretney et al., 2025; Jasanoff & Kim, 2015). For example, in introducing the term, Jasanoff and Kim use the concept to explain the divergent ways that nuclear technology was conceived and harnessed in the United States and South Korea. The authors linked the moral and social framings of nuclear technology's perceived risks and societal benefits in each country to the different ways the technology was adopted, developed, and regulated (Jasanoff & Kim, 2015). Subsequent research in energy social sciences, a field that has readily adopted the STI concept, traces how different energy imaginaries and their enshrinement in policy do more than envision projected future technologies. Imaginaries of energy futures also relate to forms of political organization that legislate change and promote adherence, underwrite technological development and research, and communicate moral and social commitments (Echevarria et al., 2023; Eschrich et al., 2018; Hess & Sovacool, 2020; Sovacool et al., 2020). Far from being descriptive, imaginaries are potent generative political and social forces that harness the direction of scientific development to influence societal trajectories. Imaginaries are further stabilized and empowered through anticipatory governance practices that enable certain forms of foresight over others, giving rise to particular popular imaginations of the future and wielding policy in the present as a result (Guston, 2014; Muiderman, 2022; Vervoort & Gupta, 2018). As a tool for critical adaptation studies, these concepts enable a better accounting for the ways adaptation science and practices both shapes and are shaped by the normative expectations and desires that characterize future visions.

Scholars working within adaptation studies have increasingly integrated STS's critical-analytical approach to the future. These studies link the fields by assessing how future visions form around imaginations of adaptation and the transformations to society it could or should deliver. For example, Paprocki (2018) examines the construction of a dominant state-led adaptation imaginary in coastal Bangladesh that renders residents' own imaginaries and desires to adapt in place inviable. Across multiple articles, Paprocki explains how the future vision articulated by the state was co-produced with historical and current preferences and policies promoting urbanization, rural commercialization, and dispossession (Paprocki, 2018, 2020, 2022a,b). The future imaginary advanced by the state enrolls the making and application of adaptation knowledge in accordance with its normative positions on preferable social trajectories. As a result, the coast is depicted as unlivable in a process that Paprocki calls "anticipatory ruination" which wields adaptation science to support existing directives for rural resettlement and land commercialization (Paprocki, 2022a, 2022b). In another example, Celemajer et al. (2024) describe how three prominent sociotechnical imaginaries of climate change, "business-as-usual", "techno-fix", and "apocalypse" are motivated by different normative commitments in society (Celermajer et al., 2024). The respective imaginaries envision science and adaptation evolving in ways that are compatible with parallel normative desires. The authors contrast these dominant imaginaries with empirical examples of what they describe as alternative "grounded" or material imaginaries taken from around the world (Celermajer et al., 2024, pg. 1019). The grounded imaginary examples are derived from the practices of community organization and interrelation which reflect transformations to the ways the respective communities' understand nature and the climate crisis. The authors draw from new materialist work in describing the technological decisions and prefigurative development practices exhibited in each example as performative material sources of alternative climate imaginaries.

Kanarp (2024) uses document analysis and interviews with local government officials and employees to identify the prevailing imaginaries of climate adaptation in Northern Sweden (Kanarp, 2024). They find that adaptation is consistently integrated into an incremental and economically oriented future imaginary. However, when prompted to consider timeframes beyond the shorter cycles of municipal planning, participants discussed transformational change that diverged from status quo economic and social practices, suggesting that the formal means of anticipation practiced by the local governments constrain and co-produce prevailing adaptation imaginaries (Kanarp, 2024).

Together, these studies and the concept of sociotechnical imaginaries help communicate considerations for adaptation studies' engagement with the future. First, working through STS's analytical approach to the future enables moving beyond a recognition that multiple possible adaptation futures exist to demonstrate how certain imaginaries gain traction to shape adaptation policy in the present (Cretney et al., 2025; de Jong et al., 2024; Jasanoff, 2020; Milkoreit, 2017). In this way, imaginaries complicate critical adaptation's calls for additional transformational future visions by revealing the necessary performative and political mechanisms that give rise to and sustain imaginaries (McNeil, et al., 2016; Jasanoff & Kim, 2015). Relatedly, imaginaries connect shared visions of the future with political and socio-technical actions in the present that work to bring about a desired future (Muiderman et al., 2020; Muiderman, 2022). Finally, these cases demonstrate the inseparability between the making of adaptation's descriptive visions of the future with the social and normative desires for certain futures. This is key in identifying other powerful narratives such as economic growth or rural commercialization and how these may work in tandem to co-produce future visions and structure desired forms of adaptation.

Harnessing and integrating the explanatory powers of sociotechnical imaginaries and anticipatory governance for adaptation entails a more thorough accounting for the political and performative landscapes through which imaginaries are created and contested. In this sense, typical approaches in adaptation studies focused on revealing or eliciting different transformational futures should also contend with the uneven landscape on which futures are imagined. Research applying the STI concept shows that the mere presence of alternative imaginaries or futures does not induce transformational change or the ascendance of a new narrative (Beck et al., 2021). Rather, narratives of the future and the forms of adaptation they endorse are mediated by the formal means of visioning seen in anticipatory governance and the future visions and normative commitments of powerful actors in society.

Discussion

To synthesize the topics I lay out above and chart a path forward for their greater integration into adaptation studies, it is helpful to reaffirm what common ground the two fields stand on. Work in critical adaptation studies has coalesced around a drive to amend and transform the shortcomings of incremental adaptation that dominate adaptation practices globally (Bauriedl & Müller-Mahn, 2018; Berrang-Ford et al., 2021; Cretney, 2014; Webber, 2016). In doing so, adaptation studies establishes the insufficiencies and frequent maladaptive consequences of these common interventions (Mikulewicz, 2019; Ojha et al., 2016; O'Lear, 2016; Steig & Oels, 2025). At the same time, critical adaptation scholarship details the alternative transformational arrangements adaptation could take to yield more equitable, context-specific, and empowering outcomes (Comelli et al., 2024; Dilling et al., 2023; Nightingale et al., 2022). Further, the limited benefits of prominent adaptation practices and the potential for transformations to sidestep or overcome these outcomes are no longer the positions of outsider critique. Rather, the call for transformational

adaptation has moved to the mainstream of climate change science and policy (Dahl et al., 2023). Applying contributions from STS, these positions of adaptation studies can be re-read as establishing the contingency and interpretive flexibility of adaptations' arrangements, mirroring STS's commitments in stating that the prevailing forms of adaptation not only could, but should, be made otherwise (Mikulewicz, 2019). Yet, work in this area often struggles to bridge between these two core commitments. This is not to say that adaptation studies provides no explanation as to why common forms of adaptation assume familiar forms and reproduce similar outcomes, often invoking the durability and influence of political power and socioeconomic orders in shaping adaptation (Dolšak & Prakash, 2018; Eriksen et al., 2015; Henrique & Tschakert, 2019; Ribot, 2011). Rather, it is the dexterity and analytical detail with which STS explains how these systems and power imbalances are enrolled and remade in science that proves so valuable to the adaptation studies field's attempts to create adaptation differently in the future.

In this Chapter, I show how the analysis afforded by STS and concepts such as co-production can serve to explain how and why adaptation is so frequently reproduced through familiar forms and with familiar liabilities (Eriksen et al., 2021; Klöck & Fink, 2019; Nightingale et al., 2020; Rodina, 2019). For the adaptation studies field, I argue that STS's attention to just *how* broader social orders ensnare adaptation is a significant contribution of STS to the critical study of adaptation science and practices. Haverkamp (2021) encapsulates this potential in their case-study of a state-led adaptation initiative in Peru. They identify a need for "adaptation otherwise" that transcends patterns of state-led, developmentalist, and status quo imaginaries stabilized through constrained collaborative adaptation practices (Haverkamp, 2021). This study explains why a well-intentioned attempt at representative and collaborative adaptation planning was unsuccessful, as it was unable to overcome deeply rooted ontological differences between local agro-pastoralists and the

privileged views of the initiative's institutional sponsors and the state. Haverkamp notes that the adaptation initiative did not lack alternative renderings of adaptation put forward by local residents, but that these were never viable pathways given the co-production of adaptation alongside existing normative assumptions and structures (Haverkamp, 2021). Haverkamp leans on the analytical bite of STS to show how this occurs in the making of adaptation in place, and in doing so, convincingly demonstrated the capacities of STS to extend and enrich adaptation studies. More broadly, synthesis between STS and adaptation studies offers a more attentive means of explaining why adaptation may fail to meet its aims, as well as unveiling points of departure for amending future adaptation practices that go beyond more of the same. As I have attempted to show, STS can contribute to adaptation studies through its attention to the mechanisms by which particular formations of science and society are co-produced (Jasanoff, 2004). STS explanations go beyond naming the limitations of adaptation and into revealing how adaptation is ushered towards incremental or unjust formations in its co-production with society across the four themes I discussed. Crucially, this capacity also exposes common characteristics and opportunities for revision that span across these four themes. These commonalities that link the four themes are starting points for applying the insights of STS practically towards the reworking of adaptation.

The first of these is what I will call *inheritance*. Co-production, and work across STS, takes care to point out how current manifestations of epistemic and normative orders bear histories that led to their present form. This is true in its demonstrated and potential applications to adaptation as well. For example, Paprocki (2018) linked historical development practices and state priorities to the current epistemic practices that comprise current adaptation regimes (Paprocki, 2018). Nost (2019) showed how established economic priorities were drawn in to the modeled worlds made within adaptation (Nost, 2019). Mahony (2023) reveals how something as seemingly benign as

weather data bears a colonial history in the location of observation stations, leading to a still presently uneven geography of measurement and knowledge (Mahony, 2023). In each of these examples, STS makes clear the value of considering "what" adaptation is built and accreted upon so that it can be made differently in the future.

The second consideration for reconstruction is in the making of *identities*. STS connects questions of *what* and *why* of science and society to causes that show *who* is acting is also critical in the making of any particular socio-technical arrangement. Adaptation, too, is keenly attuned to identities in asking adaptation for whom, for instance (Cretney, 2014). As seen in the four themes elaborated above, the making of adaptation can also help construct identities, in addition to recognizing them (Chilvers & Kearnes, 2020; Mills-Novoa et al., 2020). In this sense, STS complicates the static notion of identities across the four topics I develop in important ways. In modeling, governing, convening collaborations, or depicting particular futures, adaptation both draws from contingent social distinctions while helping further realize these in society. Chilvers (2016) makes this clear in their discussion of the performativity of participation, but it is also present in Ribot's (2020) discussion of climate migrants and the examination of the making of adaptation subjects by Mills-Novoa et al., (2020). As with the challenge to consider what adaptation inherits, considering the creation of identities does not necessitate paralysis in practice. Instead, it should impart an understanding that the question and answer to "adaptation for whom?" neither originates from a neutral plane nor is static.

A final opportunity for adaptation seen in these four themes is the role of *creativity*. Creating anew is part and parcel to the interpretive flexibility that drives inquiries in STS. Indeed, a key capability of STS is in considering all the various forms *otherwise* could be (Latour, 2004). This need not just be in the restricted confines of the adaptation planning process, where repeated calls for more

creativity and divergent visions prove largely ineffectual in realizing distinct and transformative outcomes (Wakefield, 2025). Instead, STS points to the broader ways creativity might be leveraged across the four themes I discuss. Whyte (2018) offers one example in advancing a distinct form of Indigenous science fiction as a liberatory and sustaining narrative for adaptation and the future. The creativity Whyte advances is not limited to select venues, but pervades relationships, practices, and the creation of institutions (Whyte 2017, 2018). Celermajer et al. (2024) also points to the functions of creativity, tying the material practices of prefiguratively living otherwise to the creation of new climate imaginaries made through creative reforms to living and relating with one another and nature. STS, in essence, shows that what is commonly viewed as the rightful topics and means for creativity has also suffered from atrophy through the co-production of adaptation. Creativity prompts us to look for ways to construct adaptation outside of the usual channels and narratives that impart a priori limitations, rather than simply think and act differently within them. Haverkamp's (2021) earlier example helps reinforce this idea, arguing that diversifying visions of adaptation was insufficient to break from foundational assumptions on which an adaptation initiative was built, which requires more expansive roles for creativity and reimagination.

Bringing the insights of STS into closer dialogue with adaptation studies reveals that adaptation's prevailing forms are not the inevitable result of climate risk, but the outcome of co-productive dynamics that unfold through how climates are represented, where epistemic boundaries are drawn, how participation is structured, and which visions of the future are made actionable. Across these four themes, STS underscores how prevailing orders scaffold and constrain adaptation. However, integrating STS with adaptation studies and critique also illuminates openings to redirect adaptation's current trajectories. Such as acknowledging the historical legacies that guide present arrangements, the ways adaptation both reflects and remakes social subjects, and the possibilities

that emerge when creativity is freed from narrow procedural confines. The synthesis of STS and adaptation studies can do more than parallel critique. It provides a purposeful agenda for reworking adaptation by short-circuiting its co-production with society in ways that foreclose its transformational possibilities.

Chapter 3 – *Beyond Prediction: A Case Study of Regional Adaptation Planning on the Olympic Peninsula*

Introduction

Pledges to reduce greenhouse gas emissions seek to stave off apocalyptic climate futures; however, decades of deferred action now promise marked change (Hausfather & Peters, 2020; IPCC, 2022). This uncertainty over the future reflects the inability for sustained collective action on a planetary scale. Yet, it also opens opportunities to create futures worth living (Jasanoff, 2021a). What possible climate futures, then, are on the horizon and how are they actively produced and advanced?

The field of critical climate adaptation studies can help explore this inquiry. In its broadest form, critical adaptation studies critiques dominant practices of creating and living with climate-altered futures and develops approaches for emancipatory, just, and sustainable adaptation (Bauriedl & Müller-Mahn, 2018; Mikulewicz, 2020; Paprocki, 2022b). These approaches criticize the incremental nature of many adaptation initiatives, which often insulate existing societal values, norms, and systems from physical climate exposures. Critical perspectives instead emphasize the need for transformational changes to socioeconomic and political arrangements, which are understood to produce and sustain differential vulnerability to climate change (Nightingale et al., 2020, 2022; Orlove, 2022; Pelling et al., 2015; Shi & Moser, 2021; Kates et al, 2012; O'Brien et al., 2007; Ribot, 2014; Thomas et al., 2019). Transformational adaptation thus affords opportunities to imagine alternative futures characterized by new social arrangements that disrupt social vulnerability (Pelling, 2010; Ribot, 2011; Shi & Moser, 2021).

Different adaptation pathways can enable transformation or reinforce current arrangements through incremental interventions (Colloff et al., 2021; Pelling et al., 2015; Paprocki, 2020). The distinct practices, material interventions, and consequences of incremental and transformational approaches are well-documented in critical adaptation scholarship. However, the conditions that enable adaptation to assume one pathway over another remains at the vanguard of current adaptation research (Nightingale et al., 2022)—a focus of this Chapter.

Drawing from Science and Technology Studies (STS) approaches, this Chapter contributes to, and advances, adaptation "evaluation" literature. Much of this work assesses the technical efficacy, sustainability, and equality of adaptation initiatives (Araos et al., 2021; Owen, 2020; Swanson, 2021). This research has clarified the often incremental, inequitable, and maladaptive outcomes of adaptation (Eriksen et al., 2021). My analysis extends conventional assessments, contributing to a diverging branch of adaptation studies that has moved to explore how broader assumptions and patterns of formal adaptation may reproduce such outcomes (Forsyth & McDermott, 2022; Jasanoff, 2021a; Nightingale et al., 2020; Orlove, 2022; Shah et al. 2025).

In this Chapter, I analyze the underlying processes and interactions that create and stabilize certain adaptation conceptualizations and pathways over others using a case study from the Olympic Peninsula, Washington State (U.S.). I explain how a particular conceptualization of adaptation and its relationship to the future materialized using analytical frames from STS. In doing so, I focus my attention on the "deep co-production" of adaptation (qtd. Forsyth & McDermott, 2022; Goldman et al, 2018; Nightingale et al., 2020). Co-production, elaborated below, captures how a continuous and cyclical dynamic between the epistemic and normative foundations of society makes and remakes adaptation planning processes (Jasanoff, 2004, 2020; Nost, 2018).

A diverse array of STS, political-ecological, and increasingly, critical climate adaptation scholarship have employed co-production (Bandola-Gill et al., 2023; Bremer & Meisch, 2017). For example, Paprocki's analyses of adaptation in coastal Bangladesh reveal how the pursuit of adaptation and prevailing notions of what this should resemble can only be understood when contextualized within the preceding era of development (Paprocki, 2018, 2020, 2022a). Paprocki details how adaptation is co-produced alongside existing development directives for urbanization and commercialization, steering adaptation to also take up these aims (Paprocki, 2018, 2020, 2022a). Forsyth and McDermott (2022) provide another example, documenting how the definitions of "what" and "who" within formal adaptation projects in Nepal's Middle Hills region are informed by local politics of recognition and institutional priorities, rather than being foremost informed by the conditions that produce vulnerability locally (Forsyth, 2022; Forsyth & McDermott, 2022). Finally, Nost's case study of Louisiana's coastal master plan illustrates how models of coastal erosion and the questions they are tuned to answer reflect dominant economic, political, and social framings, producing winners and losers in the problems the models recognize and the interventions they support (Nost, 2018, 2022).

I contribute to this interdisciplinary STS-adaptation literature by providing empirical and conceptual specificity in my accounting of co-production in formal local adaptation. I also attempt to build a more approachable and navigable bridge between the STS and transformational adaptation literatures through my explicit use of co-production and illustration of the connections between co-production, imaginaries of adaptation, and transformation. Co-production serves as a valuable analytical frame that helps explain how and why an adaptation initiative assumes its resulting form and why alternative possible adaptation trajectories go unpursued. Building on

recent works (Forsyth & McDermott, 2022; Shah et al., 2025), I demonstrate how processes of co-production structure and legitimize a regional adaptation outcome.

I begin with an overview of the STS concepts of co-production and sociotechnical imaginaries. I then introduce the context and methods of this case before turning to my results. My results are divided into two sections: **Co-production processes** and **alternative imaginaries of adaptive futures**. The former elaborates processes I observed in the case study that enabled adaptation to be co-produced through entwined societal and scientific orders. The latter section stitches together and narrates alternative future visions expressed by respondents that describe diverging adaptation pathways. I discuss these results by linking the stabilizing forces of co-production in adaptation planning to the transformational citizen-state-nature relations observed in alternative imaginaries. Ultimately, I demonstrate how STS concepts can serve a key analytical role in "evaluating" adaptation planning and outcomes in ways that illuminate why incremental adaptation so often prevails, as well as where openings for transformation may be better recognized in formal adaptation projects.

Theoretical Framework: Co-production

STS demonstrates that scientific practices do not dispassionately supply truths of nature or impartial representations of the world (Baker et al., 2023; Goldman et al., 2011). Instead, epistemologies are shown to bear histories and to reflect a selective assembly of ideas, principles, and goals (Watson-Verran & Turnbull, 1995). How a certain set of practices and governing objectives become embedded within, and characteristic of, science stems from what is judged objective and relevant, but also what is congruent with the organization of social life and its expectations (Jasanoff, 2004; O'Lear, 2016; Law, 2015).

Extending contributions from STS necessitates examining climate adaptation as a joint construction between science and prevailing social orders (Beck et al., 2024). Politics, power, and place-specific contexts produce the ways science is employed in the making of adaptation (Haverkamp, 2021). In turn, the products of adaptation science assume and advance the prevailing ordering structures of social life, stabilizing their presence as natural (Jasanoff, 2017; Nost, 2024). The conceptualization of adaptation in earlier Intergovernmental Panel on Climate Change (IPCC) Assessment Reports, and the solutions that followed from the IPCC's decision-support, have been examined along these lines. The IPCC initially framed adaptation in accordance with its global and apolitical "view from nowhere" to justify and sustain its social authority (Borie et al., 2021; Jasanoff, 2017; Miller, 2004). As a result, adaptation was conceived of as responses to the residual risks of atmospheric emissions (Beck & Forsyth, 2015; Jasanoff, 2010; O'Brien et al., 2007; O'Lear, 2016; Wynne, 2010). This framing of how climate change harms linked risk to emissions induced hazards, rather than how hazards are experienced (and importantly, experienced differently). In turn, this framing reduced adaptation's operating space to those responses that flow from an atmospheric form of risk, obscuring responses that may originate in vulnerability or justice framings of adaptation (Baker et al., 2023; Beck et al., 2024). While later IPCC Assessment Reports expanded adaptation to include social and justice determinants of vulnerability, the example from early editions through which critical STS evaluations demonstrated the convergence of sociopolitical and epistemic sight, highlights STS's value in understanding how and why adaptation manifests as particular outcomes. As seen in this notable example, assessing adaptation using an STS perspective requires unveiling and questioning the assumptions, decisions, and structures that bind scientific and social orders and govern what adaptation can be.

This notion, that science is both a product and producer of social interests, is known as **co-production** (Jasanoff, 2004). Jasanoff's foundational essays in "States of Knowledge" established co-production and launched its uptake in STS and other disciplines (Bandola-Gill et al., 2023; Jasanoff, 2004; Miller & Wyborn, 2020). Jasanoff has described co-production as, "the ways in which we know and represent the world (both nature and society) are inseparable from the ways in which we choose to live in it" (Jasanoff, 2004, pg. 2). That is, "knowledge, power, and social order are inseparable and mutually constituted" (Daly, 2016, pg. 172). The term co-production often appears in the resilience and adaptation literature in another context: as the deliberate co-creation of knowledge through collaborative governance processes (Wyborn et al., 2019). This form of co-production is further associated with the sustainability science field and describes intentional, goal-oriented, efforts to create more actionable science through participatory and co-creative methodologies (Bremer & Meisch, 2017; Norström et al., 2020). This notion of co-production is termed normative or instrumental co-production to distinguish it from the analytical or descriptive form, which is employed in this Chapter. While the normative strand describes discrete acts, analytical co-production is "going on in the world, like it or not" (Jasanoff qtd. in Turney, 2014, n.p.). This STS form of co-production (hereafter, co-production) can serve as a valuable framework for understanding the formation and ambition of adaptation initiatives as it allows us to understand the pathways through which social contexts and expectations shape adaptation's intentions, and the ways adaptation comes to secure these expectations into the future.

What does such an analysis afford to critical adaptation studies? Co-production draws attention to sociotechnical agendas made marginal, inaccessible, or wholly unasked in other domains (Law, 2023). By casting social structures as both an ingredient and a product of science and technology, co-production expands the pathways through which we acknowledge science and knowledge are

duly crafted and could be done differently (Daly, 2016; Wyborn, 2015). In applying co-production, Jasanoff offers that it functions less as a "full-fledged theory claiming lawlike consistency or predictive power" and more as "an idiom—a way of interpreting so as to avoid the strategic deletions and omissions of other approaches" (Felt et al., 2016; Jasanoff, 2004, pg. 3). This breadth, which limits any single prescriptive use of co-production, does not leave researchers unequipped. Rather, it emphasizes researchers understand and trace co-production as it occurs at particular sites and through particular instruments (Bremer & Meisch, 2017; Jasanoff, 2004; Laurent, 2024).

Taking this into account, co-production prompts researchers to examine the *processes and interactions* that enable social and scientific *orders* to jointly underwrite and stabilize a common perspective of the world and society. This draws our focus to the features of sociotechnical arrangements that enable mutual constitutions of science and society, rather than isolating co-production's signature in discrete *occurrences* (Muñoz-Erickson, 2017). In other words, co-productionist accounts do not rest on identifying individual outcomes. They instead prompt researchers to contextualize those discrete instances as illustrative of broader patterns and mechanisms of co-production (Miller & Wyborn, 2020; Pickett et al., 2020).

The co-production of social and scientific orders is continuous and ubiquitous but proceeds along identifiable and consistent pathways (Goldman et al., 2018; Jasanoff, 2004; Mahony & Hulme, 2018). These pathways, or ordering instruments, as described by Jasanoff, lend guidance for conducting an empirical case study (Pickett et al., 2020). Instruments describe the features and sites of sociotechnical arrangements that form at the nexus of social and scientific ordering (Jasanoff, 2010; Miller & Wyborn, 2020). For example, institutions work as an instrument of co-production. Numerous studies have documented how the design and actions of influential international bodies covering climate, sustainability, and biodiversity issues, such as the IPCC,

IPBES, and Future Earth enable latent normative frames and objectives to structure the scientific work these institutions support and amplify (Law, 2023; Miller, 2004). Jasanoff describes four instruments of co-production that maintain social and scientific integration and allow for the mutual exchange of influence (Jasanoff, 2004, 2010). I briefly outline these instruments to demonstrate how this approach to co-production can aid in my attempt to explain the realization of adaptation in a particular arrangement.

First, the making of identities is one co-production instrument described by Jasanoff. The creation and stabilization of identities, both individual (as in an "expert") and collective (as in a "community") open opportunities to reshuffle or retain order across scientific and social planes (Jasanoff, 1987; Simmet, 2025). For example, Daly and Dilling's (2019) case study documenting the development of an adaptation information platform for Tanzanian farmers demonstrates how identity categories shape and are reified by science. The creation of "expert" and "user" and the demarcation of scientific from local knowledge introduced assumptions of what makes information credible and to who in ways that limited the project's success in the eyes of its target audience (Daly & Dilling, 2019). Second, institutions are another instrument identified in Jasanoff's contributions. Institutions offer a powerful latent structure into which new knowledge is received and reconciled (Beck & Mahony, 2018; Lövbrand, 2011). The creation of knowledge, too, reflects the marriage of institutional ways of knowing with scientific practices (Miller, 2008). As a result, knowledge creation often stabilizes the continuation of institutions, tacitly or intentionally, and their models of proper social order (Miller, 2004). Muñoz-Erickson's (2014) account of municipal sustainability policy making in San Juan, Puerto Rico illustrates the function of institutions as co-production instruments. Their research highlights the ways a city government "conditioned" knowledge to align with existing governmental structures and visions for the city

through processes of evaluation, abstraction, and selective integration (Muñoz-Erickson, 2014; Muñoz-Erickson et al., 2017). Third, the making of discourses is identified by Jasanoff. Discourse allows for the strategic bordering of topics and the intrusion of normative claims into technical classifications (Forsyth, 2023; Hulme, 2011; O'Lear, 2016). How a discourse emerges around or meets a topic of science or technology offers inroads to mold that topic into the folds of social life (Jasanoff & Kim, 2015; Wynne, 2006). For example, Goldman et al. (2018) connect the dominant discourses of the human dimensions of climate change field, particularly the terms adaptation, resilience, and vulnerability, to anti-political and exclusionary modes of understanding how climate change is experienced. They describe how the prevailing interpretation of these terms implicitly favors technocratic solutions and flattens diverse experiences of the environment to only those elements that support a coherent narrative of global climate change (Goldman et al., 2018). Fourth, Jasanoff raises the making of representations as an ordering instrument. Scientific representations necessitate abstraction and deletion, making their subjective design instruments of power and politics as well as explanation (Mahony, 2012; O'Neill & Smith, 2014). The representation of climate change through global circulation and temperature models has been discussed by numerous scholars. Models are shown to underpin new modes and spaces of governance and endorse solutions that obfuscate the historical injustices that produced the climate crisis (Mahony & Hulme, 2018; Miller, 2004; O'Lear, 2016; Jasanoff, 2010). These four instruments derived from Jasanoff's (2004) contributions offer a foundation for exploration—not a rigid framework to work within. I adopt Jasanoff's motion to approach co-production through instruments in my analysis of this case, but do so in the spirit of the idiom's flexibility and attention to the context to which it is applied, as noted above (Jasanoff, 2004). By this, I mean that I borrow the *concept* of instruments to explain the occurrence and consequences of co-production, rather

than adopting Jasanoff's instruments themselves. Through my analysis, I developed a novel set of three instruments and mechanisms that describe the co-production processes which structured adaptation planning in the case study examined.

Sociotechnical Imaginaries

The concept of Sociotechnical Imaginaries (STI) was developed in constructivist STS and flows from the theoretical principles that support co-production (Jasanoff, 2020; Jasanoff & Kim, 2015). Where co-production illuminates the mechanisms by which science and technology assume and stabilize particular values and interests, sociotechnical imaginaries describe how the co-production of science and society extends to collective visions of progress and a desirable future (Jasanoff & Kim, 2015; Kanarp et al., 2025; Miller, 2023). Jasanoff describes STIs 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" (Jasanoff & Kim, 2015, pg. 6).

This definition communicates STI's collective, political, and performative nature. Imaginaries are social, as they are exchanged and contested across populations and communities, distinguishing them from an individual's capacity to imagine (Broto et al., 2024; Wakefield, 2025). STI's are also performative, which means the desirable futures they describe are sustained through representation and communication (Hendriks et al., 2025; Jasanoff & Kim, 2015; Milkoreit, 2017; Oomen et al., 2022). Finally, STI's are political in their connection of selective notions of a desired future to the levers of power at work in the present to realize this future over others (Konrad et al., 2017).

As an extension of co-production, STIs help explain why marked rearrangements can overtake stability in sociotechnical systems when new future narratives unseat previously stable visions. STIs also account for the diverging trajectories of societies towards different sociotechnical arrangements, despite sharing similar social or technological preconditions (Jasanoff & Kim, 2015). Imaginaries and related concepts of speculation, visioning, and alternative futures have received increasing attention within adaptation scholarship, particularly for their potential to narrate different conceivable adaptation pathways as a response to climate and other crises (Celermajer et al., 2024; Comelli et al., 2024; Cretney et al., 2025; Pelling et al., 2024; Wakefield, 2025; Waters et al., 2023). A key capacity of STI's for examining adaptation processes is the concept's entertainment of plural futures and the relationships between them (Friedrich & Hendriks, 2024; Milkoreit, 2017; Miller, 2023). The STI concept problematizes any singular notion of an inevitable or desirable future trajectory, simultaneously making naturalized narratives visible as subjective and introducing the possibility for alternative plausible futures contingent on different tradeoffs and arrangements between society, technology, and the environment (Baker et al., 2023; Jasanoff & Simmet, 2021). I leverage STIs in this Chapter as an explicit extension of co-production, characterizing the future vision visible in the case's planning processes as a co-produced sociotechnical imaginary. The inclusion of STIs within this co-production framework also allows me to draw in the discussion of alternative transformational conceptions of a desirable future circulating in the region and discuss these alternative adaptation narratives in comparison to the prevailing imaginary of the planning process.

Case Study

This Chapter uses co-production to explain the features of a regional adaptation planning initiative in Washington State's North Olympic Peninsula region. The adaptation planning initiative was

organized by the North Olympic Development Council (NODC), a federally recognized economic development district. The NODC consists of a small staff and primarily serves a planning, convening, and facilitation role in furtherance of regional economic and environmental priorities. The NODC works across Jefferson and Clallam counties, the two northern counties that comprise the North Olympic region. NODC members include the region's city and county governments, Tribal nations, environmental organizations, industry groups, and nonprofits (NODC, 2020).

The Olympic Peninsula is well-known for its striking and diverse landscapes. Maritime weather patterns drive Western Washington's characteristic climate, and these dynamics are on full display across the Olympic Peninsula, giving rise to landscapes and communities shaped by the interface of land and water (NODC, 2022). The population is concentrated along the Northern coast in the cities of Port Townsend, Sequim, and Port Angeles. Outside of these cities, residents are spread across productive agricultural areas in the east, and the largely rural and isolated "West End" of the Peninsula (NODC, 2020). Six Tribal nations are also located in the North Olympic region. These include the Jamestown S'Klallam, Lower Elwha Klallam, Makah, Hoh, Quileute, and Quinault Tribes. The region's Tribal nations engaged in the NODC's adaptation planning processes to varying degrees, and some have led similar planning processes focused on their own adaptation priorities.

The Peninsula's varied geography, community composition, and climatic variability form a unique and complex setting for adaptation planning. Recent and ongoing shifts to the economic and social fabric of the region similarly produce the context for adaptation and shape residents' desires for the regional trajectory adaptation might support. Historically, the region's economy was based in natural resource industries, particularly logging, wood products, maritime activities, and fishing. The industrial economic engine, most prominently logging and wood products, has significantly

declined over recent decades, resulting in widespread economic hardship (NOPRC, 2023). As a result, the economic base of the region has moved from industry and resources to a greater proportion of services and tourism (NOPRC, 2024; NODC, 2021). The economic upheaval of the last 40 years is consistent with a broader dynamic of change present throughout the case. Respondents expressed diverging perspectives on what they view as the region's changing nature and its possible futures, noting desired and perceived changes to the region's economic, political, demographic, and ecological landscapes. Prominent among these topics is the potential arrival of climate refugees, the causes, consequences, and proper solutions to a housing crisis, and the shifting character of the regions' communities amidst economic transition. The concurrent narratives of change and their varied imprints on the planning processes make this a compelling case for examining how adaptation planning assesses and integrates social and political negotiations over the future. Regional dialogues around socioeconomic revitalization and resilience, and the potential for broader transformation that acts across both climate and social change, provide a valuable context to investigate how local adaptation planning incorporates, or distances itself from, complex community realities through co-production.

My analysis covers the NODC's decade-long adaptation planning initiative and its two participatory planning processes. The first of these was held in 2014-15 and the second in 2022. Both planning processes included employees of member governments, organizations, civic groups, and industry representatives. They were facilitated by contracted consultants specializing in adaptation planning and a local steering committee or "core team" comprised of representatives from NODC member organizations. Both centered on a series of meetings where the organizers and participants developed categories of priority adaptation areas, such as critical infrastructure or water resources, and then more specific concerns or vulnerabilities within these areas (Petersen et

al., 2015; NODC, 2022). The 2014-15 process began with three focus areas of *Water Resources, Natural and Managed Ecosystems*, and *Critical Infrastructure*, developed initially by the project steering committee. The 2022 process used a ranking exercise to winnow a participant generated list down to eight categories. These priority areas of concern were then used to generate more specific vulnerability topics, as well as corresponding adaptation strategies or objectives. For example, the 2022 plan identified *Wildfires and Wildfire Smoke* as a priority area. Within this priority area, reducing wildfire risk in forests and the wildland-urban interface was a more specific vulnerability topic, and remodeling structures with fire-preventative materials was one of several adaptation solutions presented regarding this topic.

Methods

My research began as an inquiry into the role of information, particularly climate-related, introduced and created within the NODC's adaptation planning processes. That is, I sought to understand how information acts as a site of co-production in shaping conceptualizations of adaptation and vulnerability within planning processes. As I began my interviews, I found that the narrow focus on information in some of my interview questions strained participants' recollections, and importantly, did not fully align with their experiences and perceptions of what influenced the resulting form of adaptation seen in the adopted plans. When asked about whether and how information guided the creation of components of the plan, many respondents found it difficult to recount where and how information was presented or used. Instead, they explicitly and implicitly invoked broader institutional interactions and orders as influential in shaping the adaptation vision seen in the plans. This pattern encouraged an analysis delineating how co-production dynamics more thoroughly configured the adaptation initiative and the ways in which preferred modes of living and planning coincide.

My exploration of the NODC adaptation planning process uses a case study design. Case studies are suitable when exploring phenomenon within the contexts that produce them, which is suitable for assessing regional or local adaptation planning initiatives (Crowe et al., 2011; Ragin, 2019; Yin, 2017). For these reasons, critical adaptation and empirical co-productionist studies turn to case studies as a methodology because of their ability to develop context-specific explanations of adaptation processes, and their capacity to disrupt assumptions and generalizations about how adaptation planning takes shape (Daly, 2016; Jasanoff, 2004; Pickett et al., 2020).

I collected and analyzed primary and secondary data including interviews, a focus group, and published planning documents. Interview data represents the largest share of material collected and analyzed, which is reflected in the presentation of my results. Interviews focused on how participants understood the procedures, topics, and products of the adaptation planning processes, and how these elements reflected the adaptation trajectories desired by respondents. I conducted twenty-six (n = 26) semi-structured interviews in June—November 2024. Interviews were primarily conducted over video calls, with two occurring in person, and were approximately one-hour in duration. This study used participation in just one planning process meeting as its inclusion criteria, although many respondents attended multiple meetings across the 2014-15 and 2022 planning processes. The names and affiliations of the participants were made publicly available following the planning initiatives as part of the published plan documents. These participant lists served as an initial contact pool of possible respondents. In some cases, respondents suggested other relevant interview participants who met the inclusion criteria.

Respondents included county, city, state, and Tribal nation employees, elected city representatives, as well as members of civic groups, non-profit employees, and employees of consulting companies contracted for the respective planning processes. The interviews followed a semi-structured

interview protocol which covered a respondent's background, the main activities of the planning process, the information used in planning, and respondent perceptions of the vulnerability contexts and climate hazards of the region and the planning processes' treatment of these. Interviews were recorded with a digital recorder and auto-transcribed using Trint software. I reviewed and edited the transcripts line-by-line using the original audio to ensure accuracy.

In addition to my interviews, I conducted a thematic analysis of the published plan documents created in the two adaptation planning processes. The 2014-15 planning process produced a plan published in 2015 which is referred to as the 2015 plan. The 2015 and 2022 plans had somewhat different intents and structures, as conveyed by the plan's respective authors and respondents who participated in both planning processes. The 2015 plan had a stronger focus on synthesizing existing climate science and projections covering the region to serve as the region's first comprehensive climate vulnerability assessment. The 2022 report summarizes this focus of the earlier effort, stating "The 2015 … Plan … leveraged existing regional climate change research and offered a summary of observed changes and projections for future climate change on the peninsula" (NODC, 2022, pg. 3). The 2022 plan states that it builds off the scientific basis of the 2015 plan and comparatively places increased focus on generating adaptation strategies that were framed as implementable and relevant to the plan's regional, multi-jurisdictional, scope. The plans also contain different levels of detail that capture their participatory processes. Participant comments and meeting minutes are included in the 2022 plan, but not the 2015 plan.

I also reviewed several supplementary documents associated with both plans, such as sea level rise projections, vulnerability and adaptation ranking exercises, individual meeting summaries, and a toolkit generated in the 2022 process to aid regional adaptation capacity building. Last, I undertook field visits, attended meetings in the region, and reviewed additional plans such as hazard and

comprehensive plans, all of which contributed to my understanding of this case and developing the descriptions I use to explain my findings. Two important instances of this were a focus group I hosted with the WSU Clallam County extension office staff and attending a climate resiliency summit hosted by the NODC. Both experiences provided an opportunity to discuss my preliminary findings with prior interview respondents. I was also able observe a participatory adaptation planning process similar to those in the 2014-15 and 2022 planning processes as part of the NODC summit, which helped further situate my analysis of the planning documents. These experiences furthered my understanding of the case, particularly in relation to broader regional narratives.

I employed a two-phase coding process that combined inductive and deductive coding strategies applied to both the primary interview and secondary planning document data (Saldaña, 2015). The primary and secondary data was coded in NVivo. Prior to coding, I developed preliminary themes reflective of my experiences during data collection, field visits, and transcript review (**Table 1, Left Column**). These represented general main codes, such as "planning process," "local context," and "adaptation." The formal coding process in NVivo explicated subcodes within these main codes (**Table 1, Left Column)**. The process of coding was iterative, and resulted in merging and collapsing codes, as appropriate. A "descriptive" coding strategy was first employed, which entails assigning labels to data passages describing their topic (Saldaña, 2015). Descriptive coding enabled me to break the data into recurring topics, sentiments, and descriptions that appeared across respondent's reflections and the planning documents. One example of a descriptive code was "process framing" (**Table 1**). This refers to data in which a respondent or a document describes the purpose or result of elements of the planning process. **Table 1** displays descriptive codes often applied in this "first round" of qualitative coding.

Table 1: List of frequent codes generated from the data collected.

Main Codes and Descriptive Codes (Indented)	Description
Adaptation	**How adaptation was defined and enacted**
Adaptation Alternatives	**Adaptation options not pursued or future interventions**
Adaptation Framing	**Participant's or processes' conceptualization of adaptation**
Adaptation Interventions	**Adopted policies**
Local Context	**Region specific and contextual elements of case**
Capacity and Barriers	**Factors limiting planning or implementation**
Vulnerability	**Conditions that heighten susceptibility to climate impacts**
Climate Impacts	**Inclusive of physical, financial, emotional, etc., as described by participants and plans**
Local Vulnerability Context	**Conditions that create heightened vulnerability locally**
Planning Process	**Descriptions of the planning processes**
Planning Activities	**What occurred in planning sessions**
Planning Alternatives	**Suggested alterations to sessions**
Planning Information	**What information was used in creating plans**
Planning Topics	**What was covered in adaptation plans and sessions**
Process Framing	**How participants and documents describe plan's focus and effectiveness**

Next, I re-coded the descriptively coded sections of text for their resonance with i) processes of co-production, and ii) prevailing or alternative sociotechnical imaginaries. I used both inductive and deductive approaches to generate these "second-round" coding categories, which became the pathways of co-production and alternative imaginaries detailed in the **Results** section.

I developed co-production codes following Jasanoff's notion of instruments of co-production (deductive) as well as other empirical applications of co-production that assume a similar approach (see Beck & Mahony, 2017; Lövbrand, 2011; Mahony & Hulme, 2018; Miller, 2004). These approaches analyze cases through the processes and encounters that enable co-production (Honeybun-Arnolda et al., 2024; Jasanoff, 2004). Taking up this approach, I re-coded my descriptively coded passages (**Table 2, Right Column**) for recurrent patterns and topics that demonstrated negotiation between scientific and social motivations and meaning-making within the adaptation planning process. In other words, examples of how both social and scientific practices *together* defined adaptation in this case were coded for in this "second round." To accomplish this, I developed co-production-process codes (**Table 2, Left Column**) using Jasanoff's (2004) instruments, co-production mechanisms discussed in STS literature (and cited above), knowledge of the STS instruments and pathways elaborated in **Chapter 2,** such as "boundaries," and my own interpretations of coproduction mechanisms that fit the descriptively coded data. I later re-coded certain instances into other co-production codes once each category's definition became stable, and consolidated redundant or underused co-production codes as needed. Not all data assigned a descriptive code were recoded with a coproduction-process code. The categories I developed do not mirror exactly those Jasanoff (2004) describes, nor was this the intent given the case-specific treatment that is required to illustrate mutual epistemic and normative ordering in particular contexts and moments (Jasanoff 2004, 2010). **Table 2** provides examples to highlight this process.

Table 2: List of second round co-production codes with examples of recoded descriptive passages.

Co-production-process Code	Example of Descriptively Coded Passage Assigned to Co-production Code
Boundary-Making: Explicit and implicit processes and decisions that defined what counted as adaptation in this case.	*"This topic was removed because it has been covered in other plans. Additionally, the evidence base to support climate migration is still being developed."* (NODC, 2022, p.16)
Mainstreaming: Attempts to integrate adaptation into the roles and responsibilities of local governments.	*"Why we're doing this is the regulations, trying to meet those benchmarks, meet those flow rates.…And the city of Port Angeles tries to meet and also enforces those regulations. So that's really the driver."* (Interview #3, 7-22-24)
Institutional Interactions: The ways social institutions, such as legal precedent and the local economy, were accommodated in adaptation planning process.	*"Our system of land use, planning and property ownership is incentivizing that [suburbanization], even though it's manifested through individual decision makers, both by the property owners and developers and city bureaucrats or county bureaucrats all in the system together."* (Interview #16, 9-3-24)

I used a similar approach to generate categories of sociotechnical imaginaries—a second feature of my **Results** (see **Table 3, left column**). Again, I re-coded descriptively coded passages from "round one" (**Table 1**) and identified passages that described or alluded to elements of a socio-technical future imaginary (**Table 3, Right Column**). This includes text that described how adaptation could be used to bring about societal transformations, what a transformational adaptation pathway could deliver or resemble, as well as critiques of other potential future trajectories and the transformations (or lack thereof) those futures imply. I consolidated the categories of alternative futures where appropriate as the category descriptions solidified. **Table 3** provides examples to highlight this process.

Table 3: List of second round sociotechnical imaginaries codes with examples of recoded descriptive passages.

Sociotechnical Imaginary Code	Example of Descriptively Coded Passage Assigned to Sociotechnical Imaginary Code
Urbanizing Vision: Desires for adaptation through affordable housing development, transportation, and a greater focus on equity and social vulnerability.	*"We got a bit of federal money for urban forestry, both in planting, but also … to kind of scope out how we are going to do this in a changing community, frankly, that's going to be more dense and require more forests to come down to make space for hopefully affordable and workforce housing."* (Interview # 9, 8-18-24)
Ecological Vision: Desires for nature-based adaptation solutions that recognizes more-than-human value.	*"I appreciate that we need the capacity, but I wonder if we can give priority to natural systems, it does multiple things more than just stormwater."* (NODC, 2022, pg. 133)
Regional Resilience Vision: Desires for adaptation rooted in robust local food systems, energy independence, and communal forms of organization.	*"This should be our top concern from the Clallam EDC perspective. We need to pursue our own energy generation so we are not completely reliant on BPA power where we are at the end of their distribution and transmission lines."* (NODC, 2022, pg. 101)

Both document coding and interview coding followed the same two-phase approach (Braun & Clarke, 2013). Critically assessing the case's planning documents offers greater insight into the organization and procedures of planning than what is accessible through interviews alone. The characteristics of the planning process available in the planning documents, such as the ways topics and concepts are formally given meaning and prioritized, are symptomatic of the tacit structuring of adaptation that this study attempts to illuminate and untangle.

Two key points of clarification are necessary. First, I am not seeking to stake any normative claim about the NODCs adaptation planning processes or its outcomes. This research project, its data collection protocols, and analysis were not structured to elicit findings on the efficacy of this adaptation plan or its potential alternative formations. Instead, I aimed to explore how the form

adaptation assumes gains legitimacy and stabilizes itself with and within a parallel social order through the processes of co-production. Second, I am not advancing the alternative visions as more representative or desirable. In calling attention to these alternatives, I do so to show their latency within a community and to highlight the possibilities for adaptation planning to more meaningfully engage with these alternative visions of the future and the transformational changes they suggest.

Results

My analysis revealed two findings about the NODC's regional adaptation planning initiative. Adaptation manifested as (i) **a predictive exercise and imaginary** amidst a broader set of (ii) **alternative imaginaries of adaptation**, which challenge the assumptions and social orders the predictive adaptation imaginary sustains.

The NODC's adaptation planning initiative was principally framed around identifying external sources of climate risk and change that pose challenges to the continuation of current social orders. I characterize this overarching position of the planning processes as predictive in both application and vision. Prediction describes the perspective of the process's generative actions, such as the plan's chosen focus areas and synthesis of regional climate projections. I also describe the planning process as reflecting a predictive future adaptation imaginary. This is the projection of a socioeconomic and sociotechnical future for the region that largely resembles the present. This section details how this predictive framing developed through three co-production mechanisms: adaptation boundary work, mainstreaming as a stabilizing force, and selective engagement with institutions.

Making Boundaries

The co-production of a predictive form of adaptation in this case transpires through negotiations over what adaptation planning should include and inspire in practice. Adaptation's subjective definition invites social norms and expectations into the meaning of adaptation and the ways it is pursued (Forsyth & McDermott, 2022; Paprocki, 2018). This is consistent with the concept of boundary work in STS. Boundary work refers to the specific practices of mobilizing and defining science and expertise in ways that maintain their perceived distinct and privileged epistemologies in relation to policy and politics. (Beck & Mahony, 2018; Gieryn, 1983; Lamont & Molnár, 2002).

In the NODC's case, the scope of adaptation was explicitly and tacitly remade to limit engagement with politically charged topics. Such topics unsettle an incremental trajectory by demanding transformational interventions and broaching radical changes that unsettle a predictive imaginary. In my interviews with planning participants and organizers, respondents expressed that adopting a more expansive and ambitious definition of adaptation risked getting nothing done at the expense of agreeable and accessible interventions: *"If you try to address everything, you can't do anything"* (Interview #22). Adaptation was bounded by a sense that politically charged or complex topics, such as those related to root causes of social vulnerability, threatened the credibility and efficacy of the planning process and required a scale of response beyond the reach of the plans creators and implementing actors. Relying on consensus to develop topic areas and interventions pushed the planning process to address *"low-hanging fruit"* (Interview #17), as one respondent described, or *"paths of least resistance"* (Interview #22) in the words of another, while avoiding topics that provoke conflicting values and worldviews. Streamlining adaptation to maintain its focus on apolitical and tractable concerns stemmed from a desire to create an adaptation plan that is implementable and agreeable. However, delineating adaptation as such helped secure the

predictive functions of the planning process by sidestepping interventions that necessitate transformational change.

Concrete examples demonstrate how boundary drawing served as a mechanism of co-production. One example is the exclusion of housing from planning efforts. Lack of adequate, affordable, housing in the region was raised as a key concern and source of vulnerability during the planning process. Despite housing ranking as a top concern among planning participants as well as in surveys of the greater population of the region, housing was not carried forward as a topic of adaptation intervention. The following quotation, by a planning participant with significant knowledge of the planning process, demonstrates this exclusion of housing:

> ***Respondent****: "I actually remember that being an issue with the NODC Climate Resilience Plan. Like, [name removed] really wanted to put boundaries on it, because housing is a big issue and [name removed] didn't want to go there."*
>
> ***Author****: "Do you know why that was? Or was it just because it felt like it would sidetrack the whole thing?"*
>
> ***Respondent****: "Yeah, I think it was because it would sidetrack the whole thing. And I know, I know, it's hard because all these things are interrelated. But at some point, you do have to draw your boundary. And you're like, this is what this plan is about, right?"* (Interview #26, 11-13-24).

I approach this instance and quote not as an aberration, but as a clear example of the mutability of adaptation's boundaries in practice. The organizers of the planning effort were acutely aware of the housing issue as a key concern of regional residents and recognized its relevance to climate vulnerability and adaptation. The move to exclude housing despite this emanated from a desire to

insulate the planning process from politicization and the expected derailment that would accompany it. The "there" referenced at the end of the second sentence of the quote distinguishes the rational-technical process of adaptation the planners hope to maintain and project from the realm of politics. The resulting boundary being negotiated between adaptation and everything else is then less an effort to sustain the privileged position of science, its epistemic practices, and the identities of those deemed credible. Rather, it serves to protect adaptation's image as a discrete practice immune from the contention and complexity that might overwhelm it.

A second example is the exclusion of the topic of "climate migrants and refugees" from policy development and discussion. The possibility for migration to the region as a result of climate-driven displacement and amenity-driven relocation frequently arose in interviews with participants. This topic was also raised by participants during the early phases of the planning process but was also excluded from further discussion. This quotation captures the complexity that the topic of climate migrants generates, drawing in related issues of housing, local inequality, and individuals' perspectives on a desirable future community:

> *"So, the inequity in resources, especially housing resources, it is a thing and it's [housing] not climate related, although... Like, a friend of mine that's a real-estate agent. She said that ten years ago about 20% of her clients were climate refugees and now it's 100%. But these are also people that can afford to move. So, there's going to be a lot of folks that can't afford to move ... We're already seeing the migrations moving northward from South and Central America, some of which is climate related. I mean, it's a lot of mismanagement of governments, but, you know, those folks just pack up what they can on their backs and they leave on foot. And I think we're going to be seeing that. Right now, we're just seeing people that can afford to move out of the California fire zones or*

> *out of the Florida hurricane zones. Texas everything zones. I did hear something really scary yesterday...And this is from [name removed] ... She says, I'm not naming names, but, you know, we have this Hood Canal Bridge that comes over to the Olympic Peninsula. And she says she knows folks that are actually going to be armed and not letting people across the bridge like when the quote migration happens, they're going to stop it there"* (Interview #11, 8-9-24).

This quote illustrates how salient social issues such as housing intersect and produce vulnerability in the eyes of respondents, while remaining distinct in the planning process. The respondent perceived future migrants as exacerbating an existing regional housing crunch, the first signs of which being visible with new arrivals from California or Texas. Fear and contention over migration is also clear, given the mentioned discussion, even if only hypothetical, of an armed resistance to climate migrants. Across my interview data, participants described the prospect of climate migration to the region variously as a presently occurring phenomenon, an inevitability, a source of risk and exacerbated vulnerability, and an inevitable impact of climate change that can be adapted to. Amidst these circulating opinions on the consequences of climate-driven relocation and the interwoven issues of housing, inequity, and changes to the region's character they bring forward, the planning process remains silent on the matter. Boundary drawing in this case allowed adaptation to sidestep complex topics that resist standardization and invite controversy, even as they anchor regional discourse around climate change, such as with migration.

These two decisions represent a broader desire to retain adaptation's neutrality through the laying of boundaries that insulate adaptation from contentious issues and corresponding actions. The topics of housing and migration appear frequently in my interview data, as well as in my review of additional plans and field visits. It is in their conspicuous and deliberate omission from the

planning process, despite their apparent relevance to participants and community members, that helps clearly illustrate the potential for boundary drawing to shape adaptation. These issues are positioned as better handled elsewhere, in the case of housing, or lacking sufficient scientific grounding for inclusion, in the case of migration, as justifications for their exclusion. And while neither issue is deemed insufficiently serious, the political gravity that these issues possess and the challenges they pose to maintaining adaptation's framing as a technical, rational, and scientifically grounded pursuit motivated their exclusion. As a result, the planning process develops and sustains a predictive future vision that does not need to contend with the transformational adaptation approaches or social changes that housing and migration propose.

Stabilization through Mainstreaming

Mainstreaming adaptation into government is another mechanism of co-production. Mainstreaming offers a pathway to adaptation's continuation and implementation. However, it gives primacy to the existing pathways of government action and vision as the only accessible avenues for adaptation to proceed. My findings show that the structure and resulting objectives of the regional adaptation initiative primarily target and implicate the region's governments and their respective offices and obligations. Area governments are key members of the NODC's member coalition, so seeing them prominently reflected in the plans participants and policies is not unexpected. In fact, the 2022 planning process was explicitly designed to support adaptation capacity and collaboration between regional governments. However, the assumption that adaptation is primarily the domain of the region's governments also structured adaptation's epistemic role to preferentially reflect the topics and means of action governmental actors' control and recognize. Mainstreaming as a co-production mechanism enabled the reproduction of existing regional government structures in adaptation's representation of the world. This allowed

adaptation to appeal to and leverage government's capacity but also engrained the constraints and omissions of a governmental perspective as well. The following quote describes a participant's perspective on the framing of adaptation through the structures and agency of local governments, highlighting the limitations this placed on adaptations ambition:

> *"It's much more complicated from a governmental standpoint to, sort of, do that kind of thing [make coastal land use decisions]. So, more, it's just about, like, 'OK, when we do build something new, or when we, you know, when we do make a transportation decision, when we, you know—um, when we're doing a redevelopment. Then we're making sure that we use culverts that are sized for future water flows, that we set the building back as far as we can on the property so that it buys as much time as possible if it starts to flood.' You know, those are the kinds of things that seem to be happening"* (Interview #17, 9-13-24).

This respondent remarks that the region's adaptation approach became synonymous with adjustments to inevitable future government decisions. Adaptation might include accommodating changing climatic conditions by resizing new culverts, as stated in the quote, but rarely would this extend to imagining altogether new venues of response or revised obligations in citizen-state-environment relations. This sentiment is further reflected in the model policies, potential funding streams, and recommended interventions of the case's adaptation plans. The respondent contrasts the ability for individuals to make more significant adaptation decisions, such as relocating away from the coast, with the forms of adaptation pursued by governments, which is framed as inherently reactionary. Through mainstreaming, the means and meaning of adaptation were restricted to the decisions and systems already under the government's umbrella.

Embedding the structure of governments in adaptation also extends to the creation of adaptation knowledge within the planning process. Below, another respondent recounts how lack of

representation in planning outside of government representatives led to the topic area of community vitality being dropped from the 2015 planning process' vulnerability assessment.

> *"We originally had it [community vitality topic] in the 2014 plan, there was a sort of social aspect to it that we had as a focus area, and just had a hard time getting traction on it. I think we had, when we had a workshop, you know, we ended up not getting... and it was probably somewhat the players that are around the table. You know, we probably didn't have enough of maybe the social health organizations around the table, so we didn't get a lot of detail on that. We had more the city, you know, public works folks, and those sorts of folks around the table. So yeah, we had it as an area and then ended up not really carrying it forward because we just didn't have much meat. We weren't able to generate a lot of meat in the, in the workshops. And I think that was probably just the focus of... who was there, who was around the table"* (Interview #12, 8-29-24).

In this example, community vitality topics were sidelined without a clear path forward through the operative channels of this adaptation arrangement. Constructing adaptation on top of existing practices and functions thus favored a predictive role for adaptation, in that adaptation is mobilized by modifying and anticipating challenges to present governmental obligations as well as envisioning these into the future. At the same time, this reduced the potential for adaptation to serve as a venue for novel imaginations of the region's future and the corresponding alterations in relationships between communities and the state such imaginaries invoke.

Institutional Frames

As was illustrated in the role of adaptation mainstreaming, the functions of government as a purveyor of public services invite the inclusion of adaptation as a logical extension. It is also the

broader functions of government as an institution ordering the divisions of social life, one granted the powers of recognition and definition that are so central to co-production, that influences the creation of adaptation knowledge and its underwriting of the government's worldly perspective (Jasanoff, 1990, Lynch, 2004 in Jasanoff, 2004; Irwin 2017). Co-production as an analytical lens prompts a deeper examination of institutional integration in this regard, accepting the influence of institutions in how they apply knowledge and frame problems visibly, but also accounting for how their structure loops back to inform the production of knowledge and the discourses through which phenomenon are described (Jasanoff, 2004, 2010; Pickett et al., 2020). My findings indicate how a broader swath of social institutions beyond government shape adaptation in this cyclical sense more subtly. The following quotes illustrates how established legal precedents protecting individual property rights, themselves co-produced institutions reflecting social norms and expectations, cast a shadow over the possibilities for climate adaptation.

> *"But when it really gets down to it, though it's a balance, because people will push back. There are politics involved because there are property rights, interests, that ... People have this idea that they should be able to do on their property, whether it's on the shoreline or not. And so that's what makes it tricky I think, on the big scale...Until we sort of collectively think about things differently. We are always going to have that struggle"* (Interview #10, 8-22-24).

> *"This question about, like, 'OK, like, should people be allowed to build in these places that are—if they're not a hazard zone now, they definitely will be in the future?' But it's really just the question being, 'When?' Right? Like, what, what—you know, how far do local governments get to go in, sort of, like, making those decisions about where development should happen and where it shouldn't? Especially, you know, it's a—for some people, the answer is obvious, but for me, it's not"* (Interview #17, 9-13-24).

Coastal properties vulnerable to sea level rise, particularly those situated on retreating bluffs, capture the attention of planning participants and local officials engaged in adaptation, as seen above. Co-production helps explain the dichotomy between what is discussed casually but obscured within the formal planning process. The imprint of private property and legal institutions on the epistemic practices of planning reflexively partition adaptation from formally engaging in the thorny issues of takings and costal retreat. Property rights delimit adaptations available forms in effect, making certain interventions or land restrictions inaccessible. This relationship loops back to the production of adaptation knowledge within the planning process as a co-production mechanism, reducing discussion of the physical processes and policy mechanisms most relevant to home flood risk. Seeing private property as enduring largely eliminated adaptation interventions that implicate private lands within the formal planning process, even as planning participants and area residents recognize their acute exposure.

Property and the legal institutions that protect its status in social life are a particularly salient example of institutions inflecting adaptation, but legal precedent is not unique in this role. Institutions also shaped how adaptation and the plans elements were interpreted and implemented, functioning as a co-productive mechanism outside of the confines of the formal planning process. While I underscore that this study was not designed to assess the implementation or success of these plans, respondents nevertheless stressed that the conceptualizations and policies spelled out in the assessed plans were subject to further mediation through social institutions, beyond their initial crafting and deliberation in the planning process. Respondents stated that institutional decision making was vital to the interpretation and implementation of the advanced adaptation priorities, or stood in as barriers to this, working to shape adaptation's meaning and scope in practice just as in the planning process itself. A key example of this is the allocation of funding

and staff capacity to adaptation. Many of the plan's proposed actions rely on successfully securing funding and resource investment, both from reallocation on a local level and from additional funding sources, such as federal grants. As result, the realization of the plan's objectives was subject to prioritization by those tasked with carrying it out, such as local government agencies or private industry. One respondent described the importance, yet relative lack of consideration, for the intervening processes that lead from a plan to its material effects.

> *"If we're thinking that the point of the planning process is to effect change on a local, regional or national scale then that speaks to all of the other considerations that need to be front ended as a part of the planning process"* (Interview #1, 7-3-24)

This respondent stressed that adaptation planning practices must acknowledge and proactively account for the ways social institutions will interpret and selectively implement a plan's language or vision. In their perspective, the planning process is only one piece of the making of adaptation, and that numerous institutional hurdles and filters further shape its meaning in how a plan is and is not put into practice. In this way, the co-production of adaptation was not restricted to the planning process, but continues in how the knowledge a plan puts forward is interpreted and filtered through institutional channels.

Overall, the processes of co-production detailed in this section connected the technical and scientific elements of adaptation planning as a site of knowledge and future making to the institutions, conventions, and expectations that undergird present social life. That is, the sociotechnical arrangement underpinning the NODC's adaptation initiative yielded a rendering of adaptation that stabilizes present social orders. This occurred through the melding of the institutions and expectations that structure society into the planning process. The epistemic work of the planning process then further preserves and performs these normative structures, cyclically

stabilizing and extending a predictive imaginary of adaptation and the future. Additionally, social institutions like government and industry were often the designated implementers tasked with making the changes spelled out in the adaptation plans, making their adherence and interpretation of the plans in practice a key step in producing the effects of the plans.

Sociotechnical Adaptation Imaginaries

I now highlight alternative imaginaries of adaptation that diverge from and contest the identified predictive imaginary. These alternative imaginaries are narrative compositions drawn from respondents and the planning documents. These include an urbanizing vision (which relates adaptation to densification and interconnection within the region's cities), an ecologically-oriented future (adaptation as a more-than-human endeavor) and independent local food and energy systems (self-determination and resilience through community connectivity).

Urbanizing vision

Some respondents shared a vision for an urbanizing North Olympic region characterized by increased affordable housing development, improved public transit, and stronger restrictions on sprawl as a pathway to a more equitable and resilient future. This imaginary foregrounds connections between social issues like housing, healthcare access, and broader inequality to climate vulnerability. The urbanizing imaginary engages adaptation and mitigation jointly, a pattern visible in its emphasis on transportation sector adaptation strategies. Urbanization's proponents seek to make the area more resilient and sustainable through transformational changes to the region's spatial organization, while setting aside concerns that densification and multimodal interconnection undermine the region's identity as largely rural, with quaint cities. Respondents articulating this vision assess the socioeconomic character of the region as already and irreversibly in flux, moving from a remote outpost and resource-based economy to a desirable destination for

travel and relocation with widening socioeconomic inequality. The vision acknowledges these challenges to the region's communities and their compounding effects on regional climate vulnerability. The following quotes and adaptation plan excerpts lay out salient elements of the urbanizing vision and underscore its orientation towards naming and navigating change through adaptation.

> *"We need to make the urban more urban and actually make the rural more rural... It's going to look and feel like parts of Kitsap County or the suburban parts of King County or Pierce County. It's not going to be the desirable place that anyone moved here or anyone who grew up here wants to live in"* (Interview #3, 7-13-24).

> *"Prior to COVID, this area was "found" for its natural beauty and other attractions. How to accommodate for inevitable growth?"* (NODC, 2022, pg. 47).

> *"Port Townsend is starting to have signs as a destination for climate refugees, exacerbating housing crunch and wealth and income inequality. All point to the need to adapt land use to actual urban, walkable, non-transportation-dependent urban uses and protect resource and agriculture uses"* (NODC, 2022, pg. 46).

The urbanizing imaginary positions current development trends as leading to a region akin to its Puget Sound neighbors, replete with undesirable traffic, unaffordability, and fragmented natural landscapes. New residents and suburbanizing pressures are perceived as inevitable, necessitating an adaptation pathway for the region that contends with these changes and their exacerbation of climate vulnerability. Regional growth is thus a risk and potential solution to climate change's impacts and the drivers of vulnerability in the region. Urbanization suggests harnessing and shaping community growth in new directions and forms that yield reduced climate risk. The

adaptation vision of the urbanizing imaginary does this by foregrounding adaptation strategies that straddle the interconnected challenges of mitigation, adaptation, and inequality through transformational changes to the urban form of the region's cities, as seen in the final quote above. Respondents also recognized that transformation of the region's spatial organization and development patterns requires corresponding changes to social systems and assumptions that favor current practices.

> *"And honestly, if I were in charge of the world, we need to blow up the system that we've got and completely create a new one. But that isn't going to happen tomorrow. It'll happen in incremental ways. But, you know, the housing crisis here is just because people can't afford to live here. Can't get work at the restaurants, can't staff their restaurants. So, it's a very much of an immediate need that is completely not thought of in a climate change way"* (Interview # 10, 8-22-24).

The quote illustrates how expanding the technical forms and venues of adaptation to include strategies such as modifying the incentives and assumptions that drive current development will also require political change. The urbanizing imaginary acknowledges that its vision for transformational adaptation will likely need corresponding socio-political reform to achieve equitable climate resilience. The prospect of merely discarding current forms of government and institutional orders, as the respondent suggests, does not suggest a fully-fledged alternative. However, this respondent's remarks sufficiently capture the broader belief that realizing equitable and sufficient adaptation requires sociopolitical revision beyond tinkering within the technical aspects of the planning process or adaptation interventions on their own.

Ecological vision

Respondents shared elements of an imaginary characterized by nature-based adaptation and a stronger social value placed on the region's unique ecological systems. This **ecological imaginary** proposes a vision for adaptation which restores and enhances the natural functions of socio-ecological systems that lend resilience. Examples of this are controlling invasive species for wildfire risk reduction, protecting forests for water storage, and managing watersheds and floodplains for both salmon recovery and flood risk mitigation. It de-centers the socioeconomic motivations behind other adaptation visions to embrace a more-than-human approach. For example, one respondent commented:

> *"So not being able to make money from what we do but protecting ... functions on the landscape that provide incomes at a much broader and distributed scale... Not on water storage projects for municipalities or mapping of where development should be with respect to sea level rise. All of those are important…But they're all about development and specific industries and not about ecosystems"* (Interview #8, 8-9-24).

This respondent stresses the tension between what they view as the economic underpinnings of the region's dominant adaptation discourse, and their desire for adaptation to be more directly linked to preserving and acknowledging ecosystem services and the innate value of the natural world. For respondents promoting an ecological vision and adaptation trajectory, ecosystems supersede (and sustain) regional economic activity, and that this ordering should be reflected in adaptation planning priorities. The following quotes make the linkage between economic reprioritization and an ecological imaginary more explicit.

> *"But it's got to be normal to see that the planet does have limits. It's normal to understand that these days and that growth isn't what we thought it meant"* (Interview #6, 7-31-24).

> *"The more we can protect the forest from the sprawling development that we see around Sequim...And keep the forest functioning for wildlife, for water storage, for biodiversity, and for timber, the better off this whole place will be in terms of its ability to sustain healthy ecosystems, healthy life, and support the people that are here with the clean water and clean air and wildlife"* (Interview #7, 8-7-24).

These quotes highlight the ecological imaginary's disillusionment with growth, both in the abstract and with the specific example of sprawl impinging on forests and impacting their life sustaining functions. The ecological imaginary links economic and growth agendas to ecological collapse and resulting climate vulnerability. The ecological vision casts the tools and technology of adaptation as properties of the ecosystems and natural spaces that climate change and unfettered growth have imperiled. Adaptation in this future imaginary is thus a process of removing constraints and pressures, economic and otherwise, that hinder innate ecosystem service functions, rather than introducing novel technologies in the name of adaptation. Proponents of the ecological imaginary view adaptation interventions like new reservoirs, net-pen fish farming, or ocean carbon dioxide removal skeptically and as posing further potential risks to ecosystems while allowing the root issue of growth to continue. A final pair of examples reflects the ecological imaginary's distrust of technical adaptation interventions in its conception of a desirable future.

> *"I'm all for this [promoting local food systems and fisheries], EXCEPT the inclusion of farming fish in pens in the Salish Sea"* (NODC, 2022, pg. 122).

> *"…It just doesn't make sense to destroy ecosystems like we're getting asked now on the North Olympic Peninsula to really entertain the idea of marine carbon dioxide removal, which basically is, you know, grinding up mountains and scattering rock powder everywhere"* (Interview # 6, 7-31-24).

The adopted adaptation plans include overtures to the ecological vision such as nature-based solutions for shoreline armoring or water storage, or the example of fish farming in the first quote. However, these solutions are viewed as being pursued instrumentally, serving the continuation of practices that are causes of socio-ecological harm and vulnerability. An ecological vision contends that adaptation should not be reducible to human vulnerability and human systems. Rather, adaptation and the corresponding technical, political, and social interventions it triggers, should reflect a recommitment to more than human flourishing as its orienting mission.

Regional resilience vision

A final alternative imaginary depicts adaptation organized around the region's characteristics of self-reliance and independence. The regional resilience imaginary embraces and leverages elements of the unique history, socioeconomic and geographic contexts, and social fabric of the region as its inspiration. This imaginary is characterized by an adaptation pathway under which the region becomes more independent yet grows further interconnected as a set of communities. Foremost among these are adaptation strategies that support robust local food and energy systems.

Local food production was recognized in the NODC's planning efforts as a key component of regional climate resilience. However, respondents and plan comments indicated a desire to link adaptation and the region's prominent local food systems further. Respondents described a desirable and resilient future for the region characterized by greater regional food production and

distribution, resulting in strengthened community networks. The region experienced severe supply chain disruptions during COVID due to its remote location. This experience emphasized the underlying risks of a centralized food system and the importance of local food production, especially in times of crisis. Proponents of the regional resilience imaginary advocate for stronger protections for the region's farms, farmland, and food producers as a means of adaptation. They contend that local food networks are supportive of broader regional resilience, adaptive capacity, and form the backbone of a more equitable economy, in addition to supplying food. Proponents of this vision also express added layers of reciprocity and mutual aid that exist through the regional resilience imaginary's invigorated food networks. The following two quotes from a single interview highlight the connections between localized networks of food and care.

> *"The other, I think, adaptive plan, is for everyone to learn how to grow their own food or at least some part of it. And that could even be in apartment houses in a window box. And during World War Two... It was, I think 35% of all of the produce grown in the United States was grown in what they called victory gardens. Just everybody had to band together for the war effort. And so the victory gardens were people's yards. And I think this really needs to happen, you know, in our schools, is that kids need to know how to grow food"* (Interview #11 8-13-24).

> *"Well, you know, like I said, it goes back to that food, water and shelter... Food resiliency. How do we support the local farmers? How do we encourage people to quit buying crap at Walmart? You know it's like, like the whole like support your local economy. You know, that that benefits everyone. And, and then how do we support the people that are like the unhoused folks? Like the food...our county serves unbelievable numbers of people who are food insecure. It just floors me how many families visit the Foodbank. And that's hard to, you know,*

it could be that those families are food insecure, but they're relying on family or friends to support them, too, that they don't show up at the food banks" (Interview# 11, 8-13-24).

The respondent links the region's capacity to grow and supply food to its greater capacity to weather disruptions and climate impacts. The regional resilience imaginary depicts a future region that is untethered from precarious food distribution networks, as well as the negative externalities that such economic models sustain. This is made even clearer in the following plan comments regarding the broader community functions of a localized food system in the region.

"The purpose of a local food system is to provide food to the population. Framing potential solutions in terms of economic viability may include an assumption that the dominant economic system we currently live with will continue. This could impede innovative solutions that are not currently economically viable but might be needed in some future scenarios" (NODC, 2022, pg. 121).

"We should be promoting public support of our local/regional food system. It is a vital public good" (NODC, 2022, pg. 122).

The first comment contends that measuring an adaptation strategy's economic viability to assess its worthiness does not apply a neutral yardstick, such as a challenge to subsidies to the local food systems as an adaptation policy. For respondents and participants that engage the regional resilience imaginary, the full value of a localized food system is not captured in its profit-making ability or properly recognized in a market-based society that overlooks the non-monetary values of a localized food system. Like the ecological imaginary example, the food networks of the regional resilience imaginary challenge prevailing conceptions of value in operating economic orders. A regional resilience imaginary contends that reimagining food distribution as a means of

adaptation can enact new networks of care and connection. The shift to a localized and decoupled food system would in turn catalyze a more resilient community.

The regional resilience imaginary's desires for local energy generation and distribution systems mirror the sentiments surrounding localized food systems. Planning participants envision creating a regional energy system that is less dependent on vulnerable distribution lines and distant powerful suppliers. In its place, the regional resilience imaginary creates a system of distributed local energy production that enables greater regional self-sufficiency. Similar to the region's experiences with disrupted food supplies, frequent, widespread, and long-duration power outages are common in the North Olympic region, especially during winter storms. This is due to the region's location at the end of distribution lines and the current transmission infrastructure's single line service through large remote forested spans. As a result, building region-wide energy resilience was a central topic in the NODC's adaptation planning processes. Respondents and plan comments raised topics such as community solar and storage, wave and tidal energy, and ending the region's reliance on Bonneville power, which supplies the region's electricity. The following excerpted comments from the 2022 planning effort illustrate the interconnections between food, energy, and resilience in the region's adaptation discourse, in addition to the inherent linkage between notions of technical and social progress:

> *"Resilience and resiliency are important terms that often go undefined. Are we planning for "preventive" resilience in an effort to maintain the current energy system? Or are we planning for adaptive resilience that will allow us to still have a functioning food system, for example, when other systems such as our global energy system collapses?"* (NODC, 2022, pg. 101).

> *"Intentional communities (village based), off grid, with central communal alternative energy"* (NODC, 2022, pg. 61).

"Peninsula - island potentially if cut off after an extreme event. Self-resilience after these events to survive" (NODC, 2022, pg. 51).

The first quote surfaces a question of what adaptation should mean, technically and socially. It captures the regional resilience imaginary's embrace of transformational change as a response to this. Rather than build resilience for fragile current distributed systems, a regional resilience vision centers adaptation around self-sufficiency and self-determination through new localized food and energy systems. Taken together, the three comments show how this narrative pairs the physical and technical decoupling from centralized systems as a means of resilience building to corresponding reforms of social values and forms of political organization that similarly promote regional independence and community connection. The final comments go so far as to suggest that the resilient regional energy infrastructures of the future should underpin new "intentional" and "communal" forms of community organization, melding social and technical future desires.

Overall, the alternative sociotechnical imaginaries of urbanization, ecology, and regional resilience diverge from the prevailing incremental or "predictive" vision. They foreground transformations not only in the material and technical aspects of adaptation, but within the region's broader political and social organization. These alternative imaginaries conceive of adaptation in forms that go "beyond technical fixes" that sustain current arrangements (Nightingale et al., 2020). Each vision points to distinct political and social revisions that are co-produced with the imagined policies and technologies of adaptation. These alternative imaginaries call for more creative and expansive forms of adaptation in daily life, and in so doing, resurface the co-production forces that may limit adaptation from accessing these alternative pathways. In the following section, I turn to discussing how combining contributions from critical adaptation studies with these STS concepts can help explain the narrowing of possible transformational adaptation futures.

Discussion

In "Ordering knowledge, ordering society" Jasanoff (2004) closes their discussion of co-production by theorizing its potential, offering two key turns of phrase to link the preceding **Results** sections and pave a path forward to leverage its insights. Jasanoff states:

> "To the extent that co-production makes apparent deep cultural regularities, to the extent that it explains the contingency or durability of particular socio-technical formations, it also allows us to imagine the pathways by which change could conceivably occur. It illuminates, in this way, new possibilities for human development" (Jasanoff, 2004, pg. 42).

Applied to this case, Jasanoff's notion of *deep regularities* points to the ingrained institutions, subjective categories, and forms of social organization that both gave shape to, and are sustained by, adaptation in the NODC's planning processes. One can also recognize the emergent adaptation arrangement of this case as deeply regular, in line with adaptation writ large and the predominantly incremental forms it often takes (Berrang-Ford et al., 2021). Critical adaptation literature indicates that transformational adaptation which disrupts both incremental responses and the durable social structures that produce vulnerability is an urgent necessity, should we hope to mitigate the worst harms of climate change (Leichenko & O'Brien, 2024). However, these desired and needed forms of adaptation are also shown to be elusive (Nightingale et al., 2022; Scoones et al., 2020). Probing why adaptation regularly follows this pattern towards incrementalism is of critical importance to adaptation studies, and a question relevant for STS (Beck et al., 2024; Jasanoff, 2021a). As a field, adaptation studies forcefully demonstrates the insufficiencies or abject harms of incremental adaptation while also describing how alternative, transformational, arrangements could lead to better outcomes (Bertana et al., 2022; Eriksen et al., 2021; Forsyth & McDermott, 2022; Thomas et al., 2019). For example, Eriksen et al.'s (2021) synthesis of empirical adaptation evaluations

details the recurrent negative consequences of adaptation realized as incremental reforms, finding that adaptation absent transformational change risks compounding harms for society's most vulnerable (Eriksen et al., 2021). Yet, even where the field aligns behind a call for transformational adaptation, navigating the terrain towards such desired futures remains a challenge (Bentz et al., 2022; Few et al., 2017). Critical adaptation studies is not blind to this and has yielded numerous theoretical and empirical entries that probe this exact question. For example, Pelling et al., (2015) and O'Brien et al., (2014) narrate the pathways for possible transformation, and in doing so, note where social inertia and preferences across adaptation's political, personal, and technical activity spaces can obstruct transformations (O'Brien et al., 2014; Pelling et al., 2015). Similarly, Nightingale et al., (2020) focus on "moments of concealment" within conventional adaptation approaches, like the field's focus on hazard exposure and severity, that tacitly steer adaptation practices away from transformational framings or future visions (Nightingale et al., 2020). Recently, Shah et al., (2025) propose that the recurrence of maladaptation, or adaptation practices that exacerbate vulnerability, is symptomatic of adaptation being produced within and taking the shape of an unjust society, rather than flowing from ill-conceived planning practices (Shah et al., 2025). These examples, and wider work in critical adaptation studies, show the adaptation field's attention to what Jasanoff terms above as the "durable sociotechnical formations" impinging on the "new possibilities for human development" that transformation proposes (Jasanoff, 2004). However, this literature still consciously struggles to show how the former propagates through adaptation to inhibit the latter in practice (Feola, 2015; Vogel & O'Brien, 2022). As I have shown in my results, STS and concepts like co-production further enables critical appraisals of adaptation in moving beyond naming the durable social roadblocks to transformation to narrate how these institutions and assumptions are actively enrolled into the making of adaptation and the future.

The promise of STS for critical inquiries into the transformational adaptation gap is further exemplified in work that reconciles the respective field's conceptualizations of the future. Increasingly, adaptation theory and practice has engaged the future as an object of inquiry and an intervention space open to a greater diversity of possible adaptation pathways (Bai et al., 2016; Cork et al., 2023; Kanarp et al., 2025; Kenis & Mathijs, 2014). This is particularly visible in planning methodologies that frame adaptation as an act of normative future-making, such as in scenario-based planning (Comelli et al., 2024; Nalau & Cobb, 2022; Pelling et al., 2024). Others in the field broaden this framing of adaptation beyond such explicit futures-based planning efforts, characterizing adaptation, generally, as a practice in active future-making (Bauriedl & Müller-Mahn, 2018; de Jong et al., 2024). Engaging the future in this way nominally frees adaptation from retaining the assumptions and structures that might limit its realization of possible transformational forms. Yet, the insights of STS and the concepts used in this Chapter demonstrate that visions of possible futures do not emerge as acontextual fabrications, nor do they circulate on neutral ground (Konrad et al., 2017; Jasanoff & Kim, 2015; Milkoreit, 2017). Imaginaries of the future and the possibilities for adaptation within them are themselves co-produced with prevailing social orders, desires, and epistemic practices (Jasanoff, 2020; Oomen et al., 2022). STS scholarship offers vital insight for adaptation in its hopes of realizing more transformational outcomes by operationalizing the future. STS takes seriously the multiplicity of possible adaptation futures, while clarifying that only certain imaginaries of adaptation may be rendered visible, legitimate, or actionable (Broto et al., 2024; Diezmartínez et al., 2025). To advance transformations, contributions from STS reflect the need to contend with the forces that prefigure and constrict what adaptation futures get imagined, and what imaginaries are rendered powerful.

Innovative scholarship within adaptation studies that operationalizes STS's critical and performative understanding of the future reveals future imaginaries do more than simply describe possibilities for adaptations pathways: They actively configure perceptions of adaptation's attainable and preferred forms, and work in the present to realize certain future outcomes. Paprocki (2022a) shows how agrarian livelihoods and adaptation imaginaries envisioning their continuity are rendered unviable under powerful state-circulated visions of climate futures in Bangladesh. State practices of rural dispossession and urbanization are demonstrated as co-producing a prevailing future imaginary that positions adaptation as necessitating rural abandonment (Paprocki, 2018, 2022a). Wakefield (2025) discusses the routinely conservative outcomes of scenario-based urban planning that ostensibly seek to generate transformational adaptation planning visions. Wakefield argues that while such practices mobilize imaginaries, they also "severely encage" them by operating with the assumption that any imagined future carries forward the forms and functions of the city at present (Wakefield, 2025, pg. 93). Finally, Forsyth (2022) applies the concept of technologies of futuring, or the processes by which social values are embedded in projections of the future, to distinguish between three transformational visions for adaptation in Nepal. Forsyth proposes that by starting with different implicit assumptions about the nature of risk and social agency in the face of environmental change, the imaginaries of needed and proper adaptation diverge starkly (Forsyth, 2022). These examples demonstrate where the processes of co-production that shape deeply regular and insufficient forms of adaptation are also at work in creating and constraining the transformational visions of adaptation that critical scholars and practitioners strive to realize. The addition of STS's perspective, as seen in these examples, shows that enrolling the future as a *tabula rasa* for creative forms of adaptation is a mirage, and

that realizing transformational adaptation futures also requires disrupting the regularizing tendencies that fix adaptation's future potentialities.

I employed co-production and sociotechnical imaginaries concepts in my analysis to show how visions of adaptation's possible forms and the processes that construct them interact and operate relationally. My results do more than document the presence of a dominant incremental and transformational alternative imaginaries. The processes that construct and stabilize the predictive imaginary are also visibly at work in precluding the legitimation of alternative adaptation trajectories.

The processes of boundary making that restricted the inclusion of contentious topics in adaptation are active in the foreclosure of the urbanization imaginary from greater integration within the planning process as well. Excluding topics of housing and migration in defining what adaptation should be in practice also closed down adaptation planning as a venue for imagining new urban and community forms that address these topics. As such, boundary drawing extends to the imaginative landscape of adaptation in addition to adaptation's epistemic and ontological politics (Jasanoff & Simmet, 2021; Milkoreit, 2017). Boundary drawing effectively divorces adaptation from the processes through which community structures are seen as already evolving and could be imagined as evolving differently. In short, boundary drawing not only acted to separate adaptation from contentious topics; in doing so it also separated adaptation from a landscape of alternative contested futures that originate in solutions to these same issues.

From the viewpoint of the ecological imaginary, the predictive form of adaptation forgoes an opportunity for a wider retooling of societal values by embedding and protecting the same misaligned virtues of growth and accumulation within adaptation that imperil natural spaces and their life sustaining functions. However, the institutional inertia of growth as imperative within

adaptation overrides the ecological imaginary's alternative convictions. The co-production of adaptation with economic institutions helps explain why more-than-human and de-growth aspirations for adaptation were illegible to or excluded from the workings of the planning process. Ecosystem services are present in the adaptation planning process but are considered in service and subordinate to the embedded economic ordering of society and by extension, the predictive vision's ordering of the future. By tacitly conforming to institutional perspectives and extending these to the future, such as with the privileged continuation of a capitalist economy, the planning process subverts alternative adaptation imaginaries that diverge from this ordering of society.

Finally, the relationship between the regional resilience vision and the predictive imaginary of the planning process demonstrates how co-production through governmental mainstreaming restricts the presence of additional alternative future imaginaries. Taken to its most radical endpoint, the regional resilience imaginary suggests selectively severing ties with broader centralized systems. This intentional "islanding" echoes other alternative imaginaries that critical geography and urban studies scholars have characterized in places like Miami, Europe, and the Pacific (Gugganig & and Klimburg-Witjes, 2021; Weatherill, 2023; Wakefield, 2025). These imaginaries entertain novel forms of government, economic, and social organization through the autonomy that localized systems of production enable. By foregrounding cooperative governance and distributed infrastructures, the regional resilience imaginary breaks with the mainstreaming of adaptation into established government channels and means of organization. Simultaneously, mainstreaming as a form of co-production subverted the regional resilience imaginary through its performance of the continuation of existing forms of community organization and recognition as delivering resilience now and into the future.

Uniting the STS concepts of co-production and future imaginaries enables an examination of how the contingent construction of an adaptation arrangement comes to frame the future at the expense of other possibilities. In their case study of future-oriented forest planning in Sweden, Andersson and Westholm term a similar phenomenon as "closing the future" (Andersson & Westholm, 2019). The authors demonstrate how the initiative developed a consensus future vision through the alignment of industry interests and scientific representation, eliminating the potential for exploring diverse future scenarios as initially intended. The NODC case demonstrates a similar pattern. Applying the notion of adaptation as future-making discussed above, the creation of the predictive future vision throughout the NODC's planning process not only contributes to a landscape of possible futures, but works at critical junctures within the planning process to close down the horizon of alternative futures for adaptation as well. Together, co-production and STI concepts prove immensely valuable for the adaptation studies field. They contend that realizing transformation and closing the transformational adaptation gap is not only about imagining the future differently, but also, crucially, about identifying the specific ways durable social institutions are embedded in adaptation, making transformational adaptation futures inaccessible.

Limitations

Despite their stated advantages, case studies have notable limitations. Case studies embrace multiple present factors to explore a phenomenon in situ, but this limits the replicability of case studies. For example, a similar review of the NODC's adaptation planning process in the future would likely require interviewing different respondents and would occur alongside different current global and regional events, factors that may alter a hypothetical replication study's conclusion (Yin, 2009). Case study findings are also not easily generalized. The contextual integration that a case study enables hampers attempts to broadly explain similar phenomenon in

different settings through the explanation offered by the case study (Yin, 2013). These limitations are valid but can misconstrue the role of the case study in knowledge and theory development. I, too, would caution against attempts to generalize from the specific mechanisms and observations seen in this case, noting the importance of a case's context in the appearance and implications of co-production. Case studies do, however, allow for analytical or conceptual generalization. This means that a case's proposed explanation of its observed phenomenon and its demonstration (or contradiction) of theory are its generalizable findings, rather than a statistical claim about the population or additional cases (Polit & Beck, 2010; Yin, 2009). This means that a well-designed case study can offer lessons about additional cases, such as the relevance of co-production in shaping adaptation. Case studies seeking to allow this type of generalizability should be firmly situated in existing literature, noting how a case's proposed theory of change and its ultimate observations exhibit or break from relevant theory (Cassell et al., 2004; Gomm et al., 2009).

Case studies are also often critiqued for a lack of internal validity, in addition to the challenges of external validity just mentioned. In this case, questions of internal validity rest on whether the co-production mechanisms I propose are truly and strongly related to the observed outcomes. I address this limitation in a few ways. First, this internal validity threshold is most relevant to explanatory case studies that attempt to develop a clear cause and effect relationship (Yin, 2013). My approach to this case is more reflective of a descriptive case study (Yin, 2009). I target my analysis on uncovering and describing features of the case that demonstrate co-production's presence in adaptation planning, as well as characterizing the imaginative form of the resulting plan amidst alternative imaginaries. While I do attempt to situate the places and patterns of co-production I observe within the resulting features of the plan, I avoid leveling claims regarding the direct causal relationship between these elements of the case, as other factors I note throughout similarly

influence the resulting form of adaptation seen in this case. Secondly, even as I attempt to sidestep the challenges of an explanatory case study, I do employ strategies such as triangulation, pattern matching, and member checking to increase the credibility of my findings. For example, I incorporated multiple data sources in my use of interviews and planning documents to produce a more holistic description of the case. Additionally, I conducted a focus group and held conversations with respondents during field visits that allowed me to test my initial findings regarding the case. These components of this case study bolster its validity in addition to aiding in my own understanding of the case's details and the broader regional context it resides in.

Conclusion

This Chapter has illustrated how a regional climate adaptation planning initiative exhibits processes of co-production that stabilize existing sociotechnical orders while marginalizing more transformative possibilities. Through an STS-informed case study of the North Olympic Peninsula's adaptation initiative, I demonstrated how adaptation is rendered as a predictive exercise anchored to the continuation of present governance structures, institutions, and regional identities. At the same time, this study surfaced a set of alternative sociotechnical imaginaries that depart from the continuity of the dominant adaptation imaginary and reflect more expansive conceptions of resilience.

Bridging critical adaptation studies with the analytical insights of STS offers a valuable perspective for examining why adaptation planning so often defaults to conservative trajectories, even in contexts of apparent or desired change. My analysis shows not only how adaptation reflects dominant social and epistemic orders, but how planning processes actively reproduce these. In doing so, I reveal key procedural features of planning that close down the future to transformational

change and that may serve as opportunities for cultivating more transformational engagements with adaptation futures.

Taking up this last point, I note that despite co-production's inescapability, the planning outcomes I describe are not inevitable. As a practical matter, this Chapter's findings suggest that adaptation planning practices should more openly acknowledge, or even foreground the expectation, that influential social forces will come to bear on the workings and meanings of adaptation initiatives. As observed in this case study, there was no lack of ambition for impactful or transformational adaptation. Rather, the ultimate vision for adaptation was constrained through its retrofitting into established social orders. Accounting for this starts with added reflexivity for the ways theoretical elements of adaptation are practically defined in planning. This also requires recognizing the ways everyday practices and social structures like legal codes, economic prioritization, and financial systems and constraints will prefigure adaptations conceptualization and later implementation. While these measures may seem disproportionate to counter the influence of deeply seated social and cultural practices, planning with such considerations top of mind takes to heart a central consideration of co-production, naming and reckoning with the broader expanse of tacit forces that shape socio-technical arrangements.

At the same time, the study points to opportunities for imagining new targets and venues for adaptation that may avoid these constraining dynamics. A number of participants pondered how the plan's proposed actions might be achieved in the face of limited resources and weak institutional buy-in. These reflections signal both a commitment to adaptation and an awareness for the durable systemic barriers that currently limit its ambition and reach. Rather than channeling this energy into efforts that remain tied to delivering adaptation through existing arrangements, planners and decision makers could direct it toward planning communities and systems that are

themselves capable of delivering adaptation's desired benefits and outcomes locally. My suggestion is not simply to solve planning's shortcoming through a more ambitious planning endeavor. Instead, this case presents empirical support for adaptation planning practices that can incentivize adaptation's desired outcomes in a community while alleviating its reliance on top-down administration. This proposal may appear more radical than the suggestion above, but it resonates with the alternative imaginaries voiced by participants themselves and their descriptions of alternative pathways towards resilience and vulnerability reduction. As a parting lesson for practitioners, this case contends that adaptation planning might not only look to predict and manage risks within current orders but also deliberatively chart the contours of new ones that can leapfrog systemic inertia to deliver needed reductions in vulnerability.

Chapter 4 - Conclusion

This thesis orbits a deceptively simple question: "*Why does climate adaptation so often reproduce incremental outcomes despite calls for transformation."* It is sometimes assumed that the "calls" for transformative adaptation I reference are simply not loud enough, or that they remain confined to narrow academic circles. These were key assumptions I held entering this thesis research. Throughout it, I developed a deeper understanding of the climate adaptation field, including through meeting with adaptation practitioners, advocates, and scholars—each engagement slowly chipping away at the rudimentary assumptions listed above.

Through these engagements, I found that the broader adaptation field now embraces a contextual and social understanding of vulnerability and the transformational demands it places on adaptation (Ford et al., 2018; Nalau & Handmer, 2015; Nalau & Verrall, 2021). This was evident in the fieldwork conducted, per Chapter 3. Yet, an evident tension exists: If vulnerability is co-produced by social orders and arrangements, and if vulnerability reducing "solutions" extend beyond incremental adjustments to climate and weather, why do transformational adaptation commitments and conceptions still lack? This thesis explores this so-called transformation gap (Arteaga et al., 2023). In doing so, it brings Science and Technology Studies (STS) approaches further into conversation with adaptation studies. STS injects reflexivity and rigor to help explain why desired transformations have proved so difficult to achieve in adaptation to date.

Even while transformative adaptations are embraced, dominant policies and practices remain insufficient, hazard-focused, and technocratic. Critical adaptation scholars have documented these patterns and their consequences. But the question of *why* adaptation so reliably assumes familiar insufficient or inequitable forms and *how* this occurs despite countervailing desires, remains

paramount. Chapter 2 introduces STS, its constructivist perspective and the concept of co-production, to argue that STS theories and methods are highly relevant to these questions. The Chapter identifies four themes useful in understanding the transformational adaptation gap. These themes emerge from examining topics in STS that are closely tied to the concerns of the adaptation field and applied practice. These include representations, boundaries, the future, and politics and participation. This interpretive and conceptual chapter demonstrated how STS complements and extends critical adaptation research by focusing attention on the consequences of the contingent *making* of adaptation and society together through each of these four themes. Within each section, I lay out how both fields have approached the topic, and highlight work that has spanned the two, bringing STS's discerning constructivism and revisionism to work on climate adaptation. I closed each section, and the Chapter's discussion, by suggesting ways that further adaptation scholarship might deepen this integration and reap its benefits.

Chapter 3 then applied the proposed insights of STS empirically through a detailed case study of a regional adaptation planning initiative on Washington State's Olympic Peninsula. I approached the adaptation planning process as a site of co-production between epistemic and normative commitments, and through my analysis developed a set of co-production mechanisms that detailed how the very meaning of adaptation was negotiated through social and political, as well as technical, processes. The result was a *predictive* adaptation logic, one that sought to anticipate and buffer climate risks while largely preserving existing social arrangements. I identified three mechanisms: boundary-work, mainstreaming, and institutional accommodation, through which this predictive form was co-produced.

Chapter 3 also presents results on the presence of alternative sociotechnical imaginaries (STI) articulated by planning participants that offered divergent conceptions of adaptation and the

futures it could help realize. These are alternative conceptions of adaptation from the one developed by the planning process and the future it envisions. Though present within the planning process, these imaginaries were also overridden by the prevailing predictive frame and the modes of anticipatory governance it endorses. Drawing on previous work in STS, I close this Chapter by arguing that adaptation planning not only reflects current sociotechnical orders but also works to stabilize them into the future, a process that may in turn foreclose alternative transformational futures in the process.

Key Contributions

This thesis makes three main contributions to the adaptation studies field. I now return to these to synthesize the achievements of both substantive chapters and to communicate the key messages that this thesis provides as a cohesive text for future work.

First, this thesis offers a detailed accounting of work in STS that stands to benefit adaptation studies. I aimed to incorporate STS more substantively into the core of critical adaptation scholarship beyond the present sporadic borrowing. In stating this, I am not discounting adaptation studies scholarship that has dutifully worked with STS concepts. However, a pattern holds throughout a broader swath of literature to merely broach these terms, rather than contend with their vital commitments. In this thesis, I attempt to reap the benefits of STS concepts on their own terms and follow the research traditions through which they developed. The benefit of which is a greater capacity to ask and explain how and why of adaptation.

I also bring a broader selection of relevant STS literature and theory into adaptation studies than what is typically attempted. Co-production is an organizing theme of this thesis and already enjoys steady crossover with adaptation (although it is not immune to the ahistorical applications I note).

However, co-production is not the only valuable contribution of STS worth taking up in adaptation studies. In this thesis, I note how theories and scholarship detailing scientific representations, boundary work, politics, and the future are also valuable for examining the construction of adaptation knowledge and the stabilization of particular forms of adaptation response. Further, I put a handful of these concepts to use in my third Chapter, using the concepts of boundary work and STI's in my analysis. Throughout, I situate STS not simply as a new critical vocabulary but as revised and reflexive mode of inquiry and scientific praxis.

The second contribution of this thesis is the specificity with which I document and explain co-production empirically in Chapter 3. As I note in the previous contribution, co-production has successfully expanded beyond STS circles. But rarely do these entries make plain how co-production occurs. Co-production is often raised to hint at the complex entanglements of scientific practice and normative orders, but is often done so in a way that frames co-production as an explanation for an outcome itself, rather than a phenomenon in need of further explaining (Beck et al., 2021). In Chapter 3, I offer a concrete and methodologically transparent example of how co-production can be studied empirically through qualitative case study research. Drawing on Jasanoff's "ordering instruments" as an analytical frame (Jasanoff, 2004), I identify three specific mechanisms–boundary work, mainstreaming, and institutional interactions–through which epistemic and normative orders converge around a predictive and incremental form of adaptation. This process-oriented account makes visible the often-overlooked moments and practices that structure, legitimize, and narrow adaptation arrangements and advance particular futures.

Finally, this thesis adds to adaptation studies' limited engagement with sociotechnical imaginaries as tools for describing transformational outcomes, doing so in a way that re-anchors them in their co-productionist tradition. Imaginaries have gained traction in sustainability and planning

literature, where they are seen as an attractive conceptual tool for identifying and describing plural futures (Hendriks et al., 2025; Nalau & Cobb, 2022). STS scholars, however, caution against descriptive applications of imaginaries that are divorced from their political and performative environments. Doing so omits their essential role in explaining why certain futures become assumed (Jasanoff & Kim, 2015). In this thesis, I work to reconnect sociotechnical imaginaries to their origins in co-production theory (Jasanoff & Simmet, 2021), explaining how dominant adaptation imaginaries are never just present, but are made persuasive through institutional routines, representational strategies, and participatory designs. I argue in the discussion of Chapter 3 that placing imaginaries at a nexus between co-production and adaptation arrangements can work to further empirical and theoretical explanations for forestalled transformations, even where alternative visions are articulated. Engaging imaginaries in this way represents a more practical accounting of pluralistic accounts of transformational futures, in assuring that these aren't seen as existing on equal footing. This acknowledges that simply eliciting alternative visions does not inherently engage the processes of political and social amplification that lead to transformational visions being realized, while also shedding light on durable barriers that could be amended which presently interrupt the ascendance of alternative future visions.

Limitations

This thesis' findings should be interpreted in light of several methodological limitations. Chapter 2 employed an interpretive review of Science and Technology Studies (STS) and adaptation scholarship, synthesizing insights across four thematic domains without applying formal review protocols or systematic inclusion criteria. While this approach enabled creativity and breadth in identifying connections between the two fields, it also reflects my selective engagement and interpretation of the literature.

Chapter 3 describes a single-site qualitative case study of adaptation planning in Washington's Olympic Peninsula, drawing on planning documents and participant interviews. As is true with other case studies, the findings I present are context-dependent and not statistically generalizable. Additionally, while my analysis attempts to link the observed planning outcomes to co-production mechanisms, the case should be read as a descriptive account, rather than establishing strong causal claims. These constraints do not necessarily diminish the conceptual contributions of the case and generalizability in that regard. Particularly in its illustration of how co-production occurs in the adaptation planning process. However, these limitations do limit my ability to claim the observed planning outcomes are a result of the co-production processes I describe.

Future Implications

This thesis poses a handful of implications and provocations for future work in critical adaptation studies. First, the integration of STS into adaptation studies enforces the value of reflexivity in adaptation research and practice. As I discuss in Chapter 2, adaptation inherits particular ontological and epistemological positions that prefigure the nature of problems at hand and the available or imaginable solutions. Reflexivity asks for a more thorough accounting of these inheritances and works to bring researchers, tools, data, and methodologies into the field of questioning.

Second, the research I surveyed and conducted complicates the relationship between intention and outcome in adaptation research and practice. The various examples I raise in Chapter 2 and the NODC's case in Chapter 3 demonstrate how attempts at representative, equitable, and transformational adaptation may still yield outcomes that marginalize perspectives or close off potential adaptation pathways. Throughout this Chapter, I have shown how the methods of

adaptation knowledge production and practice are inseparable from the outcomes of any process. Future work in adaptation must acknowledge that the thickness and complexity of the systems and processes through which adaptation is interpreted and enacted will invariably alter and direct its outcomes. As such, this thesis points to more thoughtful considerations for the *doing* of adaptation with the hope of fostering certain outcomes (see Chapter 3 for elaboration).

Third, this thesis develops pathways to constructivism beyond critique *ad infinitum*. The wedding of the topics and concepts I chose to highlight, and the broader alignment between STS and adaptation studies I propose, satisfy a need to understand what adaptation at present fails to deliver. However, these same concepts uniquely offer means for reconstructing adaptation in ways that service the omissions and harmful assumptions of current renderings. Such tools and concepts not only point to the ways adaptation could be different but uncover the social and epistemic conditions that must also be in place to make such alternatives capable of being thought and achieved.

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