Evolution of Electric Sector Water Use Under Alternative Electricity Futures

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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

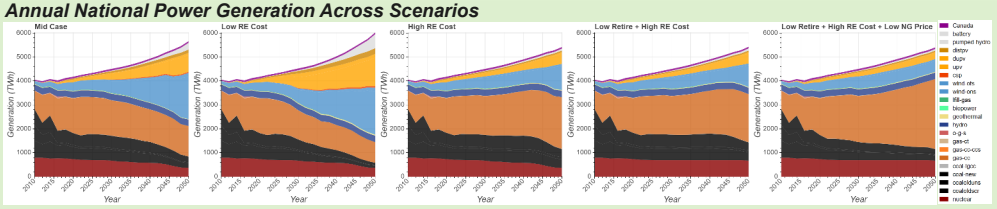
Scenario	ATB[1] RE Cost Scenario	Retirement Scenario	AEO[2] 2019 Natural Gas Price Scenario
Mid Case	Mid	Reference	Reference
Low RE Cost	Low	Reference	Reference
High RE Cost	High	Reference	Reference
Low Retire + High RE Cost	High	Longer coal and nuclear lifetimes	Reference
Low Retire + High RE Cost +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

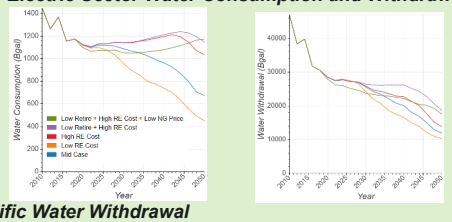
[2]AEO = Annual Energy Outlook, annual scenario analysis with projections for U.S. energy markets from the U.S. Energy Information Administration (https://www.eia.gov/outlooks/aeo/).

Results

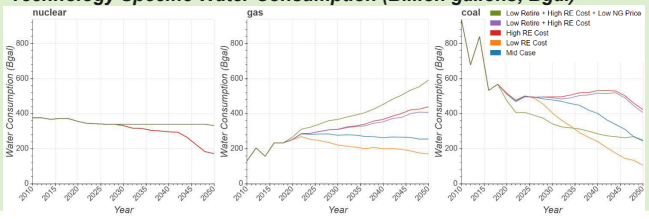
Annual National Power Generation Across Scenarios



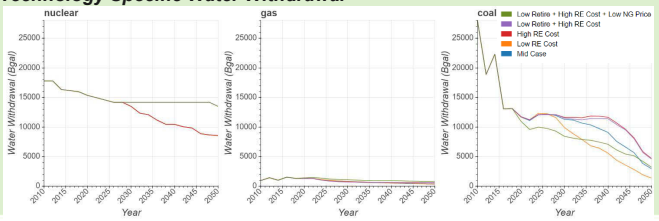
Electric Sector Water Consumption and Withdrawal



Technology Specific Water Consumption (Billion gallons; Bgal)

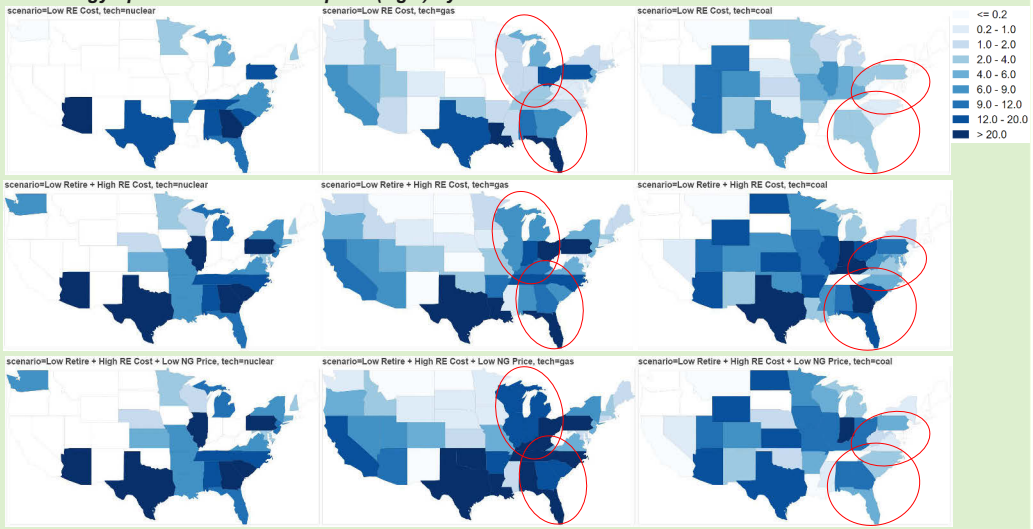


Technology Specific Water Withdrawal



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

Technology Specific Water Consumption (Bgal) by State in 2050 Across Select Scenarios



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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