CLIMATE CHANGE IMPACTS ON THE ELECTRIC POWER SYSTEM IN THE WESTERN UNITED STATES

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(1) Overview

Results from general circulation models show a wide variation in projected climatic changes across the United States. Future changes in regional temperature and precipitation patterns may have significant implications on the existing and future power system infrastructure. In this paper, we use results from regional climate models to examine the impacts of projected changes in temperature and precipitation on the development and operations of the power system in the Western United States. We study three scenarios to evaluate potential effects of climate change on the electricity demand, hydropower generation levels, and power supply side capacity expansion. Impacts are measured in terms of changes in investment and operational costs, fuel and generation mix, emissions of greenhouse gases (GHGs), and thermal power water consumption. We conclude with some observations regarding the vulnerability of our electricity supply system to projected regional climate changes.

(2) Methods

Weather and climate affect all major aspects of the electric power sector, including electricity generation, transmission and distribution systems, and end-user demand for power. For example, power plants may become less efficient, transmission losses may increase, and the growth in demand for electricity may be accelerated; all resulting in increased strains on the system. We address these issues in a full system-level modeling framework that spans the spectrum from demand forecasting, investment and expansion modeling, simulation of renewables and non-dispatchable resources, and unit-level probabilistic dispatch analysis.

We start with results from the U.S. Climate Change Science Program Synthesis and Assessment from October 2007 that we use to translate projected temperature increases into accelerated electricity demand growth. This higher demand leads to additional generation capacity requirements that are determined using a long-term investment algorithm that takes into account interdependencies between hydroelectric, thermal power, and non-dispatchable resources, such as wind turbines. Our modeling framework also includes temporal aspects associated with hydropower energy constraints, wind variability, thermal power plant availability, and hourly load profiles. Thermal power plant availability and resulting generation and fuel consumption are based on maintenance outage schedules and a probabilistic dispatch algorithm that accounts for random forced outages. The dispatch model provides us with information on annual fuel consumptions, operational costs, GHG emissions, and thermal power water consumption levels.

(3) Results

A warmer climate is projected to lead to an increase in the demand for electricity by more than 9 percent by 2050, or 29 GW higher than under the reference scenario. Approximately 34 GW of additional generating capacity will need to be constructed to reliably meet the increased peak load. Much of this additional capacity will be coal-fired, while natural gas-fired technologies make up the second largest block. Generation technologies that rely on renewable energy sources such as wind and solar will also be used to meet the increased demand for electricity. In terms of net present value (NPV), the capital investment cost to build the additional capacity above the base case is projected to be about $8.9 billion in 2005 dollars. The NPV for additional fuel and variable operating and maintenance (O&M) cost over the analysis period (2005-2050) is about $36 billion or about 4.9% higher than the base case.

Two additional climate change scenarios were analyzed focusing on the effects of changes in precipitation patterns and water availability for hydropower generation. Our first hydrological scenario assumes both warmer temperatures and lower hydrological conditions resulting in a 10% decrease in hydropower production relative to the base case. The second hydrological scenario assumes a 6% increase in hydropower productions. Hydropower assumptions are based on a study conducted by the California Department of Water Resources in 2006. A warmer climate in combination with drier conditions is projected to increase the NPV of fuel purchases and variable O&M costs above the base case by about $61 billion through 2050. This is mainly attributed to higher utilization rate of relatively expensive peaking technologies such as natural gas-fired gas turbines. However, if the climate becomes wetter than the current climate, but still warmer, production cost increases are expected to be smaller; that is, approximately $25 billion above the base case. In addition to costs, under climate change scenarios both fresh water consumption by thermal power plants and CO2 emissions are expected to be up to 13% higher than under the base case.

(4) Conclusions

The study and its findings should be viewed as a preliminary investigation of the problem. Although we incorporated many technical aspects at a detailed level of granularity, such as the inclusion of roughly two thousand individual generating units and the compilation of control area data to estimate hourly loads, we realize the limitations of our modeling process and continue to make refinements to our analysis. For example, we are currently in the process of adding additional details to the analysis by including a detailed treatment of the transmission system. This will allow for a more accurate estimate of the effects of climate on the operations of the generation and transmission system. We are also working on reflecting various carbon policies in our analysis. In addition, as the demand for electricity swells and consumption of fossil fuels for power generation increases, the upward pressure on fossil fuel prices, and particularly natural gas, will be of interest. This aspect is not included in the current analysis. Another, possibly minor, aspect of the analysis that is currently not included is the feedback of higher CO2 emissions under the climate change scenarios on the climate itself. Similarly, under a drier climate, thermal water consumption is projected to increase potentially exacerbating the limited water situation. These dynamics underline the importance of looking at the climate change problem from many different angles by incorporating people's reactions to climate change into the analysis. These reactions may either help mitigate the problem or exacerbate climate change.

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