Water's Links to Energy and Greenhouse Gases

A briefing paper produced by a collaborative effort of Northern Colorado water providers with technical support from The Brendle Group, Inc.

For more information, please visit water.brendlegroup.com.

December 2007

Abstract

Utility managers are increasingly recognizing the links between water, energy, and greenhouse gas emissions. Significant amounts of energy are required to use water in Colorado, from its withdrawal and treatment to its conveyance, consumption, and disposal. Conversely, energy production and use frequently requires large amounts of water, such as the water needed in energy plants, or for cooling of industrial processes. By recognizing this energy-water relationship and taking steps to manage these resources in a more integrated and holistic way, utility managers can not only be critical facilitators of water conservation, but also of energy conservation and subsequent efforts to reduce greenhouse gas emissions associated with the combustion of fossil fuels.

Background

Utility managers are routinely accustomed to managing energy and water resources independently of one another. On the one hand, energy is frequently the focus of conservation initiatives – utilities and other energy providers actively promote energy conservation through altering rate structures, providing energy efficiency education and technical support, and offering rebates and incentives for energy conservation. Similarly, water utilities manage water conservation programs with the intent of reducing water use by promoting initiatives such as greater end-use plumbing efficiency, or changes in outdoor irrigation practices.

In fact, water resources and energy resources are far more closely linked than many utility managers realize—what's more, the management of both of these resources is linked with the management of greenhouse has emissions that contribute to climate change. Recognizing this energy-water-greenhouse gas relationship and integrating together the management of these three elements provides utility managers with significant opportunities to save energy through water conservation efforts, save water through greater energy conservation, and reduce greenhouse gas emissions through both greater water and energy efficiency.

This briefing paper outlines the links between energy, water, and greenhouse gas emissions so that policy makers and resource managers can better understand the potentially significant opportunities and benefits offered by integrated energy and water resource management.

Energy Use of Water Resources

The use of energy by water resources is significant. A tremendous amount of energy is used not only to heat, cool, and pump water in homes and offices, but also to treat water to potable quality, convey water from it source to users, and to process and dispose of wastewater. These energy requirements are often referred to as the "embodied energy" of water resources -- the energy consumed by all of the processes associated with the production, delivery, consumption, and disposal of water. Embodied energy is typically expressed in kilowatt hours per gallon of water (kWh/gallon). As this paper discusses, the recognition of embodied energy offers significant opportunities for saving energy while more efficiently managing water resources, and by extension opportunities for reducing greenhouse gas emissions.

It is estimated that the use of water consumes approximately 8 percent of the nation's energy for its treatment, conveyance, use (including heating), and disposal. The California Energy Commission estimates that over 20 percent of electricity and 30 percent of natural gas use in that state is associated with the use of water (Cohen, Nelson, and Wolff, 2004). While this may be a high figure compared to other states due to the large quantities of water pumped over long distances in California, the embodied energy of water in western states, where water may be similarly conveyed over long distances and pumped over mountains, is no doubt significant. By extension, the energy use required for water use is also a critical factor in the consideration of strategies to reduce the emissions of greenhouse gases.

The energy requirements of a particular water supply reflect energy use at five stages of the water cycle: extraction, treatment, distribution, use, and disposal. The energy requirements of each of these stages are discussed below.

Extraction and Treatment. Energy is required for the extraction of water from its source, such as a surface water body or groundwater, typically by pumping. Once water has been extracted, it then may undergo treatment to create water of a potable quality. The level of treatment required—and the concurrent energy required for treatment—can largely vary. Energy may be consumed by chemical feed pumps, aerators, and other equipment used in standard filtration plants. Reverse osmosis, which provides a high level of treatment, also uses large amounts of energy to maintain the system at high pressures through the use of pumps.

Case In Point: City of Fort Collins

The City of Fort Collins utilities department determined that in 2000-2001 the embodied energy in the City's water supply was approximately 2.2 kWh/kgal for consumptive uses and 0.5 kWh/kgal for non-consumptive uses.

For consumptive uses, this included the energy required for both water treatment (23 percent of total) and wastewater treatment (77 percent of total), while treatment only was required for non-consumptive uses, primarily irrigation.

This energy use resulted in the generation of an estimated 10,779 tons of carbon dioxide equivalent.

Source: The Brendle Group

Distribution. The distribution of water can also result in a significant use of energy, though energy use will depend on factors such as the length of conveyance, and whether or not pumping is required compared to reliance on gravity flow. If pumping is required, some of the energy embodied in water pumping it uphill can be extracted as water falls down the other side with well placed hydroelectric facilities.

Water systems must transport water from intake source to treatment facilities, then to local storage facilities, and finally to the customer. In fact, most of the energy consumed by municipal water systems is used for pumping. For a city of 50,000 people, it is estimated that approximately 2 million kWh/yr are required for all plant operations, with more than 1.6 million kWh of that amount needed for pumping alone (Cohen, Nelson, and Wolff, 2004).

Many proposed new water supply projects in Colorado involve moving water over significant distances because of the scarcity of undeveloped water near population centers. Unallocated water is usually far downstream or even across mountain ranges from the anticipated point of use. In these cases, Colorado's geography may impose potentially significant pumping requirements, with the potential for significant increased energy consumption and resulting greenhouse gas emissions (Center for Climate Strategies, 2007). In 2003, approximately 513 GwH was consumed for pumping by the Colorado-Big Thompson project—approximately 30 percent of the total system's hydroelectric energy generation in that year (U.S. Bureau of Reclamation, undated).

Many urban water distribution systems were also constructed underground more than 50 years ago, and leaks caused by corrosion of pipe material or other problems can lead to the loss of significant amounts of potable water. Distribution system losses increase the energy intensity of water supply by requiring utilities to consume additional energy to treat and convey water that will be lost. Losses vary significantly among urban suppliers—typically loss rates range from 6 to 15 percent, but they can be as high as 30 percent.

End Use. The end use of water by consumers—especially for energy intensive uses such as washing clothes and taking showers—consumes more energy than any other part of the urban water conveyance and treatment cycle, and therefore generates the highest amount of greenhouse gases of any step in this cycle. A recent study of the energy cost of water by the San Diego County Water Authority found end use is the single largest component of water related energy cost. This suggests significant potential savings from using water more efficiently. Greater end-use conservation saves not only onsite energy for its use, but also "upstream energy" required for treatment and conveyance, and "downstream" energy for treatment and eventual disposal.

Employing high-efficiency plumbing products in new building and home construction as well as retrofits can result in significant energy savings, and help to reduce greenhouse gas emissions. As an example, the average high-efficiency dishwasher increases the energy intensity of dishwashing by 30 percent, but it reduces water use by 34 percent. As a result of using less water—and therefore less energy to convey water from the source to the dishwater—the net total energy required to wash dishes would decline by an estimated 14 percent. While ultra low-flow toilets do not save end use energy because toilets do not use hot water, reducing toilet water use can save conveyance, distribution, and treatment energy consumption and associated generation of greenhouse gases.

Research on the water use of Colorado's commercial, industrial, and institutional sector indicates that the sector may account for 30 percent or more of urban water demand (City of Westminster, 2000). Recent studies of comparable uses in California estimate that cost-effective conservation could reduce the sector's water use in that state by 15 to as much as 50 percent, resulting in significant energy savings and reduction in greenhouse gas emissions.

Disposal. On the downstream end of the water cycle, the energy required to collect, pump, treat, and dispose of wastewater is also significant. The more than 60,000 water systems and 15,000 wastewater systems in the United States are among the country's largest energy consumers, using about 75 billion kWh/year nationally—or about 3 percent of annual U.S. electricity consumption. This demand is equivalent to the entire residential demand for the state of California without including energy for consumer end use (Cohen, Nelson, and Wolff, 2004). Even if all of this power came from relatively clean natural-gas-fired power plants, producing the energy used by water systems would release approximately 30 million tons of the greenhouse gas carbon dioxide—the equivalent of more than 4 million cars.

Water Use of Energy Resources

As water utility managers are recognizing the energy benefits of conserving water, energy utilities are realizing the water-saving benefits of conserving energy.

Just as treatment, conveyance, use, and disposal of water contains embodied energy, energy power plants require "embodied water" to cool systems, transfer heat, generate hydropower, and for other processes. Embodied water is typically expressed in gallons per kWh.

Thermal power production—principally to cool steam at fossil fuel plants—requires large amounts of water. In 2000, fossil fuel plants in Colorado used 20 billion gallons (just over 61,000 acre-feet) of water, consuming 500 gallons per megawatt-hour generated (The Clean Air Foundation and Land and Water Fund of the Rockies, 2003).

Proposed new sources of energy including ethanol and oil-shale production also have large water requirements. Ethanol produced from corn grown in Colorado requires approximately 1,000 gallons of water per gallon of ethanol produced, including water used to grow corn. Oil shale production uses approximately 200 gallons of water for each barrel of oil (The Clean Air Foundation and Land and Water Fund of the Rockies, 2003). These statistics offer opportunities to more accurately estimate the true water costs -- and embodied energy costs -- associated with potential new sources of energy.

Summary of the Relationship of Energy and Water to Climate Change

As has been discussed throughout this paper, the energy use required for the consumption of water is directly linked to the emission of greenhouse gases, including carbon dioxide. Therefore, greater integration of energy and water resources management also has direct implications on and relevance for both greenhouse gas reduction strategies as well as efforts to adapt to climate change. In general, the greater the embodied energy of water, the greater the emission of greenhouse gases, since most embodied energy in water is produced with non-renewable energy resources.

There is a growing scientific consensus that increasing emissions of greenhouse gases to the atmosphere are increasing the temperature and variability of the Earth's climate. Recognizing the implications that global warming and climate variation could have on the economy, environment, and quality of life in Colorado is an important consideration for both water and energy resource managers (Center for Climate Strategies, 2007).

The impacts of climate change on freshwater systems and their management are mainly correlated to the observed and projected increases in temperature, evaporation, sea level, and precipitation variability (The Dialogue on Water and Climate, 2003). In Colorado, the projected impacts of climate change include less winter snow pack, longer growing seasons, more drought, and increased water needs for longer growing seasons (Center for Climate Strategies, 2007). Climate change will likely affect the function and operation of existing water infrastructure as well as water management practices. Adverse effects of climate on freshwater systems are likely to aggravate the impacts of other stresses, such as population growth and resulting land use change and urbanization, as well as a changing economy.

Water use for cooling buildings and other weather-dependent uses could increase with an increase in temperature—such increased water use would also increase energy use and the associated greenhouse gas emissions. Climate change could also have significant implications for hydroelectric power generation. Changes in runoff have a direct impact on the amount of hydropower generated both because hydropower production decreases with lower flows and because higher flows often must be spilled past dams without producing any power. During droughts, there are two types of hydroelectric losses: less water runs through the turbines in powerhouses, and the lower reservoir level reduces the "head," thereby reducing the power produced by a given amount of water. As hydropower generation decreases, energy users are likely to turn toward fossil fuels, thereby increasing emissions that contribute to climate change. During the first five years of the 1987 to 1992 California drought, hydropower losses cost California ratepayers $3 billion and led to an increase in greenhouse gas emissions of 25 percent over normal levels (Anderson, 1999).

The state's Climate Action Panel is developing 14 recommendations for adaptation to climate change with respect to water resources. By developing strategies to conserve water to adapt to projected changes in Colorado's climate, the energy associated with water can be saved too, which can help to reduce greenhouse gas emissions and contribute to reducing further climate change impacts.

Conclusions and Recommendations: Benefits of Integrated Water, Energy, and Greenhouse Gas Management

Based on the strong connections between energy, water, and greenhouse gas emissions, water managers can benefit by considering more holistic, integrated approaches to the management of energy, water, and greenhouse gases. Greater integration allow utility managers to better understand the energy and climate implications of water management options, as well as the water implications for energy use and generation. While results will vary based on each state's energy requirements for managing its water resources, preliminary estimates from the California Energy Commission indicate that energy savings in that state through water conservation may be more cost effective than savings through more typical energy conservation measures. For example, previous research in California has shown that water conversation measures in San Diego would save enough energy to power one-quarter of the city's homes (Cohen, Nelson, and Wolff, 2004).

Encouraging use of more efficient end-use fixtures is one strategy that offers water managers significant energy saving opportunities. It is estimated that the residential water use associated with pre-1980 plumbing fixtures (toilets, showerheads, faucets) consume 57 kWh of energy per capita per year. In comparison, post-1994, higher efficiency plumbing fixtures required by the federal Energy Policy Act of 1992 only require 22 kWh of energy per capita per year -- a savings of over 60 percent, and a significant energy savings when aggregated nationwide (deMonsabert and Liner, 1996). Energy is saved even by plumbing fixtures that do not use hot water by reducing energy requirements for pumping, distribution, drinking water, and wastewater treatment.

Case In Point: The University of Colorado at Boulder

In 2003, the University of Colorado at Boulder completed a campus assessment of water use and conducted several upgrades that have saved the University both water and energy and reduced campus greenhouse gas emissions. Measures addressed toilets, urinals, showers, and faucet upgrades; cooling tower operations; kitchen operations; once-through cooling applications; and irrigation system upgrades.

The project resulted in a significant annual water savings of 76,698 kgal/year. Simultaneously, with a determination that the embodied energy in the University's water added up to 0.8 kWh/kgal, the project also resulted in an energy savings of 5,113 kWh/month, resulting in a reduction of greenhouse gas emissions of 4.5 tons per month. The project has resulted in economic benefits too, including a shorter payback time, which has helped to finance additional energy projects.

The water portion of the work was estimated to save $400,000 per year in water utility costs. The relatively short paybacks and magnitude of the savings on the water side, when packaged with the energy projects, helped to significantly reduce overall payback.

Colorado's original Water Conservation Act of 1991 not only created the Office of Water Conservation, but it also required that all covered entities, including retail water providers who sell 2,000 acre-feet or more of water annually, to submit a water conservation plan to the Colorado Water Conservation Board for approval. The 2004 version of the Act amending the 1991 Act further defined the requirements for water conservation planning. As Colorado water entities move forward in water conservation planning, water managers are encouraged to address not only water use, but linked energy use and greenhouse gas emissions as a strategic and systemic approach to climate change. From an economic standpoint, such systemic analysis will also create opportunities for developing integrated water-energy efficiency projects, and help to improve payback on capital projects through greater efficiency, linking water conservation outcomes to impacts on climate change.

References

The Clean Air Foundation and Land and Water Fund of the Rockies. 2003. The Last Straw: Water Use by Power Plants in the Arid West. The Energy Foundation and The Hewlett Foundation.

Anderson, C. 1999. Energy Use in the Supply, Use, and Disposal of Water in California. California Energy Commission, Sacramento, CA.

Center for Climate Strategies. 2007. Colorado Climate Project Final Draft Report (unpublished). Available at: http://www.coloradoclimate.org/Climate_Action_Panel.cfm.

Cohen, R., Nelson, B, and Wolff, G. 2004. Energy Down the Drain: The Hidden Costs of California's Water Supply. Natural Resources Defense Council, Oakland, CA.

deMonsabert, S. and Liner, B. 1996. WATERGY: A Water and Energy Conservation Model for Federal Facilities. Paper prepared for CONSERV'96, Orlando, Florida January 6, 1996

The Dialogue on Water and Climate. 2003. Climate Changes the Water Rules: How Water Managers Can Cope With Today's Climate Variability and Tomorrow's Climate Change. Available at: www.waterandclimate.org/report.htm.

U.S. Bureau of Reclamation. Undated. Description of the Colorado-Big Thompson Project. Accessed at: www.usbr.gov/gp/aop/cbt/03cbt.pdf.

U.S. Department of Energy. 2006. Energy Demands on Water Resources, Report to Congress on the Interdependency of Energy and Water. Author, Washington, D.C.