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Climate Decision-Making

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Abstract

Climate change decision-making has emerged in recent decades as an area of research and practice, expanding on an earlier focus on climate policy. Defined as the study of decisions relevant for climate change, it draws on developments in decision science, particularly advances in the study of cognitive and deliberative processes in individuals and organizations. The effects of climate, economic, social, and other framings on decision-making have been studied, often showing that nonclimate frames can be as effective as, or more effective than, climate frames in promoting decision-making and action. The concept of urgency, linked to the ideas of climate crisis and climate emergency, has taken on importance in recent years. Research on climate decision-making has influenced numerous areas of climate action, including nudges and other behavioral interventions, corporate social responsibility, and Indigenous decision-making. Areas of transformational change, such as strategic retreat in the face of sea-level rise, are emerging.

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1. INTRODUCTION

1.1. Overview

This article examines climate decision-making, which has emerged in recent decades as an area of research and practice. It focuses on climate change–relevant decisions (CCRDs), defined as decisions leading to actions that have consequences for climate change, particularly through mitigation and adaptation. It traces the emergence of this field out of earlier approaches to climate change, which focused more narrowly on policy.

Climate change–relevant decisions (CCRDs): decisions leading to actions that have consequences for climate change, particularly through mitigation and adaptation

Urgency: subjective or objective time pressure, in which delays for action will lead to increased risk or harm; climate urgency linked to framing climate change as a crisis or emergency

The discussion reviews developments in decision science, particularly advances in the study of cognitive and deliberative processes in individuals and organizations. Of particular importance is the relationship between the notion of rationality and growing understanding of multiple decision mechanisms within individuals and organizations. These decision mechanisms, in turn, mediate the effects of physical and social context on decision-making, and affect the use of scientific information in decision-making. The capacity of individuals and organizations to draw on different frames to guide decisions has been a major topic of study; nonclimate frames, particularly social frames, have often been effective. The concept of urgency, linked to the ideas of climate crisis and climate emergency, has taken on importance in recent years. It has been discussed in normative terms, as a potentially important stimulus to decision-making. It has also been applied empirically, to assess the effects of urgency on decision-making; early results are interesting but still insufficient to be conclusive.

Although much research has focused on specific decisions related to climate change, with a narrow temporal focus, other work has broadened the temporal frame relevant to climate change. Some decisions focus on plans rather than single actions, so they directly entail other decisions at future times. In addition, there has been research on behavioral spillover, where one decision

leads to later decisions made by the same individual or organization, and on interpersonal and interorganizational spillover, where decisions made by one individual or organization lead to decisions made by others. Taken together, these can lead to decision pathways, where path dependencies have been observed. They create risks of negative path dependencies and maladaptation, but mechanisms have been developed to reduce these risks.

Of particular importance is the linkage between research on climate decision-making and climate action. This article examines numerous areas of such linkage, including climate communications; choice architecture, nudges, and other behavioral interventions; corporate social responsibility; and Indigenous decision-making. Areas of transformational change, such as strategic retreat in the face of sea-level rise, are emerging.

Spillover: the influence of one decision on another, whether made by the same individual or organization, or made by others

1.2. From Climate Policy to Climate Decisions

This article reviews the emerging body of literature on climate change decision-making, with particular attention to decision-making processes. Although a few articles on this topic date back to the close of the past century (1), the discussion of this topic has developed principally in the past 10 years and has expanded recently. Its intellectual roots are older, tracing back to the middle of the past century, with the study of limits to rationality in economics and sociology, research on judgment and decision-making in cognitive and social psychology, and work on natural hazards in geography and adaptation in anthropology.

We attribute this growth to three major sources: the emergence of complementary bodies of research on limits to rationality; developments in the fields of governance and management; and shifts in climate risk management, broadly understood. The first source, the problematization of notions of rationality, began within economics, most notably with Herbert Simon's work on bounded rationality (2, 3), for which he was awarded the Nobel Prize in economics in 1982. Simon's path-breaking work on administrators (senior managers within corporations, civil servants within public agencies) showed that their decision-making did not consist of maximizing objectives, but rather of satisficing—selecting outcomes that were satisfactory (4). Writing at the same time, Selznick (5, 6) studied complex organizations, finding that their resistance to rationalization lay in their embeddedness within various wider institutional environments and in the roles played within organizations by individuals, whose priorities could diverge from the organization's priorities. Of particular significance for our discussion are studies of cognitive processes of decision-making, which differ from rational optimization of outcomes; the wide influence of this research was signaled by the awarding of the Nobel Prize in economics to the psychologist Daniel Kahneman in 2002 and by broad popularity of books on this topic in the following years (7, 8). This examination of psychological processes of decision-making has been applied to many decision domains, including finance and health.

The second source draws on the emergence of a wide interest in the notion of governance—understood broadly as the exercise of political, economic, and administrative authority necessary to manage the affairs of a collective body (9), including not only governmental agencies but also private firms and civil society organizations. This idea represents a broadening from a consideration of policy (understood to be associated with branches of the state) to a wider examination of action by a variety of decision-making individuals and organizations. Its acceptance overlaps with the rise of NGOs, the development of co-management schemes for resource management and planning, the expansion of public-private partnerships, and other forms of action that do not correspond neatly to state institutions or market institutions alone (10).

The rise of project management has taken place at the same time as this expansion of governance, and is associated with it. Though some elements of project management can be traced

to the distant past, modern forms built on scientific management and Taylorism in the early twentieth century (11). Contemporary project management emerged in military planning and engineering projects in the middle of the twentieth century and grew significantly in the final decades of that century (12). Before then, the study of decision-making, including Simon's path-breaking work, was focused on ongoing programs rather than specific projects and was targeted principally at administrators (senior managers within corporations, civil servants within public agencies) who formed part of the management of large stable vertically integrated institutions. A set of transformations—globalization, the end of the Cold War, and new forms of capitalism—greatly altered these institutions and accelerated the pace at which they changed. Institutional environments became more complex, institutional goals more diverse, and ties between institutions denser. New opportunities arose for managers to develop projects, which could draw together stakeholders from different organizations rather than relying on support from within (13). Shorter-term projects have become more prominent, as longer-term programs have receded in importance. The focus on decision-making associated with project management has characterized not only corporations, but also NGOs and other nonprofit organizations (14) and government agencies (15).

The third source of growth, specific to climate change decision-making, has been a broadening of those who are concerned about climate change. More specifically, the set of actions to address this issue has expanded from climate policy alone to include climate decision-making. The policy-centered focus emerged in the late 1980s and early 1990s simultaneously with the formation of the two major organizations to address climate change, the United Nations Framework Convention on Climate Change (UNFCCC) and the Intergovernmental Panel on Climate Change (IPCC). Both of these, established by agencies within the United Nations, are governed as associations of national governments; they address national governments—closely tied to policy-making—as their constituencies. The UNFCCC provides a context for the creation of policy agreements of national governments, and the IPCC conducts policy-relevant assessments of scientific research.

Observers soon noted that policy-makers faced challenges to reach and implement policy decisions; the complexity of climate change science and the uncertainties associated with it impeded the formulation of alternative policy choices and the selection among these alternatives (16). They also recognized that the multiple outcomes which could result from each policy alternative rendered the comparison of these alternatives more difficult (17).

By the early years of this century, an additional characteristic of decision-making received increasing attention in discussions of climate policy-making: the involvement of a variety of actors, in addition to policy-makers, in the policy process. These include private firms and organizations that represent various sectors of the economy, civil society organizations, researchers, and professional organizations that influence the decisions of policy-makers and who make decisions on their own. As frustration grew in many social sectors over the slow pace of climate mitigation and adaptation by national governments, many observers examined the actions of these individuals and organizations outside the policy sector. These observers understood these actions not merely as the result of adoption and implementation of policies but as decisions in their own right (18). This attention to a broad array of climate decisions provides a motivation for this article.

1.3. Defining Decision-Making: Cognition, Rationality, and Action

Before addressing the questions of climate decisions, we indicate some general points of our treatment of decisions in this article. Decision theory, understood as the study of choices made by actors, is a very broad field, including a wide range of human actors (both individuals and

organizations) and extending to nonhuman animals and virtual agents. We focus on human actors, although we recognize the growing importance of artificial intelligence (AI) in decision-making.

We distinguish between decision processes and decision outcomes, with the former being the mechanisms (psychological, social, organizational, structural, etc.) that influence how particular decisions are made by individuals or organizations as they face situations with alternatives, and the latter being the alternatives that they select. These two components are indissolubly connected, given that decision processes arise to produce outcomes, and decision outcomes can come into existence only through decision processes; nonetheless, much research focuses primarily on one or the other.

The term rationality can be applied to both. The decision outcomes that are characterized as rational are the ones that best match the goals or preferences of individuals or organizations, granted their resources and the constraints within which they operate. Although some refer to decision processes that generate rational outcomes as rational, others speak of rational decision-making, or rational thought, as a careful weighing of costs and benefits of alternatives. Our terms for decision processes are influenced by the work in psychology that argues that human cognition consists of two systems (19, 20). These are often termed System 1 and System 2. The former, an evolutionarily older set of processes, is more rapid and automatic; it draws on the mind's capacity to make associations on the basis of instinct and associative learning. Much of it is preconscious. The latter, newer in evolutionary terms, is slower, and involves hypothetical thinking. It is largely conscious and is often described as reflective or deliberative. System 1 is also termed heuristic because of its use of cognitive shortcuts; System 2 is called analytical for its reliance on sequential thinking and application of judgment rules. Following some recent work that questions the alignment of this and other distinctions with the contrast between System 1 and System 2 (21), we do not equate System 2 with rational decision-making, because we think that its scope is broader; it includes forms of deliberation and weighing of alternatives that do not rest explicitly on trade-offs of costs and benefits. Moreover, System 1 often achieves effective decision outcomes (22).

This work, centered on individual decision-making, has parallels in research on organizational decision-making. Simon's early research noted that organizations face constraints imposed by a finite capacity to pay attention to the world around them. More recent work on the limitations of organizational attention has developed notions of serial and parallel processing that closely resemble System 1 and System 2 (23, 24).

A final point of our treatment of decisions is our consideration of the temporal limits of decisions. Although much of the literature on decisions focuses on short-term individual decisions, limited to the interval between the identification of a situation with alternatives and the selection of one alternative over others, decisions often extend further in time. Some decisions lead directly to future decisions, whether intentionally or not. For example, a person who purchases a bicycle will eventually decide how to maintain that bicycle, opening a sequence of decisions. The sequences often include explicit plans. The person who purchases a bicycle may plan to undertake future actions (to obtain a map of bicycle paths, or to learn how to make bicycle repairs), which in turn entail additional decisions. Over time, these sequences often contain a shift from deliberative System 2 weighing of alternatives to automatic System 1 responses, which can be termed habits (or, in the case of organizational decision-makers, routines); the person who purchases a bicycle may at first ponder the choice of riding a bicycle or driving to a particular destination, but later may take the bicycle for certain frequent trips to nearby places as automatically as putting on shoes before going out. These sequences may also create intertemporal changes in the agent, as a person who buys a bicycle may acquire new skills, capabilities, goals, or identity, which in turn could lead to new decisions that would not have been made earlier (e.g., participating in local organizations

to promote bicycle paths) (25). In a similar vein, organizations often undertake decisions that lead to subsequent decisions, to new routines, and to new goals and identities (26).

2. DEFINING CLIMATE CHANGE DECISION-MAKING

For the purposes of this review, we define climate change decision-making in broad, inclusive terms under the label climate-relevant decisions. Nearly all our focus is on CCRDs; however, we recognize that other climate processes, including climate variability and climatology, interact with climate change, and thus influence CCRDs (see also Section 3.4, titled The Urgency of Climate-Related Decisions, which distinguishes climate variability from climate change).

As opposed to a narrow definition of climate change decision-making—which defines decisions with respect to the underlying mitigation-driven or adaptation-driven motives or goals held by the decision-maker—our definition of CCRDs includes any explicit decisions made by an actor or set of actors (i.e., individual, household, community, organization, society) that have implications from the perspective of the systems that affect, or are affected by, climate change. In other words, CCRDs may or may not explicitly acknowledge climate change. Thus, an individual's transportation mode choice (e.g., personal vehicle versus public transit versus bicycle) is a climate-relevant decision (because of the implications such a decision has for that individual's transportation-related greenhouse gas emissions), even if that individual is not explicitly thinking about climate change when making the mode choice decision. Similarly, when a business decides to build its next factory well away from current flood zones despite higher upfront construction costs (e.g., cost of property), this is a climate (adaptation) relevant decision, one with important implications for future impacts of climate change. Indeed, countless decisions made by households and organizations for nonclimate reasons (e.g., supply chain and sourcing choices, energy conservation efforts) are nevertheless considered CCRDs within our framework.

The choice to define climate change decision-making in this broad, inclusive manner is an important one, in part because it helps to reveal the true scope of the challenges involved in improving climate-related outcomes through changes in individual, organizational, and societal decision-making. If we want to understand how diverse actors make decisions that have implications for coupled human and natural systems within the context of climate change, it is critical to consider not only actions taken explicitly in response to or anticipation of climate change but also the much broader universe of decisions that have implications for climate change.

That said, we also constrain the universe of relevant decisions in two important ways. First, we focus primarily on what we call reflective decisions, that is, decisions that are made by actors after a period (however brief) of conscious thought. Thus, for the purposes of this review, we direct less attention to most behaviors (i.e., actions) that are pursued out of habit or with little consideration, except where insights from the behavioral and decision sciences provide tangible advice to policy-makers and social planners interested in disrupting and redirecting such automatic or habitual actions (e.g., breaking transportation mode choice habits; 27). Second, our definition leads us to focus on decisions that have the most direct or immediate implications for climate systems; recognizing the complex entanglements of nearly all human action with the climate system, we do not consider as extensively the more indirect or remote decisions. Thus, whereas transportation mode choice is clearly a CCRD (whether made reflexively or not in the moment), for our purposes here, an individual's choice of whether to live near a public transit line or not is less firmly a climate-relevant decision. Even though that decision does have second-order implications for the transportation-related decisions that individual will subsequently make (and thus have downstream effects in terms of greenhouse gas emissions), we exclude most such distal decisions from our framework in order to maintain a more focused orientation toward those decisions that

individuals, organizations, communities, and societies make that have direct and significant climate change implications.

CCRDs vary on numerous important dimensions. Perhaps most obvious is the locus of decision-making (e.g., individual versus household versus organization). CCRDs are made at essentially all levels or scales of human organization, from individuals and households (e.g., decisions about energy use behaviors), to organizations and businesses (e.g., supply chain sourcing, employee benefits programs), to municipalities and other collective decision-making types (e.g., land use policies, infrastructure development and retrofits). CCRDs also encompass a wide range of domains and sectors, from transportation and energy (production and consumption) to agriculture, water, and disaster management. Importantly, CCRDs are differentiated with respect to scale (e.g., small versus large impact decisions, direct versus indirect impacts, local versus global) and time (e.g., short- versus long-term impacts), both of which can vary within a given domain. For example, corporations dedicated to fossil fuel extraction may have relatively short-term climate implications (as methane is a short-lived, though extremely potent, greenhouse gas), whereas those same companies' decisions about where and whether to locate new natural gas wells and infrastructure (e.g., pipelines) have longer-term implications for greenhouse gas production.

Considerations of time and scale are also related to the dimension of frequency (e.g., routine and repeated actions versus one-off or infrequent decisions), as the timescale-related implications of a given decision are in part a function of the frequency with which that decision has to be made or revisited. Similarly, CCRDs differ with respect to how they are most often framed or understood by decision-makers, partly due to how they are discussed in public discourse: Whereas some behaviors or decisions have been strongly linked with climate change impacts or implications and are viewed by many people through the lens of climate change (e.g., energy consumption, vehicle purchasing decisions), others are less frequently framed in climate change–related terms (e.g., dietary choices, family planning, infrastructure investment by municipalities, and natural resource managers). Such framing matters to the extent that climate change as an issue or motivating factor unto itself shapes the decisions that different groups or types of people make (e.g., there is evidence that explicitly connecting natural disasters to climate change decreases some subpopulations' support for ameliorative or restorative action) (28). (See Section 3.3 for a fuller discussion of framing.)

2.1. Climate Change–Relevant Decisions: A Process-Based Account

On some occasions, individuals and organizations undertake a formal decision with an institutional process for integrating climate information with other decision criteria (29, 30). This would be thought about as a decision where System 2 dominates, in which the decision is made more slowly and deliberately. At other times, climate and other relevant information are perceived or sought out in an informal decision process. Such decisions are often characterized primarily by System 1, involving faster and more emotional decision-making utilizing heuristics and biases (8).

It is unlikely that households or individuals will undertake a full formal analysis of a CCRD, so most System 2–type analyses take place in a business or public agency context. The typical analyses one might conduct include a cost-benefit analysis, a risk assessment, or an environmental impact assessment (29), but these are not always well suited to a CCRD that deals with a timeline of decades, a broad range of criteria not easily monetized, and high levels of uncertainty and complexity. To deal with these challenges, there are some frameworks that have been developed specifically for formal deliberate System 2 climate decisions. For example, multi-criteria decision analysis has been used to help decision-makers balance competing goals of managing water resources under climate change and urbanization or developing energy policy (8, 30). Methods such

as robust decision-making and info-gap have strengths in dealing with uncertainty by utilizing a range of climate futures and evaluating how decision options perform over those futures (31). These formal decision analysis tools often improve decisions by helping to identify and structure and appropriately weight the information in a methodical way. However, they still entail evaluations and choices, such as what discount rates are used in the cost-benefit analysis or how to treat uncertain information, which are subjective in the sense that they reflect the preferences of specific individuals or organizations. In addition, these decision analysis tools often do not account for social and political factors in the decisions. Although these tools are an important development in climate decision-making and deserve a review in their own right, the majority of CCRDs are made without formal decision-making tools. Moreover, even when organizations use formal decision tools, their selection of a specific tool from a set of possible tools can draw on System 1 processes (rapid thinking, reliance on emotion, etc.) (32). We therefore discuss in detail what is known about System 1 climate decision-making that involves unstructured processing of information in a home, community, organizational, government, or business setting, although we include some treatment of System 2 CCRDs as well.

2.2. Internal Components of Climate Change–Related Decisions

Perhaps the key insight that comes from the past decade of research on behavioral drivers of CCRDs is this: Understanding how and why people make particular CCRDs requires moving beyond traditional rational-actor models of human behavior through the incorporation of more sophisticated and nuanced mechanisms, and the recognition of specific factors at the level of individuals and organizations. Doing so is critical for policy-makers and others interested in being able to predict more accurately how individuals, communities, organizations, and nations will act in the face of a changing climate over the coming decades, as factors well beyond self-interested utility maximization shape how people understand and react to such a complex issue.

Traditionally, models of human decision-making used in the CCRD space adopt classic assumptions about human behavior and motivation (i.e., actors are rational, decisions are fully informed by unbiased information processing aimed at maximizing consistent and stable preferences). Yet a burgeoning literature that utilizes a behavioral framework has demonstrated that CCRD preferences and actions are powerfully influenced by a constellation of factors often underrepresented (or fully absent) in these traditional models. These factors include emotions, social cues, intertemporal discounting, incomplete information search and processing, experiential learning, and rapid decision-making processes (e.g., status quo bias, anchoring, loss aversion) (33).

Given the scale and potentially catastrophic implications of climate change, much recent research has examined how people's emotional reactions to learning about climate change impacts and possible solutions to the problem influence CCRDs. Empirical findings provide a complex and nuanced picture of the relationship between emotion and CCRDs (34). For example, emotional responses have been shown to overpower deliberative or strictly rational decision-making processes, yet the ultimate effects on behavior are highly context and decision-maker specific. Sometimes emotional responses lead to suboptimal responses; e.g., overwhelming feelings of despair or guilt in the face of climate change can inhibit people from taking ameliorative action (or even denying that a problem exists). Yet other times, emotional reactions promote more adaptive action by providing additional input into the decision-making process above and beyond immediate financial implications; e.g., anticipating future emotional responses to one's own behavior can promote positive CCRDs (35). Although organizations do not experience emotions as individuals do, some research has examined emotion-like processes within organizations, such as the building

of trust (36); these processes can support collaboration between organizations on climate action and contribute to the development of long-lasting ties between them (37).

Nonfinancial motives—including social cohesion and peer pressure, moral values and concerns, as well as personal and public health—have also been shown to play an important role in influencing CCRDs at the individual and organization level (38). For example, adoption of rooftop residential solar systems has been shown to be influenced not only by upfront installation costs and projected savings but also by perceptions of adoption as normative within one's own neighborhood (e.g., people are more likely to install these solar systems on their own homes in areas where more neighbors around them have already adopted them) (39). There is also now a robust literature on the role that moral considerations and values play in motivating CCRDs, generally showing that some people's CCRDs are motivated by concerns about the impacts of their own and others' behavior on the well-being of other people and species (now and in the present) (40).

One of the critical findings from the behaviorally informed research on CCRDs is that such decisions are highly sensitive to processes that influence how individuals and organizations make decisions with long time horizons and under conditions of high uncertainty, including hyperbolic discounting, risk aversion, and learning from experience (41). As with the role of emotion in shaping behavior, these effects are not always consistent with respect to the directionality of their impacts on CCRD: Sometimes, for example, the long time horizons and uncertainty inherent in much of the CCRD space increase people's willingness to make personally costly decisions that are socially beneficial, whereas other times (or among certain subpopulations), these same features can promote selfish behavior that is counterproductive from a climate mitigation or adaptation perspective (42). Similarly, a recent review of the empirical literature that examines effects of personal experience with climate change impacts (e.g., natural disasters and hazards) on future CCRDs (both mitigation- and adaptation-oriented actions) showed mixed implications of personal experience—sometimes (and for some people) past experience with climate-related impacts promotes more proactive CCRD-making (e.g., improving resilience to flooding through infrastructure improvements), whereas in others there is little effect (or possibly even a negative effect, when past events objectively inhibit individuals' and communities' capacity to take adaptive action due to decreases in financial or social capital following disaster) (43).

3. CLIMATE CHANGE–RELEVANT DECISIONS: CONTEXTUAL FEATURES AND EMERGING PROPERTIES

3.1. Features of the Decision-Making Environment

Climate-relevant decisions are shaped, and often constrained, by features of the decision-making environment within which they are made by individuals, households, organizations, communities, and other groups. Indeed, much of the empirical and theoretical literature that has sought to explicate CCRD processes and outcomes focuses explicitly on the constraints and guardrails that contextual factors—e.g., transportation infrastructure, dominant and alternative economic systems, available technologies, as well as local and regional climatic conditions—place on decision-makers at every level of decision-making. For example, within the United States, transportation accounts for a large proportion of household greenhouse gas emissions (44), in large part due to a weak public transportation system combined with relatively large distances between major urban areas (e.g., relative to continental Europe); most Americans simply have a limited number of mobility options (particularly for long-distance travel), often times leading to poor CCRD outcomes (e.g., heavy reliance on personal automobiles and air travel). Longstanding policies, including zoning regulations and rules regulating availability and cost of insurance (e.g., US National Flood Insurance Program), can also not only work to constrain the choices available to decision-makers but

also actively encourage counterproductive and maladaptive behavior (e.g., rebuilding structures and infrastructure in increasingly flood-prone coastal areas).

To understand these constraints and opportunities, it is important to recognize that they often emerged from, and are maintained by, the exercise of power, defined as the ability of one group or person within society to influence another's decisions and to obtain its goals. Power is a significant but often invisible element of decision-making; it is important to recognize that historical exercises of power determine the context of current CCRDs. For example, in this article, we discuss many household mitigation decisions that fall within consumption. In advocating for a focus on production over consumption decisions in researching environmental degradation, Gould et al. (45) made a strong argument that "consumer choice devolves from (*a*) the constraints of specific prior production decisions, (*b*) specific prior economic distribution decisions, and (*c*) a specific distribution of policy and decision-making power" (p. 301). This perspective identifies the significance of power in bounding decision options.

Critically, constraints within the decision-making environment often limit decision-makers' climate-relevant preferences and motives. Sometimes these constraints lead to decisions that are counterproductive from a climate mitigation or adaptation perspective (as in the case of transportation mode choice in the United States), yet other times the power of contextual factors can produce more adaptive behavior than would otherwise occur given existing citizen or organizational preferences (e.g., default enrollment in green power programs results in much higher initial and sustained enrollment, even when households are given an opportunity to opt out) (46). Thus, a key insight from the research on CCRDs over the past few decades is that explaining and accurately predicting CCRDs at multiple scales of decision-making, including individuals, households and organizations, require a clear understanding of both individual-level and contextual factors that work in concert to shape available options, preferences, and ultimate decision-making.

3.2. Linkages Between Climate Change–Related Decisions

A critical issue in the study of CCRDs is the influence of specific decisions on decisions made at subsequent decision points. This influence can occur both within and between decision-makers. Three related phenomena have received attention by behavioral scientists, sociologists, and economists in this regard: behavioral spillover, interpersonal spillover, and decision pathways, also known as path dependencies.

The term behavioral spillover is often used to refer to the downstream effects of a particular decision or choice on subsequent goal-aligned or same-context decisions made by an individual or other decision-making unit (e.g., household) (see 47 for an initial model of behavioral spillover with explicit reference to CCRDs). An initial decision (e.g., turning lights off when leaving one's home) can have one of three possible relationships with subsequent, related actions (i.e., household energy use decisions): neutral/no relationship (i.e., the first decision has no bearing on the next decision that is made), positive spillover (i.e., the first decision makes a particular subsequent action more likely—e.g., the individual then turns the thermostat down to further conserve energy, motivated in part by a desire to act consistently with the motivation underlying the initial action), or negative spillover (i.e., a goal- or motivation-aligned subsequent action becomes less likely—e.g., the individual leaves a television on because they feel good about having saved energy by turning off the lights). Research on behavioral spillover in the context of CCRDs finds that all three patterns emerge in real-world settings (see 48 for a recent meta-analysis); this research has not fully advanced from such descriptive work to causal analysis which would be able to better predict when negative versus positive versus no spillover effects will emerge, though such effects can have important implications in this domain, particularly in the context of behavioral interventions

aimed at changing not just one behavior but entire sets of interrelated CCRDs (see also recent integration of social practice theory in this domain; 49). (See Section 4.3.2 on intervention.)

Spillover in the CCRD space is also documented in the context of interpersonal effects, particularly with respect to the diffusion and adoption of new technologies and social practices. Complementing the discussion of downstream effects within decision-making units discussed above, economists and others use the term spillover to refer to the effects that one actor's decisions (e.g., adopting roof-top solar or xeriscaping by a business or household) have on other actors exposed to that decision (e.g., neighbors, competing businesses). A robust and growing literature suggests that such interpersonal, intergroup, or interorganizational spillover effects may be powerful forces that shape CCRDs in both productive and antagonistic ways (50); moreover, the presence of such between-actors spillover effects indicates an important set of tools for encouraging particular CCRDs that are not revealed through traditional models of decision-making (e.g., importance of recruiting early adopters who are well-connected members of their respective social networks). This research builds on earlier work within social psychology on the importance of social influence on decision-making, including on CCRDs (51).

Initial actions taken by actors also influence subsequent CCRDs through the creation of decision pathways and path dependencies (52). A well-developed and highly technical multidisciplinary literature examines and identifies the numerous ways in which earlier CCRDs act to constrain and direct the opportunities available at later time points. These include obvious decisions such as the development (or not) of large-scale infrastructure projects and systems (e.g., siting of public transit conduits and housing developments) as well as more micro- and meso-scale decisions (e.g., purchasing a car makes subsequent use of a personal vehicle much more likely, even when alternatives exist). Of particular importance is that planners, managers, and policy-makers understand and appreciate the decision pathways they are creating (as well as the paths they are cutting off) for future decision-makers when making CCRDs in the present, particularly those with especially long-lasting time horizons. The IPCC has underscored the importance of one type of pathway, a climate-resilient development pathway, defining it as "a continuing process for managing changes in the climate and other driving forces affecting development, combining flexibility, innovativeness, and participative problem solving with effectiveness in mitigating and adapting to climate change" (53, p. 1106).

Such longer-term decision frameworks create the possibility of maladaptation, given that actions undertaken to achieve positive outcomes in the short run may have negative consequences further in the future (54). Researchers have identified processes that can reduce such risks. In particular, adaptive management and iterative decision-making in a changing climate are some of the tools used to modify and improve subsequent or intergroup decisions (55–58). They help steer away potential negative outcomes of path dependencies and promote corrective actions, based on the dynamic nature of social-ecological systems.

3.3. Framing and Climate Decisions

Climate change is a newly emerging phenomenon that is difficult to experience across space and time (59). This characteristic means that making sense of climate change can be particularly challenging for nonexpert individuals, groups and societies, and opens space for consideration of the concept of framing, which has had separate although overlapping intellectual trajectories in anthropology, sociology, psychology, and communications. A frame, as sociologist Erving Goffman (60, p. 16) first described it, consists of "words and nonverbal interactions that help individuals negotiate meaning through the lens of existing cultural beliefs and worldviews." Within the literature on CCRDs as well as in more general treatments, the concept of framing overlaps with

related notions of discourse and narrative (61) and of sense-making (62). Psychologists Tversky & Kahneman (63) found that under conditions of uncertainty, message framing is especially significant in influencing responses. In fact, framing might be one of the most common factors in research approaches to CCRDs as policy frames, media frames, public engagement frames, social movement and countermovement frames, community frames, and organizational frames have all been studied in reference to understanding and acting on climate change. In addition, researchers have studied the framing of climate change as a social problem. Studies on framing often answer at least one of three questions: (*a*) What frames are used, (*b*) how were the frames constructed and by whom, and (*c*) how do those frames impact engagement and decision-making? (52, 64).

Framing is a significant part of the decision-making process in many contexts. For example, DeWulf (65) described adaptation as a series of decisions (understanding, planning and decision-making, and managing the problem) and identified numerous significant dimensions in which framing is important at each step. As mentioned above, framing also emerges as a key part of a whole process of sense-making and action in the organizational and group decision-making literature. In a striking case, Dew et al. (66) showed how dominant frames in the US Navy blocked nearly 20 years of efforts to introduce LED lighting; they reviewed, and excluded, numerous alternate hypotheses for this lack of climate change action. Wright & Nyberg (67, p. 1633) described the use of framing as a key mechanism to describe how businesses subsume the "grand challenge" of climate change into the "mundane and comfortable concerns of 'business as usual,' " leading to nonradical changes in practices. They suggested that businesses first reframe climate change as a business concern (framing), then senior and middle managers align the climate change challenge with local practices of the business to compromise between competing goals (localizing the frame), and then those involved in decision-making throughout the firms realign earlier climate change initiatives with the dominant organizational discourse of maximizing shareholder value (normalizing). Similar organizational processes to address climate change have been identified in emerging industries. York et al. (68) identified how the wind industry hybridized economic and ecological logics by "constructing specific new frames, practices, and arrangements that integrate previously incompatible goals" (p. 600).

Frames are often thought to influence decision-making in three ways. Frames can be diagnostic—identifying the problem and placing blame (69). Conservative movements have actively framed climate change as uncertain, as not caused by humans, and even if occurring, as entailing impacts that are manageable (70). This frame was then mobilized in the media and governance mechanisms (i.e., congressional testimony) to advance opposition to the ratification of the Kyoto Protocol (71–74). Researchers, along with various segments of the climate movement, have meanwhile sought to find a diagnostic frame for climate change that counters the conservative movement's campaign, seeking a frame that names a problem that resonates with the public and incites action (75). Researchers and activists have identified climate change as an existential crisis, a problem of public health (76, 77), a threat to national security (78), an economic risk (79), and as a moral issue (60). The framing of blame in climate change has been challenging with a lack of an obvious enemy. The enemy (or target of change) has been named as the carbon military industrial complex, capitalism, government inaction, and ourselves or humanity (80). The nature of the identification of climate change as a problem, within any given diagnostic frame, influences the perception of whether there is a problem, the evaluation of whether a different decision needs to be made, and the determination of the entity which should be held responsible for solving the problem.

Frames can also be prognostic in that they suggest appropriate solutions and responses to the problem, suggesting what actions should be taken and by whom (69). Indeed, there is a tension

within the literature between the competing frames of whether climate is an emissions problem implying mitigation as a solution or an impacts problem implying adaptation (65). Mitigation frames have been studied to identify what kinds of gains or losses motivate support for fossil fuel free energy adoption or policies including health benefits, green jobs, or energy dependence (75, 81–83). And nonclimate frames have been studied as well. In their study of responses of mountain communities to glacial retreat, Orlove et al. (84) found that the community frame was far more dominant, promoting an identification of the community as the unit of adaptation and underscoring the specific local context for those adaptive actions; they noted that local residents were familiar with the climate change frame as well, allowing them to identify global influence in the changing environment, but made little reference to this frame, especially at community meetings, where decisions are taken.

Finally, frames can be motivational, creating the reasons and the urgency as to why the intended audience should decide to act about climate change now, rather than delaying or postponing (see also Section 3.4 on urgency). In the social psychological research literature, studies of these effects have often focused on how lessening the psychological distance of climate change through messaging or experiences could increase relevance and motivation (85–87). In the broader climate discourse, this has recently taken the form of apocalyptic, disaster, climate crisis, or climate emergency frames that seek to create a sense of urgency (88) with others seeking to provide a hopeful perspective to motivate action. There is an active discussion on how feelings of fear and threat can create (or inhibit) a sense of urgency and thus work to empower action to reduce climate risks without paralyzing decision-makers (71). Risk communicators generally agree that increased threat perceptions can motivate climate actions, but only when accompanied with clear, effective actions decision-makers can undertake to reduce the threat (i.e., decision-makers need a sense of efficacy in order to act on perceived threats) (72).

Because of the power of frames to influence CCRDs, collective framing of climate issues can become a political process. Sociologists who study social movements have focused on framing as a collective process where interests such as government, industry, and social movements compete to influence the dominant frame, offer alternative frames, and endow frames with new meanings (69). Those groups compete to position their frames as dominant given that framing bounds and constrains CCRDs. It is important to recognize that frames are generated and become dominant through the exercise of power by various interest groups. Farrell found that organizations with corporate funding were more likely to write and disseminate texts meant to polarize the climate change issues and that the claims made in those texts were influenced by corporate funding over time (89). Political scientists Workman et al. (23) linked frames to limits on attention, arguing that they allow individuals and organizations to prioritize information and establish agendas. Related work noted that changes in CCRDs often derive from shifts from one frame to another and suggested that the establishment of shared frames allows individuals and organizations to coordinate their CCRDs and actions (90).

3.4. The Urgency of Climate-Related Decisions

We discuss here the notion of urgency, which has been used frequently in recent years to describe CCRDs and the need for climate action. It has been widely recognized that good CCRDs are based on firm information on climate change impacts, the levels of exposure and vulnerability to the major risks associated with these impacts, and advantages and disadvantages of alternative options to reduce these risks (91). However, the costs associated with the collection of this information are high, especially under time constraints, suggesting that time constraints—perceived or actual—can adversely affect the ability to make good decisions. This effect of time constraints is well-known

in the general literature on decision-making; it has been observed for individuals (92), groups (93, 94), organizations (95), and political bodies (96). Psychological research on the impact of time constraints on decision-making has distinguished between the separate but related notions of time pressure and time urgency (97). The former, time pressure, typically refers to externally imposed time constraints that are shaped by the decision-making context. Time urgency, by contrast, refers to internally imposed time constraints that characterize the decision-maker, often as a feature of personality for individuals and of established operating patterns for organizations.

These issues of time pressure and time urgency have gained significant attention in the study of climate decision-making. There has been a growing sense in the academic community and society in general that climate change is a matter of urgent concern (98), a sense also reflected in the language now commonly used to describe climate change and even to reframe it—especially terms such as climate emergency and climate crisis (99). This awareness stems from the growing recognition that climate change impacts are not in the distant future, but in coming decades, and even occurring in the present (100). Numerous reports attribute specific observed extreme weather events to climate change, a marked contrast to earlier research, which presented climate change as a future risk (101, 102).

This shift represents a growth in recent years of the sense of time pressure in climate decision-making—a sense that has implications for the choice process. Psychological research on this topic has documented that time-urgent individuals perform better in decision tasks when they are faced with time pressure, but they are generally averse to uncertainty and adversely affected by it, because of overreliance on previously successful strategies that do not always match novel situations (103, 104). Individuals with low time urgency are the opposite: They generally thrive in uncertain situations but perform poorly under time pressure (105).

This emerging literature on urgency in climate decisions does not draw extensively on this body of work within psychology. As noted above (see Section 3.3 on framing), numerous researchers have proposed that framing climate change as urgent can serve to promote action. We turn here to empirical investigations of the effects of perceived urgency on CCRDs.

Some studies focus on the direct effects of scientific research in creating time pressures on policy-makers. An early paper on the topic explained low levels of urgency as the result of scientific uncertainties about the timing and scale of the impacts of greenhouse gasses, so that time pressure was weakened (106), whereas a more recent study found that a sense of urgency was created by the tendency of the latest IPCC reports to indicate lower levels of uncertainty and also to find increases of climate change impacts that are more rapid than those presented in earlier studies (102). A World Bank study noted that urgency to undertake adaptation and mitigation actions is greatest where inertia could lead to delays, or where there are risks of lock-in to unsustainable pathways or of irreversible changes; it finds that these concerns often create greater urgency for action in developing countries (107). It cites water and infrastructure as sectors where such action is particularly urgent. Other studies have also found that the prospect of irreversible changes creates a sense of urgency (108).

Other studies examine these direct effects of scientific research on policy-makers through an application of the concept of windows of opportunity, a form of time pressure. Rural communities in Central America took advantage of a climate-induced shock to initiate institutional changes, which increased their resilience to subsequent extreme events (109). A study of adaptation in the agricultural sector across several regions noted the existence of short-lived conditions that favored what it termed "early action" (110, p. 19691). The study encouraged decision-makers, including policy-makers, private firms, and researchers, to take advantage of this juncture, and noted that delay was to be avoided because it was unjustified (because some climate impacts are already inevitable, due to historic emissions) and dangerous (because risks are growing, and will hence be

greater in the future than at present). In a related vein, a prominent economist noted that action on mitigation will become more difficult if decarbonization of energy systems is postponed (111).

More recent work has focused on indirect effects of emerging scientific research in creating time pressures on policy-makers (112). This work draws on the effects of attribution science, which links specific extreme events to climate change; this attribution science is widely reported in the media, building greater awareness of it (101). Recent studies note that these events create a sense of emergency within society as a whole, leading to the formation of social movements that focus on climate change as a vitally important priority for collective action and that strongly voice a concern for rapid transformation (108, 113). Another study presented national governments as the key actors influenced by this attribution research; they may recognize that delays will make mitigation more difficult and seek to reduce their emissions through a balance of short- and long-term actions (114).

In addition, a small body of research examines the effects of different levels of time pressure and time urgency on actual or potential climate decisions. A study (115) of fisheries and shipping managers in the Rhine River basin examined the effects of urgency on decision-making by applying the concept of adaptation turning point, defined as the time when current management strategies will fail to meet key objectives because of the accumulated effects of climate change impacts. The study found that the projected pace of climate change in this setting places this time horizon at 2050–2070 for fisheries and 2070–2095 for shipping. Although this level of time pressure did not lead river managers to take action at present, it was sufficient to promote regional agencies to undertake additional scientific studies so that they would be prepared for concrete measures in coming decades. A questionnaire study of 341 elected officials in 199 local boards and councils in New Zealand found higher levels of climate change adaptation activities in localities in which the public had higher perceived urgency of climate change (116).

Rooney-Varga et al. (117) conducted a role-playing game that simulates multiple rounds of international climate negotiations. They found that participants who experienced higher gains in urgency had higher levels of desire to learn more about climate change and stronger intentions to undertake climate actions than those who experienced lower gains, whereas those who experienced gains in climate knowledge alone did not have such associations. Rinscheid et al. (118) conducted experiments in which a large population of voters in the United States were presented with a variety of possible policy options to accomplish a full transition to electric vehicles (EVs); they varied the timing and cost of the options as well as their specific form (subsidies to EVs, taxes on non-EVS, and bans of non-EVs). They found that the participants who thought that climate change impacts would arrive sooner were more likely to favor policies that sought to complete the transition earlier in this century; their examination of perceptions of the timing of impacts also led them to suggest that some policy mechanisms, particularly subsidies for EVs, could effectively be implemented earlier than other mechanisms, such as taxes and bans on fossil fuel vehicles, which were less likely to receive support in the near future. In a related vein, another study by the same first author (119) reports on similar experiments among voters in Germany, who were presented with a variety of policy options to phase out coal as a source of electricity production. Those who held stronger beliefs about the consensus among scientists that climate change was due to human action were more likely to favor an early phase-out; this study also found that different policy mechanisms attracted varying levels of support (119).

Taken together, these empirical studies offer support for the suggestion, discussed in a previous section, that framing climate change as urgent could promote action. Given that these studies show differences that depend on the specific details of the time pressure as well as characteristics of decision-makers and of their environments, further research would be of interest. We turn now to areas in which CCRDs led to concrete actions to address climate change.

4. CLIMATE DECISIONS AND CLIMATE ACTION

4.1. The Use of Climate Information in Climate Action

As discussed above, decision-makers may or may not be thinking of their decision as linked to climate change. If a decision-maker perceives a decision under consideration as climate change relevant, then that decision-maker may seek climate information (including information on physical processes, on the impacts of these processes on natural and social systems, and on the risks associated with these impacts) and use this information in the decision.

There is a robust body of research on how and when climate information is used in decision-making. This research has spanned a variety of decision-makers including local, state, and national governments (120); water managers (121–123), foresters (124, 125), and farmers (126); private firms (127–129); and households (130). Research has accumulated more on those directly using short- to medium-term climate information in natural resource decision-makers, like farmers and water managers, and to a lesser extent on those that climate impacts will be second order (i.e., those that will be impacted by changes in agricultural production beyond farmers). Over the past couple of decades, the focus on how users do or do not use climate information has been used to inform process and design features for decision-support tools.

A recent review by Lemos et al. (131) concluded that climate information is not used as frequently or optimally as would be expected to inform decisions. The specific reasons for this pattern vary across decision-making sectors but can generally be put into several categories: (*a*) the characteristics of the information itself; (*b*) the decision context, such as institutional constraints or other driving decision factors; and (*c*) individual characteristics of the decision-maker, such as risk perceptions (131, 132).

Characteristics of the information itself that can influence its use include the level and characterization of uncertainty and geographic relevance. For example, an early freeze can be very detrimental for sour cherry trees. As a result, cherry tree growers would like to know how climate change will impact local yields, but also how it will impact the sour cherry market overall, both of which had challenges of geographic applicability and deep uncertainty. The PILEUS project at Michigan State University undertook analyses to provide farmers downscaled information about first freezes (133); to project market impacts of climate change, it subsequently developed a framework for thinking about how to model climate information across multiple regions to assess these impacts (134).

Even when the climate information is potentially useful, the decision context may prevent its integration into decision-making. In their study of water managers in California, the Pacific Northwest, and metro Washington, DC, Rayner et al. (123) found that although the managers characterized the probabilistic climate information as unreliable, further investigation found that institutional factors, specifically complexity and conservatism, played a larger role in their nonuse of climate information. For example, the overall purpose of these institutions was to deal with irregularities in water availability and smooth out those fluctuations—to address irregularities on a regular basis. The institutional values of water management institutions were reliability, quality, and low costs. These values all stemmed from the desire to not become a political target—or, in other words, to achieve "political invisibility" (123, p. 207). The drive toward these values meant that if the use of climate information was perceived to introduce an element of unreliability or any additional uncertainty, it would not be used, even if it could provide potential benefit.

In addition to the characteristics of climate information and decision context, individual users have cognitive processes and varied psychological attributes such as aptitudes and attitudes toward using climate information in their decisions. These can include technical knowledge, professional background, and broader ideological or political orientation.

One significant dimension of climate change decision-making is temporal—it is a problem where our actions to mitigate now have varied present costs and benefits, but these actions lock in negative climate impacts for future generations. Rickards et al. (128, p. 753) concluded that senior business and government officials "are strongly focused on their 'local' professional context and near-term pressures, including reputation among peers, relationships with competitors, and real-time financial status." This focus is not surprising in institutional competitive settings. However, studies that have manipulated the time of climate change impacts and asked citizens about their intent to mitigate have generally found no effect of timing on intentions (86; see also Section 3.2 on the temporality of decision-making and Section 3.4 on urgency).

At the household and individual level, decisions such as whether to evacuate are very commonly made using weather information such as hurricane, flood, or tornado predictions (135, 136). In this regard, an emerging question in the research is how people relate the weather that they have experienced to climate and their subsequent climate beliefs, adaptation, and mitigation. McCright et al. (75) reviewed 13 studies that report on the influence of observed temperatures and climate trends on climate beliefs; they found mixed results. Research emerging in this field on people's experience of natural disasters and perceptions of climate suggests that (*a*) natural disasters do make people more likely to believe in climate change and more willing to take mitigative and adaptive actions and that (*b*) prior beliefs in climate change and related political orientations influence the extent to which natural disasters shift people's beliefs (137–139; see also Section 2.2 on the role of personal experience and emotion in CCRDs).

The findings that document the limited use of climate science in relevant decisions have spurred research on how to produce climate change information that is more usable and that fits specific decisions. Drawing on research on the factors that influence the use of scientific assessments such as IPCC reports, Cash et al. (140) found that scientific information was likely to be influential if it was perceived to be credible, salient, and legitimate. The credibility depends on whether the science is seen as adequate and technically proficient. Saliency is the relevance of the information to what the decision-makers need. And a scientific assessment's legitimacy is derived from stakeholders' perceptions that the process of producing the knowledge was unbiased and respectful of diverse stakeholders' beliefs.

Understanding how climate science can become more credible, salient, and legitimate so that it will be used more extensively has led to work on how climate scientists can move away from a one-way "push" of climate science to users to a two-way collaborative process of knowledge construction; this latter form is also known as coproduction (26, 141). Part of the work on how climate science can engage end-users in coproduction has highlighted the role of boundary organizations (122, 142–148)—those social arrangements, networks, and institutions that increasingly mediate between the institutions of science and the institutions of politics (146), where agents from the science side, political side, and third-party intermediaries interact (149). Other research has identified multiple possible models of coproduction based on end-users' needs (132, 150, 151).

4.2. New Methods for Climate Change Decision Research and Support

Newer methods in decision-making incorporate AI, broadly defined as a set of techniques that mimic human cognition and reasoning using machines supported by faster computations and bigger data (152, 153). AI options range from decision-support to decision-making and from automated aid to augmented decisions. AI-driven decisions often embrace maximum expected utility, employing Bayesian methods and artificial neural networks to support rational decision-making and to make probabilistic inferences (154, 155). To incorporate imperfections in the form

of bounded rationality, biases, and constraints, computational rationality calls for trade-offs between the limited time for action and the availability of computational power and accuracy (156).

Weather forecasting, land change, and water management are notable areas that make use of sensors and machine learning to further develop agent-based modeling, neural networks, and multi-risk frameworks. The objectives of these data-driven models are to provide predictions and to help decision-makers prepare for climate change (154, 157–159). An example of such models is the forecasting of reservoir streamflow given different hydrological and climatic conditions, which assists policy-makers to achieve efficient operation. Such streamflow forecasts have used random forest, artificial neural network, and support vector regression to predict one month in advance the inflow of reservoirs (160). Another example is the use of convoluted neural networks to train publicly available daytime satellite images so that they can predict trends in local economic livelihoods; this information can track and project the extent of poverty, helping policy-makers determine the level and type of investment required to ameliorate such problems (161). Such efforts can be considered part of AI's contributions to climate change adaptation, which integrate various strands of data-driven adaptation studies to support decisions and generate scenarios (162).

In the use of AI for decision-making, ethical considerations need to be made on accountability, authority, and level of trust (163, 164). For example, automation requires careful monitoring and oversight that are often ignored by the user. In addition, lack of knowledge on the limitations of automation and data-driven outcomes can obstruct good decision-making (163). Fairness of AI-processed decision-making is also debated. For example, antidiscriminatory rules applied in loans in the manufacture of algorithmic decisions do not necessarily avoid discrimination, although race and gender information are eliminated (165). This is partly because of the use of variables that are highly correlated with race. Spiess & Gillis (165) suggest one way to overcome this issue. They propose including a factor such as race in the initial design phase and give less weight to an applicant's credit score based on its race profile. This debate on the ethics of AI in the discussion of aggregate social choice, moral standards, and varying values (166, 167) will be very relevant as the use of AI techniques and methods to advance CCRDs increases over time.

4.3. Social and Behavioral Domains for Climate Action

The broadening of social actors engaged with climate change and the growing sense of urgency about it have led to a number of applications of research on climate decision-making, in order to promote action. These applications are spread across a diverse number of domains, which differ by scale, by type of social actor, and by type of intervention. These include communications, nudges and other behavioral interventions, corporate social responsibility, and Indigenous decision-making. Areas of transformational change, such as strategic retreat in the face of sea-level rise, are also emerging.

4.3.1. Communications. Numerous studies in the past 15 years (see Sections 2.1 and 2.2) have shown the influence of cognitive and affective processes on climate risk perception, and have documented the obstacles to action created by climate heuristics such as uncertainty bias and delay discounting. These and other papers point to the potential value of communication to promote climate-related decisions. However, relatively few studies document the effectiveness of such communication. As a recent review noted, one of the "persistent challenges" to climate "communication research and practice" is the slowness in "transitioning from awareness and concern to action" (168, p. 345; see also 34).

This effectiveness has received some support from some laboratory research that assesses variables associated with real-world decisions and actions. For example, a recent study showed that

subjects who were shown messages indicating the high level of scientific consensus on climate change agreed more strongly with a statement supporting public action to reduce global warming than those who were not; this effect was mediated by increases in belief in and worry about global warming, as well as belief in human causation of global warming (169). Another example is provided by a study of a role-playing game, in which participants took the roles of delegates to international climate negotiations; they were provided with simulations that gave feedback on the projected results of the agreements that they negotiated. The researchers found two variables, hope and a sense of urgency, which influenced the willingness to act, as measured by responses to questions about the effects of participating in the game on motivation to address climate change and about plans to accomplish that goal (117).

Some studies directly show the effectiveness of communication in promoting climate decisions. A set of studies has examined the effects of messaging on household electricity use, both general motivational statements and information on the household's use in comparison to neighbors and peers; these show the importance of social norms (e.g., bringing energy use to the community average, receiving messages from respected community leaders that link energy conservation and community values) (170). A second set of studies has focused on the effects of messaging on the decisions of hotel guests to use towels for multiple days in a row, rather than receiving fresh towels each day; although these actions have been understood in terms of resource conservation, particularly water, they are also plausibly climate decisions, because of the energy involved in washing and drying towels. Framings that draw on social norms are generally the most effective (171).

Some research into communication and climate decisions has explored other realms. A group of researchers conducted two laboratory studies on the effects of economic and environmental framing on intentions to take action to reduce emissions (checking automobile tire pressure to promote greater fuel efficiency) and found that the latter was more effective. A field experiment confirmed this result through observable behavior; those researchers displayed messages at pumps at a gas station, which provided environmental, economic, safety, and control appeals to tire pressure checks and indicated that oil-change stations would provide such checks free of charge upon presentation of a coupon. Coupons were attached to the message boards. The environmental message elicited action at a significantly higher rate (172).

4.3.2. Interventions. Behavioral science research on CCRDs provides at least two critical insights for intentionally shifting behavior in positive directions. First, this body of work helps to identify boundary conditions and key moderating factors that affect the success of traditional approaches to shaping human behavior, e.g., price signals, regulations, and information provision. Reviews of the established field of energy conservation research have identified the ways that different types of interventions work in different contexts and population segments (173, 174). For example, studies of active commuting found that changes to built infrastructure meant to increase objective and subjective safety of nonvehicle travel (e.g., addition of sidewalks and crosswalks) positively influenced transportation mode choice only among people who already held positive attitudes toward active commuting (175); in turn, this finding suggests that psychological and social factors need to be taken into account (and, often times, directly targeted) when designing interventions aimed at changing behavior through traditional approaches. Second, the past two to three decades of research on CCRDs reveals a novel set of soft behavioral tools for shifting CCRDs in a desired direction. Perhaps the best known of these is the intentional leveraging of the "status quo" bias, actors' tendency to stay with the default or automatic choice even when there is the ability to switch to a more preferred option; in the CCRD context, there is evidence that setting climate-friendly defaults may be a powerful way to harness consumer behavior to promote mitigation and adaptation goals (46). Yoeli et al. (176) provided a concise overview of such tools

and intervention approaches that have been used in the context of shifting CCRDs at the individual and household levels. A review (177) showed that carefully designed information delivery systems can influence climate-related decisions in domestic energy use, promoting reductions in energy use. A meta-study of numerous choice architecture interventions also demonstrated their effectiveness in food systems, including producers and consumers (178). In a cautionary note, a recent study documented the importance of economic institutions and social contexts that can impede such interventions (179); a large meta-study of behavioral interventions also pointed to limitations in their effectiveness (180).

Indigenous climate decision-making: the responses of Indigenous peoples and communities to climate change, based on their internal decision-making processes rather than imposed externally

4.3.3. Social responsibility within the private sector. A recent overview of corporate climate decision-making emphasized the importance of profit motives in shaping decisions, suggesting that corporations seek to reduce emissions when such behavior is aligned with risk reduction or firmly enforced regulations; it also noted the importance of reputational factors, linked to corporate sensitivity of other stakeholders such as investors, lenders, customers, and employees (181). A broad review noted that climate issues influence corporate decision-making more strongly in organizations that are networked with other organizations that also consider this issue; it discussed the importance of organizational learning, through direct experience with climate-related events (182). It suggested that corporate engagement with social responsibility frames was more effective when this frame was present in the context of strategic planning. In a related vein, a study of corporate energy use indicated that the social networks that link corporations with other corporations and with government bodies influenced their decisions to comply with regulations to limit emissions (183). Another study found that participation in social networks of corporations influenced the decisions of individual corporations to include information of climate risk in their planning and in their public communications; it also suggested that supply chain management—another area of interorganizational networking—constitutes an active area of corporate climate decision-making (184).

4.3.4. The emergence of Indigenous climate decision-making. Numerous recent studies have focused on another emerging form, Indigenous climate decision-making, which can be defined as the responses of Indigenous peoples and communities to climate change impacts, based on their internal decision-making processes rather than imposed from above or outside. We present below four recent cases for which relatively full accounts are available and note commonalities among them, to signal this emerging area of research, practice, and action.

These cases share three characteristics. The first is orality. The decisions were reached through face-to-face conversations in Indigenous languages, whether taking place in formal settings of meetings or in informal settings. Indigenous knowledge featured prominently in these discussions. Although some written records were also kept, the conversations, typically with wide participation, were central to reaching decisions. The second is embeddedness. Indigenous climate decisions are taken within long-established social institutions and cultural frameworks from which they draw their legitimacy. The third is articulation. Indigenous climate decision-makers interact with other parties, particularly representatives of national government and NGOs; this articulation can provide valued support, although it can also undercut the autonomy of Indigenous decision-making. We recognize that these three concepts also apply to climate decision-making in numerous other settings; however, they have some salience in Indigenous contexts, because of the cultural distinctiveness of Indigenous peoples, the concepts encoded in Indigenous languages, the remoteness of the settings where Indigenous people often live, and their marginality within national governments.

Hunters in Unalakleet, an Iñupiat village in Alaska, noted a sharp decline in populations of caribou, a major element in their diet, and recognized that this decline was the result of climate change as well as of shifts in their mobility patterns due to external economic and political drivers (185). Community leaders called for meetings (note: orality) of three different local organizations (note: embeddedness), where different options were discussed. The organizations all agreed to declare a multi-year moratorium on hunting, with coordination with the Alaska Department of Fish and Game. This department is the only agency with the formal authority to declare moratoriums; it enforced the exclusion of non-Indigenous private hunters and outfitters, who previously were granted permission to hunt in the territory of the village (note: articulation). Later discussions at village meetings and in informal settings established community regulations for enforcing the moratorium. The households that were most reliant on hunting were granted exceptions and could hunt one animal a year. The caribou populations expanded, permitting a return to traditional hunting.

In Gilgit-Baltistan, an arid region in northern Pakistan, agriculture among the Hunza populations has long been supported by irrigation canals that are supplied by meltwater from snowfields and glaciers (186). The construction and maintenance of these gravity-fed irrigation canals is carried out by community associations known as *jirga*, which also periodically reallocate water rights (note: embeddedness). As glaciers retreat due to climate change, water sources at the edge of glaciers have been impacted, reducing water available for irrigation; severe floods, also associated with climate change, have also damaged the canals. In response, villagers organized meetings of male household heads (note: orality), who agreed to relocate fields with better access to remaining water supplies, and planned and constructed new channels accessing more distant water for irrigation needs (187). A regional NGO supported this substantial task by providing funding; by drawing on local residents for staff, they have coordinated closely with Indigenous decision-making processes (note: articulation) (188).

Increased glacier meltwater has caused lakes on the Tibetan Plateau to increase in size, covering pasture areas and leading pastoralists to alter their patterns of seasonal movement; the pastoralists had also been affected by a program of the Chinese government to privatize the formerly communal pastures. A detailed study of one Tibetan village affected by this flooding reports that observations of flooding led village leaders to call a meeting (note: orality) in which villagers decided to share remaining pastures collectively (note: embeddedness); they decided as well that all households would provide material and social support to the relocation efforts of those whose houses were flooded (189). The villagers also requested that the leaders speak with county officials to support village management of pastures; the officials granted approval for this system, which is at variance with other policies regarding privatization of landholdings (note: articulation).

A recent study of a village in the southern Peruvian Andes, composed of several small hamlets, documented the decisions made by Quechua-speaking alpaca herders in response to increasingly irregular patterns of rainfall, as well as to economic and political pressures (190). With the breakdown of the marked separation of a dry and rainy season, hamlet members can no longer rely on customary seasonal migration patterns. They speak frequently with each other (note: orality), noting changes in the availability of fodder and in animal behavior and reach consensus on the timing of movements of household herds between different pastures associated with the hamlet. They also gather occasionally at assemblies in the village center (note: embeddedness) to resolve disputes over boundary trespasses between hamlets and to consider a possible reorganization of the form of access to pasture, in which communal access to hamlet pastures would be replaced by a division into household pastures, accompanied by greater investment in veterinary practices. The former movements are conducted autonomously by the villagers, whereas the latter reorganization would entail interactions with government agencies and NGOs (note: articulation).

4.4. Transformational Adaptation

Transformational adaptation: an adaptation effort that (*a*) is adopted at a very large scale or intensity, (*b*) is genuinely novel in a region or sector, or (*c*) fundamentally alters places

As vulnerable populations are exposed to increasing climate change impacts, decision-makers are faced with a kind of adaptive decision-making termed transformative or transformational adaptation. According to Kates et al. (191), an adaptation effort can be categorized as transformational rather than incremental if it is adopted at a much larger scale or intensity, if it is truly new to a particular region or resource system, or if it fundamentally alters places and shifts locations. Examples of increased scale or intensity include the bottom-up regreening of the Sahel and adding new higher barriers on the Thames. Cases of new adaptations in a region or resource system are shown by genetically modified water-efficient maize or using weather-indexed crop insurance in Africa. Resettlement or managed retreat are examples where the adaptation transforms places and shifts locations; they are the category of transformational adaptation perhaps getting the most attention currently (191). Transformational adaptations involve a "fundamental change to the functioning of systems" that "opens new areas of policy response by going beyond existing systemic forms. . . and allows deep-rooted causes of risk and vulnerability to be addressed as part of the reorientation of development pathway toward social justice and sustainable development" (192, p. 117). Examples of transformational adaptations to date are often in response to extreme weather events that may be framed as climate related or not. For example, Koslov (193) documented "agnostic adaptation" in Staten Island buyouts after Hurricane Sandy, referring to the absence of firm belief about climate change in this area, and Kates et al. (191) discussed the bottom-up regreening of the Sahel by individual farmers who were motivated by providing food, animal fodder, fuel, and crop protection.

Transformational adaptation decision-making is characterized by both its collective action nature and its novelty, given that it requires coordination to coalesce to create and implement new visions. It thus often necessitates the development of new kinds of decision-making institutions or the profound remaking of current ones. Although proactive decision-making is infrequent (86), some scholars have examined anticipatory and deliberate decision-making around transformative change (192, 194), noting that the need for these new institutions can create opportunities to reshape whole social systems (192, 195). As mentioned, such transformation is driven by the intersection of environmental change and vulnerability, and thus often entails confronting such social vulnerabilities. The social nature of these vulnerabilities is highlighted by Koslov's (196) findings that Staten Island residents framed their buyouts in moral terms, making personal sacrifices to protect others further inland against future harms. Pelling et al. (192, p. 118) envisioned a process where "reflexive decision-making based on the continuous observation and monitoring of adaptive outcomes" will lead to society adjusting its preferences, coming to favor transformative adaptation over the two alternatives of resistance to adaptation, and incremental adaptation. In this instance, the work that has been done on managed large-scale sociotechnical transitions around mitigation can provide some paths forward, given that it has grappled with agency in large systems, institutional change, and power dynamics that influence decision-making (197–199).

5. CONCLUSIONS

Our review has discussed the emergence of the field of climate decision-making as an area of research and practice. It locates this field in a context of deep apprehension about climate change and a strong public concern to include a wider range of forms of action in addition to policy. It shows the importance of considerations of governance and broader developments in decision science.

We have developed a focus on CCRDs, defined as decisions leading to actions that have consequences for climate change, particularly through mitigation and adaptation. We show the

relevance of advances in the study of cognitive systems within individuals and demonstrate the importance of this work for organizational decisions. Our discussion of framing is particularly detailed, given that the research in this area shows its effectiveness in shaping decisions. We have examined as well the extensive efforts to link climate decision-making to climate action by a variety of actors, including individuals, organizations, corporations, communities, Indigenous peoples, and state agencies.

We have highlighted several emerging areas of climate decision-making. Four are of particular importance. The first is the temporality of decision-making, moving beyond the short-term focus of much research on decision-making in climate and other domains. We show that some decisions lead actors to undertake plans, rather than individual actions, and thus to commit themselves to other future decisions. We also examine spillover, in which one decision can contribute to later decisions made by the same individual or organization, or by others—these can combine to form decision pathways; such longer frameworks create risks of unfavorable path dependencies and maladaptation, but tools are available to reduce such risks.

The second is the concept of urgency, a widely used term that we seek to examine systematically. We show its connection to ideas of climate crisis and climate emergency, which are attracting increasing attention. A review of earlier work on time pressure and time urgency provides some guidance for work in this area. We discuss some promising initial empirical studies, which suggest that the effects of urgency depend at least in part on the specific time pressures involved and the characteristics of the social contexts in which decision-makers act.

The third is the area of Indigenous decision-making. Although there is an extensive literature on Indigenous knowledge in relation to climate change, as well as in relation to biodiversity and other environmental topics, there has been less work on Indigenous communities and peoples as decision-makers. The general issues of framing and of context apply to Indigenous climate decisions as they do to such decisions made by others. We propose three key features of Indigenous climate decision-making: the embeddedness of decisions in social and cultural contexts, orality (an emphasis on spoken face-to-face communication, often in Indigenous languages), and articulation (interactions, whether equal or unequal, supportive or conflictive).

The final area is the notion of transformational change. Although decisions can often be seen as small in scale and iterative, some climate-related decisions led to fundamental changes in systems. We provide examples, such as strategic retreat from coastal areas threatened by sea-level rise and regreening of fragile environments that face desertification, and explain the importance of triggering events and framing in facilitating such processes.

We close by emphasizing that these four areas all signal the growing scale and scope of climate decision-making, by expanding the temporal scale and, through urgency, what can be called the temporal pressure; by including formerly marginalized participants such as Indigenous peoples; and by seeking not only improved action, but also broad transformation. It is our hope that research and practice in climate decision-making will continue to expand further in scale and scope, contributing to understanding, to action, and above all to solutions to the immense crisis faced by all humanity and indeed by all forms of life on our planet.

SUMMARY POINTS

1. Climate change decision-making has emerged in recent decades as an area of research and practice, expanding on an earlier focus on climate policy. This expansion draws on several trends: the emergence of complementary bodies of research within economics,

psychology, and sociology on the limits to rationality; developments in the fields of governance and management that focus on new domains of decision-making; and shifts in climate risk management to include a broad array of actors and actions.

2. The study of climate change decision-making draws on developments in decision science, particularly advances in the study of cognitive and deliberative processes in individuals and organizations. It recognizes that many elements once deemed anathema to rational decision-making, including emotion and intuition, can often support effective decision-making.
3. Where earlier work focused on single decisions, recent research has examined linkages between decisions. These linkages include spillover, in which one decision influences future decisions, whether by the same actor or organization, or by another, and decision pathways, in which sequences of decisions can lead to significant change. Because these linkages can have negative effects, including maladaptation, when the linkages lead to negative decisions, decision tools and other methods have been developed to address this risk.
4. The effects of climate, economic, social, and other framings on decision-making have been studied, often showing that nonclimate frames can be as effective as, or more effective than, climate frames in promoting decision-making and action.
5. The concept of urgency, linked to the ideas of climate crisis and climate emergency, has taken on importance in recent years. Recent empirical studies trace the effects of an increased sense of urgency in leading actors to avoid delay in undertaking action.
6. Research on climate decision-making has influenced numerous areas of climate action, including nudges and other behavioral interventions, corporate social responsibility, and Indigenous decision-making. There has been growing attention to emerging areas of transformational change, such as strategic retreat in the face of sea-level rise.

FUTURE ISSUES

1. Future research could provide fuller accounts of the mechanisms that influence behavioral spillover, where one decision leads to later decisions made by the same individual or organization, and interpersonal and interorganizational spillover, where decisions made by one individual or organization lead to decisions made by others. It could indicate contextual factors that influence spillover and provide guidance on interventions to promote effective climate decision-making through both forms of spillover.
2. Future research could examine more fully the effects of increased urgency on climate decisions. It could disentangle urgency-related issues, such as time pressure, from other closely related risk dimensions, such as scale and uncertainty. It could decompose urgency into components, such as an acceleration of initiation of action on existing goals and an increased prioritization of certain goals over others.
3. Future research could examine the parallels between information processing in individuals and organizations, which generate similar forms of climate decision-making in these different domains. Potential topics of research include the costliness of information

processing, the greater reliance on information obtained from experience over information obtained from description, and the reliance on frames to guide selection among a large number of attributes of particular objects, contexts, and situations.

4. The topic of Indigenous decision-making is much newer within the study of climate decisions than the topic of Indigenous knowledge. The construction of a large sample of cases, developed in conjunction with Indigenous researchers, could facilitate fuller understanding of this type of decision-making and its wider incorporation into climate action.
5. The topic of strategic retreat has recently become the object of research, particularly in urban coastal settings. It is found in a wide variety of contexts, including inland flood zones and mountain areas impacted by decreased water supply following glacier retreat. The attributes of decision-making in such settings are still incompletely understood. Further research could be of great importance for supporting this potentially transformative type of climate decision-making.
6. An emerging topic of research is the effects of climate movements such as youth movements, both on direct participants in them and on others exposed to them, on climate decision-making, including the selection of domains in which to act, and the selection of scales of action (from individual and household to local, regional, national, and global).

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B.O. participates in a local climate action network, JCAN, in New York.

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