

Draft CEC PIER-EA Discussion Paper

Adaptation and Vulnerability

Prepared by:

Dr. Susanne C. Moser – University of California-Santa Cruz
With Assistance from Dr. Wendy Chou – Consultant

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Sacramento, CA 95814

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Disclaimer

The purpose of this paper is to inform discussions among CEC staff, other state agency staff, non-governmental representatives, representatives of academia and other stakeholders regarding the state of the research on vulnerability and adaptation and other social science contributions to California's climate change research. In particular, this discussion paper will identify gaps in our understanding and recommendations for future research initiatives with the end goal of supporting informed and systematic planning for climate change. Note that this paper is not intended as a research proposal and should not include recommendations regarding specific research projects.

1.0 Description of the Research Topic

Vulnerability and adaptation as the human-environment interface

Climate change projections and assessments of potential impacts are, in a sense, only meaningful to the extent that they imply people, or something people value,¹ are at risk of being affected by these environmental changes, and that these risks are significant enough (positively or negatively) that society must respond and adapt to them. This dictum is almost too obvious to need mentioning. In fact, the notion that people are influenced by their environment and, in turn, shape their environment and interactions with it to their benefit (or detriment) is at the heart of all fields of study concerned with the human-environment relationship (e.g., in geography, anthropology, sociology, psychology, and various neighboring and applied fields of study). Yet, without recalling this intimate relationship between humans and the environment as a basis of existence, economic activity, welfare, well-being and cultures, it is hard to justify and sketch out the scope of a research focus on vulnerability and adaptation.

Vulnerability

Vulnerability research has a rich and diverse intellectual history in several social science disciplines and, therefore, no commonly accepted definition.² In the broadest sense, it could be defined as a susceptibility to harm or a potential for change or transformation. Vulnerability can apply to any region, community, population, economic sector, technological or social-ecological system of interest, though its conceptualization—the

¹ This could range from economic opportunities, to the intrinsic existence value of a species, ecosystem, or place, to the right to a prosperous life for their children.

² Vulnerability studies have their roots in largely separate fields, such as the hazards tradition in geography, risk and disaster studies, and the poverty/hunger reduction and livelihood in development studies, with more recent fields emerging around climate change impacts and adaptation, and in the context of environmental management (for recent critical reviews see, e.g., O'Brien et al., 2007; Adger, 2006; Eakin and Luers, 2006; Fussler and Klein, 2006; Thomalla et al., 2006).

scale of analysis, the influences considered, and data available to operationalize it at each scale or in different contexts—as well as the employed assessment methodologies, can be quite different. In this sense, vulnerability assessments are quite similar to climate projections; the models, data, embedded causalities, and scale-dependent resolutions and findings vary considerably.

There is a persistent division in global change studies around the conceptualization of vulnerability. It is important to point out this division, as different research traditions yield rather different insights. On one side of this divide are those who understand vulnerability as the *context of* or as *initial condition* of a social, ecological or social-ecological system, which will then experience a hazard (be they rapid-onset events—such as storms, floods, and droughts—or slow-onset, long-lasting threats—such as sea-level rise and higher average temperatures). This approach (more common in the hazards tradition within geography, political ecology, and poverty and development studies) is deeply interested in the multitude of interacting (societal and environmental) factors that lead specific systems to experience different degrees of exposure, sensitivity, and response capacity to deal with the hazard. Climate becomes one of multiple interacting stressors, rather than the only relevant one to the question of vulnerability. By examining each factor carefully, it can distinguish systems that may be highly exposed and sensitive to a stressor like climate change, but also have substantial adaptive capacity such that their overall vulnerability may be fairly low. Alternatively, it may find systems with somewhat lower exposure and sensitivity, but very restrained adaptive capacity and, therefore, higher overall vulnerability. This approach offers insights into the differential levels of vulnerability and related equity concerns, the causes of vulnerability, and the range of interventions that could be used to make a system less vulnerable or more adaptive.

On the other side of the divide are those who understand vulnerability as the *outcome* or *net impact* of a (climatic) threat after the exposed system has experienced a disturbance and implemented a range of adaptive responses.³ This approach is exemplified by the framing of the Intergovernmental Panel on Climate Change (IPCC) (Parry et al., 2007; McCarthy et al., 2001). It is first and foremost interested in the magnitude of the climatic change or stressor as the most important determinant of initial impacts, societal responses and net impact or vulnerability. Much of California’s climate change impacts (and adaptation-relevant) research to date has followed this tradition. While it has proven critical for identifying climate-related risks and raising people’s awareness to them, and illustrating the benefits of avoiding extreme climate change, it is insufficient for identifying non-climatic factors that affect social system vulnerability and capacity to respond, and hence offers little insight into intervention opportunities.

³ O’Brien et al. (2007), building on Kelly and Adger (2000), term the former a “human-security framing,” which sees “contextual vulnerability” as a starting point for analysis, and the latter (somewhat unfortunately) a “scientific framing” which views “outcome vulnerability” as the end point of analysis. Fussler (2007), in parallel, calls adaptation needs assessments that use the former approach “vulnerability-based”, and distinguishes them from “hazards-based” ones that use the latter approach.

Adaptation

Adaptation, just like vulnerability, has a similarly diverse set of intellectual roots, meanings, and components. At the most general level, “Adaptation [...] usually refers to a process, action or outcome in a system (household, community, group, sector, region, country) in order for the system to better cope with, manage or adjust to some changing condition, stress, hazard, risk or opportunity” (Smit and Wandel, 2006, p.282). Commonly (though not uniformly), researchers distinguish coping or “adjustments” as the shorter-lived, relatively minor responses to climate variability and extremes, from adaptation as the deeper, longer-term, structural changes, including cultural and ultimately evolutionary, biological responses. Both coping and adaptation can involve incidental, unplanned, uncoordinated and reactive activities, or purposeful, planned, integrated and proactive ones. In the climate change context, the greatest research focus has been on planned adaptation as a way to anticipate, prepare for, prevent, or minimize potential negative impacts, and take advantage of possible opportunities.

Whether or not a system is able to cope or purposefully plan for and implement adaptation actions depends on its response capacity (overarching term for its coping and adaptive capacities, which may or may not be the same) and the ability to translate that capacity into real actions (i.e., its capacity to overcome barriers). In turn, these depend on a number of factors: sufficient economic resources, appropriate technologies, adequate infrastructure, institutional support and strong governance mechanisms, highly educated and skilled workforce, widespread public awareness and adequate information/knowledge to support decisions, sufficient natural resource base and functioning ecosystems, and equity in access to the above resources and institutions (e.g., Yohe and Tol, 2002; Smith, Klein and Huq, 2003; Brooks, Adger and Kelly, 2005; Pelling and High, 2005; Gallopín, 2006; Smit and Wandel, 2006; Adger et al., 2007).

The study of adaptation encompasses critical examinations of these factors and how they are employed toward achieving adaptation goals, where they may be limited, or how they may be strengthened to allow societies to deal with a rapidly changing environment. In addition, adaptation research examines the range of adaptation measures that may be considered in different contexts, including the respective timing, planning horizon, actors involved, institutional context, and other stressors that may impact the ability to carry out a particular adaptation strategy. More recent research also focuses on barriers and limits to adaptation, cross-scale as well as cross-sector interactions among adaptive responses, as well as the interactions between mitigation and adaptation, and how to embed (or mainstream) adaptation measures for climate change into larger economic development, poverty reduction, or sustainability goals.

Resilience: the means and goal of adaptation

A third concept is frequently brought into the discussion of vulnerability and adaptation: resilience. The concept originated in the ecological sciences, but many social scientists have adopted and used it in widely varying ways in the study of vulnerability and adaptation. Some equate “adaptive capacity” with “resilience” in a narrow sense. In a wider sense, resilience increasingly is seen as the capacity of a system to bounce back from a disastrous event and thus to withstand wholesale change for some time, but also, past a certain point, to transform while continuing or regaining the ability to provide essential functions, services, amenities, or qualities (see, e.g., Walker and Salt,

2006). Resilience is recognized as scale-, context-, disturbance-specific, and as an “emergent property” that arises from the interaction of a particular system, its wider environment, and the forces that act on both (Moser, 2008).

In general, the understanding of resilience in ecosystems is better than that in social systems. The growing social science interest in resilience, especially in the context of climate change, is welcome, as it brings attention to the goals of vulnerability reduction and adaptation, to the interplay between gradual and punctuated change, the specter of abrupt change, and the difference between responses to a one-time extreme vs. repeated extremes (e.g., Folke, 2006). Important research here focuses on such mechanisms as foresight and predictive capacity, social memory, social capital, learning, response capacity and exhaustion over time, as well as deep structural, institutional and even cultural adaptation.

According to CEC (forthcoming), the goal of adaptation is neither prevention of all negative impacts from a variable and changing climate (an impossibility), nor merely clean-up after each climatic disturbance or disaster. Rather, the goal of adaptation is long-term resilience; to create the conditions in which society and managed ecosystems are largely able to absorb the impacts from climate variability and change, such that any residual impacts beyond their coping capacity remains within (socially defined) acceptable limits of risk. Very little research to date has examined what those acceptable limits may be, or how to stay within them, though the internationally-relevant discussion of “avoiding dangerous climate change” is relevant here.

Summary: importance of research area and relevance to PIER’s research goals

Fully understanding the real importance and potential severity of climatic change for California—both the impacts experienced locally and those affecting other regions but impacting California indirectly—requires placing climate change into the real-world context of multiple stressors, on-the-ground vulnerabilities, and the actual capacity of communities, businesses, and local and state government institutions to respond to rapidly unfolding changes in the physical and social environment. The knowledge base to date is partial at best, leaving California ill-prepared to effectively face these changes.

The 2003 PIER research plan did not explicitly recognize the need for (nor explicitly discourage) social-science vulnerability and adaptation research, apart from calling for economic impact assessments and cost-benefit analyses of different adaptation options in the water/agricultural sectors. At the same time, the 2003 plan did recognize the vulnerability of California’s key sectors—such as water, agriculture, ecological resources, and coasts—to climate change, but its approach to date has been largely physical science and climate scenario-driven, rather than focused on a more comprehensive assessment of the factors that make each of these sectors vulnerable, what each sector’s adaptive capacity may be, where potential adaptation strategies may encounter barriers and limits, and how such barriers may be overcome. These questions require analysis of a far broader set of issues than standard technological and economic assessments might consider, including social, socio-economic, demographic, institutional, legal, ethical, organizational and cultural aspects of societal functioning, management, and policy-making. Thus, for California to be able to reduce its communities’, economy’s, and infrastructure’s vulnerability, and identify economically, socially, institutionally and politically feasible response options, an investment in social

science research that examines societal vulnerability and adaptation options and barriers is a critical complement to its existing climate research portfolio.

2.0 Summary of PIER Program Research and Accomplishments to Date on Vulnerability, Adaptation, and Resilience

PIER-funded social science research on vulnerability and adaptation has been limited to date. A first conceptual study in this arena was done by Luers and Moser (2006). Their study presented a framework to assess the on-the-ground preparedness for climate change of resource managers, including their awareness of climate change risks, analytic capacity to process relevant information and develop adaptive responses, and the adaptation actions actually taken to address climate-related risks. Empirical testing of the framework was relatively limited in this first paper. A follow-up study, also funded by the PIER Program, tested that framework in the coastal sector to assess coastal managers' preparedness for climate change (Moser and Tribbia, 2007a;b;c).

These two projects have resulted in several peer-reviewed publications (Moser and Luers, 2008; Moser, 2007; Moser and Tribbia, 2006/2007; Tribbia and Moser, 2008), but their impact has gone far beyond science, including:

- Raising awareness among decision-makers, state legislators, and in the wider public of the degree of un-preparedness for climate change in one of the most vulnerable sectors in California;
- Calling attention to state, local, and federal agency staff of the need to provide far better decision support to resource managers if they are expected to address climate change risks; and
- Creating motivation within the PIER Program and in other state and federal agencies to support additional social science research to better understand vulnerability, adaptation options and barriers, and decision support needs.

It is probably not overstating the case that this limited research has generated both openness to, and demand for, additional social science research to support California's emerging adaptation efforts. The impact of a small grant has been relatively large and thus points toward the benefit and cost-effectiveness of future research in this area.

One additional study, Basu and Ostro (2007), has recently been completed that laid the methodological foundation for assessing the differential vulnerability (strictly only in the sense of exposure) of different populations to extreme heat events and worsening air pollution, as projected by future climate scenarios (see below for how this work is now being taken forward).

3.0 Non-PIER Accomplishments in this Area and Opportunities for Collaboration

Academic research at California research institutions

As the wide scope of the vulnerability, adaptation and resilience (VAR) field described above indicates, research could be and is being done in any number of sectors, at various scales of analysis, in different California communities, and on a wide range of specific VAR-related questions. In fact, the nature of much single-investigator, social science research is to focus on relatively narrow lines of investigation and examine them in

relatively small-scale, often case study-based research, which is laborious to find and track. While it is beyond the scope of this paper to conduct a thorough literature review for each sector or issue relevant to California conducted by local researchers and others operating from outside the state, the elicitation of expert input conducted in preparation of this paper has lead to three important conclusions:

- (1) there is no centralized convergence of relevant expertise, no highly visible “go-to” institution or research center for vulnerability-, adaptation-, and resilience-related research in California; rather, expertise is spread across the entire University of California system, and other state and private research institutions;⁴
- (2) there is, however, a considerable amount of relevant and related (but at present not necessarily climate change-focused) social science research done or underway (e.g., on water rights and conflicts, management of scarce resources, disaster preparedness, risk communication, institutional mechanisms for conservation planning, land-use planning and smart growth, urban sustainability, evaluation of policy instruments); and,
- (3) a collective effort to take stock of these disparate research endeavors, synthesize their insights, relevance, and applicability to climate change, and identify important policy-relevant research frontiers promises to be an extremely fruitful endeavor.

The national and international picture

That said, while there is an extensive and rapidly expanding literature, and understanding of vulnerability and adaptation (see, e.g., the selective syntheses in the IPCC assessment, e.g., Adger et al., 2007; Klein et al., 2007; Schneider et al., 2007; and, Yohe et al., 2007), even a cursory search for social science literature that explicitly addresses vulnerability and adaptation to climate change in California is meager at best. In this sense, California is not much different from most other U.S. states, or, for that matter, most other developed nations. Because of a long-standing assumption that rich/developed nations are less vulnerable, and have greater adaptive capacity than poor/developing ones, little serious and systematic research effort has been directed to date at the challenges faced by developed nations (exceptions with extensive research efforts in this area include the United Kingdom, Norway, and some beginning efforts in several U.S. cities and states [e.g., Moser, 2009; Moser et al. 2008; Pielke et al., 2007; O’Brien et al., 2006]). With the excessive heat-related deaths in Europe in 2003, Hurricane Katrina in 2005 in the United States, and damaging droughts in Australia in 2006, as well as acknowledging the very slow adoption of adaptation measures in developed nations overall, both scientists and practitioners increasingly recognize the need to better understand vulnerability and adaptation in the “global North.”

⁴ There is currently an effort underway to build a vulnerability and adaptation-focused research program at Stanford University, tentatively called the *Program on Reducing Vulnerabilities to Climate Change* (RV2C). If approved and funded, this program will involve numerous faculty from several departments and schools and will be directed by Stephen Schneider, Terry Root, and Mike Mastrandrea. Several of the initial research projects proposed for RV2C are focused on California, and will involve several researchers already involved in PIER-funded research.

Relevant research conducted or supported by other state agencies

Besides the research mentioned above (related and relevant, but not climate change specific), which is being conducted at academic institutions, some state agencies other than CEC also conduct or fund adaptation-related research. For example, the California Department of Water Resources (DWR) and the California Ocean Protection Council (OPC) have in the past and are currently conducting studies or funding outside research to help them assess different adaptation options. For example, DWR is investigating different supply and demand side water management strategies, while OPC is comparing different policy options used in other U.S. states and internationally to manage sea-level rise. Similarly, the California Department of Public Health (DPH) is conducting research on heat-related morbidity and mortality and other climate change related impacts. Overall, DPH's work aims at establishing a statewide collaborative of public health scientists, developing community vulnerability assessments which employ a "Social Vulnerability Index" (accounting for age, poverty, health status, and social isolation) to assess differential vulnerability at the county scale, and establishing an ongoing monitoring, preparedness, emergency, and education/outreach program to deal with health-related impacts of climate change, and bring greater equity to public health services in California (English et al., 2007; Margolis and English, 2007). This work deepens the analysis and understanding put forward several years earlier by a non-governmental group (Redefining Progress, 2004), which investigated the differential burden and equity implications of climate change in terms of the growing costs of electricity, water, and so on.

The following examples are suggestive of certain observations related to social science in the climate arena, although they are by no means comprehensive:

- state agencies vary in their degree of concern with climate change impacts and—partly due to the pre-dominance of physical/natural science-trained agency personnel, and a dearth of social-science trained staff—in their awareness and appreciation of relevant social science insights that could inform their work;
- state agencies also vary in the degree to which they have begun soliciting social science inputs in assessing their vulnerability to climate change and adaptation options;
- the need for social science input is rapidly growing as California (under the leadership of Tony Brunello, Resources Agency) embarks on statewide adaptation planning; and
- to date, state agency interest in social science related to vulnerability and adaptation has been more or less ad hoc, accidental, and uncoordinated; without a concerted effort to reach out to the relevant social science expertise in the state, agency interest has not benefited as much as it could from existing or ongoing relevant research.

4.0 Research Underway/Committed to via PIER Process

In preparation of the 2008 Scenarios Report, several research projects are underway that include foci on adaptation. Most of these, however, are conducted by natural scientists (with additional contributions from economists and epidemiologists), and

predominantly follow the climate scenario-driven (“hazards-based”) approach to vulnerability/adaptation assessment described above. For example, in the coastal sector, several studies (by Knowles and Gleick et al.) are exploring the extent of flooding or inundation that could occur during a storm event (or permanently) under different sea-level rise scenarios. Early results reveal the extensive areas in the San Francisco Bay that are exposed to sea-level rise and flooding, and provide estimations of the infrastructure, buildings, and economic assets at risk from unmitigated sea-level rise. These inundation estimates may further increase as the coincident impact of increased runoff into the Bay and Delta regions are taken into account (Bromirski et al. project). A parallel set of studies for the open coast (by Adams and Pendelton et al.) point to erosion hotspots, and the potential economic losses to beach tourism and recreation, as well as the potential cost of replacing lost beach sand.

In the water sector, research projects are underway (by Dracup, Lund, and others) that build on earlier work, e.g., using the WEAP (Water Evaluation and Planning) model to explore water management options under different climate change and socio-economic scenarios in the San Joaquin Valley, and another using the CALVIN (California Value Integrated Network) model, considering both drought, flooding, and saltwater intrusion conditions.

In the forestry sector, research is being conducted on the dynamics of land-use change, land values, and changes in landowner management priorities. In addition, this study will assess the policy implications of shifting timber species distributions and timber values on public lands. Another project is conducting a case study on the potential impacts of climate change on forest production and the identification of potential adaptation options.

The epidemiological work cited above (Basu and Ostro, 2007) in public health is being taken forward to assess whether different demographic or ethnic groups exhibit differential vulnerability to heat extremes and air pollution.

Finally, in the 2008/09 solicitation of proposals, PIER has specifically called for adaptation-related research, and received a limited number of adaptation-related proposals of varying quality. The list of projects to be funded has not yet been released.

5.0 Gaps in Research/Knowledge Relevant to California

As the above discussion has made clear, compared to other areas of climate change-related research, the social science contributions to our understanding of climate change vulnerabilities, impacts and adaptation options in California has been extremely limited to date. Whatever related and relevant knowledge does exist is not yet brought to bear on the existing understanding.⁵ This means there is a large knowledge gap and a need to add more to what is already known.

In light of this wide-open research arena, the question of “knowledge gaps” turns into one of “beginnings” and “strategic guidance and priorities.” While prioritization is discussed further in the concluding section, the suggestions below fall into topical rather than disciplinary or sectoral classes of social science research. They follow the forgone

⁵ This challenge is further discussed in the discussion paper on decision support and increasing the social science contributions more generally.

review, draw on expert input elicited in preparation of this paper, and research priorities identified in the most recent IPCC assessment, the 2008 U.S. Climate Change Science Program (CCSP) update of its strategic research plan, and other relevant documents.⁶ The suggestions offered below *address critical research needs*, and thus, would make important contributions to the extant vulnerability and adaptation literature, and are policy- and practically relevant to California's emerging concern with and planning for adaptation.

Vulnerability-focused research

- *Developing, inventorying, and monitoring of key vulnerability indicators.* Projecting future vulnerabilities requires adequate understanding of current conditions, trends, and causalities. This is widely recognized in the natural sciences, but the development and ongoing monitoring of telling social indicators has lagged much behind. In some areas, data are not gathered or stored; in others they are potentially available for analysis, but currently not in accessible or easily used formats (e.g., economic activity data at the community level). Much information is not geo-referenced, thus is not easily integrated with other data. In some instances, the challenge lies in inconsistencies or in integration, while in others, it is still conceptually challenging to develop meaningful vulnerability indices—though a growing literature on this topic exists. What is known has only rarely been applied to California; spatial or sectoral coverage, much less recording of vulnerability indicators over time, are almost entirely missing. Indices should be provided in formats that are intuitive and easily integrated with decision-making (e.g., spatial models of vulnerability should be done alongside integrated assessment models).
- *Improving understanding of all components of vulnerability (exposure, sensitivity, and response capacity).* As mentioned above, vulnerability work to date in California has focused mostly on the exposure to the physical hazard (e.g., sea-level rise related inundation, extreme heat); only in the public health context have efforts to date also focused on selected factors that affect sensitivity (e.g., age or ethnicity), or response capacity (e.g., social isolation, poverty). From the study of risk perception, communication, and management, we know that many more factors (e.g., cultural, institutional, social) affect the different components of vulnerability and response capacity of individuals and communities. These should be explored more fully in the health and other climate-sensitive sectors.
- *Improving understanding of multi-stressor causes of vulnerability.* To individuals, resource managers, policy-makers, and business leaders, climate is just one of many factors that may influence their small daily and larger, episodic decisions. Because non-climatic factors can significantly impact people's priorities as well as their vulnerability to additional climatic stressors, it is important to understand this real-world context in which current or future climate stresses may fall. For example, under what circumstances does globalization increase or decrease vulnerability? Projecting these non-climatic conditions forward is fraught with uncertainty, but could be explored through historical case studies as well as scenario- and sensitivity

⁶ Development of specific information databases and adaptation tools is discussed in the discussion paper on decision support.

analyses, recognizing that socio-economic conditions can change quite rapidly (e.g., economic down-turns at regional or national scales, job losses, illnesses, loss of insurance coverage at a personal scale, etc.). They could also be investigated in sensibly-focused regions—such as a metropolitan area like Los Angeles—where multiple stressors constantly interact in a spatially and functionally coherent context. Investigating the multiple influences that cause vulnerability offers intervention options that are independent of any climate projections; reducing non-climatic sources of vulnerability may increase a system’s resilience, effectively presenting an adaptation strategy. Legislative, institutional, or managerial approaches tested in non-climate contexts may offer possible insights that can be transferred to the climate arena.

- *Determining distributional impacts of environmental changes in key sectors.* To date, most climate change impacts work in California has been for entire sectors (e.g., water sector, agricultural sector, energy sector)—as if they are homogenous and will be affected equally by climatic stresses in the future. But the water sector is a case in point; climate-induced water scarcity impacts will be felt quite differently by communities supplied by large water utilities compared to communities not currently connected to these large water suppliers. Some social science research thus distinguishes weather-related water scarcity and human-induced scarcity. Questions of access and political power, not just traditional water rights, are important and must enter the discussion of adaptive response. The capacity to identify and implement different response options may change completely, or at least majorly refine the picture of sectoral vulnerability. Similarly, while the differential sensitivity of various crops is widely recognized, the economic impacts to growers with more or less diverse productions, as well as different financial reserves, access to water, transportation hubs or population centers, will vary significantly. Understanding which communities, regions or businesses may be hardest hit will allow identification of “hotspots of vulnerability” and, thus, prioritization of adaptation support.
- *Investigating ripple effects and higher-order impacts.* To date, almost no studies exist anywhere of the higher order impacts of climate change, though historical experience with extreme events (climatic or otherwise) suggests they may be at least as important and sometimes longer-lasting than the initial incident. Studies on the social amplification (or attenuation) of risks suggests that even such initial events can result in completely unintended consequences. Both historical analyses and future-oriented scenario studies that systematically trace the evolution of ripple effects within sectors or regions would be useful. Similarly, studies that examine the (experienced or expected) impacts of climate change that may be experienced outside of California, but which are likely to affect California through market-based mechanisms, transportation, energy or information infrastructure, or other mechanisms, are completely missing.
- *Understanding impacts in the “forgotten” sectors.* There is a temptation to focus impacts and adaptation studies almost exclusively on economically-important, politically-sensitive, culturally-significant, or most climate-sensitive sectors or regions. While these and other reasons all present defensible justifications to continue doing so, it is

equally defensible to ask: *what are we missing?* Experience demonstrates again and again that unexpected interactions, consequences, sources of vulnerability, and constraints on response capacity are to be found where the answers to this question lie. For example, thus far, there is hardly any literature on the expected consequences of climate change for small businesses, even though much local economic activity, countless (irreplaceable) jobs, potentially significant wage losses, and critical community interactions are bound up in this sector. Moreover, what may happen in smaller economic sectors—such as the winter tourism sector, the wine growing sector, organic farming, fisheries—in terms of contribution to state GDP, may be crucially important to local or regional vulnerability and response capacity, affecting vulnerabilities to other climatic or non-climatic shocks. Food security and safety issues, especially in poorer California communities and social strata, have also not been investigated.

- *Horizontal impacts within sectors under stress conditions.* Historical periods when climate extremes affected certain sectors may well serve as analogues to improve our understanding of who is vulnerable and why, and who responds how to which set of circumstances. For example, what happens when several communities are affected at once by a series of coastal storms? How do communities deal with situations when fire fighting resources are stretched thin during times with great numbers of wildfires across the state? Who suffers, who collaborates, who fights, who wins, and who goes dry when most of California is under drought conditions? What mechanisms do affected entities employ to deal with such widespread, stressful situations? Findings of studies investigating such cases can ground assessments of different adaptation options in empirical reality, unearth potential conflict situations, and offer opportunities to address them preemptively. They can also assist learning from the past to improve future responses.

Adaptation-focused research

- *Developing methodologies for integrated, cross-sector impacts of climate change and of adaptation responses.* Perhaps one of the most challenging research questions is how to conduct integrated assessments of climate change across sectors. Such integrated assessments would need to take into account the direct impacts of climate change (which may be similar or different in the sectors considered) and the additional direct and indirect impacts of adaptation responses to the experienced climate changes. A similar challenge lies yet ahead in investigating the mutual influences of mitigation and adaptation responses. While individual studies of potentially positive or negative synergies of different societal responses or policies exist (sometimes drawing on relevant research on product and process life cycles), such assessments are not conducted systematically or routinely, and certainly not as standard procedure prior to passing legislation or implementing policies. Developing cross-sector or cross-policy impact assessment methodologies would require multi-disciplinary, cross-sector teams, adoption of a systemic perspective, careful analyses of causal connections, and systematic sensitivity analyses of different assumptions and linkages.
- *Understanding the factors that allow, facilitate, and increase adaptive learning.* There is a substantial literature on adaptive assessment and management and all manner of

social learning. While the former has been promoted repeatedly as the most appropriate form of resource management under highly uncertain environmental, social and policy conditions, the approach has run into countless hurdles in practice. On-the-ground, experimental research (“learning by doing”) on how to implement adaptive management could be helpful and relevant in several natural resource sectors (e.g., habitat conservation, fisheries, marine area management, forestry, etc.). Scenario-based experimentation and learning may also yield critical insights.

More general, however, is the question of how organizations, individual decision-makers, and entire societies learn, and can be induced – against the all-too-common tendency to prefer familiarity, well-established rules, and a daily life with little alteration and risk taking – to learn faster and better in the face of rapidly-changing conditions. Important questions about incentives and disincentives for learning, knowledge networks and impediments to knowledge flow relevant for adaptation decisions, the importance of leaders, and about processes of diffusion of adaptation innovations remain to be answered and tested empirically.

- *Exploring feasibility (limits) of adaptation strategies.* The research to date on adaptation has predominantly focused on adaptive capacity – on what it is, which factors contribute to it, and how it may be limited in specific contexts. Much less research has focused on specific ways to actually build it when it is lacking, and link it to broader sustainable development goals. More recently, a number of researchers have called for a more explicit focus not just on adaptive capacity but on the ability to actually use it in realizing adaptation actions on the ground. For example, many adaptation strategies proposed to date have been quite general without systematic testing of their feasibility (technological, economic, environmental, institutional, organizational, social, political, or cultural) in specific contexts. Such assessment of adaptation barriers may not only give a more realistic sense of real-world, context-specific adaptive capacity, but also lead to a more realistic set of adaptation strategies that overcome existing constraints. Such analyses also shed light on the role of non-climate drivers in adaptation decision-making. More cost-benefit analyses of different adaptation measures are called for, but offer only partial insight into the questions on feasibility and barriers.

While adaptation actions will frequently (but certainly not exclusively) be local and, therefore, dispersed and difficult to coordinate or efficiently inform, it may be possible to draw “decisions maps” – reflections of real-world decision procedures, e.g., in siting decisions, long-term planning processes, operational management and so on, clearly marking all relevant steps and inputs from contributing institutions or individuals – and thus identify leverage points at higher levels and early on to affect widespread change in climate-relevant decision-making (effectively, identifying “mainstreaming” opportunities). Similarly important is to explore ways for cross-scale integration of adaptation responses as systems at different levels either require support from others or affect their adaptation decision space. Finally, a significant contribution can be made by the behavioral sciences through improving our understanding of ways to foster behavior change in the wider populace, which will clearly be needed to politically support and practically implement both mitigation and adaptation policies.

- *Assessment of capacity and limits to short-term coping responses under increasing frequency of extreme events.* One of the clear messages from climate change research to date is that climatic extremes will become more frequent, and in some instances (such as heat waves) more intense. If extreme events are more frequent, public and private resources to prepare for, deal with, and recover from them will be taxed more frequently. Time between events will be shorter, increasing the potential for maladaptations; hasty responses may reduce vulnerability in the short-term but increase it in the long-term, or create new and unintended negative consequences. Historical experiences with disasters also suggest that local resources are typically insufficient to deal with large disasters, thus requiring supralocal resources. If extreme events become more widespread, however, questions arise as to the reliability of this sort of external support. Both interactive, scenario-based experiments and modeling studies investigating how response capacity may fare in a high-frequency extremes future would reveal important new insights on vulnerability, and how to improve the state's emergency response and long-term adaptation plans.
- *Prospects of adaptation to abrupt change (climatic or otherwise).* Most of California's climate change impacts and adaptation research under the auspices of PIER funding uses a common set of climate scenarios (a set also commonly used by IPCC) to facilitate comparison and integration. While this practice is laudable and great progress over work done a decade ago, it would be advisable for California to expand its set of climatic assumptions, at least for this strand of research. In fact, in the most recent IPCC assessment, scientists called for more exploration of the outlier trends, the "uncomfortable" (difficult to predict) tails of the distribution, or even scenarios of abrupt change, rather than solely focus on central tendencies. Because abrupt change is virtually impossible to predict, if it happens, it will impact Californians (and the world) unawares. To avoid being so completely blind-sided, several European countries and the state of Oregon have conducted exploratory research on scenarios of extreme and abrupt climate change, using a number of interactive, qualitative and quantitative scenario analyses. Such research promises to reveal otherwise unexplored, hidden vulnerabilities, allows opening up of "taboos" and seemingly untouchable assumptions, and enables creative thinking of adaptation options otherwise not considered.

6.0 Conclusions and Prioritized Recommendations

6.1 Conclusions

PIER climate change-related research is undertaken "to support California's intensifying efforts to understand how climate change will affect the state's social, economic, and natural systems; and to help provide policy-makers with the knowledge and tools they need to anticipate and plan for these impacts" (Franco et al., 2003, p.ES-1). The argument is made in this paper that this goal cannot be met without a significantly stepped-up, complementary, and integrated effort in policy-relevant human dimensions research.

To date, social science contributions to the climate change research portfolio has been extremely limited, save for a small number of studies which explored preparedness for

climate change impacts and actions taken to address climate change risks, and which illustrated the differential vulnerability (in the sense of exposure) of communities to heat-related public health risks. Several studies are currently underway that explore physical exposure to sea-level rise and storm-related flooding, as well as various adaptation options in the water, coastal, and forestry sectors.

Research gaps in the arena of vulnerability, adaptation, and resilience are pervasive, and almost all research would be better than none at all. Vulnerability-focused research is recommended in the following areas:

- Developing, inventorying, and monitoring of key vulnerability indicators;
- Improving understanding of all components of vulnerability (exposure, sensitivity, and response capacity);
- Improving understanding of multi-stressor causes of vulnerability; (
- Determining distributional impacts of environmental changes in key sectors;
- Investigating ripple effects and higher-order impacts within sectors and regions, and from impacts occurring outside of California but affecting the state;
- Investigating impacts in currently understudied, “forgotten” sectors; and
- Exploring horizontal impacts within sectors under stress conditions.

Future adaptation-focused research should include projects that address one of the following areas of research:

- Developing methodologies for integrated, cross-sector impacts of climate change and of adaptation responses, considering direct impacts of climate change, indirect impacts of adaptation responses, and the interaction between mitigation and adaptation responses;
- Improving understanding of the factors that allow, facilitate, and speed up adaptive learning;
- Exploring the feasibility (limits) of adaptation strategies, including: identification of the range of barriers to adaptation and how to overcome them; identification of leverage points to affect widespread change in management; exploring ways for cross-scale integration of adaptation responses; and identification of ways to promote public behavior change that is needed to support and implement adaptation policies;
- Assessment of capacity and limits to short-term coping responses under increasing frequency of extreme events; and
- Examining the prospects of adaptation to abrupt change (climatic or otherwise).

6.2 Prioritized Recommendations

PIER research funds are prioritized according to the following criteria: (1) relevance to PIER objectives (i.e., concerning the energy sector); (2) likelihood of generating scientifically and/or policy-relevant results within no more than four-to-five years; (3) potential applicability to California policy-making related to climate change; (4) technical quality and potential to advance scientific understanding; (5) potential to

generate “co-benefits” (i.e., in science or policy not directly related to climate change); (6) likelihood of eventually securing co-funding from other agencies; and, (7) the clear need for state support to reach the level of funding necessary to address these issues adequately.

The research topics identified above are subjectively rated (by the author) in the table below according to these criteria using a simple three-point scale (1 – low rating; 2 – medium rating; 3 – high rating).

Suggested Research Focus	PIER Evaluation Criteria (numbering follows description in text)							Total
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	
Vulnerability focus • Developing, inventorying, and monitoring of key vulnerability indicators	1	3	3	2	3	3	3	18
• Improving understanding of all components of vulnerability (differential exposure, sensitivity, and response capacity)	2	3	3	3	3	3	3	20
• Improving understanding of multi-stressor causes of vulnerability	2	2	3	3	3	1	2	16
• Determining distributional impacts of environmental changes in key sectors	2	2	3	3	3	2	3	18
• Investigating ripple effects and higher-order impacts - within sectors and regions - experienced outside of California, but affecting the state	2–3	2	2	2	3	1	3	13–14
• Understanding impacts in the “forgotten” sectors	1	2	3	3	3	1	3	16
• Horizontal impacts within sectors under stress conditions	2	2	3	3	3	2	3	18

Adaptation focus <ul style="list-style-type: none"> • Developing methods for integrated, cross-sector impacts of climate change and of adaptation responses <ul style="list-style-type: none"> - Direct impacts of climate change - Impacts of adaptation responses - Interaction between mitigation and adaptation responses 	2–3	1–2	2–3	3	3	2	2–3	15–19
<ul style="list-style-type: none"> • Understanding of factors that allow, facilitate, and speed up adaptive learning 	1	2	3	3	3	1	2	15
<ul style="list-style-type: none"> • Exploring feasibility (limits) of adaptation <ul style="list-style-type: none"> - Identifying multiple barriers and ways to overcome them - Identifying leverage points for widespread change in management - Explore ways for cross-scale integration of adaptation responses - Public behavior change needed to support and implement adaptation policies 	1 (3 in energy sector)	3	3	2–3	3	1	3	16–19
<ul style="list-style-type: none"> • Assessment of capacity and limits to short-term coping responses under increasing frequency of extreme events 	1 (3 in energy sector)	3	3	3	2–3	2	3	17–20
<ul style="list-style-type: none"> • Prospects of adaptation to abrupt change (climatic or otherwise) 	1	1–2	2	2	1–2	1	2	10–12

In light of the fact that the PIER Program has no history of research in this area, the criteria assessed above may not suffice to assess the relative importance and need for funding of this type of research relative to other research priorities. The California Energy Commission may thus also include in its deliberations the following considerations:⁷

⁷ This section draws heavily on a discussion paper by Roger Kasperson, a member of the National Research Council (NRC) Committee reviewing progress of, and proposing research strategies for, the U.S. CCSP.

- Experts tend to have different perspectives on what the most important research priorities should be compared to what policy-makers, resource managers, or different stakeholders in the wider public believe they ought to be. The August 20–24, 2008 workshop offers one important (but maybe not sufficient) opportunity for non-academics to provide critical complementary, “corrective” input into the ranking of research priorities. For example, since vulnerabilities and adaptive responses vary by scale, local communities can be expected to have very different research priorities than state-level agencies, yet the former’s input will be limited at the Sacramento workshop.
- While “policy relevance” is an explicitly stated endpoint of PIER-funded research, it may not meet this goal for all relevant stakeholders, nor may “policy-relevance” be sufficiently attractive to engage the broader social science community. Moreover, it is not inherently clear which specific policy goals are to be met (e.g., risk reduction, equity, economic benefit, or some measure of sustainability). Prioritization by the PIER criteria does not answer these questions.
- Programmatic balance can be achieved by a number of different metrics, including balance relative to stated program goals, balance by sector, balance by research that produces results relevant to short-term decision needs or more basic research that will result in policy relevance only after significant investment and maturation, or balance that aims to fill research gaps previously not addressed (e.g., a greater balance between physical, ecological, economic and other social scientific research). Several of the topics proposed above constitute challenging research problems and will require a longer funding commitment before significant progress can be demonstrated. At the same time, they may present some of the most important areas in terms of societal benefit.
- The criteria used above to rank research topics are not weighted, though clearly different experts, agency staff, and stakeholders may assign different importance to them. Thus, the ranking total is almost certainly misleading. Deliberate, structured decision processes would be required to rank these research priorities appropriately.
- Finally, results of the research proposed here might themselves shape subsequent research prioritization. Unexpected economic impacts, social inequalities, unacceptable levels of compound risk from multiple stressors—currently not yet known—may well modify prioritization in the out-years. Frequently revisiting this list in light of emerging research findings is therefore highly recommended.

Summary

Vulnerability and adaptation research ought to assume a high priority in the next PIER research plan in light of past neglect, a virtual guarantee that impact assessments conducted in a “vacuum,” insulated from social, economic, institutional, political and behavioral realities, will undoubtedly misrepresent the real risks and opportunities faced by Californians, and the rapidly growing need for social science insights to support the development of adaptation plans in the state. A better understanding of the

distribution and causes of vulnerabilities, and the identification of vulnerability hotspots, would be the best foundation for adequate development of adaptation options and for priority setting, but adaptation research should not have to await results from vulnerability research to begin. Rather, California faces a critical opportunity now to develop a comprehensive social science research agenda and commit to an investment promising high returns.

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Appendix 1: Expert Consultations

The following experts have been consulted for input to this discussion paper. Most spoke to the Vulnerability/Adaptation focus and to the Decision Support focus, as well as related questions about social science contributions to policy-relevant climate change research in California, so they are listed for this and the complementary paper.

Name	Affiliation	Expertise	Sector	Vulnerability Adaptation	Decision Support	Bigger picture
Meg Caldwell	Stanford	Law, land use policy, coastal mgmt	coastal, land use	x	x	x
Kirstin Dow	University of South Carolina	Vulnerability, adaptation, risk, HDGEC	water, general	x	x	
Judith Kildow	MBARI	Economics, policy analysis	coastal, marine	x	x	x
Helen Ingram	UC-Irvine, Univ. Ariz.	Water, decision support	water, agricult		x	x
Roger Kasperson	Clark University	Vulnerability, adaptation, risk HDGEC	general	x		x
Ruth Langridge	UC-Santa Cruz	Water mgmt, conflicts	water	x		
Daniel Mazmanian	University of Southern California	Governance, institutions, sustainability, env. policy	general	x	x	x
Max Moritz	UC-Berkeley	Extension specialist, wildfire	forests		x	
Paty Ramero-Lankao	NCAR	Vulnerability, adaptation, urban areas	urban, agricult	x		
Peter Richerson	UC-Davis	Cultural evolution, adaptation	general	x		x
Steve Schneider	Stanford	Climate-society interactions, risk, extremes	general	x		x
Elaine Vaughan	UC-Irvine	Risk perception, communication vuln., responses	risks, health	x		x
Anthony Westerling	UC-Merced	Economics, forests, wildfire	forests	x	x	
Steve Wheeler	UC-Davis	Land use planning	land use, agricult	x		
Oran Young	UC-Santa Barbara	Institutions, HDGEC	general	x	x	x