Electricity

SUBSECTORS

Electricity Demand

Electricity is an essential element of modern life. It lights and cools our homes, powers our computers, supports the production of goods and services, and enables critical infrastructure services such as water treatment and telecommunications. The generation of electricity in the U.S., most of which comes from fossil fuels, also contributes to climate change, accounting for approximately 30% of U.S. greenhouse gas emissions.[1]

HOW IS THE ELECTRICITY SECTOR VULNERABLE TO CLIMATE CHANGE?

Climate change has implications for electricity production, distribution, and use.[2] For example, coastal electricity infrastructure, such as power plants and substations, are vulnerable to storm surge and wind damage. Elevated temperatures diminish thermal power plant efficiency and capacity, and can reduce the capacity of transmission lines. In addition, effects on water supply alter the quantity and temperature of cooling water available for thermoelectric generation.[3] On the demand side, warmer winters decrease the demand for heating. However, this reduction is smaller than the increase in electricity demand for cooling due to higher summer temperatures. Across the U.S., higher minimum temperatures increase the number of days in a year when air conditioning is needed, and higher maximum temperatures increase the peak electricity demand, further stressing our aging power grid.

WHAT DOES CIRA COVER?

Numerous studies highlight the potential for emission reductions in the electricity sector, yet fewer studies have explored the physical, operational, and economic impacts of a changing climate on this sector. CIRA assesses the impacts of rising temperatures on electricity demand, system costs, and the generation mix needed to meet increasing demand across the contiguous U.S. through 2050.[4] Importantly, impacts to the demand and supply of other energy sources (e.g., fuel for transportation) are not estimated. Also, the electricity supply analysis does not include the effects of climate change on hydropower and water availability for thermoelectric power generation. Additional work is necessary to further evaluate climate change impacts on electricity supply, particularly the effects of extreme heat events and storm damage on capacity and reliability. Finally, future work to improve connectivity between the CIRA electricity, water, and agriculture analyses will aid in better understanding potential cross-sector impacts.

Electricity Supply

KEY FINDINGS

1. Without global GHG mitigation, rising temperatures will likely result in higher electricity demand across the country, as the increased need for air conditioning outweighs decreases in electric heating requirements. The estimated percent increase in electricity demand for air conditioning is highest in the Northeast and Northwest regions.

2. Global GHG mitigation, which lessens the rise in temperature, is projected to lead to lower electricity demand across all regions of the country relative to the Reference scenario.

Climate Change and Electricity Demand

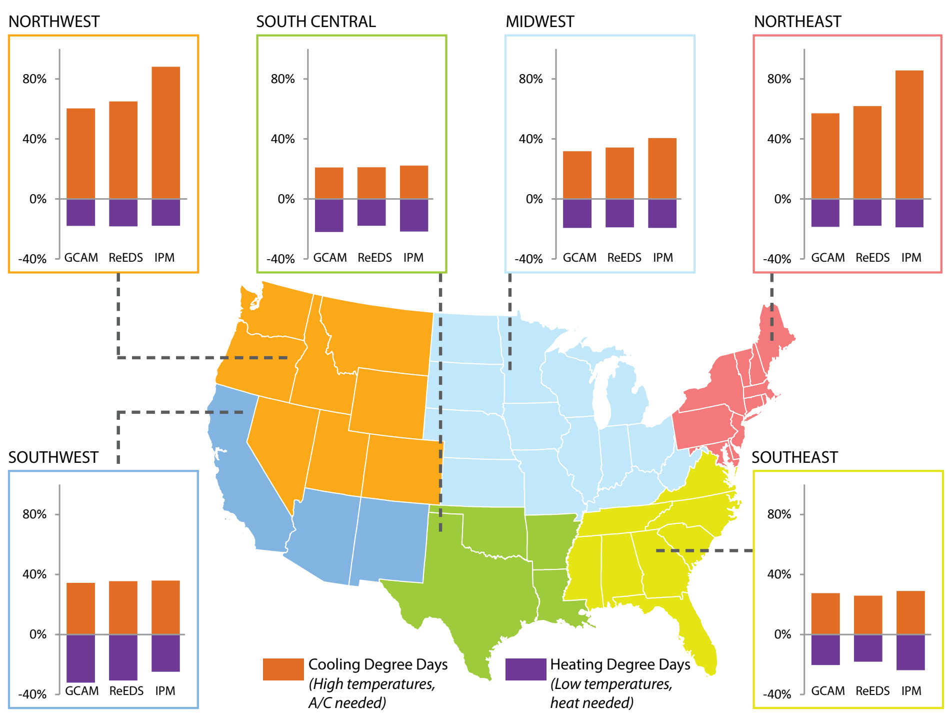
As air temperatures rise due to climate change, electricity demands for cooling are expected to increase in every U.S. region.[5] Higher summer temperatures, particularly during heat waves, will likely increase peak electricity demand, placing more stress on the electricity grid and increasing electricity costs. Although the majority of U.S. residential and commercial cooling demand is met with electricity, less than 9% of heating demand is met with electricity.[6, 7] Therefore, although higher average temperatures are expected to reduce electricity demands for heating, net electricity use is projected to increase under climate change. This section presents estimated impacts on electricity demand, but does not consider impacts on demand for other fuel sources used in residential cooling or heating.

Risks of Inaction

Rising temperatures are projected to increase electricity demands for cooling. Figure 1 shows the percent change in regional heating and cooling degree days (HDDs/CDDs, see Approach for definitions) from 2005 to 2050 in the Reference scenario. Results are presented for the three models used in the analysis (GCAM, ReEDS, and IPM), which exhibit similar trends of falling HDDs (shown in purple) and rising CDDs (shown in orange). These trends are consistent with projections described in the assessment literature.[8] Across the U.S., HDDs decrease between 18%-29% on average, with greater decreases occurring in the South due in part to already-high temperatures. The increase in CDDs is highest in the Northeast and Northwest (68% and 71% on average, respectively). The projected changes in HDDs and CDDs have implications for regional electricity demand. Average U.S. electricity demand is projected to increase under the Reference by 1.5%-6.5% by 2050, compared to a Control with no temperature change. Across the regions and models shown in Figure 2, electricity demand is projected to increase by 0.5%-9.0%, with the exception of the ReEDS model in the Northwest, which projects a decrease of 0.5%.[9]

Figure 1. Projected Impact of Unmitigated Climate Change on Regional Heating and Cooling Degree Days from 2005 to 2050

Percent change in HDDs and CDDs from 2005 to 2050 under the Reference compared to a Control with no temperature change. Results are presented for six regions and for the three models used in the analysis.

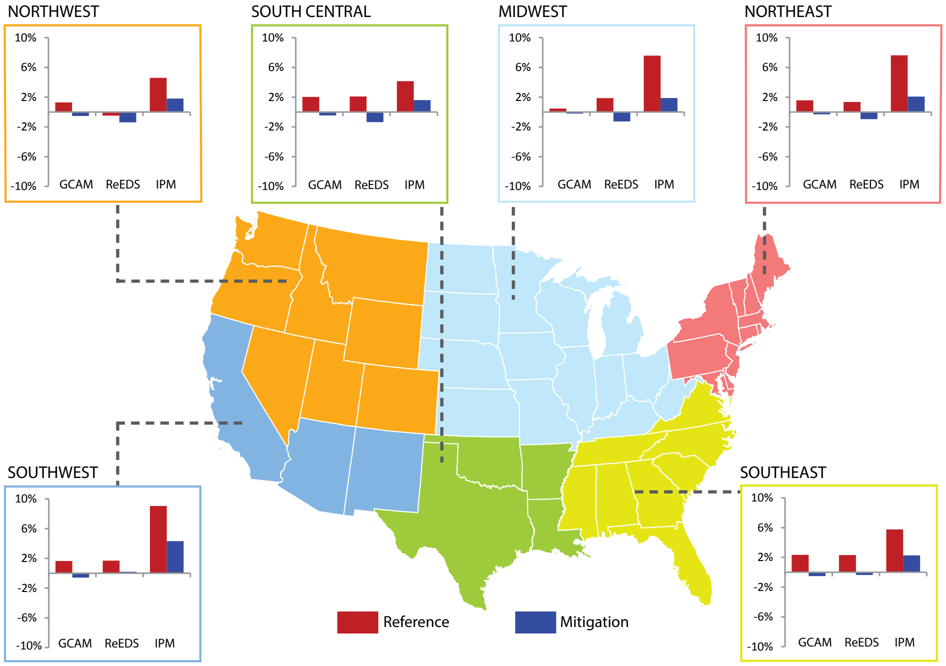


Reducing Impacts through GHG Mitigation

Global GHG emissions reductions under the Mitigation scenario result in smaller increases in temperatures compared to the Reference, thereby reducing cooling demand across the country. Figure 2 illustrates this effect, presenting the change in regional energy demand in 2050 in the Reference and Mitigation scenarios relative to a Control with no temperature change. As shown, the change in demand in the Mitigation scenario is consistently lower than in the Reference across all of the models. This decrease in demand is due in large part to lower temperatures under the Mitigation scenario compared to the Reference, and in the GCAM and ReEDS models the lower demand is also due to an increase in electricity costs associated with reducing GHG emissions. The impact of GHG mitigation on electricity supply is discussed in greater detail in the Electricity Supply section of this report.

Figure 2. Change in Regional Electricity Demand in 2050 with and without Global GHG Mitigation

Change in regional electricity demand for the Reference and Mitigation scenarios relative to a Control (no temperature change). Results are presented for six regions and for each of the three models used in the analysis (GCAM, ReEDS, and IPM).



APPROACH

The CIRA analysis examines how rising temperatures under climate change will affect electricity demand. It applies a common set of temperature projections from IGSM-CAM to three models of the U.S. electric power sector:

- Global Change Assessment Model (GCAM-USA): a detailed, service-based building energy model for the 50 U.S. states;[10, 11]
- Regional Electricity Deployment System Model (ReEDS): a technology-rich model of the deployment of electric power generation technologies and transmission infrastructure for the contiguous U.S.;[12] and
- Integrated Planning Model (IPM®): a dispatch and capacity planning model used by the public and private sectors to inform business and policy decisions.[13]

The models project changes in electricity demand as functions of changes in heating and cooling degree-days (HDDs/CDDs). HDDs and CDDs are one way to measure the influence of temperature change on energy demand. They measure the difference between outdoor temperatures and a temperature that people generally find comfortable indoors. These measurements suggest how much energy people might need to use to heat and cool their homes and workplaces. The analysis compares the results across the CIRA scenarios, while also accounting for non-climate changes in electricity demand (e.g., population and economic growth). To assess the effect of rising temperatures in the Reference and Mitigation scenarios, changes in heating and cooling degree days and electricity demand are compared to a Control that assumes temperatures do not change over time.

For more information on the CIRA approach and results for the electricity demand sector, please refer to McFarland et al. (2015).[14]

Electricity Supply

KEY FINDINGS

1. Projected electricity supply is higher in all three electric power sector models under the Reference scenario, reflecting a higher demand for cooling, and lower under the Mitigation scenario as a result of lower temperatures and the demand response to GHG mitigation.

2. The relative magnitude of costs to the electric power system are similar under the Reference and Mitigation scenarios, highlighting that the costs associated with rising temperatures in the Reference are comparable to the costs associated with reducing GHG emissions in the Mitigation scenario. Specifically, the higher demands under the Reference scenario increase system costs by 1.7%-8.3% above the Control. Under the Mitigation scenario, system costs increase by 2.3%-10% above the Control, or 0.6%-5.5% above Reference scenario costs.

Climate Change and Electricity Supply

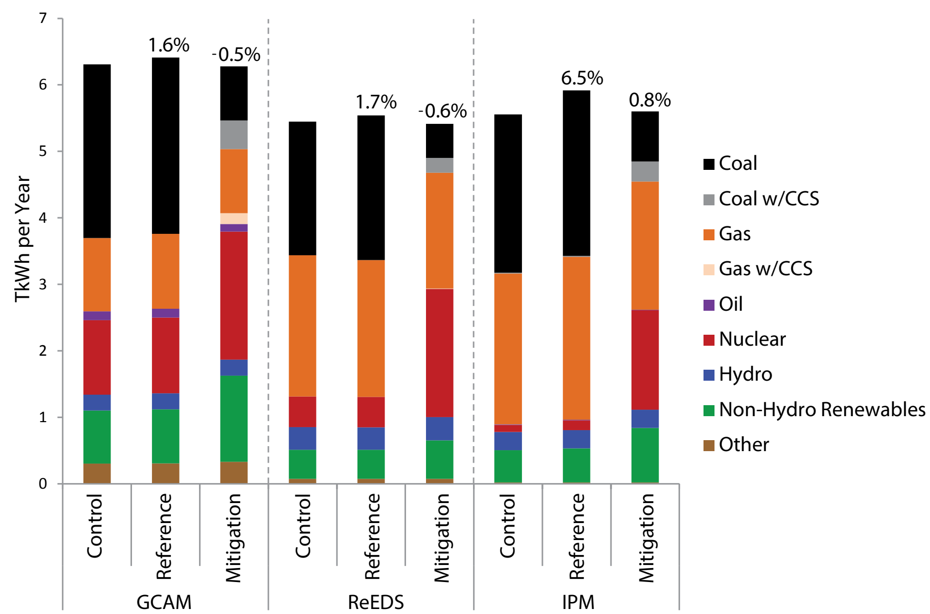
As described in the Electricity Demand section, warmer air temperatures under climate change are expected to result in higher demand for electricity, leading to the need for increased capacity in the power system to meet this demand. At the same time, higher temperatures reduce the capacity of both thermal power plants and transmission lines.

The power sector accounts for the largest share of GHG emissions in the U.S.,[15] and is also considered the most cost-effective source of emission reductions under mitigation policies.[16] A variety of impacts and changes are therefore expected to occur in this sector, including changes in sector emissions, system costs, and generation mix (i.e., the assortment of fuels used to generate electricity).

Effects on Electricity Generation

In the CIRA analyses, a large amount of CO_2 reductions in the U.S. under the Mitigation scenario occur in the electricity sector.[17] As a result, the generation capacity and mix of energy sources used to produce electricity is projected to change over time. Figure 1 shows the projected change in generation mix in 2050 from the three electric power sector models under the CIRA scenarios. Projected electricity supply is higher in all three models under the Reference, reflecting a higher demand for cooling, and lower under the Mitigation scenario as a result of lower temperatures and the costs of reducing GHG emissions. For any given model, the supply mix in the Reference does not differ substantially from the Control, which accounts for future population and economic growth, but no temperature change. However, all three models under the Mitigation scenario project substantial reductions in coal generation and expanded generation from nuclear and renewables.

Figure 1. Electricity Generation by Technology and Scenario in 2050 with Percent Change in Generation from Control[18]

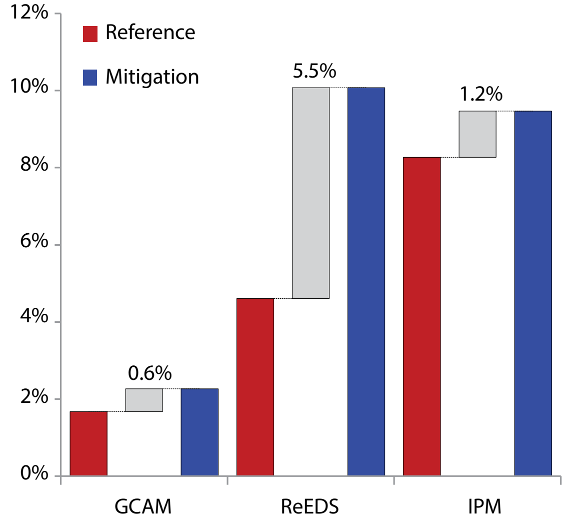


Change in System Costs

Rising temperatures under both scenarios, especially under the Reference, result in higher demands for electricity and increased power system costs to expand capacity. At the same time, altering the generation mix to reduce GHG emissions imposes costs on the power system. Figure 2 presents the percent change in cumulative system costs under the Reference and Mitigation scenarios compared to a Control with no temperature change (2015-2050, discounted at 3%). The costs increase by 1.7%-8.3% under the Reference and by 2.3%-10% under the Mitigation scenario. The incremental system costs of the Mitigation scenario above the Reference are 0.6%-5.5%, highlighting that the costs to the electric power sector associated with rising temperatures in the Reference are comparable to the costs associated with reducing GHG emissions in the Mitigation scenario. It is important to note, however, that this does not account for benefits of GHG mitigation outside of the electricity sector, nor does it examine other effects of climate change on electricity supply, such as changes in cooling water availability or extreme weather events.

Figure 2. Percent Change in Cumulative System Costs (2015-2050) in the Reference and Mitigation Scenarios Compared to the Control

Grey bars represent the difference between the Reference and Mitigation scenarios.



APPROACH

The CIRA analysis assesses impacts on the U.S. electricity sector's supply side using the same three models described in the Electricity Demand section. The models project changes in the generation mix needed to meet increasing demand due to future warming and socioeconomic changes (e.g., population and economic growth) under the CIRA scenarios. The three models also estimate the corresponding system costs—comprised of capital, operations and maintenance, and fuel costs—and the changes in CO_2 emissions over time. This analysis is unique compared to the other sectoral analyses of this report in that the costs of GHG mitigation in the electric power sector are estimated alongside the benefits. The three electric power sector models simulate these costs over time, and the rationale for presenting them here is to provide a comparison between the increase in power system costs due to mean temperature increases under the two scenarios and the costs associated with reducing GHG emissions from electric power generation. It is important to note that the effect of temperature change on generation accounts for only a small portion of the total effects of climate change on electricity supply. Other important effects, such as changes in hydropower generation or the availability of cooling water for thermoelectric combustion, are not included. Inclusion of these impacts on the electricity supply system would likely increase the benefits of mitigation to this sector.

For more information on the CIRA approach and results for the electricity supply sector, please refer to McFarland et al. (2015).[19]