PROGRAM facts

U.S. DEPARTMENT OF ENERGY
OFFICE OF FOSSIL ENERGY
NATIONAL ENERGY TECHNOLOGY LABORATORY

Innovations for Existing Plants

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NETL

INNOVATIVE APPROACHES AND TECHNOLOGIES FOR IMPROVED POWER PLANT WATER MANAGEMENT

Background

The production of electricity requires a reliable, abundant, and predictable source of freshwater—a resource that is limited in many parts of the United States and throughout the world. The process of thermoelectric generation from fossil fuels such as coal, oil, and natural gas is water intensive—an average of 25 gallons of water is needed to produce a kWh of electricity. Requiring more than 97 billion gallons of freshwater a day, the existing fleet of fossil-fuel-fired power plants is second only to agriculture (irrigation and livestock) in terms of water use in the United States.

As a growing economy drives the need for more electricity, demands on freshwater supplies for thermoelectric power generation will also grow. However, electric utilities will have to compete with demands from other off-stream-use sectors such as public supply, domestic, commercial, irrigation, industrial, and mining. In addition, the need to leave water in streams and rivers to achieve environmental, ecological, and recreational goals will further complicate the future allocation of the nation's freshwater resources. As such, the availability of adequate supplies of freshwater to produce electricity as well as the potential impact of power plant operations on freshwater quality are receiving increased attention.

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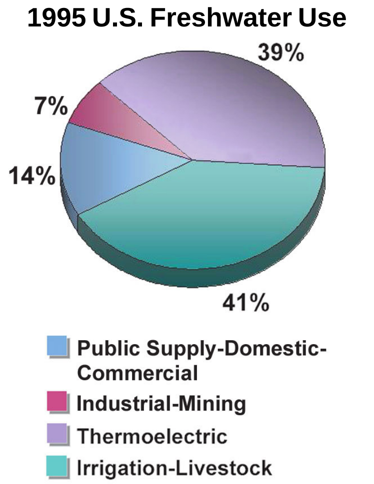
Power Plants & Water

When discussing water and power plants, it is important to distinguish between water use and water consumption. Water use typically describes the direct impact of a cooling system on a water source, for example water withdrawal. Water consumption describes the loss of water from a water source, primarily through evaporation.



Note: Total greater than 100 due to individual rounding

In 1995, fossil-fuel-based thermoelectric generators were second only to agriculture in total freshwater withdrawals. In that year, which represents the most recent data from the United States Geological Survey (USGS), fossil powered steam electric generators withdrew more than 34 trillion gallons from fresh surface and ground waters.

Although thermoelectric generators are the second largest withdrawal category, more than 97% of all withdrawals were returned to the source. Of the 36.5 trillion gallons of U.S. freshwater consumed* in 1995, thermoelectric generators were responsible for less than 3.5% of the total, making it the smallest consumer category of U.S. freshwater resources. In comparison, 61% of the water used in irrigation is consumed.

Research Description

In response to the intimate link between water and electricity, the U.S. Department of Energy's National Energy Technology Laboratory (DOE/NETL) has initiated a power plant-water research and development (R&D) activity under its Innovations for Existing Plants (IEP) program. This effort is directed at developing technologies and approaches to better manage how power plants use and impact freshwater resources. The research encompasses laboratory and bench-scale activities through pilot-scale projects and is built upon partnership and collaboration with industry, academia, and other government and non-government organizations. The overarching goal of the IEP program's water R&D activity is to reduce the amount of freshwater needed by power plants and to minimize potential impacts of plant operations on water quality.

Project Summaries

In August 2003, DOE/NETL selected five projects under a targeted solicitation entitled Innovative Water Management Techniques and Concepts for Coal-Fired Electric Utility Boilers. These projects are described below.

Strategies for Cooling Electric Generating Facilities Utilizing Mine Water: Technical and Economic Feasibility — West Virginia University (WVU)

WVU is assessing the feasibility of using underground coal mine water in the northern West Virginia and southwestern Pennsylvania region as a source of cooling water for power plants. The amount of mine water available, the quality of the water, and the types of water treatment needed are all factors that will be analyzed during this one-year effort. The use of this "impaired" water would not only reduce the amount of freshwater needed for cooling and other industrial purposes, but would also minimize the potential for untreated underground mine waters to discharge into local rivers and streams.

Use of Produced Water in Recirculated Cooling Systems at Power Generation Facilities — Electric Power Research Institute (EPRI)

Produced waters are a by-product of natural gas and oil extraction and can often present a disposal issue. Produced waters could serve as a source of make-up water for re-circulating cooling systems in water poor areas of the nation, thereby minimizing or eliminating the disposal concern. EPRI, in collaboration with Public Service of New Mexico, Ceramem, and Water and Waste Water Consultants are carrying out a two-year project to evaluate and develop the use of produced waters at a New Mexico power plant. The project will investigate the feasibility of using produced water to meet up to 25% of the approximately 16 million gallons/day cooling water demand at the San Juan Generating Station.

Water Extraction from Coal-Fired Power Plant Flue Gas — University of North Dakota Energy & Environmental Research Center (UNDEERC)

UNDEERC, along with the Siemens Westinghouse Power Corporation, is testing a desiccant-based dehumidification process that removes water from the exhaust gas of coal-fired power plants. This two-year project will attempt to develop an economical and environmentally beneficial technology to substantially reduce the water consumption of fossil fuel-fired power plants by recovering a large fraction of the water present in the plant flue gas. An engineering evaluation will also be performed to determine how this technology can be integrated into various power-generating systems, not only to recover water and improve efficiency but also to reduce emissions of acid gases and carbon dioxide.

Environmentally Safe Control of Zebra Mussel Fouling — New York State Education Department

The colonization of zebra mussels on cooling water intake structures can lead to significant plant outages. There is a need for economical and environmentally safe methods for zebra mussel control where this invasive species has become problematic. Researchers with the New York State Education Department are conducting a three-year study to evaluate a particular strain of a naturally occurring bacteria Pseudomonas fluorescens that has shown to be selectively lethal to zebra mussels but benign to non-target organisms. Testing is being conducted on the house service water treatment system for Rochester Gas and Electric Corporation's Russell Station that withdraws 4 to 5 million gallons/day from Lake Ontario.

Fate of As, Se, and Hg in Passive Integrated Systems for Treatment of Fossil Plant Waste Water — Tennessee Valley Authority (TVA)

Mercury, arsenic, and selenium are pollutants often present at trace-levels in power plant flue gas and wastewater. In addition, ammonia "slip" from selective catalytic reduction systems (SCRs) for reduction of NOx emissions can appear in wastewater streams such as FGD effluents and ash-sluice water. TVA and EPRI are conducting a three-year study of a passive treatment technology to remove trace levels of arsenic, selenium, and mercury as well as ammonia and nitrate from fossil power plant wastewater. An extraction trench containing zero-valent iron for removal of trace contaminants is included in the work in order to evaluate an integrated passive treatment system for removal of these trace compounds.

Cooling Water Technologies

The most prominent cooling technologies used at thermoelectric power plants today are once-through systems and recirculating wet cooling towers. Recently, indirect dry systems have also been considered as potential cooling options. While all three systems require some type of cooling fluid, typically water, the amount of water withdrawal needed for each technology varies.

Although once-through systems withdraw the largest volume of water, they are the most efficient cooling systems for power generation and tend to have the lowest capital investment costs. Wet cooling towers require less water than once-through systems, but may require significant pretreatment for makeup water and have higher capital costs.

While indirect dry cooling systems have negligible water withdrawals, they are the least efficient of the three systems and have the highest capital costs. Additionally, dry cooling systems can have relatively high parasitic power requirements for operation of pumps, fans and other equipment. Furthermore, retrofit applications can present other problems including increased turbine back pressure, increased air emissions relative to net power output, and also have larger footprints than most other cooling options.

In addition to the projects selected under the Innovative Water Management solicitation, several other projects make up DOE/NETL's power plant-water research portfolio and are described below.

Use of Coal Drying to Reduce Water Consumed in Pulverized Coal Power Plants —Lehigh University

This three-year project will determine the feasibility of using low-grade power plant waste heat to dry low-rank coals prior to introduction into the boiler. Heat from condenser cooling water will be extracted upstream of the cooling tower and used to dry the coal. Lowering the temperature of the return cooling water will reduce evaporative loss in the tower, thus reducing overall water consumption. In addition, drying the coal prior to combustion can improve the plant heat rate and efficiency, thus reducing overall air emissions. Data from lab-scale testing will be used to develop drying models and to assist in the design of a full-scale prototype dryer module for Great River Energy Corporation's (GRE) Lignite Fuel Enhancement Project funded under DOE's Clean Coal Power Initiative (CCPI).

Demonstrating a Market-Based Approach to the Reclamation of Mined Lands in West Virginia — Electric Power Research Institute

EPRI will demonstrate a market-based approach to abandoned mine land (AML) reclamation by creating marketable water-quality and carbon-emission credits. The two-year project will involve the reclamation of thirty acres of AML in West Virginia through (1) the installation of a passive system to treat acid mine drainage, (2) application of fly ash as a mine soil amendment, and (3) reforestation for the capture and sequestration of atmospheric carbon dioxide (CO_2). Water quality and CO_2 uptake will be measured and conventional economic principals will be used to develop the costs and environmental benefits of the remedial treatments. Potential eco-credits include water quality credits due to decreased acid mine drainage and other benefits resulting from the soil amendment, as well as potential credits for carbon dioxide sequestration due to the more than 36,000 seedlings planned for the site.

A Novel Concept for Reducing Water Usage and Increasing Efficiency in Power Generation — University of Pittsburgh

The University of Pittsburgh is developing a cooling system that uses ice to cool the intake air for combined-cycle plants. The inlet air temperature can affect the efficiency of the turbine, and this process could potentially help U.S. power generation facilities increase total power output during peak periods and lower fuel costs through higher overall efficiency. Although several types of intake air cooling have been used on natural gas-fired turbines, the use of a chilling system linked to ice thermal storage offers the benefit of making ice during off-peak periods and then using that ice to cool intake during peak loads therefore increasing the output available for sale during peak demand period. Also, the pure water condensate could be used for cooling tower make-up or other facility water needs.

An Innovative Freshwater Production Process for Fossil-Fired Power Plants Using Energy Stored in Main Condenser Cooling Water — University of Florida

The University of Florida will investigate an innovative diffusion-driven desalination process that would allow a power plant that uses saline water for cooling to become a net producer of freshwater. Hot water from the condenser provides the thermal energy to drive the desalination process. Using a diffusion tower, saline water cools and condenses the low pressure steam and freshwater is then stripped from the humidified air exiting the tower. This process is more advantageous than conventional desalination technology in that it may be driven by waste heat with very low thermodynamic availability. Cool air, a by-product of this process, can be used to cool nearby buildings.