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WATER RESOURCE AVAILABILITY: PRESENT AND FUTURE TRENDS

Electric power generation requires reliable access to large volumes of water, primarily for cooling of thermal power plants

Demand Exceeds Supply

Global water demand could exceed supply by 40% by 2030 [1]. According to the U.S. Geological Survey, roughly half of the water withdrawn per day in the United States is used for electric power generation [2]. As the world population grows, the pressure on water resources continues to increase due to accelerated economic activity and consumption. With finite high-quality water resource, the water supply might no longer be sufficient. In the near term, this will prove to be a critical challenge for the power generation industry in the face of stronger demand accrued from increased electrification across the board. Longer term, however, the industry's water consumption should moderate as the sector transitions to technologies that are less carbon-intensive. For example, non-thermal renewables, such as photovoltaics (PV) and wind, have the lowest water consumption factors as compared to concentrating solar power (CSP) technologies that have the highest water consumption values when using a recirculating cooling system [3].

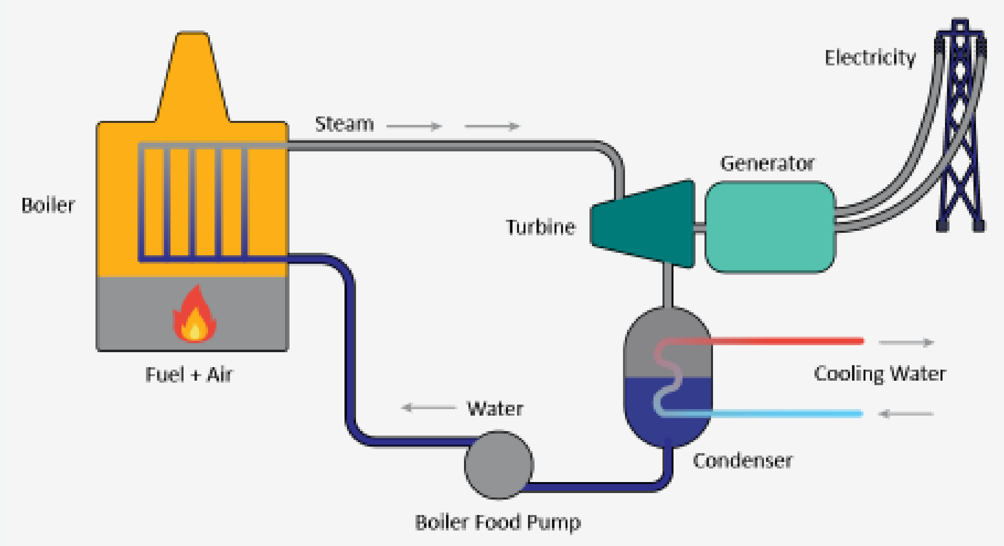
Water bodies across the globe are witnessing more severe weather events as mean air temperatures continue to rise and precipitation patterns change. Power generation relies heavily on quantity and quality of water to generate electricity, which makes this sector highly susceptible to changing climate conditions.

Key drivers of change in water trends:

1. **Climate** impacts the water cycle by determining the time, volume, and location of precipitation, influencing streamflow intensity and groundwater levels.
2. **Landscape** influences surface runoff patterns. Impervious surfaces increase water runoff and decrease water infiltration to groundwater reservoirs.
3. **Water use** within a local area tends to be proportional to population and use by other sectors, so areas with growing populations and economic activity usually have increasing water usage.
4. **Regulations** to control water quality and quantity can impose withdrawal and discharge limits.

Why Are Power Plants so Water Intensive?

Most power plants use a steam turbine to generate electricity. The primary source of water consumption is the amount of water lost through the cooling towers to evaporation during this process. Power plants with once-through cooling systems do not consume much of the water withdrawn because it is discharged to the receiving water body after cooling the condenser. According to the CDP Water Security 2019 Reporting Guidance, *water consumption* is defined as "the amount of water that is drawn into the boundaries of the organization and not discharged back to the water environment or a third party over the course of the reporting year."



To learn more about water resource availability and its implications on the power sector, read 1019866 and 3002011025

WATER AVAILABILITY PATTERNS COULD HAVE VARIABLE IMPACT ON POWER GENERATION

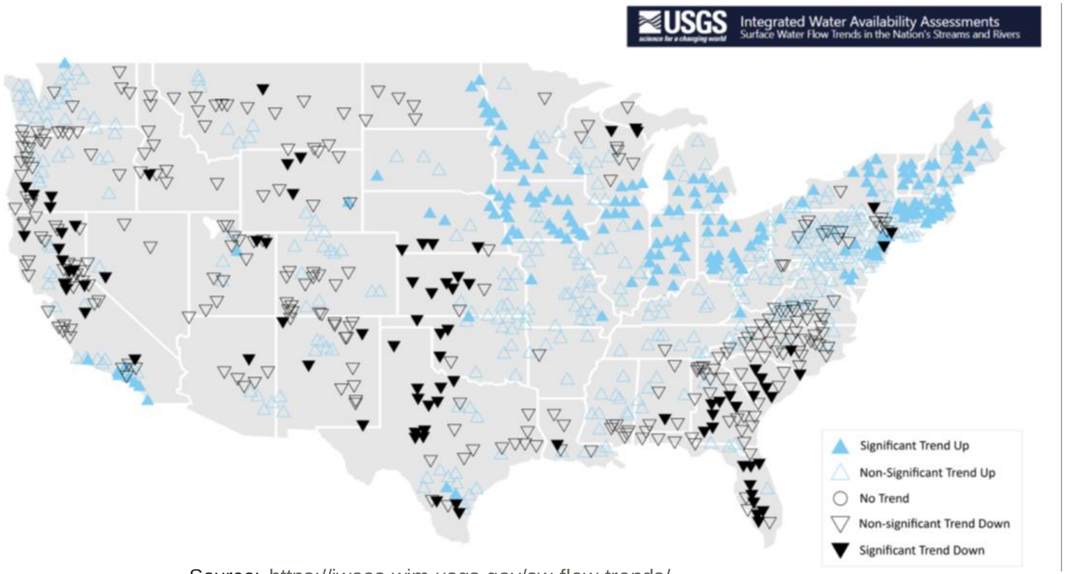
Change in quantity and quality of water resources

Mean annual streamflow describes the average rate of water carried by a river or stream over a year. Increases or decreases in average annual streamflow impact the operation and infrastructure of utilities, including intakes and spillways. As can be seen in the graph (top image) on the right, mean annual streamflow increased from 1966 to 2015 in the northeast, northwest, and Midwest regions of the United States. In other regions, such as the west, south, and southwest, streamflow declined from 1966 to 2015 due to an increase in the duration and intensity of droughts, which has now resulted in drought-like conditions for many power plants (bottom image). Seasonal trends of high and low flows are showing wider ranges as a result of exacerbating drought conditions and earlier snowmelt periods, posing a threat to the existing power generation infrastructure in some regions of the country.

Trends

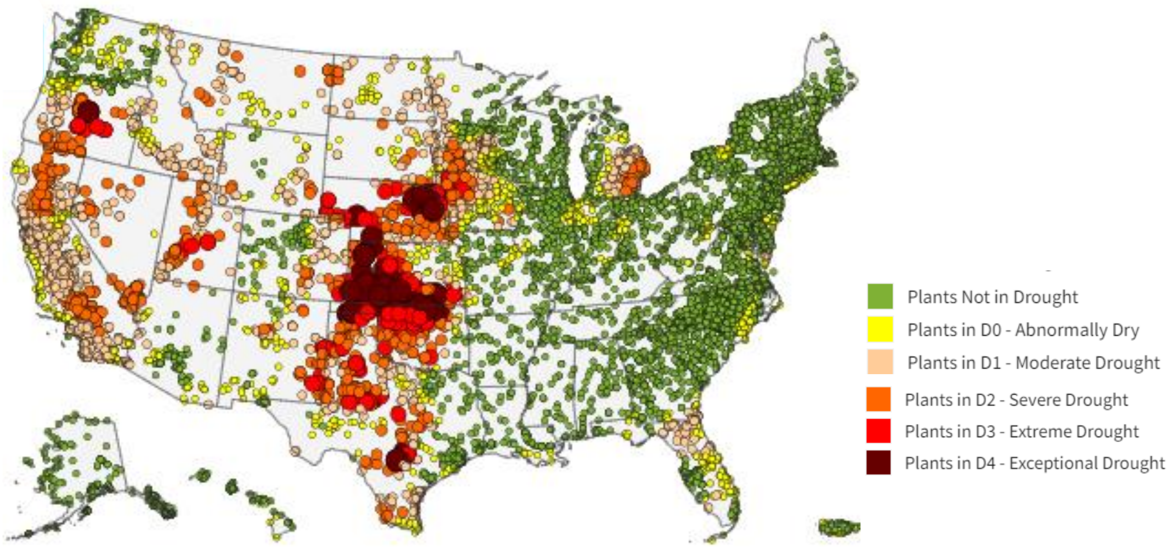
- **Decrease in total flow volume:** A prolonged period of low flow of water during dry weather might decrease the water supply to facilities, leading to a temporary or permanent shutdown.
- **Increase in total flow volume:** Periods of high flow during high precipitation might cause infrastructural damage to the facilities and lead to temporary shutdowns.
- **Increase in water temperature:** With global air temperatures rising and land use patterns changing, water temperatures in some regions have been shown to be increasing. High temperatures can sometimes make it difficult to comply with thermal discharge limits and increase turbine back pressure, leading to lower power output.
- **Increase in concentrations of nutrients:** Recent trends have shown that increases in some contaminants make water treatment before and after power production challenging, complicating compliance with water discharge regulations.
- **Change in generation mix:** As the generation mix changes, the electric power industry's needs for water will likely change as well, and this might vary regionally.

Mean annual streamflow trends, 1966–2015



Source: https://iwaas.wim.usgs.gov/sw-flow-trends/

U.S. power plants in drought (as of February 9, 2023)



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POTENTIAL IMPACTS AND CHALLENGES FOR THE POWER INDUSTRY

Challenges for the Power Industry

- **Physical challenge** pertains to the risk posed by changes in the available quantity of water due to a decline in groundwater level or withdrawal restriction during drought, or changes in the quality of water caused by a rise in water temperature or increase in pollutants, which will require additional treatment.
- **Regulatory challenge** is when a utility faces restrictions and sanctions under regulations such as the Clean Water Act on both the quantity and quality of water.
- **Financial challenge** may arise as a consequence of physical or regulatory risk. Utilities might need to incur expenditure to maintain water supply by purchasing more water or manage load demand by purchasing electricity through the open market.
- **Reputational challenge** has recently gained importance with the rising concern and awareness about sustainability among consumers and other relevant stakeholders of the utility industry.
- **Equity challenge** is the risk of exposing the communities near power plants to issues such as reduced water availability for residential use and deteriorated water quality.

Regulatory Challenges with Hydropower Projects [1]:

- More than 30% non-federal hydropower licenses in the United States are set to expire by 2030.
- 41 hydropower projects submitted license surrender over past 10 years.
- One-third of hydropower asset owners are considering decommissioning.
- Hydropower relicensing takes 8–10 years.

2023-2030		
Power plants with license expiring by 2030	License application due by 2030	Power plants at a regulatory risk
216	179	37

Data collected from https://www.ferc.gov/licensing.

Impact on the Power Industry

1. **Regulations:**
   - Compliance with laws regulating minimum streamflow becomes difficult, leading to reduced hydropower production or plant shutdown.
   - Sometimes utilities are unable to get water permits for unrestricted access to water.
   - Regulatory requirements for scrubbers and carbon capture might increase water demand.
2. **Infrastructure:**
   - Modifications, such as lowering intake structures to access water in periods of low flow, could be needed.
   - Power plant infrastructure might be at risk in high flow periods.
3. **Competition for common pool resource:**
   - Increase in competition with nearby regions or power plants requiring water from the same source as the power plant.
   - Uncertainty in upstream releases might lead to higher water temperature and a decrease in the quantity and quality of water available for the power plant.

WATER AVAILABILITY: WATER CHALLENGES CONCERNS FOR POWER SYSTEMS

Water-related risks can potentially affect a spectrum of generation units and infrastructure of electric power facilities. Risks associated with plant water management included water risk effects on scheduling, cooling, scaling, and fouling, among other issues.

Within the electric power industry, there can be different types of water impacts on infrastructure, operations, and supply chains.

Rising water temperature and reduced water flow in waterways may lead to operational disruptions during hours of peak demand. Elevated water temperature as a result of changing climate and rising temperatures [1] could lead to elevated temperatures of discharges, decreases in dissolved oxygen, and increased potential for algal blooms.

Hot and dry periods resulting in reduced supply of cool water may lead to a decrease of up to 16% of a thermal power plant's generating capacity [2].

Water-related concerns vary between power generation types. Nuclear plant operators have previously indicated [4] that rising water and air temperatures, frazil ice, excess cold, and debris all pose a risk to overall plant operations [3].

Hydropower facilities, however, noted more significant risks regarding capacity and flooding. Research suggests that up to 61% of hydropower plants across the world will be at a high risk of water scarcity, excessive flooding, or both by 2050 [5].

Challenges for utilities

Scheduling

- Hydropower plants use scheduling to maximize the gross utilization of power generation during specific periods while meeting operational and environmental constraints [6].
- This utilization of scheduling is based on long-term average flows. Year-to-year flows may vary drastically due to a drought or flood, which can lead to operational risks [7].

Cooling

- Cooling is the process of condensing the after-turbine steam in the internal circuit and recycling it [8].
- Higher water temperatures could make the design and operation of the component cooling systems problematic or impossible [8].

Scaling

- The formation of scaling due to physical changes in the parameters of water, such as increased dissolved solids, higher pH, temperature, and ion concentrations, leads to minerals exceeding their solubility limit [9].
- Formation of scaling can reduce heat transfer capacity and increase energy consumption and cooling water consumption [9].

To learn more about advanced cooling options for nuclear plants, visit https://www.epri.com/research/products/1025068

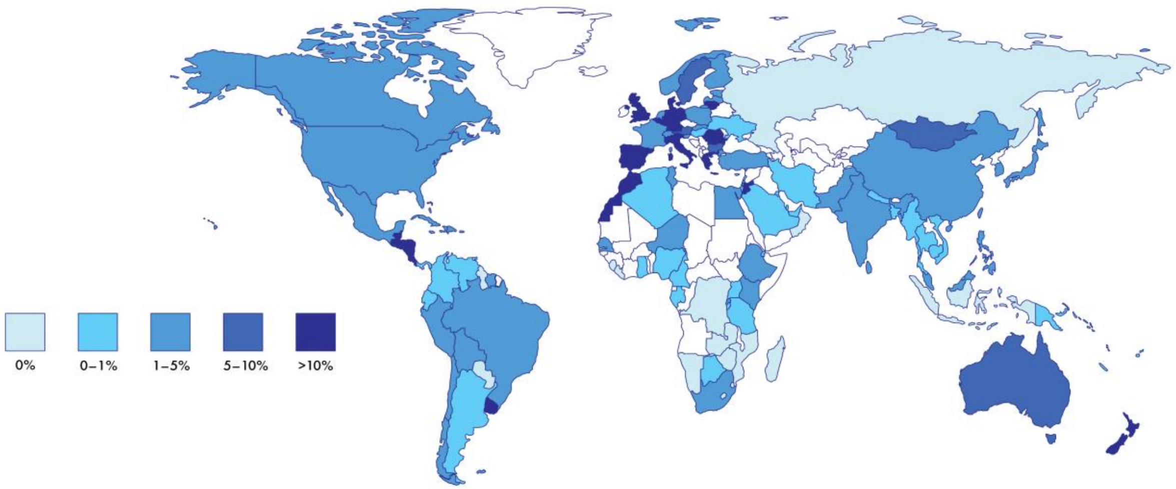
WATER AVAILABILITY: CHALLENGES REGARDING WATER AVAILABILITY

Much of the world's thermal and hydroelectric capacity lies within regions of high water stress. Freshwater withdrawals for the power sector account for 18% of all water withdrawals globally [1]. Countries with more solar and wind capacity generally consume less water in power generation.

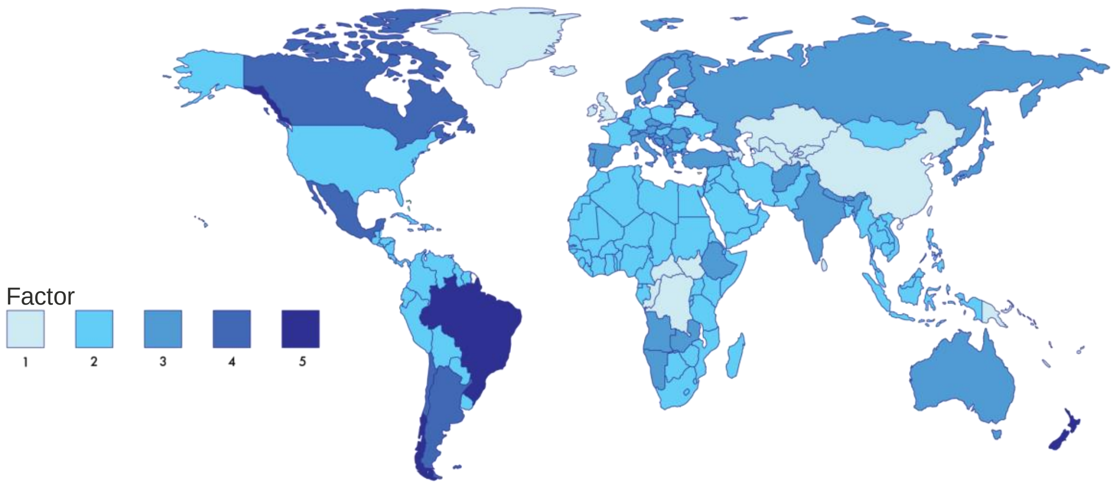
In general, countries that generate less grid power from renewable sources consume water at higher rates per unit of purchased electricity. Less than one-tenth of countries generate more than 5 percent of grid power from solar and wind. These are the countries that consume less water for power generation.

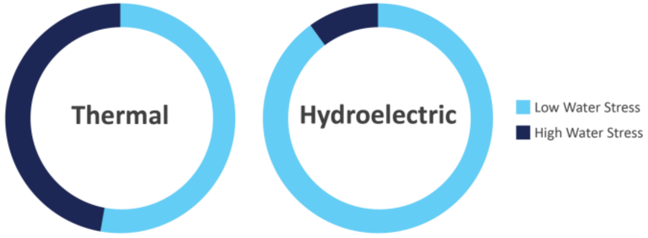
Countries like France, Germany, England, who produce a higher percentage of renewable energy, tend to have a lower water a consumption factor of 1 or 2. On the other hand, countries like, Brazil, Argentina, Chile produce less renewable energy, and have a higher water consumption factor of 4 or 5.

Grid power from solar and wind, %



Water Consumption Factor for Grid Power, Gallons per kWh[1]





Power generation and water stress

Dwindling supplies of freshwater pose a material business risk: one estimate shows that the lack of clean freshwater threatens some $425 billion of value across more than 500 companies [2].

When a region withdraws 25% or more of its renewable freshwater resources, it is said to be under water stress. Water stress occurs when demand exceeds the available water supply [3].

Assessing the potential water and carbon savings from using more renewable energy requires a granular analysis of site-level factors. These factors could be driven by the company strategy or sustainability goal.

To learn more about water resource availability and its implications on the power sector, visit https://www.epri.com/research/products/000000000001019866.

WATER AVAILABILITY: SOLUTIONS FOR ADDRESSING CONCERNS

Temporary solutions might be enough during droughts. However, long-term solutions may be needed to address increasing population, decreasing water levels, and increased regulatory requirements. Coping with the coming era of water scarcity may require a major overhaul of all forms of consumption, from individual use to industrial.

Temporary solutions [3]:

Installing temporary diesel pumps allows for pumping of water if source water levels fall too low.

Identifying contingency sources of water in upstream reservoirs could be a key to ensure consistent water supply.

Portable cooling towers might also help in dealing with thermal impacts often associated with low water flow.

Water planning [3]:

Increased state and regional water planning efforts will lead to more scrutiny of new projects but may not directly lead to permit limits.

New siting options [3]:

Siting new power plants in restricted water areas is becoming difficult. Expanding existing facilities becomes challenging, too.

New technologies:

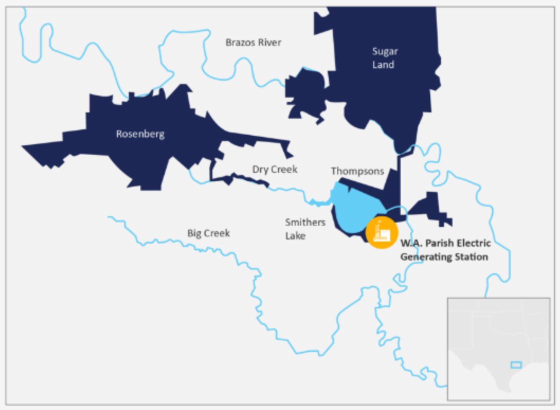
Implementing dry or hybrid cooling or water-efficient renewable energy sources could pose concerns such as technical challenges, economic barriers, and limits with space requirements [4].

Developing new policies and regulations [2]:

Individual state ordinances and regulatory strategies control specific uses of water, such as transfers of water from one watershed to another or withdrawal of groundwater. Having policies that support sustainable water practices and agreements may enable water managers to effectively meet needs.

Diversification of water sources:

Stormwater Source for Parish Electric Generating Station, Texas[1].



Lake Smithers, an artificial lake, acts as a stormwater runoff source for Parish Electric Generating Station, Texas. The runoff is supplemented by water purchased from the canal system of the Richmond Rice Association

Brackish Inland Water for Oklaunion Power Station, Texas[1].

The Oklaunion Power Station sources its water from Lake Diversion. The lake's brackish water acts as a cooling source for the plant.

No large water body:

The absence of a large water body in an area could affect the utility's ability to obtain an unrestricted water withdrawal permit at the site. This usually leads to utilities sourcing sufficient cooling water from multiple sources. Buying municipal water could be cheaper than installing a dry or hybrid cooling system [3, 5].

Reclaimed water [1]:

Rainwater harvesting and recycled wastewater can help lower water stress in arid regions. Reclaimed water also eases the pressure on groundwater and other water bodies.

To learn more about water resource availability and its implications on the power sector, visit https://www.epri.com/research/products/000000000001019866.

WATER RESOURCES: POTENTIAL SOLUTIONS WITHIN THE POWER SECTOR

EPRI has a variety of available research products across several key research areas, including Program 55: Ecosystem Risk and Resiliency, which provides a strategic, systematic framework to evaluate risks related to water, climate, and ecosystems.

EPRI Technical Update: *Review of Tools to Evaluate the True Cost of Water*

Key Research Question: A current issue is the undervaluation of the full cost of water, which includes direct and indirect costs as well as risk impacts. This study reviews existing tools that evaluate how the full cost of water risks manifest as financial impacts.

Key Findings: Three tools that have the greatest applicability to EPRI members:

Water Risk Monetizer→ provides a monetary estimate of the full value of water using a risk-adjusted water cost

True Cost of Water → estimated the true cost of water to help companies mitigate production risks

WAVE → Water and Value, converts water risk values into financial impacts for a given site [1]

EPRI, 2019, 3002016552.

EPRI Technical Brief : *Update on Waters of the United States (WOTUS) Developments*

Key Background: The objective of this technical brief is to provide Ecosystem Risk and Resilience (P55) members with a timely update on the WOTUS regulations. It reviews developments from 1986 through September 2022, with an emphasis on June 2021 to September 2022.

Key Findings: The report is intended to help EPRI members prepare for upcoming regulatory changes in the definition of WOTUS, as the Biden administration, EPA, and Army Corps are currently reviewing the existing definition [2].

EPRI, 2021, 3002022992.

EPRI Technical Brief: *Can Alternative Water Supplies Effectively Support Power Generation?*

Key Background: Electric power facilities have successfully used water supplies for decades to meet primary or backup supply needs. A set of 17 case studies describe drivers for alternative water supply use, benefits, challenges, lessons learned, and other site-specific findings.

Key Findings: The case studies illustrate that a variety of alternative water supply types can provide a reliable source of sufficient-quality water to facilities, reducing water-related risks and, in some cases, providing regulatory and reputational benefits [3].

EPRI, 2017, 3002012044.

CASE STUDY: “A FRAMEWORK TO NAVIGATE CLIMATE-RELATED WATER RISKS”

August 2022, summary of three-year EPRI Research Initiative

Research Background:

- Wabash River Basin (runs through Ohio, Indiana, Illinois)
- San Juan River Basin (runs through Colorado, New Mexico, Utah)
- Shared water characteristics: temperatures and precipitation patterns within these regions changing due to the effects of climate change
- “In the Wabash basin, changes are likely to include a general increase in annual precipitation, albeit with more extremely wet and unusually dry years. Flooding could be more of a challenge at times, as could water quality issues due to higher water temperatures. The San Juan River Basin is increasingly subject to extreme drought conditions that drastically reduce the availability and flow of water throughout the region.”
- Understanding the impacts of climate change on river basins is important for the electric power industry.
- Access to reliable water resources is necessary to cool nuclear and fossil fuel power plants and to generate electricity in hydropower plants.

EPRI Study Areas:

1. Evaluating the climate and water data and models available to grasp possible changes to water resources
2. How energy companies could take what they learned from models and data to understand better the risks they face
3. Adaptation strategies that energy companies could implement to effectively manage climate-related changes to water resources

Two models selected for the analysis: Watershed Assessment Risk Management Framework and the Soil-Water Assessment Tool

Research results: *Quantifying Potential Impacts of Water-Related Risks Associated with Climate Change* [1]

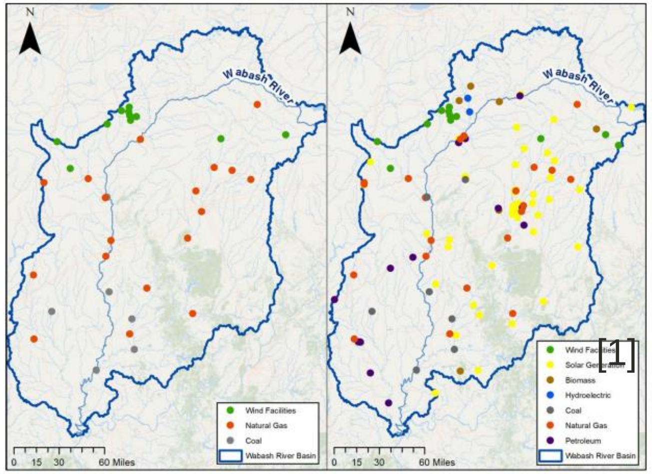


Figure 3-3
Wabash electric generating facilities: greater than 25MW nameplate capacity (left) and all active generating facilities (right) (EIA-860, EIA-860M and EIA-923, 2021)

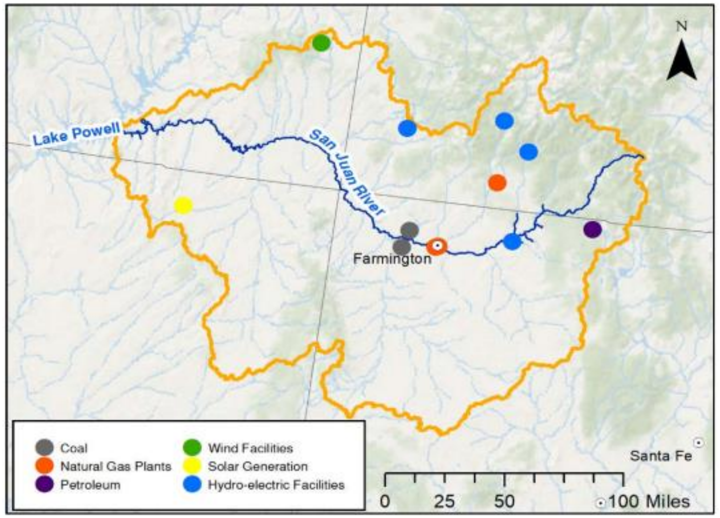


Figure 2-4
Power facilities in the San Juan River Basin

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ACKNOWLEDGMENTS

EPRI Insights documents provide a snapshot of current events, industry forecasts, and R&D with the goal of providing insights that may inform energy strategy. These reports aim to cover the full electricity and integrated energy system pipeline while also providing deeper looks at key technologies and trends each quarter.

While based on sound expert knowledge from research programs across EPRI, they should be used for general information purposes only and do not represent a position from EPRI.

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