THE WATER - ENERGY NEXUS IN UTAH

2012

Meeting the Water and Energy Challenge

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Utah Division of Water Resources
1594 West North Temple, Suite
310P.O. Box 14201
Salt Lake City, Utah 84114

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EXECUTIVE SUMMARY

Water provision can be a highly energy intensive process and energy generation can use vast quantities of water. In locations where scarcity of one or the other exists, they can develop a constraining relationship where lack of one disrupts supply of the other. This is what is described by the term "water-energy nexus." Utah's water and energy relationship is as unique as the state itself. The expenses related to water and energy have historically been quite low compared to the rest of the United States, and this has in turn brought Utahns a high standard of living and a low cost of doing business. However, the state's population is growing fast – it is projected to double by 2050 – which will necessitate new ways of thinking about resource issues.

In Utah, water is scarce in the more arid regions. However, Utah's mountainous areas receive an abundance of precipitation and snow, which is stored until each spring runoff, when the water is captured and distributed. Communities have typically been situated at canyon mouths and at the bases of mountains where they can divert runoff and use gravity to pressurize their water systems. Much of this, less energy-intensive and less expensive water has been developed. New water development's will likely require more energy to capture, treat and distribute to consumers. Utah also has much in the way of energy resources such as coal, natural gas, wind, hydroelectric, petroleum, with potential for oil shale, nuclear and solar energy. Although water used for thermoelectric power generation is currently only a small percentage of the total water withdrawn in Utah, it could increase dramatically if the state chooses to develop more of its resource using more water-intensive methods. Thermoelectric power plants around the state use water for cooling and can be very water-intensive. Because energy generation water usage varies from minimal to large amounts it would be prudent to account for this when planning for energy resource development in an arid state.

This document discusses these ideas and refers to research done to estimate how much energy and water are devoted to each industry around the state. The second chapter provides a summary of a case study of an urban water system in Utah that may be representative of other water systems around the state. Data from the case study were used to evaluate what might occur under several commonly envisioned scenarios. The first addressed energy saved when residents respond to a water conservation program successfully. The second scenario estimates energy impacts of water transfers from agricultural to municipal and industrial uses. The third evaluates the energy impacts of reduced surface water availability when groundwater is used to compensate. Other potential changes on the horizon that would require water utilities to use more energy, such as increased water quality regulation, are discussed. Rural energy use for water is also reviewed using water withdrawal and case study data. Analyses of statewide water usage using case study data suggest that Utah's energy requirement for the water sector is lower than other states – using approximately 7% of its total energy budget, excluding transportation energy consumption.

The third chapter provides an overview of water resources used for energy generation around the state. An estimate of how much water is used for each energy generation method is provided. As with water, several potential scenarios are reviewed, such as the impact of decreasing water availability and proposed energy legislation. Finally, chapter four contains recommendations (more integrated water/energy planning, increased support for water/energy efficiency, increased funding for basic water/energy science and data modeling) intended to ease and mitigate some of the discussed challenges. Implementing some or all of these proposals will assist Utahns in maintaining their high standard of living and low cost of doing business, while also targeting a more resilient and sustainable water and energy future. The coming decades will bring many challenges to Utahns related to their water and energy resources. A proactive and forward-looking water and energy policy will help maintain the high quality of life Utahans currently enjoy.

The Water - Energy Nexus in Utah

MEETING THE WATER AND ENERGY CHALLENGE

1 | INTRODUCTION

Water and energy are two inextricably linked resources. Each has the potential to limit the development of the other. The lack or shortage of available water can limit energy production, and the alternate relationship – that of energy limiting water production – is also of concern. The demand for both resources is predicted to increase in tandem with population growth, potentially creating or adding to conflict in regions of water and/or energy scarcity. Utah is a semi-arid state that receives an average of thirteen inches of precipitation each year and is the second driest state in the United States (Figure 1). Meeting future water demand, while also minimizing regional conflict, will require a host of strategies and tools, not just one solution. The first and foremost strategy will be a water conservation strategy utilizing education and new programs aimed at reducing the per capita water usage in the state. The Utah Division of Water Resources (UDWRe) is the state's water planning and development agency and has strategies in place that will ensure the state meets its future water demands with respect to a growing population. The State of Utah currently has a goal to reduce the

FIGURE 1 - MUCH OF UTAH RECEIVES LESS THAN ONE INCH OF RAIN EACH MONTH

2000 per capita water use by at least 25% the year 2050. Additional strategies will likely include new surface water development projects, conversion of agricultural water to municipal and industrial uses, water reuse, conjunctive use, and additional groundwater development. Some of these approaches to meeting future water demand could require pumping water over longer distances and from greater depths. The newly developed resources could also require more rigorous treatment to reach potable drinking water standards before being delivered to customers. Sewage water will need to be treated to higher discharge standards, or to an even higher standard for water reuse. This reclaimed water will likely need additional infrastructure to deliver it to its new point of use. All of these non-conservation oriented development approaches have some commonalities. They will cost more than water projects of the past since much of Utah's less expensive water sources have now been developed and they will be more energy intensive.

Why should this be of concern for water planners, managers and consumers alike? Water is an extremely heavy molecule. It takes a substantial amount of energy to do the work of raising even one acre-foot (ac-ft) of water to an elevation of 100 feet, and the greater the flow-rate and elevation, the greater the energy requirement. To give an example, California's State Water Project (SWP) is the state's largest energy consumer; using an average of 5 billion kilowatt-hours (kWh) each year to pump water over the Tehachapi Mountains. Southern California's other major source of imported water, the Colorado River, requires 2,000 kWh per ac-ft of water delivered.[1] No water system in Utah is quite so large, but local water utilities still use large amounts of energy to move and treat water. Pumping water is usually a utility's largest operational cost, followed by water treatment. In some rural areas of Utah, pumping groundwater for irrigation is one of the largest costs for farming and agricultural communities.

The phenomenon of limited water availability and greater costs in Utah is juxtaposed with an abundance of energy resources, primarily in the form of traditional and non-traditional fossil fuels. Coal combustion, natural gas, hydropower, and petroleum all contribute to the low cost of energy in the state of Utah, enabling a high standard of living for its residents and contributing to the state's overall prosperity. However, each energy source has a requisite water demand that also draws on a limited water supply. Renewable energy resources, such as geothermal, solar power, bio-fuels and wind, also have a "water footprint" that can either exacerbate or facilitate water supply issues (Figure 2).

[1] Wolff, G. "Energy Down the Drain: The Hidden Costs of California's Water Supply." *Natural Resources Defense Council, Pacific Institute*, Oakland Ca.

FIGURE 2 - SOME METHODS OF ENERGY PRODUCTION REQUIRE SIGNIFICANT VOLUMES OF WATER, WHILE OTHERS DO NOT

Nationally, energy production is one of the largest water withdrawal and use sectors in the U.S.[2] As Utah's population grows, and energy demands grow nationally, energy production utilities may find themselves to be in greater competition for the state's remaining water resources. Understanding how available water resources in Utah limit or enable energy production – and how energy costs can potentially limit water provision – is key to managing them both in a proactive and integrative fashion.

Purpose and Goals of this Study

The purpose of this document is to highlight some important issues surrounding Utah's particular "water-energy nexus." Very little has been published about how much water is currently used for energy generation facilities and processes in Utah. Energy requirements for water-related services around the state are also not well understood. This document attempts to answer some basic but essential questions:

- How much water is currently used by energy utilities in Utah?
- How much does the amount of water vary by energy generation method?

[2] Department of Energy (DOE), (2006). "Energy Demands on Water Resources: Report to Congress on the Interdependency of Energy and Water." *United States Department of Energy*.

- How much energy is required to bring water to consumers across the state?
- How does this vary geographically across the state and why?
- What are some of the potential impacts on the horizon for these resources?
- How can water and utility managers prepare for these impacts successfully?

To answer these questions, this document gathers together available water usage data on energy producers around the state. It establishes a preliminary survey of water efficiencies amongst different energy production methods commonly used in Utah. A review of water-related energy usage around the state is conducted. For urban water providers, a case study is highlighted and used to estimate how much energy water-related services require in an urban setting based on topography and key water system components. A broad survey was conducted of recent literature on the likely impacts to both the energy and water sector when considering future water availability, potential climate change, carbon legislation, water quality regulation, and many other potential variables. Possible ways to mitigate these impacts are also proposed for further study. While the data are incomplete and are not yet sufficient to portray Utah's water and energy relationships fully, they offer the reader a first glimpse at Utah's "water-energy nexus."

The Water-Energy Challenge

Utah is a prime example of a state affected by three driving forces of the water and energy challenge: a rapidly growing population, limited water resources and growing energy consumption. Due to its natural geographic advantages, long-range water planning and today's engineering technologies, enough water has been developed in Utah to adequately keep up with its demand. So much so, that water is one of the least expensive utilities provided to Utah's residents. It is an often overlooked and underappreciated resource given Utah's relative aridity and limited water resources. Likewise, energy, mostly in the form of fossil fuels, has remained inexpensive and abundant. Since 1980, Utah has been a net energy exporter – able to produce a significant amount of energy for neighboring states and beyond. However, with an increase in population, greater environmental impacts, more stringent water quality regulation and a decrease in easily developable water and energy supplies, the future holds new water-energy challenges.

Population Growth

Utah has and is projected to grow at a more accelerated pace than the rest of the nation. In 2010, the Utah Governor's Office of Planning and Budget (GOPB) estimated the state's population at approximately 2.76 million people, and projected that it would grow at an average annual rate of 2.3 percent through 2030, and a little more slowly through the year 2060 (Figure 3). Even with slower growth through later decades, a total of 6.8 million residents (or 4 million new residents) will require basic services by 2060, with commensurate increases in energy and water demand.[3]

FIGURE 3 - THE POPULATION OF UTAH IS PROJECTED TO GROW BY FOUR MILLION BY 2060

Regional Water Conflicts

Growth is not isolated to only Utah. Almost every western state is projected to grow at a rapid pace through 2030. Conflict over diminishing resources, especially water, could create new legal action and expensive litigation between water users. Water allocated from the Colorado River Basin has often been the focus of inter-state negotiations. Utah has spent a significant amount of time in negotiations with the state of Nevada in recent years over the proposed pumping and transfer of groundwater from an aquifer shared by both states. Pipeline diversions that would tap water from the Green River and transport it to Colorado have concerned Utah's water agencies about meeting environmental requirements for local endangered species, as well as effects on Utah's ability to develop its own Colorado River allocation.

In 2003 the Bureau of Reclamation published a map of areas that they perceived were likely to experience conflict over water supply by the year 2025.[4] Shown in Figure 4, most metropolitan areas in the west are highlighted in red, illustrating the many areas where potential water conflicts exist.

[3] Utah Governor's Office of Planning and Budget (2008). "2008 Baseline Projections: Utah Economic and Demographic Summary." *Utah Governor's Office of Planning and Budget*, Salt Lake City, Ut.

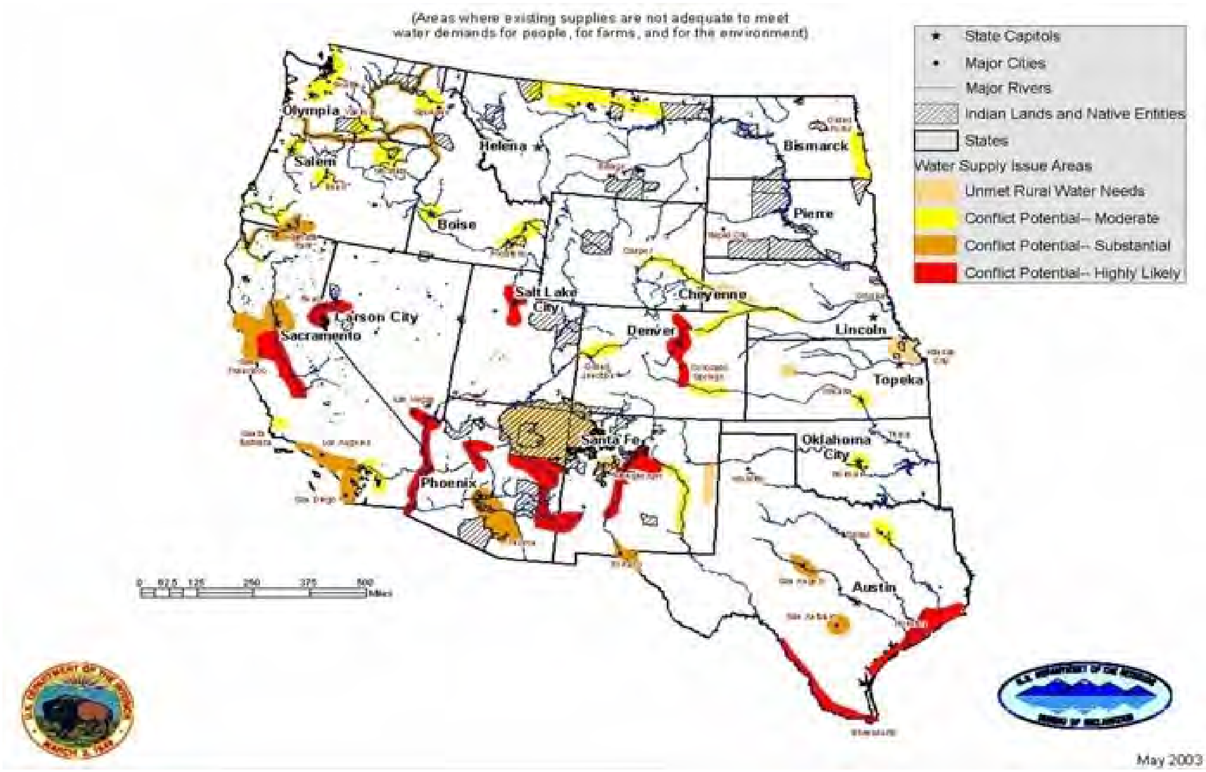

FIGURE 4 - REGIONS AND MUNICIPALITIES OF POTENTIAL WATER CONFLICT IN 2025

Salt Lake City and St. George, Utah were both included in the Bureau's water supply crisis survey. However, with careful planning, collaboration and monitoring of water resources that are in question, it may be possible to avert or avoid a substantial amount of regional conflict altogether. The UDWRe, through its extensive river basin planning process, is helping local water providers ensure that the residents of Utah will have adequate water supplies through at least 2060.

Climate Change

Another facet of the water-energy challenge is the phenomenon of a changing climate. Some climate scientists predict that parts of the west will be both hotter and drier in the coming years. They are also predicting that droughts will be both longer and more intense than what has been experienced in recent history. Higher temperatures during warmer months would result in higher evapotranspiration rates, which in turn would result in a higher water requirement to irrigate crops and landscapes during the growing season. Changes in rainfall and runoff are also predicted. A recently released study by the Bureau of Reclamation evaluated several climate models, and explained results from their own in-house models, for precipitation, timing and runoff changes for sub-basins in the Colorado River Basin. Their estimates for change in mean annual runoff at Lees Ferry and upstream were -2% to -9% by 2070. The Bureau's report summarized the potential impacts to

[4] Bureau of Reclamation (2003). "Water 2025: Preventing Crises and Conflict in the West." http://wwa.colorado.edu/western_water_law/docs/Water2025_USDOI.pdf

rainfall and runoff for the Colorado and surrounding basins, and also reiterated the need for more research to be conducted to address the uncertainties of current climate science estimates.[5]

But what is the connection between energy, water and climate change impacts? In Utah, if climate change brings about an increase in temperature, changes in precipitation patterns, more infiltration at higher elevations and reduced runoff, greater volumes of water will be necessary to irrigate cropland. This, in turn, would reduce the amount of water available in streams, surface storage reservoirs, and eventually Utah's aquifers. As gravity-fed surface water represents the bulk of Utah's inexpensive water supply, any reductions in surface water will likely result in more energy-intensive, and therefore more expensive options for providing the same amount of water.

> *"It must be recognized that there is already substantial stress on the water sector today even in the absence of climate change… Climate change may pose additional stresses and could result in thresholds being reached earlier than currently anticipated…"*
>
> *Western Governors' Association*
> *Water Report*

The relationship between climate change, available water and the energy necessary to provide it is understandable. How water supply choices impact climate is less apparent. A case study may more easily show the connection. In 2009, a California study was conducted that evaluated the energy requirement for meeting future demand in 2030 using different water supply options: additional imported water, desalinated seawater, desalinated brackish groundwater and recycled water.[6] What they found was that, if the state chose to primarily use desalination – a highly energy intensive source of water – that it could increase California's energy allotment used for water from about 19%, as it is currently, to 52%. In essence, over half of the energy used in California would be used to convey, treat, heat, cool and retreat water for its residents. Researchers found that using high-energy water sources cascaded into requirements for new energy infrastructure, which also resulted in higher greenhouse gas (GHG) emissions. The average Californian's energy footprint for water each year would increase from 360 kilograms (kg) of carbon dioxide (CO_2) emitted to 800 kg. Alternately, if Californian's chose to use reclaimed water for meeting future demand, this would use much less energy, only slightly above current energy requirements. Although this California example does not relate to Utah's water supply situation, it does show why such large differences in impact make a

[5] Bureau of Reclamation (2011), "Reclamation Managing Water in the West. SECURE Water Act Section 9503(c) - Reclamation Climate Change and Water 2011." http://www.usbr.gov/climate/SECURE/docs/SECUREWaterReport.pdf
[6] Stokes, J., Horvath, A. (2009). "Energy and Air Emission Effects of Water Supply." *Environmental Science & Technology*, 43(8), 2680-2687.

compelling case for including energy requirement as a criterion in the decision-making process when evaluating future water supply sources.

Future Water Needs in Utah

Utah's State Water Plan, published by the Utah Division of Water Resources in May of 2001, provided a comprehensive summary of the status of water use and water planning for the state at that time. In the report, water planners discussed how water demand had been met in the past and developed strategies for how it would be met in the future.[7] When published, Utah's population projected for 2050 was for about five million residents. The report indicated that, at their current usage rate, new municipal and industrial demand would essentially double from 900,000 ac-ft to 1,950,000 ac-ft diverted annually from Utah's rivers, reservoirs and aquifers. These same figures were updated in 2008 to incorporate the 2060 horizon.[8] The new estimate for municipal and industrial water demand was increased to 2,553,000 ac-ft. However, water planners estimated that local suppliers would still be able to meet this larger future demand and maintain a reliable supply surplus, if a variety of strategies were employed.

The report indicated that water conservation will play the lead in reducing the amount of water needed to meet future demand. Water conservation is the least expensive source of water supply available to water planners at the current time and was cited as a critical element in Utah's plan to meet future needs. The state water plan devoted an entire chapter to discussing water conservation and efficiency initiatives and its importance to the state in meeting its water supply goals. It elaborated on a statewide water conservation media campaign called "Slow the Flow," begun in 2000, with the goal of reducing municipal and industrial water consumption by at least 25 percent by 2050. In more detailed terms, the goal specified a reduction in gallons per capita per day (gcpd) water demand, from 295 gcpd in the year 2000 down to 220 gcpd by the year 2050. This would amount to nearly 600,000 ac-ft of water that would be conserved and not have to be developed. The success to date of water conservation efforts within the state from 2000 to 2010 is shown in Figure 5. The figure also projects the desired water conservation outcome in 2050.

In addition to water conservation, future demands will be partially met by a transfer of agricultural water to the municipal and industrial sector, as farmland is converted to more urban uses. The Utah Division of Water Resources estimates that about 400,000 ac-ft could be developed through such means. Additional water supplies would be obtained through more efficient management of existing developed supplies and additional water development projects. The final phases of the Central Utah Project will supplement water supplies around the Uintah, Utah Lake and Jordan River basins. The Bear River Development Project, currently

[7] Utah Division of Water Resources (2001). "Utah's Water Resources: Planning for the Future." *Utah Division of Water Resources*, Salt Lake City, Ut.
[8] Utah Division of Water Resources (2008). "Meeting Utah's Future M&I Water Needs." *Utah Division of Water Resources*, Salt Lake City, Ut.

in the early planning stages, will bring additional water to Utah's major urban corridor along the Wasatch Front.

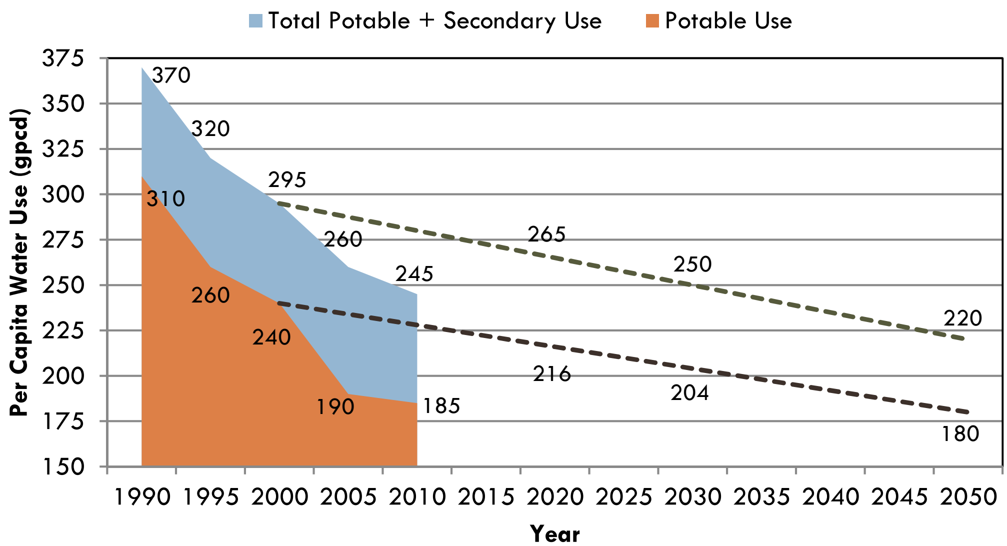

FIGURE 5 - PER CAPITA WATER USE AND WATER CONSERVATION INITIATIVE PROJECTIONS FROM 1970 TO 2050

The Lake Powell Pipeline Project, currently in the environmental impact study phase, is planned to divert 86,000 ac-ft of water to Utah's Washington County, Kane and Iron Counties. Many smaller and local water projects will supplement water supplies as well. Figure 6 charts the additional water supply development options with and without water conservation.[9] Utah will have an adequate water supply to meet future demands through the 2060 horizon. However, one theme does emerge from these newer proposed projects: that the era of easily developable inexpensive and low energy-consuming water sources is coming to a close.

With the exception of water conservation, all of these proposed methods of meeting future water demand require infrastructure development and energy to divert, pump and convey water from one point to a new point of use. Additional energy will also be required to treat the water to drinking water standards and the effluent wastewater to discharge standards.

[9] Utah Division of Water Resources. "Municipal and Industrial Water Uses." *Utah Division of Water Resources*, Salt Lake City, UT 2005.

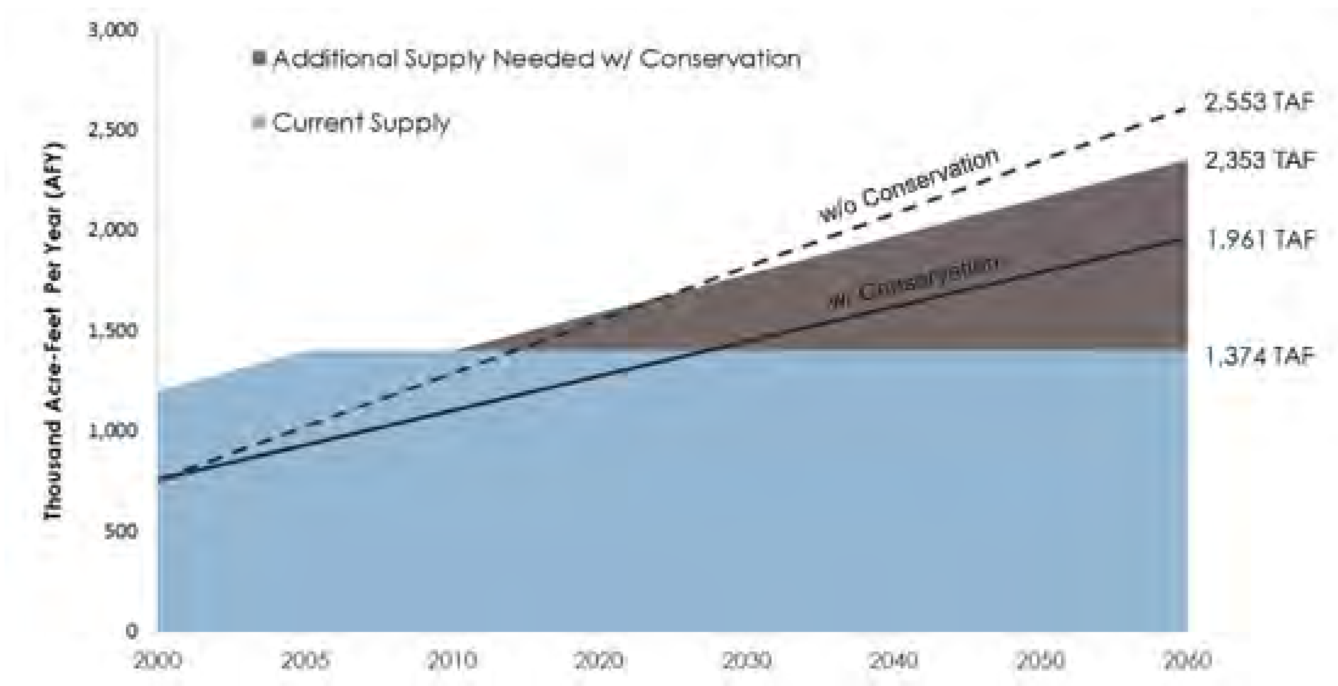

FIGURE 6 - UTAH'S MUNICIPAL AND INDUSTRIAL WATER DEVELOPMENT AND FUTURE DEMAND

Future Energy Needs in Utah

Energy production in Utah comes primarily from fossil fuel sources such as coal, petroleum, and natural gas – about 97% percent in fact.[10] Only a small component of Utah's energy profile is derived from renewable sources such as hydropower, geothermal, wind or bio-fuels. Figure 7 illustrates the relative proportions of Utah's energy profile, while Figure 8 shows the same for the rest of the U.S for 2009.

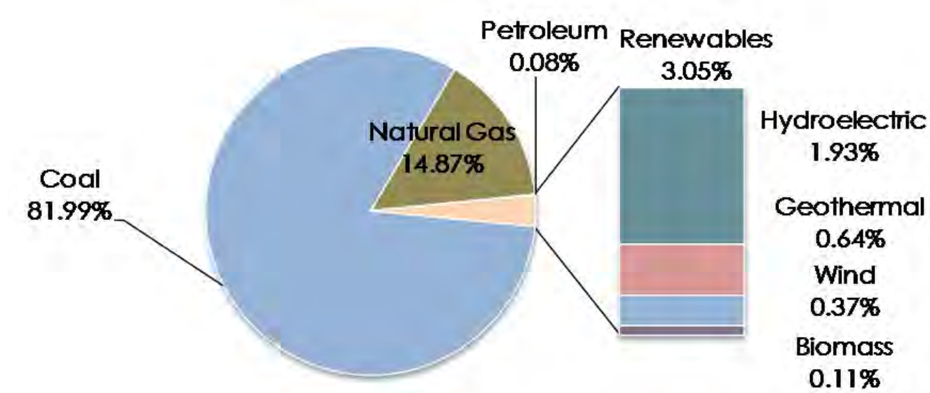

FIGURE 7 - UTAH'S ENERGY GENERATION PROFILE IN 2009

[10] U.S. Energy Information Administration (2009). "State Energy Profiles: Utah." http://www.eia.doe.gov/state/state_energy_profiles.cfm?sid=UT.

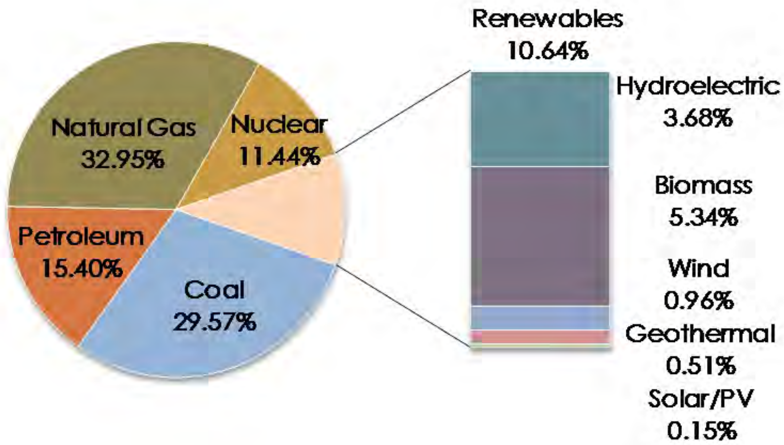

FIGURE 8 - THE U.S. ENERGY GENERATION PROFILE IN 2009

Coal is the most heavily used source for electricity generation in Utah, while natural gas is a distant second and used primarily for heating homes and businesses. An abundance of these natural resources have led to inexpensive utility rates and a generally high standard of living for most Utahans. Since 1980, Utah has remained a net exporter of energy, selling almost 30 percent of its total energy produced in 2008 to users outside of the state. The graph presented in Figure 9 reveals a trend that, at least since 1970, energy consumption and energy-related expenditures in Utah have risen in tandem with population growth, with periods of economic recession seeing a corresponding increase in expenditures.

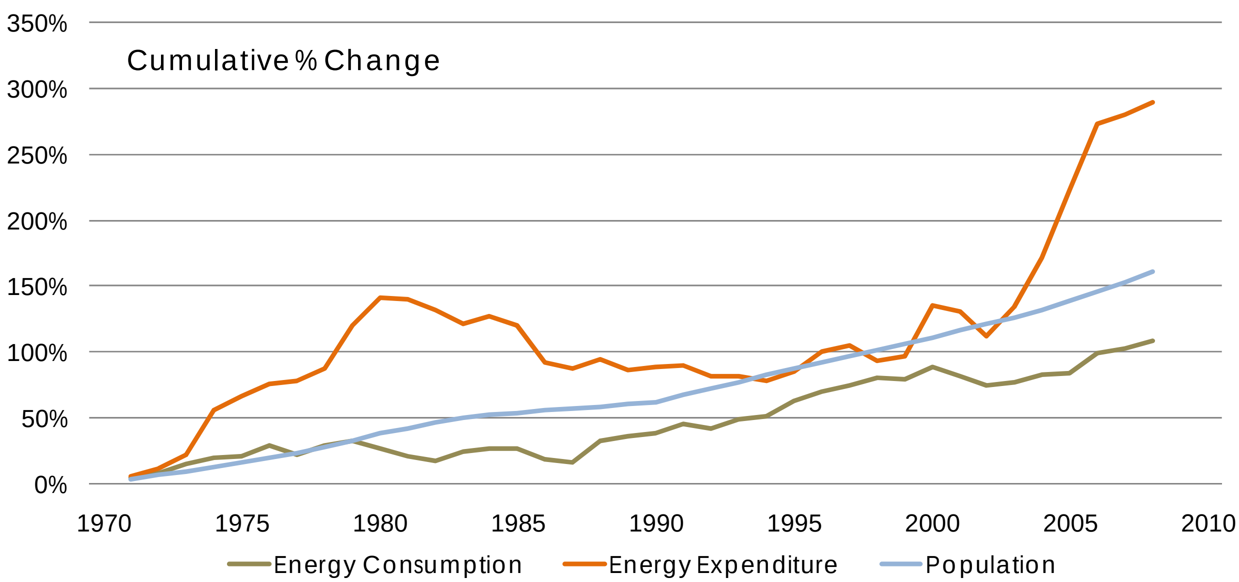

FIGURE 9 - UTAH'S CUMULATIVE ENERGY CONSUMPTION, EXPENDITURES AND POPULATION GROWTH

However, despite any dampening experienced in energy consumption during the most recent economic downturn, it is clear that expenditures for energy have increased in recent years. During 2007 through 2008, when gasoline and energy prices rose to new heights, Utahns began to express concerns about the cost of energy and their energy infrastructure. A survey conducted by the Utah Foundation in 2008, found that energy related issues, including utility and gasoline pricing, were the number one concern of Utah's residents, over those of education, government spending, healthcare and immigration reform.[11] The results of the poll are shown in Figure 10. In a report following the survey, the Utah Foundation pointed out that, even though Utah has produced more energy than it has consumed since 1980, its fossil fuel resources are finite. Their projections relating to future energy development in Utah gave fossil fuel based resources a limited lifespan. This change in Utah's energy resource base, if not adequately planned for, could threaten the standard of living that Utahns have enjoyed thus far.[12]

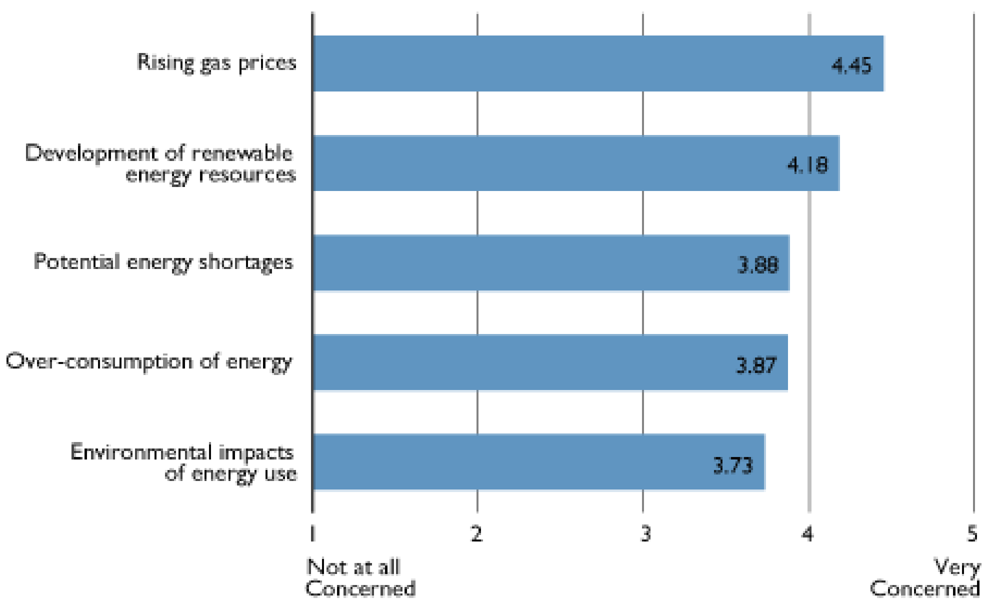

FIGURE 10 - UTAH FOUNDATION POLL INDICATED ENERGY WAS THE NUMBER ONE PRIORITY OF UTAH'S RESIDENTS (2008)

[11] Utah Foundation (2008). "The 2008 Utah Priorities Survey: The Top Issues and Concerns of Utah Voters for the 2008 Election." *Utah Foundation*, Report 683, Salt Lake City, Ut.
[12] Utah Foundation (2008). "Utah's Energy Use & Resources: Powering our Standard of Living." *Utah Foundation*, Report 685, Salt Lake City, Ut.

2 | ENERGY FOR WATER

Water's Life-Cycle and Energy Intensity

Water-related services can be energy-efficient or they can be energy-intensive. When trying to understand how much energy is consumed to acquire and use water, it is helpful to define different stages or segments of municipal and industrial water supply and consumption. Figure 11 is a conceptual diagram of the breakdown of commonly occurring water supply and consumption cycle. It illustrates how water is first gathered from a source, is conveyed to a point of treatment, and then distributed to a point of use. After the water is put to use or consumed, any remaining water typically flows to a wastewater facility and after treatment flows directly back into the natural

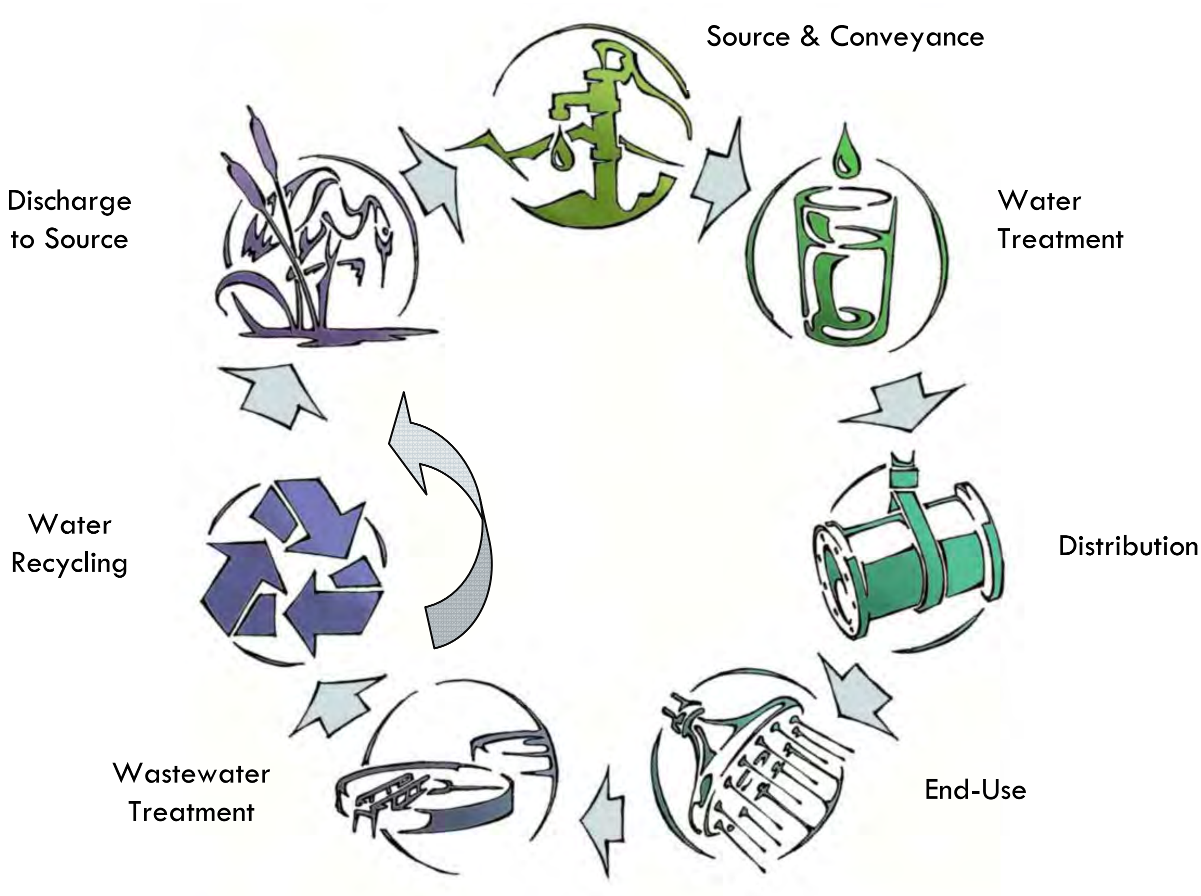

FIGURE 11 - CONCEPTUAL ILLUSTRATION OF MUNICIPAL AND INDUSTRIAL WATER SUPPLY AND CONSUMPTION CYCLE[13]

[13] Larsen, Sara G. (2010). "Determining Energy Requirements for Future Water Supply and Demand Alternatives." *M.S. Thesis, University of Utah*, Salt Lake City, Ut.

environment. If water reuse is utilized, there may be an additional treatment stage for reuse projects before the water is eventually discharged. Researchers have found that breaking the water supply and consumption cycle into phases helps them to understand how much energy is required to perform each stage and for the system as a whole.

Estimating the amount of energy used by each segment or subgroup of water's life-cycle is made easier by eliminating the year-to-year fluctuations of water volume involved. For example, if a set of diversion gates, pumps and a SCADA system are used to convey 100 ac-ft of water in a given year to a treatment facility, and it requires 10,000 kilowatt hours (kWh) of energy to do so, that "source" of surface water would have an energy intensity of 100 kWh for each ac-ft (kWh/ac-ft) conveyed, and would likely remain close to that amount from year to year under similar operational procedures. Likewise, if a groundwater well pumps 10 ac-ft during a given year and requires 8,000 kWh, its energy intensity would be 800 kWh/ac-ft. Using this approach greatly facilitates an understanding of energy requirement. It can provide a general picture of how much energy is consumed within different phase sub-categories, components and even treatment processes.

Pertinent Studies

In 2005, the California Energy Commission (CEC) published a report of their water–related service's energy requirement for facilities "outside of the retail meter," while estimating the amount of energy used in the end-use phase from electrical utility data.[14] By further disaggregating each of the other phases, they could isolate with increasing accuracy where the bulk of their water-related energy was being used. The results of their study suggested that California's water systems and end-use consumption were surprisingly energy intensive – about 19 percent of their total energy demand budget for the state – and it tended to fluctuate by water supply source and the level of treatment required. This report brought the concepts surrounding water and energy relationships to the table for discussion. When discussing different methods of meeting California's future water demand – whether by additional groundwater usage, new supplies, desalination or water reuse – it became clear that energy requirement of future water supplies needed to be included in the planning process.[15]

Prior to the CEC study, the Electric Power Research Institute (EPRI) performed a nationwide survey of conveyance, initial treatment and wastewater treatment energy usage, to arrive at a very broad estimate of energy needed for the water sector in the future.[16] They found that, generally the more advanced and thorough the water treatment process, the more energy intensive. However, they also found great efficiencies

[14] California Energy Commission (2005). "California's Water-Energy Relationship." *California Energy Commission*, Sacramento, Ca.
[15] Stokes, J., Horvath, A. (2009). "Energy and Air Emission Effects of Water Supply." Environmental Science & Technology, 43(8), 2680-2687.
[16] EPRI (2002). "Water & Sustainability (Volume 4): U.S. Electricity Consumption for Water Supply & Treatment – The Next Half Century." *Electric Power Research Institute*, Palo Alto, Ca.

among large capacity facilities that could take advantage of economies of scale. Combined, the EPRI and the CEC studies provided a picture of the state of energy usage by the water sector at a broad scale, but most of the action related to water planning and administration is on a local scale, district by district, county by county, each with unique topographies, water supply sources, treatment methods, etc. When assessing what methods would be appropriate for estimating energy use in Utah, these studies did not reflect and couldn't take into account Utah's unique geographic advantages, and would have over-estimated its energy requirement. A new approach had to be developed for estimating energy for individual systems and for the state water planners that was refined enough for an acceptable degree of confidence, but also general enough for a water manager to get estimates quickly and easily.

In 2009, the UDWRe cooperated in a thesis study of a major water provider in Utah, which was conducted to take a "first look" at how much energy its water supply systems needed, and might require in the future under a variety of scenarios.[17] It addressed the following questions:

- What are the energy costs associated with different water sources?
- What are the energy costs to treat and re-treat those sources to drinking water, and wastewater effluent standards?
- How would this energy requirement respond to a successful demand reduction program?
- How would it respond to changes in application, such as a transfer from agricultural to municipal and industrial uses?
- How would it change with a reduction in surface storage, such as during periods of drought, reservoir sedimentation or with climate change?

The results of the case study suggest that Utah has some natural advantages for water provision that have made it an inexpensive resource for its residents, which are directly related to energy requirement. However, it also suggests that the era of easily developable water is rapidly coming to a close and new water development will become more expensive and more energy-intensive.

[17] Larsen, Sara G. (2010). "Determining Energy Requirements for Future Water Supply and Demand Alternatives." *M.S. Thesis, University of Utah*, Salt Lake City, Ut.

FIGURE 12 - UTAH'S SNOWPACK IS ONE OF ITS PRIMARY WATER SUPPLY SOURCES

Background

Utah's climate is classified as semi-arid, receiving an average of only thirteen inches of precipitation each year. It is the second driest state in the nation behind Nevada. Much of its water supply falls as snow in the mountains during winter months, which melts into rivers and streams in the spring. Early Mormon pioneers settled at the base of these mountains, close to canyons, where they could capture high quality snowmelt runoff or spring water easily, and divert it to their communities and adjacent fields.

Today there are hundreds of storage reservoirs in Utah that capture snowmelt runoff and store it for communities and farmland at lower elevations. A significant portion of runoff that is not captured eventually makes its way into underground aquifers, which serve as additional storage reservoirs that can be tapped during the summer months when surface flows are at their lowest. Groundwater aquifers supply over 50 percent of the public water supply currently used by Utah's rural and urban communities.

Utah's topography provides its residents with an important benefit – a significant portion of water supply systems in Utah use gravity to pressurize their water system distribution, which would otherwise require a great deal of energy for pumping. In addition, some agencies use water released from reservoirs to generate electricity, which they sell to local power grids or use onsite to offset their energy costs. In order to maintain constant pressure, many municipal systems along the Wasatch Front have installed pressure reducing valves to dissipate the energy of their gravity-fed systems. These agencies could potentially benefit from micro-hydropower or in-line turbine power generation. Since much of Utah's water is supplied via surface storage and gravity-fed canals and pipelines, it makes sense that significantly less energy and infrastructure is required to transport and treat water, and then distribute it to consumers. Another contributing factor to low energy costs in Utah is the amount water provided through separate secondary irrigation systems for outdoor landscape irrigation. These pressurized irrigation systems use untreated surface water to irrigate landscapes. Energy requirement for secondary water is minimal because the water doesn't need to be treated to drinking water standards and in most systems takes advantage of gravity to provide pressure.

In addition to natural topographic advantages, Utah's high-quality snowmelt, springs and groundwater require very little initial treatment to reach drinking water standards.[18] Communities below surface storage facilities are usually the first users of the water, as opposed to taking water from a source that also contains discharge from another upstream community. Many water districts simply treat their pumped groundwater supplies or springs with chlorine and that is sufficient to make it suitable for domestic consumption. Around the country, wastewater treatment requires greater amounts of energy to treat water back to effluent discharge standards, but most wastewater systems in Utah employ less energy-intensive trickling filter technologies or sewage lagoons. This treatment regime requires much less energy than those of an advanced treatment facility, which may treat for added nitrogen removal, employ ozonation for disinfection, or even use micro-filtration to treat water to tertiary standards for reuse projects. When compared to energy costs for water treatment around the nation, which can include brackish water, water reuse and seawater desalination, Utah's are generally much lower.

[18] U.S. Geological Survey (2002). "Water-Quality Assessment of the Great Salt Lake Basins, Utah, Idaho, and Wyoming – Environmental Setting and Study Design." *United States Geological Survey*, Water-Resources Investigations Report 02-4115, Salt Lake City, Ut.

FIGURE 13 - WATER IS INEXPENSIVE IN UTAH IN PART DUE TO ITS MINIMAL USE OF ENERGY TO CONVEY AND TREAT

The above factors and many others combine to make water one of the least expensive resources for Utah's residents. The average cost of 1,000 gallons of drinking water for a typical homeowner is $1.34.[19] Based on data gathered by the American Water Works Association (AWWA), Utahns pay 43 percent less than the rest of the nation, and 45 percent less than nearby states for their water.[20] However, as Utah's population continues to grow, the inexpensive and less energy intensive sources of water are becoming rarer. Much of this "easy" water – flows that originate from mountain ranges and can easily be diverted and treated – has already been developed. Beyond water supply, possible future requirements for wastewater treatment may lead to much more energy intensive processes to remove nutrients and other contaminants. If it is true that Utah's easily developable water supply and wastewater treatment is at an end, the issue of energy consumption takes on a new importance and should play an role when considering water and wastewater policies, guiding water planning and deciding which water projects to fund.

Urban Case Study: Jordan Valley Water Conservancy District

Jordan Valley Water Conservancy District (JVWCD) is a large water system situated primarily on the south-western quadrant of the Salt Lake Valley and has supplied an average of 118,000 ac-ft per year to its member agencies and other customers from 2004 to 2008.[21] Member agencies are comprised of municipalities and other water districts, which supply, sell and distribute water directly to retail customers. In total, JVWCD and its member agencies deliver water to about half of the population living in Salt Lake County.[22] Their water supply sources include snowmelt runoff conveyed from the Wasatch and high Uinta mountains, via tunnels, diversions and canals, over 300 miles to the Salt Lake Valley. They also supplement this

[19] Utah Division of Water Rights (2006). "2006 Community Water System Survey." *Utah Division of Water Rights*, Salt Lake City, Ut.
[20] American Water Works Association (2006). "2006 Water and Wastewater Rate Survey." *American Water Works Association*, Denver, Co.
[21] JVWCD (2009). "Summary of Operations 2008 – 2009." *Jordan Valley Water Conservancy District*, West Jordan, Ut.
[22] Utah Division of Water Resources (2009). "Municipal and Industrial Water Supply and Uses in the Jordan River Basin." *Utah Division of Water Resources*, Salt Lake City, Ut.

supply with an array of groundwater wells. The district's geographic extent, shown in Figure 14, is large, but their facilities are typical of a water wholesale-to-retail system.

In 2009, JVWCD, twelve of its member agencies, and the two wastewater treatment plants within JVWCD's boundary agreed to participate in this study of their energy requirements. This involved acquiring their utility data (electrical, natural gas, diesel, propane and also methane generation) for the study period of 2004 through 2008. Pacificorp, the electric utility that serves the district, provided monthly utility billing for any water-related, fixed facility that was directly involved in conveying or treating water for the district and member agencies. For example, utility bills for pump stations, SCADA controls, meters, diversion gates, and treatment plants were included in the study, while office facilities were not (with the exception of centralized wastewater facilities, which are not itemized). Energy consumed by office or field personnel and vehicular or

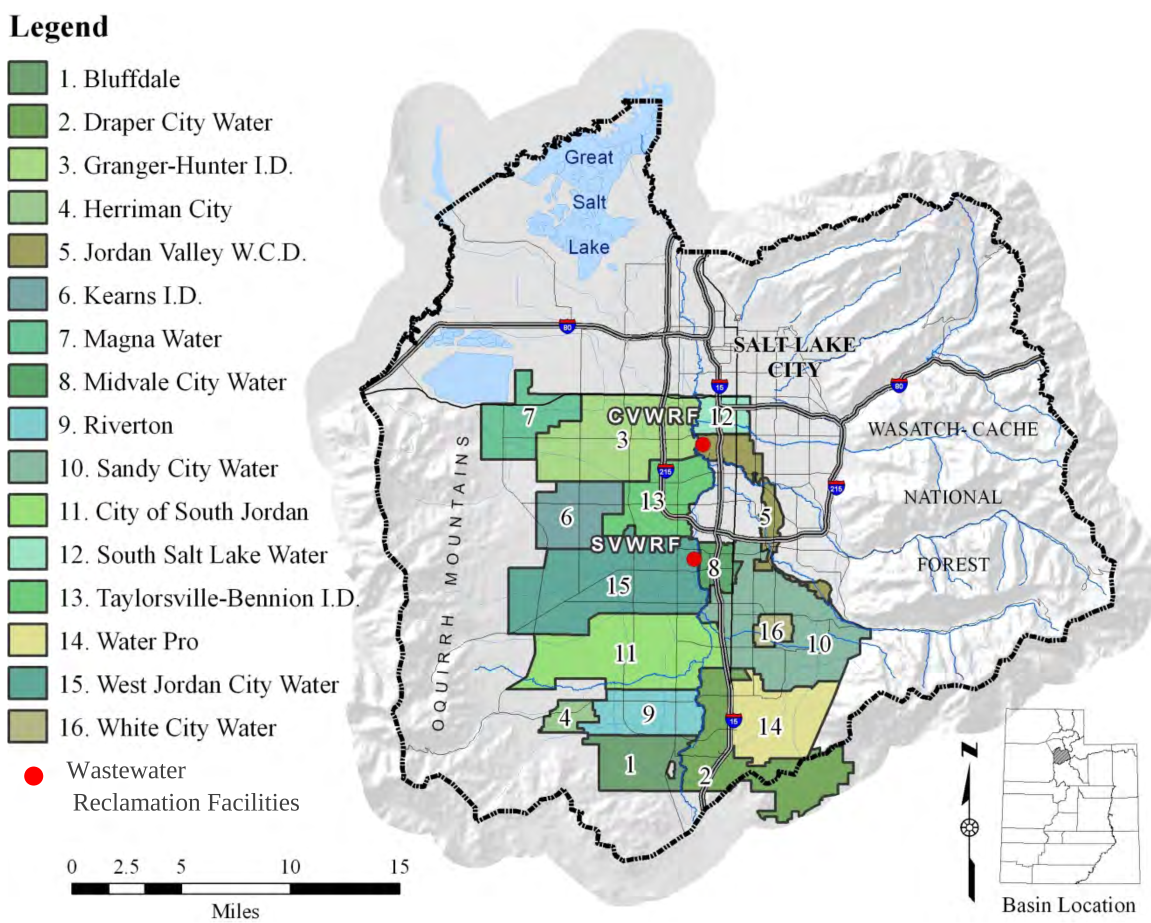

FIGURE 14 – JORDAN VALLEY WATER CONSERVANCY DISTRICT SERVICE BOUNDARIES, MEMBER AGENCIES AND WATER RECLAMATION FACILITIES

transportation activities were omitted from the study. Any other water infrastructure energy data, such as propane tanks, natural gas and diesel pumps, were also gathered. Each billing item was categorized into its most relevant water supply phase. Some of these phases were disaggregated even further to reflect different water supply sources, methods of treatment or capacity, for more refined energy estimates.

By assembling the case study data together in a common format, a picture began to emerge of where JVWCD's water-related energy was being used. The resulting dataset was analyzed for differences between water wholesale systems and those of smaller retail agencies. Table 1 compares the resulting energy intensities for different phases of the water supply cycle for JVWCD to those published in the CEC's 2005 and 2006 revised report for California.

TABLE 1 - COMPARISON OF JORDAN VALLEY WATER CONSERVANCY DISTRICT AND CALIFORNIA ENERGY COMMISSION ENERGY INTENSITY RANGES

Water Cycle Phase	JVWCD EI Range (kWh/ac-ft)	CEC 2005 EI Range (kWh/ac-ft)	CEC 2006 EI Range (kWh/ac-ft)
Source & Conveyance Facilities			0 - 4500
Surface Water	0 - 100	0 - 3500	
Groundwater	700 - 950	600 - 950	
Recycled Water	10	130 - 400	
Water Treatment	40 - 50	30 - 5200	30
Distribution	140 - 220	230 - 400	400
Wastewater Treatment	400 - 850	360 - 1500	400 - 700
Recycled Water Distribution			400 - 1000

*Does not include desalination to make an accurate comparison to JVWCD's system

Several of the categories are lower than California's, indicating a lower-energy requirement for those phases of the water supply cycle. Using the energy factors from JVWCD and its member agencies as a framework, a model was developed that would help estimate energy costs for other systems. Water providers searching for a simple way to estimate costs for their own systems, could enter their data (such as water volume or pump depth) for the year of interest. These would then be multiplied by their appropriate range of energy factors to arrive at an estimate of energy usage. To further validate the model, three cities/water agencies of varying complexity supplied their water and utility data. Using the energy intensities listed above, the model predicted the energy usage for those systems with a margin of error within 20 percent of actual use. This high value was due in part to an overestimation of the energy requirement for very small communities or very simple systems, such the one used to provide water in Delta, UT. It also didn't take into account that communities with larger water reuse projects, like St. George, UT, which have to pump reclaimed water to higher elevations to be used elsewhere. Modeling errors like these reveal interesting facets of water systems that can be incorporated into later iterations of the model for greater accuracy.

Energy for Water Supply – Surface Water, Springs and Groundwater

Surface water sources comprised 81 percent of total water withdrawals made in Utah in 2005.[23] This high percentage is in large part due to agricultural irrigation, which is by far the largest end-use of diverted surface water. However, for M&I withdrawals, surface water makes up approximately 45 percent of total M&I withdrawals while groundwater makes up 55 percent.[24] Within the JVWCD district, by contrast, the percentage of water supply from imported surface water was quite high – about 91 percent over the study period. The remaining 9 percent of water supply was pumped groundwater.[25] Reliance on surface water decreased to 75 percent when individual member agency groundwater sources were figured in. The imported surface water energy factor related to the JVWCD system (0 – 100 kWh/ac-ft) was comparable to the lower end of the CEC's ranges. The upper limit of the CEC's ranges, at 3,500 and 4,500 kWh/ac-ft, are a result of the high energy costs associated with pumping surface water in southern California and for desalination.

The JVWCD range for surface water was comparatively low due to their surface water supply arrangements with other water agencies. See Figure 15 for a schematic of JVWCD system. Each year JVWCD purchases large volumes of water from other water wholesalers who pass their energy costs along in the form of water pricing. Without also doing extensive analysis of all interrelated water systems, it is difficult to arrive at a perfect estimate for imported surface water for the JVWCD system. After reviewing the hydropower generation upstream of JVWCD's procurement, it is likely that their total energy factor range for surface water would be reduced even further, and might become negative due to energy production at Jordanelle and Deer Creek Reservoir. The canals and streams that provide water to the JVWCD region divert snowpack runoff from the high Uinta Mountains to the east and span hundreds of miles. Most of the conveyance energy costs in the study were for simple telemetry, measurement and control devices such as SCADA systems, diversion gates, and debris screens. The total energy required to operate such infrastructure is small when compared to the volumes of water conveyed by them.

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[23] U.S. Geological Survey (2009). "Estimated Use of Water in the United States in 2005." *United States Geological Survey*, U.S. Geological Survey Circular 1344, Reston, Va.

[24] Utah Division of Water Resources (2005). "Conjunctive Management of Surface and Ground Water in Utah." *Utah Division of Water Resources*, Salt Lake City, Ut.

[25] JVWCD (2009). "Summary of Operations 2008 – 2009." *Jordan Valley Water Conservancy District*, West Jordan, Ut.

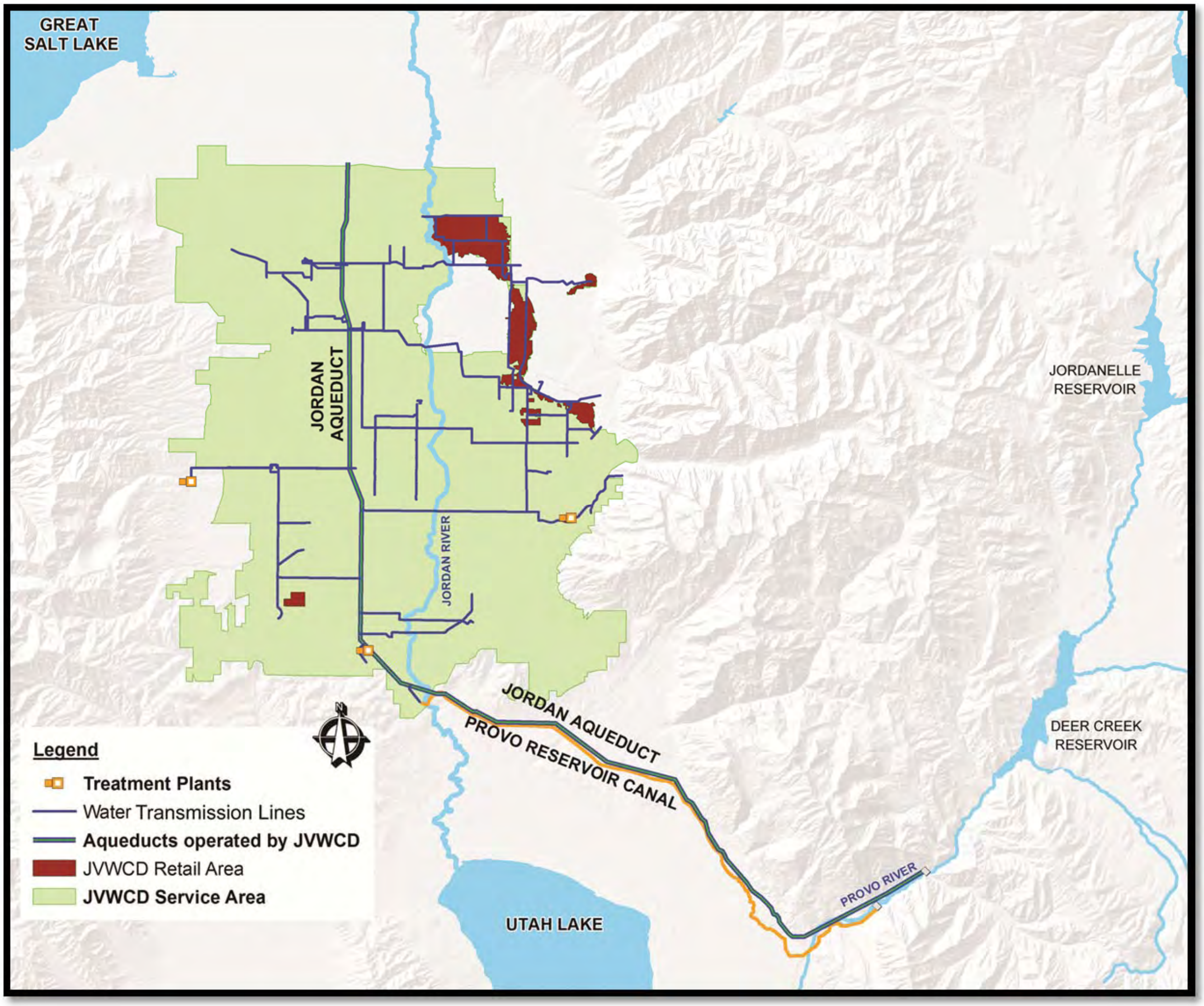


FIGURE 15 - SCHEMATIC MAP OF THE JORDAN VALLEY WATER CONSERVANCY DISTRICT SYSTEM

Groundwater comprises a smaller portion of the water delivered within the JVWCD system, including member agencies – only 25 percent compared to the statewide total of 55 percent. However, some member agencies have found that groundwater withdrawals are an advantageous water source for their systems and rely on them almost entirely. EPRI estimates that groundwater sources are generally more energy intensive than surface water sources by about 30 percent, but the case study found that the difference in energy requirement for these sources within the JVWCD system is much higher – about seven times more so than surface water sources in Utah.[26] When compared to the CEC groundwater energy intensity range, JVWCD's was slightly higher. Much cheaper energy costs for surface water likely explain the higher energy costs

[26] EPRI (2002). "Water & Sustainability (Volume 4): U.S. Electricity Consumption for Water Supply & Treatment – The Next Half Century." *Electric Power Research Institute*, Palo Alto, Ca.

associated with pumping groundwater for the case study. The proportions of surface water to groundwater deliveries vary with climatic conditions, such as surface water availability, precipitation received, and how hot and dry the summer tends to be for a given year. Energy rates and groundwater availability (as well as aquifer yield safety margins) are assumed to also play an important role in decision-making for water managers, and these factors may become more important in the future as demand for water in the Salt Lake Valley approaches its supply.

FIGURE 16 - THE PROVO RIVER BEGINS HIGH IN THE UINTA MOUNTAINS AND IS AN IMPORTANT SOURCE OF WATER FOR MUCH OF THE WASATCH FRONT

Energy for Water Treatment and Distribution

In the case study, JVWCD's water treatment energy costs were found to be lower than the CEC's estimated range – in part because the CEC's included extensive treatment of brackish and saline groundwater. Utah's snowmelt runoff has remarkably high water quality, and groundwater from deeper aquifers also requires very little treatment to meet drinking water standards. In areas where groundwater is impaired, it can often be blended with higher-quality water from other sources to meet regulation standards. The JVWCD system has two water treatment plants, Jordan Valley Water Treatment Plant (JVWTP) and Southeast Regional Water Treatment Plant (SERWTP), with a combined design capacity of 200 million gallons per day (mgd). Actual flows through both plants averaged 68 mgd in the 2008/2009 fiscal year with a maximum flow of

166 mgd. Retail water providers also have small-scale chlorination facilities to disinfect water within their systems, but these are usually tied to a distribution system feature such as a booster station or a groundwater well house. This makes small-scale treatment and disinfection energy costs difficult to determine. Nonetheless, Utah's naturally high water quality and efficient operation of water treatment facilities results in water treatment energy costs that are comparatively low.

A reduced energy intensity range for distribution systems was also a reflection of the efficiency of regional gravity-fed systems. JVWCD's distribution system is comprised of booster stations, metering vaults, pressure reduction valves and cathodic protection. Almost all facilities in this category are minimally energy intensive within the JVWCD system. The main exceptions are booster stations along the network that lift or pressurize water. The average dynamic lift of a JVWCD booster station is almost 270 feet.[27]

Energy for Water in the End-Use Phase

Gathering end-use energy requirement data was not included in the JVWCD case study. Its focus was to estimate how much energy was required to deliver and remove water to and from consumers. Because of the nature of end-use water consumption, it is extremely difficult to estimate how much energy is used in a consumer's home or a commercial site dedicated strictly to water-related activities. To estimate energy use in this sector, the CEC segregated utility data into percentages of energy usage in the home for water-related activities (mostly energy used to heat water) and, based on these estimates, extrapolated end-use energy usage to be approximately 73 percent of the total energy used throughout the cycle. This proportion is later applied in this report for end-use energy in Utah, to provide a rough preliminary picture of total water-related energy requirement.

Even though end-use was not included in this particular study, research conducted on this topic suggests that the greatest energy efficiency gains to be made in many locations are found with reductions in water demand itself. Using a case study site in Melbourne, Australia, Flower et al. found that, with a combination of structural and non-structural demand management strategies, individual household water consumption could be reduced by 65 percent and greenhouse gas emissions by 63 percent.[28] The water conserved had energy-saving effects from the end-user phase throughout the entire water supply and consumption cycle. They proposed that, with carefully targeted demand reduction programs, the environmental and economic benefits would not only be seen by consumers, but by water agencies that would be able to delay costly water development and treatment. Interestingly, after reviewing the costs of their water and energy efficiency programs, the CEC

[27] JVWCD (2009). "Summary of Operations 2008 – 2009." *Jordan Valley Water Conservancy District*, West Jordan, Ut.

[28] Flower, D.J.M., Mitchell, V.G., Codner, G.P. (2007). "The potential of water demand management strategies to reduce the greenhouse gas emissions associated with urban water systems." *Proceedings of the Combined International Conference of Computing and Control for the Water Industry, CCWI2007 and Sustainable Urban Water Management, SUWM2007*, Leicester, U.K., 593-600.

also estimated that it would be possible to meet 95 percent of their energy efficiency goals indirectly through less expensive water efficiency programs, emphasizing the gains to be made in the end-use phase, especially for California.[29,30]

FIGURE 17 - END-USE REQUIRES MORE ENERGY THAN ANY OTHER PHASE AND WAS NOT INCLUDED IN THIS STUDY

Energy for Wastewater Treatment

Wastewater treatment was the second most energy intensive phase of the water cycle presented by the case study. It required between 450 and 875 kWh/ac-ft depending on the wastewater facility in question. The energy intensity range generated from the case study was calculated using the average energy use/ac-ft of the two wastewater facilities, weighted by the proportion of member agencies that sent effluent to each. Because they receive inflows from municipalities outside the case study, the inflows to the plants from case study agencies were estimated based on the water supplied to each member agency, multiplied by an indoor depletion rate of 15 percent.[31] The depletion is the amount of water used consumptively indoors during the end-use phase by municipal users, which includes both residential depletion and industrial depletion. The remaining water received by collection systems is then conveyed to wastewater treatment plants.

[29] California Energy Commission (2005). "California's Water-Energy Relationship." *California Energy Commission*, Sacramento, Ca.
[30] Alliance for Water Efficiency (2008). "Transforming Water: Water Efficiency as Stimulus and Long-Term Investment." *Alliance for Water Efficiency*, Chicago, Il.
[31] Utah Division of Water Resources (2009). "Municipal and Industrial Water Supply and Uses in the Jordan River Basin." *Utah Division of Water Resources*, Salt Lake City, Ut.

Both wastewater treatment plants in the case study are state-of-the-art facilities with advanced treatment technologies, and both are large enough to take advantage of the efficiencies present in economies of scale. Central Valley Water Reclamation Facility (CVWRF) has an additional energy recovery step in an anaerobic digestion process. Methane gas released from waste effluent is mixed with natural gas to power five engine generators at the plant. This additional energy recovery supplies extra energy to the plant, thereby cutting

FIGURE 18 - WASTEWATER TREATMENT IN UTAH IS GENERALLY LESS ENERGY INTENSIVE, BUT IS LIKELY TO INCREASE WITH HIGHER WATER QUALITY STANDARDS

back on the plant's utility costs.[32] The second plant, South Valley Water Reclamation Facility (SVWRF), has a lesser capacity and requires greater amounts of energy than its northern counterpart. A bio-reactive aeration phase is the largest consumer of energy on site, followed by solids drying and disinfection. SVWRF also has an additional nitrification phase that is more energy intensive.[33]

Personal communications with both plant managers indicated that increased water quality standards are at the forefront of their concerns. They anticipate more stringent effluent treatment standards in the very near future and foresee the necessity of updating plant infrastructure to meet them. CVWRF managers indicated

[32] Fisher, R., Holstrom, T., Day, R. (2009). Personal interview. 21 Oct. 2009.
[33] Hedges, H. (2009). Personal interview. 9 Nov. 2009.

that they had additional space to install treatment facilities, but that the capital and energy costs would be much higher to remove phosphorus and other micro-pollutants. SVWRF already has the ability to treat for removal of some nutrients, but lacks significant additional space if new facility buildings become necessary.

Using Case Study Data for the State of Utah

One final benefit of having localized energy intensities in hand is the ability to estimate energy usage on a regional scale, not just into the future. For example, extrapolating the JVWCD energy intensities on a statewide scale, suggests that Utah's water-related energy usage is lower than California's estimate of 19 percent. Given recent data from the U.S. Geological Survey for surface water withdrawals, groundwater withdrawals and public water supply, Utah uses approximately 7 percent of its total energy budget (not including transportation sector energy consumption) to provide water to its citizens and for end-use water activities, as presented in Table 2.

TABLE 2 - PERCENTAGE OF UTAH'S ENERGY CONSUMPTION USED FOR WATER-RELATED ACTIVITIES

	Water (ac-ft/yr)	Energy Intensity (kWh/ac-ft)	Energy Used MWh/year
Source & Conveyance			
Surface Water/Springs[1]	4,659,200	100	465,920
Groundwater[1]	1,069,600	950	1,016,120
Recycled Water[2]	8,512	10	85
Water Treatment[3]	679,840	50	33,992
Water Distributed[4]	4,869,480	220	1,071,286
End-Use[5]			8,245,469
Wastewater Treatment[6]	543,872	850	462,291
Total Non-Transportation Water-Related Energy Use in Utah			11,295,163
		Million BTU	**MWh**
Total Non-Transportation Energy Consumption in Utah[7]		561,000,000	164,429,100
% of Utah's Energy Budget for Water			**6.9%**

[1] U.S. Geological Survey (2009). "Estimated Use of Water in the United States in 2005: Table 1. Total water withdrawals by source and State, 2005."

[2] Utah Division of Water Resources (2005). "Water Reuse in Utah."

[3] U.S. Geological Survey (2009). "Estimated Use of Water in the United States in 2005: Table 2. Public-supply water withdrawals, 2005."

[4] Estimated percentage of total withdrawals entering a distribution system of 85%.

[5] CEC (2006). Applied CEC's estimate of 73% of water energy-use "Within the Retail Meter" for end-use category

[6] Estimated indoor depletion of treated water/public water supply of 20%

[7] Utah Geological Survey (2009). "Energy Consumption and Expenditures in Utah, 1960 - 2008." and "Energy Consumption in Utah by End Use (Trillion Btu), 1960 - 2008."

This is substantially less than the energy use reported elsewhere and reflects the natural geographic advantages discussed earlier. Acquiring utility data from more water systems over a period of years would likely generate a more geographically and climatically refined energy intensity dataset, which would further educate managers as to what critical features of a water system contribute the most to energy use. Continued investigation of end-use phase energy data would also help clarify the water-energy requirement in Utah.

Energy Use for Water Supply & Treatment in Rural Utah

Rural Water Supply

Approximately 80% of the total water withdrawn in Utah is for agricultural irrigation. Of that water, almost 88% is surface water and the other 12% is groundwater. Since much of the surface water is gravity-fed, groundwater pumping comprises the bulk of the energy used for water supply in some parts of Utah. The amount of energy needed to pull water from a deep aquifer can be substantial. Figure 18 is a map of groundwater depths throughout the state between 1980 and 2005. Groundwater areas monitored by the United States Geological Survey (USGS) are overlaid on top of the depths. The USGS also reports how much water they estimate has been withdrawn annually for each area. By extracting the mean and the maximum water depths within each monitored region and multiplying it by an appropriate energy factor, it is possible to estimate the spatial extent and magnitude of the energy required for groundwater withdrawals. Table 3 lists the mean depths for each region and the estimated energy required. It also contains a 'Map ID' number that corresponds to the regions numbers on a map of groundwater depths presented in Figure 19.

TABLE 3 - GROUNDWATER ENERGY USE IN UTAH

Map ID	Basin Name	Mean Depth to Groundwater (Feet)	Estimated Energy Intensity - Mean Depth (kWh/ac-ft)	2010 Groundwater Withdrawals (ac-ft)	Energy Required (GWh)
10	Salt Lake Valley	122	590	140,000	82.6
16	Utah Lake/Goshen	97	570	109,000	62.1
9	East Shore Area	78	560	90,000	50.4
3	Curlew Valley	100	570	43,000	24.5
5	Cache Valley	77	560	62,000	34.7
21	Juab Valley	91	570	39,000	22.2
12	Tooele Valley	173	620	38,000	23.6
33	Beryl-Enterprise	69	550	33,000	18.2
26	Milford Area	69	550	34,000	18.7
32	Cedar Valley	110	580	22,000	12.8
31	Parowan Valley	62	550	29,000	16.0
34	Central Virgin River	411	830	24,000	19.9
24	Sevier Desert	84	560	46,000	25.8
23	Pahvant Valley	226	670	106,000	71.0
22	Central Sevier Valley	67	550	26,000	14.3
	Other Areas	138	600	134,000	80.4
	Total			**975,000**	**577**

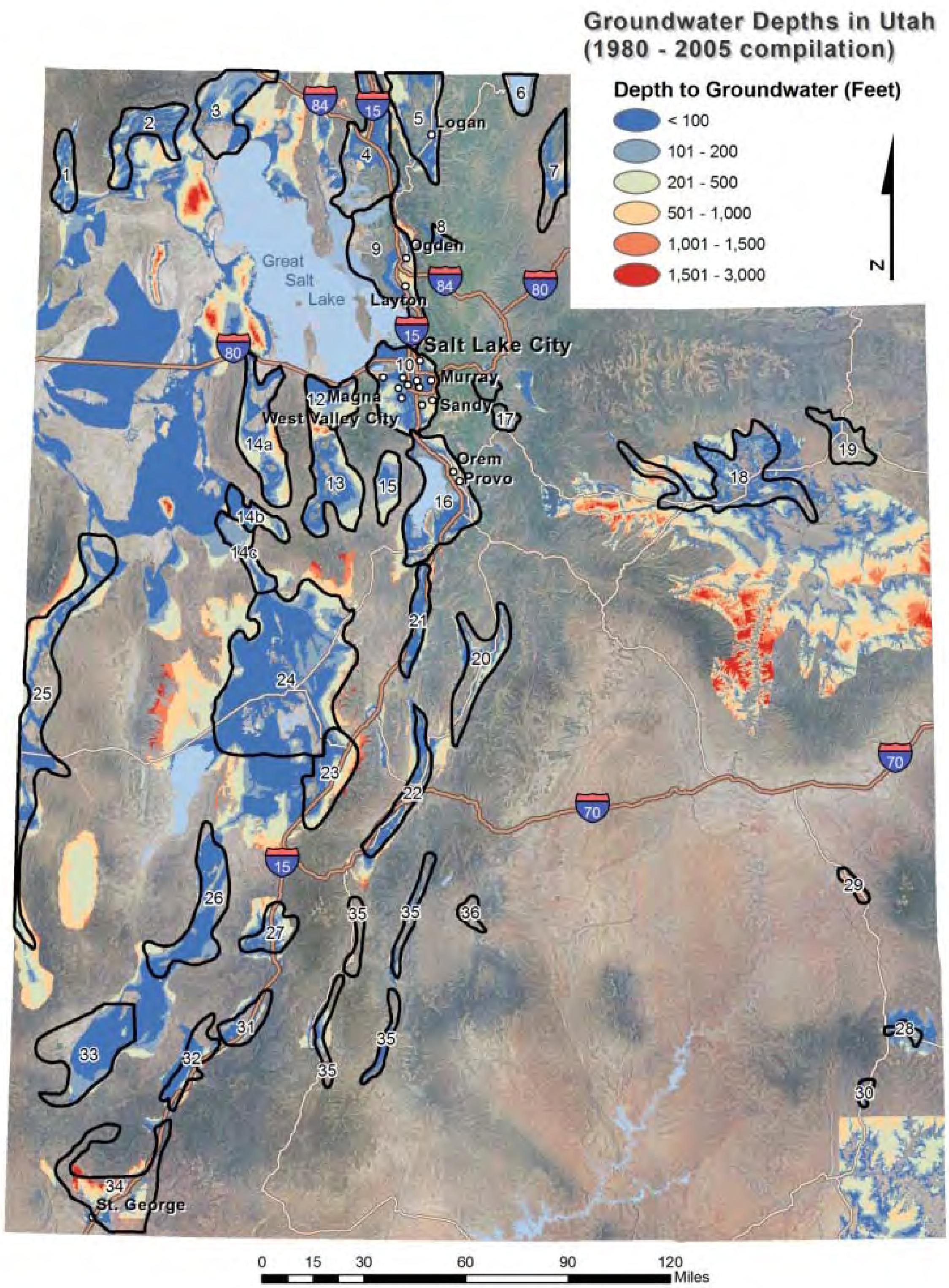
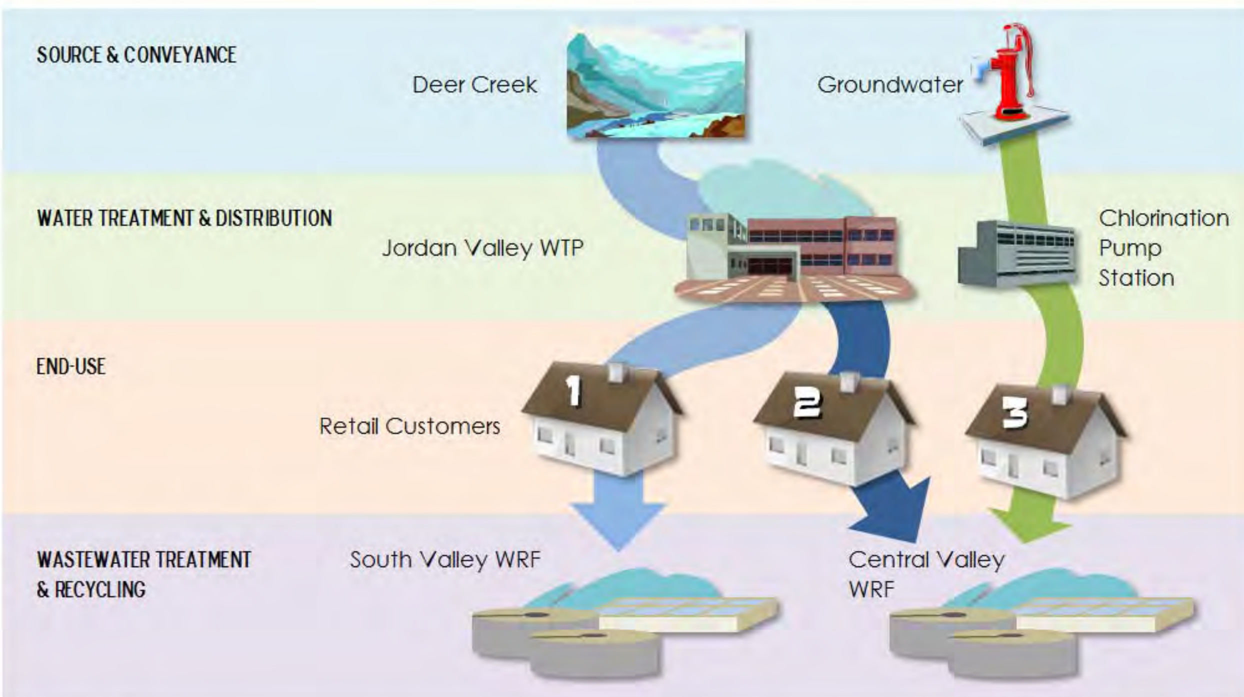


FIGURE 19 - COMPILATION OF GROUNDWATER DEPTHS AND MONITORED AREAS IN UTAH

Jordan Valley Water Conservancy District – Energy for 295 Gallons of Water

After the JVWCD case study provided estimates for energy intensities for its system, operators wanted to help assist their member agencies and customers understand the concepts of water-related energy usage and also to show how much water conservation reduce their costs and environmental impact. Using the energy intensities from the case study, 295 gallons per capita per day water use in Utah in the year 2000, were traced from Deer Creek Dam through the water cycle to final treatment. The results show that the energy necessary to provide water varies greatly with the customer's supply path. Paths that employ groundwater or advanced treatment methods such as those used at SVWRF are more energy-intensive, but they also respond the most to water conservation efforts. Just for reference, if you use a 1,000 watt appliance, such as a window air conditioner, for one hour, that is one kilowatt hour.



Water Trace Paths	Energy Used Annually	Energy Saved with 25% Less Water
1. JVWCD --> Member Agency 1 --> Customer --> SVWRF	about 1,150 kWh	about 165 kWh
2. JVWCD --> Member Agency 2 --> Customer --> CVWRF	about 1,020 kWh	about 200 kWh
3. Member Agency 3 Groundwater --> Customer --> CVWRF	about 1,500 kWh	about 300 kWh

Rural Wastewater Treatment

Wastewater treatment was the second most energy intensive and costly phase of the water supply and consumption cycle presented in the JVWCD urban case study. In rural areas around the state of Utah (excluding the Wasatch Front Ogden – Salt Lake – Provo corridor) there are close to 340 wastewater treatment facilities. Most of these consist of plants that operate simple trickling filter and sewage lagoon processes. Return flows to wastewater treatment plants vary such that it is tremendously difficult to estimate how much is treated without acquiring inflow data from each facility.

Energy Usage Related to Future Water, Demand, Supply & Wastewater Regulations in Utah.

Water Demand Reductions

With estimates for two components – the baseline energy usage for a water system and its energy intensities – projections about energy by water supply phase and by individual components can be made. For example, if an agency or municipality is successful with a water conservation program, all phases of the water cycle that are sensitive to the volume of flows are likely to be reduced. Using this assumption, energy savings possible through water conservation programs can be better quantified. In the case of the JVWCD system, a predicted demand reduction of 25 percent, producing a corresponding demand reduction from the most energy-intensive source of water (that of groundwater pumping), was predicted to save 28 percent of energy from their "business as usual" scenario.

Secondary benefits of such a major reduction include significant utility savings for JVWCD, fewer greenhouse gas emissions and other harmful particulates, and delayed capital improvement costs. Interestingly, after the states' "Slow the Flow" water conservation program began in 2000, in 2010 JVWCD operators have seen an approximately 24 percent reduction in gpcd water demand.[34] JVWCD estimates that the success of its water conservation program thus far has resulted in not only reduced utility costs, but resulted in millions of dollars of savings in delayed capital improvement projects and avoided water treatment costs.

[34] Utah Governor's Water Conservation Team, (2011). "Year End Per Capita Water Use Compared to Salt Lake County Net ET, 2000-2010." Utah Division of Water Resources, Salt Lake City, Ut., 2011.

Agricultural Transfers to Municipal & Industrial Applications

Eighty percent of the water used in Utah is currently allocated to the agricultural sector – most of it taken from surface water sources. At least some of Utah's future municipal and industrial water demand is likely to be met with a transfer from one application to the other. Since this surface storage has already been developed and conveyed to a point of use, an assumption can be made that the bulk of increased energy costs from such a transfer would be from additional treatment to meet drinking water standards, end-use and wastewater treatment. JVWCD delivers about 30,000 ac-ft of agricultural water annually that may at some time in the future be assessed for a possible transfer. Using their baseline energy costs and energy intensity, it was estimated that energy use would increase by 20 percent to transfer that volume of water. Of course, the energy required could increase substantially depending on the quality of the water transferred or if another water treatment facility needed to be built for the new supply. For example, if the water is brackish, reverse osmosis may be required to treat the water to drinking water standards. The same volume of water could require up to 5,000 kWh/ac-ft., as opposed to the case study's much lower estimate of 100 kWh/ac-ft.

FIGURE 20 - MOST OF UTAH'S WATER WITHDRAWALS ARE FOR AGRICULTURE

Reductions in Surface Storage Water Supply

Groundwater is one of Utah's more expensive sources of water, and it is used most by municipal and retail water systems when less expensive surface water isn't available. "Drawdown" within a groundwater aquifer demonstrates a fundamental hydraulic principle. When groundwater is withdrawn faster than the natural system can replenish it, the water level drops and even greater amounts of energy are required to pump water to the surface. When periods of greater demand coincide with drier years or drought, this condition is exacerbated. During such periods, groundwater sources may be used to compensate and in effect, create a "lose-lose" feedback loop, wherein the resource is depleted and the energy to retrieve it also rises.

If it is assumed that reduced surface storage availability results in added groundwater withdrawals, JVWCD's baseline energy and energy intensities can be used to project the additional energy cost of groundwater compensation. The model used for the urban case study identified a historic pattern of groundwater withdrawal vs. surface water availability specifically for the JVWCD system during both severe drought years and normal years of precipitation (2000 - 2008) to estimate future groundwater withdrawals. For the JVWCD system, a 35 percent reduction in the availability of surface water is estimated to require an 18 percent increase (primarily from added groundwater pumping costs) in energy requirement from their current usage.

Also of note is that reductions in reservoir storage with hydroelectric power generation facilities can adversely impact energy production. Only a small percentage of Utah's energy production comes from renewable sources, but the bulk of that is from hydroelectric power plants. Reduced storage would result in a decline in available "clean" hydroelectricity, which may have to be compensated for with traditional fossil-fuel based sources, further increasing greenhouse gas emissions. Water quality of reservoir storage is also adversely impacted by sediment loading, reduced streamflow and warmer water temperatures.

FIGURE 21 - SURFACE STORAGE FLUCTUATES WITH DROUGHT, SEDIMENTATION AND REDUCED PRECIPITATION

Increased Water Quality Regulations

Water treatment and wastewater treatment are two of the most energy intensive phases within the water supply and consumption cycle. Only a portion of the water of a particular source may need to be treated to drinking water standards. Water used for agricultural purposes or within a secondary system (untreated water designated for residential and commercial landscape irrigation) has minimal or no water treatment energy costs. However, many water suppliers suggest that some of their future water supply will be found by converting agricultural water to municipal and industrial uses.[35] The additional energy cost required to treat agricultural/secondary water is usually low, but can become expensive if the water is heavily contaminated or brackish. For this reason one of the main concerns for water treatment plant operators is that of new and more stringent water quality standards. Energy costs for water treatment rose in the mid-1990s in response to new environmental regulations as mandated in the Clean Water Act (CWA).[36] These regulations placed new restrictions on pollutants that were previously unregulated and also required reductions in disinfection byproducts. To meet those new standards and for safety reasons, more water suppliers explored alternative water treatment technologies such as ozonation and ultraviolet light disinfection. These methods of treatment require more energy than traditional flocculation, settling and chlorination disinfection processes.[37]

Similarly, wastewater treatment facilities are currently meeting discharge water quality standards, but there is growing evidence that the nutrient loads in wastewater can be damaging to the environment. Wastewater treatment facility managers are concerned about more aggressive nutrient removal regulations, possibly necessitating additional infrastructure and energy costs. It has been estimated that advanced wastewater treatment with additional nitrogen removal can triple energy costs compared to simpler treatment methods like trickling filtration.[38] Alternate disinfection methods of treatment such as ozonation and ultraviolet light disinfection are more energy-intensive than traditional chlorination. Endocrine disrupting compounds (EDCs) and other micro-pollutants are of concern for human and ecosystem health, would likely increase required treatment energy substantially and are under review for inclusion in water quality standards.[39] Pilot projects exploring EDC removal, such as granular activated carbon, ozone, membrane filtration and reverse osmosis, are underway in the U.S., the European Union (E.U.) and the United Kingdom (U.K.).[40,41] These methods of water purification are used for drinking water treatment already, but may be environmentally and fiscally undesirable for large-scale wastewater application due to their high energy costs and related emissions.[42] More aggressive contaminant removal is presumed to benefit the aquatic systems within the receiving body of water and the environment as a whole, but a corresponding higher energy demand and greater emissions should be considered as well. The consensus among wastewater industry professionals is not if more regulation

[35] Utah Division of Water Resources (2004). "Utah's Water Resources: Planning for the Future." *Utah Division of Water Resources*, Salt Lake City, Ut.
[36] Neukruq, H., Burlingame, G., Wankoff, W., Pickel, M. (1995). "Water-quality regs: staying ahead." *Civil Engineering*, 65(1), 66-69.
[37] Douglas, J. (1993). "Electrotechnologies for water treatment." *EPRI Journal*, 18(2), 4-13.
[38] EPRI (2002). "Water & Sustainability (Volume 4): U.S. Electricity Consumption for Water Supply & Treatment – The Next Half Century." *Electric Power Research Institute*, Palo Alto, Ca.
[39] Ternes, T. (2007). "The occurrence of micropollutants in the aquatic environment: a new challenge for water management." *Water Science & Technology*, *55*(12), 327-332.
[40] Benotti, M.J., et al. (2009). "Pharmaceuticals and Endocrine Disrupting Compounds in U.S. Drinking Water." *Environmental Science & Technology*, 43(3), 597-603.
[41] Clara, M., et al. (2005). "Removal of selected pharmaceuticals, fragrances and endocrine disrupting compounds in a membrane bioreactor and conventional wastewater treatment plants." *Water Research*, 39(2005), 4797-4807.
[42] Jones, O.A.H., et al. (2007). "Questioning the Excessive Use of Advanced Treatment to Remove Organic Micropollutants from Wastewater." *Environmental Science & Technology*, 41(14), 5085-5089.

will be enacted, but simply a matter of when and how much. Whatever additional water quality regulations are put in place will likely affect the industry in a broad fashion and require more infrastructure and energy. The impacts and financial cost of treating water to more stringent standards, especially with the possible inclusion of micro-pollutant removal, are not well understood but are likely to increase substantially.

3 | WATER FOR ENERGY

Energy Production in Utah

Utahns enjoy a high quality of life thanks in part to the abundance of energy producing resources in the state. These resources allow the state's residents to heat, cool and light their homes, at an extremely competitive cost relative to the rest of the nation. It has become a fundamental resource upon which our activity and economy is based. Utah ranks 36th in the nation for energy consumption, at 293 million British thermal units (Btu) per capita annually – less than the national average of 327 million Btu per capita. However, when reviewing Utah's "carbon footprint" per capita, it is the 14th highest in the nation because so much of the energy produced in-state is derived from coal and exported.[43,44]

FIGURE 22 - COAL-FIRED, THERMOELECTRIC POWER PLANTS PROVIDE THE MAJORITY OF ELECTRICITY FOR UTAHNS

[43] U.S. Energy Information Administration, (2009). "Table R2. Energy Consumption by Source and Total Consumption per Capita, Ranked by State, 2008." http://www.eia.doe.gov/emeu/states/sep_sum/plain_html/rank_use_per_cap.html.
[44] Eredux, (2010). "Utah Energy Portal: Utah's Carbon Footprint." http://www.eredux.com/states/state_detail.php?id=1144.

Almost 82 percent of the energy produced in Utah is from coal, compared to only 30 percent for the rest of the U.S in 2009.[45] For this reason it is important to understand where our energy comes from, how much we produce, export and consume, and how our consumption impacts our standard of living and our environment.

Resources in Utah

Of the nation's coal energy production, about 2 percent is generated in Utah, with about two-thirds of that going to local customers. The other third is shipped via railway out of state, primarily to Nevada and California. Utah produced 24,365 short tons of coal in 2008, a small decline from previous years. Utah's coal fields currently in production are situated in Sevier, Carbon and Emery counties. Kane and Garfield counties also contain coal field reserves that could be utilized in the future. The coal not exported out of state is used by electric power plants for electricity generation, which powers the homes and activities of Utah's residents.

FIGURE 23. WIND TURBINS AT THE MOUTH OF SPANISH FORK CANYON

Utah extracted almost 2.2 million barrels of crude oil in 2008, and has a ranking of 13th in the U.S for crude oil production. Most crude oil extraction in Utah is located in the Duchesne, Uintah and San Juan counties. While Utah's proportion of U.S. oil reserves is small, known reserves have almost doubled to 334 million barrels over the past 30 years. There are five refineries in Utah that can process the oil into more refined energy sources; primarily gasoline. Currently, there is not enough oil to meet the demands of Utah refineries and Utah supplements this supply with imports of petroleum products from neighboring states and Canada. Utah also exports refined petroleum products to Washington, Oregon and Idaho.[46] In 2008 Utah refineries produced 31 million barrels of refined automobile gasoline, a little less than half of which was then exported to neighboring states. Most of the petroleum consumed in Utah is by the transportation sector. The future of oil, and unconventional oil reserves such as tar sands and oil shale, will be driven by local and global demands, availability and pricing.

[45] U.S. Energy Information Administration (2009). "State Energy Profiles: Utah." http://www.eia.doe.gov/state/state_energy_profiles.cfm?sid=UT.
[46] Utah Foundation (2008). "Utah's Energy Use & Resources: Powering our Standard of Living." *Utah Foundation*, Report 685, Salt Lake City, Ut.

Utah ranked 8th in the nation for natural gas production in 2008. That year natural gas companies extracted 433.6 billion cubic feet of gas from the Uintah and Carbon county regions. In Carbon county, natural gas is found primarily in the form of coalbed methane. Natural gas has grown significantly as an energy source over the last few decades. Newly discovered reserves of natural gas have increased the known supply by over 300 percent over the last 30 years. What was once a small proportion of Utah's energy production now comprises almost 12 percent of the total available energy produced.[47] Most homes in Utah use natural gas for heating, but local customers account for only half of Utah's natural gas usage. The remainder is delivered out of state to customers in Wyoming, Nevada, Colorado, Idaho and elsewhere. The use of natural gas for electric power generation, heating, and fuel has fewer negative environmental and health impacts because it is a cleaner burning energy source, consumes less water, and is easier to extract than more traditional fossil fuels.

Renewable energy sources comprise the smallest percentage of Utah's energy production at only 3 percent in 2009. However, this amount reflects a doubling of renewable energy production in only a few years. Compared to other states in 2009, Utah now ranks 37st in renewable energy generation with a total of 653 MW capacity. With the recent addition of a substantial wind farm in the southwestern quadrant of the state, most of Utah's renewable energy is generated by wind farms, followed by hydroelectric, geothermal and biomass. Many new facilities for renewable energy are also under investigation and the above figure is likely to increase in coming years. In March of 2008, Utah adopted a voluntary and non-binding Renewable Portfolio Standard (RPS). Utah's RPS suggests a goal to generate 20 percent of the state's energy with renewable resources by 2025.[48] In order to achieve its RPS goals, the state commissioned the Utah Renewable Energy Zone (UREZ) Task Force to identify areas within the state of Utah that would be ideal for renewable energy generation, estimate the amount of energy that could be generated from new solar, wind and geothermal sources, and identify existing and new transmission routes for this energy. After reviewing over 13,000 square miles of Utah's geography, the UREZ Task Force found 837 gigawatts (GW) of potential renewable energy generation capacity, through a combination of new solar, geothermal and wind installations.[49]

Unconventional fuel sources in Utah include extensive oil shale deposits over the Uinta Basin area and tar sands located in the Uintah, Emery, Carbon and Garfield counties. These reserves are estimated to contain approximately 105 billion barrels of shale and tar sand oil. The Rand Corporation estimated that oil shale and tar sands could become a competitive energy source when the price of petroleum reaches $75 to $90

[47] Vanden Berg, Michael, D. (2009). "Utah's Energy Landscape." *Public Information Series 95: Utah Geological Survey*, Salt Lake City, Ut.
[48] U.S. Energy Information Administration (2009). "State Energy Profiles: Utah." http://www.eia.doe.gov/state/state_energy_profiles.cfm?sid=UT.
[49] Berry, Jason, et al. (2009). "Utah Renewable Energy Zones Taskforce Phase I Report: Renewable Energy Zone Resource Identification." *Miscellaneous Publication 09-1: Utah Geological Survey*, Salt Lake City, Ut.

dollars per barrel.[50] If the price of petroleum remains high, the demand for unconventional fuel sources will increase.

Water Use by Energy Production Method

All methods of energy production come with a requisite water requirement. The amount of water withdrawn and consumed by each varies greatly. The impact of energy production on water supplies throughout the United States cannot be underestimated. Figure 24 highlights the amount of water withdrawn by all sectors according to the most recent U.S. Geological Survey (USGS) report of "Estimated Use of Water in the United States in 2005."[51] Thermoelectric power generator facilities account for almost half of all water withdrawals. Most of this water is returned to the natural environment – albeit with a raised temperature change and altered water quality – where it can be used again downstream. This is considered a water diversion, as opposed to a depletion or consumption of the water. Many newer power plant facilities now use re-circulating or "closed loop" cooling, which consumes more water than its "once-through" counterparts, but requires less water be withdrawn overall. In a 2006 report commissioned by the U.S. Congress, the Department of Energy gave a broad overview of the energy sector's emerging demands on domestic water resources.[52] They estimated that if power plants continued to be built with evaporative cooling the electrical energy sector's water consumption could double from 3.3 billion gallons per day to 7.6 billion gallons per day – eventually equal to the entire country's water consumption in 1995. The DOE's report to congress also noted that several instances have occurred in recent years where energy production facilities have been delayed or shelved indefinitely due to a lack of available water supply.

Water Use: Coal, Petroleum and Natural Gas

In Utah, the majority of electricity production is by thermoelectric power plants, with coal, petroleum or natural gas as their energy source. In their publication "Estimated Use of Water in the United States in 2005," the U.S. Geological Survey estimated that Utah withdrew 62.2 million gallons per day – almost 70,000 ac-ft annually – for the "closed loop" cooling of thermoelectric power generation. When compared to other water-use sectors in Figure 25, withdrawals for agriculture largely eclipse the amount of water used for energy production, but over time the proportion for thermoelectric application is likely to increase.

[50] Bartis, James T., et al. "Oil Shale Development in the United States: Prospects and Policy Issues." *Rand Corporation*, Santa Monica, Ca.
[51] U.S. Geological Survey (2009). "Estimated Use of Water in the United States in 2005." *United States Geological Survey*, U.S. Geological Survey Circular 1344, Reston, Va.
[52] DOE (2006). "Energy Demands on Water Resources: Report to Congress on the Interdependency of Energy and Water." *United States Department of Energy*.

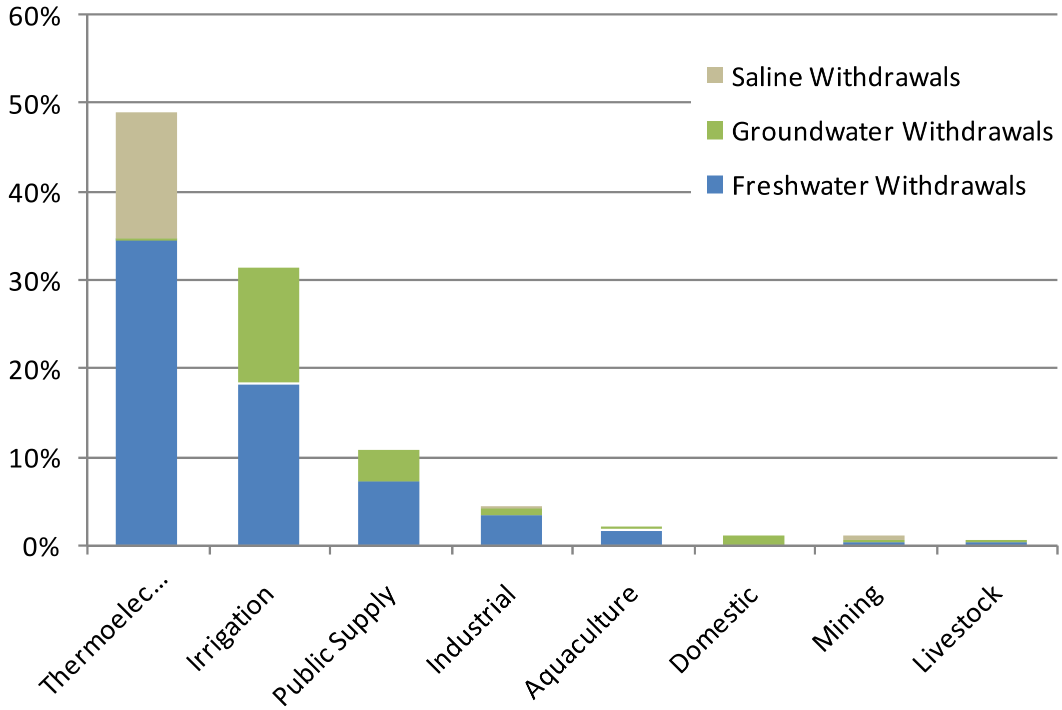


FIGURE 24 - U.S. WATER WITHDRAWALS BY SECTOR

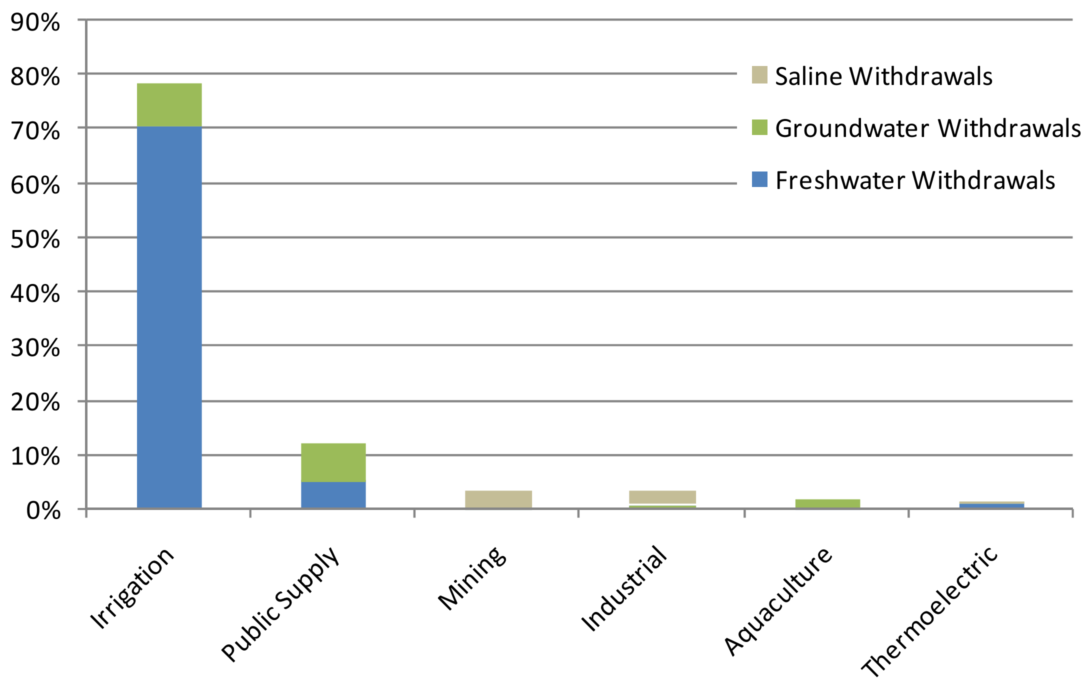


FIGURE 25 - UTAH'S WATER WITHDRAWALS BY SECTOR

Data on quantities of water needed for different kinds of electricity generation is difficult to obtain. The Utah Division of Water Rights monitors the use of industrial sector water withdrawals, but the information is proprietary. The Utah Geological Survey recently released a report that assesses some of the air quality, public health and fiscal benefits of an increased incorporation of renewable energy sources into Utah's energy portfolio and an increased emphasis on energy efficiency.[53] In the report, they also included a brief section on potential co-benefits to the water sector. Using data garnered from the Environmental Protection Agency, the Utah Division of Water Quality, and by inferring some water usage rates based on plant characteristics, they were also able to estimate the approximate water usage at the largest twenty-seven thermoelectric power plants in Utah. They broke their findings down into water volume specific energy use – specifically gallons of water used per megawatt hour (gal/MWh) produced – and found a wide range of water usage among power units, from as high as 6,761 to 0 gal/MWh. Table 4 contains the breakdown of water consumption as reported to the EPA, among the various energy units in Utah and their respective technologies employed (some values are estimated due to lack of specific data).

The higher water-consuming units incorporate water scrubbing or misting strategies to increase plant efficiency or increase pollutant removal. The lowest water-consuming plants employ air or dry-cooling techniques that used minimal amounts of water. When separated into coal and gas-fired plants, excluding those that used misting or water for extra scrubbing, the two energy resources showed a marked difference in the amount of water necessary for operation. The coal-fired plants required an average of 523 gal/MWh, while natural gas fired power plants using gas turbines and closed cycle turbines much less, between 10 and 100 gal/MWh. Figure 26 compares the water costs associated with different types of thermoelectric energy generation around the U.S., including some emerging technologies.[54,55]

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[53] Fisher, J., et al. (2010). "Co-Benefits of Energy Efficiency and Renewable Energy in Utah: Air Quality, Health and Water Benefits." *Synapse Energy Economics, Inc.,* Cambridge, Ma.
[54] U.S. Energy Information Administration, (2005). "Annual Steam-Electric Plant Operation and Design Data: EIA Form 767 Data Files." http://www.eia.doe.gov/cneaf/electricity/page/eia767.html.
[55] EPRI (2002). "Water & Sustainability (Volume 4): U.S. Electricity Consumption for Water Supply & Treatment – The Next Half Century." *Electric Power Research Institute*, Palo Alto, Ca.

	Fuel Type	Mover	Water Consumption (Gal/MWh)
1	Natural Gas	Gas Turbine	0
2			10
3			10
4			10
5			10
6			10
7			10
8			10
9			10
10			10
11			10
12		Combined Cycle Turbine	100
13			100
14			100
15		Steam Turbine	6,761
16			3,147
17			1,092
18	Coal	Steam Turbine	673
19			762
20			745
21			642
22			621
23			630
24			634
25			505
26			460

TABLE 4 - WATER CONSUMPTION BY UTAH'S POWER GENERATING UNITS

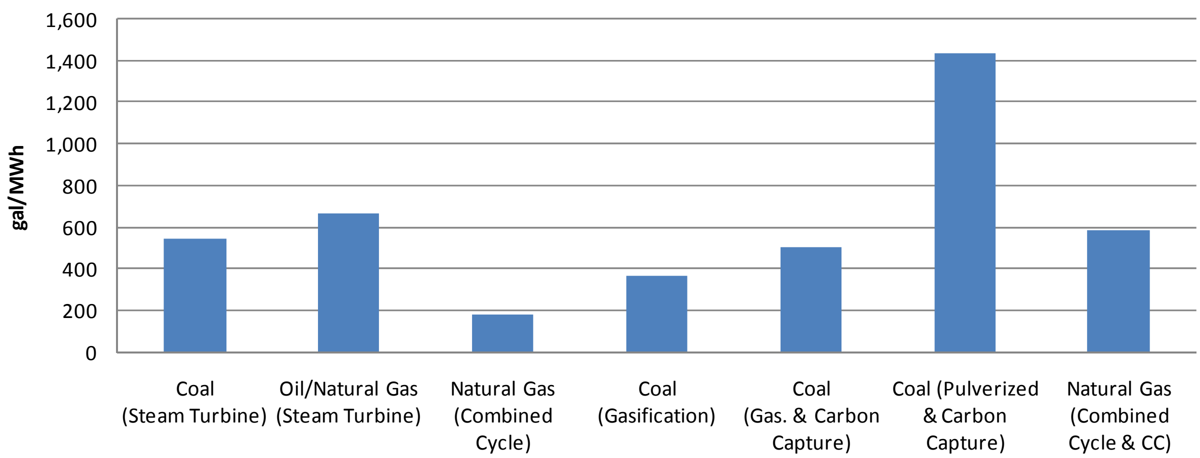

FIGURE 26 - WATER USE BY THERMOELECTRIC ENERGY PRODUCTION METHOD

Water Use: Non-traditional Energy Sources

Utah has vast deposits of oil shale, also known as marlstone, and tar sands in the Uinta Basin and Carbon, Emery, Wayne, and Garfield counties. The Utah Geological Survey recently conducted a survey of the deposits to assess how much recoverable oil could be mined from this unconventional source. They made a conservative estimate of seventy-seven billion barrels.[56] Only a handful of developers are pursuing extraction of oil shale at this time, but with increased global and local demand for oil and petroleum derivatives, mining oil shale may become more attractive to developers in the future. When oil shale development was first investigated as an energy source, it required 3 to 5 barrels of water for each barrel of oil produced. With newer technologies in recovering oil shale the amount of water required has lessened to approximately 1 – 3 barrels, making extraction much more feasible in locations where oil shale is to be found. The Department of Energy recently estimated that oil shale production efforts on a scale of 2.5 million barrels per day would require 163 to 373 mgd (180,000 to 420,000 ac-ft of water each year).[57] In the DOE's fact sheet, they specify that one of the primary sources of water for development of oil shale would likely be withdrawals from the Colorado River, transfers from other sectors, increases in water recoveries, etc. Since most of Utah's water withdrawals are made by agricultural diversions, it is assumed that transfers would need to be made to accommodate the new industry. Indeed, the Bureau of Land Management explicitly stated in an environmental impact statement on oil shale development that such transfers would likely result in a loss of traditional irrigated agriculture.

There are no nuclear facilities in Utah to date, although there are uranium mines in the southeast corner of the state. The potential for a new nuclear facility situated near the community of Green River, Utah is currently

[56] Vanden Berg, Michael, D. (2009). "Utah's Energy Landscape." *Public Information Series 95: Utah Geological Survey*, Salt Lake City, Ut.
[57] U.S. Department of Energy, (2006). "Fact Sheet: Oil Shale Water Resources." *DOE Office of Petroleum Reserves – Strategic Unconventional Fuels*, Washington D.C.

being investigated, with hearings concerning water rights allocations held at the beginning of 2010.[58] The issues with nuclear power revolve around the large amounts of water required for plant cooling processes. The plant being investigated would have a capacity of 3,000 megawatts (MW), and has been approved by the State Engineer to consumptively use 53,600 ac-ft of water from the Green River.

Utah's Renewables: Wind, Hydropower, Geothermal, Biogas and Solar

Utah has not yet begun to take full advantage of its renewable energy resources. The state is currently ranked 37th in the U.S. for total renewable net energy generation capacity when compared to the latest available renewable energy data of other states. Its existing renewable energy portfolio consists largely of wind and hydroelectric power, primarily from a new wind farm in Milford, UT. and a handful of other installations, and from Flaming Gorge. This is followed by geothermal and biomass energy production. Figure 27 shows the changing proportion of each for 2005 – 2009, but does not include the latest new renewable energy sources.[59]

Hydroelectric power is emission free during the operational stages of its life-cycle, can generate large amounts of energy during periods of high flows and high reservoir storage, and consumes no water in the traditional sense. However, there are environmental concerns with the installation of reservoir storage and the impact of the newly impounded water to both upstream and downstream habitats. There can be impacts on wildlife and to the native biota. Even with these impacts, reservoirs and hydropower facilities are emission-free during their operational phase and can mitigate the potential impacts of climate change, or changes in precipitation and runoff by providing additional storage. Interestingly, the Utah Renewable Energy Zone (UREZ) Task Force did not include hydropower installations or micro-hydropower as potential renewable energy sources in their analysis, considering only new sites for solar, wind and geothermal installations.

Utah is home to two of only a handful of geothermal facilities operating in the U.S., with a current total capacity of 48 MW of energy generation. The UREZ Task Force identified an additional 745 MW of potential energy from identified geothermal sites, with an estimated 1,413 MW from future as-yet undiscovered geothermal sites. The water requirements for geothermal energy production vary depending on the technique used (wet or dry cooling) at the facility, but is estimated to be somewhere between 0-1,700 gal/MWh.[60] If the remaining identified 745 MW of geothermal sites in Utah are developed using a hybrid technology mid-range estimate of 800 gallons per MWh, about 16,000 ac-ft of water would be required. Most geothermal plants in the U.S. typically function with a binary cooling system, but are moving toward air-

[58] Fays, Judy, (2010). "Green River nuclear plant announces major funding source." *Salt Lake Tribune*, June 30, 2010.
[59] Vanden Berg, Michael, D. (2009). "Utah's Energy Landscape." *Public Information Series 95: Utah Geological Survey*, Salt Lake City, Ut.
[60] Clark, C.E., et al., (2010). "Water Use in the Development and Operation of Geothermal Power Plants – Draft." *Argonne National Laboratory: Energy Sciences Division*, Chicago, Il.

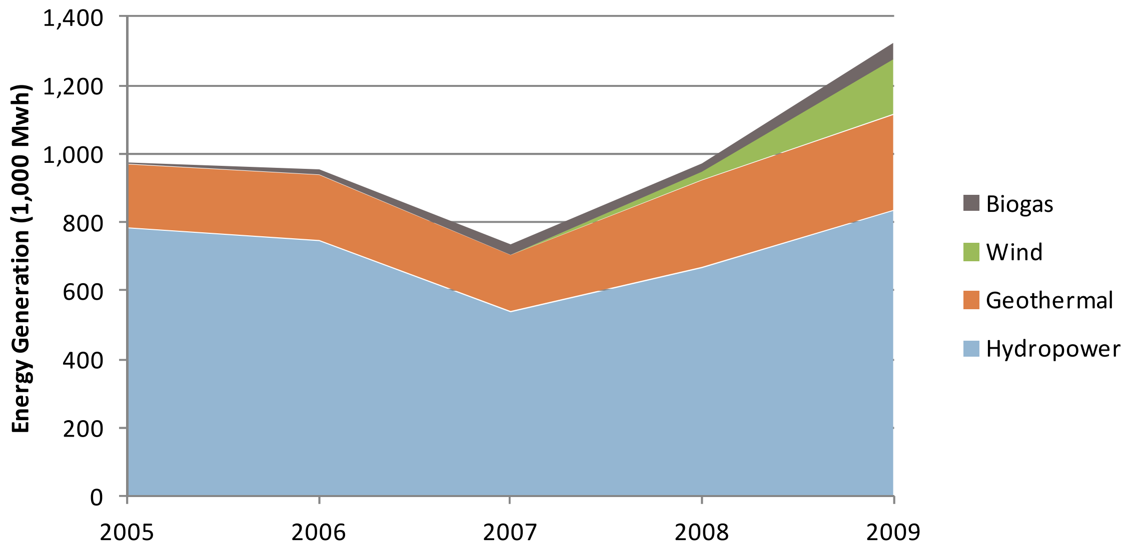

FIGURE 27 - RENEWABLE ENERGY PRODUCTION IN UTAH

cooling technologies. This suggests that lesser quantities of water may be needed as technologies surrounding geothermal power production improve. Also, geothermal operations do not require water that is treated to drinking water standards and can take advantage of brackish or saline water sources.

Utah has only two small solar arrays at this time. A 100 kilowatt array located in St. George and another 50 kilowatt array located at Natural Bridges National Monument west of Blanding. Despite this, solar power resources have vast potential in Utah, as identified by the UREZ Task Force. They found 6,731 square miles of land that, under their available criterion, were optimal areas for solar power generation, with a total possible capacity of 837 gigawatts (GW) using 50 MW plants, with concentrating solar power (CSP) troughs. In addition, the BLM is currently analyzing BLM lands within the state that have solar potential. However, this assumes that there is water available for the solar farms. CSP can have a significant water footprint on par with thermoelectric power production if wet cooling technology is used. On the other hand, photovoltaic solar technology minimizes water use. Depending on how the proposed 837 GW were developed, it would require between small volumes of water up to thousands of ac-ft each year varying with the technology used. Based on the local water supply available, it would appear that CSP may be limited or that photovoltaic solar technology may be preferable.

Wind facilities have also increased in Utah, with power production initiated in 2009 totaling 347 MW. As mentioned, a new facility in Milford, Ut. has increased this number substantially, adding another 306 MW of power capacity, for a total of 653 MW. The UREZ Task Force identified an additional 9,145 MW of potential wind development across the state. The water footprint of wind power is negligible and is used primarily for materials and construction, not during the operational lifetime of the facility. This method of energy production has no operational emissions and also no water requirement, which makes it an excellent alternative especially in water scarce regions.

Potential Impacts on Energy Production

Decreasing Water Availability

The arid Southwest's populations are growing, indeed with some of the highest growth rates in the nation. An abundance of natural resources, clean air and water, and the low cost of living and doing business, will host growing families and continue to attract new residents. It is likely that as the west's population grows, water (now fully allocated in some states) will continue to be developed and will also shift from lower value markets to those of higher value. An example cited earlier would be a transfer of water from agricultural activities to energy production or commercial and domestic uses. In tandem with new water development, water rights changes and reallocations, the actual amount of water available varies from year to year. The drought experienced in Utah from 1999 to 2004 underscored the importance of being able to capture and store runoff from precipitation, but even longer droughts are predicted by climate scientists. If these predictions prove accurate, water may become more of a limiting resource. As only a small percentage of water is currently withdrawn for thermoelectric power generation in Utah, a decrease in available supply is unlikely to impair energy production, but may require more immediate transfers from lower market applications.

Energy Policy and Legislation

The enactment of substantial policy or legislation concerning energy demand, production and carbon dioxide emission reductions could have extended impacts on the energy sector. Policy groups and statements, such as the Western Governors' Association, the Western States Water Council, and Utah's adoption of a Renewable Portfolio Standard (RPS) can lend support to some energy production methods and emerging technologies that would otherwise remain on the sidelines. For example, the RPS adopted by Utah would effectively foster a broader range of energy choices for Utahns. In the Utah Geological Survey's "Co-Benefits of Energy Efficiency and Renewable Energy in Utah: Air Quality, Health and Water Benefits," the authors described substantial economic and environmental benefits to be gained by an increased incorporation of renewable energy sources, including better air quality, public health, and water savings. Encouraging water and energy efficiency and conservation remains one of the most obvious, least expensive and most effective policy tools to achieve energy/water savings and also to accommodate future growth. These types of initiatives tend to encourage consumers to 'do the right thing' while having minimal negative impacts on the economic sectors that provide such resources and services.

Recently more aggressive policy tools are being proposed at a national level that may have a significant impact on the energy and water sectors if passed through both houses of the U.S. Congress. Legislation that proposes to impose a cap on the amount of carbon dioxide an industry can emit would likely result in substantially increased costs for both electricity producers and also for energy consumers. In some proposed legislation, larger emitters would be required to reduce their carbon dioxide emissions to certain levels and/or be allowed to purchase or trade carbon dioxide offsets. However, this pre-supposes that these offsets would be available. In Utah, potential carbon offsets have not been developed on a scale that would make a measurable difference to large fossil-fuel based energy producers in the region. As an example, Pacificorp sponsored a study, conducted by EPRI, of the effects of the Waxman-Markey Bill – a carbon cap-and-trade bill that passed through the House of Representatives in 2009 – on the costs of providing energy to the Rocky Mountain region.[61] They found that, were offsets unavailable for purchase, the price of providing energy would increase substantially for a typical commercial or residential customer. Secondary impacts from such an increased cost would be seen in all economic sectors, including water markets.

Improvements in Technology

It is reasonable to assume that improvements to energy generation technologies will be made that make it more efficient, safer, cleaner and less expensive to provide. Current avenues of research include new ways of treating coal to minimize polluting impacts and waste, carbon sequestration techniques for mitigating greenhouse gas emissions, bio-fuels, in-situ techniques for oil shale development, geothermal hybrid technologies, and solar charging membranes, among many others. What impacts these technologies may have on water requirement remains to be seen. When coal-fired power plant emissions began to be 'scrubbed' by steam and water, they became much less damaging to the environment, but the water required for the additional step was substantial. Such trade-offs may have to be made to navigate a new path to a more sustainable energy and water future. Finding new sources of each resource, such as using recycled water for nuclear power cooling or using photo-voltaic solar power, that break the co-dependencies of the relationship between water and energy may help with this task.

[61] Niemeyer, V., et al., (2010). "Preliminary Analysis of Waxman-Markey (H.R. 2454) Using NEMS for Pacificorp." *Electric Power Research Institute*, Palo Alto, Ca.

4 | CONCLUSION

Utah will need to confront new challenges on the horizon concerning its water and energy resources. An abundance of both resources and inexpensive pricing has led to a relaxed attitude about water and energy use. New ways of thinking about energy and water will be needed to meet future demands for both. Research conducted concerning Utah's energy used for water provision reveal that its topography and proximity to mountains provide many benefits in terms of water quantity, storage, quality and distribution. These benefits have made Utah's water an inexpensive resource in the past, but costs are likely to increase in the future. When using estimated energy values to evaluate usage on a statewide scale, energy costs used for water-related services comprised about 7% of the state's total non-transportation energy budget. On the other end of the water/energy equation, Utah's use of water for energy production is relatively small when compared to other withdrawals and uses, but is predicted to grow as more energy sources are explored and developed. Different energy sources have varied water requirements, which highlight the importance of incorporating water use into the energy planning process as a possible constraint. Below are some recommendations that would facilitate the cooperative and adaptive management of these vital resources and help Utah track a more sustainable future.

Recommendations

Integration of Resource Planning and Management

Traditionally, from the lowest level of governance to that of federal regulation and oversight, water and energy resources have been managed separately, with very little overlap between the two domains. Often water use is not considered in energy research, development programs and initiatives. An example of this is a push toward bio-fuel production during the last decade. Bio-fuels are an alternative to tradition fossil fuel-based energy production, but also require vast quantities of water.[62]

Similarly, energy has not often been considered of primary importance, or viewed simply as an operations and maintenance cost, when considering new water projects. Without planning for the energy-intensity of water over a longer time horizon, it could quickly become a more expensive resource. As an example, research conducted by Stokes et al. analyzed different energy and greenhouse gas impacts of meeting California's water demand in 2030 using different sources – from minimally energy intensive recycled water, to highly energy intensive desalination.[63] Their conclusions suggested that if California tried to meet their future water demand strictly with more energy-intensive options, the proportion of their energy budget

[62] Pate, Ron, et al., (2007). "Overview of Energy-Water Interdependencies and the Emerging Energy Demands on Water Resources." *Sandia National Laboratories*, Albuquerque, Nm.
[63] Stokes, J., Horvath, A. (2009). "Energy and Air Emission Effects of Water Supply." *Environmental Science & Technology*, 43(8), 2680-2687.

devoted to water supply would rise from 19 percent (as it currently stands) to approximately 52 percent by 2030 – over half of the state's energy use consumed just by the water sector. They suggested a more palatable alternative would be the increased use of recycled and brackish water. This strategy would limit energy increases to only 22 percent of the state's energy budget, a substantially less energy-intensive path for meeting future water demand.

To this end, Utah policy makers and water and energy planners should look for ways to manage the two together or jointly to optimize their full potential. The development of a statewide plan for water/energy resource planning may assist local and regional shareholders with a framework for coordination. Likewise, convening broad-based stakeholder meetings amongst local water and utility managers, state, federal, academic and other interested agencies could facilitate greater integration. Such meetings would further inform water and energy managers of what challenges lie ahead in terms of availability, meeting future demand and mitigating possible climate impacts. At the same time Utah water managers could convey to their academic and research counterparts what their needs are in terms of basic data gathering and models that would benefit both day-to-day and long-horizon water and energy plant operation.[64]

Increased Funding for Basic Water/Energy Science, Data and Models

Currently, water and energy managers rely heavily on models that use a variety of parameters as vital input. U.S. Geological Survey water programs on consumption and sector uses, snow pack surveys, streamflow data, climate and air quality sensor data all figure heavily into models that help managers make decisions. There are new data needs related to water quality, groundwater modeling, and how watersheds and sub-watersheds will respond to a changing climate, which require a higher resolution than it is currently available. Further examination and validation of climate change predictions could benefit water/energy stakeholders by clarifying the issues at stake with both pro-active 'green' and 'business-as-usual' approaches to management. Improved planning and decision-support tools are also needed to help both urban and more rural communities increase their resiliency and sustainability.

Foster Energy and Water Values at Home

Saving water saves energy and saving energy saves water. Heating and cooling at the end-use phase is the largest user of energy in the water supply and consumption cycle. At the same time, consumers use more water turning their lights on, watching television and powering their electronic devices than when showering. Because of this phenomenon, demand-side management for both resources is an important policy tool for achieving more sustainable levels of consumption. Additional incentives, conservation programs and education can have beneficial effects on consumer's pocketbooks, the environment, and indirectly on human health by reducing

[64] Western Governor's Association, (2006). "Water Needs and Strategies for a Sustainable Future." Denver, Co.

use, reducing greenhouse gas emissions and other harmful particulates, and delaying the need for major capital improvement projects. Generally, but especially in the west, water and energy have historically been undervalued. There are many legal and regulatory frameworks in place that make this a difficult issue to address, but we can begin to place greater value on the inexpensive services we are provided by not using them wastefully.

Expand Use of Non-traditional Water Supply

Reclaimed water and brackish water of lesser quality can be used to either replace water supplies for some applications or replace treated water completely in industrial sectors. Treatment of this non-traditional water supply requires additional energy to treat the water to a higher standard, but the total amount is generally less than that needed for development of freshwater sources. Education, research and infrastructure development for added water reuse projects should be fostered, especially if the intended use is for energy generation.

Incorporate Water Efficiency into Energy Planning

Energy production technologies such as hybrid dry cooling geothermal, wind, photo-voltaic or dry-cooling concentrated solar thermal power are renewable forms of energy with few negative externalities. They also have a double benefit of being minimally impactful on water resources. Fostering growth in these technologies by identifying and facilitating plant sites and further adoption of Utah's Renewable Standards Portfolio goals will benefit the environment and human health over the long term. An increased reliance on renewable energy serves as an effective risk management strategy against future fossil fuel pricing volatility and increased emissions/environmental compliance regulations. To the extent that fossil-fuel energy production continues and is further developed, project managers should try to minimize impacts on local or regional water supplies by incorporating closed loop, dry-cooling, hybrid and saline/brackish/recycled water cooling technologies whenever possible.

Incorporate Energy Efficiency into Water Planning

The withdrawal, conveyance and treatment of water can be highly energy intensive. When viewed over a long timeline, water planning choices made today can impact energy use immensely. Even though Utah has been fortunate to have a primarily gravity-fed water supply thus far, the future of water development is likely to be more expensive and energy intensive. Incorporating energy efficiency planning and life-cycle impacts into Utah's water policy today will pay off for future generations.