CHAPTER 4

Possible Indirect Effects of Climate Change on Energy Production and Use in the United States

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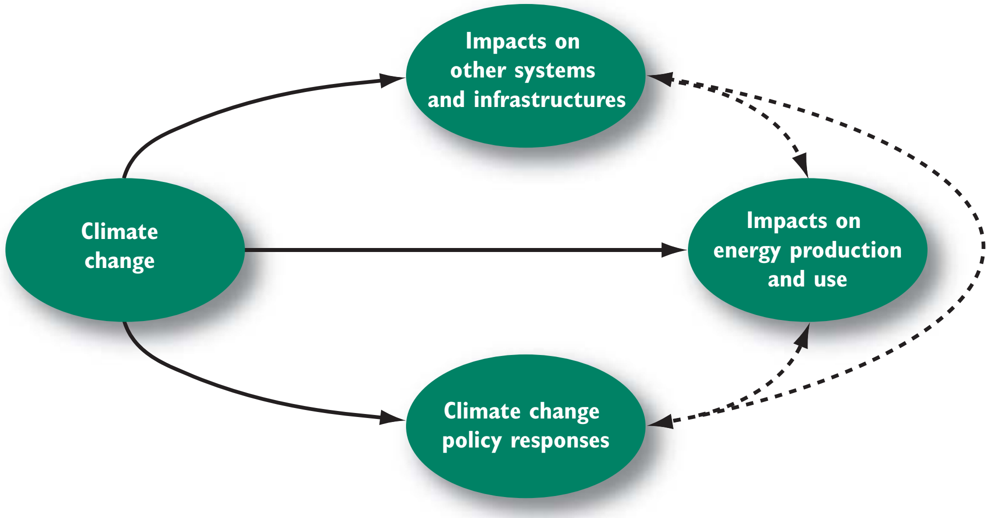
4.1 INTRODUCTION

Changes in temperature, precipitation, storms, and/or sea level are likely to have direct effects on energy production and use, as summarized above; but they may also have a number of indirect effects—as climate change affects other sectors and if it shapes energy and environmental policy-making and regulatory actions (Fig. 4.1). In some cases, it is possible that indirect effects could have a greater impact, positive or negative, on certain institutions and localities than direct effects.

In order to provide a basis for such a discussion, this chapter of SAP 4.5 offers a preliminary taxonomy of categories of indirect effects that may be of interest, along with a summary of existing knowledge bases about such indirect effects. Some of these effects are from climate change itself, e.g., effects on electricity prices of changing conditions for hydropower production or of more intense extreme weather events. Other effects could come from climate change related **policies** (e.g., effects of stabilization-related emission ceilings on energy prices, energy technology choices, or energy sector emissions) (Table 4.1).

Most of the existing literature is concerned with implications of climate change mitigation policies on energy technologies, prices, and emissions in the U.S. Because this literature is abundant, relatively well-known, and in some cases covered by other SAPs (such as SAP 2.2), it will be only briefly summarized here, offering links to more detailed discussions. Of greater interest to some readers may be the characterization of other possible indirect effects besides these.

Figure 4.1 This Chapter Is Concerned With The Dashed Lines In This Flow Diagram Of Connections Between Climate Change And Energy Production And Use



4.2 CURRENT KNOWLEDGE ABOUT INDIRECT EFFECTS

4.2.1 Possible Effects On Energy Planning

Climate change is likely to affect energy planning, nationally and regionally, because it is likely to introduce new considerations and uncertainties to institutional (and individual) risk management. Such effects can arise either through anticipated changes in climate-related environmental conditions, such as hydropower potentials, possible exposure to storm damages (see Chapter 3), or changed patterns of energy demand (see Chapter 2), or through possible changes in policies and regulations.

For instance, a path-breaking study supported by EPRI and the Japanese Central Research Institute of Electric Power Industry (CRIEPI) assessed possible impacts of global climate change on six utilities, five of them in the United States (ICF, 1995). The study considered a variety of scenarios depicting a range of underlying climate, industry, and policy conditions. It found that GHG emission reduction policies could cause large increases in electricity prices, major changes in a utility's resource mix related to requirements for emission controls, and significant expansions in demand-side management programs. Major impacts are likely to be on Integrated Resource Planning regarding resource and capacity additions and/or plant retirements, along with broader implications of increased costs and prices. In another

Table 4.1. Overview Of The Knowledge Base About Possible Indirect Effects Of Climate Change And Climate Change Policy On Energy Systems In The U.S.

Indirect Effect On Energy Systems	From Climate Change	From Climate Change Policy
On energy planning and investment	Very limited	Considerable literature
On technology R&D and preferences	Very limited	Considerable literature
On energy supply institutions	Very limited	Limited
On energy aspects of regional economies	Very limited	Some literature
On energy prices	Almost none	Considerable literature
On energy security	Almost none	Very limited
On environmental emissions from energy production/use	Very limited	Considerable literature
On energy technology/service exports	Almost none	Very limited

example, Burtraw et al., 2005 analyzed a nine-state northeastern regional greenhouse gas initiative (RGGI), an allowance-based regional GHG cap-and-trade program for the power sector. They found that how allowances are allocated has an effect on electricity price, consumption, and the mix of technologies used to generate electricity. Electricity prices increase in most of the cases. They also note that any policy that increases energy costs in the region is likely to cause some emission leakage to other areas outside the region as electricity generation or economic activity moves to avoid regulation and associated costs.

Electric utilities in particular are already sensitive to weather as a factor in earnings performance, and they utilize weather risk management tools to hedge against risks associated with weather-related uncertainties. Issues of interest include plans for capacity additions, system reliability assurance, and site selection for long-lived capital facilities (O'Neill, 2003). Even relatively small changes in temperature/demand can affect total capacity needs across the U.S. power sector, especially in peak periods.

Some current policy initiatives hint at what the future might be like, in terms of their possible effects on energy planning. U.S. national and state climate policy actions include a variety of traditional approaches such as funding mechanisms (incentives and disincentives); regulations (caps, codes, and standards); technical assistance (direct or in kind); research and development; information and education; and monitoring and reporting (including impact disclosure) (Rose and Zhang, 2004). Covered sectors include power generation, oil and gas, residential, commercial, industry, transportation, waste management, agriculture, and forestry. These sectors cut across private and public sector facilities and programs, as well as producers and consumers of energy (Peterson and Rose, 2006).

A variety of policy alternatives and mechanisms are described and analyzed in published literatures, including production tax credits (incorporated in the Energy Policy Act of 2005), investment tax credits, renewable energy portfolio standards, and state or regional greenhouse gas initiatives.

4.2.2 Possible Effects On Energy Production And Use *Technologies*

Perhaps the best-documented case of indirect effects of climate change on energy production and use in the United States is effects of climate change policy on technology research and development and on technology preferences and choices.

For instance, if the world moves toward concerted action to stabilize concentrations of greenhouse gases (GHG) in the earth's atmosphere, the profile of energy resources and technologies being used in the U.S. – on both the production and use sides – would have to change significantly (CCTP, 2005). Developing innovative energy technologies and approaches through science and technology research and development is widely seen as a key to reducing the role of the energy sector as a driver of climate change. Considering various climate change scenarios, researchers have modeled a number of different pathways for the world and for various regions, including the U.S., in order to inform discussions about technology options that might contribute to energy system strategies (e.g., Edmonds et al., 1996; Akimoto et al., 2004; Hoffert et al., 2002; van Vuuren et al., 2004; Kainuma et al., 2004; IPCC, 2005a; Kurosawa, 2004; Pacala and Socolow, 2004 and Paltsev et al., 2005). Recently published scenarios in CCSP SAP 2.1a, explore the U.S. implications of alternative stabilization levels of anthropogenic greenhouse gases in the atmosphere, and they explicitly consider the economic and technological foundations of such response options (CCSP, 2007a). In addition, there have been important recent developments in scenario work in the areas of non-carbon dioxide GHGs, land use and forestry emission and sinks, emissions of radiatively important non-GHGs such as black and organic carbon, and analyses of uncertainties, among many issues in increasing mitigation options and reducing costs (Nakicenovic and Riahi, 2003; IPCC, 2005b; van Vuuren et al., 2006; Weyant et al., 2006; and Placet et al., 2004).

These references indicate that an impressive amount of emissions reductions could be achieved through combinations of many different technologies, especially if diversified tech-

nology advancement is assumed. Although the full range of effects in the future is necessarily speculative, it is possible that successful development of such advanced technologies could result in potentially large economic benefits, compared with emission reductions without significant technological progress. When the costs of achieving different levels of emission reductions have been compared for cases with and without advanced technologies, many of the advanced technology scenarios projected that the cost savings from advancement would be significant (CCTP, 2005; Weyant, 2004; IPCC, 2007; CCSP, 2007a). Note, however, that there is considerable "inertia" in the nation's energy supply capital stock because institutions that have invested in expensive facilities prefer not to have them converted into "stranded assets." Note also that any kind of rapid technological transformation would be likely to have cross-commodity cost/price effects, e.g., on costs of specialized components in critical materials that are in greater demand.

4.2.3 Possible Effects On Energy Production And Use Institutions

Climate change could affect the institutional structure of energy production and use in the United States, although relatively little research has been done on such issues. Institutions include energy corporations, electric utilities, governmental organizations at all scales, and nongovernmental organizations. Their niches, size and structure, and operation tend to be sensitive to changes in "market" conditions from any of a variety of driving forces, these days including such forces as globalization, technological change, and social/cultural change (e.g., changes in consumer preferences). Climate change is likely to interact with other driving forces in ways that could affect institutions concerned with energy production and use.

Most of the very limited research attention to this type of effect has been focused on effects of climate change policy (e.g., policy actions to reduce greenhouse gas emissions) on U.S. energy institutions, such as on the financial viability of U.S. electric utilities (see, for instance, WWF, 2003). Other effects could emerge from changes in energy resource/technology mixes due to climate change: e.g., changes in renewable energy resources and costs or changes in energy R&D investment patterns.

Most of these issues are speculative at this time, but identifying them is useful as a basis for further discussion. Issues would appear to include effects on planning, above.

4.2.3.1 Effects on the Institutional Structure of the Energy Industry

Depending on its impacts, climate change could encourage large energy firms to move into renewable energy areas that have been largely the province of smaller firms, as was the case in some instances in the wake of the energy "shocks" of the 1970s (e.g., Flavin and Lenssen, 1994). This kind of diversification into other "clean energy" fields could be reflected in horizontal and/or vertical integration. Possible effects of climate change on these and other institutional issues (such as organizational consolidation vs fragmentation) have not been addressed systematically in the research literature; but some large energy firms are exploring a wider range of energy technologies and some large multinational energy technology providers are diversifying their product lines to be prepared for possible changes in market conditions.

4.2.3.2 Effects on Electric Utility Restructuring

Recent trends in electric utility restructuring have included increasing competition in an open electricity supply marketplace, which has sharpened attention to keeping O&M costs for infrastructure as low as possible. Some research literature suggests that one side-effect of restructuring has been a reduced willingness on the part of some utilities to invest in environmental protection beyond what is absolutely required by law and regulation (Parker, 1999; Senate of Texas, 1999), although this issue needs further study. If climate change introduces new risks for utility investment planning and reliability, it is possible that policies and practices could encourage greater cooperation and collaboration among utilities.

4.2.3.3 Effects on the Health of Fossil Fuel-Related Industries

If climate change is associated with policy and associated market signals that decarbonization of energy systems, industries focused on the production of fossil fuels, converting them into useful energy forms, transporting them to demand centers, and providing them to users could face shrinking markets and profits. The coal industry seems especially endangered in such an eventuality. In the longer run, this type of effect depends considerably on technological change: e.g., affordable carbon capture and sequestration, fuel cells, and efficiency improvement. It is possible that industries (and regions) concentrated on fossil fuel extraction, processing, and use will seek to diversify as a hedge against risks of economic threats from climate change policy.

4.2.3.4 Effects on other supporting institutions such as financial and insurance industries

Many major financial and insurance institutions are gearing up to underwrite emission trading contracts, derivatives and hedging products, wind and biofuel crop guarantee covers for renewable energy, and other new financial products to support carbon emission trading, while they are concerned about exposure to financial risks associated with climate change impacts. In recent years, various organizations have tried to engage the global insurance industry in the climate change debate. Casualty insurers are concerned about possible litigation against companies responsible for excessive GHG emissions, and property insurers are concerned about future uncertainties in weather damage losses. However, it is in the field of adaptation where insurers are most active, and have most to contribute. Two hundred major companies in the financial sector around the world have signed up to the UN Environment Program's - Finance Initiative, and 95 institutional investment companies have so far signed up to the Carbon Disclosure Project. They ask businesses to disclose investment-relevant information concerning their GHGs. Their website provides a comprehensive registry of GHGs from public corporations. More than 300 of the 500 largest companies in the world now report their emissions on this website, recognizing that institutional investors regard this information as important for shareholders (Crichton, 2005).

4.3 POSSIBLE EFFECTS ON ENERGY-RELATED DIMENSIONS OF REGIONAL AND NATIONAL ECONOMIES

It is at least possible that climate change could have an effect on regional economies by impacting regional comparative advantages related to energy availability and cost. Examples could include regional economies closely associated with fossil fuel production and use (especially coal) if climate change policies encourage decarbonization, regional economies dependent on affordable electricity from hydropower if water supplies decrease or increase, regional economies closely tied to coastal energy facilities that could be threatened by more intense coastal storms (Chapter 3), and regional economies dependent on abundant electricity supplies if demands on current capacities increase or decrease due to climate change.

Attempts to estimate the economic impacts that could occur 50–100 years in the future have been made using various climate scenarios, but the interaction of climate and the nation's economy remains very difficult to define. Most studies of the economic impacts of global warming have analyzed the impacts on specific sectors (such as agriculture) or on regional ecosystems (e.g. Fankhauser, 1995; Mendelsohn and Neumann, 1999; Nordhaus and Boyer, 2000; Mendelsohn et al., 1994; Tol, 2002; Nordhaus, 2006). However, not many impact studies have concentrated on the energy sector. Significant uncertainties therefore surround projections of climate change induced energy sector impacts on the U.S. or regional economies. Changnon estimated that annual national economic losses from the energy sector will outweigh the gains in years with major weather and climate extremes (Changnon, 2005). Jorgenson et al., 2004, studied impacts of climate change on various sectors of the U.S. economy from 2000 – 2100. In three optimistic scenarios, they conclude that increased energy availability and cost savings from reduced natural gas-based space heating more than compensate for increased expenditures on electricity-based space cooling. These unit cost reductions appear as productivity increases and, thus, improve the economy, whereas other three pessimistic scenarios show that electricity-based space conditioning expe-

riences relatively larger productivity losses than does space conditioning from coal, wood, petroleum or natural gas; accordingly its (direct) unit cost rises faster and thus produces no benefits to the economy. Additionally, higher domestic prices discourage exports and promote imports leading to a worsening real trade balance. According to Mendelsohn et al., 2000, the U.S. economy could benefit from the climate change induced energy sector changes. However, Mendelsohn and Williams, 2004 suggest that climate change will cause economic damages in the energy sector in every scenario. They suggest that temperature changes cause most of the energy impacts. Larger temperature increases generate significantly larger economic damages. The damages are from increased cooling expenditures required to maintain desired indoor temperatures. In the empirical studies, these cost increases outweighed benefits of the reduced heating expenditures unless starting climates are very cool (Mendelsohn and Neumann, 1999; Mendelsohn, 2001) (also see Chapter 2).

In California, a preliminary assessment of the macroeconomic impacts associated with the climate change emission reduction strategies (CEPA, 2006) shows that, while some impacts on the economy could be positive if strategies reduce energy costs, other impacts might be less positive. For example, the study emphasizes that even relatively small changes in in-state hydropower generation result in substantial extra expenditure burdens on an economy for energy generation, because losses in this "free" generation must be purchased from other sources; for example, a 10% decrease in hydroelectric supply would impose a cost of approximately $350 million in additional electricity expenditures annually (Franco and Sanstad, 2006). Whereas electricity demand is projected to rise in California between 3 to 20 % by the end of this century, peak electricity demand would increase at a faster rate. Since annual expenditures of electricity demand in California represent about $28 billion, even such a relatively small increase in energy demand would result in substantial extra energy expenditures for energy services in the state; a 3 % increase in electricity demand by 2020 would translate into about $930 million (in 2000 dollars) in additional electricity expenditures (Franco and Sanstad, 2006). Particular concerns are likely to exist in areas where summer electricity loads already strain supply capacities (e.g., Hill and Goldberg 2001; Kelly et al. 2005; Rosenzweig and Solecki, 2001) and where transmission and distribution networks have limited capacities to adapt to changes in regional demands, especially seasonally (e.g., London Climate Change, Partnership 2002).

Rose and others have examined effects of a number of climate change mitigation policies on U.S. regions in general and the Susquehanna River basin in particular (Rose and Oladosu, 2002; Rose and Zhang, 2004; Rose et al., 1999; Rose et al., 2006). In general, they find that such policy options as emission permits tradable among U.S. regions might have less than expected effects, with burdens impacting at least one Southern region that needs maximum permits but whose economy is not among the nation's strongest. Additionally, they discuss Pennsylvania's heavy reliance on coal production and use infrastructure that increases the price of internal carbon dioxide mitigation. They suggest that the anomalies stem from the fact that new entrants, like Pennsylvania, into regional coalitions for cap-and-trade configuration may raise the permit price, may undercut existing states' permit sales, and may be able to exercise market power. Particularly, they raise an issue of the "responsibility" for emissions. Should fossil fuel producing regions take the full blame for emissions, or are the using regions also responsible? They find that aggregate impacts of a carbon tax on the Susquehanna River Basin would be negative but quite modest.

Concerns remain, however, that aggressive climate policy interventions to reduce GHG emissions could negatively affect regional economies linked to coal and other fossil energy production. Concerns also exist that climate change itself could affect the economies of areas exposed to severe weather events (positively or negatively) and areas whose economies are closely linked to hydropower and other aspects of the "energy-water nexus."

4.4 POSSIBLE RELATIONSHIPS WITH OTHER ENERGY-RELATED ISSUES

Many other types of indirect effects are possible, although relatively few have received research attention. Without asserting that this listing is comprehensive, such effects might include the following types.

4.4.1 Effects Of Climate Change In Other Countries On U.S. Energy Production And Use

We know from recent experience that climate variability outside the U.S. can affect energy conditions in the U.S.; an example is an unusually dry year in Spain in 2005 that led the country to enter the international LNG market to compensate for scarce hydropower, which in turn raised LNG prices for U.S. consumption (Alexander's Gas & Oil Connections, 2005). It is important, therefore, to consider possible effects of climate change not only on international energy product suppliers and international energy technology buyers but also on other countries whose participation in international markets could affect U.S. energy availability and prices from international sources, which could have implications for energy security (see below). Climate change-related energy supply and price effects could be coupled with other price effects of international trends on U.S. energy, infrastructures, such as effects of aggressive programs of infrastructure development on China and India.

As indicated in Chapter 2, a particularly important case is U.S. energy inputs from Canada. Canada is the largest single source of petroleum imports by the U.S. (about 2.2 million barrels per day) and exports more than 15% of the natural gas consumed in the U.S. (EIA 2005a, 2006). In 2004, it exported to the U.S. 33 MWh of electricity, compared with imports of 22.5 MWh (EIA, 2005b). Climate change could affect electricity exports and imports, for instance if electricity demands for space cooling increase in Canada or if climate change affects hydropower production in that country.

4.4.2 Effects Of Climate Change On Energy Prices*

A principal mechanism in reducing vulnerabilities to climate-related (and other) changes potentially affecting the energy sector is the operation of the energy market, where price variation is a key driver. Effects of climate change on energy prices are in fact interwoven with effects of energy prices on risk management strategies, in a dynamic that could work in both directions at once; and it would be useful to know more about roles of energy markets in reducing vulnerabilities to climate change impacts, along with possible adaptations in the functioning of those markets. Although price effects of climate change itself are not analyzed in the literature, aside from effects of extreme events such as Hurricane Katrina, substantial research has been done on possible energy price effects of greenhouse gas emission reductions.

Estimates of costs of emission reduction vary widely according to assumptions about such issues as how welfare is measured, ancillary benefits, and effects in stimulating technological innovation; and therefore any particular set of cost estimates includes considerable uncertainty. According to an Interlaboratory Working Group (IWG, 2000), benefits of emission reduction would be comparable to costs, and the National Commission on Energy Policy 2004 estimates that its recommended policy initiatives would be, on the whole, revenue-neutral with respect to the federal budget. Other participants in energy policymaking, however, are convinced that truly significant carbon emission reductions would have substantial economic impacts (GAO, 2004).

Globally, IPCC, 2001 projected that total CO_2 emissions from energy supply and conversion could be reduced in 2020 by 350 to 700 Mt C equivalents per year, based on options that could be adopted through the use of generally accepted policies, generally at a positive direct cost of less than U.S.$100 per t C equivalents. Based on DOE/EIA analyses in 2000, this study includes estimates of the cost of a range of specific emission-reducing technologies for power

* Adapted in part from *CCSP SAP 2.2, State of the Carbon Cycle Report*, Chapter 6, "Energy Conversion."

generation, compared with coal-fired power, although the degree of uncertainty is not clear. Within the United States, the report estimated that the cost of emission reduction per metric ton of carbon emissions reduced would range from –$170 to +$880, depending on the technology used. Marginal abatement costs for the total United States economy, in 1990 U.S. dollars per metric ton carbon, were estimated by a variety of models compared by the Energy Modeling Forum at $76 to $410 with no emission trading, $14 to $224 with Annex I trading, and $5 to $123 with global trading.

Similarly, the National Commission on Energy Policy 2004 considered costs associated with a tradable emission permit system that would reduce United States national greenhouse gas emission growth from 44% to 33% from 2002 to 2025, a reduction of 760 Mt CO_2 (207 Mt C) in 2025 compared with a reference case. The cost would be a roughly 5% increase in total end-use expenditures compared with the reference case. Electricity prices would rise by 5.4% for residential users, 6.2% for commercial users, and 7.6% for industrial users.

The IWG 2000 estimated that a domestic carbon trading system with a $25/t C permit price would reduce emissions by 13% compared with a reference case, or 230 Mt CO_2 (63 Mt C), while a $50 price would reduce emissions by 17 to 19%, or 306 to 332 Mt CO_2 (83-91 Mt C). Both cases assume a doubling of United States government appropriations for cost-shared clean energy research, design, and development.

Net costs to the consumer, however, are balanced in some analyses by benefits from advanced technologies that are developed and deployed on an accelerated schedule due to policy interventions and changing public preferences. The U.S. Climate Change Technology Program, 2005: pp. 3–19, illustrates how costs of achieving different stabilization levels can conceivably be reduced substantially by the use of advanced technologies, and IWG (2000) estimates that net end-user costs of energy can actually be reduced by a domestic carbon trading system if it accelerates the market penetration of more energy-efficient technologies (see Section 4.2.2 above).

4.4.3 Effects Of Climate Change On Environmental Emissions

Climate change is very likely to lead to reductions in environmental emissions from energy production and use in the U.S., although possible effects of climate change responses are complex. For instance, cap and trade policy responses might not translate directly into lower total emissions. In general, however, the available research literature indicates that climate change policy will affect choices of energy resources and technologies in ways that, overall, reduce greenhouse gas and other environmental emissions (see indirect impacts on technologies above).

4.4.4 Effects Of Climate Change On Energy Security

Climate change relates to energy security because different drivers of energy policy interact. As one example, some strategies to reduce oil import dependence, such as increased use of renewable energy sources in the U.S., are similar to strategies to reduce GHG emissions as a climate change response (e.g., IEA, 2004; O'Keefe, 2005). Other strategies such as increased domestic fossil fuel production and use could be contradictory to climate change policies. The complexity of connections between climate change responses and energy security concerns can be illustrated by choices between uses of biomass to reduce fossil fuel use in electricity generation, a priority for net greenhouse gas emissions, and uses of biomass to displace oil and gas imports, a priority for energy security policy. Although the relative effects of the two options are not entirely unrelated (i.e., both could have some effect in reducing oil and gas imports and both could have some effect in reducing net greenhouse gas emissions), the balance in contributions to these two policy priorities would be different.

As another example, energy security relates not only to import dependence but also to energy system reliability, which can be threatened by possible increases in the intensity of severe weather events. A different kind of issue is potential impacts of abrupt climate change in the longer run. One study has suggested that abrupt climate change could lead to very serious international security threats, including threats of global energy crises, as countries act to defend and secure supplies of essential commodities (Schwarz and Randall, 2004). Clearly, then, relationships between climate change response and energy security are complex, but they are potentially important enough to deserve further study.

4.4.5 Effects Of Climate Change On Energy Technology And Service Exports

Finally, climate change could affect U.S. energy technology and service exports. It is very likely that climate change will have some impacts on global energy technology, institutional, and policy choices. Effects of these changes on U.S. exports would probably be determined by whether the U.S. is a leader or a follower in energy technology and policy responses to concerns about climate change. More broadly, carbon emission abatement actions by various countries are likely to affect international energy flows and trade flows in energy technology and services (e.g., Rutherford, 2001). In particular, one might expect flows of carbon-intensive energy forms and energy technologies and energy-intensive products to be affected.

4.5 SUMMARY OF KNOWLEDGE ABOUT INDIRECT EFFECTS

Regarding indirect effects of climate change on energy production and use in the United States, the available research literature tells us the most about possible changes in energy resource/technology preferences and investments, along with associated reductions in GHG emissions and effects on energy prices. Less-studied but also potentially important are possible impacts on the institutional structure of energy supply in the United States, responding to changes in perceived investment risks and emerging market and policy realities, and possible interactions between energy prices and roles of energy markets in managing risks and reducing vulnerabilities. Perhaps the most important insight from the limited current research literature is that climate change will affect energy production and use not only as a driving force in its own right but in its interactions with other driving forces such as energy security. Where climate change response strategies correspond with other issue response strategies, they can add force to actions such as increased reliance on domestic noncarbon energy supply sources. Where climate change impacts contradict other driving forces for energy decisions, it is much less clear what their net effect would be on energy production and use.