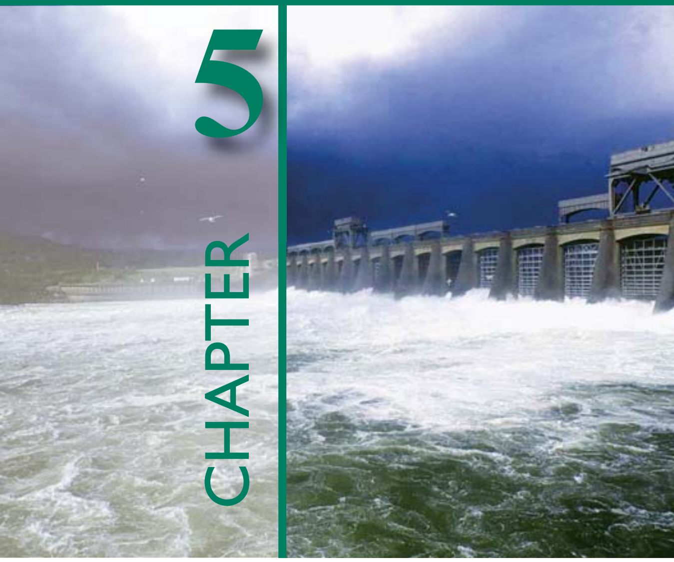

CHAPTER 5

Conclusions and Research Priorities

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5.1 INTRODUCTION

The previous chapters have summarized a variety of currently available information about effects of climate change on energy production and use in the United States. For two reasons, it is important to be careful about drawing firm conclusions about effects at this time. One reason is that the research literatures on many of the key issues are limited, supporting an identification of issues but not a resolution of most uncertainties. A second reason is that, as with many other categories of climate change effects in the U.S., the effects depend on a wide range of factors beyond climate change alone, such as patterns of economic growth and land use, patterns of population growth and distribution, technological change, and social and cultural trends that could shape policies and actions, individually and institutionally.

Accordingly, this final chapter of SAP 4.5 will sketch out what appear, based on the current knowledge base, to be the most likely types of effects on the energy sector. These should be considered along with effects on other sectors that should be considered in risk management discussions in the near term. As indicated in Chapter 1, conclusions are related to degrees of likelihood: likely (2 chances out of 3), very likely (9 chances out of 10), or virtually certain (99 chances out of 100). The chapter will then discuss issues related to prospects for energy systems in the U.S. to adapt to such effects, although literatures on adaptation are very limited. Finally, it will suggest a limited number of needs for expanding the knowledge base so that, when further assessments on this topic are carried out, conclusions about effects can be offered with a higher level of confidence.

5.2 CONCLUSIONS ABOUT EFFECTS

Based on currently available projections of climate change in the United States, a number of conclusions can be suggested about likely effects on energy *use* in the U.S. over a period of time addressed by the research literature (near to midterm). Long-term conclusions are difficult due to uncertainties about such driving forces as technological, change, institutional change, and climate change policy responses.

- Climate change will mean reductions in total U.S. energy demand for space heating for buildings, with effects differing by region (virtually certain).
- Climate change will mean increases in total U.S. energy demand for space cooling, with effects differing by region (virtually certain).
- Net effects on energy use will differ by region, with net lower total energy requirements for buildings in net heating load areas and net higher energy requirements in net cooling load areas, with overall impacts affected by patterns of interregional migration – which are likely to be in the direction of net cooling load regions – and investments in new building stock (virtually certain).
- Temperature increases will be associated with increased peak demands for electricity (very likely).
- Other effects of climate change are less clear, but some could be nontrivial: e.g., increased energy use for water pumping and/or desalination in areas that see reductions in water supply (very likely).
- Lower winter energy demands in Canada could add to available electricity supplies for a few U.S. regions (likely).

A number of conclusions can be offered with relatively high levels of confidence about effects of climate change on energy *production and supply* in the U.S., but generally the research evidence is not as strong as for effects on energy use:

- Changes in the distribution of water availability in the U.S. will affect power plants; in areas with decreased water availability, competition for water supplies will increase between energy production and other sectors (virtually certain).
- Temperature increases will decrease overall thermoelectric power generation efficiency (virtually certain).
- In some regions, energy resource production and delivery systems are vulnerable to effects of sea level rise and extreme weather events, especially the Gulf Coast and the East Coast (virtually certain).
- In some areas, the siting of new energy facilities and systems could face increased restrictions, related partly to complex interactions among the wider range of water uses as well as sea-level rise and extreme event exposures (likely
- Incorporating possible climate change impacts into planning processes could strengthen energy production and distribution system infrastructures, especially regarding water resource management (likely).
- Hydropower production is expected to be directly and significantly affected by climate change, especially in the West and Northwest (very likely).
- Climate change is expected to mean greater variability in wind resources and direct solar radiation, substantially impacting the planning, siting, and financing of these technologies (likely).
- Increased temperatures and other climate change effects will affect energy transmission and distribution requirements, but these effects are not well-understood.

Overall, the current energy supply infrastructure is often located in areas where climate change impacts might occur, but large-scale disruptions are not likely except during extreme weather events. Most of the effects on fossil and nuclear electricity components are likely to be modest changes in water availability and/or cycle efficiency.

California is one U.S. state where impacts on both energy use and energy production have been studied with some care (See Box 5.1: California: A Case Study).

About *indirect effects of climate change on energy production and use* in the U.S., conclusions are notably mixed. Conclusions related to possible impacts of climate change policy interventions on technology choice and emissions can be offered with relatively high confidence based on published research:

- Climate change concerns are very likely to affect perceptions and practices related to risk management behavior in investment by energy institutions (very likely).
- Climate change concerns, especially if they are expressed through policy interventions, are almost certain to affect public and private sector energy technology R&D investments and energy resource/technology choices by energy institutions, along with associated emissions (virtually certain).
- Climate change can be expected to affect other countries in ways that in turn affect U.S. energy conditions (very likely).

Other types of possible indirect effects can be suggested as a basis for discussion, but conclusions must await further research:

- Climate change effects on energy production and use could in turn affect some regional economies, either positively or negatively (likely).
- Climate change may have some effects on energy prices in the U.S., especially associated with extreme weather events (very likely).
- Climate change concerns are likely to interact with some driving forces behind policies focused on U.S. energy security, such as reduced reliance on conventional petroleum products (likely).

These conclusions add up to a picture that is cautionary rather than alarming. Since in many cases effects that could be a concern to U.S. citizens and U.S. energy institutions are some decades in the future, there is time to consider strategies for adaptation to reduce possible negative impacts and take advantage of possible positive impacts.

BOX 5.1 California: A Case Study

California is unique in the United States as a state that has examined possible effects of climate change on its energy production and use in some detail (also see Box 2.2). Led by the California Energy Commission and supported by such nearby partners as the Electric Power Research Institute, the University of California–Berkeley, and the Scripps Institution of Oceanography, the state is developing a knowledge base on this subject that could be a model for other states and regions (as well as the nation as a whole).

Generally, the analyses to date (many of which are referenced in Chapters 2 and 3) indicate that electricity demand will grow due to climate change, with an especially close relationship between peak electricity demand and temperature increases (Franco and Sanstad 2006), and water supply – as an element of the "energy-water nexus" – will be affected by a reduction in the Sierra snowpack (by as much as 70-90 % over the coming century: Vicuña et al. 2006). Patterns of urbanization could add to pressures for further energy supplies. Adaptations to these and other climate change impacts appear possible, but they could be costly (Franco 2005). Overall economic impacts will depend considerably on the effectiveness of response measures, which tend currently to emphasize emission reduction but also consider impact scenarios and potential adaptation measures (CEPA 2006).

Other relevant studies of the California context for climate change effects reinforce an impression that effects of warming and snowpack reduction could be serious (Hayhoe et al. 2004) and that other ecosystems related to renewable energy potentials could be affected as well (Union of Concerned Scientists 1999).

5.3 CONSIDERING PROSPECTS FOR ADAPTATION

The existing research literature tends to treat the U.S. energy sector mainly as a *driving force* for climate change rather than a sector *subject to impacts* from climate change. As a result, there is very little literature on adaptation of the energy sector to effects of climate change, and the following discussion is therefore largely speculative.

Generally, both energy users and providers in the U.S. are accustomed to changes in conditions that affect their decisions. Users see energy prices fluctuate with international oil market conditions and with Gulf Coast storm behavior, and they see energy availability subject to short-term shortages for a variety of reasons (e.g., the California energy market crises of 2000/2001 or electricity blackouts in some Northeastern cities in 2003). Energy providers cope with shifting global market conditions, policy changes, financial variables such as interest rates for capital infrastructure lending, and climate variability. In many ways, the energy sector is among the most resilient of all U.S. economic sectors, at least in terms of responding to changes within the range of historical experience. For instance, electric utilities routinely consider planning and investment strategies that consider weather variables (Niemeyer, 2005); and one important guide to adaptation to climate *change* is what makes sense in adapting to climate *variability* (Franco 2005).

On the other hand, such recent events as Hurricane Katrina (Box 5.2: Hurricane Katrina and the Gulf Coast: A Case Study) suggest that the U.S. energy sector is better at responding to relatively short-term variations and uncertainties than to changes that reach beyond the range of familiar short-term variabilities (Niemeyer 2005). In fact, the confidence of U.S. energy institutions about their ability to reduce exposure to risks from short-term variations might tend to reduce their resilience to larger long-term changes, unless an awareness of risks from such long-term changes is heightened.

Adaptations to effects of climate change on energy *use* may focus on increased demands for space cooling in areas affected by warming and associated increases in total energy consumption costs. Alternatives could include reducing costs of cooling for users through energy efficiency improvement in cooling equipment and building envelopes; responding to likely increases in demands for electricity for cooling through expanded generation capacities, expanded interties, and possibly increased capac-

BOX 5.2 Hurricane Katrina and the Gulf Coast: A Case Study

It is not possible to attribute the occurrence of Hurricane Katrina, August 29, 2005, to climate change; but projections of climate change say that extreme weather events are very likely to become more intense. If so (e.g., more of the annual hurricanes at higher levels of wind speed and potential damages), then the impacts of Katrina are an indicator of possible impacts of one manifestation of climate change.

Impacts of Katrina on energy systems in the region and the nation were dramatic at the time, and some impacts remained many months later. The hurricane itself impacted coastal and offshore oil and gas production, offshore oil port operation (stopping imports of more than one million bbl/d of crude oil), and crude oil refining along the Louisiana Gulf Coast (Figures 3.4 a-d). Within only a few days, oil product and natural gas prices had risen significantly across the U.S. As of mid-December 2005, substantial oil and gas production was still shut-in, and refinery shutdowns still totalled 367, 000 bbl/d (EIA 2005) (see Chapter 3).

Possibilities for adaptation to reduce risks of damages from future Katrinas are unclear. They might include such alternatives as hardening offshore platforms and coastal facilities to be more resilient to high winds, wave action, and flooding (potentially expensive) and shifting the locations of some coastal refining and distribution facilities to less vulnerable sites, reducing their concentration in the Gulf Coast. (potentially very expensive).

ities for storage; and responding to concerns about increased peak demand in electricity loads, especially seasonally, through contingency planning for load-leveling. Over a period of several decades, for instance, technologies are likely to respond to consumer concerns about higher energy bills where they occur.

Many technologies that can enable adaptations to effects on energy *production and supply* are available for deployment. The most likely adaptation in the near term is an increase in perceptions of uncertainty and risk in longer-term strategic planning and investment, which could seek to reduce risks through such approaches as diversifying supply sources and technologies and risk-sharing arrangements.

Adaptation to *indirect effects* of climate change on the energy sector is likely to be bundled with adaptation to other issues for energy policy and decision-making in the U.S., such as energy security: for instance, in the development of lower carbon-emitting fossil fuel use technology ensembles, increased deployment of renewable energy technologies, and the development of alternatives to fossil fuels and effects on energy institutional structures. Issues related to effects of climate change on other countries linked with U.S. energy conditions are likely to be addressed through attention by both the public and private sectors to related information systems and market signals.

It seems possible that adaptation challenges would be greatest in connection with possible increases in the intensity of extreme weather events and possible significant changes in regional water supply regimes. More generally, adaptation prospects appear to be related to the magnitude and rate of climate change (e.g., how much the average temperature rises before stabilization is achieved, how rapidly it moves to that level, and how variable the climate is at that level), with adaptation more likely to be able to cope with effects of lesser amounts, slower rates of change, and less variable climate (Wilbanks et al., 2007).

Generally, prospects for these types of adaptations depend considerably on the level of awareness of possible climate changes at a relatively localized scale and possible implications for energy production and use – the topic of this study. When the current knowledge base to support such awareness is so limited, this suggests that expanding the knowledge base is important to the energy sector in the United States.

5.4 NEEDS FOR EXPANDING THE KNOWLEDGE BASE

Expanding the knowledge base about effects of climate change on energy production and use in the United States is not just a responsibility of the federal government. As the work of such institutions as the Electric Power Research Institute and the California Energy Commission demonstrates, a wide variety of parts of U.S. society have knowledge, expertise, and data to contribute to what should be a broad-based multi-institutional collaboration.

Recognizing that roles in these regards will differ among federal and state governments, industry, nongovernmental institutions, and academia and that all parties should be involved in discussions about how to proceed, this study suggests the following needs for expanding the knowledge base on its topic, some of which are rooted in broader needs for advances in climate change science.

5.4.1 General Needs

- Improved capacities to project climate change and its effects on a relatively fine-grained geographic scale, especially of precipitation changes and severe weather events: e.g., in order to support evaluations of impacts at local and small-regional scales, not only in terms of gradual changes but also in terms of extremes, since many energy facility decisions are made at a relatively localized scale;
- Research on and assessments of implications of extreme weather events for energy system resiliency, including strategies for both reducing and recovering from impacts;
- Research on and assessments of potentials, costs, and limits of adaptation to risks of adverse effects, for both supply and use infrastructures;
- Research on efficiency of energy use in the context of climate warming, with an em-

phasis on technologies and practices that save cooling energy and reduce electrical peak load;

- Research on and assessments of implications of changing regional patterns of energy use for regional energy supply institutions and consumers;
- Improvements in the understanding of effects of changing conditions for renewable energy and fossil energy development and market penetration on regional energy balances and their relationships with regional economies;
- In particular, improvements in understanding likely effects of climate change in Arctic regions and on storm intensity to guide applications of existing technologies and the development and deployment of new technologies and other adaptations for energy infrastructure and energy exploration and production in these relatively vulnerable regions; and
- Attention to linkages and feedbacks among climate change effects, adaptation, and mitigation; to linkages between effects at different geographic scales; and relationships between possible energy effects and other possible economic, environmental, and institutional changes (Parson et al., 2003; Wilbanks, 2005).

5.4.2 Needs Related To Major Technology Areas

- Improving the understanding of potentials to increase efficiency improvements in space cooling;
- Improving information about interactions among water demands and uses where the quantity and timing of surface water discharge is affected by climate change;
- Improving the understanding of potential climate change and localized variability on energy production from wind and solar technologies;
- Developing strategies to increase the resilience of coastal and offshore oil and gas production and distribution systems to extreme weather events;
- Pursuing strategies and improved technology potentials for adding resilience to energy supply systems that may be subject to stress under possible scenarios for climate change;
- Improving understandings of potentials to improve resilience in electricity supply systems through regional intertie capacities and distributed generation; and
- Research on and assessments of the impacts of severe weather events on sub-sea pipeline systems, especially in the Gulf of Mexico, and strategies for reducing such impacts.[4]

Other needs for research exist as well, and the process of learning more about this topic in coming years may change perceptions of needs and priorities; but based on current knowledge, these appear to be high priorities in the next several years.

[4] Note that CCSP SAP 4.7, The Impacts of Climate Change on Transportation: A Gulf Coast Study, considers imacts on pipelines and other transportation infrastructures in the Gulf Coast region (CCSP, 2007b).