ATLANTIC COUNCIL

ENERGY FOR WATER AND WATER FOR ENERGY

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A Report on the Atlantic Council's Workshop

How the Nexus Impacts Electric Power Production in the United States

The Atlantic Council promotes constructive U.S. leadership and engagement in international affairs based on the central role of the Atlantic community in meeting the international challenges of the 21st century. The Council embodies a non-partisan network of leaders who aim to bring ideas to power and to give power to ideas by stimulating dialogue and discussion about critical international issues with a view to enriching public debate and promoting consensus on appropriate responses in the Administration, the Congress, the corporate and nonprofit sectors, and the media in the United States and among leaders in Europe, Asia, and the Americas. The Council is also among the few forums conducting educational and exchange programs for successor generations of U.S. leaders so that they will come to value U.S. international engagement and have the knowledge and understanding necessary to develop effective policies.

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The Energy and Environment Program at the Atlantic Council explores the economic and political aspects of energy security and supply, as well as international environmental issues. Major shifts in policies, behavior, and expectations are increasingly required throughout the world to meet the challenges of maintaining secure and sustainable energy supplies and protecting the environment while maintaining economic competitiveness. The Energy and Environment Program facilitates international cooperation on developing strategies, policies, and regulations to address the energy security, environmental and economic challenges posed by increasing energy demands and climate change.

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How the Nexus Impacts Electric Power Production in the United States

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October 2011

Acknowledgment: "This material is based upon work supported by the Department of Energy under Award Number DE-FE0000016."

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The Atlantic Council would like to thank the U.S. Department of Energy and Areva for their generous sponsorship of this workshop.

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Foreword

Many factors are driving increasing public and government leaders' interest in energy and water issues throughout the world. Global population continues to grow and with it demand for freshwater supplies for agriculture, industry, energy and recreation. The majority of this growth will be in emerging and developing countries that are already experiencing water and energy security challenges. Insecure energy supplies are bumping up against reductions in water supplies that are also becoming more costly. Heightened awareness of changes in climate patterns further drives the current debate.

The United States faces energy and water challenges as well. The energy sector is the fastest growing water consumer, and the growth is mainly in areas of the country that are facing stressed water supplies and intense competition for these limited freshwater supplies. As US demand for energy increases alongside a growing population, two major realities need to be examined and addressed. First, water is needed in every aspect of energy production. Water is used for the extraction, production, refining, processing, transportation and storage of primary energy fuels for transportation and electricity production. Water is necessary for every form of electricity generation, except for wind. Second, increasing amounts of energy are needed to pump water from increasingly deeper groundwater sources, to clean water from a wide variety of sources, to transport it, and to recycle it.

This double challenge-water for energy and energy for water is "the energy water nexus" that the Atlantic Council's Energy and Environment Program will focus on over the course of the next several years. The Energy and Environment Program convened the first of two workshops on the US energy water nexus, focusing on the nexus as it relates to electricity production. Next, the nexus will be explored with regard to the US's primary energy fuels for energy generation and transportation. This work will form the backdrop for efforts in China, India and other emerging economies over the next several years.

This present report highlights the information and recommendations to create sustainable energy and water management policies for the United States that came to light in the first workshop. It was made possible due to the presentations, for which the Council is most grateful, by experts from Capitol Hill, several US government agencies and laboratories, as well as industry and academic representatives, and leaders from the non-governmental organization community. We give thanks also to those who attended the workshop as participants.

Frederick Kempe
President and CEO

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Introduction

The Atlantic Council's Energy and the Environment Program continues its efforts to inform Congress, the American public, and key policy and industry leaders on energy related issues that impact the United States' (US) ability to protect its energy, national, economic and environmental security. The Council's goal is to develop a fact based understanding of energy related issues as well as to identify technology and policy options to address them.

The energy water nexus is emerging as one of the most important and cross-cutting issues facing the United States today. Demand for both energy and water are increasing. Water restrictions due to increasingly stressed or scarce supplies, as well as environmental concerns, are making it more difficult and expensive to produce energy supplies. This in turn is negatively affecting the production and transportation of clean water. The five major energy and water issues brought out in the workshop include rising electricity and water demand; increasing clean water scarcity and its impact on the power sector; regulatory uncertainty; lagging federal and state government efforts to address the issues; and solving the nexus will require consideration of competing demands from the agricultural sector.

Given the importance of addressing the energy water nexus, the Council has initiated a two part series on the nexus issue by bringing together leading US experts to highlight the work being undertaken by Congress, US government agencies, national laboratories, private sector companies and other institutions. The Council held the first meeting on May 17, 2011, focusing on thermal electric power production, and will convene a follow-on meeting on the nexus as it relates to the production of primary energy and transportation fuels in the fall of 2011.

This report, based on the May 2011 workshop's presentations and discussions, highlights the issues, suggested solutions, and innovative programs that companies and organizations have undertaken to address the nexus problem. It concludes with preliminary recommendations to bring about common sense and effective ways to deal with the energy water nexus in the United States.

Four key solutions can begin to address the energy water nexus, including integrating development of energy and water management policies, implementing innovative technologies, conservation of energy and water resources, and instituting appropriate water pricing strategies. Recommended actions to reach common-sense and effective solutions include:

- To lay the ground rules, government at all levels must provide policy guidelines for the next several decades.
- The federal government must craft a national energy policy, or relinquish this job to the individual state governments. In either case it should: provide the states with important planning data[1] ; assist in providing public education programs; issue effective and affordable air and water regulations and efficiency standards; develop a plan to engineer and finance the needed improvements in the nation's water infrastructure; and support industry research and development efforts to make water-efficient and energy-efficient cooling technology cost competitive.
- State governments must improve policies by increasing regional coordination so that state rules and regulations will be based on regional watershed water supplies and water demands. State governments can use effective pricing policies and regulations to accomplish their goals.

- The utility industry, with the assistance of its research institutions and allied industries, must develop better ways to produce energy more efficiently; reduce water consumption per megawatt of electricity produced; and to use alternative water supplies.
- There must be a resolution of the current federal regulatory impasse that balances the economic and environmental costs of such regulations. Part of the solution to improving the energy water nexus will be matching generation choices and cooling technologies to each region and individual site's available natural resources and water availability.

Issues:

Five Major Concerns Highlighted in the Workshop

Michael E. Webber, Assistant Professor at the University of Texas at Austin, sums up the energy and water nexus and the critical importance of dealing with this issue:

Water and energy are the two most fundamental ingredients of modern civilization. Without water, people die. Without energy, we cannot grow food, run computers, or power homes, schools or offices. As the world's population grows in number and affluence, the demands for both resources are increasing faster than ever. Woefully underappreciated, however, is the reality that each of these precious commodities might soon cripple our use of the other. We consume massive quantities of water to generate energy, and we consume massive quantities of energy to deliver clean water. Many people are concerned about the perils of peak oil – running out of cheap oil. A few are voicing concerns about peak water. But almost no one is addressing the tension between the two: water restrictions are hampering solutions for generating more energy, and energy problems, particularly rising prices, are curtailing efforts to supply more clean water.[2]

The five major issues brought out in the workshop include rising electricity and water demand; increasing clean water scarcity and its impact on the power sector; regulatory uncertainty; lagging federal and state government efforts to address the issues; and solving the nexus will require consideration of agricultural sector competing demands.

Issue 1: Electricity and Water Demand Spiral Upward Together

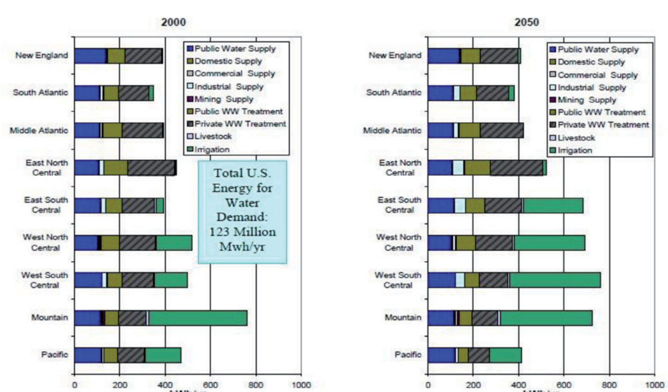
Electricity Demand Considerations

The US Energy Information Administration (EIA) estimates that by 2035, electricity demand in the United States will increase by 25 percent over 2008 demand levels. EIA projects demand will rise from 4,107 billion kilowatt hours (BkWh) to 5,123 BkWh in that time period.[7] Population and economic growth are but two factors in the increasing electricity demand projections-water is another.

An increase in US population will require more clean water for drinking, food production, and recreation needs. The mirror side of the equation is that it takes a significant amount of energy to provide that water. Approximately three percent of all US electricity today is used to pump, treat and transport water, sometimes representing a municipality's single largest operating expense, other than labor costs.[8] Some states though have significantly higher electricity related water requirements. California uses twenty percent of its electricity, 30 percent of its natural gas and 88 billion gallons of diesel fuel for sourcing, moving, treating, heating, collecting, retreating, and disposing of its water.[9]

Energy is needed to meet water demands for public, commercial, industrial, and mining supply; waste water treatment; and livestock and irrigation needs. In 2000, the US used over 123 million MWh of electricity to satisfy its water demand.[10] Figure 1 depicts each US region's energy water requirements and how they will increase by mid-century.

Figure 1: Per Capita Energy Use for Water Supply and Wastewater Treatment[11]



Realities of the Energy Water Nexus

Demand Considerations:

- Population growth +economic growth – efficiency +conservation (still)= electricity load growth
- Large quantities of water are required to generate electricity: as of 2005, 143 billion gallons per day were withdrawn and 4 billion gallons of water per day were consumed[3]
- Population growth will decrease per capita water availability
- Large quantities of electricity are required to pump, clean and transport water for increasing population requirements
- Areas of greatest population growth are in areas with constrained water supplies
- Water restrictions have already shut down some power plants and will surely lead to early closure of others[4]
- Using alternative sources of water, such as saline bodies of water, for cooling power plants will require large amounts of electricity

Cost Considerations:

- Increasing electricity costs will impact production cost of clean water
- Physical condition of water infrastructure for gathering, treatment and transportation is deteriorating, leading to wasted water, increased energy needs to compensate and overall higher costs for both energy and water
- 1.7 trillion gallons of clean water are lost annually due to infrastructure issues[5]

Supply Considerations:

- Vast quantities of the US's fresh water supplies are not in easily recovered areas like streams and lakes-an issue compounded by the fact that areas that have high water requirements such as urban areas and farmland are not always located close to available water supplies
- Water scarcity is increasing with declining aquifers and reduced usable river flows
- Water supply conflicts are growing, especially in the south and southwest, as the US faces a severe drought comparable to the Dust Bowl days
- Water is usually treated as a local concern, but aquifers span state borders whose governing bodies have competing interests

Emerging Considerations:

- Power plant siting is increasingly constrained by water issues and plant operations have been impacted/interrupted due to water availability[6]
- Regulations are becoming more stringent and costly
- Climate change effects have exacerbated concerns over pending water scarcity, and at a minimum, lead to uncertainty over future water supplies and costs
- Linkages between energy and water have grown more complex and interdependent

As shown, two regions are projected to experience large rates of growth in electricity demand for water supply and wastewater treatment needs. In the South Central states, annual per capita electricity consumption is predicted to increase from 400 to 700 kWh per year. In the West Central states, electricity demand is expected to rise from almost 500 to over 700 kWh per year. The Pacific zone is the only area in the US expected to experience a decline.

Water Demand Considerations

Data from 2000 show that the US withdrew over 340 billion gallons of water from its rivers, lakes and aquifers and consumed 100 billion gallons per day.[12] (The difference in withdrawal and consumption relates to the fact that water can be withdrawn and then returned to its source to be used again whereas consumed water is removed and not returned to its source.) Here are highlights of US water usage[13]:

The US population consumed 100 billion gallons of water per day:

- 80.8 billion gallons for irrigation
- 3.3 billion gallons for livestock
- 7.1 billion gallons for domestic uses
- 1.2 billion gallons for commercial uses
- 3.3 billion gallons for thermoelectric power production
- 1.2 billion gallons for mining
- 3.3 billion gallons for industrial purposes

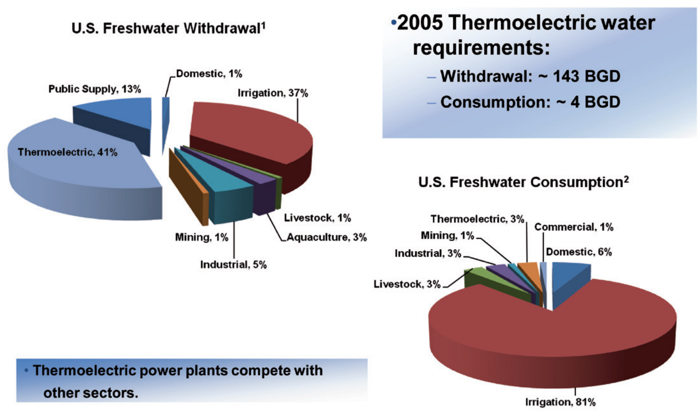
The US withdrew approximately 345 billion gallons of water per day:

- 135 billion gallons for thermoelectric power
- 138 billion gallons for irrigation
- 48 billion gallons for public and domestic supply
- 17 billion gallons for industrial supply
- Almost 3.5 billion gallons each for aquaculture, livestock and mining supply

Thermal power plants require large quantities of water to produce electricity (90 percent of which is generated by thermal power plants) and it is used for environmental control, ash handling (from coal plants), steam turbine performance and enhancement, fuel processing, boiler and reactor makeup water, and housekeeping needs. The greatest amount of water is needed for cooling purposes. Thermal power plants employ steam turbines to create electricity and the turbines are typically cooled with water to condense the steam when it exits the condenser. An increase in power production is expected to lead to significant increases in demand for both water withdrawal and consumption.[14]

As depicted in Figure 2, which compares the withdrawal and consumption of water by various sectors throughout the US, thermoelectric power plants withdraw far more water than they consume, but also consume dramatically less than irrigation/farming needs. Thermoelectric power plants, as of 2005, accounted for 143 billion gallons per day in withdrawals but only consumed 4 billion gallons per day.

Figure 2: Comparison of Freshwater Withdrawal and Consumption by Sectors[15]



Water Withdrawal Considerations

Thermal power plants account for up to 41 percent of total US freshwater withdrawals for cooling and related purposes.[16] While electricity generation has grown by a factor of 15 since 1950, water withdrawals for power have remained fairly constant since 1980.[17] Much of this progress has been due to environmental legislation that restricts once-through cooling (which requires large amounts of water) in favor of closed-loop cooling. Industry has reduced water withdrawal per unit of electricity by a factor of 3 over the past six decades.[18]

Water Consumption Considerations

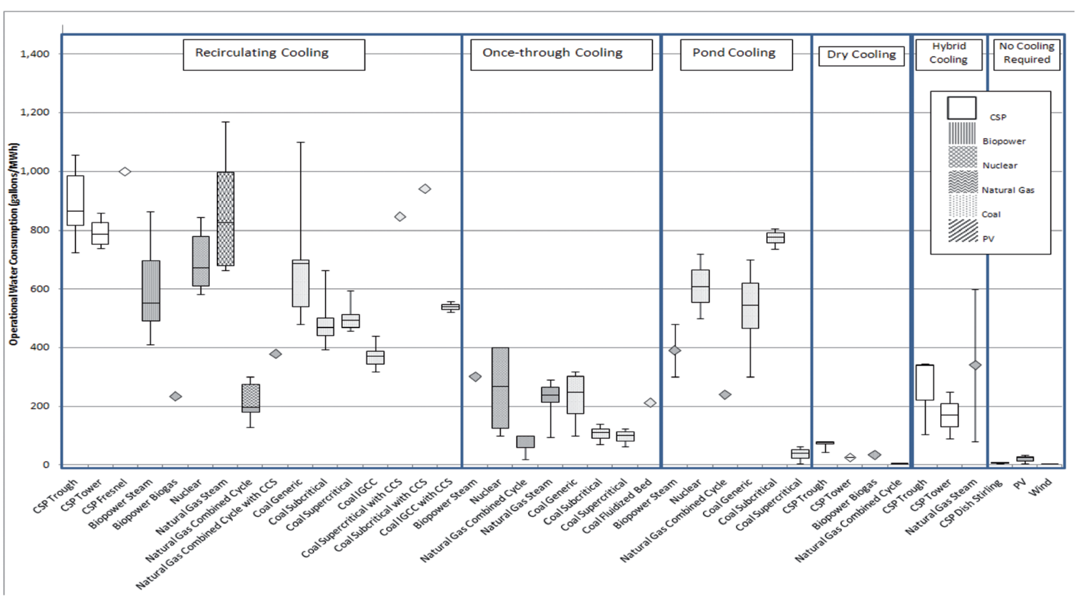
Although today thermal power plants only represent only 3 percent of water consumed in the US[19]; with increasing demand for power, water consumption for thermoelectric power is projected to increase by as much as 63 percent between 2005 and 2030.[20] As discussed in the technology section below, the trend to require closed-loop cooling measures will increase water consumption.[21] Furthermore, if climate change mitigation strategies require the full deployment of carbon capture and sequestration (CCS) technologies,[22] future water consumption for power would more than double.[23]

Figure 3 compares water consumption of power generation options. It shows that the water intensity of power generation by natural gas is lower than all of the other energy options except photovoltaic solar and wind.

Issue 2: Water Demand Bumping Up Against Stressed and Increasingly Scarce Water Supplies

The current US energy-related consumption rate of 3 percent may be considered to be a low and/or acceptable percentage today. Overall, however, this percentage is forecast to grow significantly. More importantly, several regions in the US will experience unique challenges due to water scarcity and competition for limited water resources between industrial, utility and public sectors.[25] Water demand will increase due to increasing electricity demand in water constrained states such as California, Texas, and Arizona. Water consumption may increase in states such as Texas and Pennsylvania due to hydraulic fracking, in the Southwest for solar generation, and in the High Plains states for biofuels production.

Figure 3: Comparison of Water Consumption Rates [24]



In the US, nowhere is the energy water nexus more evident than in the state of Arizona. To meet the forecasted energy needs of a population that is expected to double in size between 2000 and 2040, without aggressive energy efficiency and smart growth rules, the state could need the equivalent of four 4000 megawatt (MW) Palo Verde nuclear power plants or eight 2080 MW Hoover Dams or twenty-eight 570 MW combined cycle natural gas plants.[26] However, with Arizona's water sources rapidly shrinking, there will be serious limits on the supply of water available to cool new power plants, and the price of both electricity and water will increase. Arizona's situation epitomizes the dual threats of water scarcity and increased energy demand--and the economic consequences of both threats.

Regardless of whether water is consumed, or withdrawn and discharged for cooling purposes, the US faces growing limitations on fresh surface and ground water supplies. The vast majority of electricity generated in the US comes from thermoelectric facilities that depend on access to cooling water. Regional drought and low water flow conditions are impeding the full use of these cooling water sources. There has been little increase in surface water storage capacity since 1980. Many aquifers are facing reductions in water quality and yield. Underground reserves in arid areas replenish at very slow rates, usually less than 0.5 percent per year. If water is pumped too rapidly from aquifers, it is effect mined.[27] Compounding this situation is the fact that the regions experiencing the most growth in population – and hence growth in energy and water demand – are those already under water stresses. In several individual states, the increasing water demand picture is dire. Expected increases of 41 percent in California, 106 percent in Nevada and Arizona, and 63 percent in Florida signal serious problems to come.[28] Regionally, water demands in the Northwest and southeast are likely to increase by 165 percent and 79 percent, respectively. In the Western half of the US especially, stressed water supplies are requiring penetration to deeper water tables, in turn requiring even more electricity to pump out these deeper water supplies. Likewise, constrained water supplies often involve usage of marginal water resources that require increased amounts of energy to treat, transport and reuse. For example, surface water treatment requires 60 kilowatt hours per megaliter of water (kWh/ML) while groundwater treatment requires 160 kWh/ML, and brackish groundwater treatment energy requirements range from 1000 to 2600 kWh/ML.[29] Even under average weather conditions, most state water managers expect water shortages over the coming decade.

Issue 3: Industry Faces Significant Regulatory Uncertainties and Related Cost Increases

The electricity industry faces a myriad of regulatory issues, chief among them water related. These issues include effluent guidelines for wastewater and ash handling, changes to the Clean Water Act's (CWA) rules on water intake structures, the "Waters of the United States" rulemaking, coal combustion products rulemaking, water transfers between watersheds/regions, regional compacts for withdrawal permits and other issues pertaining to climate change and mercury limits.[30]

The Environmental Protection Agency (EPA) is expected to issue a final rule in July 2012 regarding changes to section 316(b) requirements on cooling water intake structures of the Clean Water Act (CWA). The utility industry is concerned that over 600 steam-driven electric generating facilities would be affected at a total annualized cost of $383.8 million, while only offering $18 million in benefits to the public.[31] There are a total of 1,260 existing facilities, of which only 760 are likely to conform to the proposed rules.[32] There are additional concerns that the rule could require plants to be re-engineered to replace once-through cooling systems with cooling towers, even though alternative strategies using currently available technology may work better since each power plant is unique in its location, water body source and aquatic resources.[33]

The EPA is also proposing regulations to address concerns that the volume of water withdrawn by facilities for cooling purposes is harming aquatic wildlife. Because of the pull towards the water intake screens, 40 percent of the large fish that cannot swim away from the screens die, and 60 percent of the smaller organisms that pass through the screens get trapped in the cooling system. Moving to closed-cycle cooling systems would protect the aquatic life and also minimize some of the thermal impact on the water body made by the discharged cooling water. For example, at coal fired plants, discharged water is 17 degrees F hotter than when it entered the plant. Water discharge temperatures for nuclear power plants with a once-through cooling system are up to 30 degrees F higher than the source.[34] The EPA recognizes that there are drawbacks to its proposed regulations including, water loss due to evaporation with wet cooling technology; the high cost of the technology and its energy and air impacts; and, the existence of alternative technologies available to deal with the fish impingement issue.[35]

Another proposed change in CWA rules is affecting industry. New rules on the "steam electric effluent limitations guideline," referred to as ELGs, are likely to set strict performance standards that will force technological and operational changes at existing coal-fired, nuclear, gas-fired and combined cycle plants. These standards have not been revised since 1982, and coal plants will feel the most significant impacts. These changes will address the release of toxic pollutants (e.g. mercury, selenium, and arsenic) into the flue gas desulfurization wastewater and ash ponds.[36] The final rule, expected to be published by the end of January 2014, is estimated by industry, in its present iteration to cost $43 billion over 20 years for coal ash compliance, and that physical, chemical and biological treatments at individual facilities could range between $30-200 million per facility.[37] Some of these costs may be offset through the greater beneficial use of coal ash, especially in construction.

Issue 4: Federal Efforts Lagging While State Efforts Just Developing

Congressional and federal agencies are increasing their interest in the energy water nexus; however, a review of these efforts dating back to the early 1970s shows a lack of coordination and consultation among the agencies, as well as contradictory assessments as to whether or not water availability would constrain power production over the past four decades.[38] Adding to the problem of addressing the energy water nexus now is the difficulty of reaching a consensus on legislation amid the tense political atmosphere in the 112th Congress.

Congressional and federal agencies are increasing their interest in the energy water nexus; however, a review of these efforts dating back to the early 1970s shows a lack of coordination and consultation among the agencies, as well as contradictory assessments as to whether or not water availability would constrain power production over the past four decades. Adding to the problem of addressing the energy water nexus now is the difficulty of reaching a consensus on legislation amid the tense political atmosphere in the 112th Congress.

There are limitations to the information and data collected by federal government agencies, such as the EIA and the US Geological Survey (USGS). Glaring information gaps are apparent in the understanding of advanced cooling techniques, water consumption by power plants, use of alternative water sources, withdrawal versus consumption statistics, and water usage by non-power sectors.[39]

In addition to the problem that inadequate data may be used in the state and regional planning processes is the fact that few states have catalogued the status of the energy water nexus within their own borders. Only nine states have statutes addressing the issue, with only Arizona, California and Colorado issuing statutes specifically addressing the energy water nexus. Many states have not developed official policies regarding water use by power plants and in some cases, states do not even require a state permit for water use by new power plants.[40] The California Public Utility Commission annually produces a water action plan and aggressively promotes dry cooling in desert areas.[41] Wisconsin and West Virginia have statutes that encourage water conservation and efficiency.

Issue 5: Solving the Energy Water Nexus Requires Consideration of Competing Agricultural Sector Needs

The interlinked needs of energy for water and water for energy are firmly established. While the scope of the issue is serious enough to get the attention of government and industry officials, the energy water nexus dilemma is often considered out of context. Energy-water-agriculture interconnections run deep:

- 3 percent of US electricity is used to pump, treat and transport water mainly for agriculture, public consumption and recreation uses.
- Energy is also needed to support agricultural needs for the production of fertilizers, powering farm irrigation systems, and processing and transporting food.
- The crops grown for ethanol fuels, in particular, require large amounts of water, thereby increasing water demands. Furthermore, the nutrient runoff from irrigated lands contributes to pollution of local waters.
- The extraction and processing of primary energy fuels also leads to some surface and ground water pollution.
- And on top of it all, electricity is needed to clean water supplies for public consumption, recreation purposes and other uses.

For perspective, thermal power plants withdraw slightly more water but considerably less for consumption than irrigation and livestock needs.[42] Thermal power production represents 41 percent of total US withdrawals but only 3 percent of total consumption. In contrast, irrigation and livestock represent 38 percent of withdrawals and 84 percent of consumption. Agriculture and thermal power are in direct competition for limited water resources.

The conclusion is not that the energy water nexus issue is dwarfed by the energy-water-agriculture dilemma. Rather, these energy, water and agriculture needs are interdependent parts of a larger nexus reflecting interrelationships within the earth's ecosystem. Water needs for agriculture will grow as the population grows, further constraining availability of water for competing needs for power production. As increasing water and energy demands butt up against declining aquifers, the complex interdependencies at play require the most carefully constructed, interdisciplinary strategies to balance the competing requirements.

Solutions:
New Technologies and Policies Can Address the Energy Water Nexus

The energy water nexus may be coming to a head in several areas. In the West and Southwest areas of the country, population and energy demands are increasing. In the East, environmental concerns are forcing changes to water cooling techniques and causing power plant closures.

Fortunately, the issue has not yet reached a crisis stage, and there are opportunities to tackle the problems. As discussed in the next section, the level of discourse among government, stakeholder and industry groups is rising, and there are a myriad of activities underway to find the right solutions before the nexus becomes a crisis. As noted during the workshop discussions, there is "value in creating a tool box of technologies and practices."[43]

Eight solutions suggested at the workshop that can put the US on a sustainable path of continued economic growth and protection of our ecosystems are discussed next.

1) New Federal Government Policies Called For

Before the energy water nexus can be tackled, stakeholders at the workshop argued that Congress must pass legislation establishing a clear national energy policy so that the private sector can make the investments in technology and infrastructure to safeguard our water and electricity supplies. At the federal level, agencies are addressing the current issues and Congress has considered – but not passed – comprehensive legislative solutions.

With respect to specific energy and water issues, Congress has put forward legislative proposals. In the 111th Congress, the Senate considered The American Clean Energy Leadership Act and the Secure Water Act, the former having a comprehensive energy and water title. In the 112th Congress, Senators Bingaman and Murkowski are co-sponsoring legislation to improve and expand US hydropower resources. The House has considered legislation such as the Energy Water Integration Act, which would improve coordination between 20 federal agencies on water and energy issues. Fortunately, Congress is well aware of the issues and has drafted several pieces of appropriate federal legislation, but the legislation has not been enacted prohibiting the promulgation of effective regulations and/or programs.

In the workshop, participants made the following proposals for Congressional and federal government agency action:

- Improve waterways and water transportation infrastructure to reduce the energy required for transporting water, and minimize the loss of clean water to evaporation
- Authorize a national data collection system to assess water use and supply in the US
- Improve the capacity and efficiency of existing, federally owned hydroelectric facilities
- Develop a public education campaign to educate citizens about the costs of water production and the need for water management and conservation with a goal of increasing public support for governing authorities' to approve the implementation of appropriate pricing and water management policies
- Fund research and development on water use, water efficiency of consumer products, and water conservation
- Fund research and development on reducing the hot weather penalty in power plants to make dry cooling more cost competitive
- Fund research and development on using alternative water sources for cooling purposes from agricultural drainage, seawater, storm water, municipal effluent,

water produced by oil and gas wells, and saline ground water

- Perform comprehensive research on the interdependencies between energy, water, food and ecosystems
- Provide technical assistance and funding to rural communities to improve their infrastructure and conservation opportunities

2) State Government Level Actions Needed

Recognizing that a vast number of decisions governing the usage of water and permits for thermoelectric power plants are made at the state level, state governments also have a responsibility to address the problem. Suggested state government level actions and solutions were put forward, including:

- States and regions should assess their own energy water nexus
- Adopt legislation suited to their needs, keeping the region and common waterways/aquifers in mind
- Establish safe water yields in states with the most critical problems, such as Arizona, New Mexico, Nevada, California, Colorado, Florida and Georgia
- Consider following California's lead and create state water action plans; regions could consider adopting a similar approach to good governance
- Consider adoption of more aggressive renewable and energy efficiency standards that lead to adoption of electricity generating options that use considerably less or no water
- Reassess funding for urban water projects, so that they do not incentivize projects that increase water consumption in areas where water needs to be conserved

3) Good Governance Strategies Envisioned

Good governance strategies are needed at every level of government. However, they are crucial at the watershed level which requires city and state government agency cooperation. There was considerable discussion by the workshop participants that in developing solutions to the energy water nexus, proper risk management must include strategies that address the combined influences of population growth, land use change, technological advances, and climate variability – at the regional level.[44] Integrated regional planning solutions should take into account:

- Siting of power plants
- Regional aquifers
- The capacity of existing transmission systems
- Regional needs for industry, agriculture, recreation
- All stakeholder concerns
- Urban growth plans

Such a cooperative, regional, stakeholder management strategy, based on the needs of an entire watershed area, may lead to wiser use of water resources for power generation, agricultural production, recreation, and the other competing water needs than if only addressed state-by-state.

4) Effective Regulatory Requirements are Essential

The workshop participants examined the tension between federal regulatory bodies and the electric power industry, with particular emphasis on the proposed revisions to the CWA. A bright spot emerged in the experience that Duke Power had in its Catawba-Wateree Comprehensive Relicensing Agreement, which was initiated in 2003 and completed in August 2006.[45] This experience demonstrated that successful outcomes can be obtained when solutions integrate multiple users, stakeholders, and perspectives at the watershed level, rather than simply imposing a static regulatory approach at a single power plant source.

The conference participants offered a host of potential state and federal regulatory policies that would lead to energy and water efficiency, water conservation, and more appropriate uses of water by all water consumers. They included:

- Reuse of municipal and industrial waste water for cooling and agriculture where possible
- Co-location of power plants and water treatment facilities
- Development of smart software (e.g. smart grids) to control the use of water for landscape uses
- Requirement that consumer products embrace water efficient-not just energy efficient- technologies

5) Electricity Generation Choices Can Impact Water Demand

Long term, US water demand will be impacted by choices made in the electricity generation portfolio as each technology has a different water consumption profile. Water consumption for each option, as measured in terms of gallons of water consumed, per MWh is listed below[46]:

- Over 900 for CSP with troughs
- Over 800 for nuclear power plants
- Less than 600 for CSP with cooling
- Slightly less than 600 for enhanced geothermal systems
- Slightly less than 600 for conventional coal plants
- Slightly less for supercritical than for conventional coal plants
- More than 400 for nonirrigated biomass facilities
- Less than 400 for IGCC coal plants
- Approximately 200 for natural gas combined cycle plants
- Less than 200 for binary geothermal plants
- Almost zero for photovoltaic and dish sterling solar plants and for wind farms

Recent model analysis work done by the Institute for Strategic Energy Analysis shows that increasing the role of renewables in the generation portfolio to 25 percent by 2050 could theoretically reduce US water consumption significantly. In their postulated scenario, total electricity generation would increase 38 percent in the time period, but water consumption could decline by 7 percent due to the lower water demands of renewable energy plants. Many renewable generation plants have low water withdrawal and consumption rates: wind turbine farms and photovoltaic plants require negligible amounts of water for the production of electricity, in the range of 1 gal/MWh.[47] In the workshop it was estimated that under the current Renewable Energy Standards and Energy Efficiency Resource Standards that have been adopted by many state governments, 23 billion gallons of water will be saved by 2020.[48] Furthermore, renewable energy technology can be doubly useful if used for water treatment facilities.

Not all renewable power production options necessarily result in lower water profiles. Renewable hydroelectric power plants use more water to generate a megawatt of electricity than any other form of electricity generation, requiring 4,500 gallons to produce just one megawatt. The cooling technology employed on a thermal renewable power plant is a key factor impacting renewable power's water profile. A concentrating solar power (CSP) plant needs, at minimum, a small amount of water for the steam cycle and mirror washing. A wet cooled CSP requires between 800-900 gallons per Megawatt hour (gal/MWh)-a higher consumption rate than many non-renewable technologies. In fact, in Nevada, state regulators do not approve wet cooling for solar power plants. Dry cooled CSPs have lower water consumption rates than many non-renewable technologies, consuming approximately 100 gal/MHh.[49] The drawback for the more efficient dry-cooled CSP, however, is the 3-5 percent increase in cost per MWh. In hot areas, dry cooling decreases output by approximately 5 percent.[50]

6) Changing Cooling Methods Can Reduce Water Requirements

The water withdrawal and consumption rates for thermal power plants are highly dependant on the cooling technology employed at the plant. For example, once-through (or also described as open-looped) cooling systems withdraw large quantities of water, but return most of it to the source.[51] Closed-loop systems re-circulate cooling water and remove excess heat through a cooling tower or pond. Although closed-loop systems withdraw less water than once-through systems, they consume more water due to evaporation. Other plant systems, including environmental controls, can also affect water consumption. For example, adding scrubbers on coal plants to reduce air emissions increases water consumption. CCS on fossil plants may lead to an 80 percent increase in both water withdrawal and consumption.

In general, the most effective way to reduce the water withdrawal needs of thermoelectric power plants is to simply change to a more efficient cooling method. As shown in Figure 4, which compares the withdrawal and consumption rates of fossil (coal) and biomass, natural gas, nuclear and several different renewable power plants on the basis of the cooling technology employed, water withdrawal rates are dramatically lower in the fossil, nuclear and natural gas combined cycle plants that have closed-loop cooling systems.

Figure 4 also shows that water consumption also varies primarily due to cooling method. For some renewable technologies such as photovoltaic, wind and CSP plants using stirling engines[52], the only water consumed at the plants is for cleaning (mirror washing) purposes.[53] In general, closed loop cooling systems lead to larger amounts of consumed water.

High water-consuming plants such as CSPs and natural gas steam cycle plants are not widely used in the US. The majority of the power plants that are run extensively in the US are coal, nuclear and natural gas combined cycle plants. Typical water consumption rates for these plants can be summarized as follows:

- 500-700 gallons/MWh for cooling towers
- About 200 gallons/MWh for once-through systems
- 500-700 gallons/MWh for cooling ponds
- Less than 100 gallons/MWh for dry cooling methods.

Figure 4: Water Use and Consumption for Electric Power Generation[54]

Plant Type	Cooling Process	Water Use Intensity (gal/MWhe)		
		Steam Condensing		Other Uses
		Withdrawal	Consumption	Consumption
Fossil/ biomass steam turbine	Open-loop	20,000-50,000	~200-300	~30
	Closed-loop	300-600	300-480	
Nuclear Steam turbine	Open-loop	25,000-60,000	~400	~30
	Closed-loop	500-1,100	400-720	
Natural Gas Combined-Cycle	Open-loop	7,500-20,000	100	7-10
	Closed-loop	230	180	
Integrated Gasification Combined-Cycle	Closed-loop	200	180	150
Carbon sequestration for fossil energy generation	**~80 percent increase in water withdrawal and consumption**			
Geothermal Steam	Closed-loop	2000	1350	50
Concentrating Solar	Closed-loop	750	740	10
Wind and Solar Photovoltaic	N/A	0	0	1-2

Water consumption and withdrawal can be reduced across the board with dry cooling technologies. However, there are technical, economic and supply issues to be addressed while transitioning from wet to dry cooling techniques. For the current fleet of power plants, cooling system changes may not be economically feasible. In addition, the dry cooling option for the current generation of nuclear power plants is somewhat limited. For newer nuclear plant designs, it would entail significantly higher building and maintenance costs. In coal-fired plants, dry cooling would decrease the efficiency of the plant, increasing its coal consumption with attendant increases in air and solid emissions.

In summary, thermal power plant cooling solutions exist to reduce water withdrawals and consumption. The key to moving to more efficient cooling systems, including hybrid systems which are in different phases of research and development[55], will be synchronizing regulatory requirements with concerns for the local environment, the availability of generation technology options, and the cost implications of the cooling measures. However, advanced cooling techniques are likely to result in energy production penalties and higher costs.

7) In-Plant Water Conservation Technologies and Revamped Operational Strategies are Required

In addition to cooling techniques that can improve the efficiency of the water use at any given power plant, utilities have other tools at their disposal. For example, the Palo Verde nuclear power facility uses treated sewage effluent from Phoenix to cool its turbines, resulting in 20 billion gallons of water being recycled each year. Palo Verde shows that a nuclear plant can be sited in a desert area. It further shows that the nuclear industry will be able to design nuclear power plants so that degraded and or reclaimed waters can be used for cooling, steam generation, and plant maintenance.

Going forward, utilities will increasingly develop and utilize techniques to reuse, recover and recycle water within the power plant facility. Reuse of treated wastewater is forecast to increase[57] from approximately 4 percent today to about 30 percent by 2025.[58] Concerns that use of alternative water resources may adversely affect cooling equipment or result in regulatory compliance concerns will have to be addressed.

Workshop participants learned that GE Water and Power is working on technology solutions involving advanced chemistry, equipment and membranes that may lead to 70-

85 percent water recovery as well as thermal evaporation, crystallization and bio polishing techniques that may yield 98 percent recovery rates.[59] Other technologies were mentioned during the workshop that will address the energy water nexus. The Oasys Company's Grand Challenge Project is in the process of developing a Forward Osmosis technique to dramatically increase the efficiency of water treatment and separation processes across industrial sectors. TDA Research Inc.'s government-funded effort is developing a capacitive deionization process using carbon electrodes.[60]

Where possible, industry must upgrade existing facilities as well as engineer new plants to use alternative water sources such as agricultural drainage, seawater, storm water, municipal effluent, and saline groundwater. In addition, research is needed to increase the thermal efficiency of power plants to raise power output per unit of water consumed.

8) Water Pricing Policies

The American public believes that access to cheap (or free) clean water is a "right." Like electricity, the reality is that while water is no longer free, neither will it remain cheap; the price of water will rise for all users. Pricing policies may be one tool for reducing water use, maintaining public health, providing for recreation, and maintaining the supply of water to the industries that form the backbone of the economy.

Economic research has shown that at present, the price of water does not reflect its scarcity or inherent value. Experts have found that residential water use does respond to price signals; a 10 percent increase in the price of water to residential customers reduces water demand by 3 to 4 percent in the short run and 6-7 percent in the long run. Industrial water use demand may not be as sensitive to price changes. However, a 10 percent increase in the price of "piped water" may reduce demand 1 to 8 percent in the short run depending on the industry.[61]

While price signals can be used to reduce water use and move water from lower to higher value uses particularly in the residential sector, overall, markets by themselves are not good at taking all of the costs of water quality and scarcity into account. Regulatory policies can help harness market forces and pricing signals. It was recommended that cost-effective market-based regulations should be used to reduce the utilization of water in power plants by:

- Moving toward long-run marginal-cost pricing for water
- Expanding water markets that take into consideration property rights, public goods and impacts on other stakeholders
- Introducing flexibility in water quality regulations (as discussed above in the need for smart regulation.)[62]

It is important to note that pricing and market strategies are not panaceas, and in fact, regulation plays an important role especially in guaranteeing water quality.[63]

Solutions: Innovative Solutions and Resources Showcased

Workshop participants discussed American ingenuity in developing solutions to key energy problems. Information was given about proposals to match electricity generation options with clean water needs, new technologies being developed by the defense industry that could be applied in the private sector, research programs undertaken by federal agencies and utility industry organizations, information databases being made available to the public, interactive models to help government and utility decision makers, and efforts by nongovernmental institutions to bring stakeholders together to better understand and solve energy and water nexus issues.

New proposals were examined. The Fresno Clean Energy Park concept proposes construction of a CSP plant adjacent to an alternative water source that provides the electricity to its water treatment plant and for a manufacturing facility. The project could employ a 140 MWe air-cooled CSP to provide 100,000 acre-foot/year of agricultural water, as well as water for manufacturing chemical and other products. The Fresno Clean Energy Park example demonstrates that, in the future, dry-cooled CSP or nuclear power plants that provide clean energy can be coupled with desalination plants to maximize production of clean water.

The Department of Defense (DOD) is developing advanced technologies and innovative approaches to providing energy and water supplies to military troops in areas where both are in short supply. A Memorandum of Understanding between the DOD and DOE on Clean Energy and Energy Security that was signed on July 22, 2010[64] provides a good model of cooperation between federal agencies (lacking in the past) and will help cross-fertilize the DOE's efforts to shepherd energy and water related solutions to the electric power industry.

The Electric Power Research Institute (EPRI) has catalogued energy and water sustainability research reports and has created a bibliography that points the public to a wide array of programs and reports with useful information.[65] The Union of Concerned Scientists (UCS) also has an ongoing program to research and evaluate solutions to the energy and water nexus problem.[66]

The Johnson Foundation at Wingspread began a series of initiatives in 2008 to deal with water and climate change, urban water management, the connection between water and agriculture, water and human health and the energy water nexus. By September 2010, with the input of a diverse group of stakeholders, the Foundation issued a consensus document "Charting New Waters: A Call to Action to Address US Freshwater Challenges" with a wide range of recommendations to deal with water issues.[67]

The DOE is sponsoring a number of water-related research programs to improve water management across all types of electricity generation technologies. In the fossil technology area, it is focusing R&D on alternate sources of cooling water such as mine water or treated municipal waste water, innovative water reuse and recovery techniques within the plants, advanced cooling technologies and water treatment technologies.[68] In the Office of Energy Efficiency and Renewable Energy (OEERE), there are efforts to improve the economics of CSP plants and reduce their water-related requirements by moving from water to air-cooled CSP trough plants. OEERE is also developing energy and water efficiency standards for consumer appliances such as clothes washers and dishwashers. In 2007, the government issued Executive Order 13423 requiring a 2 percent reduction per year through FY 2015 in each federal agency's water consumption.[69]

Sandia National Laboratories and its partners are developing an interactive model, the Energy Water Decision Support System (DSS), that will help be a powerful tool to analyze the potential implications of water stress when planning electricity transmission systems and scenarios.[70] Currently the Western Electricity Coordinating Council of Texas, the Western Governors Association and the Western States Water Council are providing information to Sandia so that it can develop the model and use it in their transmission planning process. This model will integrate information about thermoelectric water use including withdrawal and consumption by power plants in the current and future fleet- even with potential changes in cooling techniques and CCS requirements. The model will address water availability based on withdrawal and consumption demand, supplies from streams, transfers, groundwater, reservoirs and non-potable sources, potential drought effects and institutional factors such as interstate compacts, permits and international treaties. In addition, it will consider other water and energy linkages such as biofuel water use, irrigation needs, water for energy fuel extraction and power for water treatment projects.[71] This is an important tool that can be expanded into other regions to help integrate water and energy planning.

Conclusions:
Tools and Time Enough to Address the Energy Water Nexus

Water demand will grow alongside population increases. The population increase is driving increases in power demand which are colliding with water supply constraints. As demand for electricity grows, water withdrawal and consumption for power production will increase primarily for plant cooling purposes. In 2005, the US withdrew 143 billion gallons of water per day and consumed 4 billion gallons per day for thermoelectric power production. Water consumption may increase up to 63 percent from 2005 to 2030.

The growth in water use with respect to thermoelectric power production will be dependent upon technology and policy choices.

- Generation choices will impact water usage. Coal and nuclear plants use 2 and 2 ½ times more water than natural gas, respectively, but certain solar and all wind plants virtually consume no water. However, CSPs with wet cooling systems use copious amounts of water. Hydroelectric and geothermal plants outstrip all other forms of electricity generation in terms of the water required to produce a megawatt of electricity
- On another policy front, climate change strategies likewise may impact water usage. For example, requiring CCS on coal and natural gas plants will more than double their water consumption. Policies encouraging energy efficiency, conservation, use of natural gas as a substitute for nuclear or coal, and higher targets for certain types of renewables such as wind and solar photovoltaic plants can lead to large water savings.
- Cooling technologies equally alter US water withdrawals and consumption. Wet cooling methods reduce water withdrawals but increase consumption. Dry cooling systems can result in near zero water demands.

As the needs for energy and water potentially collide, the question becomes, must water become the "next peak oil"? Not necessarily. The Council's workshop examined the critical linkages between water and thermoelectric energy production, concluding that the issues are interlinked and must be addressed in tandem. Most importantly, tremendous areas of opportunity to solve the energy water conundrum were brought forth during the workshop. There are tools and time enough to address the energy water nexus in the US.[72]

Four key solutions can begin to address the energy water nexus, including integrating development of energy and water management policies, implementing innovative technologies, conservation of energy and water resources, and instituting appropriate water pricing strategies. Recommendations to reach common-sense and effective solutions include:

- To lay the ground rules among the competing sectors and regions, and for those producing the electricity needed to support economic growth while providing the energy to treat and transport the water supply, government at all levels must provide policy guidelines for the next several decades. It is important to recognize that state and regional decision-makers may be better equipped to tackle certain issues, and that the federal level policy makers may be better equipped to take on other tasks.
- The federal government must craft a national energy policy, or relinquish this job to the individual state governments. In either case it should: provide the states with important planning data;[73] assist in providing public

education programs; issue effective and affordable air and water regulations and efficiency standards; develop a plan to engineer and finance the needed improvements in the nation's water infrastructure; and support industry research and development efforts to make water efficient and energy efficient cooling technology cost competitive.

- State governments must improve their regional coordination decision making structures so that policies will be based on regional watershed supplies and water demands for power, clean water, agriculture, and recreation. State governments can use effective pricing policies and regulations to accomplish their goals.
- The utility industry, with the assistance of its research institutions and allied industries, must develop better ways to produce energy more efficiently; reduce water consumption per megawatt of electricity produced; and to use alternative water supplies. Engineering and technology advances are necessary to create a portfolio of options that use alternative water sources to serve the power industry and take pressure off this sector by improving the quantity and quality of water available to competing users.
- There must be a resolution of the current regulatory impasse that balances the economic and environmental costs of such regulations. Part of the solution to improving the energy water nexus will be matching generation choices and cooling technologies to each region's available natural resources and water availability. Since cooling technologies that use less water tend to cost more in terms of infrastructure requirements and tend to lower electricity output per kilowatt of capacity, economic tradeoffs should be weighed against the water availability profile of the site and the impact on the surrounding watershed.

It will be possible to integrate water supply, land use, and power plant technology and site choices, without over regulating, to optimize economic development and sustainable growth. The private sector will develop innovative technologies for cooling, reuse of municipal and industrial water and less energy intensive water cleaning procedures. Projects have been initiated to increase our understanding of water usage. The consumer will increasingly conserve water with measures such as intelligent monitoring, purchase of water efficient consumer products and solar hot water heating systems. It is inevitable that water prices will increase and send signals that lead to conservation and appropriate use of limited water supplies.

Sustainable energy production will require more than reducing the nation's carbon footprint. The water intensity of power production options must be considered if the United States is to find a balanced and sustainable approach to meeting the national, and indeed, the world's energy needs. Understanding the energy water nexus, however, requires an analysis of the issues surrounding the use of water in the extraction and production of the primary energy fuels used for power and transportation. This next aspect of the energy water nexus will be addressed in the workshop that the Council will hold in the fall of 2011.

ATLANTIC COUNCIL

ENERGY WATER NEXUS IN ELECTRIC POWER PRODUCTION

May 17th, 2011

Washington, D.C.

Welcome and Introduction – Atlantic Council

Gen. Richard L. Lawson, Vice-Chairman, Atlantic Council of the United States

Congressional Perspectives

Senate Energy and Natural Resources Committee

Tanya Trujillo, Senior Counsel for the Democratic Majority

Senate Energy and Natural Resources Committee

Josh Johnson, Staff of Ranking Member, Senator Lisa Murkowski

Congressional Water Caucus

Jaclyn Murray, Legislative Assistant, Congressman Jim Costa, Co-founder Water Caucus, House Committee on Natural Resources' Water and Power Subcommittee

Open Discussion

Session I: The Energy Water Nexus-Framework for Discussion

Defining the Energy Water Nexus

Dr. Carey King, Research Associate, Center for International Energy and Environmental Policy, John A. and Katherine G. Jackson School of Geological Sciences, The University of Texas at Austin

Electricity Demand Projections and Generation Options

Peter Balash, Sr. Economist, Office of Systems, Analyses & Planning, National Energy Technology Laboratory

Energy Demands on Water Resources and Water Availability

Dr. Howard D. Passell, Senior Member of the Technical Staff, Energy Security Center, Sandia National Laboratories

The Energy-Water collision-10 Things You Should Know

John H. Rogers, Co-Manager, Energy and Water in a Warming World Initiative, Union of Concerned Scientists

Open Discussion

Moderator: Piet Klop, Senior Fellow, World Resources Institute

Session II: Factoring Water into Electricity Production

Water Considerations for Nuclear Power Plants

Warren Kotzmann, Vice President Strategic Initiatives and Risk, Arizona Public Service Company

Clean Energy for Clean Water

Jeremy Picard, Manager, Radiological and Environmental Analysis, Areva, Inc.

Regional Water and Energy Management

Eric D. Myers, Director, Energy and Environmental Policy Integration, Duke Energy
Renewables
Doug Arent, Executive Director, Joint Institute for Strategic Energy Analysis Institute, National Renewable Energy Laboratory

Open Discussion
Moderator: Dr. Kristen Averyt, Deputy Director, National Oceanic and Atmospheric Administration, Western Water Assessment

Keynote Speech: Lynn Broaddus, Director of Environmental Programs, Johnson Foundation at Wingspread.

Session III: Emerging Regulatory Trends and Issues

Critical Water Regulations Affecting the Electric Utility Sector
C. Richard Bozek, Director, Environmental Policy, Edison Electric Institute
Office of Water Rulemaking
Mary T. Smith, Director, Engineering and Analysis Division, Environmental Protection Agency
State Level Regulations
Kris Mayes, J. D., Founding Director of the Program on Law & Sustainability, Professor of Practice, Arizona State University, Sandra Day O'Connor College of Law

Open Discussion
Moderator: David Garman, Former Under Secretary, DOE, Principal, Decker, Garman, Sullivan and Associates, Inc.

Session IV: Outlook for Water Management Technology Development

Water Availability and Use R&D
Robert Goldstein, Senior Technical Executive, Electric Power Research Institute
Industry Initiatives and Technology Development
Jon Freedman, Global Leader-Government Relations, GE Power and Water
Energy-Water Issues in the, U.S. Department of Energy Office of Energy Efficiency and Renewable Energy
Sam Baldwin, Chief Science Officer, Office of Energy Efficiency and Renewable Energy, U.S. Department of Energy
Jordan Kislear, General Engineer, Office of Planning and Environmental Analysis, U.S. Department of Energy

Open Discussion
Moderator: John R. Lyman, Director, Program on Energy and the Environment, Atlantic Council

Session V: Solutions-Innovative Initiatives and Policy Options

Sandia National Laboratories' Energy-Water Integrated Decision Support System
Vincent Tidwell, Principal Member of Technical Staff, Sandia National Laboratories
National Energy Technology Laboratory's Innovation for Existing Plants Program
Lynn A. Brickett, Director of the Existing Plants Division, U.S. Department of Energy National Energy Technology Laboratory
Pricing Strategies
Sheila Olmstead, Fellow, Resources for the Future

Open Discussion
Moderator: John Kelly, Galvin Electricity Initiative

Closing Remarks - General Richard Lawson, Vice Chairman, Atlantic Council

END NOTES

1. United States General Accounting Office, "Energy Water Nexus: Improvements to Federal Water Use Data Would Increase Understanding of Water Use Trends in Power Plants," October 2009, http://www.gao.gov/new.items/d1023.pdf.
2. Michael E. Webber, "Catch-22: Water vs. Energy," Scientific American Vol. 18, No. 4, 2008, pp.2-3.
3. Peter C. Balash, United States Department of Energy, National Energy Technology Laboratory, "Industrial Resurgence, Load Growth and Water Issues," presentation delivered at Workshop on Energy Water Nexus in Electric Power Production, the Atlantic Council, May 17, 2011, slide 24.
4. In order to avoid the multi-hundred million dollar cost of building cooling towers, and in exchange for closing down 10 years earlier than the federal permit allows the Oyster Creek Nuclear Generating Station, the New Jersey Department of Environmental Protection proposes to allow Exelon Corporation, operator of Oyster Creek, permission to operate until the end of December 2019. The Vermont Department of Pubic Service and New England Coalition filed suit in federal court against the Nuclear Regulatory Commission, accusing it of violating the Clean Water Act because it issued a new 20 year license for the Vermont Yankee nuclear power plant without the plant's operator obtaining a state water discharge certification approval. The Nevada Public Utilities Commission will not approve wet cooled technology for solar thermal projects. It is likely that Arizona will take the same position.
5. United States Geological Survey, http://www.epa.gov/nrmrl/pubs/600f07015/600f07015.pdf.
6. Jan Dell, "Balancing the Energy Water Nexus," pp. 6-8, http://www.worldenergy.org/documents/congresspapers/371.pdf
7. Peter C. Balash, United States Department of Energy, National Energy Technology Laboratory, "Industrial Resurgence, Load Growth and Water Issues," presentation delivered at Workshop on Energy Water Nexus in Electric Power Production, the Atlantic Council, May 17, 2011, slide 11.
8. See http://www.cee1.org/ind/mot-sys/ww/ww-init-des.pdf.
9. John Rogers, Union of Concerned Scientists, "10 Things They Should Know," presentation delivered at Workshop on Energy Water Nexus in Electric Power Production, the Atlantic Council, May 17, 2011, slide 7.
10. Kris Mayes, Program on Law and Sustainability at Arizona State University's Sandra Day O'Connor College of Law, "State Action on the Water-Energy Nexus," presentation delivered at Workshop on Energy Water Nexus in Electric Power Production, the Atlantic Council, May 17, 2011, slide 9.
11. Ibid.
12. Kris Mayes, Program on Law and Sustainability at Arizona State University's Sandra Day O'Connor College of Law, "State Action on the Water-Energy Nexus," presentation delivered at Workshop on Energy Water Nexus in Electric Power Production, the Atlantic Council, May 17, 2011, slide 9.
13. Ibid, slide 7.
14. Ibid, slide 8.
15. It should be noted that some argue that future power demand can be met or at least minimized through increased energy efficiency measures. However, such an acceleration of energy efficiency measures would require legislation and government financial support at the federal and state levels.
16. Peter C. Balash, United States Department of Energy, National Energy Technology Laboratory, "Industrial Resurgence, Load Growth and Water Issues," presentation delivered at Workshop on Energy Water Nexus in Electric Power Production, the Atlantic Council, May 17, 2011, slide 24.
17. Presentations at this workshop estimated that the range of water withdrawal is between 39 and 41 percent.
18. The utility industry has reduced water withdrawal per unit of electricity by a factor of 3 while energy output has increased by a factor of 15 resulting in a level net water withdrawal rate since 1980 according to C. Richard Bozek, Edison Electric Initiative, "Federal Regulations Affecting the Utility Industry: Energy Water issues," presentation delivered at Workshop on Energy Water Nexus in Electric Power Production, the Atlantic Council, May 17, 2011, slide 11.
19. Ibid.
20. For a point of reference, compare this withdrawal/consumption rate to irrigation which accounts for 37 percent of US supply withdrawals but 81 percent of the water consumed.
21. Howard Passell, Sandia National Laboratories, "The New Nexus: Energy-Water-Agriculture," presentation delivered at Workshop on Energy Water Nexus in Electric Power Production, the Atlantic Council, May 17, 2011, slide 26.
22. Howard Passell, Sandia National Laboratories, "The New Nexus: Energy-Water-Agriculture," presentation delivered at Workshop on Energy Water Nexus in Electric Power Production, the Atlantic Council, May 17, 2011, slide 25.
23. While exact relationship remains under debate, many believe increasing carbon dioxide releases are accelerating climate change impacts which in turn exacerbate water scarcity.
24. Howard Passell, Sandia National Laboratories, "The New Nexus: Energy-Water-Agriculture," presentation delivered at Workshop on Energy Water Nexus in Electric Power Production, the Atlantic Council, May 17, 2011, slide 30.
25. Jordan Macknick, Robin Newmark, Craig Turchi, "Water Consumption Impacts of Renewable Technologies: The Case of CSP," p. 10. See http://aquadoc.typepad.com/files/macknick-awra.pdf.
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33. Carey King, Center for International Energy and Environmental Policy, the University of Texas at Austin, "Defining the Energy Water Nexus: Context of Electricity," presentation delivered at Workshop on Energy Water Nexus in Electric Power Production, the Atlantic Council, May 17, 2011, slide 18.
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39. Comptroller General of the United States, "Report to the Congress of the United States: Water Supply Should not be an Obstacle to Meeting Energy Development Goals," January 24, 1980. United States Geological Survey, "Water Demands for Expanding Energy Development," Geological Survey Circular 703, July 1974. U.S. Water Resources Council, "Water for Energy Self-Sufficiency," October 1974.

40. United States General Accounting Office, "Energy Water Nexus: Improvements to Federal Water Use Data Would Increase Understanding of Water Use Trends Power Plants," October 2009, http://www.gao.gov/new.items/d1023.pdf.
41. United States General Accounting Office, "Highlights of GAO-10-23, a report to the Chairman, Committee on Science and Technology, House of Representatives."
42. Kris Mayes, Program on Law and Sustainability at Arizona State University's Sandra Day O'Connor College of Law, "State Action on the Water-Energy Nexus," presentation delivered at Workshop on Energy Water Nexus in Electric Power Production, the Atlantic Council, May 17, 2011, slides 10, 11, and 12.
43. Peter C. Balash, United States Department of Energy, National Energy Technology Laboratory, "Industrial Resurgence, Load Growth and Water Issues," presentation delivered at Workshop on Energy Water Nexus in Electric Power Production, the Atlantic Council, May 17, 2011, slide 24.
44. Robert Goldstein, Electric Power Research Institute, "Water Availability and Use R&D," presentation delivered at Workshop on Energy Water Nexus in Electric Power Production, the Atlantic Council, May 17, 2011, slide 15.
45. Ibid.
46. The Catawbe-Wateree agreement covers 13 hydropower stations, 11 reservoirs, 200 river miles, 1,700 shoreline miles, 841 megawatts of hydropower, and cooling for 8,100 megawatts of fossil and nuclear power generation.
47. Nicole T. Carter, "Energy's Water DemandL Trends, Vulnerabilities, and Management," Congressional Research Service, January 5, 2011, Figure C-1.
48. Kris Mayes, Program on Law and Sustainability at Arizona State University's Sandra Day O'Connor College of Law, "State Action on the Water-Energy Nexus," presentation delivered at Workshop on Energy Water Nexus in Electric Power Production, the Atlantic Council, May 17, 2011, slide 20.
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50. Carey King, Center for International Energy and Environmental Policy, the University of Texas at Austin, "Defining the Energy Water Nexus: Context of Electricity," presentation delivered at Workshop on Energy Water Nexus in Electric Power Production, the Atlantic Council, May 17, 2011, slide 9.
51. Jordan Macknick, Robin Newmark, Craig Turchi, "Water Consumption Impacts of Renewable Technologies: The Case of CSP." See http://aquadoc.typepad.com/files/macknick-awra.pdfsource, slide 22.
52. The primary concern with this cooling technique is the potential harm to aquatic life near the plant, which can be caused by the mechanisms used to withdraw the water, and the higher temperature of water returned to the source. Recirculating cooling towers require more water than typical once-through nuclear and coal wet-cooled systems. In the closed-cycle cooling system, water flows through thousands of metal tubes inside the condenser. Steam flowing through the condenser outside the tubes gets cooled down and converted back into water. The condensed water is re-used by the plant to make more steam. Water exits the condenser tubes warmed nearly 30ºF higher than upon entry to the condenser tubes. The water leaving the condenser tubes flows to a cooling Air moving upward past the water spraying downward inside the cooling tower cools the water. The water collected in the cooling tower basin is pumped back to the condenser for re-use. Water from the nearby lake, river, or ocean is needed to make-up for the water vapor carried away by the air leaving the cooling tower.
53. A sterling engine is a heat engine operating by cyclic compression and expansion of air or other gas, the working fluid, at different temperature levels such that there is a net conversion of heat energy to mechanical energy. See http://en.wikipedia.org/wiki/Stirling_engine.
54. Carey King, Center for International Energy and Environmental Policy, the University of Texas at Austin, "Defining the Energy Water Nexus: Context of Electricity," presentation delivered at Workshop on Energy Water Nexus in Electric Power Production, the Atlantic Council, May 17, 2011, slide 3.
55. Howard Passell, Sandia National Laboratories, "The New Nexus: Energy-Water-Agriculture," presentation delivered at Workshop on Energy Water Nexus in Electric Power Production, the Atlantic Council, May 17, 2011, slide 34.
56. See http://sustainabilityreport.duke-energy.com/2008/water/withdrawal.asp.
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58. Jon Freedman, GE Power and Water, "Efficient Water Use in Energy Production," presentation delivered at Workshop on Energy Water Nexus in Electric Power Production, the Atlantic Council, May 17, 2011, slide 6.
59. There is global interest in water reuse. Ibid slide 6.
60. Ibid slide 9.
61. Sam Baldwin, United States Department of Energy, "Energy Water Issues in the Office of Energy Efficiency & Renewable Energy, USDOE," presentation delivered at Workshop on Energy Water Nexus in Electric Power Production, the Atlantic Council, May 17, 2011, slide 22.
62. Sheila M. Olmstead, Resources for the Future, "Efficient water policies: pricing, markets, and regulation," presentation delivered at Workshop on Energy Water Nexus in Electric Power Production, the Atlantic Council, May 17, 2011, slide 5.
63. Ibid, slide 15.
64. Ibid, slide 2.
65. See http://www.fedcenter.gov/Announcements/index.cfm?id=15876&pge_id=1854.
66. See http://water-energy.lbl.gov/drupal.files/wett/5%20Bob%20Goldstein.pdf.
67. See www.ucusa.org/energy-water.
68. The recommendations of the Johnson Foundation Freshwater Summit included enhance effectiveness of existing regulatory tools; promote efficient, environmentally wise water management, use and delivery; ensure decision making is based on sound science and data; employ a long-range adaptive approach to planning and management; account for the full cost of water, and invest in sustainable water infrastructure; educate the public about challenges and solutions; and, develop and validate methods for freshwater ecosystems services markets. See http://www.johnsonfdn.org/chartingnewwaters/charting-new-waters.
69. Jordan Kislear, United States Department of Energy, "Water Management: Fossil Energy," presentation delivered at Workshop on Energy Water Nexus in Electric Power Production, the Atlantic Council, May 17, 2011.
70. Sam Baldwin, United States Department of Energy, "Energy Water Issues in the Office of Energy Efficiency & Renewable Energy, USDOE," presentation delivered at Workshop on Energy Water Nexus in Electric Power Production, the Atlantic Council, May 17, 2011, slide 23.
71. Partners include Argonne National Laboratory, Electric Power Research Institute, National Renewable Energy Laboratory, Idaho National Laboratory, Pacific Northwest Laboratory, and Michael Webber and Carey King of the University of Texas at Austin.
72. See www.sandia.gov/mission/energy/arra/energy-water.html.
73. The challenges will be greater, however, in a number of developing nations struggling with severe water shortages and rapidly growing needs for electricity and agricultural production. A number of such countries may well feel they are facing "peak water."
74. United States General Accounting Office, "Energy Water Nexus: Improvements to Federal Water Use Data Would Increase Understanding of Water Use Trends in Power Plants," October 2009, http://www.gao.gov/new.items/d1023.pdf.

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