Approaches to Scenario Planning at the Intersection of Urbanization and Climate Change

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Abstract

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What could comparative analysis of scenario planning reveal about the effects of various approaches to uncertainty on the outcomes of scenario planning, and what can such analysis reveal about the opportunities, challenges, and consequences of urban adaptation to climate change? In order to answer these question, this study applies qualitative methods to analyze selected case studies of scenario planning described in the literature. I systematically review thirteen cases from the past twenty years, sharing a framework of urbanization and climate change as their primary drivers of future change, by focusing on three sets of variables including: 1) the extent of stakeholder engagement (measured by diversity and participation), 2) the processes (objective, drivers, methods, and scenario building), and 3) the outcomes (findings, evaluation, and limitations). Based on the comparison, I identify patterns that reveal strengths and weaknesses in scenario planning. I synthesize the context of each case study, variance in approaches to urbanization and climate change impacts, stakeholder engagement and inclusivity, methodologies, and the consideration of uncertainty. Key themes across the case studies include

ways that scenario planning enables flexibility, adaptation, and innovation through driver selection and scenario design; methods for coping with uncertainty; and modes of citizen participation and agency in the scenario planning process. Synthesis of these themes yields insights about implications for the study of scenario planning.

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I. Introduction

A. Context

The future is uncertain. We know that the world is warming, as climate change disrupts the carbon cycle and triggers major environmental changes for generations to come (IPCC, 2014). We also know that the world is urbanizing, as an ever-greater percentage of the global population is living in cities and urban areas (United Nations, 2018). The unknowns embedded in systems characterized by such deep uncertainty are at the heart of scenario planning, a mode of thinking and a systematic method that envisions alternative futures based on plausible responses to different types of change over time (Peterson, Cumming, and Carpenter, 2003b and van der Heijden, 2011). Scenario planning has applications in many fields, including government, business, and technology (Foley et al., 2017), but for the purpose of this research, its role in environmental decision-making at the intersection of climate change and urbanization will be examined.

Using scenarios as a methodological tool in environmental planning reveals futures that are not predictions or forecasts necessarily beholden to a judgment of value. Instead, their scope may include what is possible, probable, or desirable. Scenario planning is a tool to guide environmental decision-making in a systemic way (Peterson, Cumming, and Carpenter, 2003b). It is also guided by an emphasis on adaptation to change, though that adaptation can take different forms (Rickards, 2013).

In urban contexts, adaptation is complicated by the significant complexity and unique challenges arising from the integration of human actors into ecological systems (Alberti et al., 2003). As the world grows increasingly more urban, it is important to recognize that urban processes are part of ecology. The framework of coupled human-natural systems is important for understanding the active human presence in ecological systems, with implications for the emergent properties of such systems in urban ecology (Alberti, 2008). Climate change and urbanization are two drivers of change with a high degree of importance as well as uncertainty.

Scenario planning generates different outcomes depending on the intentions, objectives, assumptions, and methods applied by the planners or agency leading the study (Oteros-Rozas et al., 2015). The choice of drivers is also key: The way the scenario planning team defines the scope and scale of urbanization and climate change considered in the study will shape the resulting scenario planning process and research outcomes. Furthermore, methods vary, and the emphasis on quantitative versus qualitative approaches that characterize a scenario planning process has considerable impact on the outcome. For example, a point of contention regards the role of predictive modeling in the development of scenarios (Bray, 2009), with debate over the predictive capacity of predictive models and the role they play in scenario planning. Evaluating the methods of scenario planning is still underdeveloped in the literature (McBride et al. 2017, Oteros-Rozas et al. 2015).

Part of the research framework underlying scenario planning regards the role of stakeholders, who comprise all "those who are affected by or can affect a decision or action" (Reed et al., 2013, as cited in McBride et al., 2017, p. 15). The extent to which diverse stakeholders are involved in the scenario planning process shapes the degree of participation. Who is at the table holds implications for the legitimacy of scenario planning findings, capacity for knowledge sharing, and equity. Furthermore, the content and structure of the narrative scenarios themselves have an effect on planning outcomes and interventions, whenever the scenario planning process is used to guide adaptation policy or practice in response to possible futures. These are just a few of the ways that scenario planning research design can affect planning outcomes.

B. Research Question

As climate change and urbanization continue to pose challenges for communities, planners, and policymakers, scenario planning will retain its relevance as an approach to facilitate solving environmental problems. In this study I ask: What can planners gain from a systematic analysis of case studies of scenario planning presented in the literature? What could comparative analysis of scenario planning reveal about the effects of different scenario planning approaches on the outcomes of scenario planning, and what can such analysis reveal about the opportunities, challenges, and consequences of urban adaptation to climate change in the face of deep and discrete uncertainties?

C. Research Objective

The purpose of this research is to investigate through qualitative methods trends and outcomes in scenario planning case studies that focus on the interactions between urbanization and climate change. By analyzing and comparing strategies and insights from the field of scenario planning, my intent is to distill lessons about the effectiveness of scenarios to anticipate the plausible impact of two major drivers of change: climate change and urbanization. These particular drivers were chosen due to their prominence in case studies of scenario planning, their interacting and synergistic effects, and their salience in urban ecology. This thesis examines case studies considered to engage with the framework of urbanization and climate change through a qualitative meta-synthesis based on ten variables serving as discrete evaluative criteria. It is important to note that this thesis does not intend to establish a causal relationship between any specified scenario approach and scenario outcome, or to make a claim about the preconditions for success or failure in scenario planning. Furthermore, given the limited number and relatively recent application of scenario planning methods for climate adaptation, the study does not seek the ideal conditions of a systematic comparison of case studies in scenario planning. Rather it provides an example of how such qualitative comparison can generate insight for strategic planning in the face of uncertainty.

Chapter II is a review of the relevant literature that aims to explore the intersection of urbanization and climate change, the importance of reckoning with uncertainty, and the process of scenario planning as it relates to environmental, land use, and landscape planning at multiple scales of time and space. The qualitative research design used to describe, synthesize, and evaluate case studies in scenario planning is described in Chapter III, Methods. An evaluation of thirteen such case studies is given in Chapter IV, Results and Discussion, which also reflects on insights and lessons learned from applying scenario planning as the urbanizing regions of the world anticipate great ecological and social change.

II. Literature Review

A. Introduction

Scenario planning is a systematic process used to guide decision-making with applications in a number of different fields, including business, technology, conservation biology, the military, and public policy. Scenario planning as a formal process crystallized in the mid-1970s, when Royal Dutch Shell developed a scenario planning exercise to anticipate changes to global oil markets that ultimately granted it the flexibility to adapt more readily than its competitors to that decade's oil crisis (Schwartz, 1991, Mahmoud et al., 2009, and Polasky et al., 2011) Scenario planning is one of various approaches to strategic foresight, a strategy to explore plausible futures and their potential risks and opportunities (Cook et al., 2014). Strategic foresight approaches are particularly valuable for environmental decision-making.

Most relevant for this study within urban planning is the role of scenarios in ecology and environmental decision-making. In a foundational 2003 essay on scenario planning, Peterson, Cumming, and Carpenter outline how scenarios can be used as a tool to "[think] creatively about possible complex and uncertain futures" in a systemic way (p. 359). Because they approach problem-solving with creativity and adaptability, scenarios can generate greater resilience to shock, disruption, and surprise in the face of uncontrollable environmental change. Scenarios incorporate feedback loops, major drivers of change, and alternative states of those drivers to build narratives from both quantitative and qualitative data (Oteros-Rozas et al., 2015). How those narratives take shape in the context of urbanization and climate change, how they reckon with uncertainty, and what they indicate about the meaning and practice of scenario planning itself, is the subject of this literature review.

B. Climate Change and Urbanization

Climate change, a term which I use interchangeably with global warming, is defined by the Intergovernmental Panel on Climate Change (IPCC) as "any change in climate over time, whether due to natural variability or as a result of human activity." The United Nations Framework Convention on Climate Change goes one step further, defining climate change as the product of direct or indirect human activity (IPCC, 2014). The United States is the largest emitter of the greenhouse gases that contribute to global warming, with one-third of emissions deriving from transportation alone (Ewing et al., 2007). The scientific consensus is that carbon emissions must be slowed, but even if all emissions were halted today, it would be too late to reverse the warming process. Signatories to the United Nations' 2015 Paris Agreement on climate change pledge to mitigate global warming, but there is no means to force emissions targets to be met (United Nations, 2015). As it currently stands, global temperatures are likely to rise by between 0.3 and 4.8 degrees Celsius by 2100, according to the most recent range of estimates provided by the IPCC (2014). Global consequences of these trends include increasing magnitude and intensity of precipitation and storm events, the inundation of low-lying areas (some of which are entire nations), instigating refugee crises, and triggering infectious disease epidemics (Susskind, 2012, p. 217). We are living in the Anthropocene, defined by Polasky et al. (2011) as "the most recent geologic time period, in which humans' activities have had a dominant impact on Earth systems" (p. 398) and by Dalby as an era in which "ecological disruptions and vulnerabilities are caused increasingly by human actions" (2007, p. 155). This necessitates an understanding of synergistic effects that can only be examined cumulatively.

Lawrence Susskind urges cities to reckon seriously with the risks posed by climate change. Some services threatened by climate change, both natural and human, include soil and water quality; energy production; waste disposal; and transportation (2012, 217). Other consequences of urbanization and associated increases in impervious land cover and changes to the carbon cycle include adverse impacts to nutrient and water flows, the urban heat island effect, and decreasing vegetation and canopy cover (Alberti, 2010). In urban areas, some of the most urgent hazards related to climate change include flooding, droughts, severe storms, and sea level rise, particularly as urban population concentrates in coastal areas (Rastandeh, 2015 and Birkmann et al., 2010). Under climate change, extreme events "are still typically regarded as shifts within the bounds of current system vulnerability, and urban adaptations to climate change are often conceptualized within existing management cycles" (Solecki et al., 2011).

Urban areas accumulate risk primarily because of the way they concentrate population and infrastructure, their function as nodes in larger socioeconomic systems (Birkmann et al., 2010). This makes them "both the drivers and the result of global change" (ibid., p. 186). While urban areas are crucibles for climate-related challenges and the sites where the worst effects of climate change will be most visible (Susskind, 2012), they can also be the source of solutions. For example, compact development may serve to reduce the emissions generated by car travel (Ewing et al., 2007). Dense, mixed-use developments can be a tool to improve air quality by reducing the need for vehicle miles traveled. Urban density can also be leveraged to increase the effectiveness of hazard mitigation (Garschagen and Romero-Lankao, 2015). At the same time, there are critical uncertainties in how emergent properties, feedback loops, and unanticipated consequences play out in the complex relationship between urban growth and global warming (Miller and Morisette, 2014). Garschagen ad Romero-Lankao (2015) argue that most of the existing literature on the relationship between urbanization and vulnerability to climate change focus unduly on exposure to hazards, but sensitivity and response capacity also deserve attention. Their own work suggests that urbanization can be a driver for coping with climate change.

Great uncertainty derives from insufficient understanding of the causal relationships between urbanization and vulnerability, and there is also a need for greater understanding of developing countries' risk and vulnerability as urbanization and development increases rapidly, as well as intangible factors like government capacity for risk management (ibid., p. 39). Scenario planning provides a systematic means to conceptualize urbanization as an important driver of change alongside global warming. Envisioning resultant impacts and synergistic properties simultaneously provides a basis for more informed environmental decision-making (Rastandeh, 2015).

C. Contending with Uncertainty

A major foundation of scenario planning is that decision-makers have to cope with uncertainty: what is not fully known or understood. Planning for climate change is complicated by the fallibility of forecasting and the complexity of Anthropocene socio-ecological systems (Susskind, 2012, p. 219; Polasky et al., 2007, p. 399). Berke and Lyles (2013) assert that uncertainty contributes to public risk, which relates to climate change. Unlike smaller, immediate private risks borne by individuals, public risks (like sea level rise, floods, and ozone depletion) have shared, long-term, diffuse consequences that make them difficult to predict and difficult to overcome public indifference; thus, the role of planning is to collaborate with the public to increase awareness and address risk with action (ibid., p. 183).

Uncertainty is a key consideration for scenario planners because the development of alternative scenarios is a framework for reconciling great uncertainty with our expectations for the future (Peterson et al., 2003b). Uncertainty means that technical expertise is not sufficient to justify a course of action; instead, planners need to “build support for an array of possible actions using the probabilistic language of risk management” (Susskind, 2012, p. 221). Kinzig and Starrett (2003) cite uncertainty as a major barrier to scientific communication and making policy grounded in science. Failure to cope with uncertainty results in linear, “predict-and-prescribe” forecasting strategies, in which an accurate prediction of the future is the ultimate goal (Schindler and Hilborn, 2015).

Specific causes of uncertainty may include lack of basic knowledge, errors in data, model structures, and model parameters, inadequacy in condition approximations, subjective judgment, inappropriate assumptions, ambiguously defined concepts, and errors in projections of human behavior, among others (Mahmoud et al., 2009). In a study on analytical risk-taking and embracing uncertainty, Spiegelhalter and Riesch (2011) put forth a conceptual framework of the five forms it can take. Within the model, there are uncertainties associated with the event (so-called unavoidable uncertainty), the parameters (limited information), and the model (limited knowledge). Outside it, uncertainties stem from both its creators’ acknowledged faults in the modeling process (indeterminacy) and those that are truly unknown (ignorance). Moreover, the contemporary discourse around climate change levels criticism against "projections based on complex computer models [which] have been accused of understating the deeper uncertainties about the underlying processes governing future climate" (ibid., p. 4731). Such projections are vital to the work of the IPCC, which produced "hundreds of simulations of past and future climates" at a fine resolution in order to prepare the organization's Fourth Assessment Report in 2007 (Maurer, 2007). Yet the IPCC has been criticized for obscuring such uncertainties by implementing inconsistent and statistically misleading guidance on uncertainty across the working groups that helped prepare the Fourth Assessment Report (Spiegelhalter and Riesch, 2011, p. 4733).

Indeed, a major advantage of scenario planning for decision-making is that it develops a range of plausible alternative futures and accounts for the "deep and irreducible uncertainties" inherent to ecosystem conditions changing over time at a level that we cannot predict with accuracy (Schindler and Hilborn, 2015; Peterson, Cumming, and Carpenter., 2003b). This is why Foley et al. (2017) link the narratives of scenario planning to the transformative power of storytelling, making the case for imagination and innovative thinking in dealing with problems related to urban sustainability. The tension between imaginative visioning and making future projections based on plausible facts informs particular research approaches to scenario planning, whether predictive modeling is involved in the process or not. As Bray notes, "even in the absence of real change, the perception of change may act as a human catalyst for action" (2009, p. 88).

D. Scenario Planning Processes

Alberti, Russo, and Tenneson (2013) describe scenario planning as a four-step process. First, a focal issue is defined that will determine the central question to be investigated. The scale and time frame should be selected carefully. Second, driving forces are identified. These are aggregate trends that will alter the future in significant ways, depending on the direction and magnitude of change. Third, the drivers are ranked by importance and uncertainty in order to assess those future states that are the most divergent and therefore the most compelling. Fourth and finally, scenario logics are defined. This sets the organizational structure by which to characterize cause and effect in four discrete futures. Each possible future in the standard four-frame matrix is a plausible scenario shaped by the extremes associated with each driver. McBride et al. (2017) assert that this system is popular because of its accessibility and ease of use for both researchers and participants; it is also easily adaptable to different research contexts. There are alternatives to this approach, for example morphological analysis, which considers a higher number of alternative states and therefore introduces greater complexity to the planning process (p. 16).

Beyond this basic process at the heart of scenario planning, Susskind (2012) states that next steps can be to convene stakeholders to develop and interpret scenarios, to select indicators by which to monitor change over time, and to explore possible planning responses by evaluating alternatives. The most robust plans are those that could play out across all scenarios. Thus, more than a hypothetical thought exercise, scenario planning is “a repeatable analytical approach combining climate science, ecological response modeling, and management options” (Miller and Morisette, 2014). Finally, with regard to conducting scenario planning under a shared framework that combines climate change and socioeconomic systems, there are two possible approaches. The first is to treat socioeconomic systems independently from climate change, with each providing separate inputs; the second allows for interaction between the drivers of climate and socioeconomic systems (Shackley and Deanwood, 2003).

E. Scenario Planning Praxis

Given the uncertainty inherent in the processes of urbanization and climate change, and the complexity of their interactions at multiple scales, scenario planners must choose a methodology that suits their purposes. Across the literature, participatory scenario planning is upheld as a method to engage stakeholders in the planning process and invest local communities with more power to anticipate and prepare for environmental changes. Rastandeh characterizes stakeholders as either laypeople, influential persons, experts, or local authorities (2015). Kok et al. (2007) found that stakeholders are most engaged in the process when the issues at hand are relevant and credible to them, but that there is a tradeoff between making scenarios relevant and making them consistent across different scales. Ensuring consistency can negatively impact the diversity of scenario outcomes and power structures involving stakeholders at different scales. Yet despite these challenges, scenario planning is a useful tool to engage a variety of stakeholders. Chakraborty (2010) notes that scenario planning is not axiomatically participatory, but when it does engender a participatory process, it can potentially aid regional governance. In one case study, scenario planning aided the coordination of regional decision-making.

A point of contention in scenario planning is the use of predictive models, an approach used by some researchers to assess the future effects of climate change and other drivers of change. Bray

(2009) contends that the typical approach to environmental impact assessment modeling is weakened by reliance on simple linear trajectories and a failure to account for the complexity of human behavior and society in coupled human-natural systems. This is inherently difficult to fix, because any researcher constructing a model must choose which variables to study; some will be omitted. The other problem with modeling is the question of accuracy that it poses. Some scenarios based on climate change attempt greater accuracy than others; for a less predictive approach, it is considered sufficient to use climate trends as a jumping-off point for further assessment.

However, models would benefit from incorporating the uncertainty deriving from human perceptions and decisions about climate change, even if it means reassessing current notions of quantitative rigor. Another critical perspective comes from Rickards (2013), who conceptualizes a framework for planners' and climate scientists' adaptation strategies with a dichotomy between transformation (i.e., more radical change) and adjustment (i.e., more gradual change). Rickards posits that the process of scenario planning itself is laden with value judgments and is just as socially constructed as norms of adaptation and responses to climate change. Thus, approaches to scenario planning may also lie somewhere between the conceptual poles of "predictive" and "imaginative" visions of change.

Also, scenario planning is highly context-dependent. In a study of the outcomes of scenario planning in nine European case study cities, Breil et al. (2009) found that each case city started from a similar process of engaging local stakeholders in participatory scenario planning to imagine post-carbon futures for their cities. The case studies revealed key similarities, mainly in emphasizing strong urban governance and focusing on the energy transition away from fossil fuels to renewable energy. However, the strategies and insights that each city derived from the scenario development varied due to the local context of each study site. For example, features including size, population density, economic strength, and current carbon intensity all factor into the localized outcomes of scenario planning projects. Rastandeh (2015) also examines barriers to the success of scenario planning at the local level. Focusing on the twin pressures of urbanization and climate change, one major barrier in the application of alternative future scenarios is divergence in diverse stakeholders' opinions and underlying assumptions. Another barrier is the inherent complexity of making abstract ideas spatially explicit.

Regardless, there are opportunities for greater reliance on scenario planning to expand stakeholders' perspectives and make more informed decisions about environmental management. Divergence among the methods, research frameworks, processes, and outcomes of scenario planning justifies further study of its capacity to anticipate and shape change at the intersection of complex and uncertain change driven by human and natural systems.

III. Methods

This thesis uses a systematic analysis (or qualitative meta-synthesis) of scenario planning applications to generate insights and understanding beyond the individual case study. However, the approach applied here is interpretative in nature and it is not intended to provide generalization of the findings. Rather, it aims to identify patterns that can inform the development of explanatory hypotheses in future research.

A. Case Study Selection

Selecting case studies began with a systematic review of relevant literature. Databases that were searched include Jstor, Google Scholar, and the University of Washington library archives. Additional resources were the U.S. Climate Resilience Toolkit, a site managed by NOAA's Climate Program Office which compiles federal information about managing climate-related risks and opportunities, and Resilience Alliance, a multidisciplinary research organization. The bibliographies and references of relevant literature were also examined for further reading. Key journals in the field from which literature was drawn include *Ecology and Society*, *Conservation Ecology*, and the *Journal of Applied Ecology.*

The primary criterion for selection was relevance to both urbanization and climate change; both had to be part of the scenario planning framework as drivers of change within the field of scenario planning. Literature discussing approaches to uncertainty and associated concepts in urban ecology were also compiled. My focus was on studies that use scenario planning as an analytical framework published in recent years: no earlier than 2000. To gather sources, I searched the library and journal databases described above with the primary keywords “scenario planning" as well as “scenario planning AND urbanization AND climate change,” also substituting “global warming” for “climate change” in order to compile works with alternate terminologies. Other search terms included “resilience,” “economic growth, “economic development,” “socioeconomic…” “sociocultural…” “(urban) ecology,” “infrastructure,” and “human-natural systems,” which terms aim to capture literature covering the processes and systems that inform the driving forces behind case studies of interest. Finally, it was important to synthesize and compare geographically diverse case studies, so there was no restriction placed on the region, biome, or country of study. The result of this search is a collection of thirteen case studies that investigate, to some degree and not exclusively, the combined impacts of drivers related to urbanization and climate change. These case studies, presented in the form of published research, supply indirect data which will be analyzed in Chapter IV.

The study conducted by Oteros-Rozas et al. in 2015, in which the research team analyzed 23 case studies in scenario planning, influenced my own research process both in terms of the variables evaluated in the study and the literature analyzed. In particular, with regard to the latter, the study by Oteros-Rozas et al. (2015) led me to incorporate two of the same case studies for their attention to climate change and urbanization. These were: Beach and Clark (2015) and Palomo et al. (2011). Additionally, a comparison of three case studies in Latin America by Waylen et al. (2015) led me to include the Colombian case study as documented by Farah et al. (2014).

Tables 1 and 2 provide identifying and contextual information on the case studies, while Tables 3 through 15 present a detailed repository summarizing my interpretation of the evaluation criteria for each case study. In total, thirteen case studies were selected in order to have a sufficient number to produce worthwhile results while remaining within the necessarily limited scope of this particular project. In accordance with the intent to generate geographic diversity, four of the case studies come from the United States; five from Europe; three from the Americas; and one from Africa. Inductive analysis of the relationships between case studies and the lessons one might learn from their comparison will guide my research.

I use qualitative cross-case comparison is used to draw insights and produce a reflection on current trends, strengths, and weaknesses in scenario planning. Interpretation of the results includes an analysis of points of similarity and divergence among the case studies with implications for future directions in scenario planning, the application of database analysis to this field, and preliminary lessons learned from contemporary ventures in scenario planning.

B. Limitations

A major limitation of this project is the limited data and time frame of current scenario planning cases necessary to conduct quantitative analysis of the impact of scenarios on decision making. A larger sample size of case studies could provide the basis for statistical analysis, but that is outside the scope of this thesis. Methods to collect more data to evaluate the success and challenges of case studies in scenario planning, like, for example, distributing an open-ended questionnaire to experts or study authors as noted in the literature, also fell beyond the scope of this thesis. Therefore, any generalizations made about trends in scenario planning across multiple case studies are necessarily constrained by the scope.

Another limitation is the absence of a regional focus in the compilation of case studies. They are drawn from both domestic and international studies in scenario planning. Even so, certain regions are underrepresented or not represented at all by the case studies I have selected, including Asia, Oceania, the Americas, and Africa. There is also the limitation and potential bias as an American researcher to rely mostly on American literature to survey the state of the field of scenario planning.

Finally, the recent date of publication of many studies under consideration presents a limitation. In order to perform a deeper investigation of the results of the studies, and to examine how the findings were translated into policy to greater or lesser degrees of success, access to the raw data of the studies and the means to conduct an external evaluation of success would be required. Absent that information, the conclusions drawn here are limited and missing a component that would provide valuable insights.

C. Evaluation Criteria

The central assumption underlying this project is that scenario planning generates different outcomes depending on the intentions, objectives, assumptions, and methods of those carrying out the scenario planning process. To evaluate the research design of multiple studies, and seek possible relationships between research design and the authors' subsequent findings, it is necessary to establish a set of common criteria for analyzing each study.

As mentioned above, a touchstone for comparative analysis of participatory scenario planning (PSP) is the 2015 report "Participatory scenario planning in place-based socio-ecological research: Insights and experiences from 23 case studies" (Oteros-Rozas et al.). In their words, seven criteria they explore include "the context, the original motivations and objectives, the methodological approach, the process, the content of the scenarios, the outputs of the research, and the monitoring and evaluation of the PSP process" (31).

This seven-part framework has informed the development of the ten criteria that I have selected to organize my comparative database of the thirteen case studies under consideration, aiming to consider variables extending throughout the scenario process and activities and apply a critical lens to the results. My evaluation criteria are in turn organized in three sections: 1) the extent of stakeholder engagement; 2) the process of scenario planning undertaken by those actors; and 3) the outcomes of the scenario planning process. These criteria will frame the summary, synthesis, and comparison of relevant case studies. It is important to note that the criteria do not attempt to establish cause for "success" in scenario planning or make any statement about cause and effect. Such an evaluation is beyond the scope of this project: there is not yet a body of systematic comparison in the scenario planning literature to follow. It does not exist. For this reason, the criteria will be used to denote dichotomous ends of a given spectrum and evaluate where a particular threshold lies to determine whether a criterion is met. Without trying to make a claim about the optimal conditions for such a study, my intent is only to draw a clear line between different sets of conditions, either of which constitute discrete characteristics of scenario planning research.

1. Stakeholder Engagement

Stakeholder Diversity

Per Oteros-Rozas et al., "PSP is a process in which stakeholders, frequently guided by researchers, are engaged in a highly collaborative process and develop a leadership role within some or all stages of a scenario development process to investigate alternative futures." The extent to which a diverse set of individuals' or groups are involved in the planning process shapes participatory scenario planning, and has implications for the evaluation stage. Relevant questions to evaluate stakeholder engagement include: *How were participants in the process identified, and how many people are involved? How representative is the PSP stakeholder population in the context of the case study?* According to Peterson, Cumming, and Carpenter, including a diverse group of stakeholders in the process is key to building shared knowledge. At the same time, they caution that experts and residents local to the scenario planning context cannot necessarily be considered the ultimate authority, "because scenarios often deal with poorly understood issues outside the expertise of most people" (2003b, p. 365).

Regardless, the participation of stakeholders, whoever they may be, is fundamental because "scenarios' basic resources are individually and collectively held ideas about the future" (Berkhout et al., 2002). The research framework underlying participatory scenario planning necessarily provides a role for affected stakeholders, which Rastandeh (2015) classifies into four major groups: laypeople, influential persons, experts, and local authorities. In my criteria, a case study will be considered *more diverse* in its typology of participating stakeholders if at least three of those groups are involved in the research and *less diverse* if there are no participating stakeholders or if only one group is involved.

Stakeholder Participation

Susskind (2012) argues that traditional methods of public engagement like hearings, public notice, surveys, and focus groups are insufficient to engage the public in collective risk management decisions like those at the heart of scenario planning. For this reason, scenario planning has the potential to foster co-production of climate knowledge between scientists and stakeholders to generate meaningful science, as long as the needs of scientists and stakeholders are balanced (McBride et al., 2015). When scenario planning is used in this kind of knowledge building, Meadow et al. (2015) hold that the research team's role is to facilitate the participatory process and provide technical input, but they are not equals with the stakeholders.

A trade-off between quantitative rigor and stakeholder participation emerges, under the assumption that greater rigor (particularly in modeling) constrains the ability of non-scientists' participation in the planning process. On the other hand, a benefit of active stakeholder involvement is that it clarifies and strengthens research objectives (McBride et al., 2015). And when stakeholders can define scenarios, their participation adds legitimacy to the planning project (Mahmoud et al., 2009).

The relevant question to ask is: *How much agency do affected stakeholders maintain in the identification of drivers, process of model design (if applicable), and/or the construction of scenarios?* Each case study will be evaluated by its orientation toward *greater* or *lesser* agency of participating stakeholders, as opposed to the research team, in those three aforementioned elements of the scenario planning process.

2. Process

Objective

This criterion investigates the purpose of the scenario planning process set forth by the authors and the parameters used to define "success" for their study. Oteros-Rozas et al. classify objectives under a framework that may also be useful for my research. In their analytical lens, the objective can be understood as exploratory, pre-policy, or a mix of both; additionally, the approach to scenario planning may be broadly generalized as more descriptive or normative (2015). Expected outcomes are also relevant. If the process holds surprises or diverged from the authors' expectations, that presents a valuable opportunity to draw conclusions about lessons learned. Overall, clarifying the objectives of studies in scenario planning affects their methodological trajectory and ultimate findings. The objective of each case study will accordingly be characterized as either *exploratory* or *normative*.

Drivers

The choice of the most uncertain and most important drivers is also key, based on the assumption that the way authors choose to define the scope of the forces of change (which, in this project, will fall under the overarching categories of urbanization and climate change) influences the outcome of their research. This is the crux of scenario planning; the whole process follows from the selection of drivers and the dimensions selected as a proxy to contextualize them. The drivers guide the development of alternative futures and the scenarios themselves. They are judged to be the most important long-term forces driving the dynamics of a given system, as opposed to more urgent or short-term dynamics (Susskind, 2012, p. 227).

For this reason, it is also important to consider how many drivers were selected. A typical approach is to choose two key drivers, which sets up the a four-quadrant deductive visualization of scenarios, but other case studies may have more than two drivers and, as a result, increasing uncertainty and complexity with which to contend when constructing scenarios. Moreover, the number of drivers determines how many scenarios are constructed. According to Peterson, Cumming, and Carpenter (2003b), three to four is the optimal number. More than four scenarios can become overly complicated and make communication more difficult. Scale is another important consideration, as it influences the representation of the interconnected relationships and networks of coupled human-natural systems in the scenarios (McBride et al., 2017).
The threshold for evaluation here is therefore whether each case study utilizes a *quadrant organization* based on two drivers, or a different technique.

Uncertainty

The methodological approach to scenario planning varies across the case studies, with implications for the types of scenarios developed and the authors' findings. This defines the way that authors assess climate change and socioeconomic drivers, "in order to obtain estimates of future system states" (Maier et al., 2016). The first quality to discern is how the authors approach uncertainty. To borrow a line of inquiry from Mahmoud et al. (2009), the question is threefold: how is uncertainty understood, estimated, and communicated? A simple way to evaluate the treatment of uncertainty in each case study is by the divergence of the constructed scenarios. Scenarios that are more distinct from one another necessarily incorporate a greater degree of uncertainty than scenarios that are less distinct, so the threshold is whether scenarios are *quantitatively divergent* or *qualitatively divergent.*

Methods

Following from uncertainty, another element to analyze is the mix of quantitative and qualitative methods are used in scenario planning process. For quantitative methods, models must be considered. What variables are included in and omitted from the model, what is the conceptual framework that the model sets forth to represent, and how does the model scale data to the appropriate time and spatial resolution?

When considering modeling as one quantitative tool commonly used in scenario planning, Maier et al. (2016) conceptualize three paradigms of models: either serving to consolidate best available knowledge, or treating the future as "quantifiably uncertain in order to deal with system processes and conditions that are considered insufficiently well-known to be captured within models, or considering multiple plausible futures, allowing the modeler to avoid the idea of a single (uncertain) future because "dynamics of change are not sufficiently known to be represented within a model" (155-156). Different methods of coping with uncertainty bring to bear on lessons learned, strengths, and weaknesses of varying methodological strategies in scenario planning.

Berkhout et al. (2002) contend that quantitative methods can be successful when combined with qualitative scenario approaches, in which "scenarios operate as antecedents to impact assessment or integrated assessment modeling." They conceptualize scenarios not as "empirically validated models" but as heuristic learning devices. This is a useful way to compare the methodological approaches of the case studies under consideration.

Miller and Morisette (2014) proffer that, for social-ecological systems, "simulation models are well placed to provide added rigor to scenario planning because of their ability to reproduce complex system dynamics" (n.p.). However, one potential downside is that stakeholders often have a limited role, if any, in exploring and developing simulations. With implications for limitations of a given study, there is a clear trade-off between scientific rigor and accessibility to stakeholders when choosing between an emphasis on expert-driven quantitative methods or a more bottom-up approach (McBride et al., 2017). All of this will influence the appropriateness of the analytical dimensions of the drivers, how the authors reckon with potential bias in the data, and the way that scenarios are designed. Thus, this criterion will assess whether each case study is conducted by methods that are *quantitative, qualitative,* or *mixed-methods.*

Scenarios

The content and structure of the narrative scenarios themselves has an effect on planning outcomes and interventions, whenever the scenario planning process is used to guide adaptation policy or practice in response to possible futures. Oteros-Rozas et al. (2015) consider the guidelines established by the researchers and the names and narratives given to the scenarios that are developed to evaluate how scenarios were developed, and how participants drew conclusions about that which is plausible, probable, or desired. Analysis of scenario construction can bring about better practices for conducting scenario planning in pursuit of the defined objectives.

Foley et al. (2017) advocate for synergy between personal, imaginative narrative and the predictive metrics of scenarios. As with the overall research objective, scenario content may be characterized as either normative (what ought to happen), predictive (what will happen), or exploratory (what may happen) (McBride et al., 2017). Mahmoud et al. (2009) characterize exploratory scenarios as those that describe the future by extrapolating from past trends. Rickards (2013) characterize normative scenarios as those that set up desirable or undesirable futures with an explicit intention to optimize. These are more ambitious and subjective, and may also be considered anticipatory scenarios. Policy-responsive scenarios are included in this category (Mahmoud et al, 2009).

It is also important to ask how plausible the scenarios are (Peterson, Cumming, and Carpenter, 2003b), and whether extremes or "wild cards" are represented. Rickards (2013), who conceptualizes a framework for planners' and climate scientists' adaptation strategies with a dichotomy between transformation (i.e., more radical change) and adjustment (i.e., more gradual change), posits that the process of scenario planning itself is laden with value judgments and is just as socially constructed as norms of adaptation and responses to climate change. Thus, approaches to scenario planning may also lie somewhere between the conceptual poles of "predictive" and "imaginative" visions of change. This may be demonstrated through the content and structure of scenarios and how a narrative story is developed through the process. To synthesize this component of the literature, this criterion will assess scenario construction as being *more plausible* or *more imaginative* based on their content and dimensions.

3. Outcomes

Findings

Here, the relevant concern is not merely the outcome of the scenarios themselves but the outcome of the process. Exploring the results and discussion of the case studies will likely illuminate ways that the Stakeholder Engagement and Process evaluation criteria influenced the outcome of the scenario planning process. It can certainly reveal insights about the authors' objective and methods, especially if the findings diverge from expectations. Unlike with probabilistic forecasting, surprising results can be the most helpful (Mahmoud et al., 2009).

This will also have implications for the evaluation of the process, both for the authors and for the broader planning concerns. For example, one question to ask may be how success was defined: was the intention more to translate the findings to direct policy interventions, or was greater value placed on the learning process undertaken by those who carried out the study? This distinction is what Berkhout et al. (2002) refer to as the dichotomy between scenarios as "truth machines" versus "learning machines" (p. 84). Because relative "success" in scenario planning be difficult to determine, particularly with more recent case studies where the data is simply not available, my intent is not to characterize case studies as being more or less successful in achieving their objectives, but rather to place them on either end of a spectrum of *application-oriented* or *learning-oriented.*

Evaluation

This section concerns how results may be evaluated, both by the authors themselves in the context of the study and from a post-study perspective. If any conclusions are reached about the relative strengths and weaknesses of the study, or lessons learned, then that should be considered here. Oteros-Rozas et al. (2015) define "evaluation" as "assessment of the scenario design, implementation, and results through a formal methodological approach" (n.p.), and it was alternately measured through interviews, surveys, and observation. For generalizing about scenario planning, this criterion is connected to the study's objectives and results: the authors state that "assessing participants' learning was the top reason for conducting evaluations followed by assessing the usefulness of the process, and providing feedback to the research team."

Evaluation can also be useful after the fact to investigate how scenario planning findings were translated into policy. For example, Ewing et al. (2007) claim that the Envision Utah scenario planning process, which dates to 1997, led to the implementation of a successful compact growth plan that saved the region billions of dollars in infrastructure spending. This is the kind of information that is needed for an in-depth evaluation of the long-term impacts of studies in scenario planning. Case studies will be characterized as either *possessing* or *lacking a formal evaluation process*.

Limitations

Finally, a criterion related to evaluation but separate from it is the limitations of the study. Such limitations may be acknowledged by the authors or not. This will speak to the weaknesses of the scenario planning process and possibly indicate strategies to overcome them for the benefit of future research. In Oteros-Rozas et al. (2015), timing and resource constraints were considered to be the most prominent limitations affecting the comprehensiveness of the evaluation process. Meadow et al. (2015) also found that limited resources and capacity were a primary challenge for researchers in scenario planning.

Therefore, one question to ask is how the assumptions made in the scenario planning process constrain its effectiveness in meeting the objective. Other concerns indicated by Oteros-Rozas et al. (2015) included scale and size, consensus building in the creation of alternative futures, the difficulty of rendering information spatially explicit in an accurate way, and choosing the right indicators to evaluate the alternatives produced by the scenario planning process. Each of these factors can invite limitations. For the purposes of this comparison, the limitations of each case study will be characterized by their origin in the *stakeholder engagement, process*, or *evaluation* of the research.

IV. Results and Discussion

A. Evaluation of Case Studies

In this chapter, a brief summary of each case study is presented in a table synthesizing its evaluation criteria from the previous chapter. For each case study, briefly denoted by author, year of publication, and title and numbered 1 through 13 in chronological order, the application of ten evaluation criteria is presented in the form of a table that assesses whether the thresholds described in Chapter III are met. As a preliminary summary, Tables 1 and 2, below, list the case studies in chronological order with their identifying information and with their location, respectively. Tables 3 through 15, which follow, apply the analytical criteria to each study, and insights are summarized in Table 16.

ID	**Authors**	**Year Published**	**Publication**	**DOI**
1	Bohensky, Reyers, & van Jaarsveld	2006	Conservation Biology	10.1111/j.1523-1739.2006.00475.x
2	Shaw et al.	2009	Global Environmental Change	10.1016/j.gloenvcha.2009.04.002
3	Nelson et al.	2009	Journal of Applied Ecology	10.1111/j.1365-2664.2008.01599.x
4	Kass et al.	2011	Journal of Applied Ecology	10.1111/j.1365-2664.2011.02055.x

5	Palomo et al.	2011	Ecology and Society	23
6	Carlsen, Dreborg, & Wikman-Svahn	2013	Mitigation and Adaptation Strategies for Global Change	10.1007/s11027-012-9419-x
7	Palacios-Agundez et al.	2013	Ecology and Society	10.5751/ES-05619-180307
8	Farah et al.	2014	Community-Based Management of Environmental Challenges in Latin America	N/A
9	Hoyer & Chang	2014	Applied Geography	10.1016/j.apgeog.2014.06.023
10	Beach & Clark	2015	Ecology and Society	10.5751/ES-07379-200161
11	Withycombe Keeler et al.	2015	Environmental Science and Policy	10.1016/j.envsci.2015.01.006
12	Restemeyer, van den Brink, & Woltjer	2017	Journal of Environmental Planning and Management	10.1080/09640568.2016.1189403
13	UW IHMP	2017	Institute for Hazard Mitigation Planning and Research	N/A

Table 1. Identifying information for thirteen case studies.

ID	Authors	Location of Study	
		Continent	Region
1	Bohensky, Reyers, & van Jaarsveld	Africa	Gariep River Basin, South Africa
2	Shaw et al.	North America	Delta, British Columbia, Canada
3	Nelson et al.	North America	Chesapeake Bay watershed, United States of America
4	Kass et al.	Europe	England, United Kingdom
5	Palomo et al.	Europe	Doñana region, Spain
6	Carlsen, Dreborg, & Wikman-Svahn	Europe	Botkyrka, Sweden
7	Palacios-Agundez et al.	Europe	Biscay, Basque Country, Northern Spain
8	Farah et al.	South America	Bajo Colima, Colombia
9	Hoyer & Chang	North America	Tualatin and Yamhill Basins, Northwest Oregon, USA
10	Beach & Clark	North America	Southwest Yukon Territory, Canada
11	Withycombe Keeler et al.	North America	Phoenix, Arizona, United States of America
12	Restemeyer, van den Brink, & Woltjer	Europe	Rijnmond-Drechtsteden region, the Netherlands
13	UW IHMP	North America	Plain, Washington, United States of America

Table 2. Location of thirteen case studies.

#1. Bohensky, Reyers, & van Jaarsveld. (2006). *Future Ecosystem Services in a Southern African River Basin: A Scenario Planning Approach to Uncertainty.*

Stakeholder Engagement	**Diversity**	**Less diverse**: Experts and local authorities included in user group, with expertise in agriculture, water management, tourism, and conservation.
	Participation	**More agency:** Stakeholders met with research team 5 times over 2 years to guide driver identification and scenario construction, and their input led the research team to discard a model they had no part in designing. Ultimately, stakeholder input led to the use of spider diagrams to depict scenario narratives.
Process	**Objective**	**Exploratory**: To explore possible futures for ecosystem services and human wellbeing in the study region.
	Drivers	**Non-quadrant organization:** Multiple drivers were characterized as either belonging to the political, economic, and social environment or demographic trends, a category that includes urbanization. Climate change was assumed to raise temperature by up to 2 degrees and decrease runoff in all scenarios.
	Uncertainty	**Qualitatively divergent scenarios** exhibiting extremes in market and geopolitical driving forces, described as slight or sharp increases and decreases. Major uncertainties of the system include the strength of national governance and civil society.
	Methods	**Qualitative:** Millennium Ecosystem Assessment scenarios were downscaled to generate scenarios for the study area. Narrative trends were depicted using spider diagrams showing change in ecosystem services as either a slight or sharp increase or decrease, or no change, as a result of applying driving forces.

	Scenarios	**More imaginative:** The first two scenarios envision business as usual, but Market Forces is driven by economic growth while Policy Reform is driven by sustainability in terms of society and the environment. The latter two scenarios envision a world driven by a more globalized economy, but Fortress World devotes greater concern to national security while Local Resources is more focused on local institutions.
Outcomes	**Findings**	**Learning-oriented:** Multi-scale scenario planning reveals divergence between local/regional scenarios and their broader, global counterparts and is a valuable tool for communication about environmental problem-solving.
	Evaluation	**No process:** A formal post-planning evaluation is not mentioned in the text.
	Limitations	**Findings:** One limitation acknowledged by the authors is that the study has limited relevance for informing policy. It is not intended to set forth a concrete strategy for land management in the Gariep basin.

Table 3. Evaluation criteria applied to case study #1.

#2. Shaw et al. (2009.) *Making local futures tangible: Synthesizing, downscaling, and visualizing climate change scenarios for participatory capacity building.*

Stakeholder Engagement	**Diversity**	**More diverse:** Stakeholders included influential persons (regional planners and engineers), experts (university and government researchers and scientists, non-governmental experts), local authorities (Port of Vancouver officials), and laypeople (members of community groups). Despite efforts to engage the Tsawwassen First Nation, they were not included in the study.
	Participation	**More agency:** Stakeholders shared in 3 workshops to carry out the planning process in iterative stages with considerable input given to driver identification and scenario construction.
Process	**Objective**	**Normative**: To co-produce climate knowledge to build capacity for climate change adaptation and mitigation at the local level.
	Drivers	**Quadrant organization:** 4 drivers of population, economy, energy use, and land use were used to create 4 scenarios.
	Uncertainty	**Qualitatively divergent scenarios** downscaled from a global framework.
	Methods	**Qualitative:** Stakeholders synthesized and downscaled global climate change scenarios to the local level in order to visualize Delta's vulnerabilities. A two-step qualitative approach was used for downscaling first to the metropolitan Vancouver region and second to the city of Delta.
	Scenarios	**More imaginative:** Scenarios are "Do Nothing" (high emissions and no adaptation strategy adopted), "Adapt to Risk" (high emissions and "pure" adaptation), "Efficient Development" (adaptation with moderate emissions), and "Deep Sustainability" (adaptation with strong mitigation of emissions).

		Scenarios were designed to be non-probabilistic and therefore less plausible than imaginative.
Outcomes	**Findings**	**Learning-oriented:** One key finding is that using highly specific, localized visual imagery to communicate scenarios makes the planning process and the outcomes of scenario planning more accessible to laypeople and decision-makers.
	Evaluation	**No process:** A formal post-planning evaluation is not mentioned in the text, but the authors indicate that a potential opportunity for evaluation would be to conduct a complementary study comparing their results with regional assessments of the drivers of change.
	Limitations	**Stakeholder participation, methods, scenarios:** The authors acknowledge spotty data availability as a limitation. Time and budget constraints also limited the research team's ability to produce a broad spectrum of engaging visual media in crafting the scenarios. Balancing those constraints with stakeholder participation proved challenging, and stakeholders who ought to have been involved include Tsawwassen citizens and economic experts.

Table 4. Evaluation criteria applied to case study #3.

#3. Nelson et al. (2009). *Forecasting the Combined Effects of Urbanization and Climate Change on Stream Ecosystems: From Impacts to Management Options.*

Stakeholder Engagement	**Diversity**	**Less diverse:** No affected stakeholders were involved in the planning process.
	Participation	**Less agency:** No stakeholders participated in the design of models or scenarios, which was the sole domain of the research team.
Process	**Objective**	**Exploratory**: To study the separate and combined effects of urbanization and climate change on stream ecology.
	Drivers	**Quadrant organization:** The two identified drivers were climate change and urbanization, grouped together as anthropogenic sources of change.
	Uncertainty	**Quantitatively divergent scenarios** derived from process-based models
	Methods	**Quantitative:** The methodology was model-based with 5 submodels: downscaled climate projections, hydrology, geomorphology, water temperature, and fish growth and reproduction. Fish were used as an indicator of environmental quality. The urbanization variables considered here were impervious surface, new construction, and percent of watershed that is forested.
	Scenarios	**More plausible:** 10 scenarios were developed: 1 baseline, 4 climate change scenarios, 4 urbanization and climate change scenarios, and 1 scenario with urbanization alone as a driver. Validation assessments indicated that the scenarios were consistent with observed trends.

Outcomes	**Findings**	**Application-oriented:** The central finding is that either driver, alone, was projected to significantly reduce species diversity. However, the impact was sometimes even larger when the two drivers were combined. Thus, the synergistic effect of urbanization and climate change may lead to severe changes in species composition and ecosystem services in stream ecology in the Chesapeake Bay region. The findings are broadly applicable because the species considered in the study are common across the entire eastern United States, and point to the value of proactive stream and natural resource management approaches.
	Evaluation	**No process:** A formal post-planning evaluation is not mentioned in the text.
	Limitations	**Methods:** Assumptions about food availability for fish are necessarily conservative. When it comes to modeling, not all parameters were pre-established in the literature so it was necessary to extrapolate based on assumptions. Some predictions based on species abundance were conservative, given the exclusion of impacts that could not be validated with an independent dataset. Ultimately, the overarching limitation is that models simplify reality and stream ecosystems are too complex and dynamic to be reduced.

Table 5. Evaluation criteria applied to case study #3.

#4. Kass et al. (2011). *Securing the Future of the Natural Environment: Using Scenarios to Anticipate Challenges to Biodiversity, Landscapes and Public Engagement with Nature.*

Stakeholder Engagement	**Diversity**	**Less diverse:** Stakeholders included experts (policy-makers) and laypeople (local residents).
	Participation	**Less agency:** Stakeholders did not define drivers, but did engage in a process to prioritize them. Stakeholders met in three workshops to help construct the scenarios.
Process	**Objective**	**Normative**: To advance sustainability (defined as securing the environment for future generations) through unified national scenario planning.
	Drivers	**Non-quadrant organization:** The 14 drivers developed in this process included climate change, converging technologies, demographics, energy, food security, economic power shifts, governance, health and wellbeing, infectious diseases, marine, mobility, money/wealth/economy, resources, values, and people.
	Uncertainty	**Qualitatively divergent scenarios** were created.
	Methods	**Qualitative:** Both the Ethnographic Futures Framework (using five categories to explore how change directly affects people) and the Three Horizons approach were used to construct scenarios. Interviews were conducted in ethnography. Following an iterative process, scenarios were fleshed out in the third workshop.

	Scenarios	**More imaginative:** Four scenarios were created: "Connect for Life," "Keep it Local," "Succeed through Science," and "Go for Growth." Each was told in narrative form, from the imagined perspective of someone from the year 2060. Among scenarios, the time scale demonstrated variable focus on short/medium term or long term. Each scenario described impacts to natural habitat and biodiversity and was designed to explore a range of possible futures, not just those that are plausible or preferred.
Outcomes	**Findings**	**Application-oriented:** One finding is that the EFF approach is not typically used in scenario planning, but demonstrates how local communities can identify the societal drivers of change and indicates that ethnographic inputs ought to be considered in scenario planning. The discussion also focuses on the application of study results to the UK National Ecosystem Assessment and future research.
	Evaluation	**No process:** A formal post-planning evaluation is not mentioned in the text.
	Limitations	**Methods:** The high number of drivers is unwieldy and unusual for scenario planning.

Table 6. Evaluation criteria applied to case study #4.

#5. Palomo et al. (2011). *Participatory Scenario Planning for Protected Areas Management under the Ecosystem Services Framework: the Doñana Social-Ecological System in Southwestern Spain.*

Stakeholder Engagement	**Diversity**	**More diverse:** Stakeholders included laypeople (including creative people and local stockbreeders), experts (elders with traditional ecological knowledge), and influential people, with stakeholders prioritized if they had a medium-to-high level influence in the socio-ecological system and if they were directly affected by its management.
	Participation	**More agency:** In a process of co-production of knowledge, stakeholders identified drivers and constructed scenarios through two workshops, then were surveyed afterward for their preferences to guide the backcasting of desired land management policies.
Process	**Objective**	**Normative**: To create a new plan for the management of the Doñana region based on participatory scenario planning
	Drivers	**Non-quadrant organization:** 4 drivers of change are technology, participation, climate change, and migration.
	Uncertainty	**Qualitatively divergent scenarios** were created.
	Methods	**Qualitative:** A combination of interviews, questionnaires, and workshops was used to create a framework for participatory scenario planning. The six stages of the process were identifying and prioritizing stakeholders; collecting information about the aspects of the system with highest importance; characterizing current and past trends and conditions;

		developing scenarios; characterizing the scenarios according to services provides; and proposing management strategies to backcast a desirable future. Scenarios were developed with narrative storylines and illustrations.
	Scenarios	**More imaginative:** Four scenarios were created. They are as follows: "Global Knowledge" (adapted from MedAction's Knowledge is King), "Doñana Trademark" (adapted from MedAction's Big is Beautiful), "Arid Doñana" (adapted from MedAction's Convulsive Change), and "Adaptive Doñana – Wet and Creative."
Outcomes	**Findings**	**Learning-oriented:** Scenario planning can create different visions for the future of coupled human-natural systems, and including higher diversity of stakeholders in the process is critical for improving the quality of the policy options that follow. Water appears as a central element in each of the four scenarios, showcasing its primacy in the coupled human-natural system of the study area. Scenario planning can lead to more desirable futures by determining pathways for managing ecosystem services. Finally, the authors claim that backcasting is a valid strategy for illuminating desired futures, though it is rarely used in scenario planning.
	Evaluation	**Formal evaluation process:** Participants provided feedback about scenario choice and the results of backcasting via emailed surveys disseminated after both workshops.
	Limitations	**Evaluation:** Participant response was lower than desired when solicited via email, indicating a need to find more effective ways of reaching out to study participants.

Table 7. Evaluation criteria applied to case study #5.

#6. Carlsen, Dreborg, & Wikman-Svahn. (2013). *Tailor-made scenario planning for local adaptation to climate change.*

Stakeholder Engagement	**Diversity**	**Less diverse:** Stakeholders included local authorities (municipal civil servants) and laypeople (local residents).
	Participation	**More agency:** The process was designed to be "bottom-up" rather than driven by global scenarios, with the intent of establishing scenarios informed by local input and relevant to local needs. The focal question was identified by local planners. Stakeholders were involved in the identification of drivers and construction of scenarios.
Process	**Objective**	**Normative**: To evaluate the relevance of scenario planning in making informed, local decisions about protecting groundwater aquifers.
	Drivers	**Non-quadrant organization:** The drivers identified are freshwater quality, infrastructure, institutional changes, land use competition, freshwater price, and local ecological ideology.
	Uncertainty	**Qualitatively divergent scenarios** were created.
	Methods	**Mixed-methods:** The methodology is characterized as a bottom-up approach in which workshops were used to develop drivers and scenarios. Workshops included local stakeholders and representatives of scenario users. An effort was made to engage stakeholders in the construction and application of scenarios (i.e., not just their application). The scenario tool used along with an environmental sustainability analysis tool, considering social, environmental, and ecological dimensions of drivers. The scenarios mostly focused on socioeconomic drivers, emphasizing a need for local stakeholder

		engagement but also indicating a bias for the local over regional and national. Uncertainties are depicted by modeling and downscaling emissions and socioeconomic variables.
	Scenarios	**More plausible:** 6 scenarios were created. Projecting to 2030, 1 climate scenario and 2 socioeconomic scenarios were created. Projecting to 2060, 2 climate scenarios and 1 socioeconomic scenario were created.
Outcomes	**Findings**	**Application-oriented:** The most influential drivers were not on national level but at the scale of the planning entity and market. Ultimately, a "tailor-made" methodology lowers public barriers to entry in planning process. The authors suggest combining a bottom-up approach to scenario planning with a "consistency" approach that fills in gaps in local knowledge with greater standardization of scenarios in order to mitigate local bias while keeping local perspectives.
	Evaluation	**Formal evaluation process:** A post-planning questionnaire was distributed to evaluate the planning process.
	Limitations	**Stakeholder participation:** A limiting bias for local over regional and national scale was revealed and perhaps enabled by the scenario planning process.

Table 8. Evaluation criteria applied to case study #6.

#7. Palacios-Agundez et al. (2013). *The relevance of local participatory scenario planning for ecosystem management policies in the Basque Country, Northern Spain.*

Stakeholder Engagement	**Diversity**	**More diverse:** 39 stakeholders included laypeople (landowners and farmers' union members), experts (in architecture, economics, biology, geology, engineering, teaching, and journalism), local authorities (public administration professionals and policy-makers), and influential people (environmental associations and NGO members).
	Participation	**More agency:** Collaborative decision-making was encouraged through stakeholder identification and ranking of drivers and scenario construction through downscaling of Millennium Ecosystem Assessment scenarios.
Process	**Objective**	**Normative:** To implement more effective management of ecosystem services through a clear link between scenario planning results and environmental policy.
	Drivers	**Non-quadrant organization:** Drivers included pollution, soil contamination, and climate change; ecosystem degradation and transformations in agriculture; intensive forest management; and land use and planning
	Uncertainty	**Qualitatively divergent scenarios** were created.
	Methods	**Qualitative:** Millennium Ecosystem Assessment scenarios were downscaled to the regional level. Backcasting was used to identify desired management strategies for the region. In a combination of participatory methods, back-to-back workshops were organized to maintain consistency of participants, highly

		visual scenarios were constructed, and exploratory scenarios were combined with normative backcasting through the WorldCafe approach.
	Scenarios	**More imaginative**: Scenarios through the year 2050 are described as “Oppressed Biscay,” “Global Delicatessen,” “TechnoFaith,” and Cultivating Social Values,” with the first being the least desirable and the last being the most desirable. Scenarios are more imaginative than plausible.
Outcomes	**Findings**	**Application-oriented:** The authors indicate that, in a partial fulfillment of the research objective, findings from the study are already being implemented in public policy. “Cultivating Social Values,” identified as the most desirable future, is the focus of back-casted management strategies. Developing landscape multifunctionality in forest management is identified as an appropriate solution for the region, because the scenario process showed that future directions in forest management will have a significant impact on future outcomes.
	Evaluation	**No process:** While questionnaires were distributed to participants before the planning process, there was not a post-planning evaluation.
	Limitations	**No limitations** are discussed in the text.

Table 9. Evaluation criteria applied to case study #7.

#8. Farah et al. (2014). *Stakeholder vision on perspectives for the future in the Colombia case study.*

Stakeholder Engagement	**Diversity**	**Less diverse:** Representative stakeholders included laypeople (local residents) and local authorities (Consejo Comunitarios, which serve as local councils).
	Participation	**More agency:** The research team trained some residents as coinvestigators in an effort to empower them and broaden participation in workshops.
Process	**Objective**	**Normative**: To achieve sustainability in water management and biodiversity and to evaluate scenario planning as a tool to support community-based natural resource management (CBNRM) in Latin America.
	Drivers	**Non-quadrant organization:** Population growth or decline, infrastructure megaprojects, climate change, changes in commodities markets, and changes in public policy (end states: environmental- vs. development-oriented) were the identified drivers, compiled via morphological analysis.
	Uncertainty	**Qualitatively divergent scenarios** were created.
	Methods	**Mixed-methods:** The authors developed a hybrid methodology to tackle the combination of scenario planning and CBNRM. The first step was exploring how drivers of change affected the system; the second was specifying two possible states for each driver; the third was using morphological analysis to explore potential system responses. Next, scenario planning was used to construct alternative futures, identify robust response options, and discuss the implications and requirements of those response options.

	Scenarios	**More imaginative:** Three scenarios were created: "Stable Future," "Desirable Future," and "Undesirable Future." The narrative content of these scenarios is less plausible and literally grounded in the rhetoric of desirability.
Outcomes	**Findings**	**Application-oriented:** One finding is that taking the systematic approach of scenario planning (and specifically morphological analysis) facilitated the development of systems thinking in local communities and empowered the Consejo Comunitarios in local decision-making. Scenario planning also helped to illuminate practical strategies to respond to future change. For example, the community recognized a need to engage with higher-level government to be better represented. One learning-related finding is that scenarios helped link expert knowledge to traditional ecological knowledge.
	Evaluation	**Formal evaluation process:** 3 post-workshop interviews were conducted in stages.
	Limitations	**Findings:** One limitation acknowledged by the authors is the difficulty of pinpointing exactly when and how the study findings regarding the benefits of scenario planning, emerged in the course of the study.

Table 9. Evaluation criteria applied to case study #8.

#9. Hoyer and Chang. (2014). *Assessment of Freshwater Ecosystem Services in the Tualatin and Yamhill Basins under Climate Change and Urbanization.*

Stakeholder Engagement	**Diversity**	**Less diverse:** Stakeholders were experts and local authorities representing local, state, and federal perspectives on land use in the study area.
	Participation	**Less agency:** Stakeholders gave input to the model parameters and scenario construction, while the identification of drivers and quantitative modeling process were driven by the research team.
Process	**Objective**	**Exploratory**: To investigate the response of freshwater ecosystem services to the impacts of climate change and increased urbanization and riparian buffer restoration.
	Drivers	**Non-quadrant organization:** The identified drivers were climate change (at historic, low, medium, and high pathways) and urban growth/conversion of agricultural and forest lands (at historic, low, high, and managed high levels).
	Uncertainty	**Quantitatively divergent scenarios** were created.
	Methods	**Quantitative:** The spatially explicit Integrated Valuation of Environmental Services and Tradeoffs (InVEST) modeling toolset was used to map water and the provision of services in the study area in 2050. This methodology fills a gap in assessment with InVEST, which tends not to investigate climate impacts. The model is simplified in its assumption that changes to the landscape and to the climate are unrelated. Three global climate models were incorporated. A stakeholder workshop was held to develop spatial data and scenarios.

	Scenarios	**More plausible:** 5 matrices of 16 scenarios were created. In the first, the Climate Change axis includes historic water yield plus low, medium, and future water yield. The Urban Growth axis includes historic urban growth (from 1981-2010) plus low, high, and managed high growth alternatives (2036-2065). The second and the third are the same but with total phosphorus export and total phosphorus retention, respectively, as the dimension by which to measure climate change. The fourth and fifth replace the climate change dimension with sediment export and sediment retention, respectively. A sixth matrix bundles each of the above services into a single visualization. Stakeholders encouraged the creation of plausible and realistic scenarios with regard to variables including vegetation change.
Outcomes	**Findings**	**Application-oriented:** The authors found that water yield estimates are highly sensitive to climate, especially in the lowlands. Higher winter precipitation will lead to higher rates of erosion, which will in turn increase export and retention of sediments. The model shows tradeoffs between the provision and regulation of environmental services, which allows for utility in applying the results to land management decisions. Finally, the study indicates that Yamhill restoration efforts would have a greater impact than Tualatin due to the variance in impact in both regions under different scenarios.
	Evaluation	**No process:** No post-planning evaluation was conducted. The authors state that InVEST does not have the capacity to quantitatively evaluate

		uncertainty, but such a process would enhance the reliability and legitimacy of the findings.
	Limitations	**Methods:** One limitation is that calibrating the InVEST model is difficult and imbued with a high degree of uncertainty. Estimates for ecosystem service retention do not account for limits on the system's uptake potential.

Table 11. Evaluation criteria applied to case study #9.

#10. Beach and Clark. (2015). *Scenario planning during rapid ecological change: Lessons and perspectives from workshops with southwest Yukon wildlife managers.*

Stakeholder Engagement	**Diversity**	**Less diverse:** The 15 participants were all experts and local authorities (members of the Yukon Wood Bison Technical Team and the Yukon Elk Management Technical Team). They also included members of Renewable Resource Councils, Environment Yukon, and Environment Canada. Notably, 5 of the participants were First Nations.
	Participation	**More agency:** Over the course of 3 workshops in 13 months, participants played an instrumental role in the identification of drivers (and successfully contested the research team's initial grouping of ecological-social interactions) and scenario construction.
Process	**Objective**	**Normative**: To assess the utility of scenario planning in setting wildlife management goals amid rapid ecological change in the dynamic coupled human-natural system of the Yukon Territory.

	Drivers	**Non-quadrant organization**: 46 separate drivers were characterized in three categories: changing ecological-social interactions, land use, and the human factor.
	Uncertainty	**Qualitatively divergent scenarios** were created.
	Methods	**Qualitative:** Scenarios were developed through an iterative narrative and illustration-based process. Eight scenario logics emerged from the groupings of multiple drivers, but only the most plausible logics were used to create the scenarios.
	Scenarios	**More imaginative:** 4 scenarios were created. They are described as follows: Doom and Gloom (High Cumulative Impacts, Unpredictable Change, Exploitative); Slow Boil (High Cumulative Impacts, Gradual Change, Exploitative); Confused State (Low Cumulative Impacts, Unpredictable Change, Stewardship); and Win-Win (Low Cumulative Impacts, Gradual Change, Stewardship). The scenarios are more imaginative than plausible or likely.
Outcomes	**Findings**	**Learning-oriented:** Key findings include the following: First, results indicate that collaboration enhances the potential for broad, long-term thinking ventured by scenario planning praxis. Furthermore, scenario planning is an opportunity to merge traditional ecological knowledge and local knowledge, particularly Indigenous knowledge, in a respectful and collaborative way. Overall, scenario planning can be used to help resource managers identify needs that have been overlooked in the past but may grow important in the future. One application-oriented finding is that so-called "no

		regrets" management strategies may not be constructive for the study area since there will always be trade-offs due to the context specificity of wildlife management.
	Evaluation	**Formal evaluation process:** Participants in the case study assessed the process and found that it was an effective tool for adaptive learning and collaborative knowledge-building regarding the long time scales of ecological change. Recordings of the workshops were used by the authors to evaluate the process afterwards and triangulate between discussion, notes, and the charts generated by the workshops. Participants also completed 2 post-workshop surveys.
	Limitations	**Stakeholder Participation, Methods:** One limitation was a lack of continuity between workshop participants. Also, significant time elapsed between workshop sessions, which the authors believe contributed to the loss of details in scenario creation. Contributing to this problem was vague definitions of key terms like "uncertainty," which must be clearly defined to ensure that all stakeholders are on the same page. Additionally, the authors identify cross-cultural barriers to communication as a challenge that endures for scenario planners, particularly when indigenous stakeholders are involved as in this case.

Table 12. Evaluation criteria applied to case study #10.

#11. Withycombe Keeler et al. (2015). *Linking stakeholder survey, scenario analysis, and simulation modeling to explore the long-term impacts of regional water governance regimes.*

Stakeholder Engagement	**Diversity**	**Less diverse:** Stakeholders included laypeople (local Phoenix residents).
	Participation	**More agency:** Stakeholders were involved in an iterative process to co-produce scenarios alongside the technical expertise provided by modeling. Their values and preferences were incorporated into the identification of drivers and construction of scenarios. A back-end simulation allowed stakeholders to have greater agency in the outcomes of simulation models.
Process	**Objective**	**Normative**: To create a framework for comprehensive sustainability in urban water systems.
	Drivers	**Non-quadrant organization:** Multiple drivers include whether new water is pursued, environmental water allocation, the safety of the water yield, infrastructure, energy, regulations, water use in industry and agriculture, city growth, policy instruments, and governance.
	Uncertainty	**Quantitatively divergent scenarios** were generated through diversity analysis, in the only use of that method among these case studies.
	Methods	**Mixed-methods:** The authors took a participatory, mixed-methods approach. The first step in the process was to define system variables and future projections; the second was system analysis; the third was consistency analysis; the fourth was scenario selection; the fifth was diversity analysis; the sixth was impact analysis via simulation. Notably,

		that simulation happened after the scenario planning process was complete. WaterSim 5.0 was used to model the water dynamics of the Phoenix metropolitan area to the year 2080.
	Scenarios	**More plausible:** 4 scenarios were created, visioning distinct, coherent, plausible, and normative visions of Phoenix in 2030. They are "Technical management," "Comprehensive sustainability," "Limited water," and "Water security." Scenarios were explicitly designed to be more plausible, in terms of environmental conditions and policy responses, than imaginative.
Outcomes	**Findings**	**Application-oriented:** One major finding is that more accurate predictions can have the opposite effect from what they intend, and result in scenarios that are "less salient to end users," due to increasing complexity in models and our limited capacity to comprehend such complexity. Another finding is that groundwater dependence was shown in all scenarios to increase in both the short- and long-term, but will have disparate impacts based on climatic and socioeconomic variables. Finally, each scenario requires a different governance approach.
	Evaluation	**Formal evaluation process:** A survey was distributed to participants.
	Limitations	**Methods:** Both the WaterSim model and the overall scenario process do not necessarily represent the conditions of reality and real-world governance in Phoenix. Also, scenarios are limited in their ability to define water policy capable of being implemented.

Table 13. Evaluation criteria applied to case study #11.

#12. Restemeyer, van den Brink, & Woltjer. (2017). *Between Adaptability and the Urge to Control: Making Long-Term Water Policies in the Netherlands.*

Stakeholder Engagement	**Diversity**	**Less diverse:** Stakeholders included authorities (government and regional staff, private advisors, and policymakers from England and the Netherlands) and experts (universities and research institutes). Yet involvement of local stakeholders and laypeople was minimal, which aligns with the context of the Dutch planning system, as it tends to be more technocratic and expert-driven.
	Participation	**Less agency:** Local stakeholders had a limited role in the identification of drivers, development of simulations and models, and construction of scenarios.
Process	**Objective**	**Normative**: To find robust and flexible strategies for adaptive water management at the national level.
	Drivers	**Quadrant organization:** The two identified drivers are climate change and socioeconomic growth or decline.
	Uncertainty	**Qualitatively divergent scenarios** were created.
	Methods	**Mixed-methods:** Climate change scenarios were drawn from the Royal Netherlands Meteorological Institute, while socioeconomic development projections for growth and decline were taken from the Netherlands Assessment Agencies. A fixed value was chosen for river discharge, revealing tension between flexibility and drive to "predict and control" emblematic of Dutch water management.

	Scenarios	**More plausible:** 4 scenarios were created. They are described as follows: Busy (moderate climate change, socioeconomic growth), Steam (rapid climate change, socioeconomic growth), Rest (moderate climate change, socioeconomic squeeze), and Warm (rapid climate change, socioeconomic squeeze). These four were specifically chosen to be plausible; they do not represent extremes, as the Dutch government did not intend to plan for extreme or "wild card" outcomes.
Outcomes	**Findings**	**Application-oriented:** One finding is that local stakeholders struggled with the four-scenario process and had a hard time visualizing adaptation pathways in more moderate scenarios. Overall, the preferred strategy that emerged from the process was to focus on prevention with a gradual adjustment to change.
	Evaluation	**No process:** A formal post-planning evaluation is not mentioned in the text.
	Limitations	**Stakeholder Participation, Scenarios:** One limitation is the process, being expert-driven, which suppressed public participation in the scenario planning process. Another is that the stakeholders only worked through "worst-case" Steam scenario, and effectiveness was only calculated for the Steam and Rest scenarios. This indicates insufficient follow-through in completing the process for every scenario. The authors also point to a lack of clarity in evaluating thresholds and tipping points for each scenario.

Table 14. Evaluation criteria applied to case study #12.

#13. Institute for Hazards Mitigation Planning and Research. (2017.) *Flood risks following wildland fires. A case study: Plain, Washington.*

Stakeholder Engagement	**Diversity**	**Less diverse**: Participants included laypeople (residents of Plain) and local authorities in government and nonprofit organizations.
	Participation	**More agency:** Participants' visions of community values were incorporated into the process from the beginning and used to construct the scenarios. Stakeholders, however, did not influence the development of the models used to assess risk.
Process	**Objective**	**Normative**: To determine whether approaches to wildland fire and flood risk reduction could be improved by taking long-term expected changes into account.
	Drivers	**Quadrant organization:** The drivers are the presence/absence of wildland fire and flooding, and population boom/bust, which were applied to two axes to create four scenarios.
	Uncertainty	**Qualitatively divergent scenarios** were constructed.
	Methods	**Mixed-methods:** Three rounds of workshops were completed to assess, in order: Community Values and Direction, Future Conditions (Four Scenarios), and Strategies. The approach was applying an appreciative-inquiry scenario process to Plain, the case study community. The workshops followed a narrative storytelling format to build collaborative scenarios and used the WorldCafe method. Models were used to assess flood risk and the magnitude and severity of wildfires based on existing climate and fire-severity models and data generated via HAZUS-MH.

	Scenarios	**More imaginative:** 4 scenarios were created: Local Renewal (population decreases following major fires and flooding), Community Transformation (population increases despite major fires and flooding), Local Reorganization (population decreases due to external forces as fire and floods increase), and Reactive Management (population increases as fire and floods increase). The scenarios incorporate three different time frames: 2020, 2040, and 2080.
Outcomes	**Findings**	**Application-oriented**: Major themes across all scenarios included an acceptance of increasing risk over time, an understanding that burnt forests will not be able to regenerate as past conditions allowed, and permanent damage can occur when forests experience fire stress coupled with climate change. Risk reduction approaches common to each of the four scenarios included preserving a healthy forest and reducing fire risk to life and property. A key finding was that preserving forest soil is key to reducing future risks.
	Evaluation	**Formal evaluation process:** Community review was carried out through a comment process. A survey was distributed to participants in the research process.
	Limitations	**Methods:** A challenge identified by the authors was to enhance, or at the very least maintain, community values regardless of future outcomes. With uncertain futures, it is difficult to maintain those values. Other limitations include the assumptions that necessarily constrain the parameters and inputs of the model simulations used in the study.

Table 15. Evaluation criteria applied to case study #13.

Key insights are highlighted below in Table 16, with further discussion to follow. The table is organized by evaluation criteria.

Criteria	**Insights**
Stakeholder Diversity	The diversity of participating stakeholders does not necessarily correlate with their agency in the planning process. Greater diversity may come at the expense of building consensus among stakeholders. Experts are not just experts in the domains of science and policy, but also those holding expertise in traditional ecological and cultural knowledge.
Stakeholder Participation	Stakeholders are generally granted more agency in the identification of drivers and the construction of scenarios than in the development of simulation models. Techniques to accommodate stakeholder agency and maximize participation include disseminating information prior to the research process; hosting multiple, iterative workshops in close succession to develop the scenario drivers, logics, and narratives; and attending to participants' values and concerns as they arise.
Objective	Normative and policy-oriented objectives are common, and align with more imaginative scenarios that capture extremes and that which is or is not desired. Exploratory objectives tend to align with more plausible scenario construction.
Drivers	Climate change, as a category of driving forces, tends to be more fixed than urbanization, which is more subjective and can include land use and urban planning decisions, population growth or decline, economic trends, and changes in land cover patterns. Methods used to select and rank drivers include using intuitive logics, the STEEP typology, the ethnographic futures framework, and the three horizons framework.

Uncertainty	Diversity analysis emerges as one of the methods that maximizes the divergence of scenarios. Commonly, qualitative methods are used to generate discrete, divergent scenarios.
Methods	Quantitative models are used in some studies to generate plausible futures. One approach that allows for a higher degree of stakeholder agency in an otherwise expert-driven process is to run simulations after the scenarios have already been developed to enable users to visualize future conditions. Backcasting is a useful technique for designing policy that follows from normative studies in scenario planning. Downscaling is a common method for linking scenario planning at global, regional, and local scales, with an observed trade-off between consistency across scales and relevance to participants at each scale.
Scenarios	Most commonly, scenarios are expressed as a narrative story accompanied by maps and diagrams. More imaginative scenarios tend to draw on visual representation in a greater sense than scenarios that are more plausible. Visual engagement is understood as a critical means of communicating science to the public, and this is partly accomplished through the artistic depiction of scenarios.
Findings	Researching the coproduction of knowledge between study participants and the research team is facilitated by a learning-oriented approach, while policy-making is facilitated by an application-oriented approach of particular salience in projects with a normative objective.
Evaluation	A formal evaluation process is not consistently featured in scenario planning studies, even when stakeholders have been included in the process. When an evaluation is conducted, participants may be asked to choose their most ideal scenario, express lessons they learned in the process, and evaluate the relevance of that material in their personal or professional lives.
Limitations	Common limitations include resource constraints, excessive time passing between participant workshops, data availability, the risk (and necessity) of relying assumptions that oversimplify

	complex systems, limited knowledge and scientific credibility of participants, and problems arising from the tension between normative and exploratory modes of thinking.

Table 16. Summary of insights.

B. Synthesis of Key Themes

Local and regional scenarios in a global context

4 case studies come from the US and 9 from other countries. Of the international case studies, 2 are from Canada, 5 are from Europe, 1 is from South America, and 1 is from Africa. #4 was the only case study to set a nation (England), rather than a smaller region, as the extent of the study region. Widening the scale to the national level introduces multiple biomes and geographic types, which increases complexity and uncertainty.

5 of the case studies referenced the Millennium Ecosystem Assessment (MA), undertaken between 2001 and 2003 as an international assessment of scenario planning. #2 used the 4 MA scenarios along with 4 from the Global Scenario Group and 6 from the IPCC to develop the scenarios from their conceptual framework. In a two-step downscaling methodology, assumptions about global trends were translated to the regional and then to the local level of Delta, BC (Shaw et al., 2009). #4 upheld the MA's consideration of reflexive societal responses to change as a valuable framework that deserves greater attention in scenario planning at the national level (Kass et al., 2011).

#1 is a direct assessment of the MA subglobal assessment in South Africa, and the authors found that downscaling and adapting the prototypical MA scenarios held the dual advantage of conferring legitimacy on the scenarios for study participants and allowing for comparison between scales (Bohensky, Reyers, and van Jaarsveld, 2006). Finally, #7 also downscaled MA scenarios to Biscay in the Basque region in Spain. Their results corroborated those of #1, finding that the major advantage of relying on preexisting global scenarios is their utility as a vehicle for communication when it comes to smaller projects (Palacios-Agundez et al., 2013). Yet while the MA assessment in South Africa built regional scenarios independent of the global framework, the MA assessment in Biscay took a different approach by adapting and linking global scenarios to the regional level. For this reason, Palacios-Agundez et al. attribute the preexisting connection to Biscay to an ability to "focus more on society's perceptions and reactions to the described plausible futures, and consequently, work on constructing alternatives and response options" (2013, n.p.). Developing their scenario exercise with the MA scenarios concurrently available allowed for enhanced consistency across scales.

An alternate global scenario planning assessment, conducted by MedAction, was applied by #5 to the Doñana region in Spain. The authors found that MedAction's main drivers (technology, market forces, and climate change) translated well to the case study. The preset drivers conditioned scenario development but still allowed for creativity and adaptability in applying the multinational framework to a local context with particular needs, such as a more substantial evaluation of agriculture (Palomo et al., 2011). Interestingly, some aspects of MedAction's framework, including a technological optimism and an emphasis on social learning, were similar to the findings of the MA, showing that similar drivers can generate similar outcomes.

Tradeoffs and concerns regarding stakeholder engagement in the planning process

The case studies range in their level of stakeholder engagement in the planning process. By my evaluation criteria, 9 of 13 may be characterized as engaging a lower diversity of stakeholders, with one or two of the broad types (laypeople, influential persons, experts, and local authorities) participating in the study. Yet lower diversity does not automatically correlate with a reduction in participant agency: that only held true in three case studies (#4, #9, and #11). #9 is highly quantitative, with a limited capacity for stakeholders to have a stake in the research design, while #4 and #11 are projects on a higher-level national scale with less participation by local stakeholders. In 4 case studies, local stakeholders fall on the "less agency" side of the threshold for the identification of drivers, the design of simulation models, and the construction of the other 9, stakeholder participation was instrumental to the objective of the study itself and the design of scenarios.

In #1, local residents associated with agriculture, water management, tourism, and conservation were involved in the case's development of objectives, scenario design, normative policy responses. They had the agency to reject the results of models proposed by the research team as too complicated with regard to drivers of change, which led the researchers to switch to a more interactive approach that used arrows to show the direction and magnitude of change. This was said to create a sense of "ownership, not spectatorship" in the planning process (Bohensky, Reyers, & van Jaarsveld, 2006, p. 1059). In #11, local Phoenix residents played a role in the design of models to describe the area water system: their preferences and values, expressed through surveys, were used to generate variables and projections in modeling. They were then surveyed to select the scenarios used in the planning process (Withycombe Keeler et al., 2015).

This is similar to the process used in #13 to assess community values and supporting sources of natural, built, and social capital through a series of local workshops. Those values went on to inform risk mitigation responses and scenario narratives (UW IHMP, 2017). This study makes the important point that community stewards who work in emergency management, including firefighters, should not merely be informed of policy but seen as agents who share the responsibility to drive policy. Similarly, #5 directly set out to co-produce knowledge between experts and non-experts through an empowering, bottom-up approach to scenario development. A goal was also to maintain traditional cultural practices. The research team wanted to include a wide range of social actors, including creative people and elderly people with traditional ecological knowledge (Palomo et al., 2011).

The notion of ownership of scenarios emerged also in #2, where local stakeholders assisted in the development and visual design of scenarios. In #4, two frameworks unique to that case study were used to integrate people's values and worldviews into the planning process. The ethnographic futures framework, which regards how people to relate to each other and connect to society, and the three horizons framework, which regards the tension and instability of changing social paradigms, were used as analytical frames to guide communication with stakeholders and seek their input in scenario development.

#5 evinces a clear tradeoff between diversity of perspectives and the ability to reach consensus when working together. With a diverse range of participants comes a greater potential for misunderstanding and conflict. The benefit, of course, is that diversity allows for better representation of affected stakeholders, mitigates bias, and takes advantage of the extensive knowledge held by locals (Palomo et al., 2011). Another tradeoff is between local relevance and consistency at higher scales. In #6, an approach driven by the needs of stakeholders engaged local actors in city planning, health, social services, and the environment at the expense of national and regional actors (Carlsen, Dreborg, & Wikman-Svahn, 2013). One goal of including stakeholders, too, is to increase the legitimacy of the project, as in #9. There, stakeholders from the federal, state, and county level influenced the scenario design by vouching for a relatively small riparian buffer that is less ecologically ideal but more politically plausible (Hoyer and Chang, 2014).

The inclusion of indigenous stakeholders is of particular interest. 2 case studies, both located in Canada, held relevant insights for this topic. #2 attempted to include the Tsawwassen First Nation in the planning process, but members declined to participate (Shaw et al., 2009). #10 directly involved Yukon First Nations people in their study of wildlife management in the Yukon Territory. 5 of the 15 stakeholders who participated in the study belonged to either the Champagne or Aishihik Nation. Due to their input, the drivers were updated to reflect a more holistic sense of the coupled human-natural system, with social drivers like hunter patterns linked to natural drivers like moose population (Beach & Clark, 2015).

Since indigenous peoples generally have unique rights and practices regarding the land, and have also been historically excluded from institutions of planning and land use, it is important that scenario planners not neglect them when approaching local stakeholders for input and guidance. Respecting traditional ecological knowledge in the context of scenario planning is not only just and ethical but contributes to better results, in the same way that existing local knowledge made for scenario narratives grounded in local context in the case of #1.

Comparing process variables

10 case studies were found to have a normative objective, and 3 exploratory. These studies cannot be used to draw generalizations about the entire field of scenario planning, but they provide a cross-section of case studies that aim to deliver a statement about optimal or desired future conditions. While exploratory scenarios can (and often do) include stakeholders in the planning process, normative scenarios depend on their collaboration in the co-production of knowledge. The studies that developed three or four scenarios either used two or three axes to organize the scenario logics, though not every case study organized drivers via quadrant.

When evaluating driver identification, climate change is listed as a driver for each case study. Broadly speaking, its anticipated effects as described in the case studies can be summarized as warming; sea level rise; ocean acidification; changes in precipitation; increasing seasonal variability of water flow, timing, and temperature; changes to biodiversity; and changes to boreal fuel stores and flammability.

Urbanization, on the other hand, varies more by case, indicating a higher degree of subjectivity in driver selection. Population growth or decline is a driver in case studies #4, #5, #9, #11, and #13. Technology is a driver in case studies #4 and #5. Changing land use and infrastructure is a driver in case studies #3, #9, and #11. Finally, changes in governance and societal values is a driver in case studies #1, #2, and #9. The conversations about regional, national, and supranational governance and coordination present an opportunity for greater democratization, resource sharing, and a strengthened civil society (Bohensky, Reyers, & van Jaarsveld, 2006). Interestingly, #7 was the only case study to cite urban planning and land use decisions as a driver of change in and of itself.

For the studies that take such issues into consideration, the uncertainty associated with the human factors of laws, regulations, and societal values relates to decision-making in an increasingly urbanized and connected world. In #11, since decision-making depends on the governance regime that oversees it, scenario planning must incorporate institutions of governance and policy into the scenario framework (Withycombe Keeler et al., 2015). Similarly, in #12, the institutional context matters a great deal, despite the fact that governance is not a driver. Because mitigating flood risk cuts across all levels of society, multiple sectors of government need to be involved in the planning process (Restemeyer, van den Brink, & Woltjer, 2017).

Certain case studies used methods beyond intuitive logics to find the appropriate drivers. The STEEP typology of social, technological, economic, environmental, and political factors was used to select drivers in #4 and #8 (Kass et al., 2007 and Farah et al., 2014). #4 additionally used the ethnographic futures framework to choose the drivers and used the three horizons framework to rank the relative dominance and uncertainty of each (Kass et al., 2007).

Methods to cope with uncertainty

By my evaluation criteria, 7 case studies used qualitative methods, 2 used quantitative, and 4 took a mixed-methods approach. 3 case studies applied models in scenario planning: #5, #9, and #13. Of these, #5 seems to be the most intensely quantitative, integrating five models to develop scenarios based on conditions associated with climate projections, stream hydrology, geomorphology, and water temperature in the Chesapeake Bay system (Nelson et al., 2009). Another compelling method of modeling freshwater ecosystem services comes from #9, studying the combined effects of urbanization and climate change on the Tualatin and Yamhill Basins of Oregon. This was the only case study to use InVEST models, spatially linked to GIS, to model variables including the urban conversion of agricultural and forest lands and riparian vegetation (Hoyer & Chang, 2014). Uncertainty derives from input data, model parameters, and the model structure. In case study #15, models were created to simulate wildfires and flooding. Two burn variables were applied to 13 climate models and averaged to produce discrete forecasts. HAZUS-MH was used to assess flooding risk and damage from floodwaters. Variables included the buildings in the community, the depth of floodwater, and the quantifiable relationship between the two (UW IHMP, 2017).

Notably, in case study #11, model simulation took place after the scenario planning process was complete as opposed to its typical preliminary chronology. WaterSim 5.0 was used to model the dynamics of the Phoenix water system based on scenarios that had already been developed through stakeholder workshops. These simulations, which allowed stakeholders to interface with visions of the system in 2080, was intended to compensate for people's limited cognitive ability to understand complex systems. Case study #11 was also the only one to use diversity analysis to ensure that scenarios generated distinct, discrete narratives (although other case studies also exhibited quantitatively divergent scenarios). In #11, two of the original five scenarios were merged so that only four "signature" scenarios remained (Withycombe Keeler et al., 2015). In #4, the research team also started with five scenarios and narrowed them down to four, but without applying quantitative analysis to do so.

Where named, scenarios were given prototypically pithy and evocative titles (like 'Doom and Gloom' or 'Global Knowledge') in all cases except for #12. With scenarios titled "Stable Future," "Desirable Future," and "Undesirable Future" (Farah et al., 2014), #8 exhibited the most nakedly normative title descriptors. Most case studies used narrative accompanied by maps and diagrams to develop and communicate the resulting scenarios. Some case studies demonstrated innovative ways of engaging users. #5 used collage (Palomo et al.). In #10, a local graphic artist was hired to make computer images of each scenario and aid in stakeholders' visual engagement (Beach & Clark, 2015). Visual engagement was also crucial in case studies #2, #6, and #7, all of which used attention-getting visuals to spur engagement with scenario construction. Other case studies were more bare-bones, like #9, wherein scenarios were depicted as straightforward, quantitative maps aimed more at an audience of experts than laypeople (Hoyer & Chang, 2014). Overall, 5 sets of scenarios fall on the more plausible side of the spectrum, while 8 may be considered more imaginative and reaching greater extremes.

Synthesizing findings, evaluation, and outcomes

In terms of outcomes, 4 case studies displayed an emphasis on learning-oriented findings while 9 focused more on application-oriented findings. While many studies discussed both types of outcomes and were not rigidly restricted to one or the other, this is nonetheless where the line was drawn. In addition, not all case studies included a formal evaluation component at the conclusion of the planning process: 6 did, while 7 did not describe following up with participants.

With regard to limitations, as Oteros-Rozas et al. (2015) found, time and resource constraints are a major limitation across the case studies. Time is needed to develop and discuss scenarios and goals, and this often simply is not available. Additionally, lag time between stakeholder workshops was brought up in #10 as a limitation, since letting too much time pass can allow people to forget small and important details (Beach & Clark, 2015). Conducting multi-scale scenario planning, in particular, is difficult when planners have to compensate for time and budget limitations.

Data availability was a challenge particularly for #2, a study that was faced with incomplete data especially for socio-economic and governance variables. This introduces uncertainty when researchers need to make assumptions to fill in the gaps. For example, in that case, the team assumed that local mitigation responses would be equivalent to those at the global scale (Shaw et al., 2009). In general, compatibility and consistency across scales is a common challenge for scenario planning. Downscaling global climate change and socioeconomic trends requires a sacrifice of fine detail, especially when the data on variables like greenhouse gas emissions are constantly evolving.

With models, there is the risk of simplifying complex, dynamic systems. Some simplification is of course necessary to express and communicate the essential workings of the system under study, but oversimplifying reality is a pitfall. This emerged in #3, #9, #11, and #13. Each of these studies had to make assumptions based on certain variables and omit others. For example, #9 is predicated on the assumption that climate change and land use/land cover change are independent (Hoyer & Chang, 2014).

Another challenge is the porosity of regional boundaries. This arose in #5, which dealt with subjective system boundaries that resulted in confusion over whether the Doñana human-natural system encompasses only the nationally protected area or a much wider region (Palomo et al., 2011). This also has implications for shared identity around the land. Confusion resulting from unclear definitions of terms, as well as lack of clarity regarding the scenario planning process, can have a negative impact on stakeholders' ability to engage in the process. In #10, participants had difficulty understanding how each step of the process led to the end result, were not sure how to rank drivers of change, and sometimes had different understandings of the system definition and the meaning of "uncertainty" and "scenario" (Beach & Clark, 2015). Additionally, the highly technical, expert-driven nature of some parts of the process can be opaque and alienating to a lay audience, as found by Withycombe Keeler et al. (2015) in #11. There is a tradeoff, too, between relying on stakeholders' knowledge and maintaining scientific credibility and rigor by enriching local knowledge with scientific expertise, as described in #8 (Farah, 2014).

Participating stakeholders may also generate incomplete and inconsistent scenarios without the advantage of expert knowledge, in the kind of "myopic trap" described in #6 (Carlsen, Dreborg, & Wikman-Svahn, 2013). Limited knowledge of the system can generate underdeveloped narratives and is a particular challenge at local scales. At the same time, planners have an ethical obligation to communicate clearly with stakeholders. Finally, #2 explains the ethical and legal ramifications of, intentionally or not, delivering the message that the least desirable future is the most probable (Shaw et al., 2009). Such concerns speak to the importance of thorough preparation and transparency in conducting scenario planning exercises.

V. Conclusion

A. Directions for Further Research

This research holds implications for the study of scenario planning (i.e., *how* to study the field, not just how to conduct scenario planning research). The variation in the case studies discussed here shows how the methods, research frameworks, processes, and outcomes of scenario planning shape its capacity to anticipate and direct change at the intersection of complex and uncertain interactions in human and natural systems. Yet, the effectiveness of different approaches to uncertainty can only be assessed through a comparative analysis of the outcomes of scenario planning projects on decision making and implementation of climate change adaptation strategies. Future studies in scenario planning also deserve continual investigation of citizen empowerment in the planning process through stakeholder participation. Furthermore, this research indicates that indigenous peoples deserve more agency in the planning process, where they are affected stakeholders.

In all cases reviewed here, particularly those from more recent years, outcomes should be monitored into the future to evaluate the effectiveness of scenario planning projects in achieving their objectives, since translating scenario planning outcomes to actionable and sustainable environmental policy is beyond the scope of the case studies described here. Nonetheless, since several of the case studies discussed here reference contemporary policy applications of their findings, their implementation is crucial to monitor over time.

Further study of the tradeoffs inherent to studies like this (e.g., between salience to stakeholders and cross-scale consistency, or between diversity of stakeholders and ability to reach consensus) is necessary, particularly in multi-scale analysis and where many stakeholders participate in the process. Integrating a study of scenario planning under the umbrella of urbanization and climate change and their interdependent and synergistic effects will be useful in future comparative research, since this framework yields a rich cross-section of cases to compare. Quantitative analysis of trends and patterns in scenario planning ought to be further developed in future studies by applying robust metrics that reflect the evaluation criteria. Such studies could investigate the relationships between variables and outcomes across multiple case studies, establish causal links, and develop guidelines to inform best practices. These objectives were beyond the scope of this thesis.

B. Summary

This thesis uses systematic qualitative analysis of thirteen recent case studies from the past twenty years to evaluate and compare various approaches to scenario planning in environmental decision-making. Through the lens of urbanization and climate change acting as drivers, whose synergistic effects and emergent properties contribute to their high degree of urgency and uncertainty, this analysis sheds some light on the use of scenario planning to identify opportunities, challenges, and consequences of urban adaptation to climate change. The qualitative meta-synthesis of relevant cases uses comparative tables to organize and compare variables related to the key actors, processes, and outcomes of the scenario planning process for case studies from countries including the United States, the Netherlands, Sweden, England, Spain, Canada, South Africa, and Colombia in a small synthesis of the field. The capacity of scenario planning to unite experts with non-experts in the coproduction of knowledge, reconcile great uncertainty with nuance and flexibility, and communicate environmental science to the public are major strengths. Common limitations and weaknesses in scenario planning include resource constraints, miscommunication, and the risk of oversimplifying complex, dynamic systems. Archetypal tradeoffs, such as those between diversity and consensus or broad consistency across scales and narrow relevance to stakeholders, characterize the tensions and dichotomies that continue to inspire questions about how best to face an uncertain future.

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