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Defining Research and Development Needs at the Energy-Water Nexus

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DEFINING RESEARCH AND DEVELOPMENT NEEDS AT THE ENERGY-WATER NEXUS

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Abstract

Currently, electric power generation is one of largest water withdrawal and use sectors in the U.S. On the other hand, water distribution, treatment, and transmission is one of the largest energy use sectors. As future demands for energy and water continue to increase, competition for water between the energy, domestic, agricultural, and industrial sectors, could significantly impact the reliability and security of future energy production and electric power generation.

To address these growing concerns, Congress directed the Department of Energy (DOE) to assess current and emerging national issues associated with the interdependencies between energy and water. As part of these efforts, DOE initiated the development a National Energy-Water Science and Technology Roadmap. The purpose of the Roadmap is to establish a long-range research, development, and demonstration program to support the efficient use of water and energy resources and sustainable and cost-effective future energy production and electric power generation in the U.S. To support these efforts, representatives from the DOE national laboratories, the Electric Power Research Institute (EPRI), and the Utton Transboundary Resources Center of the University of New Mexico School of Law, helped assess emerging energy-water interdependencies and support the Roadmap efforts.

This paper provides a short overview of some of the emerging energy-water issues and summarizes the major Roadmap efforts to assess regional and national technical issues and needs associated with the interdependencies of energy and water. The Roadmap process was needs driven and a major element was the use of three needs assessment workshops – East, Central and West Regions - to review regional water and energy use trends and identify emerging major energy and water needs and issues. The workshops were held from November 2005 through January 2006 and included regional and national energy and water experts, representatives from national, state, tribal, and local governments, universities, private industry, and non-government organizations to solicit input on suggested improvements or changes in energy and water technology application, natural resource management, and natural resource use policies that could be implemented to ensure future energy supplies are reliable, secure, and sustainable.

Emerging Concerns at the Energy-Water Nexus

The availability of adequate water supplies has a profound impact on the availability of energy, and energy production and generation activities affect the availability and quality of water. In today's economies, energy and water are tightly linked. As illustrated in Figure 1, energy production and generation require water, and water pumping and treatment require water. As these two resources see increasing demand and growing limitations on supply, energy and water must begin to be managed together to maintain reliable energy and water supplies and sustain future national growth and economic development.

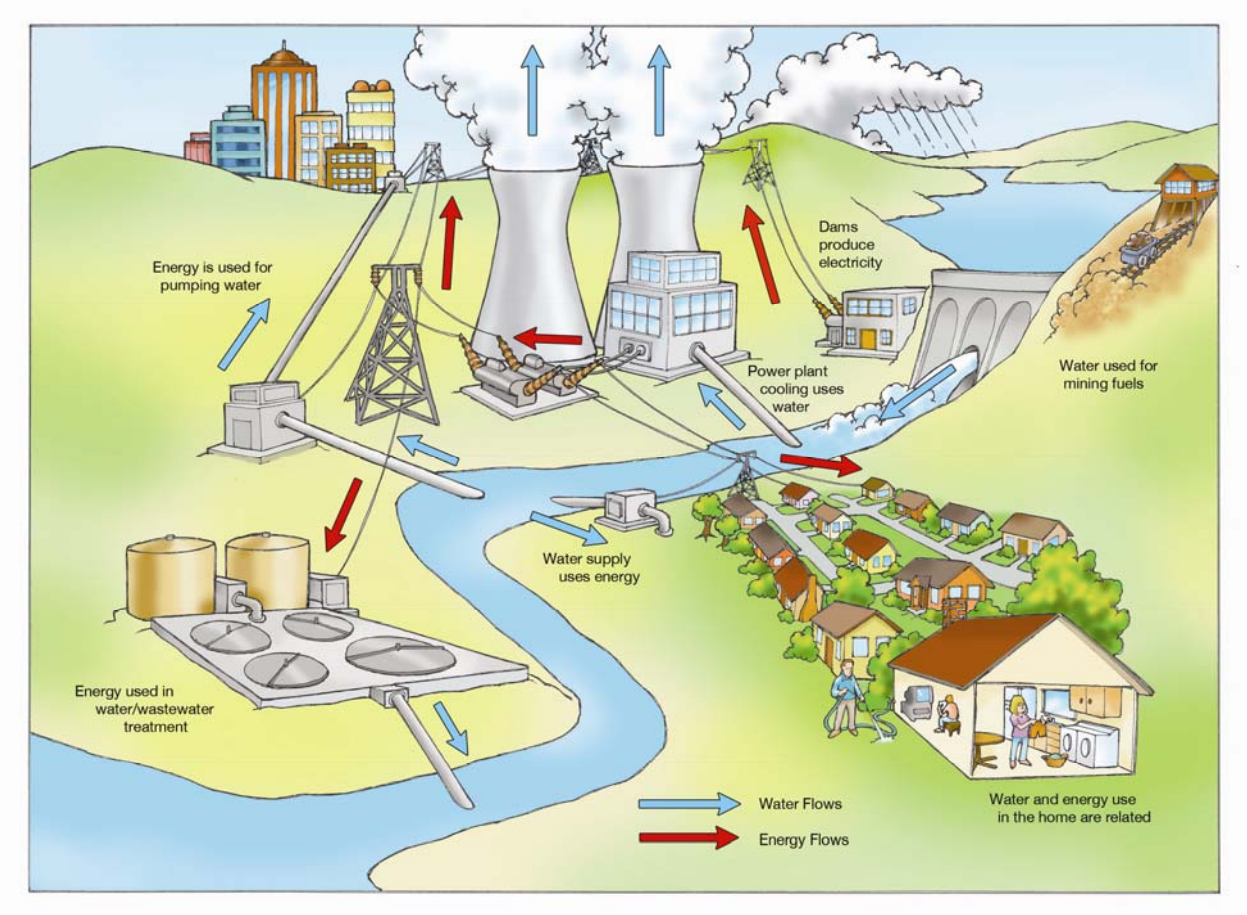

Figure 1. Examples of Interrelationships Between Water and Energy

The emerging vulnerability of the energy and water supplies and infrastructures is becoming clearer. Low water levels from drought and competing uses have limited the ability of power plants to generate power (Columbia Basin News, 2006). Additionally, water levels in aquifers in many regions of the U.S. have declined significantly, increasing energy requirements for pumping, and, in some cases, leading to ground subsidence issues. Lack of water for thermoelectric power plant cooling and for hydropower has the potential to contribute to power shortages like those of recent years that have illustrated the vulnerability of the U.S. electrical grid to unplanned generation outages, especially in hot weather.

At the same time, demand for energy continues to grow. In its reference case, the Energy Information Administration projects that demand for energy supplies from 2003 to 2030 will grow as follows: petroleum, 38 percent; natural gas, 20 percent; coal, 54 percent; nuclear power, 14 percent; and renewable energy, 58 percent. Demand for electricity from all sources is projected to increase by 53 percent (EIA, 2005). Providing this energy will require access to sufficient water resources.

Unfortunately, freshwater withdrawals already exceed available precipitation in many areas across the country. The shortfalls are most dramatic in the Southwest, in the high plains, in California, and in Florida. Population growth in these regions between 2000 and 2025 is estimated to be 30 to 50 percent. This additional population will require more water and more energy, even with current rates of improvement in energy efficiency, and supplying more energy requires more water. The challenges are not limited to these regions, however. For example, nearly the entire western shoreline of Lake Michigan has water demand above available precipitation, and aquifers in that region have declined as much as 900 feet (Bartolino et al., 2003), and are declining as much as 17 feet per year in some cases (Michigan Land Use Institute, 2003).

Management of critical water and energy resources must be integrated at the national level and coordinated across regional and local boundaries. The underlying foundation of water and energy resource data, water and energy technology, decision-support tools and models, and policy directions must also be significantly improved.

Overview of the Energy-Water Roadmap Structure and Process

Congress requested that the DOE prepare a National Energy-Water Roadmap in the Energy Policy Act of 2005. The purpose of the Roadmap is to assess the effectiveness of existing programs within the DOE and other Federal agencies in addressing energy and water related issues, and to assist the DOE in defining the direction of research, development, demonstration, and commercialization efforts to insure that:

(1) Energy-related issues associated with providing adequate water supplies, optimal management and efficient use of water, and
(2) Water-related issues associated with providing adequate supplies, optimal management and efficient use of energy,

are adequately and efficiently addressed in the future.

Sandia National Laboratories was selected to oversee and coordinate the Energy-Water Roadmap activities. This has included workshop facilitation and coordination, logistics, gap analysis coordination, research and development ranking coordination, and coordination of the development of the final report. The Utton Center, a water law center at the University of New Mexico was selected to team with Lawrence Berkeley National Laboratory to provide assistance in policy, regulatory, and economic needs identification and analysis support for the Roadmap activities, workshops, and final report.

The general process and schedule of the Energy-Water Roadmap activities are presented in Figure 2. For the Roadmap effort, two groups were established to help support the Roadmap activities. This included an Executive Committee composed of national water and energy experts representing federal agencies and water and energy associations from around the country to oversee all Roadmap efforts and processes, and an Advisory Group of DOE national laboratory representatives and EPRI (known as the Energy-Water Nexus Advisory Group) to help provide planning and guidance on all aspects of the energy and water interdependencies analyses and Roadmap activities.

To support the Roadmap efforts, three of the national laboratories on the Advisory Group - Sandia and Los Alamos National Laboratories and the National Energy Technology Laboratory - along with EPRI, collected information on emerging energy and water interdependencies issues at the national level. This work helped provide a basis and context for directing the Roadmap efforts and helped identify participants and sector representatives that would have a major interest at the needs, gaps, and technology innovation workshops. Sandia worked closely with the Executive Committee and the Advisory Group to ensure that adequate participation in the roadmap process occurred and that an appropriate and representative mix of energy and water experts and stakeholders from across the country participated in each step of the process.

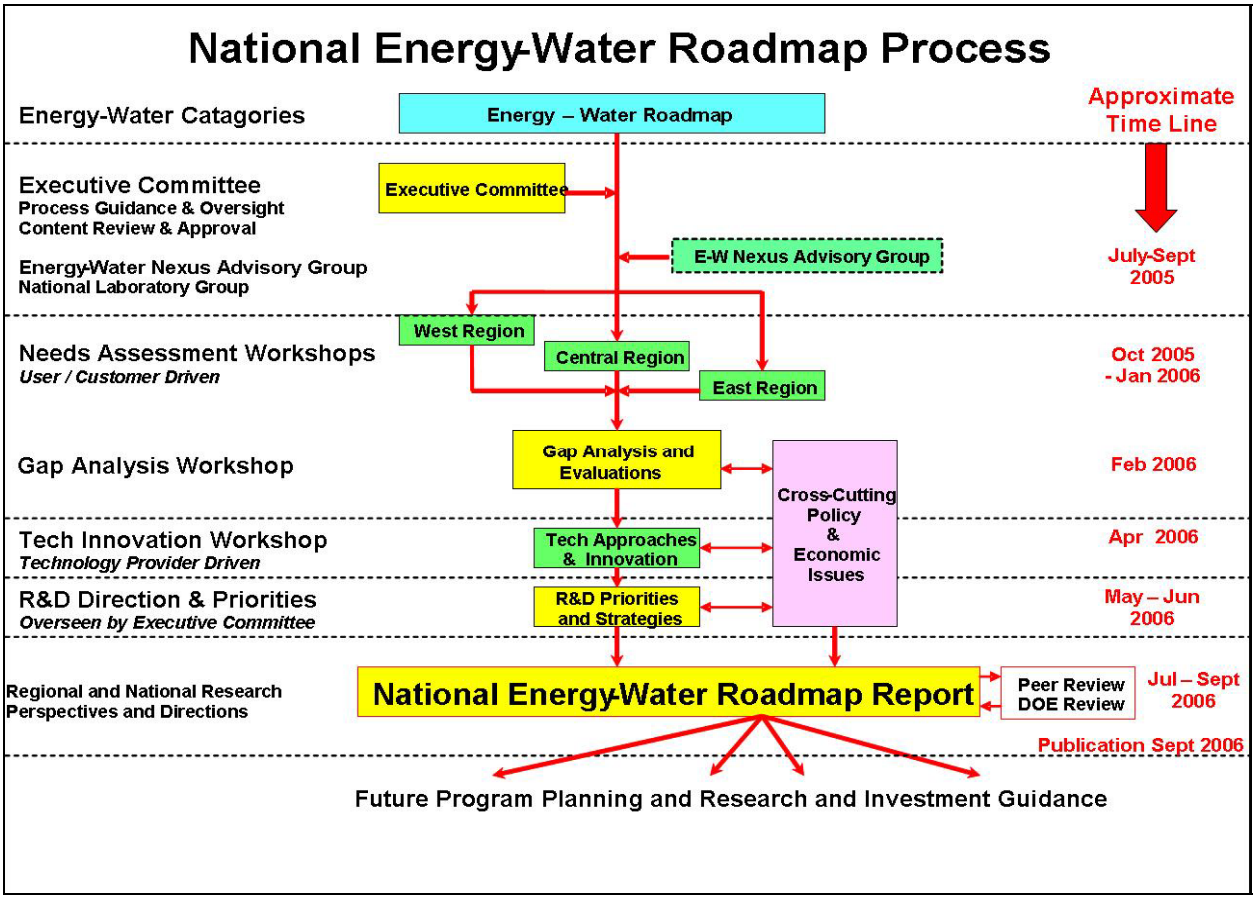

Figure 2. Energy-Water Roadmap Process and Schedule.

The Energy-Water Roadmap process was designed to assess and integrate regional issues and concerns into a nationally coordinated but regionally focused energy-water science and technology research and development program. The Energy-Water Roadmap was developed as a needs-driven process and included three major elements as shown in Figure 1:

- Identification and evaluation of regional and national energy-water issues and needs,
- Identification and evaluation of the Gaps between current programs and initiatives and future needs, and
- Evaluation of technology options that could address current or emerging issues and trends and develop these into future energy-water research strategies and priorities.

The three needs assessment workshops were designed to ensure that the establishment of current and emerging needs and issues and the research direction and prioritization criteria would be driven by the user communities. Based on the three regional needs workshops, a Gaps Analysis Workshop was held in Albuquerque in March 2006 and included a broad mix of technical experts and researchers to assess the major gaps between existing programs and the emerging issues and needs. Based on the Gaps Analysis results, a Technology Innovations Workshop was held in San Diego on May 2006 to suggest research directions and priorities necessary to meet the needs and gaps identified in the previous workshops.

Additional information regarding the Energy-Water Roadmap process, including results of the Needs Workshops, Gaps Workshop, and the Technology Innovation Workshop can be found at www.sandia.gov/energy-water. The primary product from the Energy-Water Roadmap process will be a report summarizing the needs, prioritization criteria, major gaps, innovative technical approaches and associated research needs, priorities and strategies, and associated policy, regulatory, and economic evaluations needed. This is expected to result in a roadmap that includes regional issues and cross-cutting interdependencies. Information will include suggested regional R&D issues, extramural federal and state agency R&D participation and collaboration opportunities, and suggestions for technology transfer and commercialization with industry. The final results and identified research priorities will be coordinated with DOE and peer reviewed prior to publication of the final Energy-Water Roadmap Report in September 2006.

Overview of Energy-Water Regional Needs Workshops

Three regional needs assessment workshops were held as shown in Figure 3 to identify regional needs in the West, Central, and Eastern parts of the country to help identify critical regional issues and needs. The Central Needs Assessment Workshop was held November 14-16, 2005, in Kansas City, MO, the Eastern Needs Assessment Workshop was held December 13-14, 2005, in Baltimore, MD, and the Western Needs Assessment Workshop was held January 11-12, 2006, in Salt Lake City, UT.

The regional needs workshops were designed to help ensure state and regional participation in identifying major issues in each region including technology, policy, or regulatory gaps, competing energy and water demands and concerns, and economic and environmental drivers. Each of the three regional needs-assessment workshops were to solicit issues, needs, concerns, and ideas from users and stakeholders with diverse backgrounds, expertise, perspectives, organizational affiliation, and demographics.

Figure 2. Regional divisions for the needs assessment workshops.

Seven categories of user/stakeholder participants were identified for invitation to the workshops:

1) Energy/Power/Utilities (energy mineral extraction, fossil & bio-fuels production, electric power generation)
2) Water Utilities/Water Managers/Water Planners
3) Environmental/Ecological
4) Regulatory/Policy developers and agencies
5) Economics & Economic Development
6) Other Use Sectors (Ag, irrigation districts, mining, industrial/domestic)
7) Special Interests, Tribal, and State Government associations

Overall, about 350 individuals participated in the regional workshops. Input was obtained from participants from over forty states. The final results for each of the needs workshops are presented in detail on the Energy-Water Roadmap web site, www.sandia.gov/energy-water . Based on these results, we have been able to develop a synopsis of the national and regional level needs and issues. A summary of the overarching national concerns, as well as the major regional concerns and the associated research needs are presented in the discussions that follow.

Summary of National Energy-Water Needs and Suggested Research

The recently-completed Western, Central, and Eastern Regional Energy-Water Nexus workshops possessed a variety of similarities, yet each displayed unique attributes. Looking at group dynamics, the energy level was highest in the Central and Western workshops, and lowest in the Eastern region. The workshops generated significant information regarding problems and needs, but obtaining specificity and quantification of 'Needs' was problematic. Participants either did not know how much improvement was needed in technologies/processes in the future, or were

unwilling to provide that information. That forced significant efforts in the Gaps and Technology Innovations Workshops to obtain additional detail on science and technology research and development goals and priorities.

Eastern region participants generally had a more difficult time 'seeing' the interactions between energy and water than their Western and Central counterparts, and generally did not seem to view water availability for energy production as a significant long-term problem—this may be a result of 'Eastern' water law and the relatively high precipitation rates in the region (and thus a perception that water is not now a problem).

The Central Region provided an interesting comparative look at the issues and concerns that arise when 'Western' and 'Eastern' water law collide in a region characterized by increasing water demand and energy production. The region's states display radically different approaches and levels of intensity for measuring, monitoring, and managing their water resources; this is caused by legal structures, perceptions of scarcity, and budget limitations.

Participants at the Western Region meeting, not surprisingly, were heavily engaged. It is this region that faces the greatest water-energy challenges due to high population growth and scarce water resources.

Several common problem areas were identified in all three workshops that drove suggestions for major research and development needs. These include:

- The **lack of long-term or integrated resource planning** that effectively addresses energy-water interactions at a state, watershed, or regional level. Models and decision support tools to improve this were identified as major research needs.
- Participants in all regions **express concern over (and see opportunities in) the volumes of produced waters** discharged from oil, coal bed methane, and mining activities. Technology research and development to treat and utilize these waters in an energy efficient manner to supplement water supplies were identified as major research needs.
- The **lack of consistent and detailed data, and the lack of models** that can be used to address current and emerging problems at the energy-water nexus. Development of better sensors and better ways to collect water data and manage the collected data were identified major research needs.
- Participants note that the **water intensity of conventional electricity generating technologies is a problem**, they cite the **lack of water-intensity considerations in current energy RD&D programs** as an indication of the division between energy and water communities, and **note the insufficient resources devoted to developing less-water intensive alternative electricity generation technologies** (solar, wind, etc.) Better science on dry or hybrid cooling issues and technologies as well as infrastructure improvements to improve the use of less water intensive technologies were seen as necessary. Hydropower research and compatibility with river ecology and overall management was an important research direction suggested.
- Participants note a **lack of fundamental understanding of the nation's surface and groundwater resources**, including location, quantity, quality, interactions between surface and groundwater, sustainable yield, and even the current volumes extracted or returned. They note that this **lack of understanding hampers the rational**

management of today's resources and makes long-range or integrated planning virtually impossible (This is the 'If you don't know what you have, how can you manage it?' quandary.). Improved monitoring techniques, data management, and data display were identified as major research needs.

- The **cost and value of water was also a topic of significant interest and concern** in all regions—participants note that at present, end-users do not pay the true cost of the water they consume; that water has historically been (and continues to be) undervalued in the United States; and that the legal and regulatory frameworks that bound water make it highly problematic to address this problem. Regulatory and policy studies were identified as needed to help address these issues.

Unique problem areas also appeared:

- Eastern region participants are **particularly concerned about the decay of water treatment and delivery infrastructures**, noting significant energy consumption and water loss from leakage. Research on ways to address infrastructure decay and degradation were identified as major needs.
- Central and Western region participants note **significant transmission and distribution problems and constraints**, with a lack of carrying capacity for electricity and natural gas noted. They also comment on the difficulties presented by large-scale integration of renewable energy technologies into the grid. Research on infrastructure improvements to reduce water use for energy production and generation were identified as having a major impact on future water efficiency in energy and electricity production.
- Western region participants were more **interested in climate change and its impacts on water supplies and energy production** than other groups. Research and development of validated regional climate variation models were identified as major priorities.
- **Conservation programs were a significant foci at the Western region meeting**; they noted needs for both increased energy conservation programs and the development of national-scale water conservation efforts and programs. Approaches and incentives to encourage conservation were seen as providing major improvements in energy and water efficiency.
- The **potentially massive water demand posed by ethanol production** is a significant concern for those in the Central region. New directions in national biofuels supply and demand suggest that new research into techniques that do not require crops grown with fresh water are needed.

Conclusions

The information collected during the Energy Water Roadmap process and being compiled for development into a final report suggest that most regions of the country are facing similar natural resource availability issues, needs, and concerns. Most communities and users agree that better management of critical natural resources, such as water and energy, must be integrated at the national level and coordinated across regional and local boundaries. The underlying foundation of water and energy resource data, water and energy technology, decision-support tools and models, and policy directions must also be significantly improved through science and technology research, development, and demonstration in order to sustain future national growth and economic development.

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