EPRI ELECTRIC POWER RESEARCH INSTITUTE

Energy and Environment

Climate Change Vulnerabilities of and Adaptation Strategies for New York State's Future Electric System

Project Overview

Summary

The Electric Power Research Institute (EPRI) is leading a two-year project to assess the vulnerability of New York State's electric system to a changing climate and analyze the role of various system-level adaptation strategies, taking into account the transition to a decarbonized electric grid and other socioeconomic drivers. This assessment will use a new NY-focused version of EPRI's U.S. Regional Economy, Greenhouse Gas, and Energy model (US-REGEN), a detailed electric sector optimization model, to model the performance of the electricity system under different climate conditions through 2050. Specifically, we will evaluate future climate impacts as characterized in the NY ClimAID assessment on the NYS electric system through the following climate impact pathways: 1) increased air temperature on thermal generation; 2) increased water temperature on thermal generation; 3) changes in water availability on thermal generation; 4) changes in water availability on hydro generation; 5) increased air temperature on transmission efficiency; and 6) increased air temperature on electricity demand. The project results will help policymakers and electricity planners assess system performance, vulnerabilities, and generation fleet adaptation strategies under a future climate, and, by informing the efficient deployment of large capital investments, help design an electricity system for NYS that is resilient to climate change, meets policy objectives, and keeps electricity rates down.

Technical Approach

The proposal consists of eight tasks. Task 1 is a workshop with appropriate NYS stakeholders to collect input on project design. Tasks 2 and 3 will translate ClimAID climate projections into impact drivers for the electric system (e.g., temperature levels and distributions and water flow patterns). These drivers will be incorporated into hydrological and water temperature models of select waterbodies in NYS. Tasks 4-6 will use US-REGEN, an intertemporal electric sector model that represents generators and intra-annual time segments with sufficient resolution to capture dispatch, power flow between regions, and the co-variation between intermittent renewable resources and electricity demand. Task 4 will conduct model development for US-REGEN and prepare new data to represent the NYS electric system in higher resolution with several sub-regions, and incorporate information on hydrology and water use by power plants as well as operational constraints or penalties on generation technologies and changes in demand.[1] Task 5 will apply the enhanced model to evaluate a reference scenario that is consistent with NYS technology and policy assumptions. In Task 6, this scenario will first be assessed for vulnerability, such as capacity shortfalls, when the potential climate impacts are applied *ex-post*. This assessment will be compared to model runs in which potential climate impacts are *anticipated* to reflect the least-cost approach to manage vulnerabilities (e.g., through a different generation mix or capacity additions), resulting in an adaptation scenario. Task 7 will evaluate the environmental justice implications of the US-REGEN results, including impacts on vulnerable populations. Task 8 includes a final workshop with the stakeholder group, reports, and other communications.

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[1] US-REGEN Model Documentation and other publications and resources are available at http://eea.epri.com/usregen.

Task 1: Convene Stakeholder Workshop and Utility Advisory Group

The purpose of the workshop is to bring key stakeholders together to raise awareness of the project, to ensure research is designed to produce results that are useful to policy and decision makers, and to facilitate communications and a common understanding between NY utility members, NYSERDA and other NY officials, and stakeholders of electric system climate vulnerabilities and adaptation strategies. As part of this stakeholder engagement, we will convene a Utility Advisory Group to discuss analysis and provide feedback for the duration of the project.

Task 2: Compile NY Climate Data

2.1: Gather Historical Climate Data and Identify Correlations

This task will compile data records (1970-2000) for temperature, precipitation, relative humidity, and wind speed from geographically distinct NWS meteorological stations and estimate incoming solar radiation by adjusting clear-sky radiation (latitude and day of year) by cloud cover. Stream discharge will be assessed from USGS stream gauges located near weather stations. Temporal correlations will be identified in order to capture the interaction of these variables, which is not presumed to be random in time (e.g., solar radiation peaks in June, water temperature in water bodies with extensive thermal mass likely peaks in early fall, and the lowest flows in rivers and streams usually occur in late August). Thus, it is important to maintain this temporal correlation among the different climate variables within US-REGEN.

2.2. Compile Climate Data and Climate Model Projections

This task will estimate changes in air temperature and precipitation based on the projected time series of daily temperature and precipitation developed as part of ClimAID (www.nyserda.ny.gov/climaid) and available from NASA GISS for two different Representative Concentration Pathways (RCPs). Because the projections are based on a “change factor” downscaling approach where the day-to-day variability is directly dependent on the same baseline historical period, there is little difference in temporal variability among the 70 available projections. We will evaluate only two different projection RCPs: the median change factor value and the 83 percentile value (the upper end of the central range). These downscaled air temperature and precipitation time series will feed into hydrologic models (Task 3.2) and water temperature models (Task 3.1) to estimate future water availability and water temperatures at the NY sub-region level (Task 4.1). Downscaled air temperature will be used to estimate electricity demand and changes in power plant efficiency.

Task 3: Hydrological Modeling of Future Water Temperature and Water Availability

This task will determine the relationship between air and water temperature and use hydrologic models to estimate future water availability in rivers and streams based on time series of temperature and precipitation from Task 2.

3.1. Estimate Water Temperature

Statistical regression models will be developed from concurrent historical air and water temperature records and then used to predict future water temperature from predicted future air temperature following the S-shaped logistic models. Figure 1 shows an example of an air-water temperature regression relationship for the Hudson River near Troy, NY.

3.2. Estimate Water Availability

Future water availability will be modeled for four representative inland river systems (e.g., Genesee River, Raquette River, Black River, and Schoharie Creek), which will be modeled using a bucket model in which the hydrologic system consists of flow contributions from a slow reservoir and a fast reservoir.

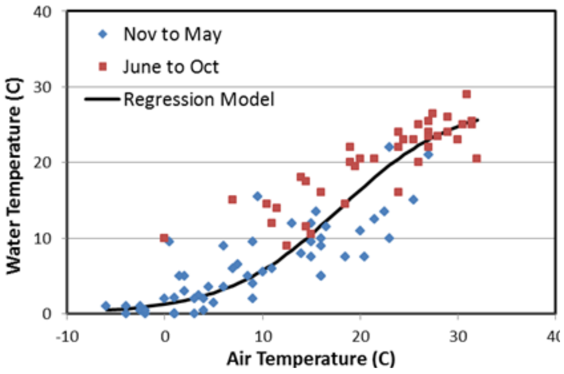

Figure 1: Air-water temperature relationship in the Hudson River

Calibration would focus on simulating low-flows and the calibration would likely be carried out on the logarithm of flow values. Simulations of future flow would be based on projected precipitation and estimates of evapotranspiration. Moses Power Station would be affected by changes in river flow. Power generation at Blenheim-Gilboa and Lewiston pumped-storage facilities will be assumed to not depend on run flow, but we will examine the observational record for limited flow availability.

Task 4: Develop New York Sub-State Data for US-REGEN Model Implementation

This task will develop new data and model structure for US-REGEN to represent the NY electric system in higher resolution, incorporate information on hydrology and water use by power plants, and reflect impacts of changing climate variables.

4.1 Break NY into Sub-regions based on NY Transmission Zones

Currently US-REGEN operates with regions defined by individual states or groupings of adjacent states. For this project, we will divide NY into several sub-regions to properly account for differences within the state along key dimensions such as electricity demand, installed generation and transmission capacity, renewable resource availability, and hydrological attributes. These sub-regions will be based on the load zones used by NYISO (Figure 2), with partial aggregation depending on zone characteristics, climate region, and computational constraints.

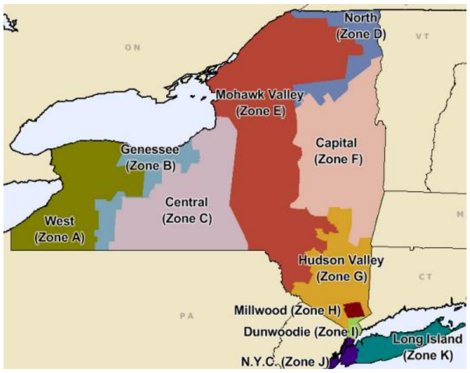

Figure 2: NY Control Area load zones (Source: FERC)

NYS electric units will be reassigned to partially aggregated capacity blocks based on hydrology. Existing thermal generating units in US-REGEN are currently aggregated in capacity blocks based on similar dispatch characteristics, primarily heat rate. For this project, the additional dimension of hydrological location will be important for determining availability impacts on dispatch. Units will be re-aggregated into capacity blocks that capture both heat rate and hydrological location (as determined in the hydrology component of the proposal), as well as any other important characteristics, such as vintage. For instance, zone E includes the Robert Moses hydroelectric facility on the St. Lawrence River as well as numerous smaller facilities on smaller streams and rivers, which could be represented by two different hydroelectric capacity blocks.

4.2 Incorporate Intra-annual Variability of Water Availability and Temperature into Representative Hours

To compute several time periods (e.g., 2015-2050) within an intertemporal, dynamic framework (e.g., power plant additions and retirements) while also adequately capturing the operational implications of intra-annual variation for electricity dispatch, US-REGEN employs a statistical approach to select roughly 100 “representative hours.” This approach is designed to ensure that co-variation between load, wind, and solar is preserved relative to the full hourly distribution (Blanford et al, 2014). Because the analysis in this project will also be concerned with future changes to water availability and temperature in accordance with the ClimAID projects (Task 2.1), the set of representative hours will be re-calculated to ensure adequate coverage in these dimensions as well.

4.3 Track Water Use (Consumption, Withdrawals) and Cooling Technology of Generation Units to Apply Future Water Constraints

Ongoing EPRI research has estimated water consumption and withdrawals at the unit level for electric generators (EPRI, 2013b). This information will be incorporated into US-REGEN, along with a specification of cooling technology employed at existing units, publicly available in Energy Information Administration (EIA) reporting. Task 3 calculates adjusted water availability as a result of changed precipitation and climate patterns in the identified climate projections, characterized in terms of the annual distribution of water availability for each sub-region of New York. In this task, we will translate projected water availability into constraints on water consumption and withdrawals by power plants in a form relevant for the US-REGEN model.

4.4 Add Efficiency Penalties on Thermal Generation and Transmission based on Air Temperature Response Functions

We will apply EPRI's annually updated State-of-the-Art Power Plant - Combustion Turbine (SOAPP-CT) model of combustion turbine and steam cycle performance to develop parametric response functions for thermal generators to climate impact drivers. Inlet air cooling technologies such as chillers or evaporative cooling may also be included in the design to augment power production. The Spencer-Cotton-Cannon method is used to determine the various properties at each stage of the steam turbine, and combined cycle heat rejection system options include once-through cooling, wet mechanical draft cooling towers, and air-cooled condensers. Design and off-design performance modeling capability facilitates parametric analysis of varying process inputs, including ambient air and cooling water temperature. The response functions will be implemented in US-REGEN.

Electricity transmission and distribution systems carry less current and operate less efficiently when ambient air temperatures are higher. This task will also implement a penalty on transmission efficiency and/or available transmission capacity reflecting this climate impact.

4.5 Develop Climate-adjusted Load Curves with Increased Cooling / Decreased Heating Demand

EPRI has developed hourly data on end-use load shapes, e.g. for air-conditioning and space-heating, that are consistent with observed temperature data and annual energy use reported in EIA building survey data. EPRI is now working on describing in more detail the evolution of end-use technologies over time and their future impact on load shapes. We will build on this existing work to develop and implement adjusted end-use load shapes in US-REGEN for air-conditioning and space-heating based on the adjusted temperature distributions derived from the ClimAID climate projections. These adjusted load shapes will allow simultaneous assessment of potential climate impacts on the supply-side and demand-side of the electric sector. In particular, the evaluation of extreme temperature events will take into account the potential for simultaneously decreased availability of generation and increased demand for cooling.

Task 5: Model Reference Scenario in Enhanced US-REGEN

The purpose of the Reference Scenario is to provide a consistent backdrop for the evaluation of potential climate impacts, vulnerability, and adaptation. EPRI will work with NYSERDA to determine the details of the Reference Scenario that reflect NYS's future electric system (e.g., agreed upon policies) through 2050 that is consistent with ongoing analyses underway in NYS. We will run the Reference Scenario in US-REGEN with the enhanced NYS features and model developments (Task 4). This model run will serve as a baseline with no climate change.

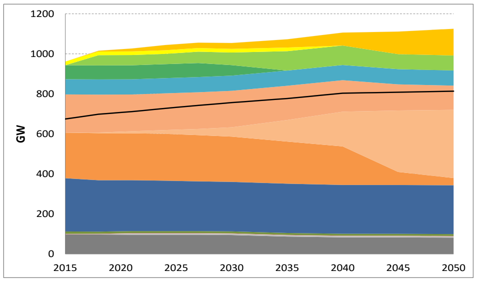

Figure 3: Illustrative US-REGEN Generation Mix

The model will be solved under these policy/technology scenarios to demonstrate a "reference" mitigation pathway for NY in which potential changes in climate are absent. Key model outputs of interest include capacity mix (e.g., new additions, retrofits and retirements), generation by technology (Figure 3), inter-regional power flows, and the price of electricity. This baseline will be a point of comparison for evaluating the potential implications of a changing climate for both the supply and demand side of electricity infrastructure and markets. This scenario will provide a snapshot of how GHG mitigation policies could change the composition of the NYS electric system under current climate conditions. Because US-REGEN models the electric sector integrated with the rest of the economy, this perspective will include the potential for electrification at the end-use and other demand-side measures to reduce GHG emissions. Additionally, US-REGEN models NYS in the context of neighboring regions, so another key output from these model runs will be the extent to which electricity trade between NY and adjacent regions might change over time.

Task 6: Model "NYS Electric System of the Future in the Climate of the Future"

Climate impacts, vulnerability, and adaptation in the NYS electric system will be evaluated using US-REGEN, focusing on the 2030 and 2050 timeframes.

6.1: Evaluate Climate Impacts on the Reference Scenario Results

This task will assess the climate impacts derived in Task 2 and 3 by applying them *ex-post* to the US-REGEN scenario results developed in Task 5 (e.g., adjusted dispatch based on efficiency and availability penalties associated with temperature and water impacts, as well as adjusted electricity demand). Capacity shortfalls and other system effects such as changes in fuel use or capacity utilization will be quantified. These results will indicate the potential magnitude of climate impacts and vulnerability in the absence of advance planning for changing climate conditions.

6.2: Evaluate Optimal Pathway Under Climate Impacts

Re-run US-REGEN, integrating the climate-related penalties, constraints, and adjustments (Task 4) to determine the least-cost electric system scenario under projected climate changes. These results will indicate the potential magnitude of climate impacts and vulnerability when changing climate conditions are anticipated and decision making is adapted accordingly. Adaptation measures could include investment in additional capacity, more advanced cooling technology, and changes in the mix of generation options. Compare these results with those from Task 6.1 and assess the differences in system costs and climate vulnerabilities of the adaptation measures employed under the optimal scenario.

Task 7: Assessment of Future Environmental Justice Implications of Project Results

This task will assess how changes to the electric system and its operation could impact environmental justice communities and vulnerable populations (e.g., the elderly). Specifically, we will evaluate how environmental justice patterns may change with changes in the electrical system assuming demographic stability. This assessment will be based on the US-REGEN results generated in Task 6 including the electricity cost profile over time, electric generation mix, addition of new capacity, and human health impacts generally associated with the fuel sources identified in the generation mix (e.g., criteria pollutants). The information identified in the assessment shall be summarized to describe how electric system changes might impact vulnerable populations in NY subregions and DEC environmental justice areas within the particular subregion.

Task 8: Dissemination of Results

Reporting and dissemination of project results to a broad group of interested stakeholders, including the electricity sector, NYS agency staff, NGOs, academia, and others.