Energy-Water Nexus State Policy White Paper Series, Volume II

Beneath the Surface

Opportunities and Strategies to Improve the Energy Performance of State Water Conveyance, Treatment, and Irrigation Systems

NASEO

National Association of
State Energy Officials

Image source: rlmartin

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The National Association of State Energy Officials (NASEO) prepared this document to assist our 56 State and Territory Energy Office members in their efforts to examine, understand, and address the energy performance of water infrastructure in their states and communities. This report is the second in a series of three reports examining the energy-water nexus authored by NASEO and the National Conference of State Legislatures (NCSL). The first report, developed by NCSL, covers the energy-water nexus for power generation facilities. The second, developed by NASEO, addresses the nexus from the perspective of water treatment, conveyance, and irrigation systems. The third, developed by NCSL examines the nexus in the context of oil and gas development. All three reports can be found on U.S. Department of Energy's webpage.

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Glossary

Biogas – A fuel that can be used in an on-site Combined Heat and Power (CHP) energy generation system to meet a portion or all of a facility's need for electricity. Anaerobic digestion is a process in which waste (human or animal) is broken down, creating biogas as an end product.

Combined Heat and Power (CHP) – an array of proven technologies that concurrently generate electricity and useful thermal energy from a same fuel source. CHP results in a total system efficiency of 75percent, compared with 50percent efficiency from grid generated electricity. CHP energy generation systems can be configured to operate on natural gas, diesel, biogas, other renewable fuel, or a combination of fuels.

Energy Efficiency Resource Standard (EERS) – A policy requiring a state's utilities to achieve a certain percentage of consumer energy savings from a specified energy load baseline by a predetermined date. Energy savings are typically achieved through a variety of customer and end-use programs designed by the utilities themselves and approved by the state's Public Utilities Commission.

Groundwater – Water existing underneath the Earth's surface in aquifers and other underground reservoirs.

Produced Water – Water existing in underground formations that is brought to the surface as part of the process of extracted oil and gas. This may also include water that was injected into oil and gas plays as part of the hydraulic fracturing process.

Prior Appropriation – A system of water use governance where water rights are apportioned on a "first-come, first-serve" basis and not tied to land ownership. This results in a "seniority" system of rights: in times of water scarcity, junior right holders must yield to senior right holders who are currently utilizing their water rights.

Public Utilities Commission (PUC) – A state governing body that regulates the commercial activities associated with the investor-owned electric, gas, and water utilities (IOUs) operating within that state's borders.

Pumped Storage – A system of energy storage in which power is used to pump water to a higher elevation reservoir or water source when electricity demand is low and from which electric power is recovered when water is allowed to flow through a hydro-turbine down to a lower elevation reservoir or water body when electricity demand is high.

Renewable Electricity Standard (RES) – A policy that mandates that a state's utilities procure a specific amount of electricity from renewables, including solar, wind, biomass, hydroelectricity, and other energy sources. Some states have enacted specific carve-out requirements for certain energy sources, like solar energy.

Riparianism – A system of water use governance where water rights are tied to land governance, and owners of that land have the right to use water that flows by the land for any reasonable purpose. A variation on riparian law, known as regulated riparianism, provides water permits for landowners not bordering bodies of water to use that water for reasonable purposes over a limited time period.

Surface Water – Fresh, brackish, or salt water existing on the Earth’s surface in the form of lakes, rivers, ponds, streams, oceans, and other water bodies as either water sources or receiving bodies for effluents. This can include all forms of both potable and non-potable waters, including drinking water, recycled water, and wastewater.

Variable Frequency Drive (VFD) – A controller that runs a motor through varying the frequency and voltage of electricity supplied to the motor. This adjusts the speed of the motor and can be used to change motor speeds on different times of the day.

Wastewater Treatment Facility (WWT) – A facility designed to treat municipal wastewater. WWTs utilize physical, chemical, and biological processes to remove contaminants and release treated waters back into the ecosystem.

Introduction

Energy and water systems are tightly intertwined. Energy is required to extract, transport, distribute, and treat water before it is released back into the environment or made available for end-use consumption.[1] Water generates electricity, cools thermoelectric power plants, helps to extract energy resources, and supports the production of fuels.

Interaction and alignment between energy and water policy have historically been limited. However, priority-setting by governors, legislatures, businesses, and consumers has led some states' energy officials to focus on the connections and interactions between the two sectors through policy and stakeholder coordination. Addressing this "energy-water nexus" is challenging but could provide many opportunities for states to improve the performance of their water and energy systems if executed effectively.

Policy and program efforts to address the energy-water nexus can take various forms, including:

1. **Reducing energy use in water systems** (the primary focus of this paper), typically measured as gallons of water transported or processed per kilowatt hour (kWh) consumed;
2. **Increasing end use water and energy efficiency** in the residential, commercial, and industrial (including agricultural) sectors;
3. **Managing and reducing water use** in energy generation; and
4. **Recovering nutrients, metals, and energy** from wastewater treatment.

States can begin to examine the energy-water nexus further through:

1. **Integrating energy and water management** through enhanced interagency and inter-sector coordination;
2. **Coordinating efforts between energy and water decision makers** by convening stakeholder meetings to discuss strategies to improve water infrastructure performance; and
3. **Testing innovative technologies and policies** through pilot programs and demonstration projects.

Energy Use in Water Systems

The energy used to power water conveyance, treatment, and irrigation infrastructure in the United States is significant: for water collection, treatment, and conveyance systems, it amounts to approximately 1.8 percent of the nation's total energy consumption.[2] This energy is "embedded" in the water delivered to users and in the waste products those users deliver back to these systems.

Improving the energy performance of water conveyance, treatment,[3] and irrigation systems is technically and financially achievable and can be cost-effective, depending on energy prices, facility size, project specifics, and access to capital. Reducing water use in water systems would not only help upgrade critical infrastructure, but also save significant amounts of energy.

However, the nation's water infrastructure is highly dispersed, and its ownership and operational structures are fragmented: 54,000 drinking water systems and 15,000 wastewater treatment facilities (WWTs) pump, treat, transport, and distribute water to more than 264 million people.[4] The sheer complexity and size of water infrastructure across the country poses significant challenges to large-scale investment in its energy performance and efficiency, as no one-size-fits-all solution is apparent.

Improving the energy performance of water infrastructure provides opportunities for energy system operators to reduce and manage loads to lower costs and enhance reliability. Onsite energy recovery in water and wastewater systems can support resilience and save money for water system operators. Energy efficiency investments can also reduce costs to local government and customers; support jobs for equipment manufacturers, installers, and service providers; promote economic development and social equity by moderating customer water and sewer bills; and offer environmental and natural resource conservation benefits. Furthermore, energy efficiency and renewable energy upgrades in WWTs can also assist states and utilities in meeting Renewable Electricity Standard (RES), Energy Efficiency Resource Standard (EERS), and State Energy Plan or State Water Plan objectives.

State Energy Officials, Governors, legislators, and Public Utility Commissioners are uniquely positioned to reduce or help eliminate the siloes that characterize energy and water policy decision-making. Coordination and communication among different state decision makers responsible for overseeing energy and water policy decisions can help streamline and drive investments in the energy performance of water systems. Such coordination can take place through state energy plans, regional resource development plans, and other policy or program development and design processes. State policy makers can use their convening power to bring together water and energy utilities and other stakeholders for discussions on the energy-water nexus. State policy makers may also engage federal entities, such as the U.S. Department of Energy (DOE), U.S. Environmental Protection Agency (EPA), U.S. Department of Agriculture (USDA), U.S. Department of the Interior (DOI) (and such component agencies as U.S. Bureau of Reclamation (USBR), U.S. Geological Survey (USGS) and U.S. Bureau of Land Management (BLM), to identify opportunities for collaboration, dialogue, and leveraging of federal and state resources.

This white paper focuses on the roles of State Energy Offices and other state entities in promoting energy performance improvements in water conveyance, treatment, and irrigation systems. It examines state and federal energy and water policies and their potential impacts (both positive and negative) on ways water system owners invest (or do not invest) in energy performance improvements. Finally, it offers case studies of State Energy Office programs and projects that address performance in water distribution and wastewater treatment systems. This white paper may serve as a reference for State Energy Office directors, staff, and state legislators who are considering strategies to address the energy-water nexus in their states.

Section 1 of this paper focuses on the natural and human factors that affect water use and distribution patterns. Section 2 offers information on the major elements of water infrastructure and opportunities to improve its performance, including examples of pertinent State Energy Office activities. Section 3 provides a description of the key actors and decision makers at the state, local, and federal levels and their main functions in developing energy or water policy, including how their decisions affect the energy performance of water systems. Section 4 describes the main interactions between energy and water decision makers concerning water infrastructure. Section 5 details the main policy challenges and considerations for improving energy performance for water distribution systems. Section 6 provides brief case studies of seven State Energy Offices implementing policies and programs to improve the energy performance of their water distribution systems.[5]

Section 1: Regional and Local Variability in Water Resources and Energy Use

Energy use in water conveyance and treatment systems in the United States varies according to geographic, climatic, seasonal, demographic, economic, and regulatory conditions. Chart 1 illustrates the wide range in percentages of water used by different end-use sectors in each state, as well as the different components of water infrastructure. In many cases, there is a direct connection between water usage and energy consumption. To illustrate, states with high water use for agriculture typically also see a higher share of energy used for irrigation systems; conversely, states where the residential, commercial, and industrial sectors account for a high proportion of water use see a larger share of their energy consumption coming from the operation of wastewater treatment systems (WWTs) and water treatment and conveyance systems, which are used to transport and treat human waste and other byproducts of human activities.

The energy needs of water infrastructure are typically heightened in water-stressed areas. Water resources are unevenly spread across the country and precipitation does not necessarily fall where water is needed, leading to increased surface water withdrawals in drier climates as well as the need to transport surface water over greater distances. The energy needed to pump groundwater increases further if water tables deepen due to overuse from irrigation, drought, heat waves, or other climate variations. As a result, arid areas in the southern and western states withdraw higher amounts of groundwater and transport water over longer distances, with higher evaporative losses than eastern states, leading to higher energy intensities for their water infrastructure.[6] This dynamic poses a problem as hydroelectric power plants or pumped storage in water-stressed regions may not be able to operate at full capacity due to water shortage, resulting in lower energy resources available when they are needed most. Different areas of the country have differing levels of available groundwater resources: states with access to larger aquifers (such as states with borders above the Ogallala aquifer), for instance, tend to withdraw greater amounts of groundwater and may require more energy to pump those amounts of groundwater to the surface.[7]

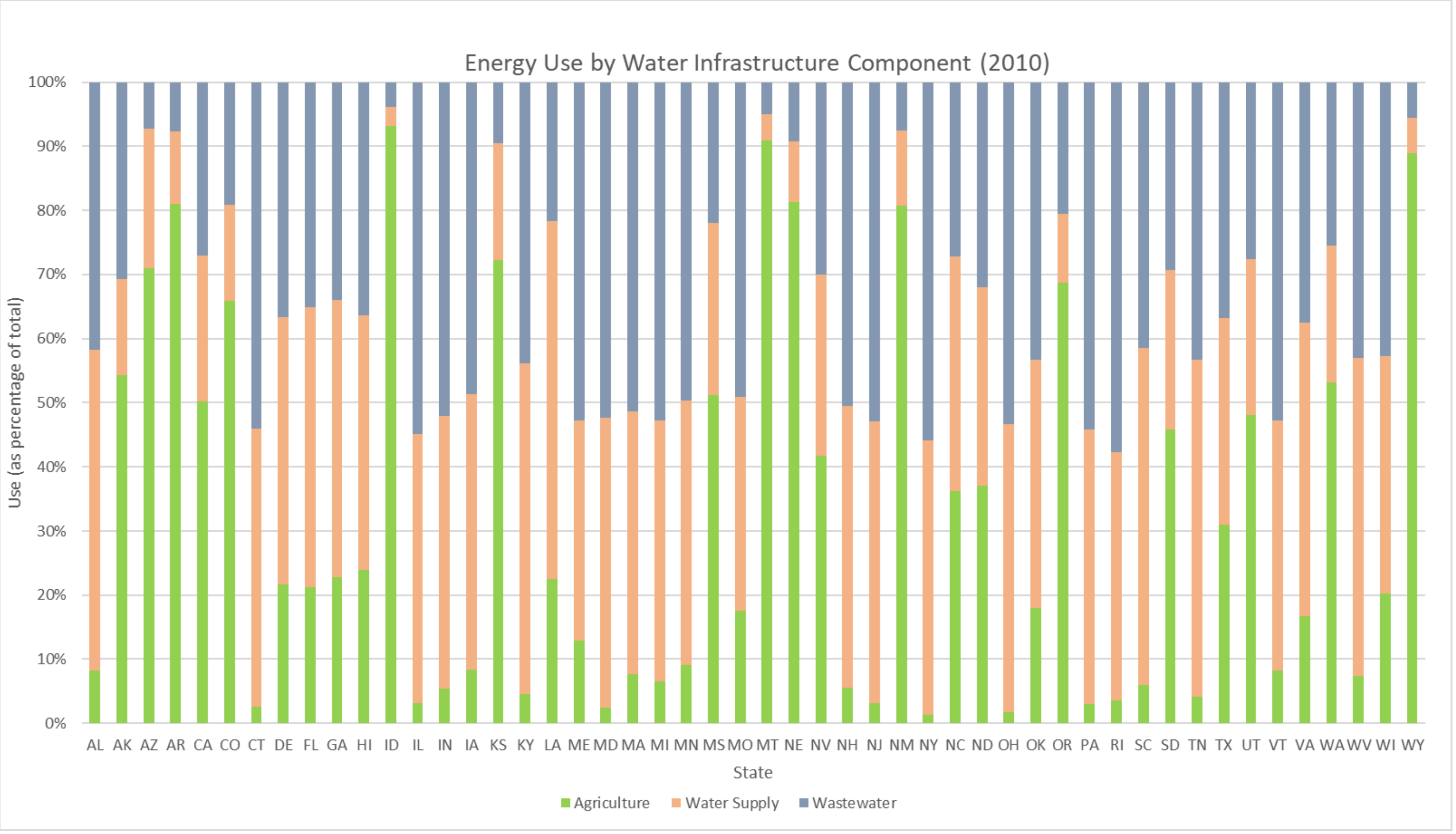
Demographic and other human factors contribute to the energy use of water infrastructure. Population fluctuations may spur changes in water demand, thereby affecting the energy used to transport and distribute potable water to homes and businesses, as well as to transport and treat wastewater before reintegrating it into the natural environment. In areas with declining populations, water utilities may have underutilized assets and difficulty paying for their existing infrastructure and the energy costs required to keep it operational. Alternately, in areas with increasing populations, utilities may need to increase investments in water (and, as a result, energy) infrastructure to accommodate additional demand.[8]

The changing composition of agricultural and industrial activity also affects local demand for water. The opening or closing of manufacturing plants or mining operations can greatly affect local water demand as well as the quantity and quality of effluent that may be treated onsite or sent to a public treatment works for eventual release. Changing crop and livestock composition and production practices similarly affect water demand and the amount and nature of effluents released to the environment.

State and local economic conditions present another variable. For example, oil- and gas-producing states generate produced and flow-back water as part of conventional or hydraulic fracturing processes; beneficial treatment and reuse of that water for “fracking” or irrigation may help to reduce net water consumption and withdrawals by the industry and conserve or even enhance water availability for other use.

However, the treatment of produced water and wastewater from oil and gas production is energy-intensive. Desalination of produced water can use more energy than desalination of seawater (1 kWh per cubic meter for seawater vs. 2 to 9 kWh per cubic meter of produced water).[9] Produced and treated waters may also need to be transported to and from oil and gas extraction sites, requiring additional

Chart 1: Energy Use by Water Infrastructure Component (2010)[10]

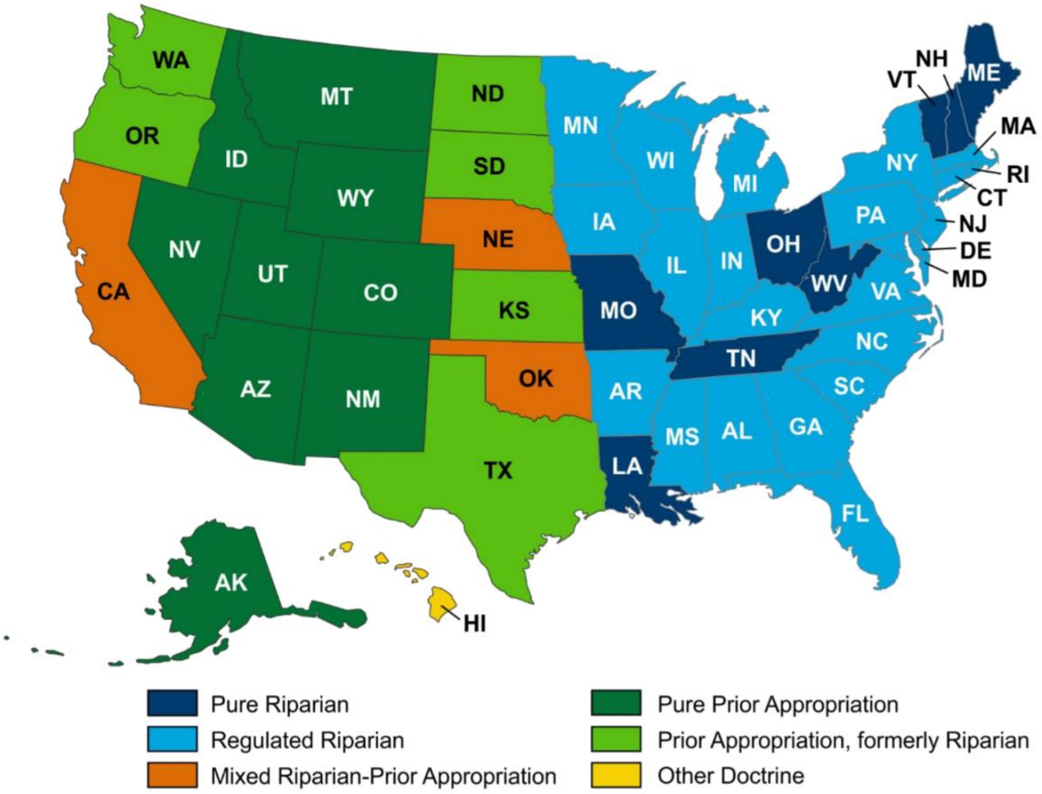


Source: Lawrence Livermore National Laboratory, Development of Energy-Water Nexus State-level Hybrid Sankey Diagrams for 2010," September 2017, p. 86-97, https://flowcharts.llnl.gov/content/assets/docs/2010_United-States_EnergyWater.pdf.

energy. Nevertheless, treatment of produced water may be attractive to states with limited water resources and those that are able to use produced water beneficially, for agricultural or other purposes.[11]

Finally, policy differences across states may affect the energy performance of water infrastructure. States in the eastern half of the country operate under riparian governance policy, where surface water use is tied to land ownership, while states in the western half of the country utilize a system based on prior appropriation, where surface water is apportioned based on a “first-come, first-served” basis and not tied to land use (see Figure 1). States with prior-appropriation doctrines have higher rates of energy-intensive groundwater withdrawals than states under riparian rules due to more restrictive access to surface waters and less surface water overall due to more arid climates. California and Texas, which operate under prior appropriation water rights policies, both utilize especially large withdrawals of both surface and groundwater (in both total volume and proportion of total withdrawal) for public supplies, irrigation and livestock needs.[12] Texas also withdraws significant amounts of water for oil and gas extraction, mining, and industrial uses.

Figure 1: Surface Water Rights Governance in the United States (By State)



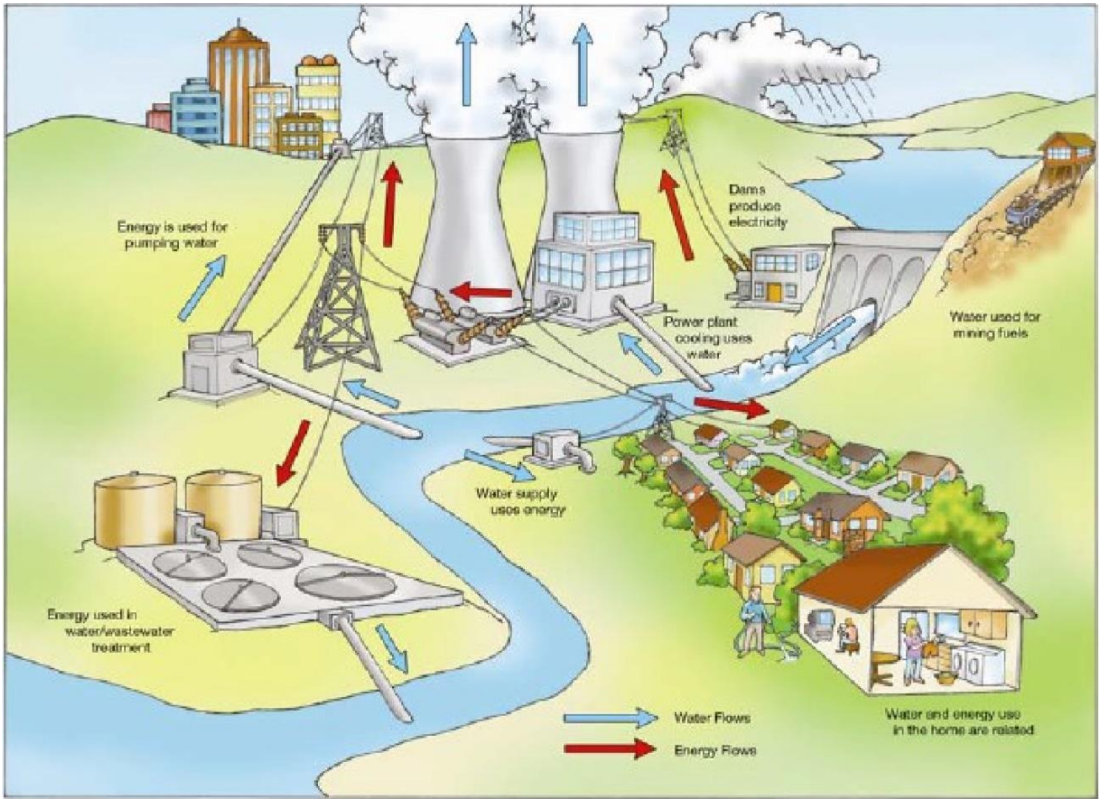
Source: U.S. Department of Energy, “The Energy-Water Nexus: Challenges and Opportunities,” June 2014, p. 56.

There is no “one-size-fits-all” policy or program solution to improve the energy performance of water systems. As a result, for many State Energy Offices, it is crucial to consider unique local needs and regional characteristics carefully when planning for energy investments in water infrastructure or providing energy-related assistance to water utilities. Potential interventions may include: implementing energy efficiency measures at WWTs; reducing leaks; generating power through the movement of water through pipelines; producing biofuels, bioproducts, and biopower from waste processed at WWTs; utilizing combined heat and power (CHP) at WWTs; and increasing coordination among various water and energy decision makers. These and other efforts to enhance the energy performance of water systems can result in tangible benefits that minimize stress to energy and water infrastructure while creating cost-saving, resiliency, and energy generation opportunities for operators and end-users.

Section 2: Energy Components of Water Infrastructure

The infrastructure that transports water from where it is located to where it is needed is multifaceted, with each individual component acting as a user and/or potential producer of energy (see Figure 2 and Table 2). Optimizing the energy performance of each part of the system could provide significant energy and water savings for utilities while simultaneously reducing costs for customers.

Figure 2: Water Conveyance, Treatment, and Irrigation System Schematic



Source: U.S. Department of Energy, Energy Demands on Water Resources, Report to Congress on the Interdependency of Energy and Water, December 2006, p. 13.

This section includes an overview of each component of the water transportation and delivery system and details relevant opportunities for energy generation or energy savings, beginning with a high-level summary in Table 1.

Table 1: Elements of Water Infrastructure and Their Roles in System Performance

	Water System Role	*Energy Impacts*
Pumped Storage	• Energy infrastructure that uses water as an **energy storage medium.** • Reservoir for **water storage**.	• *Flexibility:* Able to manage electricity capacity to match demand by storing power during periods of low load, then generating power during times of high load. • *Flexibility:* Useful for responding to demand or supply fluctuations, and balancing non-dispatchable generation, like solar or wind. • *Flexibility:* Capable of arbitraging variable electricity prices and providing grid-supporting ancillary services in addition to energy, though prioritizing the competing services (e.g., water supply, environmental flows) can be challenging. • *Net energy consumer*: Requires energy to pump water back to upper reservoir for reuse.
Wastewater Treatment Facility (WWT)	• **Treats effluent water** from human activity and releases it back into the natural water system or **recycles the water or other byproducts** for industrial or human reuse.[13]	• *Energy-intensive process*: WWTs remove organic compounds by growing beneficial organisms to consume those compounds. Approximately 50 percent of the energy in a WWT is used by aeration equipment to provide oxygen and mixing energy for these organisms. • *Energy-intensive process*: After aeration, pumping and (in some facilities) ultraviolet disinfection systems are the next two largest energy consumers • *Energy efficiency potential:* Cost-effective potential energy efficiency of 8-10 percent savings at WWTs is not uncommon.[14] • *Energy recovery potential:* Many WWTs produce biogas through anaerobic digestion. In those facilities, it may be possible to generate electricity by using the biogas as a fuel similar to natural gas. These facilities can also recover biosolids for powering vehicle fleets with compressed natural gas (CNG) and pipeline renewable natural gas (RNG), in addition to liquid fuels such as jet and diesel. • *Energy recovery potential:* Can harvest thermal energy for district heating and cooling.
Water Supply Treatment	• **Treats raw water** before it is distributed to users.[15] • Can treat to **potable or non-potable** water standards depending on intended use.	• *Energy-intensive process*: There is significant energy needed for pumps to move treated water to storage, as well as use of traditional and membrane filtration systems to filter out impurities.[16] • *Energy recovery potential:* Possible generator of electricity through turbine installation at plants, can be paired with renewable energy to reduce energy costs. • *Energy efficiency potential:* Opportunities for increasing the efficiency of the desalination process, as well as treatment of water before and after desalination has occurred.

Collection and Conveyance	• **Transports water** from where it originates to where it is needed.	• Water loss from leaky infrastructure, as well as evaporative losses, increases energy needed to pump each gallon of water to its destination, increasing costs and decreasing profits for water utilities.[17] • *Energy efficiency potential:* Opportunities to improve pump efficiency for both groundwater extraction and surface transport, especially if over varied elevations or long distances. • *Energy efficiency potential:* Opportunities to improve pump efficiency and reduce electric utility demand charges through scheduling filling and draw-downs from water towers and other water storage instruments to coincide with lower electricity rate periods. • *Energy efficiency potential:* Reduce water and embedded energy waste by preventing, detecting, and repairing leaks. • *Flexibility:* Opportunities to provide supporting services for the electric grid (e.g. frequency regulation) through use of variable speed pumps. • *Energy recovery potential:* Possible electricity generator if turbines are added to pipes that convey water down steep elevation gradients, or in place of pressure-reducing valves, if economics become more favorable.
End-Uses	• **Components** of homes, businesses, industry, and agriculture **that utilize energy and water** (i.e. energy needed for water heating, other specialty uses).	• Energy efficiency, demand response, and grid flexibility opportunities possible for the electric power system through further appliance automation and better water metering capabilities in homes, businesses, industry. • Energy needed to treat water for special conditions (e.g., on-tap reverse osmosis) or special needs (e.g., high-tech manufacturing) • *Energy efficiency potential:* Opportunities for energy efficiency when heating water for human or industrial uses. • *Energy efficiency potential:* Multiple opportunities available to conserve water use, reducing the embedded energy present in water supply. These include: ○ More efficient on-site water use, or increased graywater use where applicable, in commercial and industrial buildings ○ More efficient landscape watering practices, including xeriscaping (landscaping that reduces or eliminates the need for supplemental irrigation) ○ Agricultural irrigation efficiency, including drip irrigation ○ Stormwater harvesting for homes and businesses

Pumped Storage

Pumped storage is a system of energy storage that generates electricity, where water is pumped into a higher reservoir when electricity demand is low and released to a lower reservoir during times of peak demand to generate power. There are approximately 22 GW of pumped storage capacity in the United States, which is around 2 percent of the nation's generating capacity, and storage facilities range in size from 10 MW to 3000 MW of generation.[18] Pumped storage pairs well with renewable power generation because the stored generation capacity can be increased or utilized to complement variable solar or wind resources. Pumped storage's quick ramp-up time, low generation cost, and ability to utilize nontraditional water sources makes it a flexible low-cost option to supply electricity during peak demand periods, which can lower overall energy costs for both utilities and ratepayers. A recent study by Idaho National Laboratory found that over 2500 additional sites, primarily concentrated in the Northeast, upper Midwest, and West could be utilized or adapted to potentially provide over 25 GW of additional pumped storage power.[19] However, the length of the Federal Energy Regulatory Commission (FERC) licensing process and environmental siting issues can make financing potential pumped storage projects difficult and unattractive to potential financiers.[20] The falling costs and improved cost-effectiveness of battery electric storage may also limit development of additional pumped storage capacity.

There are opportunities to improve the energy performance of pumped storage systems. Upgrading the pumps in a pumped storage system can improve performance up to 18 percent.[21] A recent study by the Electric Power Research Institute (EPRI) found that optimizing pumped storage plants through improved automation and controls can increase performance up to 1.1 percent.[22] Furthermore, for those plants that participate in wholesale energy markets, optimizing generation scheduling provided a performance increase of up to 2.9 percent.[23] Electric utilities can choose to implement those measures and optimize the efficiency of those systems. State Energy Offices can provide funding or work with state Public Service Commissions in designing pilots to test new technologies in the pumped storage arena.[24]

Wastewater Treatment Facilities (WWTs)

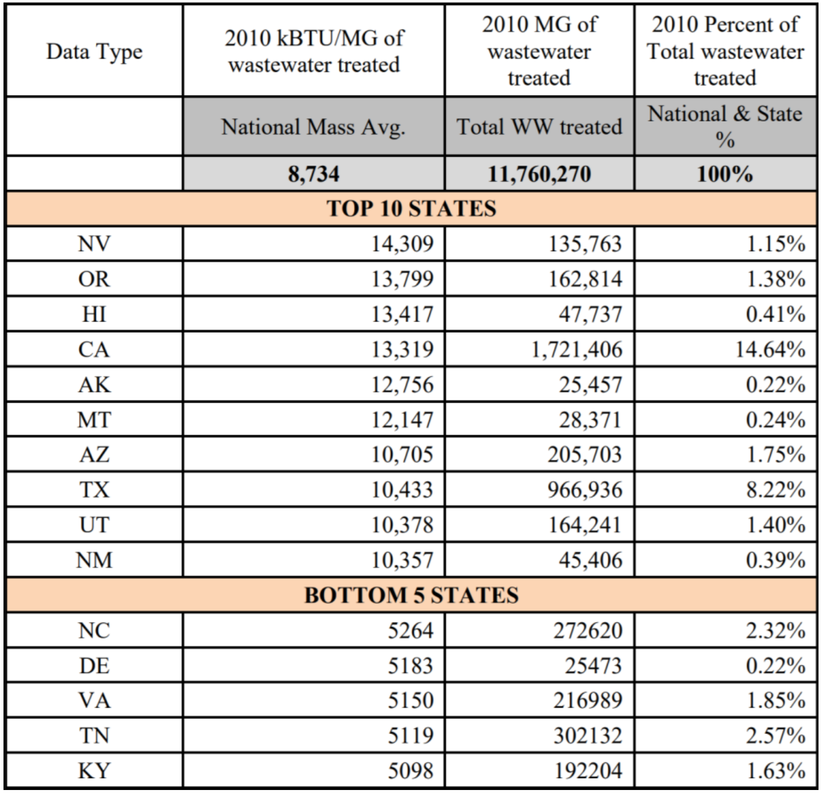
Treatment of water resources covers two categories: wastewater treatment and water supply treatment (covered in the following section).[25] Wastewater treatment is the treatment of used water to make it suitable for discharge back into water bodies or for potable or non-potable re-use. Over 15,000 WWTs in the United States treat sewage, industrial, agricultural, and landfill wastewater streams. Those facilities are energy-intensive, with energy use comprising 25 to 40 percent of total operating costs.[26] Pumps and aeration systems are the largest users of energy at WWTs and can account for up to 87 percent of their energy use. Increasing the efficiency of pumps and aeration systems can result in significant energy savings at plants of any size. For example, St. Peter, Minnesota's wastewater treatment plant, which serves a population of 12,000, conducted an audit with the Minnesota Technical Assistance Program to determine opportunities for energy efficiency improvements at the plant. The audit found that, by installing variable frequency drive (VFD) compressors for its aeration systems, the plant could save almost $14,000 per year in energy costs.[27] Implementing all the efficiency opportunities identified by the audit would result in a payback period of one year for the plant.

WWTs have opportunities to generate electricity on-site (and reduce their costs from purchasing electricity) from the resources they produce as part of the treatment process. For example, harnessing the energy potential of wastewater through biogas capture together with the use of combined heat and power (CHP) systems can help to lower operating costs and/or provide additional revenue streams for WWTs. While 214 WWTs already have CHP systems installed, a DOE study from March 2016 found that an additional 1,130 WWTs could install CHP for a combined potential capacity of 262 MW, enough to power almost 200,000 homes.[28] Installing additional renewable energy resources, such as on-site solar or wind power generation, at WWTs can also lower energy costs for those plants.

Additionally, many WWTs use anaerobic digestion as part of the treatment process. This technique produces biogas, which is similar to natural gas, as a byproduct. Biogas can be cleaned and used as a fuel for heating, electricity generation, vehicle fuel, or sold to natural gas customers.[29]

WWT operators can further reduce their energy costs by turning off aeration systems and pumps during periods of peak electricity demand or utilize onsite generators that run on biogas during those periods.[30] Heavier use of WWT systems could then shift to off-peak hours. Electric utilities can develop specific tariffs or incentives to encourage WWT operators to employ these types of practices, as well as more generalized tariffs that reward good demand management practices and accommodate the benefits from CHP systems.

Table 2: Energy Intensity of Wastewater Treatment (by State, 2010)



Data Type	2010 kBTU/MG of wastewater treated	2010 MG of wastewater treated	2010 Percent of Total wastewater treated
	National Mass Avg.	Total WW treated	National & State %
	8,734	**11,760,270**	**100%**
TOP 10 STATES			
NV	14,309	135,763	1.15%
OR	13,799	162,814	1.38%
HI	13,417	47,737	0.41%
CA	13,319	1,721,406	14.64%
AK	12,756	25,457	0.22%
MT	12,147	28,371	0.24%
AZ	10,705	205,703	1.75%
TX	10,433	966,936	8.22%
UT	10,378	164,241	1.40%
NM	10,357	45,406	0.39%
BOTTOM 5 STATES			
NC	5264	272620	2.32%
DE	5183	25473	0.22%
VA	5150	216989	1.85%
TN	5119	302132	2.57%
KY	5098	192204	1.63%

Source: Lawrence Livermore National Laboratory, Development of Energy-Water Nexus State-level Hybrid Sankey Diagrams for 2010, 2017, p. 100.

Water Supply Treatment

Water supply treatment consists of the processes used to remove disease-causing agents, chemical compounds, and sediment from water resources. It is used to disinfect water before it is delivered for end-use purposes. This includes either freshwater treatment or desalination plants, which are more energy-intensive than freshwater treatment.

One of the most energy-intensive forms of water supply treatment is the desalination of seawater for potable or non-potable uses. Desalination is the process by which salt and other minerals are removed so that water can then be used for drinking, agriculture, or other purposes. Energy needs at desalination plants can account for 30 to 50 percent of their total operating costs.[31] A recent study by DOE found that there is the potential to reduce electricity usage of desalination plants by 28 percent if best technologies and practices are used to optimize energy use, with the greatest savings coming from the desalination process itself. Additional supplemental opportunities for energy reduction are available from pre- and post-treatment of the water supply.[32] As with water treatment facilities, combining desalination treatment facilities with renewable energy generators can, in some cases and where local market rules allow it, help generate revenue for those plants from the sale of surplus electricity to the grid.[33] Water disinfection equipment and operations, whether at desalination plants or fresh water treatment plants, generally use more energy than wastewater treatment. They can also be grid-connected and participate in demand response and demand management programs to reduce load when electricity demand rises.[34]

Collection and Conveyance

Collecting, lifting, and transporting water can be highly energy-intensive (the exception being gravity-fed water distribution systems, whose energy use is very low compared to groundwater withdrawals or long-distance water pumping). Across much of the country, a vast network of pumps, reservoirs, aqueducts, and pipes transports water from where it is located to where it is needed, such as homes, businesses, schools, farms, industries, and cities. For example, in the table below, Arizona has very high energy use for its public supply systems due to the energy needed to convey water to where it is needed.[35]

The leaks present in water conveyance infrastructure contribute to higher energy and water use by water conveyance systems. According to the American Society of Civil Engineers (ACSE), leaks in water piping may result in a loss of over two trillion gallons of drinking water each year,[36] which means that as much as 14 to 18 percent of the nation's treated water is lost before it reaches its destination.[37] Every gallon of water lost due to leaks means that that the energy used to collect, transport, and treat that water was wasted and that additional energy is consumed to deliver water to customers. State Energy Offices, through the state energy planning process, can help set policy directions that encourage the incenting of water utilities to maintain pipes and more proactively fix leaks as they arise. For example, the Missouri Comprehensive State Energy Plan includes a discussion on the energy use associated with leaks and provides several recommendations to improve the state's water distribution infrastructure.[38]

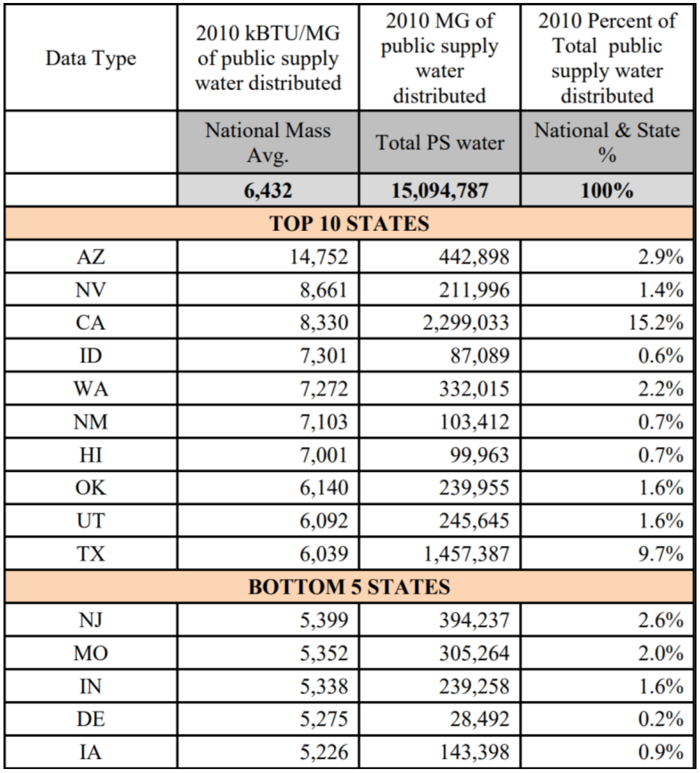
Water utilities that are proactive in fixing leaks can reduce their energy use as well as their water use. Steps these utilities can take to reduce leaks include utilizing acoustic leak detection hardware, undertaking leakage component analyses of their service territories, and reducing excessive pressure in piping systems.[39] Water utilities can also perform water audits to determine baseline flows for water use and to pinpoint problem areas for water losses so maintenance can be more efficient at reducing those water losses. Reducing the pressure on water systems can further help minimize leaks and limit the stress on pipes and joints, reducing the probability of new leaks and potentially deferring the need for repairs.

Pumping water may also require a lot of energy. Pumping and distributing surface and groundwater resources in the United States can use between 1100 and 2000 kWh per million gallons distributed, with the lowest energy requirements located in the Northeast and the highest in the Southwest.[40] Pumping water can account for up to 80 percent of the total energy required for water treatment and distribution in the United States outside of heating and end uses. It can also use up to 100 percent more energy compared to sourcing and treatment processes.[41] For example, sourcing and treating water can together use up to 1000 kWh per million gallons, while distribution by itself can use an additional 1000 kWh per million gallons.[42] Because pumping water can be very energy-intensive in areas where it is needed, upgrading water pumping systems could save much energy. For instance, variable frequency drives (VFDs) can help optimize pump energy usage based on load by adjusting motor speeds to match the energy needs of the plant; these types of pumps can save up to 50 percent more energy compared to single-speed pumps.[43] VFDs also enable ancillary services and offer demand response opportunities similar to those provided by pumped storage, where drives can operate at speeds to match the energy demands needed by water infrastructure at a given time period.

Additionally, the pipes installed when water service began may end up being an improper size for the current water needs for a community due to larger-than-expected demand, resulting in higher pressure and energy needed to pump water through them. Correcting pipe sizes for water distribution when replacing leaky pipes or ensuring that pipe sizes are correct to minimize friction when laying new pipes may result in an additional 20 percent in pumping energy savings.[44]

Finally, water system operators can generate energy from downhill flowing portions of their pipes. This energy can be sent to the electric grid or be used locally. PUCs may consider ways to incentivize water and electric utilities to support beneficial energy recovery from the water infrastructure system in light of these opportunities.

Table 3: Energy Intensity of Public Water Supply (by State, 2010)



Data Type	2010 kBTU/MG of public supply water distributed	2010 MG of public supply water distributed	2010 Percent of Total public supply water distributed
	National Mass Avg.	Total PS water	National & State %
	6,432	**15,094,787**	**100%**
TOP 10 STATES			
AZ	14,752	442,898	2.9%
NV	8,661	211,996	1.4%
CA	8,330	2,299,033	15.2%
ID	7,301	87,089	0.6%
WA	7,272	332,015	2.2%
NM	7,103	103,412	0.7%
HI	7,001	99,963	0.7%
OK	6,140	239,955	1.6%
UT	6,092	245,645	1.6%
TX	6,039	1,457,387	9.7%
BOTTOM 5 STATES			
NJ	5,399	394,237	2.6%
MO	5,352	305,264	2.0%
IN	5,338	239,258	1.6%
DE	5,275	28,492	0.2%
IA	5,226	143,398	0.9%

Source: Lawrence Livermore National Laboratory, Development of Energy-Water Nexus State-level Hybrid Sankey Diagrams for 2010, 2017, p. 96.

End-Uses

Once water is pumped and transported to where it is needed, efficiencies at the distribution end of water infrastructure can help reduce the overall energy used for water for the entire system.

There are a number of end-use actions that can reduce the energy needed for consumers' water uses. According to ACEEE, heating water accounts for 12 percent of residential and 7 percent of commercial energy use.[45] Increasing the efficiency of water heaters in both residential and commercial buildings can result in significant energy savings as heating water is perhaps the most energy-intensive use in the water infrastructure system.[46] Water and energy utilities can offer rebates to encourage their customers to install more energy-efficient gas or electric water heaters or "smarter" grid-interactive electric water heaters that can help utilities reduce demand peaks and reduce system generation costs. These efficient water heaters can reduce home energy use by 27 to 50 percent.[47]

Standards such as ENERGY STAR for residential and commercial equipment can offer joint energy and water benefits. In the residential sector, replacing water- and energy-using appliances such as clothes and dishwashers with high-efficiency ENERGY STAR labeled versions directly saves energy and water (including hot water). ENERGY STAR products have saved American households and businesses over 3.5 trillion kWh of electricity since 1992, adding up to over $450 billion in energy savings.[48] Similarly, WaterSense-labeled and other water efficient equipment also offer water and, thus, energy savings: WaterSense-labeled products saved over 630 billion gallons of water in 2017; those water savings reduced energy use by 367 billion kWh, which is enough to power over 34.1 million homes for a year.[49]

Other end-use water efficiency opportunities can be found in the commercial and industrial sector. Restaurants and car washers can implement systems to reuse wash water. Commercial buildings can employ moisture sensors to control landscape watering, or go further and implement xeriscaping, which is landscaping that reduces or eliminates the need for watering or irrigation. Industrial plants may want to consider the use of graywater for cooling water (where applicable). Food processing plants, in particular, could also consider equipment upgrades for water conservation. The full list of possibilities extends beyond the scope of this paper, but it is important to note that there are myriad options available, so commercial and industrial companies can be flexible in how they approach their water efficiency efforts.

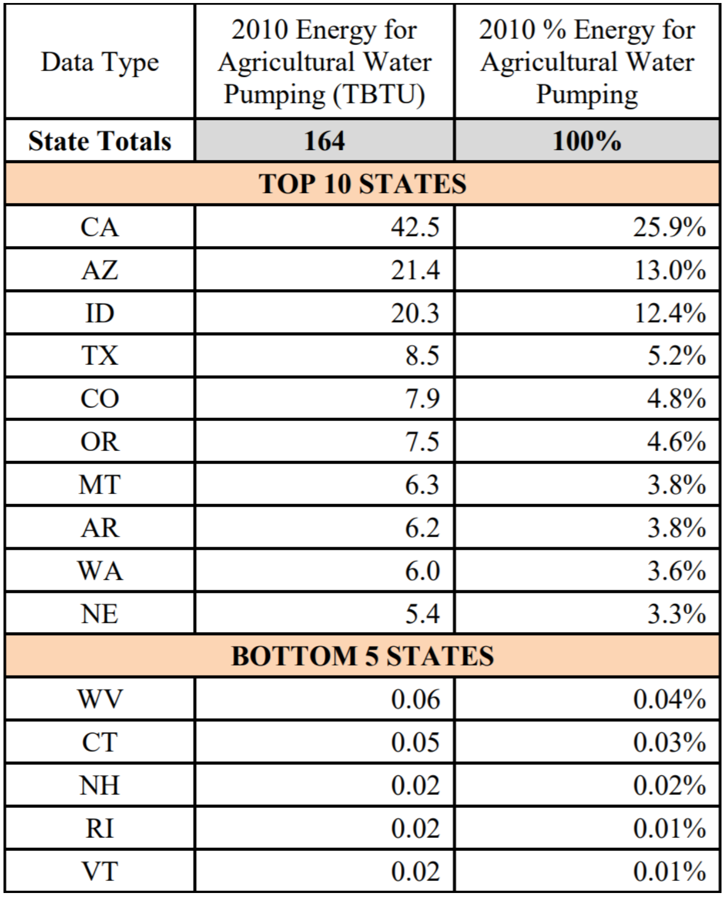
Incentives offered to end-use sectors typically drive uptake of water conservation strategies and technologies. Where allowed by law, Public Utilities Commissions can authorize water and energy utilities to offer rebates and other incentives for water and energy efficient equipment and practices. State Energy Offices may be well-positioned to provide policy guidance to regulators on incentive program design, administer state incentive programs, and/or provide technical assistance and informational and educational resources.

One option sometimes exercised by state governments during droughts or other water supply emergencies is to regulate end-uses of water by restricting water use, instituting tiered rates or conservation goals, or increasing standards for water appliances[50] or new landscaping in new developments. Such actions can also reduce the overall stress to the system and result in lower water use. California enacted a suite of measures to help reduce water use during its most recent drought in 2013-2014.[51]

Agriculture

Agriculture-specific end-use applications can provide additional energy performance opportunities for water infrastructure. Utilizing irrigation scheduling, adopting drip irrigation methods, installing wastewater return systems, upgrading irrigation systems by lining and improving canal structures, and installing remote monitoring and control systems can all reduce water use, relieve stress on the water distribution system, and result in energy savings as less water needs to be pumped and transported to farms.[52] Additionally, using rain gauges and soil moisture sensors to target irrigation when it is needed could help to optimize water use and reduce overall water and energy usage regardless of climatic conditions. (This also applies to non-agricultural landscape watering by households and businesses.) Including irrigation systems in demand response pilots can also lessen their energy intensity. California electric utilities have created some pilot programs for agricultural demand response rate schemes.[53] The pilots have helped farmers save money on both their electricity and water bills while also providing cash incentives for reducing electricity use during peak hours.

Table 4: Energy Intensity for Agricultural Pumping (by State, 2010)



Data Type	2010 Energy for Agricultural Water Pumping (TBTU)	2010 % Energy for Agricultural Water Pumping
State Totals	**164**	**100%**
TOP 10 STATES		
CA	42.5	25.9%
AZ	21.4	13.0%
ID	20.3	12.4%
TX	8.5	5.2%
CO	7.9	4.8%
OR	7.5	4.6%
MT	6.3	3.8%
AR	6.2	3.8%
WA	6.0	3.6%
NE	5.4	3.3%
BOTTOM 5 STATES		
WV	0.06	0.04%
CT	0.05	0.03%
NH	0.02	0.02%
RI	0.02	0.01%
VT	0.02	0.01%

Source: Lawrence Livermore National Laboratory, Development of Energy-Water Nexus State-level Hybrid Sankey Diagrams for 2010, 2017, p. 92.

Section 3: Key Water Decision Makers

A variety of stakeholders at the state level are responsible for influencing energy-water policy decisions. Interactions between and among these stakeholders may have a significant impact on water infrastructure and use patterns within a state or region in the United States, and their associated energy uses and costs. The following section details the functions of each stakeholder and key interactions among them, including how they might influence policy decisions pertaining to the energy-water nexus.

State Agencies

States significantly vary in how they oversee water-related topics. For example, state agencies responsible for water policy decisions can include state Departments of Natural Resources, Public Health, the Environment, Consumer Affairs or Licensing, Office of the State Engineer, or State Geological Surveys. Typically, decisions around water *quantity* fall under the purview of Departments of Natural Resources, while water *quality* issues remain under the scope of the Departments of Health or the Environment, or both. Water or Natural Resources Commissions or Boards are bodies whose members are appointed by the Governor and advise in water policy formulation, conduct drought planning, and may identify priority water rights holders in water scarcity situations.

A state Division of Water, typically a part of a Natural Resources Department, is usually responsible for administrative and permitting duties for water rights. The Division approves applications for water well permits and oversees compliance with interstate compact agreements. The Division may also provide financial and technical assistance for various water-related stakeholders as well as visibility for relevant causes and/or successful projects. Thus, the Division can make various decisions surrounding water use patterns that can affect water use. For example, a Division of Water (for any number of reasons) may refuse to provide permits for water wells, which may then lead to an expansion of water infrastructure to well-less areas. That expansion of water infrastructure will require more pumping capability, more electricity to power those pumps and more capital spent on the project as a result.

State certification boards residing within Departments of Consumer Affairs may certify water facilities or operators, although sometimes a state's Department of Environmental Protection or Quality (DEP/DEQ) may provide training and credentialing instead. In addition, DEPs/DEQs, or state Health Departments, may have purview over water supply treatment plant operators. while State Geological Surveys typically serve as an information resource for state governments. Some of those agencies may have regulatory responsibility for water, oil and gas, and land reclamation.

State Legislatures

State legislatures are responsible for setting the budgets for state agency operations, setting the direction of agencies, and directing research on energy and water. They also set energy policies that influence the growth of renewable energy, natural gas, coal and energy efficiency, which can play a pivotal role in determining the water intensity of a state's energy portfolio. In addition, the legislature creates the framework that shapes the administration, function and sale of water rights. Legislatures often play a central role in water planning efforts, setting guidelines and direction for state water commissions in the development of water resource plans.

Tribal Governments

Tribal governments are responsible for making energy and water decisions on tribal lands. Although tribes have inherent sovereign authority and jurisdiction over their lands, the federal government exercises a significant degree of control and jurisdiction, and tribes are still subject to federal laws and power.

The Supreme Court determined in *Winters v. United States* that the federal government, in establishing reservation lands for tribes, also reserved access to water to fulfill the purpose of the reservation.[54] Tribes can rely on the federal government to represent their interests, intervene in water adjudication proceedings or negotiate their water rights outside of these proceedings.[55] Tribal governments oversee water system utilities or utility boards and play a role in ensuring that their public water systems comply with federal laws, such as the Safe Drinking Water Act and the Clean Water Act.[56]

Public Utilities Commissions

Public Utilities Commissions (PUCs), also called Public Service Commissions or State Corporation Commissions, regulate investor-owned utilities (IOUs), including electric and water utilities. PUCs ensure that utility operations are safe and reliable, determine rates, and issue permits for the construction of energy infrastructure and facilities. Public Utility Commissioners, appointed by state governors in 37 states, elected by constituents in 11 others, and elected by the legislature in two, are responsible for making all final PUC decisions.[57] State legislatures can assign responsibilities to PUCs, such as soliciting bids for long-term energy contracts, conducting studies or implementing renewable energy programs. State legislation also typically dictates the scope of the PUC's authority, including its treatment of water resources.

With regulatory authority over investor-owned water and electric utilities, PUCs can shape how utilities address the energy-water nexus. For example, PUCs can require electric utilities to report annual water withdrawals and consumption data, adopt water and electricity rates that encourage conservation, facilitate partnerships between energy and water utilities, and conduct studies of alternative, less water-intensive energy sources.

Water Utilities

Nearly 50,000 water and wastewater utilities own, operate, and maintain most of the water treatment and conveyance infrastructure in the nation.[58] They install pipes and sewers, fix leaks, upgrade and maintain water and wastewater treatment plants, and develop pricing structures to pay for this infrastructure as public goods. Water utilities can be either privately-owned (investor-owned) or publicly-owned (by state or local governments). Investor-owned utilities (IOUs) are regulated by PUCs, while publicly-owned systems (municipal systems or rural cooperatives) are typically regulated by local boards of directors, or city or town councils. Utilities work with these regulators to set pricing structures for their customers according to demand and use patterns, often by sector (residential, commercial, industrial, etc.).

The proposals and decisions water utilities make regarding water pricing structures and incentives for water infrastructure upgrades can have an impact on energy use for the entire system. While many water utilities utilize a flat rate for water use, others have begun experimenting with alternative pricing structures to encourage end-use water conservation that reduces the stress on their water delivery systems, and to raise the capital needed to make improvements to those systems (improvements which may reduce their energy consumption). For instance, some have adjusting flat rates or inclining block rates to ensure that the costs of future improvements to water delivery systems are recovered.[59] Utility efforts to quickly message users about potential leaks and rapid jumps in water consumption have also been effective in reducing overall water consumption. For example, in Kansas City, the Board of Public Utilities notifies customers who use more than 188 gallons of water per day. Those customers then have the opportunity to fix those leaks; over 1,500 customers have been reached by the program.[60]

Eleven states have also authorized investor-owned water utilities to enact distribution system improvement charges (DSICs) to cover the cost of future investments to water systems.[61] Those investments could include efficiency or performance improvements designed to reduce overall energy use by their systems, including replacing leaky pipes.

Decoupling water utilities' revenues from their volumes of water sold could also incentivize energy and water conservation. This strategy could reduce utilities' need to invest in infrastructure, and thus avoid rate increases for customers.[62] Regulatory commissions in both California and New York have already allowed decoupled water rates for their investor-owned water utilities.[63] However, when implementing decoupling, water utilities need to consider the possibility that decoupled rates may lead to fixed cost balances that consumers will have to pay at a later date if overall revenues decline due to underusage of water resources. Utilities then need to recover additional revenue to meet decoupling allowances. This issue occurred in California during its most recent drought in 2013-2014.[64] Water utilities that implement decoupling may also want to consider implementing rate stabilization funds to account for unexpected changes in revenues received compared to forecasted revenues in their rate cases.[65]

Finally, water utilities could also increase their demand-side management activities to reduce peak energy and water demand. For example, Austin Water, a publicly-owned utility in Texas, offers a number of incentives for installing water efficiency measures at residential, commercial, multifamily, and school properties. Upgrades covered by those incentives include rainwater harvesters, irrigation improvements, and more water-efficient landscaping.[66]

State and Local Taxing and Financing Entities

Special state- and locally-created entities play a role in water-based decisions. Irrigation districts, which are special purpose districts with the authority to tax, borrow, and condemn over a defined region, make decisions pertaining to the distribution of water to agriculturally-productive lands within their district. Shifting the distribution of water may result in pumping water over longer distances, which can increase energy use by water infrastructure as more pumping is required.

State environmental infrastructure banks, funded through the U.S. Environmental Protection Agency's Clean Water State Revolving Fund (CWSRF), provide low-interest loans to water infrastructure projects for wastewater and recycled water.[67] Similarly, there are also Drinking Water State Revolving Funds for water supplies. In New Jersey, the Environmental Infrastructure Trust funds WWTs, combined sewer overflow abatement, nonpoint source pollution control, safe drinking water supplies and open space acquisition.[68] Decisions made by the Trust on project funding can determine which utilities or areas of the state will benefit from upgrades to their water systems, and the potential impacts of upgrade projects on energy use.

State and local green banks, financing programs, and utilities may also provide water efficiency financing and incentives. For example, the Connecticut Green Bank offers financing for water efficiency measures and water systems in multifamily housing properties.[69]

Additionally, state and local Energy Savings Performance Contracting (ESPC) programs, which enable agencies to partner with an Energy Service Company (ESCO) to upgrade public facilities and repay the cost of the project using future bill savings, implement not only energy-saving measures but also cost-effective water efficiency projects.[70] These projects often result in water use reductions and less energy needed to pump and distribute water.

State and Federal Courts

Water rights disputes and other cases reviewed by state judiciary systems can also affect energy use in water systems. While water rights are usually not contentious in areas with plentiful water sources, in arid or heavily-irrigated regions, they may be a source of competition or conflict. Disputes related to water rights are typically settled in state courts through adjudication,[71] and decisions that grant or restrict water rights to electricity generators or energy-intensive end-users may have a direct impact on energy use. For example, in 2012, a Utah district court upheld the State Engineer's approval for transferring water rights to a nuclear power plant from two irrigation districts, finding that the project met the requirements for financial solvency and project feasibility established in Utah law.[72]

Water rights decisions made by state courts can also have an indirect impact on energy and/or water use patterns within a state. For example, the Washington State Supreme Court, in its 2016 decision on *Whatcom County vs. Hirst, Futurewise, et al.*, found that counties must make their own decisions as to whether there is enough water (physically or legally) to approve building permits that rely on wells.[73] Furthermore, the Court also ruled that water is not legally available for a new well that affects a protected river or stream or interferes with an existing water right.[74] Moving forward, this decision may affect local building patterns as counties reassess their water availability based on this ruling, potentially resulting in new or different-than-expected investments in water infrastructure. In instances where it results in additional infrastructure needed to pump water over greater distances, energy use could increase.

Federal courts may play a significant role when it comes to adjudicating regional water disputes between several states. For example, the Supreme Court recently heard arguments in a water dispute between Florida and Georgia over the use of water from the rivers that the two states share, namely waters from the Apalachicola-Chattahoochee-Flint River basin.[75] The Court has also taken up a case over Rio Grande water rights disputes between Colorado, New Mexico, and Texas.[76] As in Washington, decisions stemming from these cases may result in changes to water distribution and use, with a high likelihood of impacts on energy use as a result.

Water Brokers

Water brokers, both public and private, facilitate transfers of water and/or water rights in water markets as "market makers", which can affect water infrastructure development patterns. While not formally part of state government, these market intermediaries oversee hundreds of billions of dollars annually in water transfers in the United States alone.[77]

The decisions water brokers make when purchasing or selling water rights can have economic ramifications beyond the purchase of the rights themselves. For example, municipalities looking to spur development in states with prior appropriation laws may utilize a water broker to purchase water rights to ensure that water for proposed developments is available for use. However, sometimes the only rights available or those that are most economical may be for water sources that exist far away from the proposed development. Water utilities must then pump that water from the source where the rights are located to the location of the development. This can increase the energy needed to get water to end uses than if a more convenient source was available. Thus, water brokers may (likely inadvertently) increase the energy use of water infrastructure by buying and selling rights within water markets. There may be opportunities for State Energy Officials to engage water brokers in an effort to better organize the market and avoid such inefficiencies.

Data Collection and Analysis Entities

Data on energy and water generation, transportation, and consumption patterns is essential to proper state policy planning in both sectors; organizations that collect and analyze the data from energy and water use are key players in helping inform state policy decision-making. The U.S. Geological Survey provides real-time and historical surface and groundwater quality and use data, as well as analysis of said data, for states and individual projects.[78] The United States Department of Agriculture's Irrigated Agriculture in the United States dataset summarizes structural characteristics for irrigated farms nationally, on a region-wide basis for 17 western states, and for each state individually.[79] State PUCs may keep track of energy and water data through their collection of utility reports and commissioned research and studies. Electric utilities report data on electricity sales and generation mix to PUCs through rate cases and compliance reports for RPSs and EERSs. Water utilities report water consumption statistics in their rate cases for those PUCs that regulate them. Data.gov provides aggregated data from government agencies on both energy and water as well as a host of other sectors.[80]

Section 4: Interactions Between Key Energy and Water Decision Makers

Effective coordination among entities and decision makers in both the energy and water sectors can be crucial to a state's ability to effectively plan for and address water infrastructure and its associated energy usage and costs. The siloes in which many of the agencies and departments that contribute to water policy operate can result in disjointed decision-making.

Interactions Between Energy and Water Agencies

In recognition of these challenges, states are increasingly integrating water and energy policy and program design and decision making. In Arizona, the SEO has committed to educate Arizonans, specifically water and wastewater facility owners and operators, about energy and water savings opportunities to catalyze greater action.[81]

Some states have also begun to form inter-agency working groups to examine the energy-water nexus. California established the Water-Energy Team of the Climate Action Team (WETCAT), which coordinates agencies involved in efforts to reduce greenhouse gases associated with water use in the state, including water use efficiency, recycled water, water systems efficiency, stormwater reuse, and renewable development.[82] WETCAT includes representatives from the state's Air Resources Board, Environmental Protection Agency, Departments of Food and Agriculture, Public Health, Water Resources, the state's Public Utilities Commission, California Energy Commission, Natural Resources Agency, Governor's Office of Planning and Research, State Water Resources Control Board, and the Strategic Growth Council. This working group provided input for the state's Water Action Plan, which includes recommendations on increasing energy efficiency in the water sector.[83]

In New Mexico's comprehensive state energy plan, the state recommends including the energy-water nexus as part of its Office of State Engineers regional water planning discussions.[84] In Vermont, the State Energy Office worked with the Division of Watershed Management to survey ten wastewater facilities and examine biogas energy usage at those facilities, enabling wastewater facilities to reduce their energy purchases through utilization of on-site generation.[85]

Interactions with Federal Policy, Regulatory, and Planning Bodies

The water and energy policies enacted by state and local governments do not exist in a vacuum; instead, they interact with and are influenced by the decisions made by a number of policy, regulatory, and planning bodies at the national level.

The EPA regulates water bodies at the federal level through the Clean Water Act (CWA) and Safe Drinking Water Act, publishes guidelines around wastewater, and runs voluntary programs such as ENERGYSTAR and WaterSense, which all impact state energy and water policy decisions.

The CWA creates the underlying framework that governs the nation's water quality for its surface water resources. States act as the implementers of regulations EPA promulgates through its rulemaking authority under the CWA. Through the CWA, EPA and the states regulate wastewater and stormwater treatment, as well as discharges from point sources like power plants. This is done through National Pollutant Discharge Elimination System permits.[86]

The Safe Drinking Water Act authorizes EPA to regulate contaminants in public drinking water systems and set maximum levels for various contaminants that may be found in drinking water. State drinking water programs provide oversight of water treatment systems to ensure that those standards set by EPA are met for drinking water resources. States may also apply to EPA for "primacy," or the authority to implement the Safe Water Drinking Act within their borders, if they can prove that their standards are equal to or greater than those set by EPA. All states and territories except for Wyoming and the District of Columbia currently have primacy to implement state-promulgated regulations[87] The Safe Water Drinking Act also regulates the protection of groundwater quality through the Underground Injection Control program.

Regulations promulgated by EPA may affect design, construction, and upgrade decisions for energy improvements to treatment facilities by wastewater treatment plant owners and operators and may encourage increased efficiency upgrades to keep energy costs lower. They may also act as a disincentive, as wastewater operators may not have the capital to make efficiency improvements as well as upgrade their plants to meet EPA's standards. If the standards focus plants' upgrades in ways that are not conducive to improving energy efficiency, such as focusing on physical rather than operational, energy-using infrastructure, this could be problematic as plants are forced to choose one set of upgrades over another. While clean water is an equally—if not more—important goal relative to efficient energy use, limited capital may preclude plant owners from being able to achieve both goals simultaneously.

In addition to EPA, other federal agencies play a role in the energy-water nexus. FERC regulates interstate transmission of natural gas, oil, and electricity, including electricity generated through pumped storage. FERC also licenses and inspects state hydroelectric projects, which include pumped storage projects as well as hydroelectric plants.

DOE provides technical standards, policy guidance, and technical assistance to State Energy Offices and other stakeholders through a variety of programs. DOE works with partners, including other federal agencies, state and local governments, members of Congress, foreign governments, tribal governments, private industry, academic institutions, non-governmental organizations, and citizens to pursue research, development, and deployment of key technologies, datasets, models to inform decision-making, and enhanced public dialogue around the energy-water nexus.

Interactions between state and federal programs can be collaborative or contested, or a combination of the two. WaterSense, a cooperative voluntary partnership program between EPA and manufacturers, retailers and distributors, homebuilders, irrigation professionals, and utilities, labels products and services that meet EPA's standards for water efficiency and perform as well as standard products and services.[88] Several states have integrated aspects of WaterSense with their own initiatives. For example, New Hampshire's Department of Environmental Services promoted the use of the WaterSense label in-state and educated utilities, municipalities and other stakeholders on how to partner with EPA in that program in order to increase the water efficiency of end-use systems while concurrently reducing whole-system energy use.[89]

On the other hand, litigation between states and the federal government may question the primacy of state versus federal control over local bodies of water and other water resources. It can also involve regional disputes between multiple states that federal courts end up resolving, as discussed in the previous section.

Section 5: Key Policy Considerations and Challenges

No holistic understanding of the laws, policies, and market drivers that affect the energy-water sector exists. As such, pinpointing clear policy levers and strategies to improve the energy performance of water systems is challenging and requires multi-agency, multi-sector, and multi-level coordination.

Energy and water are generally siloed sectors, and breaking those silos to increase coordination between the sectors is a crucial first step to addressing the energy-water nexus. One barrier to coordination is a general lack of understanding of what elements of each sector should or can reasonably be integrated and interconnected. That is due to variations in who makes decisions around energy and water issues at the local, state, and federal level, as well as a lack of coordination and integrated planning between different water and energy agencies that manage a state's water infrastructure. For example, a state PUC, which can regulate both electric and water utilities, may have limited interaction with a state Natural Resource Department, which runs the revolving loan funds that help those same utilities make upgrades to their treatment plants. Better coordination between such agencies could help the Commission ensure that the water utilities have adequate access to capital for any performance upgrades to their infrastructure.

Another barrier to coordination lies in the disconnection between the geographic reach of state regulatory bodies and local organizations or agencies. For example, municipal water utilities dwarf the number of IOU water utilities in most states. These utilities are not regulated by state PUCs; instead, they are typically overseen by local water boards, which may have similar or different goals and priorities than the state depending on variations in their local conditions. State-local communication, coordination, and collaboration is key to ensuring that both levels of governance are working towards the same general goals.

Furthermore, limited and inconsistent data on energy and water integration opportunities reduces potential cooperation efforts between the two sectors. This results in very different planning processes: water infrastructure is generally planned according to public interest criteria, while the development of energy infrastructure is tied to market and economic forces, although some electric facilities in states require PUC approval in order to meet public interest criteria.[90] Electric and water planning processes also follow different timeframes: where they are mandated by law, electric utilities generally update integrated resource plans (IRPs) every three years, whereas water plan timelines are more commonly measured in decades. Such differences in planning horizons can prevent coordinated technology deployment and investment to improve efficiency in both sectors simultaneously.

Capital availability for improvements poses another potential challenge. Federal spending on water infrastructure has declined as operations and maintenance costs have risen, requiring state and local governments to contribute larger amounts of funds to maintain water infrastructure[91] and potentially limiting their ability to dedicate funds for energy improvements. Additionally, changes in regulations for WWTs may compel operators to devote funds to upgrade projects that comply with new rules, instead of using capital to upgrade the energy performance of their plants.

In addition to the limited capital available to upgrade water infrastructure with existing technologies, the amount of venture capital available for clean technology start-up companies has declined by 30 percent since 2011, meaning that new technologies that reduce energy and water use have fewer avenues to commercialization. Furthermore, the amount of venture capital in the U.S. water sector is small compared to the amount of capital available for the clean energy sector $795 million compared to $19.32 billion 2000-2013), which may also inhibit the development of newer technologies to increase the efficiency of water infrastructure.[92] This reduces the potential options State Energy Offices and other decision makers have to explore the use of those technologies in water infrastructure.[93]

State energy policies and regulations themselves may also pose a barrier. For example, while many states have RESs in place, some of those RESs do not recognize biogas recovered from WWTs as eligible for generating Renewable Energy Certificates (RECs), removing a potential incentive for water utilities to generate power and invest in energy efficiency at wastewater treatment plants.[94]

Regulatory bodies can also unintentionally stymie coordination between energy and water resources. State PUCs, which often regulate investor-owned utilities in both sectors, may allow utilities to restrict the sale of excess power generated at WWTs back to the grid (conversely, they may also create rules to support distributed energy resources or require utilities to set up tariffs to incentivize distributed energy deployment). They may also require water utilities to accept low prices for wastewater-generated power, which could discourage treatment plants from investing in on-site generation. The lengthy licensing process for pumped storage projects limits the financing mechanisms available for them and can make those projects less attractive to developers.

Finally, there is a lack of consumer awareness of the energy and water benefits of lowering end-use water usage,[95] including hot water use, which is a major user of electricity in residential and commercial buildings. Water prices may have to rise appreciably before consumers will begin to change their water use patterns overall, though impacts on low-income and other disadvantaged customers should be considered for mitigation. Many consumers do not receive water use data often; most customers receive a monthly bill at most, while in some cases (for instance, master-metered properties) they may never receive data on their use.

Additionally, water utility bills are complex and broken up into a series of fees and charges, making them difficult for customers to understand.[96] Many water utilities are also smaller entities that may lack the funds to do the outreach necessary to change customer attitudes effectively.[97]

Some states and localities are implementing building benchmarking and disclosure policies. While some of those policies include water use, others do not; expanding benchmarking to cover water use could spur consumers to adopt additional end-use water efficiency measures due to increased awareness of their property's water use.[98] However, customers will need support with understanding benchmarking data and securing financing to pay for upgrades to their building water systems.[99]

Section 6: State Policy and Program Case Studies

The following case studies represent examples of State Energy Offices proactively addressing the energy-water nexus. Each case study provides an overview of the state's energy and water use profile and discusses examples of actions the State Energy Office is taking to improve the energy performance of its water conveyance, treatment, and irrigation systems.

The state policy and program approaches profiled in this section include:

- California: Improving Agricultural Water Efficiency and Electric Grid Resilience Through Demand Response Pilot Programs
- Colorado: Increasing Electricity Generation from Water Transportation and Delivery Infrastructure
- Missouri: Increasing the Use of Supply- and Demand-Side Efficiency Measures for Water Infrastructure
- Nebraska: Reducing Energy Use on Irrigation Pivot Systems and Improving Efficiency at Wastewater Treatment Plants
- Texas: Enabling Water Efficiency Through Energy Savings Performance Contracts and Leading By Example Through Water Conservation Standards in Public Buildings
- Virginia: Supporting the Development of Pumped Storage Projects Through Reform to the Permitting Process
- Wisconsin: Focusing on Energy Through Power Generation at Wastewater Treatment Plants

Each case study includes a Sankey diagram for the featured state.[100] These Sankey diagrams are graphs that are used to show the flows of energy and water by category from source through use and deposition in each state's borders. Energy and water flows move from left to right, beginning with inputs and ending with final use or disposition. The width of each arrow is proportional to the amount of flow for each input or output. The diagram helps illustrate various energy and water interactions as they are sourced, used, and expended within a state. They can help inform the development of policies and programs to improve resource management. For example, the Sankey diagram for Colorado shows that most fresh water is used for agriculture, including irrigation and livestock, of which a significant portion is consumed while the rest is returned to the natural environment. Diagrams like this can help analysts and policymakers gain a clearer picture of where potential water and energy efficiency opportunities are possible as well as where to locate the greatest potential reductions in energy and water use.[101]

California: Improving Agricultural Water Efficiency and Electric Grid Resilience Through Demand Response Pilot Programs

California Key Energy-Water Rankings[102]

#1 of 50 in per capita agricultural energy use
#2 of 50 for total irrigated acres
#3 of 50 for per capita wastewater treatment energy use
#5 of 50 for per capita public water supply energy use
#11 of 50 in water application per irrigated acre
#15 of 50 for per capita groundwater withdrawals
#31 of 50 for per capita surface water withdrawals

California Key Challenges

Possibility of recurring severe droughts in future, reducing water available for agriculture in addition to other purposes necessary to uphold economy and quality of life.

The California Energy Commission (CEC) is working on several agricultural pilot projects to help farmers reduce the energy and water intensity of their irrigation systems.[103]

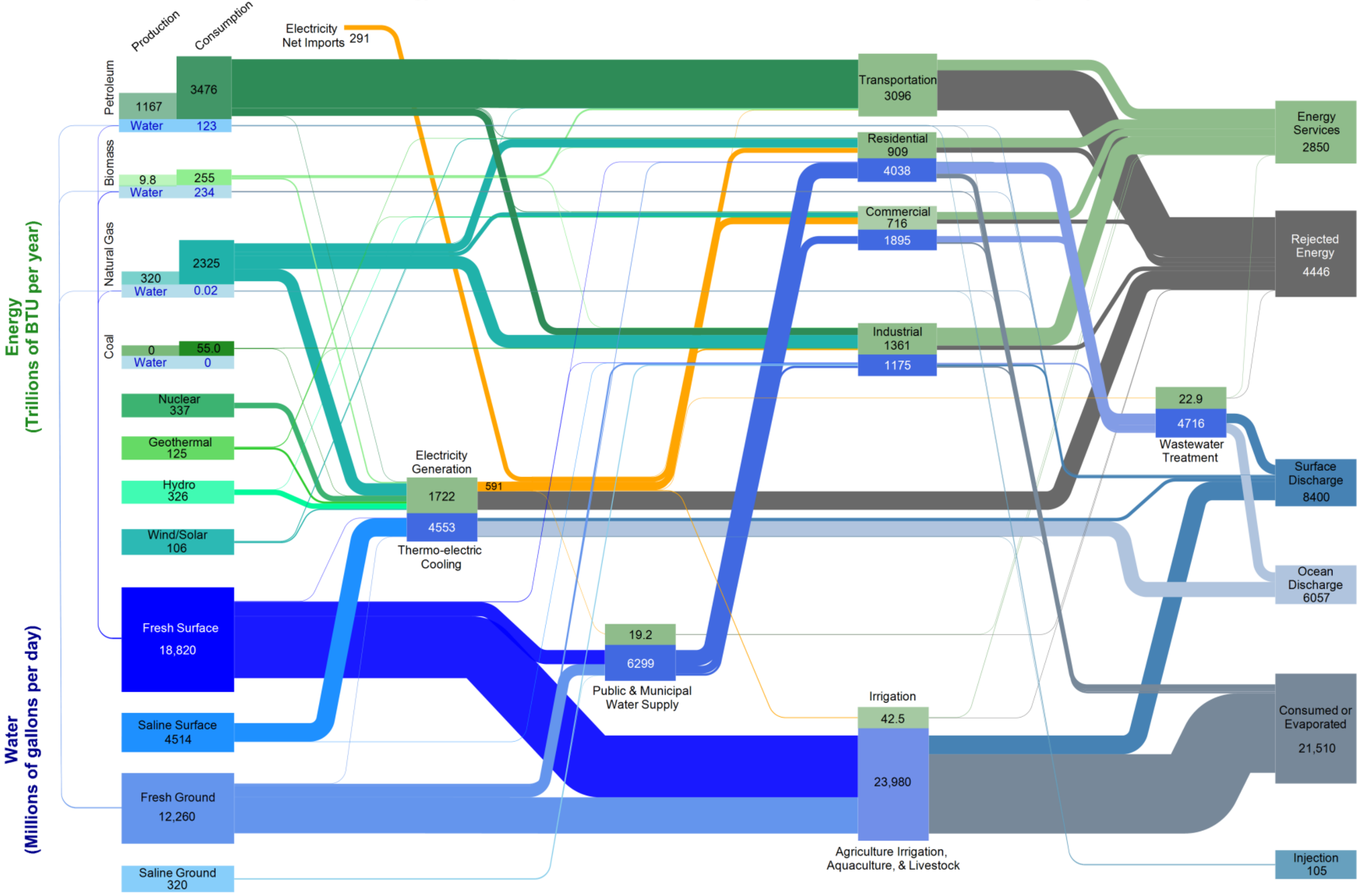
The CEC is partnering with Polaris Energy Services on an agricultural system software communications pilot program in the Central Valley. The software platform in the pilot enables irrigation control pumps and/or control systems to receive information on water and electricity prices from the state's electric and water utilities through existing cellular networks in the Valley. As the software matures, it is expected to discriminate among available wholesale electricity market prices, agricultural tariff changes, and Time-of-Use and demand response signals from utilities, and to incorporate them to adjust the load on water pumps. Farmers will then be able to meet their irrigation needs while reducing water use and energy use and costs. Similar projects are also underway with Irrigation for the Future and in the San Joaquin valley. These cooperative ventures have involved partnerships among farmers, the private sector, and the CEC.

The CEC is also working with the Irvine Ranch water district in Orange County to help the district monitor various pump stations at different times of the day and week in response to price signals from the wholesale markets to determine which price signals, if any, have an impact on the cost of the district's overall operations. The results of that project will help the CEC share information on best management practices to reduce water and energy use with other water districts in the state. The districts will be able to provide additional grid flexibility by responding more effectively to utility tariff signals as well as demand response signals.

Additionally, the CEC has a number of projects to research the impacts of deficit irrigation on various crops. The CEC partnered with a company that installed a software system using utility smart meters to determine water flows through irrigation systems, as well as to track moisture sensors and weather data. The CEC hopes to show that some crops, like grapes and tomatoes, can be grown with less water while simultaneously producing greater yields. The CEC is also working on a similar project with the Electric Power Research Institute (EPRI) and the University of California - Davis called PlantAware, where sensors measure transpiration rates of certain perennial crops. That will allow farmers to more precisely know the water needs of each plant to prevent overwatering and reduce overall water use, thus saving them money on water and reducing the energy needed to provide the water.

California Estimated Energy and Water Flows in 2010:

Energy Consumption: 7296 Trillion BTU, Water Withdrawals: 35,910 Million gal/day



Source: LLNL April, 2017. Data is based on DOE/EIA SEDS (2015), USGS Circular 1405 (2014), USDA FRIS (2013), USDA NASS (2015), and other data published in the scientific and commercial literature (see LLNL-TR-669059). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 80% for the industrial sector, and 21% for the transportation sector. Some flows are estimated from data provided for years other than the data in the chart title. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

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Colorado: Increasing Electricity Generation from Water Transportation and Delivery Infrastructure

The Colorado Energy Office (CEO) works extensively to address the energy-water nexus in support of the state's Renewable Energy Standard, which requires electricity providers to obtain a minimum percentage of their power from renewable energy sources. CEO also supports implementation of the Hydropower Regulatory Efficiency Act of 2013, a federal law which revised hydropower licensing and expedited application reviews for small and low-impact projects.[105]

Colorado Key Energy-Water Rankings[104]

- #6 of 50 for per capita surface water withdrawals
- #7 of 50 in water application/irrigated acre
- #7 of 50 for total irrigated acres
- #8 of 50 for per capita wastewater treatment energy use
- #9 out of 50 in per capita agricultural energy use
- #12 out of 50 for per capita public water supply energy use
- #16 out of 50 for per capita groundwater withdrawals

Colorado Key Challenges

Need for improvements in agricultural water efficiency due to arid climate.

Further education of stakeholders and the general public on energy-water interactions desirable due to lack of uptake of newer technologies for end-use purposes.

In 2013, CEO signed a Memorandum of Understanding with FERC to allow expedited permitting for low-impact hydropower facilities. Following, CEO commissioned an assessment that found thousands of potential opportunities for small hydropower generation by replacing pressure-reducing valves with hydro systems, offering potential generation capacity of 25 MW.[106]

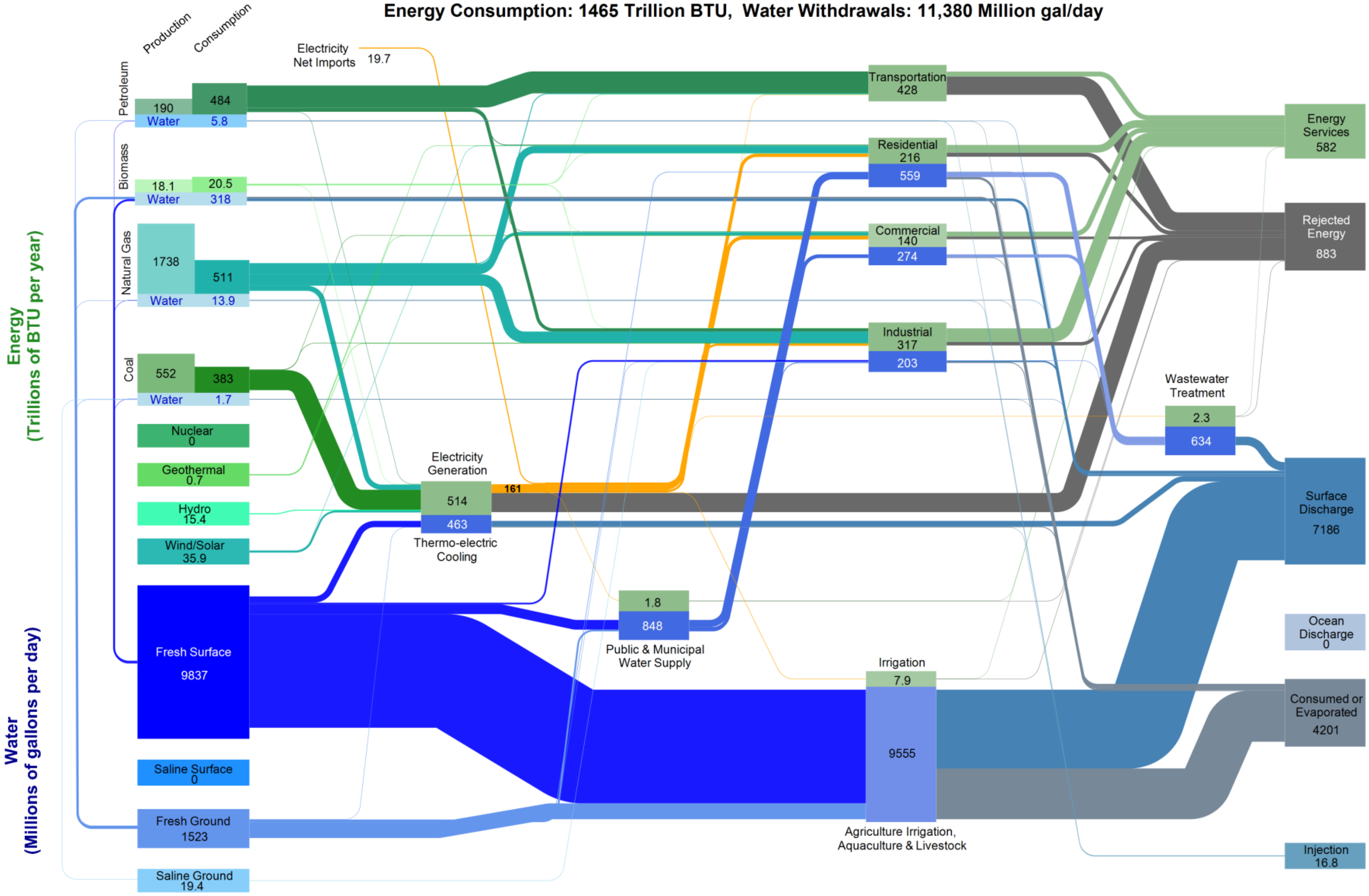
Following the release of the report, CEO sponsored workshops to help utilities spot potential hydropower projects for water delivery systems within their service territories and offered assistance in completing FERC permit forms and in receiving financing from the Colorado Water Resources and Power Development Authority. This outreach spurred Denver Water, one of the state's water utilities, to begin exploring a few possibilities to develop small hydropower projects in its service territory. Private developers' interest in these types of projects increased. leading CEO to be invited to present on its research at various conferences around the state. CEO plans to develop an online platform with fact sheets, success stories, and other materials to continue raising awareness and interest.

CEO also promotes the Small Hydropower Loan Program offered by the Colorado Water Resources and Power Development Authority, which enables Colorado's local jurisdictions, water and sanitation districts, and other agencies to finance and receive matching grants for new hydropower facilities, pipelines, and transmission lines.[107]

CEO is one of thirteen partners in Colorado working to promote the development of low-impact hydropower on new and existing pressurized irrigation systems through USDA's Regional Conservation Partnership Program (RCPP). Additional partners include the Colorado Department of Agriculture (CDA), USDA Natural Resources Conservation Service - Colorado, and USDA Rural Development – Colorado. In support of this program, the CDA has developed their ACRE3 program, which partners with and provides funding to farmers who wish to deploy small hydropower on their farms.[108] The program has a goal of installing 30 of these systems across the state in the next four years.[109] Successful projects will help to raise awareness among agricultural producers about the benefits on small hydro systems on farms and lead to greater adoption of those technologies in the state's agricultural sector.

Colorado Estimated Energy and Water Flows in 2010:

Energy Consumption: 1465 Trillion BTU, Water Withdrawals: 11,380 Million gal/day



Source: LLNL April, 2017. Data is based on DOE/EIA SEDS (2015), USGS Circular 1405 (2014), USDA FRIS (2013), USDA NASS (2015), and other data published in the scientific and commercial literature (see LLNL-TR-669059). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 80% for the industrial sector, and 21% for the transportation sector. Some flows are estimated from data provided for years other than the data in the chart title. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

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Missouri: Increasing the Use of Supply- and Demand-Side Efficiency Measures for Water Infrastructure

Missouri Key Energy-Water Rankings[110]

#11 of 50 for per capita wastewater treatment energy use
#14 of 50 for total irrigated acres
#16 of 50 for per capita surface water withdrawals
#17 of 50 for per capita groundwater withdrawals
#21 of 50 for water application per irrigated acre
#22 of 50 for per capita public water supply energy use
#23 of 50 in per capita agricultural energy use

Missouri Key Challenges

Rural small wastewater treatment plants aging and in need of upgrades.

Issues with water leakage rates in water infrastructure and inefficient end uses.

The Missouri Division of Energy promotes energy efficiency in water use and made energy-water planning a priority in the 2015 Missouri Comprehensive Statewide Energy Plan, which included the following recommendations:

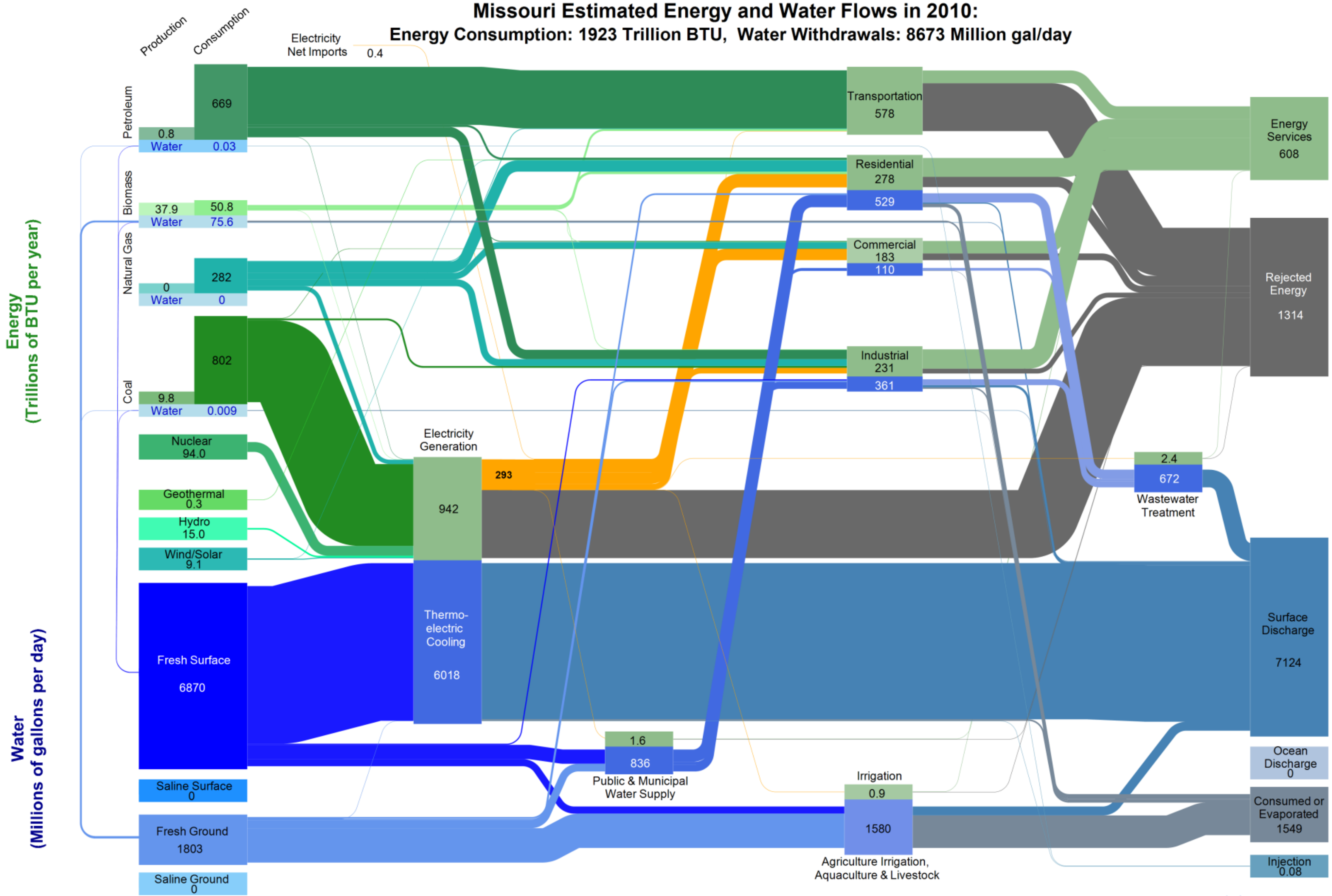
- Modify the Missouri Energy Efficiency Investment Act (MEEIA) to achieve greater levels of electric, gas, and water savings;
- Prioritize water projects that lower the energy intensity of water and wastewater treatment operations and reduce the high costs associated with the supply, distribution, and treatment of Missouri's drinking water and wastewater; and
- To improve marketing efforts and technical assistance for Missouri's Property Assessed Clean Energy (PACE) financing programs (which can be used for water efficiency measures) to increase participation rates, lowering costs to individuals and businesses and expanding opportunities for clean energy jobs.

As a result of that planning process, the Division is moving forward with a number of efforts to address the energy-water nexus in Missouri.

The Division supplements its planning efforts by intervening in both electric and water utility rate cases that come before the Missouri Public Service Commission (PSC). In the most recent rate case for the state's investor-owned water utility, Missouri-American Water, the Division filed testimony with the PSC to promote use of both supply and demand-side energy efficiency and water loss reduction. Due to the Division's efforts, the utility agreed to offer a demand-side efficiency pilot program that will include targeting towards an area with a pilot inclining block rate. The utility also committed to perform in-house energy audits for five selected water districts to improve supply-side energy efficiency, as well as conduct water-loss audits for the Jefferson City and Saddlebrook water systems to reduce supply-side water loss.

The Division also assists municipal water and sewer districts through its Energy Loan Program. The program enabled the Pulaski County Sewer District to replace inefficient pumps at six lift stations with new, more efficient pumps resulting in $11,211 annual energy savings; the city spent approximately $186,094, for a payback period of approximately 18 years. The City of Harrisonville is upgrading its wastewater treatment plant aerator, lagoon pump, basin motor and variable frequency drive raw water pump to save approximately $42,833 in annual energy costs. The city spent approximately $524,294, for a payback period of around 12 – 13 years.

Missouri Estimated Energy and Water Flows in 2010:
Energy Consumption: 1923 Trillion BTU, Water Withdrawals: 8673 Million gal/day



Source: LLNL April, 2017. Data is based on DOE/EIA SEDS (2015), USGS Circular 1405 (2014), USDA FRIS (2013), USDA NASS (2015), and other data published in the scientific and commercial literature (see LLNL-TR-669059). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 80% for the industrial sector, and 21% for the transportation sector. Some flows are estimated from data provided for years other than the data in the chart title. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

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Nebraska: Reducing Energy Use on Irrigation Pivot Systems and Improving Efficiency at Wastewater Treatment Plants

Nebraska Key Energy-Water Rankings[111]

#1 of 50 for total irrigated acres
#3 of 50 in per capita groundwater withdrawals
#5 of 50 in per capita surface water withdrawals
#5 of 50 in per capita agricultural energy use
#14 of 50 for per capita public water supply energy use
#17 of 50 for per capita wastewater treatment energy use
#35 of 50 for water application per irrigated acre

Nebraska Key Challenges

More water leaves the state than enters through rivers. Changes in rainfall patterns may influence the rate of groundwater withdrawals for irrigation.

Most irrigation fed through groundwater; groundwater management is especially critical.

Irrigation practices impact peak demand for electricity.

Nebraska's irrigation practices affect the demand for electricity in the state. The state has the highest number of irrigated acres in the United States, and peak demand for many of the states' public power entities is close to 11 PM in the summer due to irrigation systems' electricity needs.[112]

To help reduce the demand on the system from irrigation systems, the Nebraska Energy Office (NEO) received a competitive award to study the impact of variable frequency drives (VFDs) on irrigation pivot system energy use.[113,114]

NEO chose 10 counties for the study, and 100 pivot systems within each county, for a total of 1000 sites. Counties were selected based on topological differences and on the number of pivot systems within each county. The study found that pivot systems utilizing VFDs in counties with larger elevation changes could save up to 9.6 percent of their energy use, with a maximum annual cost savings per pivot of $343, whereas pivots utilizing VFDs in flatter counties saved less or no energy.[115] However, the payback periods for VFDs with the savings was found to be greater than 50 years for all counties, which is uneconomical given an expected life of 15 years for VFDs. NEO plans to continue to explore the use of these technologies through further research.

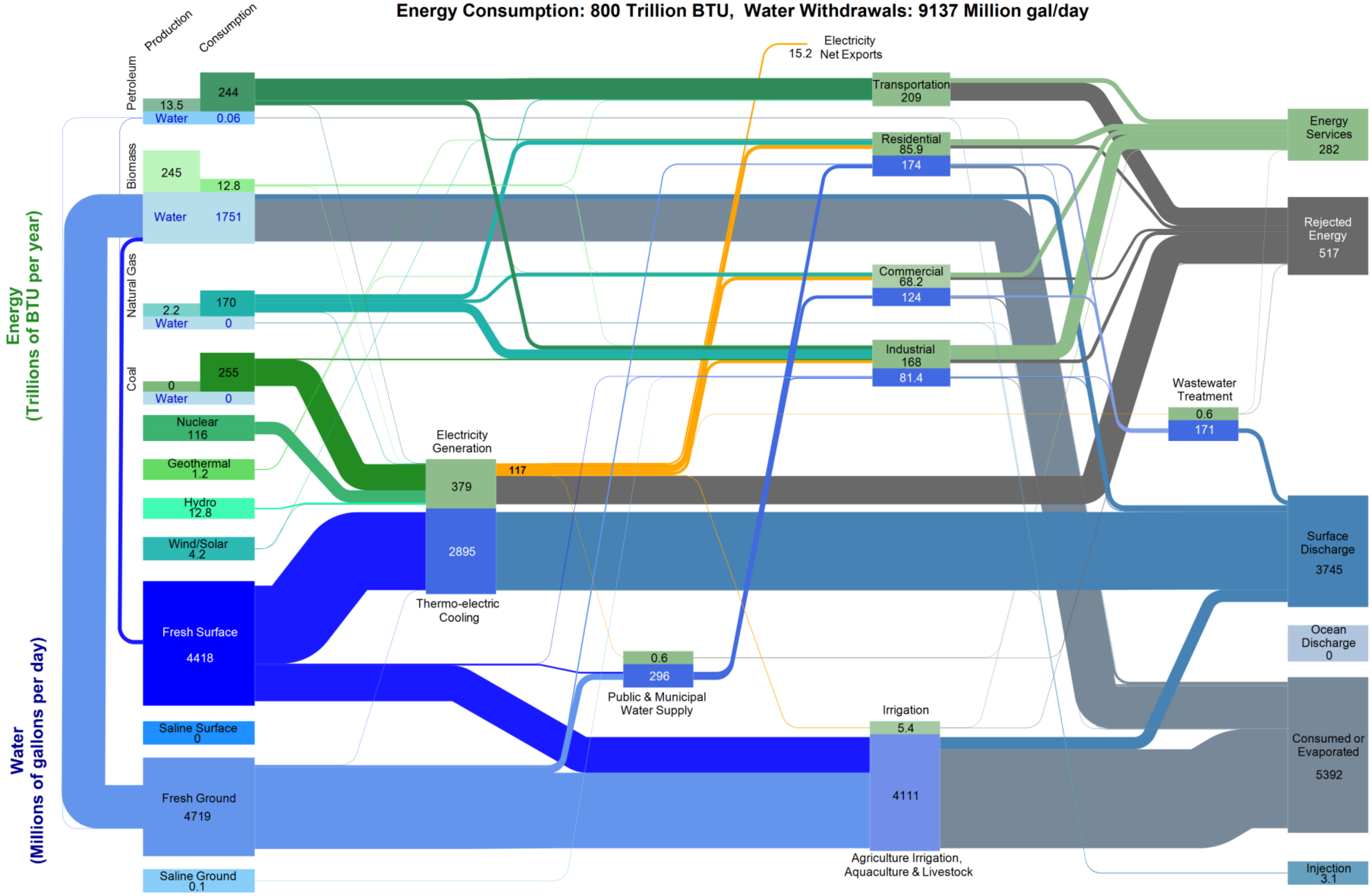
Private companies, including irrigation system manufacturers, have begun using these technologies in conjunction with geographic information system (GIS) mapping technology to provide additional support to farmers looking to optimize irrigation patterns.

In addition to its work with VFDs, in 2015 the state received a U.S. State Energy Program grant to explore energy efficiency improvements in its WWTs.[116] NEO, in partnership with the University of Nebraska, solicited energy use consumption information from 531 municipal WWTs, and then focused on 101 plants that were mechanical in nature. The university focused on energy intensity of the plants to gauge their use and to rank the best prospects for energy efficiency improvements.

Currently, NEO and the university are contacting plant operators in the ranking to gauge their willingness to do an energy audit. The university partner expects to engage up to 13 plant operators on this issue and, for additional support, NEO expanded its revolving loan fund by $5 million to provide a financing incentive for communities to make those improvements.

Nebraska Estimated Energy and Water Flows in 2010:

Energy Consumption: 800 Trillion BTU, Water Withdrawals: 9137 Million gal/day



Source: LLNL April, 2017. Data is based on DOE/EIA SEDS (2015), USGS Circular 1405 (2014), USDA FRIS (2013), USDA NASS (2015), and other data published in the scientific and commercial literature (see LLNL-TR-669059). If this information or a reproduction of it is used, credit must be given to the Lawrence Livermore National Laboratory and the Department of Energy, under whose auspices the work was performed. End use efficiency is estimated as 65% for the residential sector, 65% for the commercial sector, 80% for the industrial sector, and 21% for the transportation sector. Some flows are estimated from data provided for years other than the data in the chart title. Totals may not equal sum of components due to independent rounding. LLNL-MI-410527

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Texas: Enabling Water Efficiency Through Energy Savings Performance Contracts and Leading by Example Through Water Conservation Standards in Public Buildings

Texas law authorizing Energy Savings Performance Contracts (ESPCs) for energy efficiency retrofits in public buildings allows local governments to include water efficiency improvements in their projects. It also authorizes wastewater system operators to use ESPC to replace water meters to enhance revenue.

Texas has also implemented standards for its state buildings and public higher education facilities.[117] The Water Conservation Design Standards set targets for water-use efficiency, including to reduce the amount of water withdrawn from a single source, or to increase the reuse or recycling of water already in the system. The state hopes to utilize the standards to demonstrate water-saving techniques and concepts to the public, maximize the efficiency of public water supply systems, and promote public awareness of the benefits of saving water.

The Texas State Energy Conservation Office (SECO) runs the state's LoanSTAR program, a loan fund that provides financing to support energy and water efficiency in schools, municipal buildings, hospitals, and other public buildings. SECO works with borrowers and contractors to upgrade schools, state universities, and government buildings.

In addition to SECO, a number of sister agencies in the state also address energy and water conservation: for instance, the Texas Water Development Board, which is responsible for the preparation of the State Water Plan.[119] It contains water conservation strategies for the year 2070, which are projected to provide 2,344,541 acre-feet to help meet the projected needs for additional water supplies. This volume of water conservation represents 27.7 percent of the identified strategies to meet water supply needs in 2070. Irrigation conservation accounts for 15.7 percent, municipal conservation is 9.6 percent and other conservation is 2.4 percent. Reuse strategies add an additional 14.2 percent (1,106,614 acre-feet) of potential supplies in 2070 and includes indirect reuse, other reuse and direct potable reuse.[120] Because saving water saves energy, the strategies outlined in this plan help Texas and SECO increase the effectiveness of their energy conservation programs as well.

Texas Key Energy-Water Rankings[118]

#4 of 50 for total irrigated acres
#12 of 50 for per capita wastewater treatment energy use
#13 of 50 for per capita public water supply energy use
#18 of 50 for per capita agricultural energy use
#19 of 50 for per capita groundwater withdrawals
#20 of 50 for per capita surface water withdrawals
#20 of 50 for water application per irrigated acre

Texas Key Challenges

Possibility of drought in future, limiting water supplies.

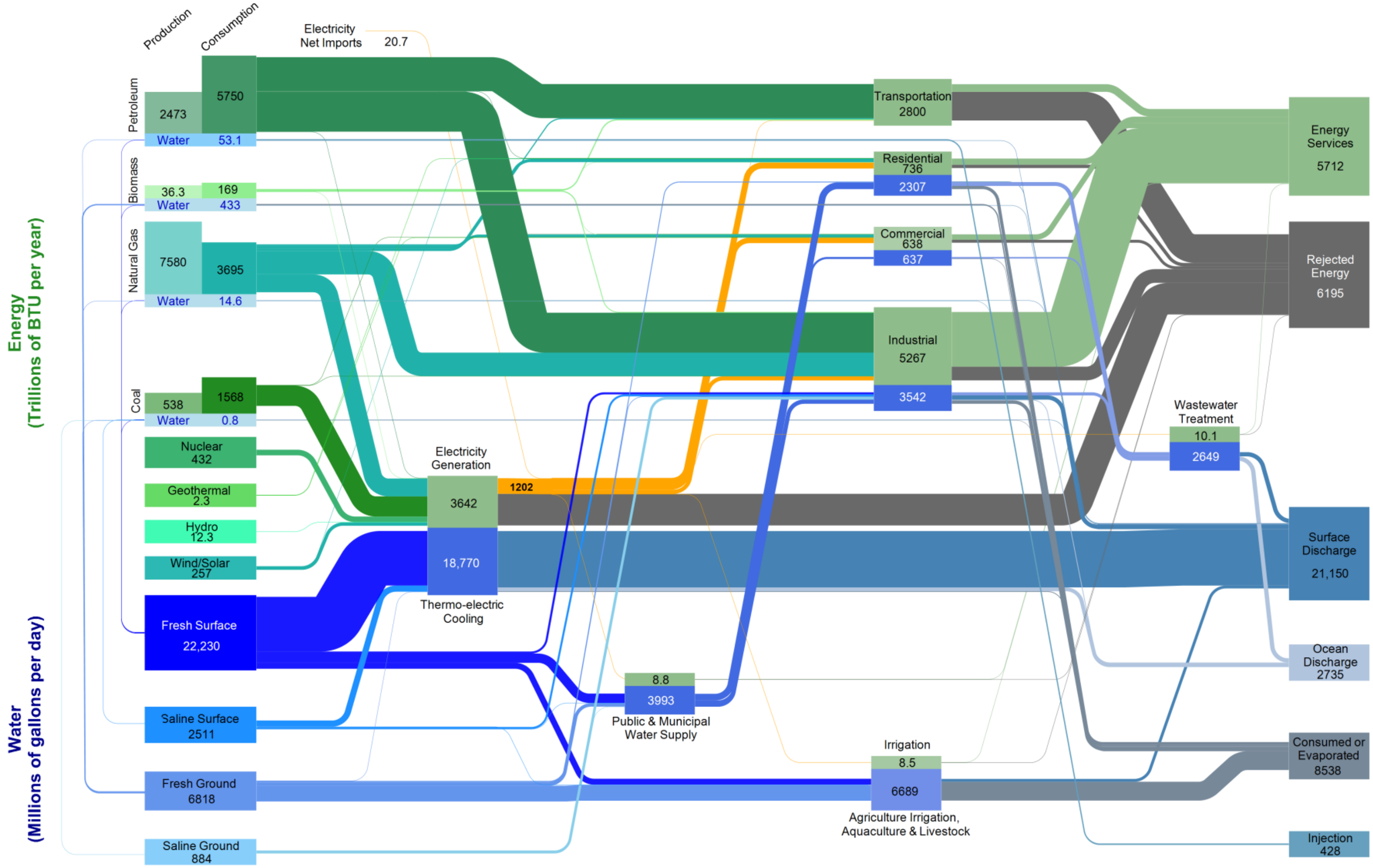
Disposal and potential beneficial use of produced and flow-back water from oil and gas extraction operations.

Growing population may stress water supply.

At the local level, some agencies have initiated pilot programs to enhance the energy performance of water infrastructure. The San Antonio water system recently executed a project with Pecan Street Inc., a data-gathering research firm in Austin, to produce and utilize a smart meter add-on that can be put on residential scale water meters at low cost without having to replace the meters themselves. The add-ons utilize the property's local wireless internet network and produce data that the firm can then use to track water use. This technology enables the water utility to better identify leaks in its infrastructure and repair them, saving water and reducing energy use throughout the entire water distribution system.

Texas Estimated Energy and Water Flows in 2010:

Energy Consumption: 11,910 Trillion BTU, Water Withdrawals: 32,440 Million gal/day



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Virginia: Supporting the Development of Pumped Storage Projects Through Reform to the Permitting Process

Virginia Key Energy-Water Rankings[121]

#29 of 50 in per capita agricultural energy use
#32 of 50 for per capita surface water withdrawals
#39 of 50 for water application per irrigated acre
#39 of 50 for total irrigated acres
#45 of 50 for per capita public water supply energy use
#48 of 50 for per capita groundwater withdrawals
#49 of 50 for per capita wastewater treatment energy use

Virginia Key Challenges

Decline of the mining industry compelled communities to seek alternatives that leveraged mine industry skillsets to develop new energy resources from mined land.

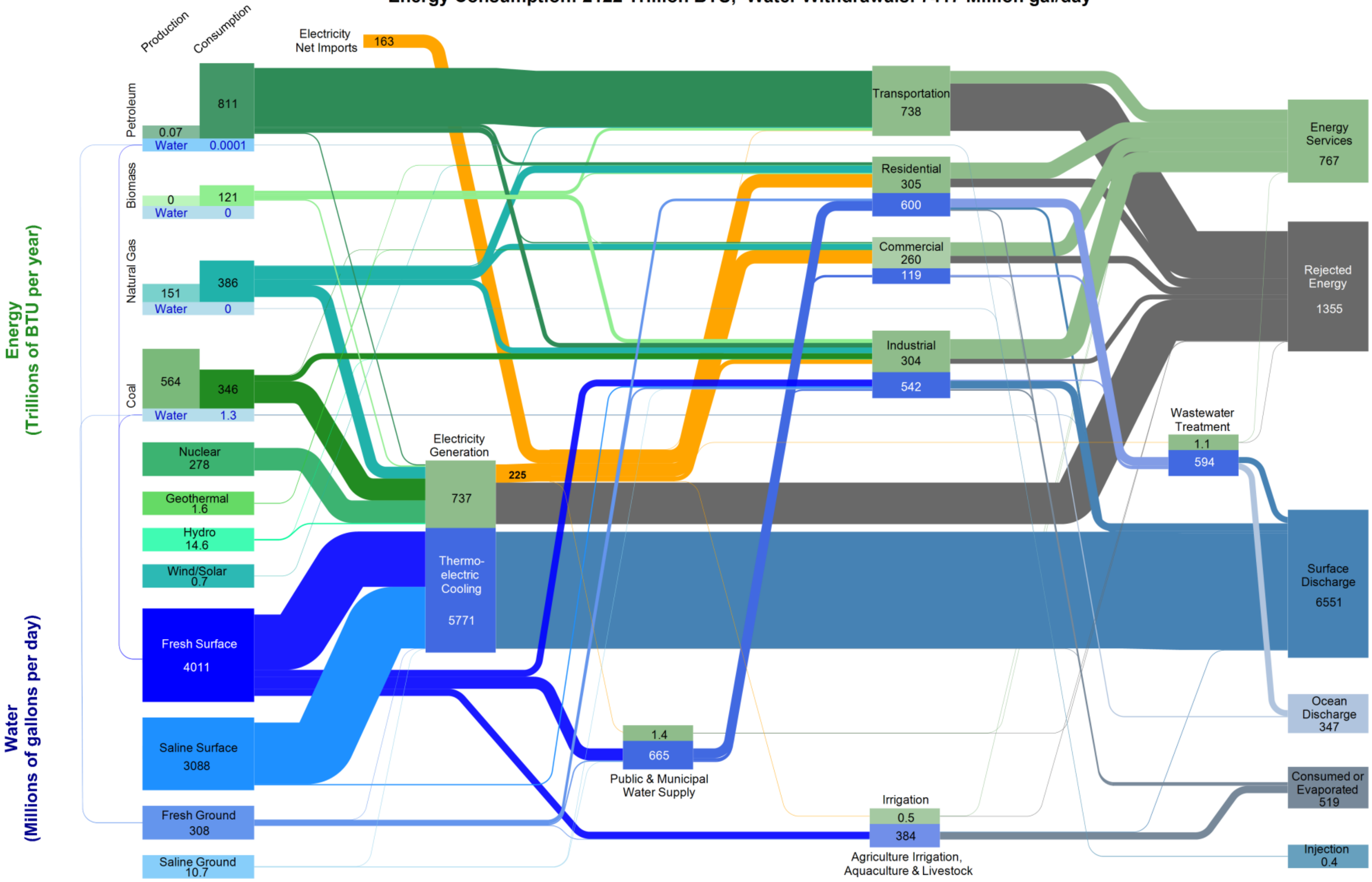
In 2017, the Virginia Department of Mines, Minerals and Energy (DMME) supported the drafting and passage of a bill to promote the development of pumped storage facilities using water from closed coal mines in the western part of the state.[122] Many stakeholders in Virginia, including utilities, mine companies, miners, localities, renewable energy developers, and various social interest and advocacy groups, supported the bill's passage due to the potential economic and environmental benefits that would result from installing pumped storage in the state's coalfields. The support of this large and diverse group of stakeholders was integral to the bill's passage through the General Assembly.

The bills (HB 1760 and SB 1418) declared the construction of pumped storage facilities to be in the public interest and would eliminate the requirement that utilities compare all options, including third party solicitations, when proposing their pumped storage projects to the Virginia Corporation Commission.[123] The bill further stipulated that the Commission should "liberally construe" provisions of the state's regulations governing electric utility regulation (in effect signaling to the Commission to streamline its approval process for such projects) and to allow electric utilities to receive full cost recovery for those projects.[124] Storage projects may also receive rate of return enhancements if renewable or nuclear energy is used to refill the pumped storage basins.

There are several sites available that could potentially store energy needed to generate up to 2 GW of power. Dominion Energy has filed a preliminary permit application with FERC to study conventional and closed loop mine pumped storage projects and has also commissioned a feasibility study.[125]

Virginia Estimated Energy and Water Flows in 2010:

Energy Consumption: 2122 Trillion BTU, Water Withdrawals: 7417 Million gal/day



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Wisconsin: Focusing on Energy Through Power Generation at Wastewater Treatment Plants

The Wisconsin Office of Energy Innovation (OEI) has focused on capturing bio-energy from WWTFs, landfills, manure, and biomass sources for many years. OEI created the Municipal Energy Efficiency Technical Assistance Program (MEETAP) in 2014 (with $400,000 of State Energy Program-SEP Competitive funding from the Department of Energy) to assist municipalities with the technical side of such projects, including reducing water losses from water utilities and upgrading water and wastewater infrastructure.

Wisconsin Key Energy-Water Rankings[126]

#24 of 50 for total irrigated acres
#24 of 50 for per capita surface water withdrawals
#27 of 50 for per capita agricultural energy use
#28 of 50 for water application per irrigated acre
#28 of 50 for per capita groundwater withdrawals
#41 of 50 for per capita wastewater treatment energy use
#46 of 50 for per capita public water supply energy use

Wisconsin Key Challenges

Projected increase in heavy precipitation events due to changing climatic conditions could impact ability of wastewater treatment plants to treat water effectively.

In a concurrent effort, funded by SEP Formula Funding, the state began to collect information on the status of anaerobic digesters and Combined Heat and Power (CHP) at WWTFs through the Wisconsin Biogas Survey. This survey, administered via phone and in-person, asked respondents about operational challenges, key financial barriers to project development, and opportunities for future development.[127] From the survey, the OEI identified four areas of concern at those facilities: (1) a need for additional maintenance and support; (2) a lack of collaboration and information-sharing; (3) insufficient revenue to implement further projects; and (4) a need for effective operation and maintenance procedures.[128]

As a result of the survey, OEI is examining a number of solutions to help WWTFs improve process efficiencies and, as appropriate, increase biogas production and onsite power generation at anaerobic digester facilities. The options OEI is considering include continuing assistance to help owners get access to national renewable energy programs, as well as further defining and refining of permitting for digesters. OEI has also considered recommending a voluntary pricing program to encourage biogas as a green power offering, but further education of stakeholders is needed.

OEI also partners with Focus on Energy (Wisconsin's utility rate-payer funded energy efficiency and renewable energy program), which aids residents in lowering their cost of living and businesses in improving their bottom lines.[129] OEI and Focus on Energy collaborated on a special initiative in 2017, the Wastewater Bridge Initiative, to advance energy efficiency and biogas capture and utilization in WWTFs[130]. The Wastewater Bridge links Wisconsin operators of WWTFs with resources from DOE's Sustainable Wastewater Infrastructure of the Future (SWIFt),[131] an accelerator within DOE's Better Buildings Challenge suite of programs and resources for state and local organizations, and also provides guidance from Focus on Energy. Focus on Energy personnel assist the WWTF with creating and maintaining a baseline of energy use and then advise the operator in implementing low and no cost measures to reduce energy use.[132]

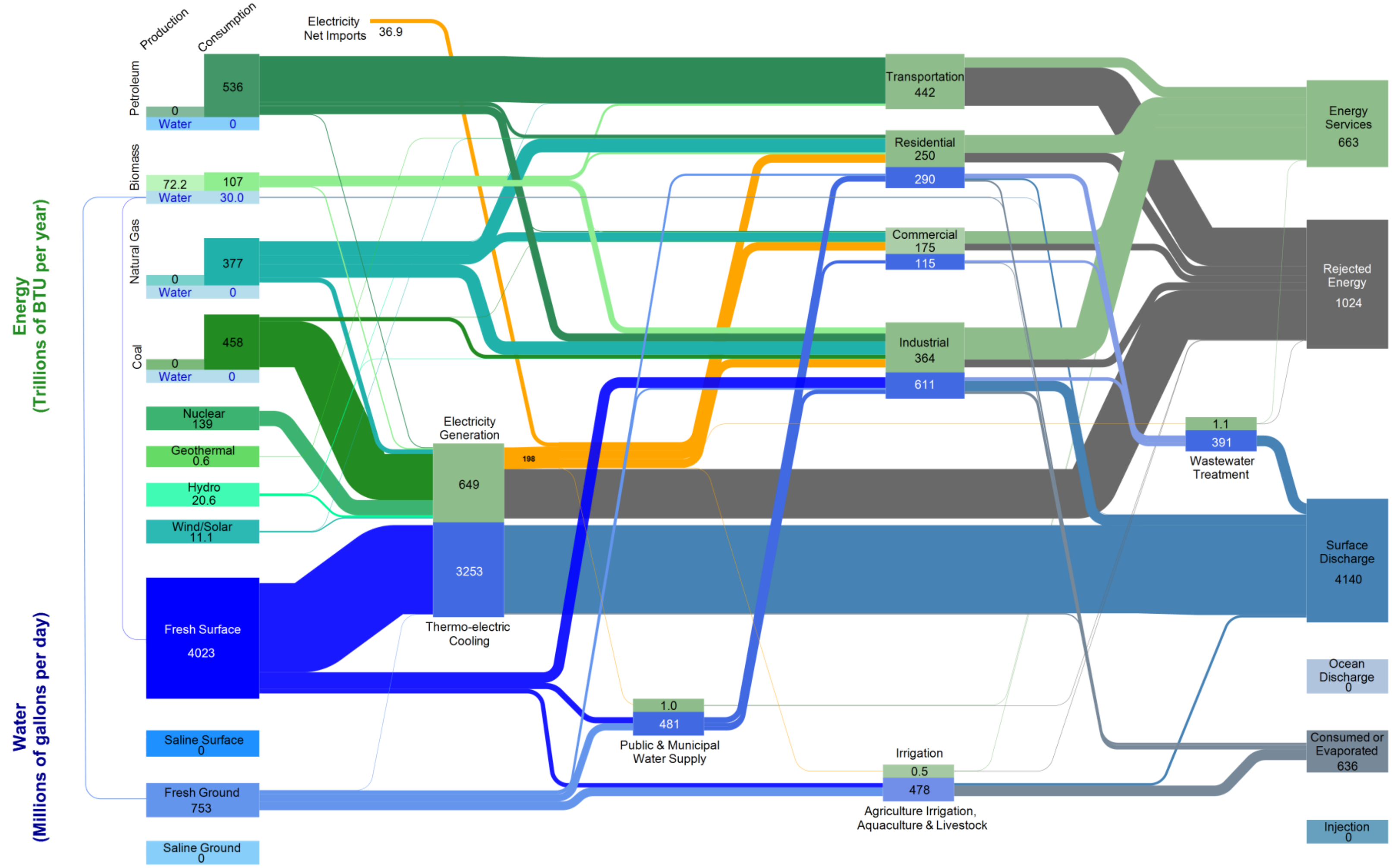
In addition to assisting with anaerobic digester adoption by WWTFs, OEI has worked on benchmarking all publicly-owned water utilities and wastewater utilities in the state. The wastewater aspect of this project was a two year collaborative effort between OEI, Focus on Energy , and the Wisconsin Department of Natural Resources. This effort was funded with $45,000 of SEP formula monies, primarily to support WDNR programmers who added five energy questions to the online Compliance Maintenance Annual Report (CMAR) that all publicly owned WWTFs must fill out every year. The balance of the SEP funding supported outreach and education which was provided by OEI and Focus in all six WDNR regions of the state. OEI provides individualized reports for each water or wastewater utility and coordinates with the corresponding Focus on Energy advisor to deliver advice to individual operators.

Through this approach, the OEI influenced several water utilities to change their behavior. First, after the benchmarking results were released, some utilities began to install variable speed drives and pumps that could vary the intensity of the water pressure and conserve energy at different times of the day. Second, some the utilities also began to conduct peak analyses of their water flows and install wireless submeters on their pumps. Data from those meters provided information allowing for operational improvements that could save energy. Once the utilities recognized the potential for further energy savings though operational changes, then they made those changes and saved money on both energy and water costs while simultaneously modernizing their water infrastructure.

Education of key decision makers has been a key factor in this program: as the utilities gained information on their performance compared to their peers, they became more willing to make changes to keep or improve their ranking in the system.

Wisconsin Estimated Energy and Water Flows in 2010:

Energy Consumption: 1686 Trillion BTU, Water Withdrawals: 4776 Million gal/day



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Section 7: Conclusions

Improving the energy performance of water conveyance, treatment, and irrigation systems will not occur overnight. Key state decisionmakers in both the energy and water spheres face numerous obstacles, including limited cross-sector coordination, data access challenges, and inadequate funding to support infrastructure efficiency upgrades. The patchwork nature of regulations for both water and energy across the federal, state, and local levels also makes upgrading the energy performance of water infrastructure uniquely challenging for state policy makers.

Key state decision makers who influence both the energy and water sectors should carefully consider how and when to address the energy-water nexus in water infrastructure. State Energy Offices and other state level actors will need to closely coordinate with local officials because municipal water utilities in most states far outnumber water IOUs.

In many cases, energy and water utilities will need to collaborate to effectively seize opportunities to improve the energy performance of water systems. State Energy Offices, PUCs, and other state decision makers will be key in convening and facilitating dialogues among these utilities. It may also be useful for SEOs and other convening entities to engage these actors more robustly in preparation for or during times of drought, taking advantage of the increased focus on water use reductions.

Successful efforts to address the energy-water nexus for water infrastructure have tended to revolve around a few key factors. Successful projects integrate communication and coordination among a wide range of actors, including state legislatures, agencies, regulators, third-party advocates, universities, agricultural groups, and electric and water utilities. Successful projects also focus on sector-specific needs and may be implemented by partners who are willing first to experiment through small pilot projects and then expand successful efforts from there.

Each decisionmaker operating within the energy-water nexus can take a number of steps to begin or continue efforts to improve energy efficiency in the water transportation, conveyance, and irrigation infrastructure. Those can include: pursuing comprehensive approaches, creating pilot programs, building coalitions, supporting infrastructure upgrades, designing financial incentives, and crafting regulatory supports.

State policy makers (including legislators and State Energy Officials) can:

- **Explore Pilots:** Fund pilot programs to test new technologies for water efficiency or power generation;
- **Build Capacity:** Ensure that key stakeholders and the general public are educated on the key interactions between energy and water resources, policies, statutes, and rules, and the efforts the state is making to maximize the benefits and efficiencies in each.
- **Build Coalitions:** Use their convening powers to bring together various stakeholders to discuss coordination opportunities, strategies, and developments;
- **Provide Financial Incentives:** Provide input on the development of legislation that incentivizes energy improvements in plans to upgrade water infrastructure;
- **Explore Pilots:** Partner with private sector entities or water and wastewater utilities to pilot new technologies or methods to increase the flexibility and energy efficiency of their water infrastructure;

- **Pursue a Comprehensive Approach:** Explore all possible avenues available to address the energy-water nexus, including planning, education/awareness, policy, utility regulation, financial assistance, and interagency coordination. Act as intervenors in relevant dockets and cases to provide policy guidance pertaining to the energy-water nexus. Convene water and electric IOUs to collaborate on new programs to encourage energy performance improvements in water infrastructure.
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Public Utilities Commissions can:

- **Pursue a Comprehensive Approach:** Create data warehouses of energy and water data from utilities to help State Energy Offices, electric and water utilities, as researchers;
- **Pursue a Comprehensive Approach:** Promote planning that enables better and deeper coordination between electric and water utilities;
- **Pursue a Comprehensive Approach:** Convene electric and water utilities, as well as other key stakeholders, to discuss better cooperation and coordination strategies for the electric and water sectors;
- **Explore Pilots:** Authorize water utilities to pursue pilot programs for water infrastructure upgrades using established or new technologies;
- **Provide Financial Incentives:** Work with electric and water utilities to design rebates for deploying more efficient end-use technologies; and
- **Update Regulatory Structures:** Assist in the deployment of benchmarking programs for water utility infrastructure.

Water utilities can:

- **Pursue Infrastructure Upgrades:** Proactively work to reduce leaks in piping distribution systems;
- **Pursue Infrastructure Upgrades:** Correct pipe sizes for water distribution when replacing older systems, or ensure that pipe sizes are correct to minimize friction when laying new pipes;
- **Pursue Infrastructure Upgrades:** Consider installing in-line turbines to generate electricity when pumping water over significant elevation gradients; and
- **Pursue Infrastructure Upgrades:** Install renewable energy resources, such as on-site solar, wind, or CHP, at WWTs and/or water treatment plants to reduce energy costs for those facilities.

Electric utilities can:

- **Provide Financial Incentives:** Offer rebates to encourage their customers to install more energy-efficient water heaters or “smarter” systems that can take advantage of lower electricity prices to heat water in homes and businesses; and
- **Provide Financial Incentives:** Develop tariffs and demand response programs that incent WWTs to operate during times of low electricity demand.

State decision makers may consider the above recommendations as they grapple with key policy challenges, so they can achieve both their energy and water conservation goals and position themselves to meet future obstacles with a more efficient and resilient water system.

Endnotes

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[1] While this is true for the vast majority of water systems, there are some systems that have filtration avoidance determinations so they do not have to treat drinking water, or have gravity-fed systems so they do not need to use energy to transport water.

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[15] This can include treatment of fresh water, or desalination of seawater, which can be quite energy-intensive.

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[17] Center for Neighborhood Technology. (2013). The Case for Fixing the Leaks. Retrieved from http://www.cnt.org/sites/default/files/publications/CNT_CaseforFixingtheLeaks.pdf

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[23] *Ibid.*

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