Evolution of Electric Sector Water Use Under Alternative Electricity Futures

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Abstract

Increasing competition for water resources in the United States could create future challenges for allocating and using thermal cooling water in the U.S. electric power sector. While thermal power plant retirements and the growth of wind and solar technologies can reduce national aggregate power sector cooling water use, local water constraints and growing demand for agricultural or municipal supply could create greater needs for higher-cost alternative water supplies such as groundwater or recycled wastewater. For some regions, these incentives could change future electricity planning and operational decisions. These relationships and impacts are studied here using the National Renewable Energy Laboratory (NREL) Regional Energy Deployment System (ReEDS), a national electric sector planning model that has recently been upgraded to include a highly detailed representation of thermal cooling water demand and supply. Thermal power technologies are differentiated by both cooling technology and water source type to track and constrain thermal cooling water use in a way that incorporates both physical and legal water considerations in the United States. This capability is exercised under a range of electricity sector futures with alternative technology costs, fuel prices, and water constraints to illustrate ways that U.S. electric sector water use could evolve under uncertain future electric sector drivers. In exploring changes to regional generation and transmission planning and operation, water requirements, and cost, we highlight the environmental and economic impacts of future power sector water decisions.

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Background and Motivation

- Increasing competition for water resources in the United States could create future challenges for allocation and usage in the power sector
- Power sector demands for water consumption and withdrawal depend on the evolution of the generation mix, the water intensity of which depends on uncertain market and technology drivers
- Local water constraints could increase demand for higher-cost alternative water supplies and, in turn, influence regional electricity planning and operational decisions
- Understanding these relationships requires a highly detailed representation of water supply and cooling water demand for electricity generation in the United States

Methods

ReEDS (Regional Energy Deployment System)

- NREL's flagship electric sector capacity expansion model for North America (nrel.gov/analysis/reeds/)
- Objective minimizes cost of operations and investment
- Includes a detailed characterization of variable renewable generation technologies
- Major constraints:
  - ✓ Electricity demand
  - ✓ Operating reserves
  - ✓ Planning reserve margins
  - ✓ Federal and state policies
- High spatial resolution: 134 U.S. balancing areas and 356 wind and CSP resource regions

Cooling water formulation in ReEDS

- Recent updates increased detail to more accurately represent existing electric sector water use
- Thermal power technologies are differentiated by multiple cooling technologies and water source types
- Unit-level water usage can be tracked, allowing for an exploration of usage by technology and source
- Water demand is represented at balancing area resolution
- Formulation is exercised across a range of scenarios to illustrate how U.S. electric sector water use could evolve within the context of uncertain future drivers

Scenario Design

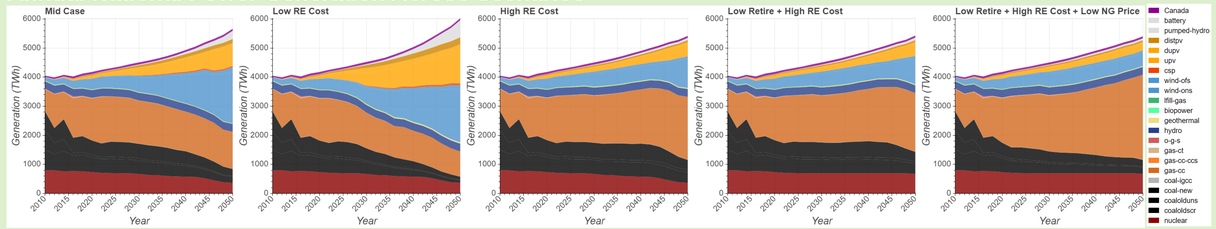
Scenario	ATB[1] RE Cost Scenario	Retirement Scenario	AEO[2] 2019 Natural Gas Price Scenario
Mid Case	Mid	Reference	Reference
Low RE Cost	Low	Reference	Reference
High RE Cost	High	Reference	Reference
Low Retire + High RE Cost	High	Longer coal and nuclear lifetimes	Reference
Low Retire + High RE Cost + Low NG Price	Low	Longer coal and nuclear lifetimes	High Oil and Gas Resource and Technology

[1]ATB = Annual Technology Baseline, annual documentation of technology and fuel costs from NREL (https://www.nrel.gov/analysis/data-tech-baseline.html).

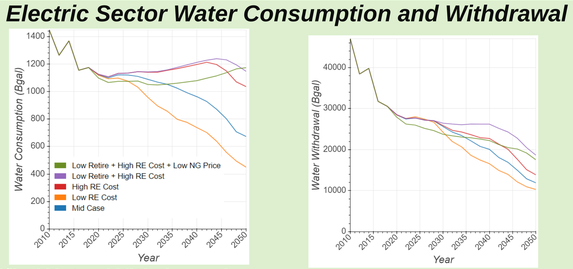
[2]AEO = Annual Energy Outlook, annual scenario analysis with projections for U.S. energy markets from the U.S. Energy Information Administration (https://www.eia.gov/outlooks/aeo/).

Results

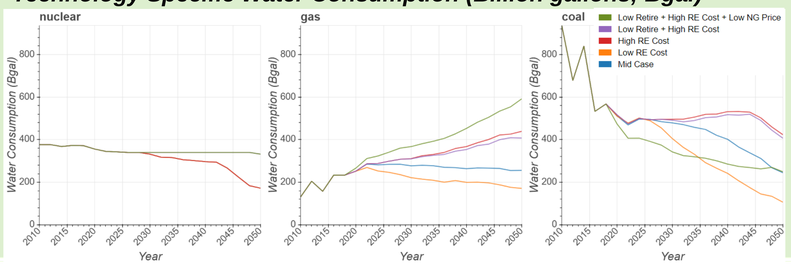
Annual National Power Generation Across Scenarios



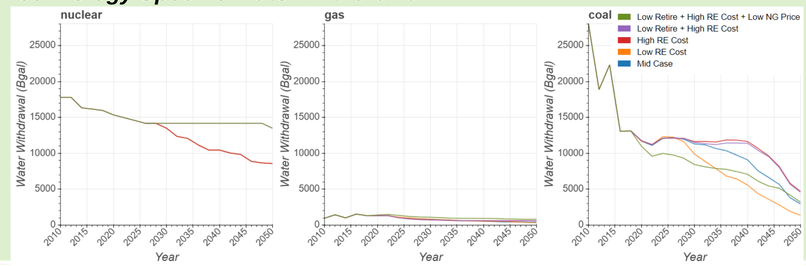
Electric Sector Water Consumption and Withdrawal



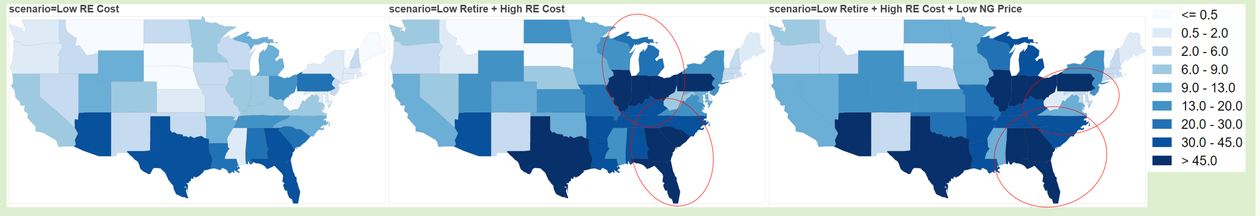
Technology Specific Water Consumption (Billion gallons; Bgal)



Technology Specific Water Withdrawal



Electric Sector Water Consumption (Bgal) by State in 2050 Across Select Scenarios



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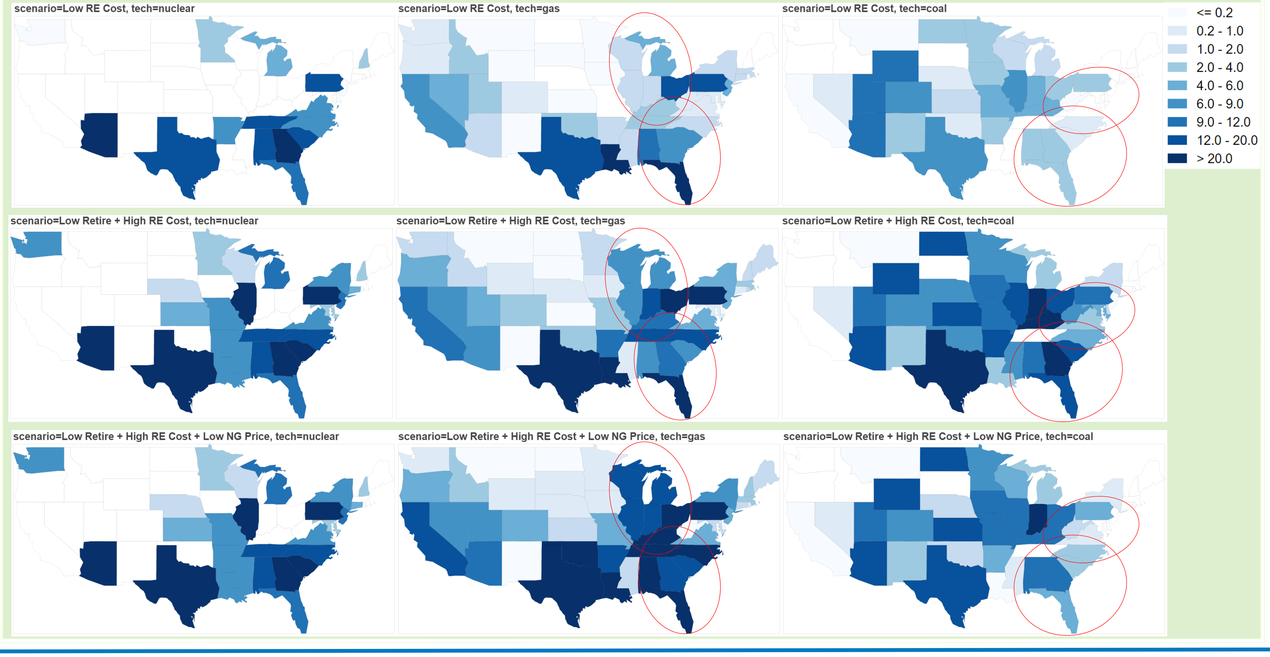

Key Takeaways

- The **Low RE Cost** scenario involves the lowest water consumption and withdrawals over time—at both national and regional scales—due to the increasing penetration of the least water intensive renewable technologies
- The **High RE Cost** and **Low Retire + High RE Cost** scenarios are the most water-intensive cases in the near term due to the increased utilization of existing coal and nuclear plants
  - The **Low Retire + High RE Cost + Low NG Price** scenario involves lower near-term water usage but higher water consumption in the out years, the latter of which is due to greater natural gas expansion by 2050
  - Total regional water consumption is similar for the **Low Retire + High RE Cost** and **Low Retire + High RE Cost** + **Low NG Price** cases, but the eastern U.S. shifts its consumption between coal and gas depending on natural gas prices
- Water *consumption* for cooling at natural gas-fired plants varies across the scenarios explored with the amount of new natural gas-fired generation, which uses recirculating cooling
- Both water *consumption* and *withdrawals* for coal-fired and nuclear plants vary across scenarios because they use a mix of once-through and recirculating cooling

Future Work

- Constrain water access by requiring access purchases for new capacity, in order to understand how legal availability of different water sources affects regional capacity expansion
- Constrain physical water access by region, season, technology, and water source, in order to illustrate the impact of high-resolution water constraints on future electric sector planning and operations decisions

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