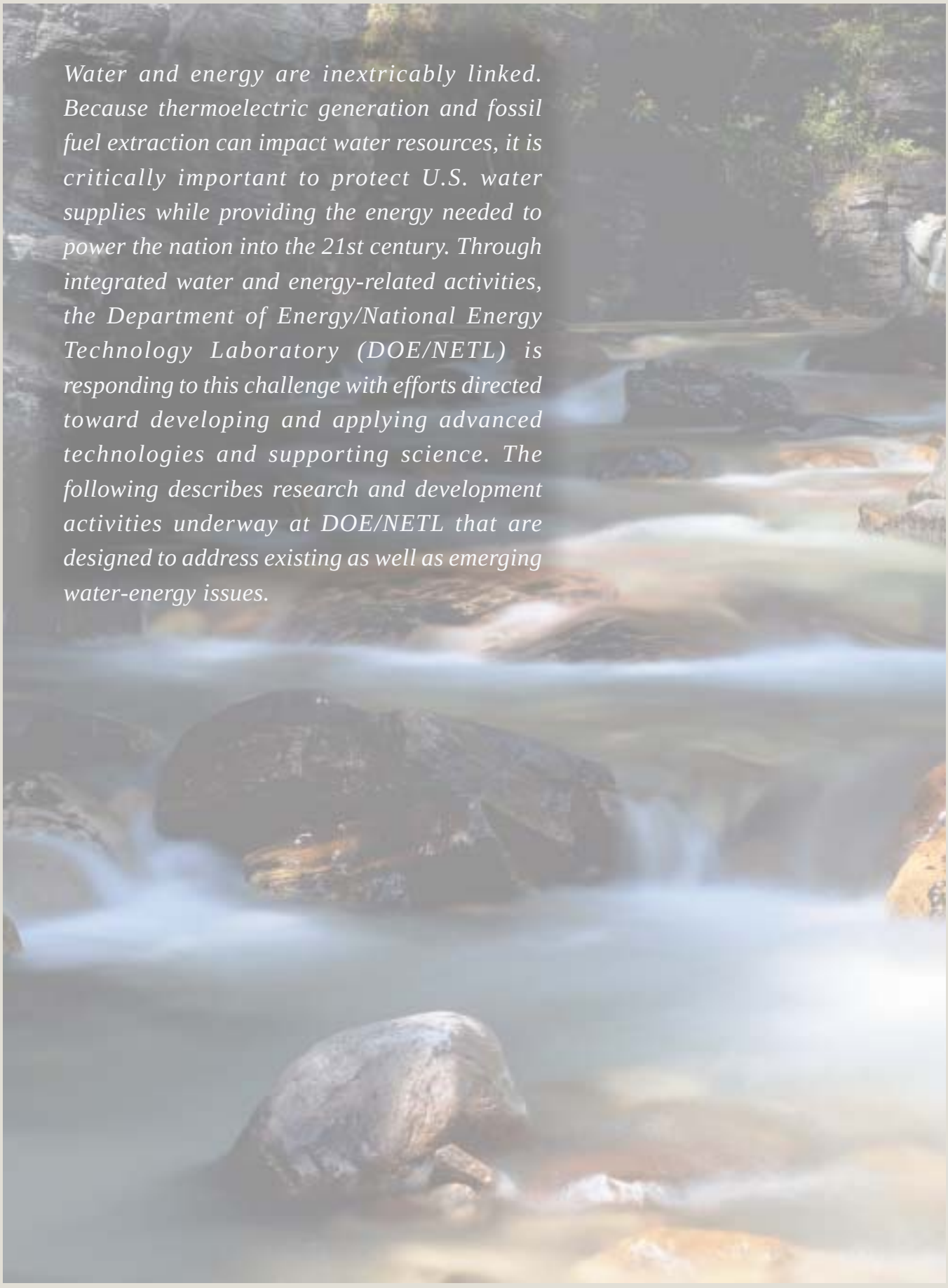
U.S. Department of Energy • Office of Fossil Energy
National Energy Technology Laboratory

WATER & ENERGY

ADDRESSING THE CRITICAL LINK BETWEEN THE NATION'S WATER RESOURCES AND RELIABLE & SECURE ENERGY

February 2004



Water and energy are inextricably linked. Because thermoelectric generation and fossil fuel extraction can impact water resources, it is critically important to protect U.S. water supplies while providing the energy needed to power the nation into the 21st century. Through integrated water and energy-related activities, the Department of Energy/National Energy Technology Laboratory (DOE/NETL) is responding to this challenge with efforts directed toward developing and applying advanced technologies and supporting science. The following describes research and development activities underway at DOE/NETL that are designed to address existing as well as emerging water-energy issues.

Introduction

The production of electricity requires a reliable, abundant, and predictable source of water — a resource that is limited in parts of the United States and throughout the world. Thermoelectric generation, the process of generating electricity from steam, represents the largest portion of annual U.S. electricity production, and coal-fired utilities generate about half of the nation's electricity supply.[1]

Thermoelectric generation is water intensive, whether from fossil fuels such as coal, oil, and natural gas, or from nuclear power. In fact, each kWh generated requires an average of 25 gallons of water. This means that U.S. citizens may indirectly depend on water to turn on lights and run appliances as much as they may directly use water to take showers and water their lawns.

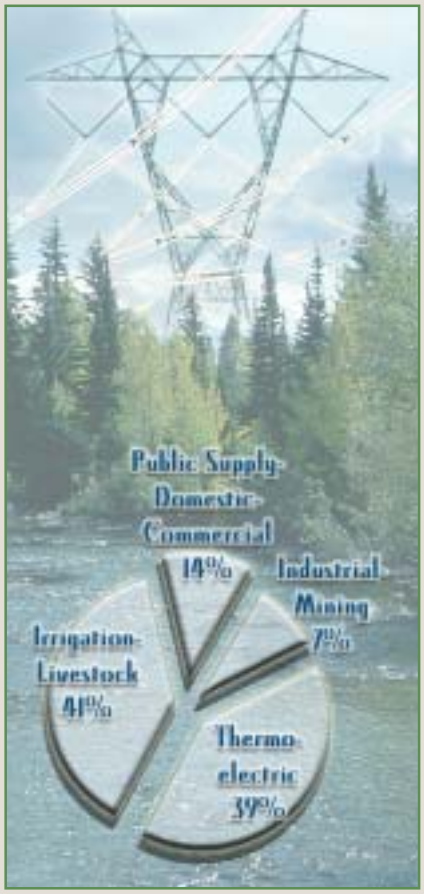
In addition to the direct need for cooling water at fossil fuel-fired power plants, fuel extraction can impact the quality and availability of the nation's water resources. Acid mine drainage (AMD) from both active and abandoned coal mining operations may compromise surface and groundwater supplies.

The process of natural gas and oil production results in significant quantities of water produced along with the gas and oil recovered. In 1995, nearly 18 billion barrels of produced water were produced in the United States.[2] Almost all of this water is reinjected for disposal or to enhance production. While much of this water has a very high salt content, a substantial quantity would be suitable for other uses with little or no treatment.

As the nation's growing economy drives the need for more electricity, demands on the use of water for power generation also will grow. The direct and indirect demand for water for energy production will increasingly compete with demands from other sectors of the economy. As a result, increased attention is being paid to the availability of adequate water supplies required to produce electricity, and to the potential impact of energy operations on water quality.

The Department of Energy's National Energy Technology Laboratory (DOE/NETL) manages a research and development program that is responding to the need to manage and protect U.S. water resources, while ensuring available energy to power the nation well into the 21st century.

DOE/NETL possesses the scientific, technical, and policy expertise necessary to help industry successfully meet the challenge of balancing energy production and utilization needs with water quality and availability concerns.



Annual U.S. freshwater withdrawals

* Total greater than 100% due to independent rounding.

Source: United States Geological Survey, *Estimated Use of Water in the United States in 1995*, U.S. Geological Survey Circular 1200, 1998.

1 Energy Information Administration, Annual Energy Review 2002, DOE/EIA-0384, 2002

2 American Petroleum Institute, 2001

Water & Power Plants

The generation of electricity from steam requires that process steam be condensed, most frequently through the use of cooling water. The most prominent cooling technologies used today are once-through systems and recirculating wet cooling towers. Recently, indirect dry systems also have been considered as potential cooling options. While all three systems require some kind of cooling fluid, typically water, the amount of water withdrawal needed for each technology varies.

Although once-through systems have the largest volume of water withdrawal, they are the most efficient cooling systems for power generation and tend to have the lowest capital investment costs. Wet cooling towers require lower water withdrawals than once through systems, but may require significant pretreatment for makeup water and have higher capital costs. Moreover, water vapor plumes exiting the tower can present aesthetic as well as other issues.

While indirect dry cooling systems have negligible water withdrawals, they are the least efficient of the three systems because of the higher ancillary power required to operate pumps, fans, and other equipment. Additionally, retrofit applications of dry cooling systems can present problems because of back pressure increases and the nature of the original steam turbine design. Furthermore, emissions of air pollutants can increase relative to net power output due to overall reductions in generation efficiency. Dry systems also tend to have higher capital costs and larger footprints than most other cooling options.

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. Once through systems have very high water use requirements, but since nearly all of the water is returned to the source body, consumptive losses are low. Recirculating wet systems have lower water use requirements, but consumptive losses through direct evaporation can be relatively high.

Atmospheric Deposition of Airborne Pollutants

Concern has been raised about the potential impact of "non-point" sources, including power plant air emissions, on water quality. The U.S. Environmental Protection Agency (EPA) undertakes a bi-annual assessment of the quality of U.S. water bodies. In the 2000 National Water Quality Inventory, EPA identified that atmospheric deposition from all sources of air pollution continues to be a significant contributor to the nation's impaired water bodies. The deposition of mercury, sulfur, and nitrogen compounds is considered a significant source of water quality impairment in the United States. Water bodies showing signs of water quality deterioration attributed to atmospheric deposition include the Chesapeake Bay, Great Lakes, and Florida Everglades.

DOE/NETL has established expertise in regional ambient air quality monitoring, and maintains a wet deposition mercury monitor in Southwestern, Pennsylvania, as part of the National Mercury Deposition Network.

Water & Energy R&D

Power plant water needs, most notably large-volume water withdrawals, are receiving increased scrutiny by both state and federal agencies. To address emerging power plant water needs, DOE/NETL has initiated a program specifically directed toward developing cost-effective approaches to better manage freshwater use and water quality impacts associated with power plants. The program addresses related research needs such as the development of non-traditional cooling water resources, advanced cooling and water intake technology, and advanced technologies for water pollutant measurement and treatment.

Non-Traditional Sources of Process and Cooling Water

Coal-burning power plants use large amounts of freshwater for cooling. Withdrawals for power plant cooling and related purposes account for 39 percent of freshwater use in the U.S., or about 97 billion gallons per day. Because water quality requirements for cooling systems can be less restrictive than many other applications such as drinking water supplies or agricultural uses, opportunities exist for the utilization of lower-quality, non-traditional water resources.

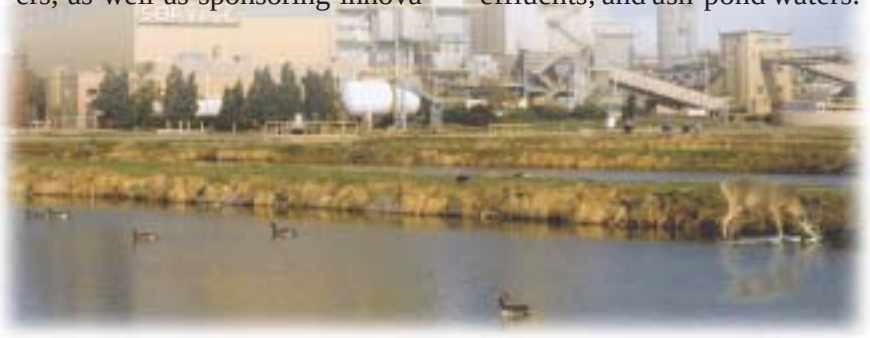
In order to reduce freshwater withdrawals, DOE/NETL is sponsoring several projects to evaluate the technological and economic feasibility of alternative water sources for use by coal-fired power plants. Projects include an assessment of issues related to using underground mine pool water and produced waters from coalbed methane extraction, as well as novel technologies such as extracting flue gas water vapor from coal-fired boilers. Promising technologies may also be applicable to non-coal based thermoelectric power plants and could provide cost-effective options to significantly reduce the impact of power generation on the nation's limited freshwater resources.

Advanced Cooling and Water Intake Technology

Regulations to protect aquatic organisms under §316(b) of the Clean Water Act may impact the operation of cooling water intake structures on new and existing power plants. DOE/NETL seeks to develop advanced methods and technologies for power plant intake structures through improvements of existing technologies such as fish handling systems, screens and others, as well as sponsoring innovative methods to control bio-fouling. From 1993 to 1999, the zebra mussel alone cost the U.S. power industry an estimated $3.1 billion. DOE/NETL is also considering research directed at advanced cooling technology to reduce the volume of water needed to operate current and future thermoelectric power generating facilities

Advanced Pollutant Measurement and Treatment Technology

Future controls of the emission of mercury and possibly other trace hazardous air pollutants have raised concerns about the ultimate fate of these contaminants once they are removed from the flue gas. Additionally, as discharge standards become even more stringent, effective removal strategies will be necessary for even low-concentration water borne contaminants. DOE/NETL research is developing advanced technologies to detect and remove mercury, arsenic, selenium and other toxic components from the aqueous streams of coal-based power plants such as blowdown water, wet scrubber effluents, and ash-pond waters.



Watershed Science & Technology

DOE/NETL has a long history of developing methods to characterize and mediate the direct and indirect impacts of coal mining. DOE/NETL has pioneered the use of state-of the-art airborne remote sensing methods as well as advanced techniques for remediating pollution resulting from mining and other resource development activities.

Geophysical Applications

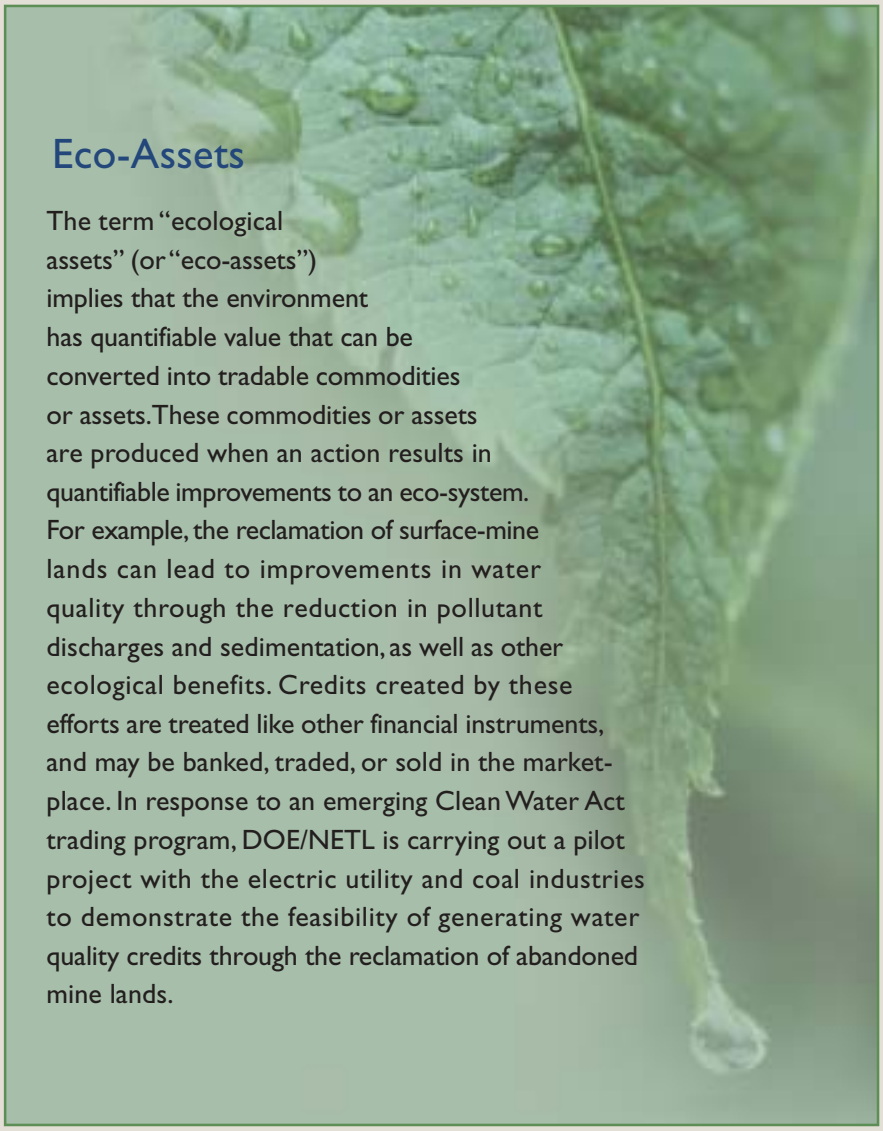
A variety of geophysical techniques have been applied by DOE/NETL to characterize underground and surface mines. The application of electromagnetic terrain conductivity, magnetometry, and very low-frequency imaging techniques can identify fractures that impact surface waters. Airborne remote sensing techniques allow for the construction of 3-dimensional profiles of watersheds that can determine the locations of water-filled fracture systems that connect surface and ground waters. Combined with watershed Geographic Information System data, geologic formation and water discharge can be correlated to accurately locate acid mine drainage as well as sources of sub-surface waters.

Treatment of Acid Mine Drainage

DOE/NETL has designed active, passive, and at-source water treatment technologies for mitigating direct discharges of pollutants from coal and hard-rock mining. Other approaches include methods to minimize the formation of acid compounds at the source.

A patented In-Line System water-treatment technology has been developed that is both effective and economical in treating AMD. DOE/NETL also has pioneered the development and use of passive water treatment technologies, such as constructed wetlands and anoxic limestone drains.

To facilitate successful technology transfer, partnerships with local and regional watershed groups, universities, and other government organizations have been developed. To date, over 1,000 passive treatment systems have been installed using DOE/NETL developed guidelines.



Eco-Assets

The term "ecological assets" (or "eco-assets") implies that the environment has quantifiable value that can be converted into tradable commodities or assets. These commodities or assets are produced when an action results in quantifiable improvements to an eco-system. For example, the reclamation of surface-mine lands can lead to improvements in water quality through the reduction in pollutant discharges and sedimentation, as well as other ecological benefits. Credits created by these efforts are treated like other financial instruments, and may be banked, traded, or sold in the marketplace. In response to an emerging Clean Water Act trading program, DOE/NETL is carrying out a pilot project with the electric utility and coal industries to demonstrate the feasibility of generating water quality credits through the reclamation of abandoned mine lands.

Acid Mine Drainage

Acid mine drainage from underground coal mines, surface mines, and coal refuse piles can represent a significant source of water pollution. AMD results when water comes into contact with pyrite associated with coal. The AMD is typically high in acidity and dissolved metals, and uncontrolled AMD discharge can compromise surface and groundwater quality.

DOE/NETL has extensive experience in the design and application of active and passive treatment systems for mitigating AMD and other pollutants from coal and hard-rock mining. Many of the technologies developed are being used throughout the world to address global energy-water problems. Additionally, geophysical remote sensing technologies developed at DOE/NETL allow for accurate AMD source identification that, when coupled with treatment technologies, can provide for effective management strategies.

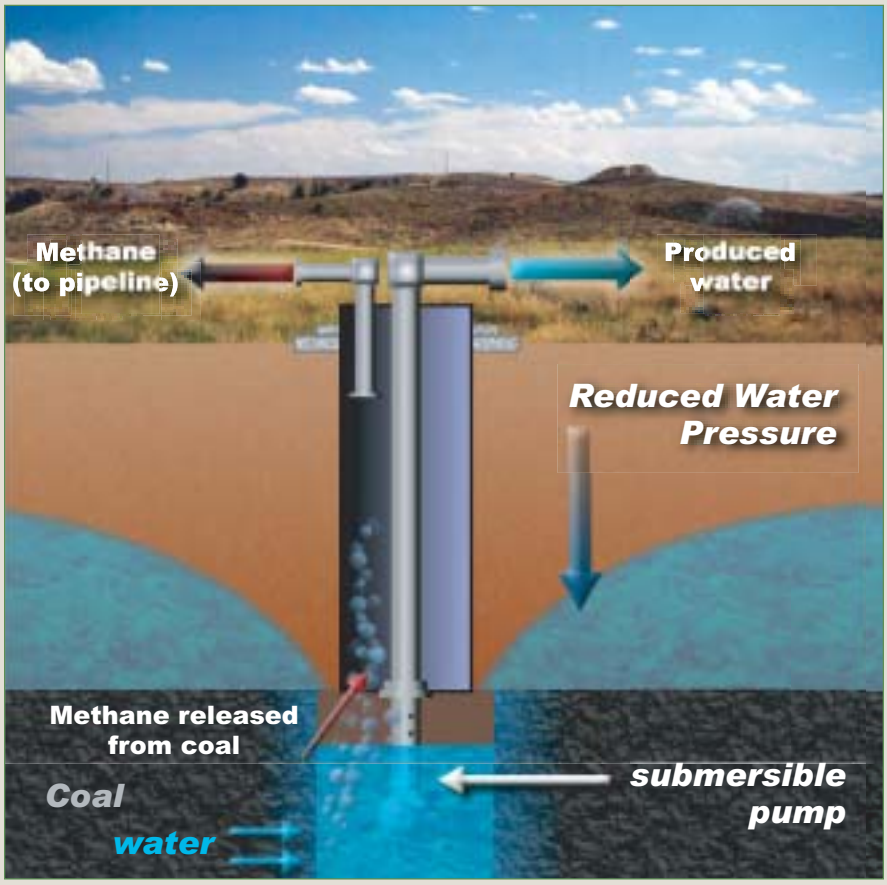
Oil & Gas Recovery

The United States is a world leader in the advancement of oil and gas recovery technologies. DOE/NETL is focused on ensuring that water produced through oil and gas development is put to beneficial use and does not adversely impact the environment.

Management of water issues is a major emphasis of DOE/NETL's Oil and Gas Environmental Program. Water-related issues include: injection of water for product recovery, produced water and its effects on the environment, treatment of process wastewater, and the availability of water in arid lands. Projects currently under way fall into three primary categories: Water Management Approaches and Analysis, Water Management Technologies, and Coalbed Methane.

Water Management Approaches and Analysis

A number of projects are in place to address regulatory issues, methods, and strategies to improve water management as well as research on water handling problems to provide input to local, state, and federal agencies. These projects focus on a number of water management concerns from initial research stages to implementation of new methods and permitting.



Coalbed methane production in the Powder River Basin

Water Management Technology

The development of new technologies to address water-handling problems is the primary focus of DOE/NETL water management technology projects. These technologies are being developed through partnerships with other National Laboratories, universities, consultants, industry, and cooperating government agencies. The outcome of these projects will provide lower cost treatment technologies to turn this waste stream into a much-needed resource.

Coalbed Natural Gas and Produced Waters

Coalbed Natural Gas (CBNG), a gas formed by the process that transforms plant material into coal, has become a significant source of natural gas in the United States. CBNG extraction is the fastest growing area of domestic natural gas production. At the end of 2001, more than 1.4 million barrels of water were produced daily from CBNG activities in the Powder River Basin. Under several current DOE/NETL projects, investigation is under way on various aspects of handling the produced waters to provide environmental protection while allowing the water to be put to beneficial uses.

Systems Analysis & Policy Support

DOE/NETL possesses strong systems analysis and policy-support capabilities directly related to the nexus between water and energy — from the extraction and mining of fossil fuels and the generation of electricity through the subsequent capture of emissions and disposal and re-use of by-products. DOE/NETL also participates in the interagency review of environmental regulatory proposals, many of which address water issues associated with energy production. This has included the review of arsenic standards under the Safe Drinking Water Act and lower reporting thresholds for lead and mercury as part of §313 of the Emergency Planning and Community Right-to-Know Act, commonly referred to as the Toxic Release Inventory. Most recently, DOE/NETL carried out process simulation modeling to approximate energy and environmental impacts of proposed cooling water intake structure regulations. In addition, a comprehensive review and analysis of the implications of water regulations on the development of natural gas resources is currently underway.

More About DOE/NETL . . .

The National Energy Technology Laboratory is a multipurpose laboratory owned and operated by the U.S. Department of Energy that conducts and implements science and technology development programs in energy and energy-related environmental systems.

A key component of the DOE/NETL mission is to "resolve the environmental, supply, and reliability constraints of producing and using fossil resources to provide Americans with a stronger economy, healthier environment, and more secure future."

DOE/NETL is located in Pittsburgh, Pennsylvania; Morgantown, West Virginia; Tulsa, Oklahoma; and Anchorage, Alaska. The Laboratory has strong expertise in fossil energy technologies, nuclear cleanup, contract and project management, system analysis, and international energy issues. To learn more about DOE/NETL, please visit our Web site at

www.netl.doe.gov

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