Energy System Impacts of Climate Change: An Overview

for
EPA/DOE Workshop on Improving the Assessment and Valuation of Climate Change Impacts for Policy and Regulatory Analysis
Research on Climate Change Impacts and Associated Economic Damages
Washington DC
January 27-28, 2011

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Assessment and valuation of the impacts of climate change on energy systems, including both effects on energy demand and effects on energy supply systems, have received considerable attention over the past 25 years. While the literature encompasses a wide range of results, recent assessments, including high-profile reports such as the Stern Review and the IPCC 4th Assessment Report that have identified a high likelihood of significant adverse impacts in other areas, have generally found modest impacts, both positive and negative, on energy systems. There is nothing in the more recent literature that suggests any major change in that assessment. Below, we review impacts on energy use for space heating and cooling which have been considered in most analyses of energy demand impacts, as well as other potential effects on energy demand. We also consider effects on energy supply systems, both new and existing. We conclude with summary observations about the analysis of energy impacts to date and identify factors that may be important in extending the literature.

Impacts on Space Conditioning Energy Demand: The most direct way in which climate change potentially affects energy demand is through its effect on energy use for heating and cooling. Some early studies of impacts on energy demand in the United States focused exclusively on the demand for electricity for cooling in the summertime. Subsequently, several papers noted that from the space conditioning perspective, the United States is a cold country, with expenditures on winter heating fuel several times higher than expenditures on electricity for cooling, and that some degree of warming would likely decrease overall demand and expenditures for space conditioning energy. The traditional grouping of "industrialized countries" -- the OECD countries plus Russia and Eastern Europe have an even larger gap between their baseline energy use and expenditures for heating and cooling, so initial warming is likely to provide savings in energy use and expenditures for space conditioning in

[1] The views expressed in this note, which draw on the author's past involvement with the literature on neregy impacts of climate change, go beyond topics that fall within the purview of the Energy Information Administration, where he now serves as Deputy Administrator. They should not be construed as reflecting the views of that agency.

those regions as well. The developing countries, which include both tropical and non-tropical areas, present something of a mixed bag, in part because the use of cooling equipment is highly sensitive to economic development as well as local climate conditions.

Any analysis of the impact of climate change on space conditioning energy use is likely to be highly sensitive to both the magnitude of climate change considered, and its detailed composition. The latitudinal, diurnal, and seasonal gradient of warming and changes in relative humidity all play a crucial role in determining whether warming reduces or increases energy use and/or expenditures for space conditioning at any particular location, or cumulatively across any set of locations. In part, the spread of results across studies on space conditioning impacts reflects different approaches to specifying the global warming scenarios that are considered.

Energy expenditure changes and measures of individual or aggregate comfort in buildings, a welfare indicator, may diverge considerably. On the one hand, the change in capital and energy expenditures for space cooling in a higher temperature and humidity scenario is likely to overstate the cost of maintaining a constant indoor summertime comfort level for those who acquire new space conditioning equipment in the face of climate change. Space cooling, unlike space heating, is subject to very significant threshold effects, even in relatively rich countries. [2] Once installed, cooling equipment is likely to be used to provide improved comfort relative to that which householders might have accepted under baseline conditions before the threshold was crossed. However, energy expenditure changes do not reflect the value of incremental indoor discomfort for those who do not cross the cooling equipment threshold. In addition, incremental summertime outdoor discomfort for the wider public, are not reflected at all in changes in space conditioning costs.

Energy implications of changes in space conditioning energy demand, which are of great interest to energy planners without regard to their value as welfare indicators, must be assessed in the context of technology changes over relevant time horizons. Assessments of energy impacts of climate change that are made without consideration of changes in energy technologies and practices can badly miss their mark. For example, the efficiency of new air conditioning units has nearly doubled since 1990, when the first studies claiming large impacts on summer peak energy load due to warming were published. More recently, the prospect of the smart grid and attendant opportunities to manage load in real time are likely to greatly ameliorate the implications of higher peak space conditioning loads for the electricity supply infrastructure, since other loads can now be more readily incentivized to “make room” for cooling loads.

[2] For example, many homes along the California coast, and in Europe, both relatively wealthy regions of the world, do not have air conditioners. It is possible that climate change could result in the crossing of a comfort threshold that leads households to install such equipment.

__Other Energy Demand Impacts__: **While space conditioning impacts have been the focus of research on energy demand impacts, some other areas, including the energy-water nexus, merit additional attention.** Significant amounts of energy are used to supply water for household, agricultural, and industrial purposes, and also to move and treat wastewater from all categories of water use. The potential impact of climate change on water supply has been considered elsewhere in this workshop. To the extent that climate change has adverse impacts on water supply, the need to provide replacement water may have significant energy implications. Many types of replacement supplies, such as desalinization plants, long-distance pumping solutions, and cleaning of wastewater to a standard that allows for reuse, can use significantly higher amounts of energy than is required to supply water under baseline conditions. The issue can be important in both developed and developing country contexts.

__Energy Supply Systems: Access to Traditional Energy Resources.__ It is well known that climate change can have significant impacts on access to traditional energy resources. For example, hydroelectricity, by far the most significant source of renewable electricity in both the United States and the world today, is quite sensitive to patterns of precipitation and snowpack accumulation, which are in turn likely to be affected by climate change. The pattern of impacts is likely to vary across locations, and also to be dependent on both the passage of time and the extent of climate change. A traditional energy resource where the initial impact on supply is likely to be positive is the Arctic oil resource, as access would be significantly improved by a reduction in Arctic ice cover. However, not all northern latitude resources will necessarily benefit from climate change, as any change in permafrost conditions and the length of that annual hard freeze period could limit the ability to build and maintain energy infrastructures needed to access certain energy resources, both onshore and offshore, at high latitudes.

__Energy Supply Systems: Impacts on Existing Energy Supply Infrastructure__. Another category of energy supply impacts that has been extensively examined involves existing energy supply infrastructures that may be affected by changes in temperature or precipitation patterns. In addition to hydroelectric dams that are directly dependent on water flows, nearly all existing generating facilities require access to cooling water. As discussed above, climate change impacts are likely to include changes in precipitation, snowpack and evaporation patterns that will affect water availability and temperature in and around existing power plants. A change in cooling water availability and temperature can affect power plant operation. Changes in ambient air temperature can also affect the effective maximum capacity of existing units. However, it is questionable whether or not any of these impacts are quantitatively important in the overall context of climate change impacts after consideration of actions to mitigate and/or adapt to them.

<u>Energy Supply Systems: Impacts on Non-Traditional Energy Sources</u>. Given that energy-related emissions from the combustion of fossil fuels account for at least three-fifths of anthropogenic greenhouse gas emissions globally, and more than four-fifths of U.S. emissions, strategies to mitigate emissions often focus on the replacement of fossil fuels with emissions-free energy sources. Expanded use of wind, solar, and biomass energy for electricity generation, and the use of biofuels in the transportation sector, are often cited as potential alternatives to fossil fuels. Given this, it is important to consider the possible impacts of climate change on these technologies.

With respect to solar, both photovoltaic (PV) and solar thermal technologies are sensitive to changes in cloud cover. Pan et al. (2004) modeled changes in global solar radiation reaching the surface through the 2040s based on the Hadley Center Circulation model and projected a solar resource reduced by as much as 20 percent seasonally in key U.S. regions for solar energy, presumably from increased cloud cover. The energy assessment published by the U.S. Climate Change Science Program in February 2008 notes that aerosols can also play a role in cloud cover, and that interactions between aerosols and greenhouse gases are complex.

Biomass already rivals hydropower as a renewable energy source in the United States, and mandates for renewable fuel use in transportation first enacted in 2005 and then significantly strengthened in the Energy Independence and Security Act of 2007 call for biofuels to significantly grow in both absolute terms and as a share of the total liquid fuels used in transportation. Biomass also has growth potential in the electric power sector, where it can be co-fired with coal in existing power plants. Much attention in the recent literature and the regulatory sphere has focused on the carbon cycle impacts of increased biomass energy use, which depends on the sustainability of biomass cultivation and proper accounting practices. The impacts of climate change on the economics of biomass energy are closely related to the effects of climate change on agriculture, which are addressed in another part of this workshop.

Finally, with respect to wind, there is little information regarding the effects of climate change. The siting of wind farms and the cost of wind generation are both very sensitive to the specific location of the wind resource. One question that arises, in addition to the impact of climate change on overall available wind resource, is if climate change will cause shifts in wind patterns within the 20- to 30-year lifetime of wind projects.

<u>Concluding Observations:</u>

1. Energy is a sector that is likely to be impacted by climate change. As climate changes considered grow ever larger, common sense suggests that negative impacts on energy use and supply will dominate, but for small to modest climate change it is quite possible that net energy ”damages” will be negative.

2. For energy, as in some other sectors where impacts must be assessed, the devil is really in the details, such as, but not limited to, the assumed latitudinal, seasonal, and diurnal gradient of climate change, and its effects on humidity, cloud cover, and wind patterns as well as its effect on temperature. Studies that make different assumptions in these areas can reach wildly different conclusions even if they are both carefully executed.
3. Future impacts of climate change on energy systems will occur in the context of future opportunities for adaptation and responses. While it is hard to predict the future, it is important to consider the implications of the past track record of technology improvements and the impact of technologies now being deployed in assessing the cost of adaptation and response strategies.
4. It is useful to distinguish between energy system impacts, which are of greatest importance to energy planners, and energy-system-related welfare impacts, which are of primary importance to cost-benefit analysis of policies to address climate change.
5. Both analysts and research funders can advance the utility and credibility of research on energy system impacts of climate change through a commitment to carefully scope and prioritize research needs in the area.