Where is the Power to Treat all the Water? Potential Utility-Driven Solutions to the Coming Power—Water Conflict

Frederick Bloetscher and Albert Muniz

Florida is a water rich state. Despite periodic droughts and water shortages that result from variations in rainfall and water management strategies, regional water budgets are the key to understanding the sources of water. Nationally, water has much competition for its use, resulting in an overtaxation of water in many areas. A water budget quantitatively accounts for inflows, outflows, and changes in storage of a hydrologic system. To address growth, water supply variability, and a host of other issues, utilities, golf courses, and even certain agricultural interests have pursued other water supply alternatives like desalination and reuse, since today's treatment technologies permit treatment of water that would otherwise fall outside the traditional water budget. However, these costs are significantly higher than current costs for doing business and create significant demands for power, which also competes for the same water. As a result, limiting the carbon footprint by lessening power needs for urban water supplies may improve local environments, increase water availability, and limit consumer costs.

One of the challenges associated with power and water is people moving into regions of the country that are water limited, like the Southeast and the Southwest, and away from water-rich areas like the Great Lakes and the Northeast. In many areas, water and wastewater plants are among the largest users on the power grid, so adding more people to water-limited areas may dramatically increase both water and power demands. Traditional long-distance power transfers are increasingly difficult to accomplish because the power grid will no longer support these transfers. However, all is not doom and gloom. When utilities can create their own power, the grid's power needs, and therefore cooling water needs, will be reduced. The result will reduce competition for limited water resources and leave more water for agriculture, residential use, and other purposes.

Water and Power Use Planning

The key for planning the utilization of water supplies is to determine how the hydrologic cycle provides water to the service area (e.g., recharge basin), in what quantities, and with what reliability. Reliability is a risk issue; is the precipitation consistent or are there significant fluctuations that disrupt ongoing basin development? Everyone recognizes the idea that:

Withdrawals = Consumption + Returns (to hydrologic cycle)

But the water cycle concept is not that simple, and the concept of "sustainable water" comes with different phraseology, depending on the profession using it. From a hydrologic perspective, it is suggested that the term "sustainable yield" is the amount of water that can be withdrawn from a source at rates that are less than their sustainable recharge potential. Typically, there are a variety of uses competing for water resources. While water is constantly recycled, its use in one sector may make it unusable by a competing sector.

All users in a basin must be considered, but how are uses prioritized, by whom, and how are treatment costs evaluated? Prior appropriation laws dictate water rights, but these rights do not address economic optimization or whether the allocations are correct to optimize opportunities. The uses of these resources cannot be separated from the opportunity costs of the same resources. The impact of these decisions ultimately affects the basin's social, economic, and ecological bases (Bloetscher and Muniz, 2008); this is the crux of the sustainability issue. However, the context is difficult to determine. In most cases there is limited historical information of the quantity of water that was initially available, so while historical water availability in any given basin has already changed as a result of water use practices, the magnitude of the change is uncertain. Water quantity and quality issues have significant fiscal impact on the potential users in the basin and there are unrealized costs and benefits that are often ignored in the current water management framework.

The need to fully to optimize management of water resources has been identified (Scanlon et al (2005). Most surficial changes decrease available recharge to groundwater. The recharge of groundwater is affected by precipitation, actual evapotranspiration, topography, land use, soil type, land cover, aquifer transmissivity, vegetation characteristics, and contributions to recharge along active stream channels (Herrera-Pantoja and Hiscock, 2008). In rural areas, increased evapotranspiration (ET) is observed in areas with large-scale irrigation, which then alters regional precipitation patterns (Moore & Rojstaczer, 2002; Scanlon et al, 2005). Evidence from other studies indicates that deforestation increases runoff, while decreasing the time of runoff and the amount of time available for infiltration. Changes in the surface cover will change surface temperatures, which can affect evapotranspiration. For example, open water bodies have higher evapotranspiration rates than land. Forest lands are known to maintain cooler temperatures on the surface (with accompanying high evapotranspiration and longer runoff times), while open areas have generally higher temperatures (heat island effect). Urban land use increases runoff due to imperviousness from buildings, parking lots, and roads and highways that replace forest or grassland cover (Bloetscher and Muniz, 2009). Examples of activities that may affect raw water supplies include delivery times of the water through piping installed to reduce flooding and replacing irrigated agriculture with paving. So, it is not just water use that af-

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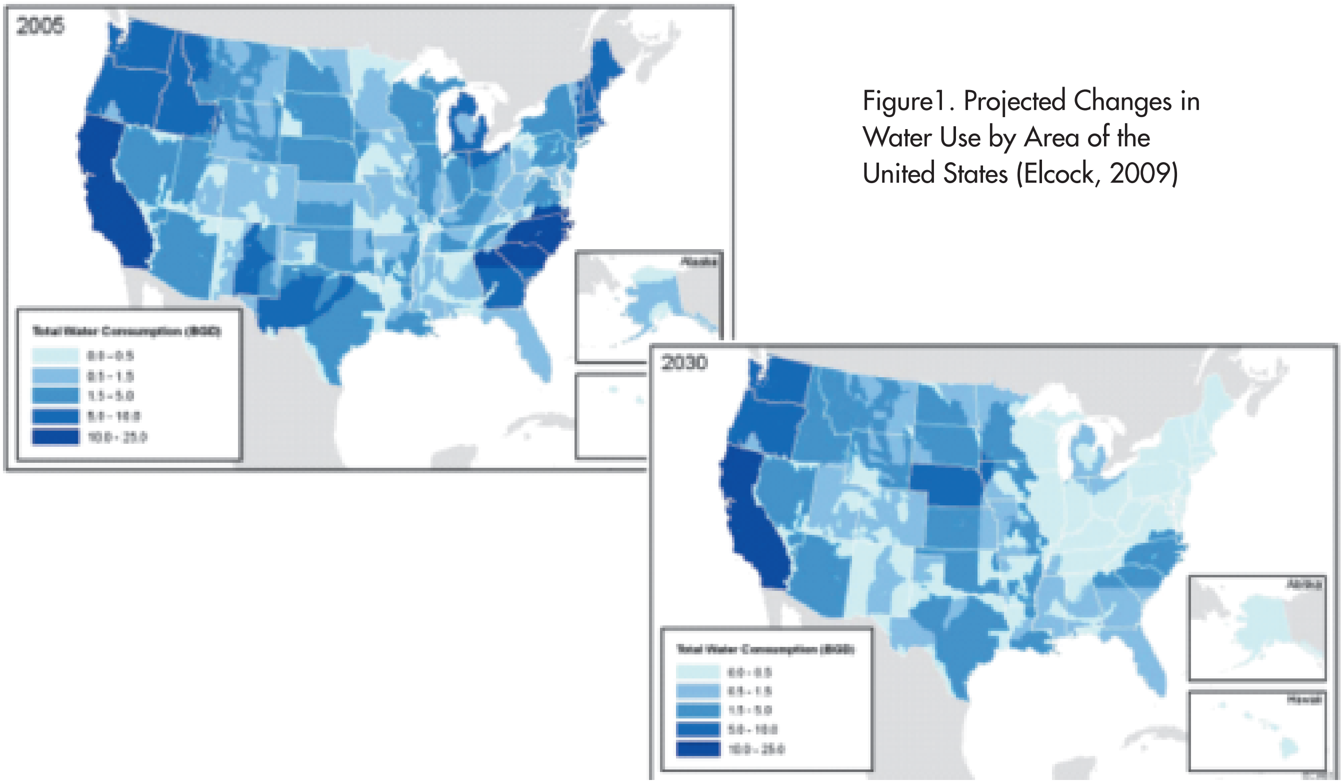

Figure1. Projected Changes in Water Use by Area of the United States (Elcock, 2009)

Table 1 – Summary of Water Demands by Power Plant Type (Shuster, 2008)

Technology	Cooling Demand MG/MW/h	Other Use or Consumption
Power Plant		
Coal Fired	0.05	0.0005
Coal - IGCC	0.0002	0.0003
Natural Gas - Open		
Loop	0.02	0.001
Natural Gas - Closed		
Loop		
Nuclear - Open Loop	0.06	minimal
Nuclear - Closed Loop	0.001	0.0001
Geothermal	0.02	0.02
Wind	0.00075	0.00075
Solar PV	0	minimal

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fects availability.

Confounding the situation are confined aquifers that are disconnected from localized recharge and often have overestimated recharge. The common practice to evaluate aquifer productivity is to pump wells that have a significant drawdown for only a few hours each day, allowing an extended period for the aquifer to recover. The United States Geological Survey (USGS) estimates that the pumpage of fresh groundwater in the United States is approximately 83 billion gallons per day (Hutson et al, 2004), which is about 8 percent of the estimated 1 trillion gallons per day of natural recharge to the nation's groundwater systems (Nace, 1960). This does not sound like a serious issue; however, another USGS study (Reilly et al, 2009), found that the areas of continued development and agricultural use coincides with areas with significant losses of groundwater supplies, which may become catastrophic in the future, affecting economic viability of local and ecological communities (Bloetscher and Muniz, 2008).

Figure 1 denotes the average water demands by area and the total water withdrawals across the U.S. There is a major population shift toward the Southeast and the Southwest, which means more water and more power demands in areas that already have low rainfall, coupled with the potential for future decreased rainfall in light of climatic changes. It's projected that regional power consumption will increase the thermoelectric capacity by 41 to 165 percent in the western U.S., and by 63 to 79 percent in the southeastern U.S., by 2025 (Elcock, 2009). Table 1 summarizes water supplies needed for power generation by type of generation. Note that the South has had repeated drought periods in the past five years, and in 2007 required nuclear power producers to reduce generation to conserve water. Surface water supplies may not be the future solution.

Figure 2 combines regional and local water-level declines for changes on a national scale. This information from the USGS reports that there is a need for a nationwide effort to organize available information on changes in groundwater storage, similar to what was done for the High Plains aquifer (Reilly et al, 2009). This figure shows water-level declines over the last 40 years throughout the United States. The Great Plains states, Texas, and the western U.S. are particularly affected. The red regions indicate areas in excess of 500 square miles that have water-level declines in excess of 40 feet in at least one confined aquifer since predevelopment, or in excess of 25 feet of decline in unconfined aquifers since predevelopment. Blue dots are wells in the USGS National Water Information System database where the measured water-level difference over time is equal to or greater than 40 feet, but note that the saturation of wells is insufficient to create "pink areas." That does not mean that aerial aquifer declines do not extend throughout the blue areas as well; it means information is lacking. All of these areas are indications of where water supplies are insufficient to provide the full needs of the community (Bloetscher, 2009).

Drilling deeper is not a solution. Deeper waters tend to have poorer quality as a result of having been in longer contact with the rock formation, allowing the minerals in the rock to dissolve into the water. Lower- quality waters are more costly to reach, and normally require additional treatment to remove impurities, resulting in additional power costs. Therefore, while some deep aquifers may be prolific, the quality of water obtained from a well may not be desirable or even usable without substantial amounts of treatment. In addition, most deep aquifers are confined and therefore are not significantly recharged, so the withdrawal of water may be a permanent loss of the resource in the long term due to the limited recharge. For example, portions of the aquifer in eastern North and South Carolina were virtually denuded due to pumpage because there is no local recharge. As a result, the aquifer was mined, exceeding its safe yield, and the large utilities converted to surface water sources that required far more extensive treatment. Most of the aquifers used in the western states of the U.S. are poised similarly since they have minimal potential for recharge. In parts of the Western Plains and the Great Basin area, the aquifers have dropped hundreds of feet, but with an average of 13 to 18 inches per year of rainfall and high evaporation rates throughout the summer, little of this water has the potential to recharge the aquifer (Bloetscher and Muniz, 2008).

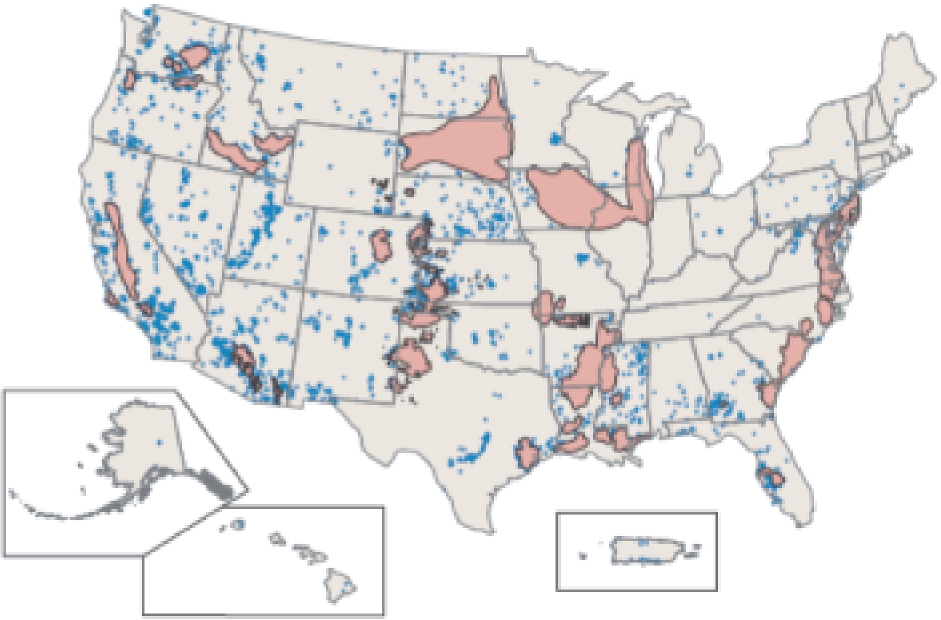

Figure 2. Water-Level Declines. Red regions indicate areas in excess of 500 square miles that have water-level decline in excess of 40 feet in at least one confined aquifer since predevelopment, or in excess of 25 feet of decline in unconfined aquifers since predevelopment. Blue dots are wells in the USGS National Water Information System database where the measured water-level difference over time is equal to or greater than 40 feet. (Reilly et al, 2009)

Treatment Process	Capital ($M)/mgd	Power (MW)/mgd
Groundwater, no treatment	0.1-2	0.1
Aeration/HSP/Wells	1	1.4
Lime Softening	1.5	2.3
Nanofiltration 125 psi	1.5-3	2.7
Low Pressure RO >200psi	3-5	3.3
Secondary WWTP	2.5-3	1.6
Secondary Pure OX	3-4	3.4
Reuse	5-7	3.4
Seawater Desalination	7-10	13

Figure 3. Water Demands for the United States by Sector (NSTC, 2007)

Water Demands are Increasing

The prior paragraphs outline the water supply challenges across the United States. Surface water, rainfall, and groundwater are far more limited in many areas, especially the West, than the current regulatory framework suggests. Couple this with increasing demands for water, especially in the Southeast and the Southwest—exactly the areas that already have limited water supplies. Population shifts will drive demands for added power, which adds to water demands in these arid or water-stressed regions. Figure 3 shows the demands for water in the United States; the largest user is for agriculture (40 percent), followed by power (39 percent). Agriculture needs are spatially extensive (NSTC, 2007), while power demands are generally confined to areas near urban centers. Agricultural uses consume the water for plants and farming, but evapotranspiration may be high and runoff can contaminate surficial water bodies during rain events. Urban demands, shown in Figure 3 (NASA, 2010), account for only 12.7 percent of national water use, but this is the sector that most impacts local economies.

The South and the Southwest rely on air conditioning due to higher temperatures, which requires more power for a larger population. This results in greater power demand, requiring more water for cooling power plants. Higher temperatures also normally result in increased water use, creating a potential conflict between power use and water supply consumers.

New water supplies often have lesser quality than existing supplies, simply because users try to pick the best water that minimizes treatment requirements. However, as lesser

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Table 2 - Power Use and Capital Costs for Various Water Treatment Plant Processes (Bloetscher, 2009)

Treatment Process	**Capital ($M)/mgd**	**Power (MW)/mgd**
Groundwater, no treatment	0.1-2	0.1
Aeration/HSP/Wells	1	1.4
Lime Softening	1.5	2.3
Nanofiltration 125 psi	1.5-3	2.7
Low Pressure RO >200psi	3-5	3.3
Secondary WWTP	2.5-3	1.6
Secondary Pure OX	3-4	3.4
Reuse	5-7	3.4
Seawater Desalination	7-10	13

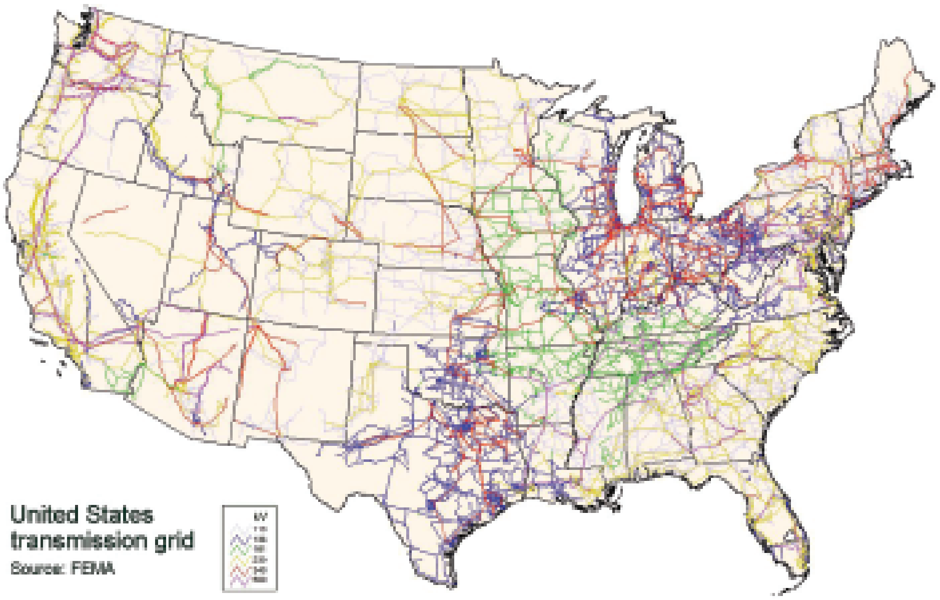

Figure 4. Existing Major Power Grid (FEMA). Note that Florida is lacking major power lines that exist in Texas and the Great Lakes states.

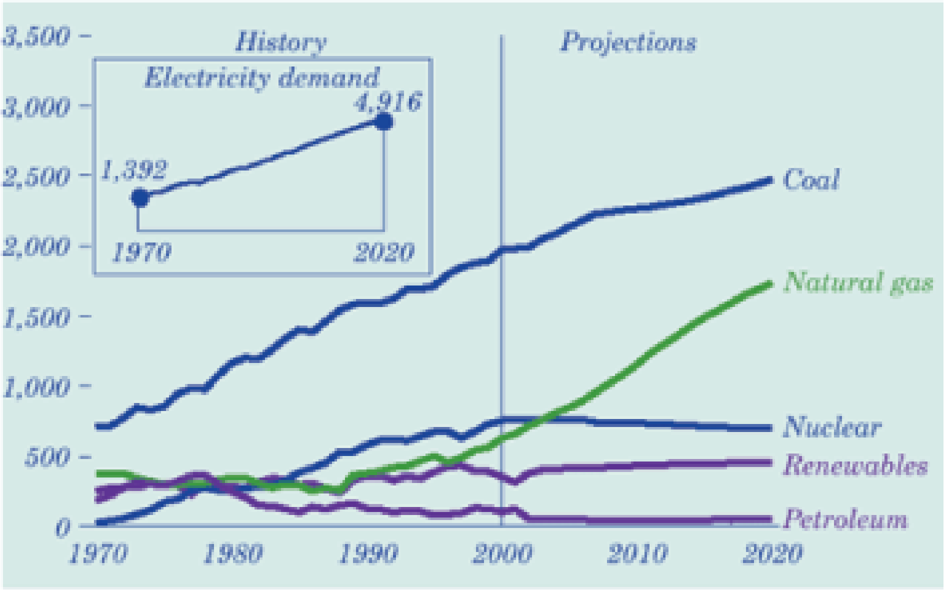

Figure 5. Summary of Power Production in the United States, projected to 2020. Coals and natural gas represent the major fuel sources. All of these plants require significant water for cooling. (EIA Annual Energy Outlook 2002 with Projections to 2020, DOE, 2010a)

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quality waters are treated, power costs increase at treatment plants. For many non-industrial communities, the local water and wastewater treatment facilities are among the largest power users in a community. Table 2 shows the typical power use per million gallons at water and wastewater plants. These numbers should be assumed to be magnitude-of-scale numbers, as the costs may include high-service pumps and other ancillary equipment. The averages eliminate variations among treatment plants.

The more energy intensive processes include treatment technologies that use membranes. It should be no surprise that desalination of seawater is the treatment that demands the most power due to additional pressures required to “cleanse” the brackish, saline water. Note that water plant costs include high-service pumps that may treat 1 megawatt (MW)/million gallons per day (mgd) of water, but secondary wastewater treatment for reuse or with more capital efficient pure oxygen, are large users as well. In wastewater systems, the plant energy requirements may be 85 percent of the total power use for the system. More stringent water quality regulatory requirements, and the need to use water sources of impaired quality for water supply, drive utilities to more expensive treatment processes. In many cases, these requirements are imposed by regulatory agencies, but others result from the competition within a given basin.

For example, in southeast Florida, water managers are considering reuse and indirect potable reuse for up to 600 mgd of wastewater, which could require the use of reverse osmosis at regional treatment facilities, plus 250 membrane distillation (MD) of brackish aquifer treatment to solve long-term water supply issues, including Everglades restoration. The reuse portion would require 1.6 gigawatts (GW) of power, in addition to the $6 billion in capital construction. The cost to treat 250 mgd of water with low pressure reverse osmosis (LPRO), with an estimated demand of 3.3 MW/mgd, would require 0.8 GW of power, in addition to the capital cost of $4.5

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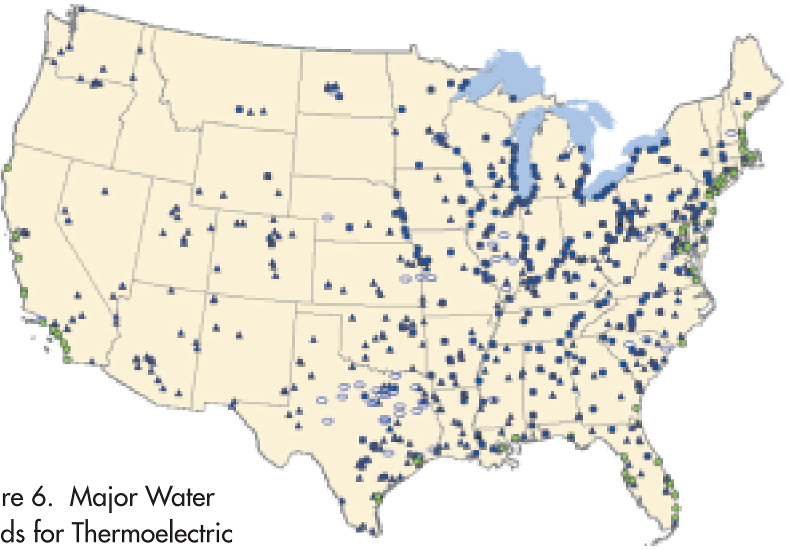

Figure 6. Major Water Needs for Thermoelectric Facilities. Green indicates saltwater used for cooling. (NETL, 2009)

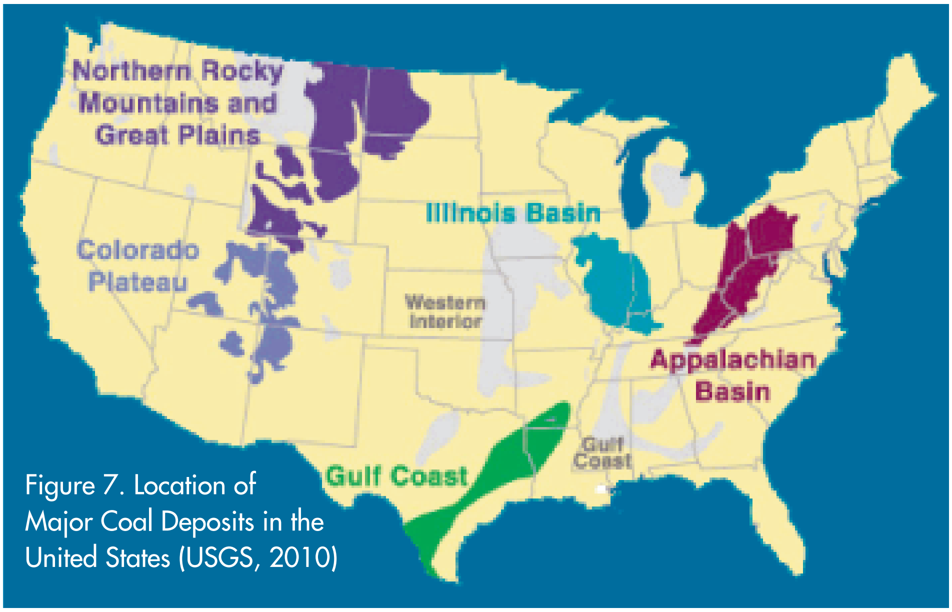

Figure 7. Location of Major Coal Deposits in the United States (USGS, 2010)

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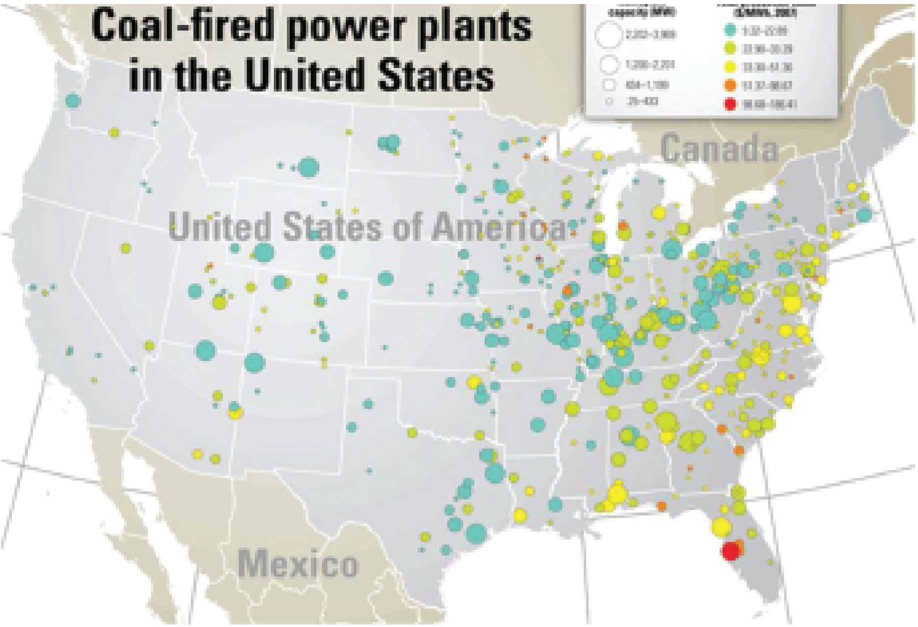
billion. The additional 2.4 MW of power required to treat both water sources is not presently available in southeast Florida and the current power grid is not capable of bringing this power to the area (see Figure 4). The local power entity appears to be looking at constructing two nuclear reactors on Biscayne Bay, at an elevation of 3 feet, National Geodetic Vertical Datum (NGVD), in part because of the potential water treatment demands in the area. Similar issues affect the Southwest and the Rocky Mountain states as well. So the question is: Where will the new demands be located and what potential power sources may be present?

Power Plants Need Water

Power plants derive their fuel from coal, natural gas, nuclear power, and other materials. Approximately 39 percent of water use in power plants is for cooling, because power plants create significant heat. This causes power plants to operate, on average, at 30 to 35 percent efficiency. As power demands increase, larger quantities of water will be required. At present, many of the future high-demand areas are not where the power plants are located, and not where abundant water supplies are available.

Figure 5 summarizes the anticipated power production in the U.S., projected to 2020. Figure 6 shows where these demands are located and the source or cooling water (green is saltwater). The map shows the location of each type of plant and indicates where deficiencies may exist and where the grid supplies power. Coal deposits are located in a series of basins in the U.S. (see Figure 7). While coal can be mined and moved long distances by rail or trucks, most coal power facilities are located in more developed areas (see Figure 8), placing them in direct competition for water resources with urban utilities. This is particularly problematic in the West, where water resources are limited. Coal-fired plants currently account for the majority of power produced, but due to the pollutants in the burning process, new coal plants are rarely constructed today.

Oil and natural gas are found in much of the Midwest and the Rocky Mountains, as are most of the plants that use these power sources (see Figure 9). The vast majority of plants con-



Source: Platts Energy Advantage and POWERmap. All rights reserved.

Figure 8. Location of Coal-Fired Power Plants in the United States (based on data from NETL, 2010a, Young, 2009)

structed in the past 20 years have been natural gas facilities due to the lower cost and fewer emissions than those powered by coal.

The Midwest has had very slow population growth, while the Rocky Mountains states, the Southeast, and the Southwest have experienced significant gains. Unfortunately, the Rocky Mountains area suffers from significant water deficits in many basins, and the water use for mining coal, shale oil, and other minerals is a current conflict issue. Adding more water demand for cooling will likely spark additional conflicts for limited resources.

The location of nuclear power plants in the U.S. is shown in Figure 10. Most are located in the eastern U.S. and along rivers in urban areas. The rivers generally act as water supply for urban users, again raising the competing resource conflict. The West, where the population is growing the fastest, has few water resources available to meet the nuclear cooling demand which, along with a series of other factors, including geologic challenges

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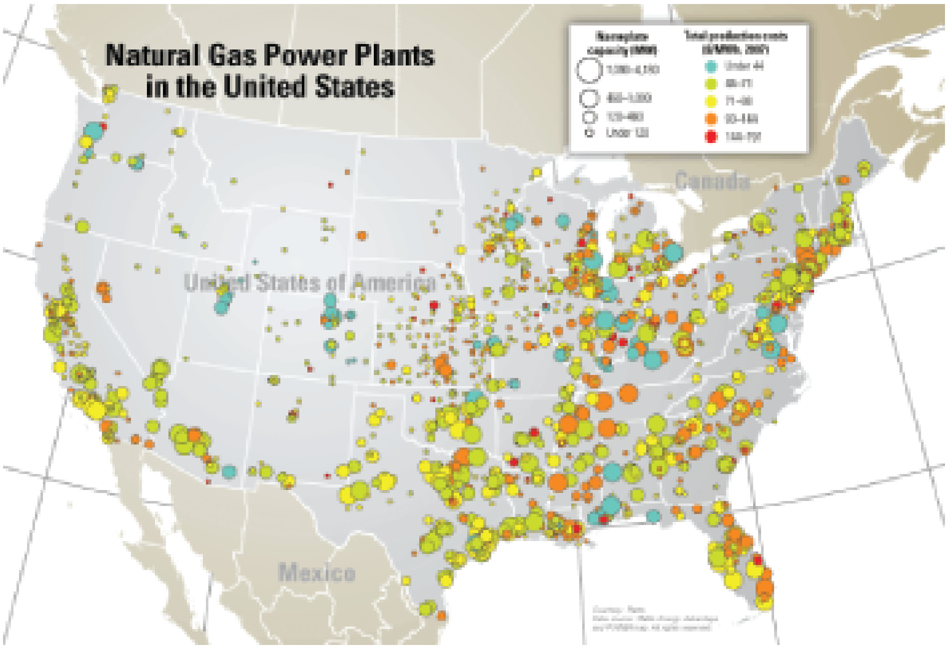
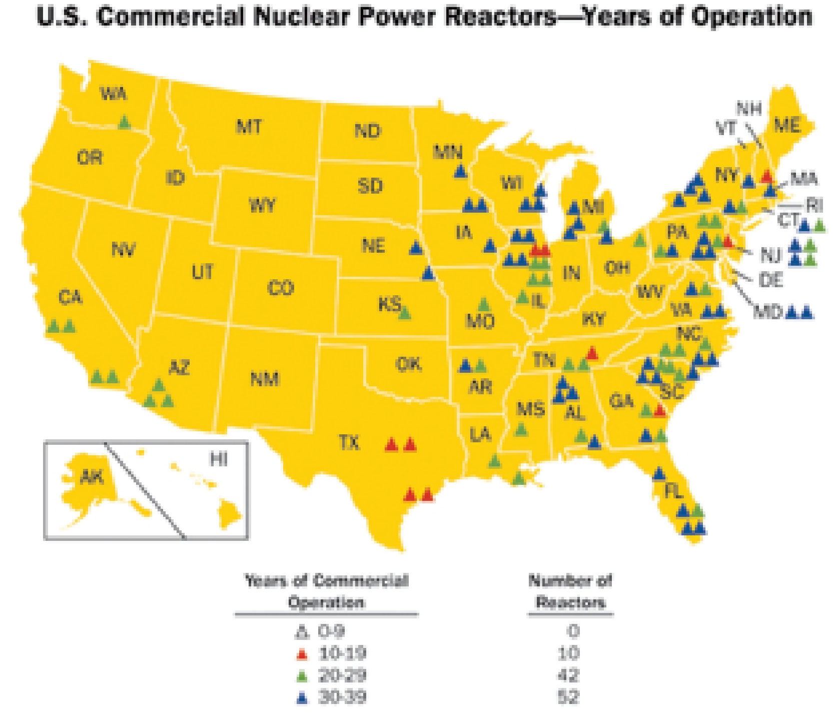


Figure 9. Location of Natural Gas Power Plants in the United States (Power magazine, 2010)



Source: U.S. Nuclear Regulatory Commission

Figure10. Location of Nuclear Power Plants in the United States (NRC, 2010)

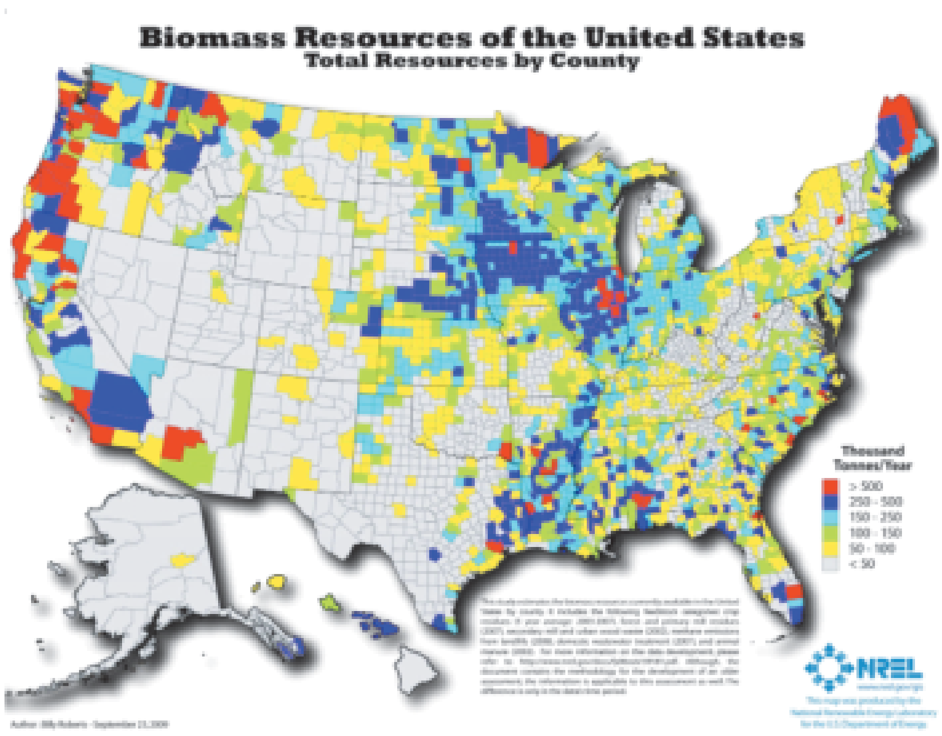


Figure 11. Total Biomass that can be Converted to Power. Much of the Upper Midwest is crop thrash, as is much of the lower Mississippi Valley. Neither in near many large population centers. (NREL, 2010a)

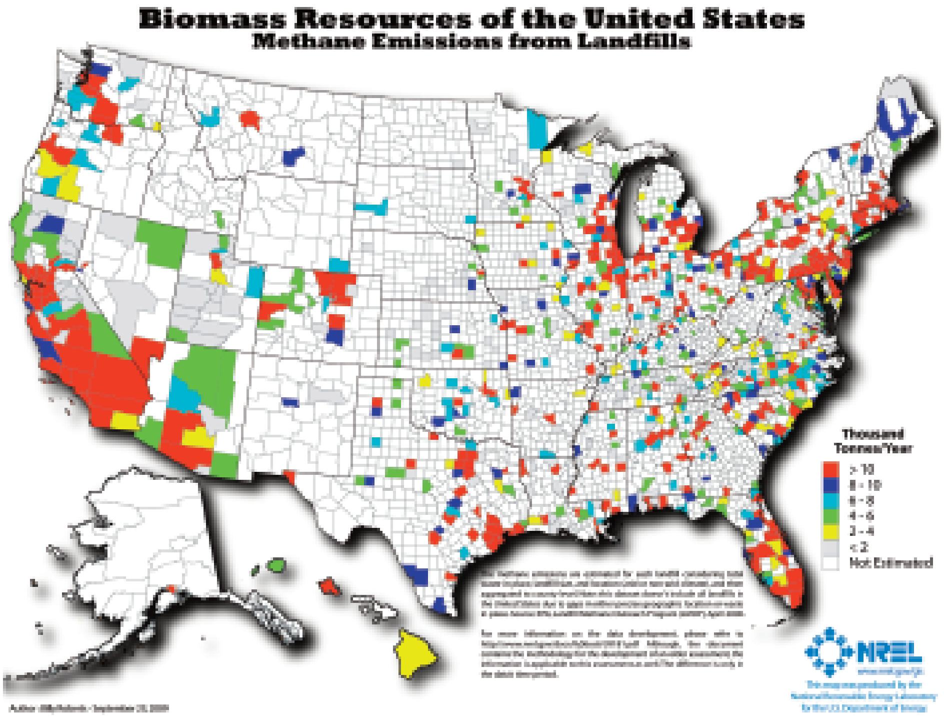


Figure 12. Landfill Methane Biomass. This is methane from landfills that could be used for feeding micro-turbines or methane fuel cells if cleaned up. Both require limited water for cooling. (NREL, 2010c)

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(faults, volcanic activity, etc.), make nuclear power unattractive. Hence, nuclear power use is likely to increase in higher growth areas in the East, especially if stimulated by other factors like water treatment. But potential problems exist; in 2007, 24 of the 104 nuclear reactors were in areas experiencing severe levels of drought (Peltier, 2008).

Figure 11 shows total biomass in the U.S. Much of the biomass in the country is not in urban areas, but in forestry and agricultural areas where the power use would be in direct competition with those sectors. Figures 12 shows landfill methane biomass and Figure13 show wastewater plant methane biomass; as would be expected, there is a correlation between the biomass location and population. This gives rise to the concept that the methane extracted from landfill and wastewater plant biomass might be useful for power generation in urban areas for turbines and generators. Landfill methane is normally of poor quality, but can be cleaned to improve efficiency.

Figure 14 shows wind speeds in the U.S. Sustained winds over 12 mph are needed for solar wind farms to be effective, which occur mostly in mountainous areas and some coastal regions. As shown, the fastest wind speeds are in the red, pink, and purple areas, well away from urban centers. However, population centers located in coastal regions could have offshore wind systems that might prove useful as they did in Perth, Australia, where its desalination plant is driven with offshore windmills.

Photovolatics and solar concentrators are emerging technologies. Photovolatics generates electric power by converting solar radiation into direct current electricity using semiconductors, while solar concentrators use mirrors or lenses to concentrate sunlight onto a small area. Figure 15 shows a map of solar intensity, which indicates that it's highest in the West. Panels using these technologies can be built in a variety of arrays from very small to very large, depending on the need. The Desert Southwest is a prime area for photovoltaic growth to meet increasing population demands.

Potential Solutions at Treatment Plants

Because water and sewer plants are often among the largest power users in communities, consideration should be given to the development of onsite power, reducing both power and the subsequent water demands. Power conservation is another option. The replacement of older pumps, motors, and fixtures with more efficient systems is one area to consider, but it would be very expensive and the return on investment needs to be considered. Energy conservation possibilities include: changing current lights to compact fluorescent (CF) bulbs; installing or retrofitting lights and heating, venting, and air conditioning (HVAC) systems that turn off automatically when not in use; installing new building roofs that have highly reflective materials (again, a major investment); increasing insulation; retrofitting the HVAC system with higher efficiency 18-21 seasonal energy efficiency ratio (SEER) air conditioning (AC) units; and using slip power recovery to improve efficiency for wells. The savings, however, from all of these measures are very small (2 to 5 percent) compared to the power needs, so more innovative solutions must be investigated.

Water plants are problematic—they do not create a by-product that has benefits as a fuel. Most of their power is for pumps, especially membrane systems. For membrane systems or plants employing high pressure systems, energy recovery turbines on the finished water (i.e., permeate), and concentrate streams that would convert pressure to power,

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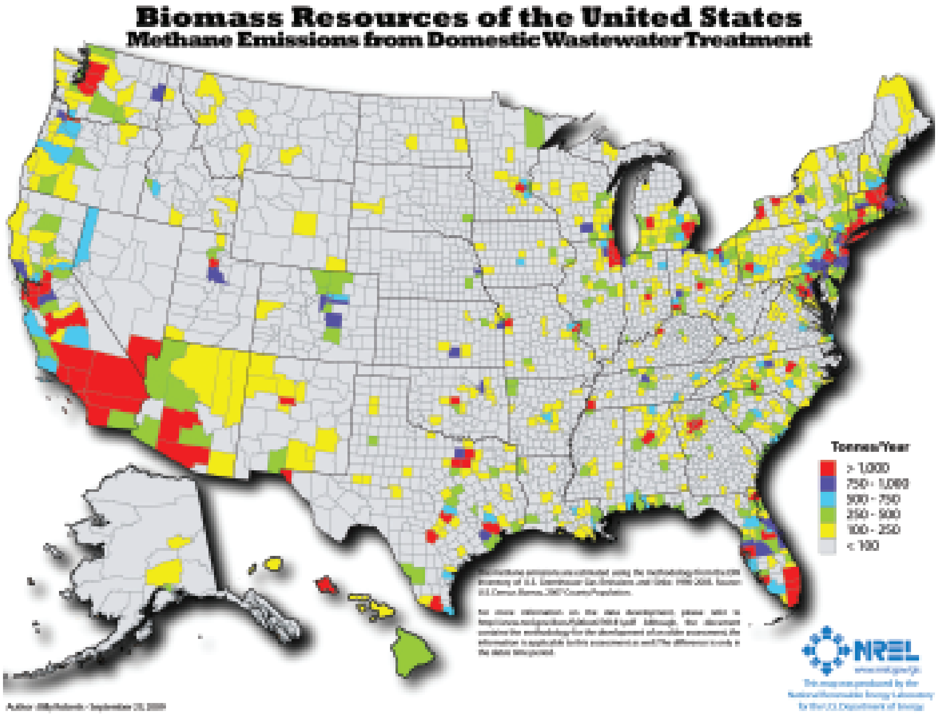

Figure 13. Wastewater Plant Methane Biomass. This is methane from wastewater plants that could be used for feeding micro-turbines or methane fuel cells. Both require limited water for cooling. (NREL, 2010b)

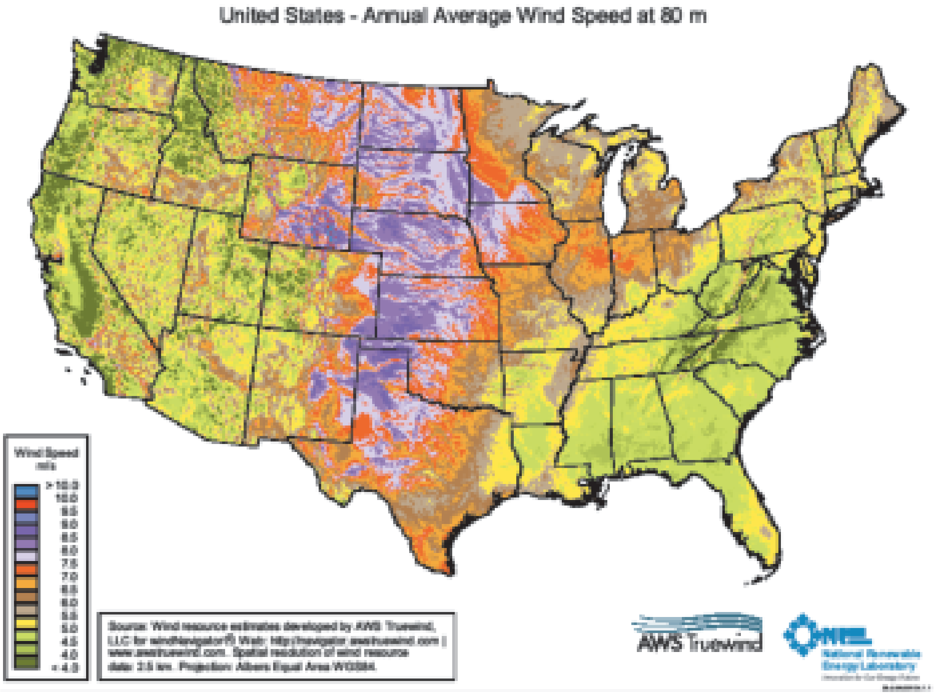

Figure 14. Average Wind Speed. Best production is the in red, pink, and purple areas, well away from urban centers, but enough population centers are located in coastal regions that offshore wind systems might prove useful as they did in Perth, Australia. (NETL, 2010)

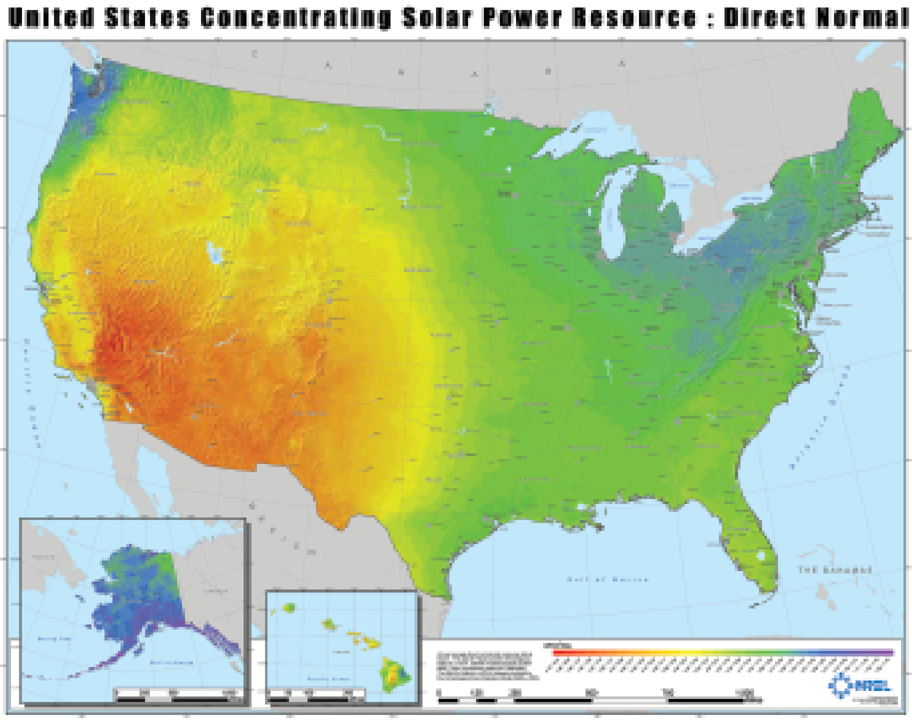

Figure 15. Solar Intensity. Much higher in the West where water is limited. (NREL, 2010d)

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could be used to operate lights, pumps, and other equipment. A membrane plant might be able to recover 10 percent of its power by using more efficient membranes and optimizing pumps (lower pressure). This has been pursued at several Florida plants when the membranes were replaced.

Wastewater plants, however, are different. The aeration modules at a wastewater plant may consume a third or more of its power. Aeration can be improved with the installation of fine bubble diffusers, variable speed drives, more efficient motors and blowers, and dissolved oxygen control systems to reduce power use by 50 percent. Wastewater plants create biosolids that can effectively be converted to methane gas, so a wastewater treatment plant can create a portion of its energy demands. Options for converting the methane to power included mini-turbines and fuel cells. A pre-manufactured fuel cell module could operate continuously to produce power usage from plant methane. A number of large wastewater plants have already made this conversion, but many smaller plants have not. There is potential energy to be gained from using methane, but there would currently be a high life-cycle cost.

Micro-turbines provide opportunities since they can create a similar amount of power and require minimal maintenance, and at a capital investment of about 10 percent of fuel cells. Micro-turbines require no major repair parts and the technology is well developed, with recoveries exceeding 80 percent. Fuel cells do however require higher capital and higher maintenance costs. Both require “cleaning” the methane of impurities, but in many cases the gas needs only limited cleaning to be efficiently burned. It should be noted that methane has 22 times the greenhouse gas effects of carbon dioxide and methane is a useful fuel, if it can be captured. Energy credits and grants for local governments wishing to pursue this type of power generation are available.

Table 3 shows that renewable fuels like wind and solar are much more efficient users of water. Neither of these is common at water and wastewater plants, but they could be. Solar panels can potentially be used at utility sites to considerably reduce power requirements, especially in those areas of the country with the highest expected growth. Virtually every surface of a building or a water tank with a cover could be shrouded with solar panels, as long as access is allowed for maintenance.

While current solar panel technology is not highly efficient, it is improving. Only limited amounts of water are required to clean the solar panel surfaces, which are available onsite and can be recaptured for treatment.

Manufacturers have begun making mini-wind turbines that are useful down to 9 mph. Smaller wind farms could be attractive at larger sites, but the wind speed issues must be considered. Mini-turbines are more adaptive for lower wind speeds, but the technology is still developing. Table 4 outlines other solutions that might be available to pursue.

Case Studies

Students at Florida Atlantic University have looked at several case studies dealing with power in the water industry. The first is a small nanofiltration expansion at a treatment plant. The plant provides water that meets all current state and federal drinking water standards, but removal of organics from the raw water supply is difficult. The current treatment process is inadequate to treat much more of the water supply due to potential formation of disinfection by-products caused by higher color in the purchased water. Therefore, the utility was looking at expanding its treatment capacity to include improved water quality. Nanofiltration was chosen as a potential solution. In this case, the proposed nanofiltration expansion was determined to require about 50 percent more power than is currently being consumed—roughly 236.5 kW per day or 1.2 kW/MG.

Power savings were focused on as a means to reduce power grid demands. Energy conservation at the existing facility was easily identified: current lights will be changed to CFs, eliminated, or turned off automatically when not in use, and variable frequency drives (VFDs) will be employed to increase energy ef-

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Table 3 – Summary of Water Needed to Develop Power Plant Fuel (Brown, 1999)

Fuel/Process	**Water Need**	**Water Use (mgd) Water/MW/h**	**Gallons of Water/Gallons of Fuel**
Oil/Gas Refining	Refining	20 to 70	1.5
Oil/Gas Extraction	Extraction	6 to 10	1.5
Oil/Shale	Refining	3 to 30	2
Oil Sands	Extraction	50 to 150	3
Biofuels - Ethanol	Growing Fuel Stock	10,000 - 100,000	1000
Biodiesel Process	Growing Fuel Stock	15 to 20	1
Biofuel - Soy	Growing Fuel Stock	50,000 to 200,000	6500
Biomass Conversion	Growing Fuel Stock	50 to 350	4

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ficiency for pumps. Insulation and 18 SEER HAVC units would help, but the savings from these measures were small compared to the power needs for the new facility (only 2 to 3 kW/day; not close, as a net of 258.9 kW/day was needed), so more innovative solutions were investigated. An easy solution was to evaluate energy recovery turbines on the permeate and concentrate streams, which would convert pressure to power that could be used to operate lights, pumps, and other equipment.

The students developed a plan that would evaluate: 1) solar cells, 2) wind turbines, 3) pressure recovery, 4) fuel cells, and 5) mini-turbines, using compressed methane derived from a local landfill and piped to the facility. Based on an evaluation of these options, the first three seemed viable because the methane fuel needed to feed fuel cells and mini-turbines was not available to the site. For the solar cell option, virtually every surface of a building or a water tank with a cover included solar panels. One solar panel vendor provided units with an estimated daily capacity of 385kW/hour, requiring a total of 415 solar panels onsite. Another option evaluated 3-foot by 5-foot solar panels without onsite battery storage, utilizing an existing commercial buyback program to sell power back to the provider during the day in exchange for off-peak power at night. The utility also owned a 10,000-square-foot parcel offsite that could be used to locate a solar field to generate 622 kW. Back-up power is required to comply with reliability standards; the Florida Power & Light Company grid can be used for this purpose. The initial cost for this option was determined to add approximately 40 percent to the price of the plant. But, by saving 236.5 kW/day, at current electricity prices, the present worth of power costs, at 6 percent a year over 20 years, generates nearly $3.5 million, which is about the cost of the installation. As efficiency improves for both options, the payback will become more attractive.

Standard wind turbines were determined to be somewhat impractical in Florida because of the low wind velocity. However, the manufacturers of mini-wind turbines indicated that the lower wind speed could be accommodated. It was determined that the mini-wind turbines had potential to provide 40 kW and can be hung on towers to increase the power generated per square foot of ground area. These small turbines could generate up to 10 kW each. The off-site location noted above could house six small wind turbines. Pressure recovery was also evaluated at a concentrate pressure of 72 pounds per square inch (psi) and flow of 48 gallons per minute (gpm). Using a recommended micro-direct current output turbine/generator, the unit was capable of recuperating 0.8 kW of power from the concentrate line. Such a small contribution, however, was not cost-effective.

The second project was a large wastewater treatment plant, which is a secondary plant with disposal of treated effluent via injection wells. A small reuse facility is located onsite that adds filtration and high-level disinfection to the treated wastewater. The average power demand is 133,000 kW/day. The aeration portion of the activated sludge process consumes half of the power needs, while the injection wells consume another 15 to 20 percent. Aeration efficiency could be improved with the installation of fine bubble diffusers, variable speed drives, and more efficient motors and blowers. Expected savings are 2 to 5 percent of the total costs. Slip power recovery would improve efficiency for the deep wells. Some improvement could be made with lighting, increased HVAC system upgrades, and lighting sensors, but this required further analysis.

Nearly 24,000 cubic feet of digester gas is flared to the atmosphere. Digester gas options included micro-turbines and fuel cells. Micro-turbines operate like the generators that most operators are familiar with. A present worth analysis determined that the use of digester gas in fuel cells and micro-turbines could generate a third of the power demands for the plant. In the case of the micro-turbines, they generate 97 percent of the energy that fuel cells can, but are priced at 10 percent of what fuel cells cost. Note that in both cases this costs less than what the power utility charges. The micro-turbines require minimal maintenance and a limited capital investment; there are also no major repair parts and the technology is well developed. Fuel cells require higher capital and higher maintenance costs. Both require "cleaning" the methane of impurities.

Table 4. Potential Mitigation Solutions

Mitigation Solutions	**Application**
PV Panels/Solar Panels	All Utility Sites
Methane Fuel Cells	WWTP, Landfills
Micro-Turbines	WWTP, Landfills
Wind Turbines	Sites with Wind < 9 mph
Energy Recovery	Membrane Applications, Pumping Systems

A small wind farm could be constructed on the site, but it is much more conducive to photovolatic power generation. Solar cells could be located on the buildings to generate power, but would not be cost- effective. However, because of the low cost of the micro-turbines, a combination of solar and micro-turbines could serve the entire site at less cost than the power company currently charges (by averaging costs per kW/hour). Securing capital funding is difficult for such investments at this time, so further study is ongoing.

Summary

Future challenges and conflicts over water withdrawals between urban users and power entities are real and should be carefully analyzed to allow sufficient time to develop cost-effective strategies. The current population shift favors the Southeast and the Southwest, but both areas are limited in power, power grid capacity, and water supplies, so the potential for immediate and future conflict exists. Utilities can be part of the solution by reducing power demands while preserving water supplies. Large water and wastewater treatment plants are often among the largest users on a power grid. As can be seen in Table 1, power costs are significant, especially as more exotic treatment is employed (seawater desalination being the most costly). Limiting the carbon footprint and lessening power capital needs will improve local economies, preserve local environments, protect water supplies, and limit consumer costs. Demands to produce water from lower-quality sources will increase the demands on the power grid exponentially, while also increasing the need for cooling water. If water and wastewater plants can generate power onsite, the power demands for the water and wastewater sector could decrease. This would create additional capacity in the present power grid for growth and development and less need for water to be diverted for cooling. This would also limit, or at least delay, the need to develop new power sources and reduce competition for limited water supplies, especially in areas where water is over-allocated.

Planners should identify the power solutions that are best acclimated to their areas (wind in the Rocky Mountains, solar in the Southwest and the Southeast, and methane at wastewater plants and landfills) to strengthen their grids. Utilities should work with power companies to evaluate means to reduce their carbon footprint and grid demands, saving themselves money in the process. Water and wastewater utilities should also work with power companies and regulatory agencies to evaluate the need for water treatment; self-inflicted power demands for water treatment should be avoided.

Power companies and utilities could seek state and federal assistance for funds to help develop solutions to future power demands if they were made available. Much of the recent American Recovery and Reinvestment Act (ARRA) monies for energy savings were unavailable to utilities. Since utilities are among the largest users, it only makes sense that reducing power at treatment facilities will yield a far bigger benefit than focusing on small businesses and homes.

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