Electric and Water Utility Integrated Planning

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Table of Contents

Introduction and Background

In the United States the USGS estimates that approximately 400 billion gallons per day (Bgp/d) of water is withdrawn from surface and groundwater supplies. Approximately half is used for thermoelectric power generation, 128 Bgp/d for irrigation, 44 Bgp/d for public water supplies, and 20 Bgp/d for livestock and industry.[1]

It is well known that it takes large quantities of water to generate electricity, and large quantities of electricity to collect, treat, and distribute water and wastewater. Electricity use required for the water and wastewater sector in the United States has been quantified as approximately 4% of the national total.[2] This interconnection between water and energy has been defined as the water-energy nexus, which has been widely written about and studied.[3] [4] Water and electricity are both necessary for a sustainable, prosperous, and secure society. There are many challenges to the supply of affordable water and electricity. These challenges include the readily available supply of fresh water, fossil fuels, climate change, population growth, and growing demand for water and electricity as greater numbers of people prosper economically around the world.

Considering the high volumes of water required for electricity and water needs there should be widespread coordination and planning between the electric and water utilities that supply water, wastewater, and electrical services to local population centers. However, to date there are few documented success stories of integrated planning between water and electric utilities. More common are acrimonious disputes over the growth of water and energy supplies.

Therefore, it is critical that a paradigm for integrated planning be developed for electric and water utilities. In the future water utilities face a growing demand for water, increased treatment requirements, and aging infrastructure. Likewise, electric utilities face increasing demand for electricity, stricter air emissions requirements, and aging infrastructure. No longer can these utilities operate independent of one another. New paradigms must be developed that remove the silos between drinking water, wastewater, and electric utilities to promote efficient consumption of electricity and water.

Water and electric utilities have many common goals. They each are required to provide a critical service without interruption to their consumers. They must also produce a product that is of the highest quality, and overcome a myriad of regulatory and geographic obstacles. These utilities usually operate separately. Each American state has a public service commission, which regulates water and electrical utilities in some manner. However, the utilities themselves are left to operate independent of each other. This has created a silo affect where the electric or water utility is only responsible and aware of their respective performance.

As noted previously, approximately half of the water withdrawn in the United States is for operating thermoelectric power plants. This fact is the subject of research by Benjamin Sovacool who has documented the pending water scarcity of the future. Increasing populations, increasing demand for electricity, and more frequent droughts will stress existing water supplies. Sovacool highlights possible National-Electric Crisis Areas, which due to possible future water scarcity could face water and electricity shortages in the future.[5] To mitigate these possible crises Sovacool recommends renewable energy, decreased reliance on thermoelectric power plants, improved cooling systems for existing thermoelectric power plants, improved price signals, and collaboration between electric utilities and their customers.

In 2012 The Environmental Protection Agency (EPA) released *Principles for an Energy Water Future*.[6] From their position paper EPA makes the following points:

- *Water and energy efficiency should form the foundation of how we develop, distribute, recover, and use energy and water.*
- *The exploration, production, transmission and use of energy should have the smallest impact on water resources as possible, in terms of water quality and water quantity.*
- *The pumping, treating, distribution, use, collection, reuse and ultimate disposal of water should have the smallest impact on energy resources as possible.*
- *Wastewater treatment facilities, which treat human and animal waste, should be viewed as renewable resource recovery facilities that produce clean water, recover energy and generate nutrients.*
- *The water and energy sectors – governments, utilities, manufacturers, and consumers – should move toward integrated energy and water management from source, production and generation to end user.*

This course is part of the foundation for ensuring a future of sustainable water and electricity. Through this course we will cover:

- The water-energy nexus
- The commonalities and differences between electric and water utilities
- Water use in the power generation process and various thermoelectric power cooling technologies
- Planning between electric and water utilities for their mutual benefit

Water-Energy Nexus and Sustainable Water

The power industry needs water to extract and transport fossil fuels, operate thermoelectric power generation plants and hydropower stations. Conversely, water and wastewater utilities need to ensure consistent electricity supplies to power their treatment processes, pump stations, and distribution or sewage collection networks. The confluence of water and energy has been labeled the water-energy nexus or the energy-water nexus. This relationship is depicted in Figure 1. Several informative relationships include:

- Sandia National Laboratories: www.sandia.gov/energy-water/
- Grace Communications Foundation: www.gracelinks.org/208/the-energy-water-nexus
- River Network: www.rivernetwork.org/water-energy-nexus

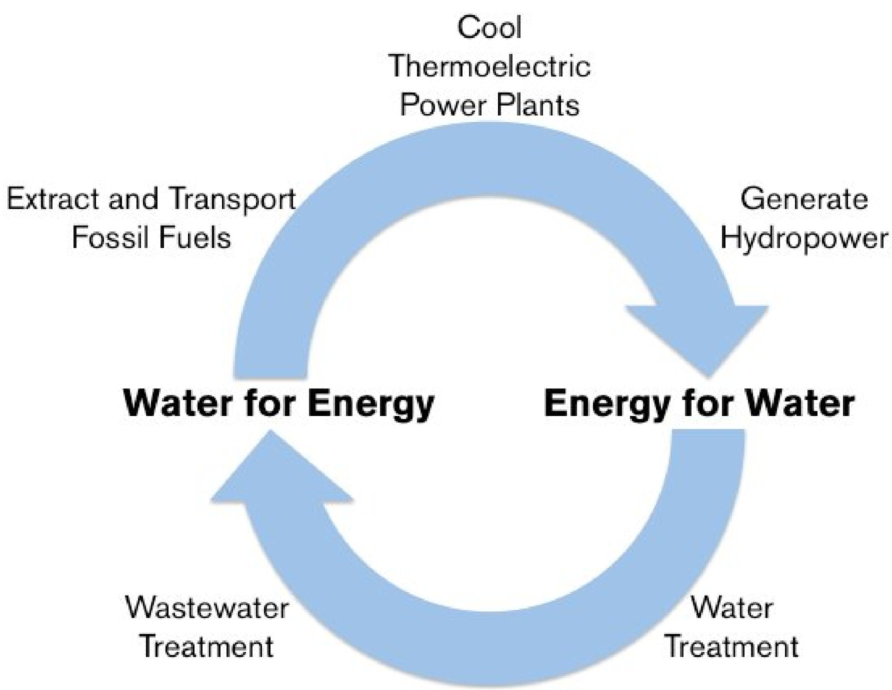

Figure 1: Water-Energy Nexus

The idea of the water-energy nexus is part of the concept of sustainable water and Integrated Water Resource Management (IWRM). IWRM is defined by the Global Water Partnership (GWP) as a process that "promotes the coordinated development and management of water, land and related resources in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems."[7] This means ensuring sufficient quantity and quality of water for everyone.

One of the challenges to water and energy issues is how society views water, wastewater, and energy. Traditionally, these sectors have been treated like silos, each separate from one another. However, new approaches in integrated water resource management (IWRM) aim to tackle this challenge. To achieve sustainability, water and electric utilities will have to collaborate with one another to ensure sufficient supplies of water and electricity for their consumers.

Current challenges to electric and water utility integrated planning include:[8]

- Policy and decision making between the water and energy sectors are disconnected.
- Approaches that consider energy security, but neglect water and climate will not be sustainable.
- There are "fundamental philosophical differences between both the organizational mandates and the individuals who operate in the water and energy sectors." These make human nature a significant barrier that must be overcome.
- Very little data has been collected with respect to water and energy utility behavior and the complex interactions between water and energy.
- Both collaborative and integrated modes of governance are central to managing water and energy. However, both must be studied, because there may not be a one-size fits all approach.
- Developing solutions to water and energy challenges will become more pressing as more and more people become urbanized.

Currently, more than half of all people in the world live in cities. According to the United Nations nearly sixty percent of the world's population will move to cities within the next 20 years. Increasing population, and especially population density, will require new ways of approaching water and energy to ensure a sustainable city of the future.[9]

Electric and Water Utility Needs

Electric and water utilities have both similar and competing needs for how they use water. Electric utilities need water to transport fossil fuels, generate steam, and cool thermoelectric power plants. Water and wastewater utilities need to supply water to their customers or treat sewage before releasing it to water bodies. Operating these water and wastewater processes require large quantities of electrical and thermal energy.

<u>Commonalities</u>

- Continual delivery of their product
- Vital for community growth and prosperity
- Governing structures can be large and bureaucratic
- Infrastructure maintenance requires community input and awareness
- Must maintain positive community relations

<u>Differences</u>

- Financing
- Customer rate structure
- Regulatory agencies
- Legal issues
- Human health – water quality
- Uses of water

The table above lists similarities and differences between electric and water utilities. Given the similarities, it is in the best interest of electric and water utilities to work together to leverage their resources and knowledge.

Thermoelectric Power Generation and Cooling Systems

Traditional thermoelectric power systems use fossil fuels to generate steam. The steam, heated to several hundred degrees Celsius, is compressed through a turbine that spins to generate electricity. In this process water is used for make up water to generate steam as well to cool the power plant. The amount of water required to be withdrawn, depending on the cooling technology, may be as high as approximately 30 gallons of water per kWh generated.

Renewable energy technologies such as biomass, geothermal, solar, or wind do not rely on water to operate. However, water is used to manufacture the component parts for renewable energy systems. In solar thermal power, water may be heated to generate steam similar to a fossil fuel power generation process.

The amount of water required for power generation varies by the fuel type and cooling process. Various values have been quantified in the table below.

Technology	Average Withdrawal (gal/kWh)	Average Consumption (gal/kWh)
Coal, Freshwater, Once-Through	27.113	0.138
Coal, Freshwater, Recirculating	0.463	0.394
Coal, Freshwater, Cooling Pond	17.927	0.804
NGCC, Freshwater, Once-Through	9.01	0.02
NGCC, Freshwater, Recirculating	0.15	0.13
NGCC, Freshwater, Cooling Pond	5.95	0.24
NGCC Air Cooled	0.004	0.004
Nuclear, Freshwater, Once-Through	31.497	0.137
Nuclear, Freshwater, Recirculating	1.101	0.624

Table 1: Water Required for Power Plant Cooling
NGCC = Natural Gas Combined Cycle. Data from National Energy Technology Laboratory, 2008.

The type of cooling system impacts the amount of water required for withdrawal as well as the amount of water consumed. The numbers should not be misleading. A 520 MW coal-fired power plant with a recirculating cooling system may evaporate (consume) as much as 5.5 million gallons per day of water.[10]

Cooling Systems

Thermoelectric power plants are cooled by different methods, which are generally categorized as wet-cooling or dry-cooling. Wet-cooling includes once-through and closed-cycle systems. Dry-cooling does not require any water; however, water will be consumed in the steam generation process.[11] The amount of water required for cooling depends on the efficiency of the steam generating equipment.

Once-though cooling, also known as open loop cooling, has a low water consumption to withdrawal ration as compared with a closed cycle system. Compared with a closed-cycle system, once-through cooling is cheaper since there are lower capital costs and lower operational costs due to less pumping. Closed cycle systems may use 40% to 80% less water than open-loop systems, but are typically more capital intensive to build and more expensive to operate.[12] One drawback of once-through cooling is that discharged cooling water is warmer than the receiving waters affecting local wildlife habits.

Electric utilities can reduce water consumption through closed-loop dry cooling or closed-loop evaporative cooling systems. Closed-loop dry-cooling, also known as air-cooling, uses high flow rates of ambient air to cool exhaust steam eliminating evaporative losses associated with using water for cooling.

Another water saving option for electric utilities is combined cycle power plants. These power plants recover heat from one steam turbine for use in a second steam turbine that also generates electricity. This increases both the water and fuel efficiency for power generation.

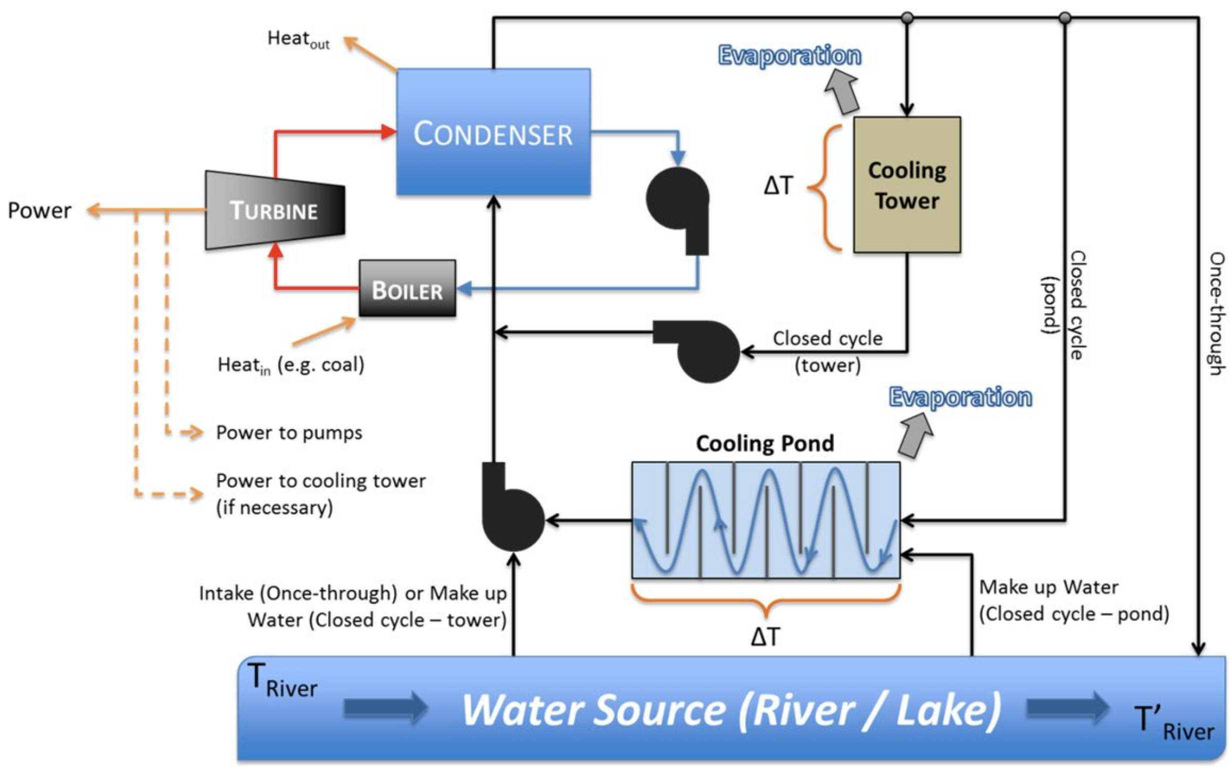

Figure 2: Power Plant Cooling Options, Courtesy of Modeling Water Withdrawal and Consumption for Electricity Generation in the United States

Opportunities for Saving Water

Reducing water use is important for both water and electric utilities. For water utilities monitoring leakage, smart water meters, and water conservation programs that promote water saving among residential, commercial and industrial water users, save water over the long term. Treating and distributing less water translates to lower operation costs, lower electricity demand, and reduced water withdrawals.

Similarly, electric utilities can upgrade their cooling and power generation equipment to be more water efficient. Saving water reduces water withdrawals, making more water available for other water users. Likewise, more water-efficient equipment is normally more efficient with respect to power generation. Combined cycle power plants use less water and generate more power, which has the added benefit of using less fossil fuels and reducing carbon emissions.

Ultimately, deployment of more renewable power such as solar and wind will reduce the need for water even more. While water is part of the manufacturing process for renewable energy equipment, the long-term operation of solar and wind power does not require water.

According to the Civil Society, a non-profit, 12,000 MW of coal fired power plants could be retired in the American West and replaced with 12,000 MW of wind power. Assuming water consumption of 0.804 gallons per kWh, this could translate into reducing water consumption by as much as 84 billion gallons of water per year.

Integrated Planning

Electric and water utilities may engage in three types of planning:

1. Water withdrawals for cooling needs
2. Electricity Demand management planning
3. Distributed generation planning

Water Withdrawals for Cooling Needs

Electric and water utilities withdraw high volumes of water, often from the same water sources, for their operations. Electric utilities as noted earlier are the largest uses of water in the United States. Coordination of water withdrawals between electric and water utilities can ensure consistent supplies for each utility. During periods of peak electricity demand electric utilities may be withdrawing higher volumes of water. This has the potential to hinder water treatment operations if each utility is withdrawing water from the same water body. In some locations, where water is becoming scarce, there is growing competition for water and how it is used.

Types of activities may include joint modeling of energy and water needs, improved communications between electric and water utilities, or developing joint programs to reduce community water use.

Electricity Demand Management Planning

Many water utilities, like other industrial users of electricity, engage in demand management programs with their electricity supplier. Water utilities plan with their electricity supplier to limit operations during periods of peak electricity demand, or agree to shed load during peak electricity demand so as to limit the electricity demand on the grid. This type of planning is ongoing, and is a building block to future types of planning. One of the most common forms of demand management is to pump and treat water during the evenings when electricity rates are at their lowest, and then store that water for distribution during peak electrical times.

Additional types of demand management programs include using Energy and Water Quality Management Systems (EWQMS) whereby water utilities continually monitor their water and electricity usage to match water demand with electricity prices while maintaining water quality and distribution. The concept of EWQMS may or may not be accomplished with a dedicated software package, and may not require long-term input from the electrical utility. However, it gives water utilities, for whom pumping may represent between 80%-90% of energy costs, an opportunity to control reduce electricity demand by reducing over pumping.

Advanced Metering Infrastructure (AMI) is another means of electricity demand management. Smart water meters enable water utilities to monitor water use in real time so they can make real time decisions about where to distribute water. AMI, like EWQMS, reduces overall pumping and monitors leakage in the water distribution system. Controlling the amount of water that needs to be treated and pumped saves electricity for water utilities and reduces electrical demand on the grid.

Distributed Generation Planning

Many water and wastewater utilities have the opportunity to generate their own electricity. Wastewater utilities, especially, have large quantities of chemical, thermal, and hydraulic potential energy. Recovering this energy for beneficial use means that the wastewater facility can limit the amount of electricity they need to purchase or send electricity back into the grid should they generate in excess of what is needed to operate their facility. Water utilities also have the opportunity, depending on geography, to recover hydraulic energy from their operations.

Additionally, water and wastewater utilities have open spaces at their facilities that are ideal for solar or wind power. Utilizing this space for a renewable energy project may be economically beneficial to the water or wastewater utility. Like the recovery of chemical, thermal, or hydraulic energy on-site, water and wastewater utilities can use renewable energy to offset purchased power or send electricity back into the grid.

Regardless of how a water or wastewater utility generates power, they must coordinate with the electric utility to deliver excess power to the grid. Likewise, as water and wastewater utilities realize the benefit of on-site power generation, they will purchase less power from electric utilities. This presents challenges related to electricity pricing and coordination of the electrical infrastructure. Agreements and methodologies must be developed to take full advantage of energy recovery at water and wastewater treatment facilities, which is becoming more common. Rather than refer to wastewater treatment plants as a treatment plant, the newer paradigm refers to these facilities as a wastewater resource recovery facility (WRRF).

Electric and water utilities must come together to plan and develop methodologies of tackling these three main issues. Each utility will benefit by getting more of what they need – water and power. Integrated planning will provide streamlined processes for permitting, communication, and developing infrastructure among electric and water utilities. In order to develop sustainable cities, electric and water utilities will have to operate in a synergistic fashion.

Conclusions

Electric and water utilities face similar challenges in the coming years as the demand for energy and water accelerates with rising populations. These utilities must work together to engage in integrated planning developing strategies for managing energy and water consumption. Integrated planning mitigates the effects of the water-energy nexus, takes advantage of synergies between electric and water utilities, and leads toward more sustainable infrastructure.

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