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Integrated Policy and Planning for Water and Energy

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We are faced with chronic water and energy vulnerabilities. Some argue that we will face two crises in the 21st century: a water crisis and an energy crisis (Brown 1998, 2003, Flavin 1999, Feffer 2008). Water will become increasingly scarce as water tables drop due to over-consumption and water quality will continue to deteriorate as a result of excessive contamination. Further, the present energy regime's dependence on non-renewable sources has added considerable stress to the environment, including the prospect of climate change (Intergovernmental Panel on Climate Change 2007). We are amidst a situation where we could be easily blamed for compromising the ability of future generations to meet their needs.

This paper first briefly describes a need for understanding the integrated considerations of water and energy in resource planning, especially during droughts. After introducing a conceptual framework of the water-energy integration, this paper reviews the results of a national survey of energy and water departments to see how these synergic benefits are explored at the state level. Lessons learned from our case studies serve as useful guidelines for state water-energy planning and program development. Finally, as an example case of the water-energy nexus, the concept of desalination is introduced with its implication on energy demand.

Energy-Water Nexus: An E^4 Framework

Given the present context, there is a need for a greater understanding of energy-water linkages in order to develop more effective policies to address their mutual vulnerabilities. I envision that the approach to resolving the issue will have to be an integrated one that exploits the synergies between the energy and water sectors. Synergic benefits derived from water and energy integration are especially significant during droughts, which are expected to intensify from global warming, which is, in turn, primarily the result of fossil fuel consumption.

The main challenge that these integrated policies will have to address is to provide sufficient clean fresh water while maintaining adequate energy supplies to sustain healthy and secure societies and ecosystems. Following the U.S. Energy Policy Act of 2005, the Department of Energy's national laboratories and the Electric Power Research Institute initiated a multi-year water-energy program, expected to cost $30 million annually until 2009[1], encompassing research and development and outreach.

Although the inter-and intra-sectoral interaction between water and energy is much more complicated, Figure 1 presents the linkages in a simplified version. It is shown that water use affects primarily the generation and consumptive aspects of the energy sector, whereas, energy utilization impacts all aspects of the water sector. In California, around 19 percent of all energy consumed is attributable to the collection, extraction, conveyance, distribution, use, and treatment of water (House 2007). The production of energy from fossil fuels and nuclear power is inextricably linked to the availability of adequate and sustainable supplies of water for cooling. In the U.S., thermoelectric power generation is one of the biggest users of water, accounting for 39 percent (135 billion gallons per day) of total water withdrawals in 2001 (U.S. Department of Energy 2006).[2] As a result of these linkages there is the potential for benefits to be accrued if an integrated

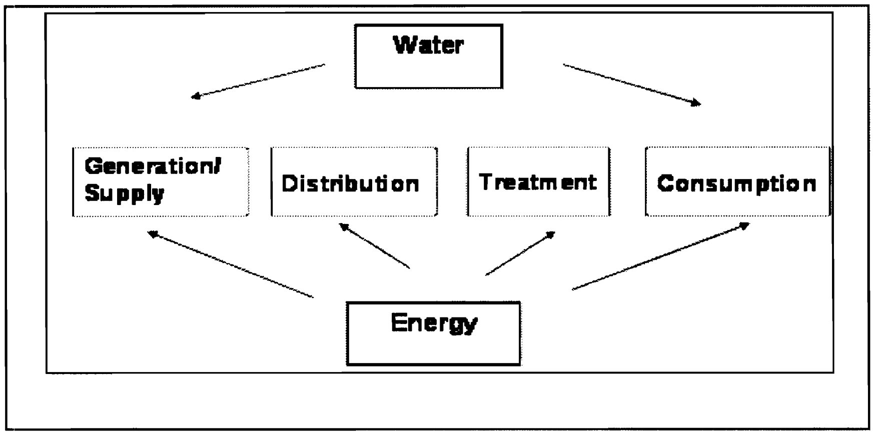

Figure 1. A water-energy integrated framework.

approach is implemented in the management of both sectors.

The integration of water and energy sector planning and management can have positive impacts on the economy, environment, energy, and equity (E^4). Water and energy conservation improves the E^4 balance, enhancing sustainability, particularly during drought events in urban areas (Smith and Wang 2007, Wang et al. 2006). Many of these benefits are interlinked and depend on the extent of the implementation of efficiency improvements that are possible through integration. The framework in Figure 2 conceptualizes the benefits of integration from the perspective of E^4 gains, especially during drought periods.

The efficient use of water and energy can result in lower utility bills for customers and bring other long term societal benefits as it can reduce or even eliminate the need for costly supply-side facilities or waste water and sewage facilities (Featherstone 1996, U.S. EPA 1998, Wang, et al. 2005), together with lowering the cost of management of droughts (*Economy*). The efficient use and reduced wastage of water will lower the amount of energy needed to supply water, in addition to a concurrent reduction in pollution emissions from power plants (Wang et al. 2006).

Conservation measures, as well as the efficient

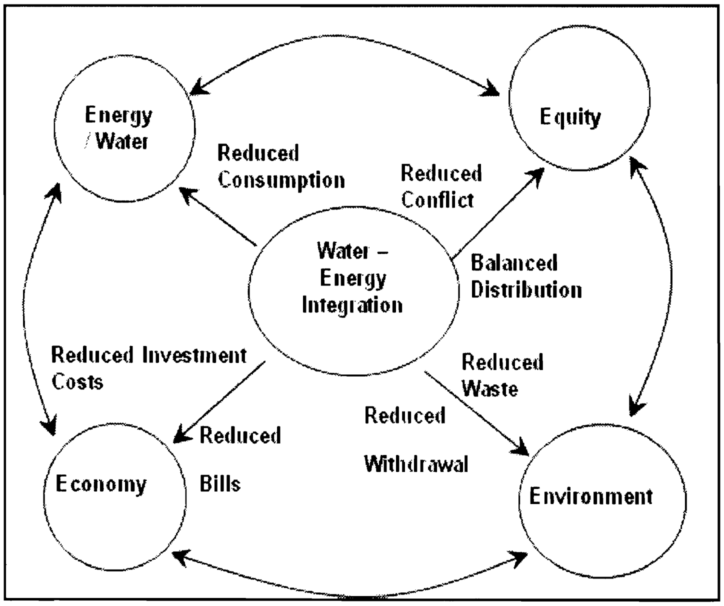

Figure 2. Increased water-energy integration benefits during drought periods.

use of water will also benefit the environment as they will reduce the need for withdrawal from surface and ground water supplies, thereby increasing the availability of surface and ground water supplies for ecological functions and restricting salt water intrusion into coastal areas (Center for Energy and Environmental Policy 2001, U.S. Environmental Protection Agency 1999) (*Environment*). In the U.S., approximately 4 percent of all electricity consumed is used to deliver water and treat waste water (House 2007). In California, water-related energy use, including water pumping for irrigation, consumes 19 percent of the state's electricity, 30 percent of its natural gas, and 88 billion gallons of diesel fuel annually (House 2007). When users adopt water-efficient appliances, energy consumption is reduced in two ways: directly, by the appliances themselves and indirectly as water utilities use less energy for surface and ground water withdrawal and waste water treatment and discharge (Cohen et al. 2004, U.S. Environmental Protection Agency 1998).

Conservation at the tailpipe end stage eliminates all of the "upstream" energy required to bring the water to the point of end use, as well as all of the "downstream" energy that would otherwise be spent to treat and dispose of this water (Cohen et al. 2004) (*Energy*). Conserving water and energy increases their availability, which makes it easier to optimize their allocation between competing users (Wang et al. 2006), especially during droughts. Successful conservation efforts will reduce conflicts over in-stream flow rights and competing uses of water, including down stream power generation sectors that are occurring with increasing frequency (Vickers 2000) (*Equity*).

National Survey and Lessons Learned

A survey conducted by the Center for Energy and Environmental Policy (2007) across all the U.S. states' energy and water departments found that only three states (California, New York, and Wisconsin) had some kind of integrated water-energy programs (Wang et al. 2007). Nine states had limited programs or were part of a regional initiative focusing on the issue of water and energy interactions (Alaska, Connecticut, Hawaii, Idaho, Maine, Nebraska, Nevada, New Mexico, Texas and Virginia). Eleven states responded that they did not have any integrated energy-water programs, and the remaining states did not respond, but a rigorous search of the literature and state websites suggested that there were no integrated energy-water programs in those states. Here resides a fertile place for future academic exploration.

Integration of water and energy is demonstrated to enhance E^4 aspects, but synergic benefits of the integration are not fully explored at the state level even with federal initiation. An important question would be why they are not fully explored and implemented. The three cases of California, New York, and Wisconsin provide some answers to the question in the three areas of information, planning and institutional coordination, and funding.

Impacts of efficiency improvements and alternative technological developments in both water and energy production on the synergic benefits need to be fully understood, especially in regards to drought events. This becomes all the more important considering that the six hottest years on record have occurred in the last ten years (Goddard Institute for Space Studies 2007), thus making us more prone to a vicious cycle of droughts or other natural calamities. The federal water-energy initiation needs to be tailored to meet the specific needs of state.

Coordination within the state includes engagement between energy utilities and water providers directed by the public service commission, statewide public-private partnerships, and the combining of water and energy audits. Water-energy integrated programs can be funded by public benefit charges. These are ancillary charges levied by an energy or water utility on its customers. Further examples of program specifics include:

1) Information dissemination is a key tool for initiating integrated water-energy planning. By sponsoring workshops, undertaking research, and developing websites, the state could begin the process of building public interest in water-energy conservation. Education of K-12 and college students about integrated conservation of energy and water opportunities could be specifically developed.
2) A pilot program in California has been used to evaluate the energy impacts of water

resources. It also analyzed water-energy savings in the commercial, institutional, and industrial sectors, and evaluated the impact of a Renewable Portfolio Standard (RPS) on water resources. States could also undertake research to evaluate the impact on water resources in achieving their mandatory RPS target.

3) Water-energy conservation partnerships have been formed in the case study states to address water and energy issues. The partnerships offer services to a range of sectors including agriculture, commercial, industrial, schools, and local government. Members of the partnerships include private and public energy and water utilities (including wastewater utilities), customer-based organizations, environmental groups, consultants, universities and various state agencies.
4) Technical and financial incentives, tax incentives, rebates, and system benefits charges have been used in the case study states to support integrated water-energy planning. These and other financial mechanisms could be used to promote and attain benefits associated with integrated water-energy conservation.
5) In the case study states, no legislation has been enacted to promote water-energy integration except for regulations on thermal discharges of water by power plants. However, green building standards, which generally focus on measures to reduce energy use, can also address water use, including water conservation.
6) Combining energy and water audits for large customers, including industrial process units, has proven effective in the case study states. Metrics for quantifying energy savings from water conservation and efficiency in water utility supply and conveyance, treatment, distribution, end use, and waste water treatment have been carefully defined in California, Wisconsin and New York.

Desalination

One area which clearly reveals the water-energy nexus is the desalination of brackish and seawater sources. Desalination efforts are fueled by growing concerns over increasingly expensive, unavailable, or controversial traditional sources of water supply. The high cost, environmental impacts, and energy requirements of desalination are main concerns. The cost issue is no longer the primary barrier because of significant technological advancement and reductions in production costs (The National Academies Press 2008), but the energy requirement is still a major issue. Even though efficiency improvements in membrane technologies reduce the energy needed to desalinate water, it is essential to look for energy-efficient ways to produce desalted water (Darwish et al. 2009). Thermally driven desalting systems from fuel-fired boilers are the most inefficient practice in terms of environment, energy, and economic perspectives.

Desalination offers a great potential to the people living in coastal areas, serving around 7 percent of the world's coastal population. This energy-intensive technology mostly mushrooms, especially in the water-poor but energy-rich nations of the Persian Gulf. The technology is now taking off in the European Union including Spain (Meerganz von Medeazza et al. 2007). If fossil fuel prices increase as predicted by pessimistic scenarios and the carbon tax is enforced, the cost advantage for nuclear desalination will be pronounced (Methnani M. 2007).

The favorable economics of nuclear desalination may not be sufficient enough to overcome technological risks and the socio-political resistance against nuclear power and disposal of its wastes. The desalination of seawater using renewable energies is an alternative option, but the conversion of renewable energies requires high investment cost and the technology is not yet mature enough to accommodate large-scale applications (Mathioulakis et al. 2007). In recent years, technological innovation in solar energy and a concurrent improvement in solar economics offer promise in the field of desalination by renewable energies, especially with solar energy applications.

A fundamental shift either in energy prices or in membrane technology could bring costs down substantially. Development of membranes that operate effectively at lower pressures could lead to 5 to 10 percent of process cost reductions due to a 15 percent decrease in energy demand (National Research Council 2008). If either happened to the extent that the marginal cost allowed for agricultural irrigation with sea water (around US\$.08/m^3 on average), some portion of the world's water supplies would shift from rivers and shallow aquifers to the sea. Besides the fundamental economic changes which would result, geopolitical thinking about water systems would also need to shift. Many which are currently dependent on upstream neighbors for their water supply, would, by virtue of their coastlines, suddenly find these roles reversed.

Conclusion

Water and energy resources are essential to human survival. A general conclusion of the analysis of the energy-water conservation programs examined in this paper is that a wide range of knowledge, receptivity, and applications of practices and programs can alleviate stresses on both the water and energy sectors. Additionally, the assessment of these programs reveals that integrating energy and water planning has the potential to save money, reduce waste, protect the environment, improve equity, and strengthen the economy.

States could utilize elements of programs and planning approaches similar to those discussed in the case study states and use such approaches as models to assist in the construction of new frameworks for the integration of water and energy conservation. The need for this integration seems all the more important in light of the recent droughts, the potential for more extreme weather due to climate change, and the demonstrated economic, environmental, equity, and energy benefits of such an integration.

Intense desalination activity has been witnessed in the coastal areas of the world, including the Arabian Gulf, the Mediterranean Sea, the Red Sea, or the coastal waters of California, China, and Australia. Despite the many benefits the technology could offer, concerns have arisen over the substantial energy demanded by the desalination process, along with potential negative impacts on the environment from returning the concentrated brine back to sea (Lattemann et al. 2008). Nuclear, fossil fuel, and renewable energies can be used as input fuels in the process of desalination, but each energy source has its own issues in terms of E^4 perspectives. Nuclear faces socio-political resistance, fossil fuels emit air pollutants, and renewables are constrained by the high initial cost.

The perception that desalination could meet ever-growing fresh water demands should be shifted. Efforts to conserve water, use water more efficiently and recycle waste water are all the more important, and the extent of desalination should be restricted to the many semi-arid and arid coastal regions in the world suffering from structural water shortages. These and other issues related to water-energy integration will be one of the vibrant research agendas for the next couple of decades.

Notes

1. For instance, Sandia National Laboratory leads the National Energy-Water Roadmap Program. Regional workshops have been held to identify specific regional issues and needs associated with the energy and water nexus.
2. It is important to note that although water withdrawal for thermoelectric generation is very high, it consumes only about 3.3 percent of the water, the remaining being returned to the source albeit with environmental impacts as a result of changes to the water temperature. This does become critical in areas where the aquatic environment is highly sensitive to temperature changes especially during dry hot weather.

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