NETL: Erik Shuster September 26, 2007

Topic
Energy/water issues

Objective
The objective of this issue note is to explore future impacts and challenges concerning water use for thermoelectric power plants on our nation's freshwater supplies

Background

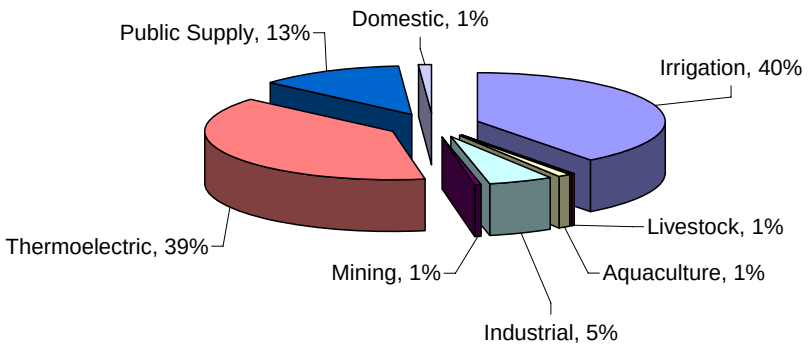
Energy-Water Issues
At the nexus of water and energy lies a wide variety of societal issues, policy and regulatory debate, environmental questions, technological challenges, and economic concerns. Water is emerging as a significant factor in economic development activities. Planning efforts must consider the availability and quality of water resources in a given locality or region to ensure that supplies are available to accommodate existing and future water consumers over the long term. Failure to do so can result in stunted growth, economic flight, inequitable development, and even open conflict. In order for the power industry to be ecologically responsible, technologically ready, and economically stable, advanced research is imperative. Energy-water issues have become increasingly visible in recent years, with a variety of concerns on the mind of industry, regulators, Congress, DOE, and the general public. A sampling of these issues includes the passing of the Energy Policy Act of 2005; repeated introduction of the Energy-Water Efficiency and Supply Technology Bill; increasingly severe regional drought conditions across the country; additional difficulty siting new power generating facilities in arid regions; and further media attention and public concern over water availability and supply.

Water Availability
Water shortages, potentially one of the greatest challenges to face all sectors of the United States in the 21st century, will be an especially difficult issue for thermoelectric generators due to the large amount of cooling water required for power generation. According to a GAO 2003 report[i], national water availability has not been comprehensively assessed in 25 years, thus water availability on a national level is ultimately unknown. However, as the report goes on to say, current trends indicate that demands on the nation's supplies are growing while the nation's capacity to store surface-water is increasingly more limited and ground-water is being depleted.

Competing Water Uses
Concerns over limited water quantities are not restricted to thermoelectric generation. According to USGS, 346 *billion* gallons of freshwater were withdrawn *per day* in the

United States in the year 2000.[ii]**Error! Bookmark not defined.** The largest use, agricultural irrigation, accounted for 40% of freshwater withdrawn (see Figure 1).

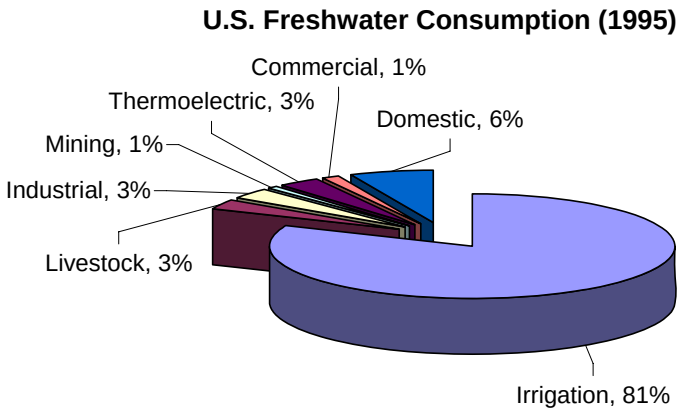
Figure 1 - Percent of freshwater withdrawal by use category



The second largest use, thermoelectric generation, withdrew 136 billion gallons per day (BGD), followed by public supply, industrial uses, aquaculture, domestic use, mining, and livestock. Interestingly, thermoelectric generation withdrew the largest amount of saline water, 60 BGD (96% of all saline withdrawn). Withdrawal of saline water (and other non-traditional waters) reduces the strain on freshwater supplies and is one research area facilitated by the IEP program.

USGS estimates for freshwater consumption for the year 1995 (the most recent year for which this data is available) is presented in Figure 2.[iii] Freshwater consumption for thermoelectric purposes appears low (only 3%) when compared to other use categories (irrigation was responsible for 81% of water consumed). However, even at 3% consumption, over 3 BGD were consumed. As a result of growing public pressures to withdraw less water, coupled with requirements under Section 316(b) of the Clean Water Act, consumption will likely increase significantly due to greater use of closed-loop cooling systems that consumes far more water than once-through cooling systems due to evaporation losses.

Figure 2 - Percent of freshwater consumption by use category



In addition to the water uses described above, increased value is being placed on in-stream freshwater uses, consisting mainly of habitat/species protection and recreational uses. In-stream uses will require a minimum flow rate or depth to be maintained in water bodies.

Because freshwater supply is limited, choices will have to be made regarding withdrawal and consumption of this natural resource. Water availability and its withdrawal and consumption are top priorities on the public agenda in many nations throughout the world. It is likely that the issue will also filter to the top of the U.S. public agenda in the near future. In water-stressed areas of the country, power plants will increasingly compete with other water users. Agriculture and public supply will most likely be the greatest competitors due to their large water withdrawal. As with all resources, tradeoffs will occur, and concerns will increasingly be raised over which use is more important: water for drinking and personal use, growing food, or energy production.

Regulatory Impacts on Water Withdrawal and Consumption

The power industry must comply with a variety of local, state and federal regulations pertaining to water acquisition, use, and quality. In considering long-term water withdrawal and consumption patterns in the power sector, the cooling water intake structure regulations established under the Clean Water Act, Section 316(b) will likely have the greatest impact. Designed to protect aquatic life from inadvertently being killed by intake structures at power stations and certain manufacturing facilities, Section 316(b) requires EPA to ensure that the "location, design, construction and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact."

EPA divided its 316(b) rulemaking into three phases: Phase I, completed in late 2001, applies to new facilities; Phase II, completed in early 2004, applies to large existing power facilities; and Phase III, due to be finalized in 2006, applies to existing manufacturing facilities. The regulations establish performance standards for cooling water intake structures based on impingement mortality and entrainment (IM&E) impacts. A minimum level of IM&E reduction is required based on the type of water

body a given facility accesses for cooling water. Compliance with 316(b) is coordinated through the individual states' NPDES (National Pollutant Discharge Elimination System) permitting program.

The largest design impact of 316(b) compliance is that most new power plants will have to use closed-loop, recirculating cooling systems or dry (air-cooled) systems. Open-loop systems are strongly discouraged unless the permit applicant can demonstrate that alternative IM&E measures can provide a reduction level comparable to that achieved through closed-loop cooling or that the compliance costs, air quality impacts, and/or energy generation impacts would outweigh the IM&E benefits and justify an open-loop system. Because 316(b) portends a greater reliance on closed-loop cooling systems, water withdrawal and consumption patterns for the thermoelectric power sector are destined to change over time. Even accounting for significant thermoelectric capacity additions, water withdrawal levels will likely remain relatively constant. Water consumption, on the other hand, is expected to increase substantially since closed-loop cooling systems consume more water, due to evaporation, than open-loop systems.

Existing and future air quality regulations will also affect water withdrawal and consumption patterns, although to a lesser extent than cooling water regulations. Tighter emission levels for sulfur dioxide, for example, have sparked a mini-boom in the flue gas desulfurization (FGD) market. The size of the U.S. FGD market is expected to increase by more than 100,000 megawatts (MW) over the next 10 years. Although FGD water requirements are a fraction of those required for cooling purposes, FGD units require a significant amount of water to produce and handle the various process streams (limestone slurry, scrubber sludge, etc.). Makeup water requirements for the FGD island at a nominal 550 MW subcritical coal-fired power plant are about 570 gpm, versus about 9,500 gpm for cooling water makeup.[iv] Nonetheless, the additional FGD systems coming online within the next decade will place a greater strain on water supplies. Notably, semi-dry flue gas desulfurization systems are available that substantially reduce water requirements for SO_2 control, and these systems are in commercial application at numerous plants, many in arid environments.

Several other regulatory actions warrant attention because of their potential impact on water withdrawal and consumption. Under section 303(d) of the 1972 Clean Water Act, states, territories, and authorized tribes are required to develop a list of impaired waters not meeting water quality standards and then establish total maximum daily loads (TMDL) for these waters. A TMDL specifies the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and allocates pollutant loadings among point and nonpoint pollutant sources. TMDL requirements could potentially constrain a power plant's ability to discharge cooling water, as well as trace metals and other pollutants from flue-gas cleanup byproducts, into a water body if the water body is impaired. The power plant may then be required to seek an alternate water source or install additional water treatment equipment.

The current debate over global climate change and carbon dioxide (CO_2) emissions could also potentially impact the water resource situation. If power plants are ultimately required to implement carbon separation and sequestration technologies to comply with

future regulations, additional water may be needed for certain process steps and groundwater could be impacted by CO_2 sequestration (in a manner similar to produced water from oil and gas recovery applications). On the other hand, water could potentially be recovered from the CO_2 stream prior to dry pumping for sequestration or reclaimed from produced waters due to underground displacement. A detailed analysis would be required to delineate the net water withdrawal and consumption associated with CO_2 separation and sequestration and is outside the scope of this study.

Legislative Activities

The Energy Policy Act of 2005 (Title IX, Subtitle G − Science, Section 979) directs the DOE to address energy-water nexus issues and assess the effectiveness of existing Federal programs to address energy-water related issues. The direction is for a program of research, development, demonstration, and commercial application to: 1) address energy-related issues associated with provision of adequate management, and efficient use of water; 2) address water-related issues associated with the provision of adequate supplies, optimal management, and efficient use of energy; and 3) assess the effectiveness of existing programs within the Department and other Federal agencies to address these energy and water related issues.

An amendment to the Energy Policy Act, the Energy-Water Efficiency and Supply Technology Bill, was originally introduced in 2004 and has gone through two revisions. The current version of the bill would allocate $5 million for the first year and "such sums as are necessary for each fiscal year thereafter." The bill would instruct the Secretary of Energy to "establish a national program for the research, development, demonstration, and commercial application of economically viable and cost-effective water supply technologies."

Drought Conditions

A Government Accountability Office (GAO) report[v] prepared in 2003 addressed the issue of freshwater supply at the state level. The report indicated that under normal rainfall conditions, state water managers in 36 states anticipated shortages in localities, regions, or even statewide in the next 10 years (2003 – 2013). The report goes on to say that "drought conditions will exacerbate shortage impacts."

During the summer of 2005, a joint effort between the Department of the Interior (DOI) and the Department of Agriculture (USDA) created Interagency Drought Action Teams to coordinate relief efforts in communities in western states facing droughts. A DOI report[vi] about the action teams quotes Secretary (of the Interior) Norton, "Much of the Pacific Northwest has been hard hit by drought this year."

Power Generation Facility Siting

Power generation facilities will have increasing difficulties siting new plants due to water concerns. Concurrently, existing plants will be under increasing pressure to reduce their water withdrawal and consumption. In 2006, RDS (NETL/DOE) contacted state government water monitoring agencies inquiring if there is a limit to freshwater withdrawal and/or consumption by thermoelectric plants in their state. Of the 33 states

that responded, 24% indicated that plants must either have a senior water right, or purchase such a water right from an entity willing to sell it. Another 18% indicated that limitations are imposed when water levels fall below the protect flow level and/or in times of water shortage. An additional 18% of states responded that water withdrawal and consumption varies regionally across the state, with some areas having no limit but other areas that are water sparse or over-allocated requiring water rights or special permits. The number of states with over-allocated water resources is expected to increase over time.

Concern about water supply, expressed by state regulators, local decision-makers, and the general public, is already impacting power projects across the United States. For example, in March 2006, an Idaho state House committee unanimously approved a two-year moratorium on construction of coal-fired power plants in the state based on environmental and water supply concerns.[vii] Arizona recently rejected permitting for a proposed power plant because of concerns about how much water it would withdraw from a local aquifer.[viii] In early 2005, Governor Mike Rounds of South Dakota called for a summit to discuss drought-induced low flows on the Missouri River and the impacts on irrigation, drinking-water systems, and power plants.[ix] A coal-fired power plant to be built in Wisconsin on Lake Michigan has been under attack from environmental groups because of potential effects of the facility's cooling-water-intake structures on aquatic life.[x] In February 2006, Diné Power Authority reached an agreement with the Navajo Nation to pay $1,000 per acre foot and a guaranteed minimum total of $3 million for water for its proposed Desert Rock Energy Project.[xi] In an article discussing a 1,200 MW proposed plant in Nevada, opposition to the plant stated, "There's no way Washoe County has the luxury anymore to have a fossil-fuel plant site in the county with the water issues we now have. It's too important for the county's economic health to allow water to be blown up in the air in a cooling tower."[xii]

Conclusion

Freshwater use is becoming a critical issue in many parts of the world. While the United States is endowed with ample water across much of the country, certain regions are encountering challenges to water supplies, particularly in the arid western states. As freshwater becomes scarce, competition arises among users, from farmers and recreation advocates to municipalities and power generation companies.

Technologies that substitute alternate water sources for freshwater and that reduce evaporation loss from cooling towers need to be explored for future reductions in water withdrawal and consumption. It should be noted that the effects of technology combinations on water withdrawal and consumption are not necessarily directly additive; care must be exercised to ensure impacts are properly measured.

References

[i] GAO, *Freshwater Supply: States' View of How Federal Agencies Could Help Them Meet the Challenges of Expected Shortages*, July 2003.

[ii] United States Geological Survey (USGS). *Estimated Use of Water in the United States in 2000*; USGS Circular 1268; March 2004.
[iii] USGS. *Estimated Use of Water in the United States in 1995*; USGS Circular 1200; 1998. http://water.usgs.gov/watuse/pdf1995/pdf/circular1200.pdf
[iv] National Energy Technology Laboratory, *Power Plant Water Usage and Loss Study*, August 2005.
[v] GAO, *Freshwater Supply: States' View of How Federal Agencies Could Help Them Meet the Challenges of Expected Shortages*, July 2003
[vi] DOI, *Federal Drought Action Team will Coordinate Drought Relief Assistance to Western States*, July 2005
[vii] Shea Anderson, Reuters, *Idaho Committee Adopts Moratorium on Coal Power*, March 14, 2006.
[viii] Land Letter. *Western Power Plants Come Under Scrutiny as Demand and Drought Besiege Supplies;* March 4, 2004; http://www.eenews.net/Landletter.htm
[ix] Billingsgazette.com. *South Dakota Governor Seeks Summit on Missouri River*, February 2005.
[x] Milwaukee Journal Sentinel. *Wisconsin Energy Just Can't Stay Out of the News with Their Intake Structures*, February 18, 2005.
[xi] Erny Zah, The Daily Times, *Desert Rock Water Agreement Passes Navajo National Committee*, February 2, 2006
[xii] The Associated Press, *Sempra Energy Halts Gerlach Project Study*, March 8, 2006