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Wind Energy Applications for Municipal Water Services: Opportunities, Situation Analyses, and Case Studies

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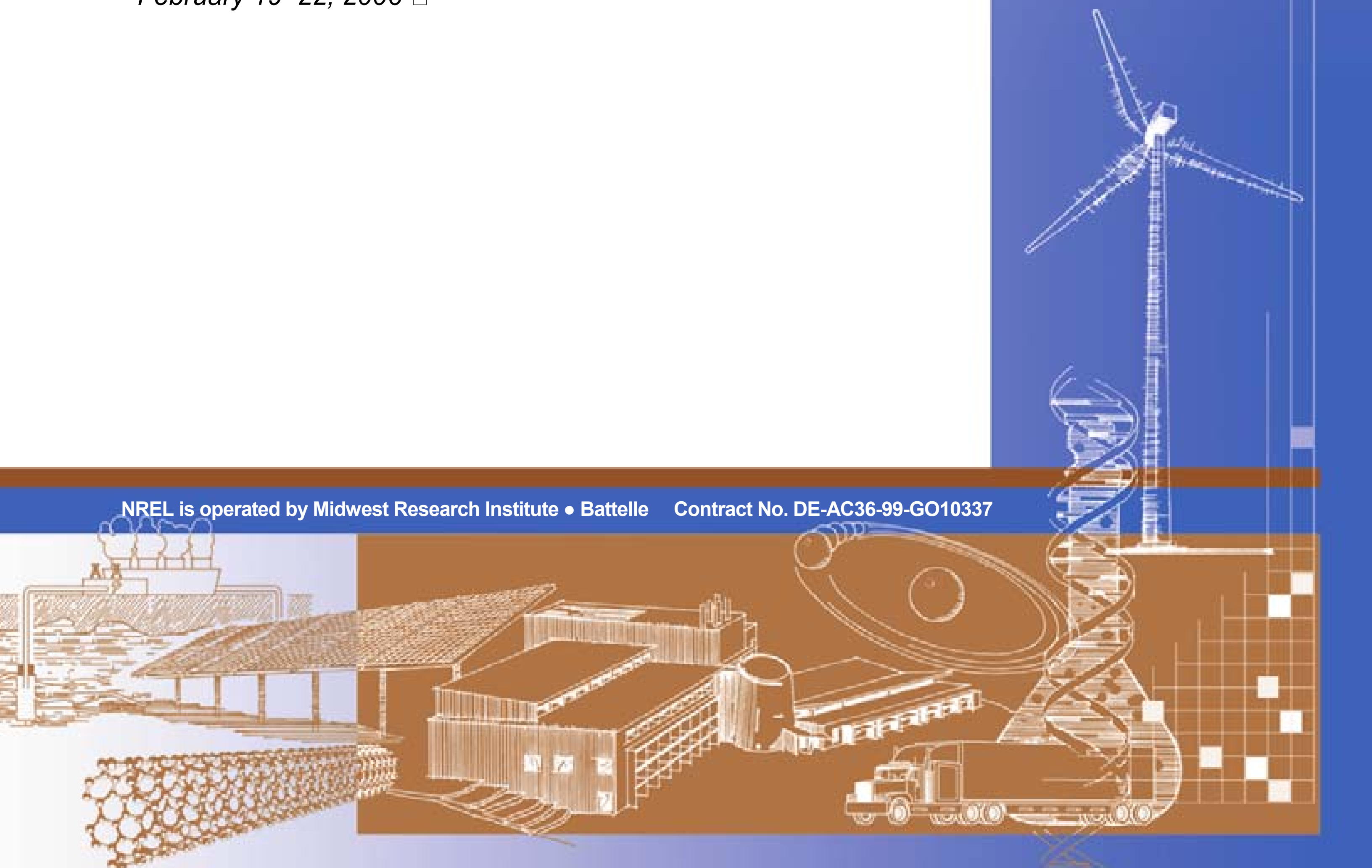

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WIND ENERGY APPLICATIONS FOR MUNICIPAL WATER SERVICES: OPPORTUNITIES, SITUATION ANALYSES, AND CASE STUDIES

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ABSTRACT

As communities grow, greater demands are placed on water supplies, wastewater services, and the electricity needed to power the growing water services infrastructure. Water is also a critical resource for thermoelectric power plants. Future population growth in the United States is therefore expected to heighten competition for water resources. Especially in arid U.S. regions, communities may soon face hard choices with respect to water and electric power.

Many parts of the United States with increasing water stresses also have significant wind energy resources. Wind power is the fastest-growing electric generation source in the United States and is decreasing in cost to be competitive with thermoelectric generation. Wind energy can potentially offer communities in water-stressed areas the option of economically meeting increasing energy needs without increasing demands on valuable water resources. Wind energy can also provide targeted energy production to serve critical local water-system needs. The U.S. Department of Energy (DOE) Wind Energy Technologies Program has been exploring the potential for wind power to meet growing challenges for water supply and treatment. The DOE is currently characterizing the U.S. regions that are most likely to benefit from wind-water applications and is also exploring the associated technical and policy issues associated with bringing wind energy to bear on water resource challenges.

Municipal water service providers face several challenges, including providing clean, reliable water supplies at low cost, wastewater treatment, and managing environmental risks. Water supply salinity, contaminant concentrations, surface water quality and groundwater withdrawal rates all play a role in these challenges. Opportunities for matching wind potential and water needs are being modeled through Geographical Information Systems (GIS) modeling. Results of the modeling will quantitatively describe the range of potential wind energy applications where various water needs exist and point out utility areas that may be good candidates for selected wind-water applications. Urban, agricultural, and industrial water services that may be served by wind generation are included. In subsequent studies, the results of the first phase—identifying promising opportunities and initial case studies—will be combined with the identification of technical and other issues, to develop detailed situation analyses to more fully characterize the application of wind generation for pumping and transporting water in the municipal sector.

KEYWORDS

Energy, wind energy, water conservation, municipal water, energy-water nexus

INTRODUCTION

Municipal water and wastewater operations are energy intensive. Energy used by water systems account for more than 3 percent of total electric demand (Burton, 1996). Additionally, thermoelectric power generation places considerable demand on water resources in terms of water withdrawals and consumption. Typical rates of water withdrawals for generating electricity in the United States now roughly equal withdrawals by agriculture, about 195 billion gallons per day (Hutson et al., 2004) or 25 gallons per kWh (Feeley and Ramezan, 2003).

Energy inputs to water systems occur at different locations in the system, from initial extraction of water from surface or groundwater sources, through conveyance, storage, treatment, distribution, end-use, wastewater collection and treatment, and discharge or reuse. Some of these inputs, in some important systems, are located hundreds of miles from the urban centers being served. For example, water is pumped from the Colorado River over a mountain range to Southern California in the Colorado River Aqueduct (CRA). These important energy inputs to water systems are sometimes located in places with significant wind energy potential. Indeed, parts of the CRA, for example, are approximate to areas of high wind energy density and in fact to existing major wind installations. However, the wind resource does not necessarily need to be proximate to urban centers to be of value to the water supply systems serving them; there is also potential for wind energy to supply some of the energy required to get water to municipal systems.

Although the focus of this analysis is municipal systems, analysts recognize that many water supply systems provide service to all types of users. It should be noted that many of the same features discussed with regard to wind energy opportunities for the municipal end-users apply to agriculture as well. For example, pumping is the largest energy use for water systems. Lifting water from groundwater aquifers and out of surface systems is the same whether the water is destined for irrigation or the city. The point is that where wind energy systems can contribute to energy inputs, and particularly to the energy required to lift and move water around, there are important overlaps in benefits between municipal and other uses. These potential benefits should be appreciated when considering this analysis.

The genesis of this report is the U.S. Department of Energy (DOE) Wind Program's interest in studying relationships between wind energy and water provision. In 2004, the Program began investing in this area with three activities: scoping six potential wind-water opportunities (irrigation, municipal, thermoelectric generation, produced water, pumped hydro, desalination); participating in the Sustainable Water Resources Roundtable; and funding a concept design study for wind-powered desalination. These activities continue in 2005, but the opportunities have been reduced to three areas of study: irrigation, municipal, and desalination (for more information, refer to www.nrel.gov/wind_meetings/wind_water/).

The Wind Program is not the only organization to examine energy-water issues in recent years. Several reports on water have considered energy a research priority (National Research Council, 2004). Further, 11 National Laboratories have formed the Energy-Water Nexus, which highlights the importance of research into relationships between energy and water; this group is currently developing – with DOE funding - a roadmap to address these research needs (www.sandia.gov/energy-water/).

The U.S. Congress has also begun to support this research area; in addition to several legislation drafts on establishing an energy-water supply program and providing financial incentives to desalination facility operators to cover energy costs, two pieces of legislation now provide support for energy-water research. The Energy Policy Act of 2005 authorized the DOE to "research, develop, demonstrate, and commercially apply" energy-related water issues, water-related energy issues, and federal coordination on arsenic treatment, desalination, and policy analysis (U.S. Congress, 2005). To fund this initiative in Fiscal Year 2006, Congress appropriated $12.5 million for the DOE to study energy and water resource management, including advanced concept desalination and arsenic treatment (in partnership with the American Water Works Research Foundation and WERC: A Consortium for Environmental Education and Technology Development), water supply technology development, and water management decision support, including demonstration programs in partnership with New Mexico and international water partnerships (U.S. House Rules Committee, 2005).

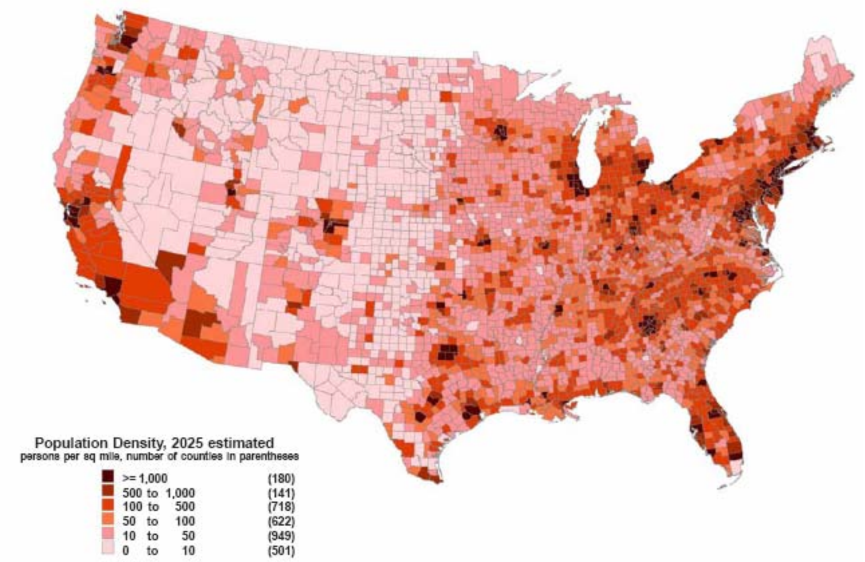
The research presented in this report describes a systematic assessment of the potential for wind power to support water utility operation, with the objective to identify promising technical applications and water utility case study opportunities. The first section describes the current situation that municipal providers face with respect to energy and water. The second section describes the progress that wind technologies have made in recent years to become a cost-effective electricity source. The third section describes the analysis employed to assess potential for wind power in support of water service providers, as well as two case studies. The report concludes with results and recommendations.

The authors would like to acknowledge the investigators for this report: Sentech, Inc., University of California-Santa Barbara, and Western Resources Advocates (WRA). Patrick Quinlan lead a team at Sentech including Sissi Liu, Nicole Rentz, and Sharon Brown who provided the bulk of the information presented here. Dr. Robert Wilkinson from UC-Santa Barbara provided some of the introductory material, and Bart Miller at WRA, along with Brian Murphy, provided case study material. Additionally, Ruth Baranowski from the National Renewable Energy Laboratory provided invaluable editorial support.

1. GROWING CHALLENGES FOR U.S. WATER SUPPLY AND WASTEWATER TREATMENT

The U.S. population currently stands at approximately 297.5 million (U.S. Census Bureau, 2005b) and continues to grow at a nominal rate of over 1 percent per year (U.S. Census Bureau, 2005a). Figure 1 shows expected population density for the year 2025 (Roy et al., 2003).

Figure 1 – County Population Density Projected for 2025



Population growth is especially significant in the Southwest where freshwater resources are not as abundant. Figure 2 shows the extent of freshwater withdrawals versus available precipitation of each of the counties in the contiguous United States (Roy et al., 2003).

Figure 2 – County Total Freshwater Withdrawal, 1995, Divided by Available Precipitation

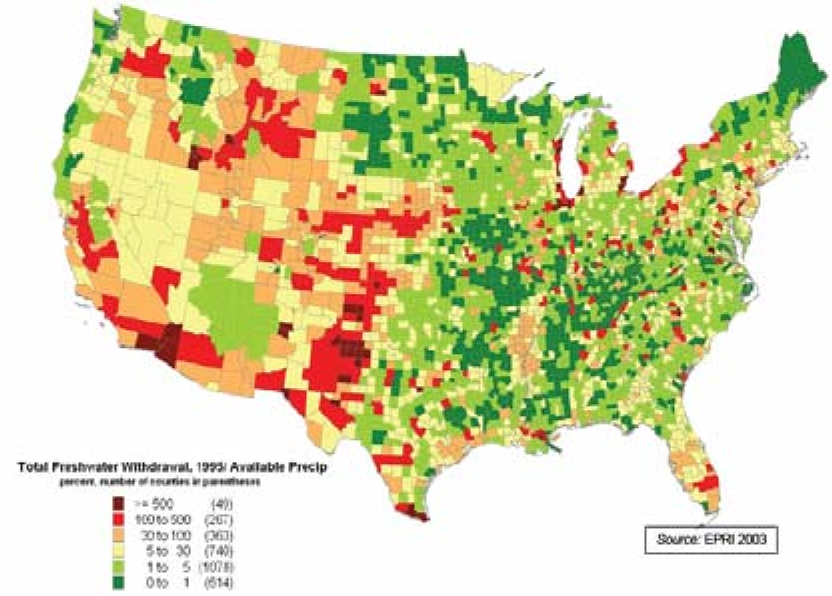
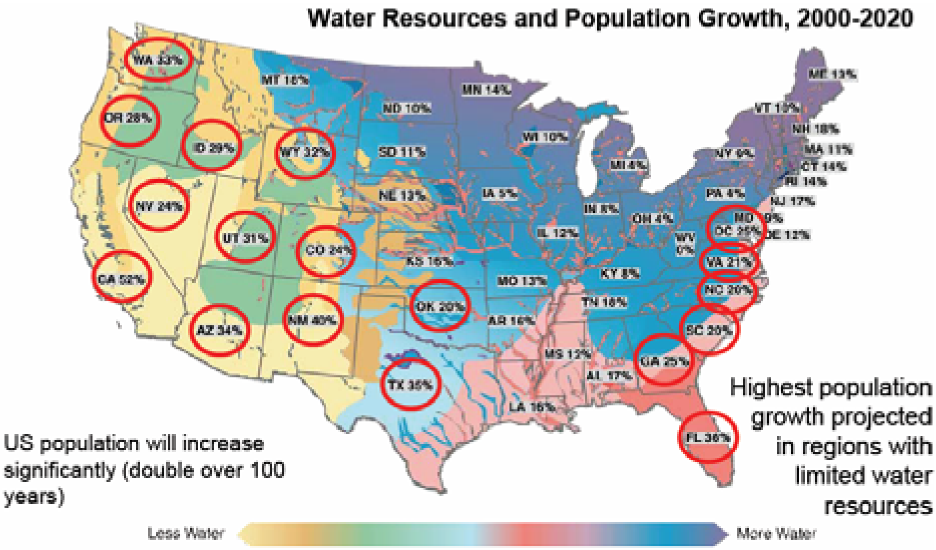


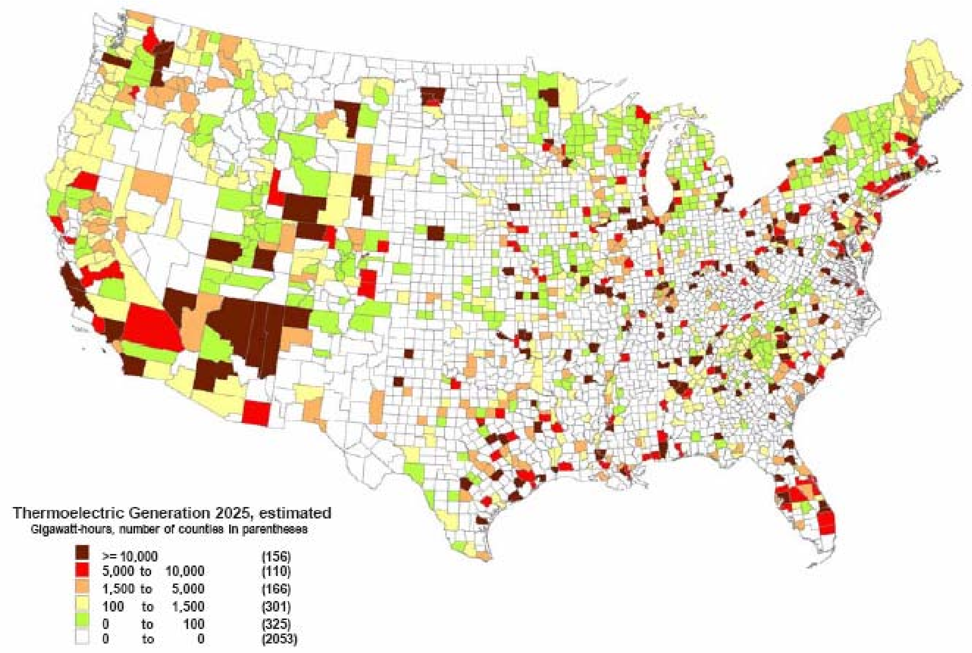
Figure 3 - Link Between Water Resources and Population Growth (Feeley, 2004)



Source: DOE/NETL (M. Chan, July 2002)

As growth in arid areas spurs demand for water, it will create commensurate additional electric demand. In recent years, increasing demand has been met primarily with new thermoelectric generation. In a water-constrained region, it will be difficult for new thermoelectric plants to gain access to water for traditional cooling needs while sustaining agriculture and other water needs. Dry cooling of thermoelectric power plants is an option, but it increases capital and operating costs and lowers efficiency in comparison to wet cooling. Figure 4 shows areas in which new generation is likely needed to meet growing demand, based on census division forecasts.

Figure 4 – County Projected Thermoelectric Generation Needs for 2025 (Roy et al., 2003)

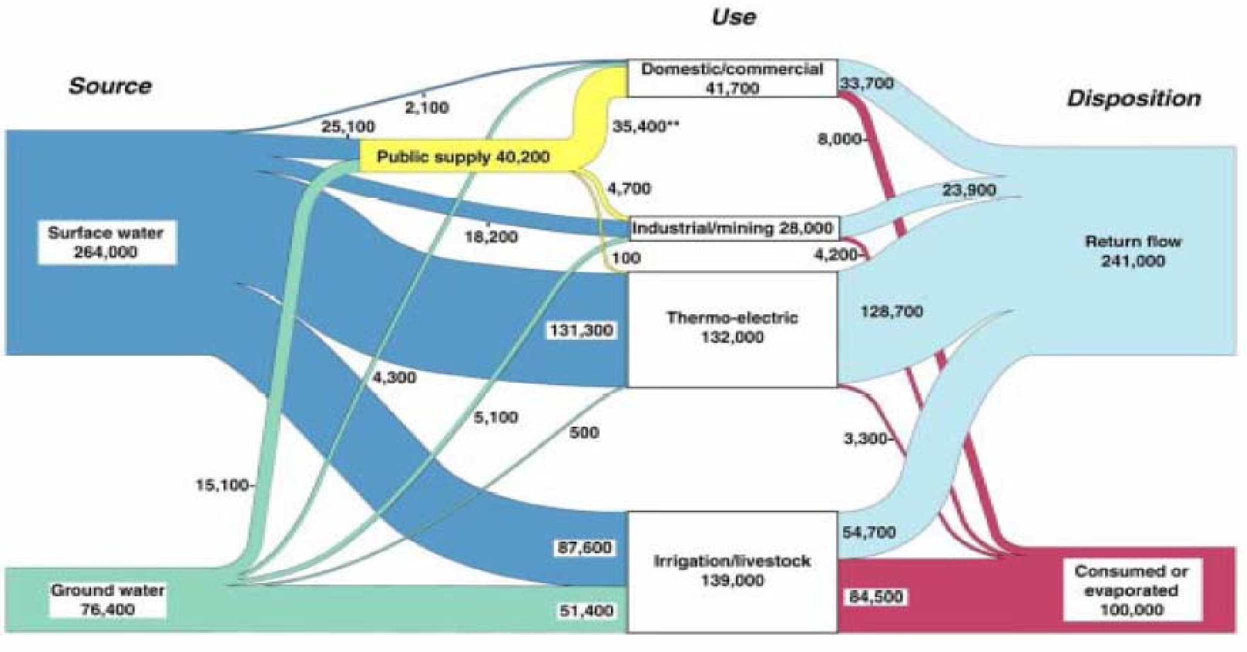


Sustainable water resources also traditionally provide environmental services to the community. Lakeside, coastal and riparian communities make use of local surface water systems for wastewater services, thermal sinks for power plants, and returns for agricultural runoff. As the capabilities of these natural systems become saturated or water is withdrawn to serve new power plant requirements, these currently low-cost services will likely shift to more expensive engineered systems.

These systems will place added pressures on farmers to accelerate fallowing of irrigated lands as water rights are sold to power plant developers, and the need for increased supplies for urban users will also create a demand for processed forms of wastewater, including the use of recycled water for landscape irrigation, greywater use, and aquifer re-injection with processed surface waters.

According to the U.S. Geological Survey, freshwater withdrawals in the United States were estimated in 2000 to be about 345,000 million gallons per day (Mgal/day) (Hutson et al., 2004). Figure 5 (based on 1995 data) illustrates the various sectors' relative water withdrawals.

Figure 5 - Estimated U.S. Freshwater Use in 1995 (Total ~341,000 Mgal/Day) (Lawrence Livermore National Laboratory, 2003)



Source: U.S. Geological Survey, Publication 1998-064214.
*In addition, 60,800 Mgal/day of saline water was withdrawn, primarily for thermo-electric use.
**Includes public use and losses of 5,980 Mgal/day.
Note: Numbers shown may not add to totals because of independent rounding.

Lawrence Livermore National Laboratory, April 2003

2. STRESSES ON MUNICIPAL WATER SERVICE PROVIDERS

As implied above, municipal water providers will need to devote greater attention to balancing competitive demands on water resources resulting from human consumption, power generation, agriculture, and environmental needs. Already, several U.S. regions have experienced a confluence of water-use issues. The Everglades management plan, Cal-Fed Bay Delta process, and Salton Sea salinity mitigation strategies are examples of the often contentious negotiations over the use of water. Although the issues of concern in these areas have mainly been the competitive claims for water across the urban, agricultural, and environmental sectors, costs for operating water utilities will become an added concern as energy becomes more expensive, with resulting increases in tariffs expected to be met with criticism from customers. Furthermore, U.S. water utilities are dealing with growth and new supply needs. At the same time, more stringent water quality requirements are placing greater demand on treatment and resulting energy needs. Arsenic, argon, MTBE, and a long list of biological contaminants are becoming more of a concern as municipalities seek out marginal resources.

With all of these stresses, due to the high initial cost of capital-intensive waterworks projects, water and wastewater utilities typically manage considerable debt. Fluctuations in energy costs create both additional risks for meeting debt-service requirements and the additional need to continually adjust rates. For many utilities, an increased pace for ratemaking can be a significant administrative burden.

2.1 Energy Requirements

Energy needed is fundamentally tied to the physical layout of the water supply system. The power needed to lift ground water can be expressed as $W = Q \times \rho \times H$ where w is the power needed, Q is the water flow rate, ρ is water density and H is the "head". For pumping water through pipes, the equation is the same, except that the total head, H, is the sum of the both the gravity head and the head loss due to pipe friction.

Dr. Robert Wilkinson defines the *energy intensity* of water as "the embodied energy, the total amount of energy, calculated on a whole-system basis, required for the use of a given amount of water in a specific location" (2000). Based on this definition, he has estimated the average energy requirement for blended (local and imported) supplies for a municipal utility in California to be as high as 2,439 kWh per acre-foot (AF). At one AF per 325,851 gallons, this translates into about 1 kWh for each 134 gallons produced. A 1996 study by the Electric Power Research Institute (EPRI) by Franklin Burton estimates the national energy use by water systems at 75 billion kWh, which at the time represented three percent of total national electricity demand (Burton 1996).

As would be expected, energy use by municipal water providers varies widely among the services provided. For example, the CEC provides several case studies that describe energy usage for a variety of water services. Figure 6 lists energy use per acre-ft (kWh/AF) of delivered water for the Inland Empire Utilities Agency in Chino, California (Wilkinson, 2000). Overall, the average energy use for water treatment in Southern California is about 652 kWh/AF (Hoffman, 2004).

As demonstrated in Figure 6, desalination is extremely energy intensive. Nevertheless, desalination water is produced all over the world, mostly in the Middle East where energy is less costly and other sources of water are more expensive. Two technologies are used: reverse osmosis (RO) and multi-stage flash (MSF) distillation. Energy requirements for RO range from 4,400 (Chaudhry, 2005) to 12,000 kWh/AF and 28,500 to 33,000 kWh/AF for MSF (Hoffman, 2004).

Figure 6 - Energy Use per Acre-Ft (kWh/AF) of Delivered Water from a CA Municipal Utility

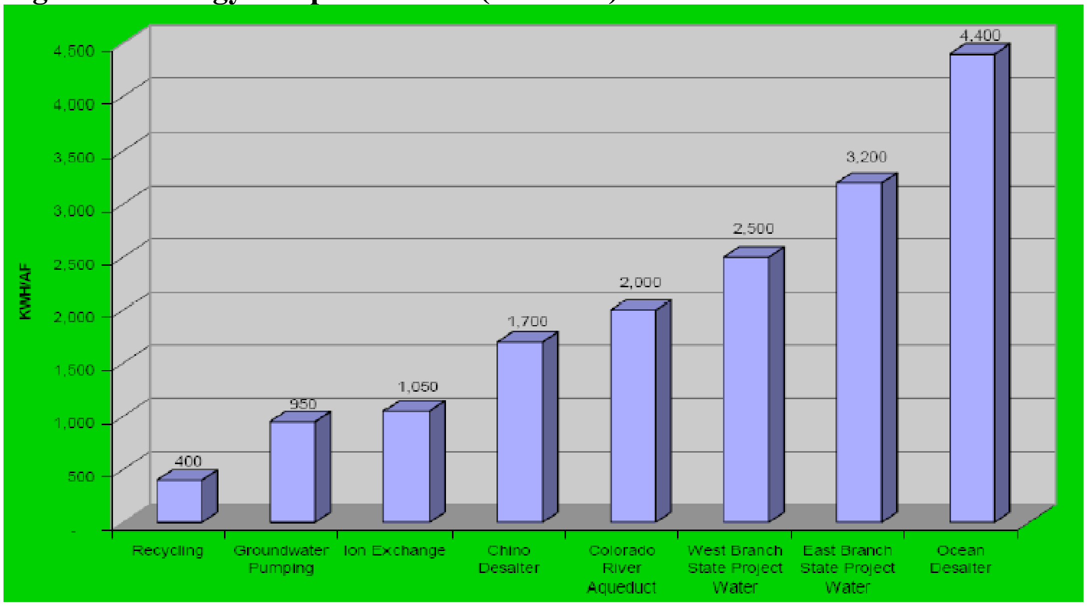


Figure 7 - Comparison of U.S. Annual Freshwater Withdrawals and Consumption, 1995 (Hoffman, 2004)

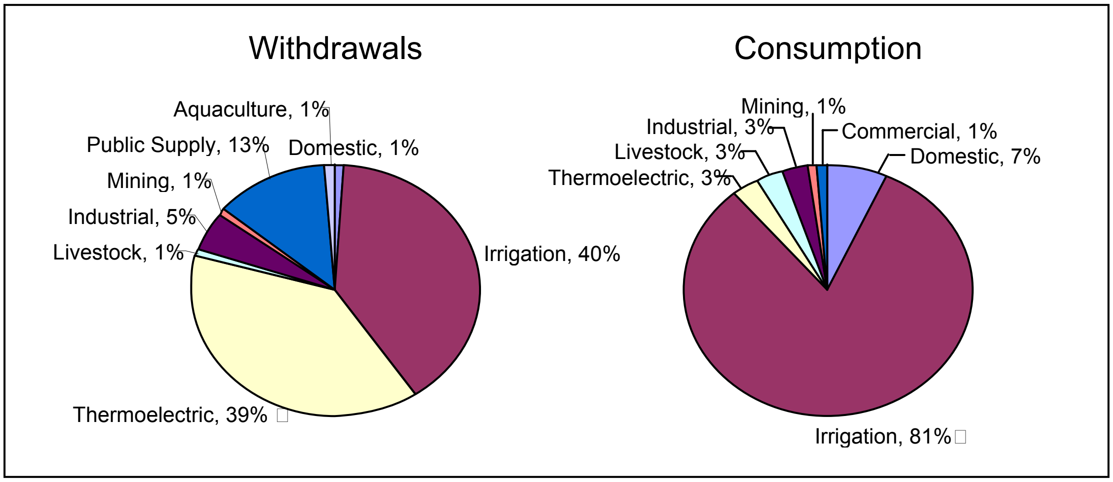


Table 1 shows the relative cooling water needs of fossil and nuclear generation, broken out by once-through (typically ocean or river-based) or wet-tower (evaporative cooling) systems (Feeley et al., 2004). It is important to note that current estimates include a shift from once-through to wet-tower systems. This shift will reduce the amount of total water withdrawals, but it will concurrently increase the amount of total water consumption by thermoelectric generation.

Table 1 - Cooling Water Needs of Fossil and Nuclear Generation (Feeley et al., 2004)

Fuel Source	Technology	Withdrawal (gal/kWh)	Consumption[9] (gal/kWh)
Fossil	Once-Through	37.7	0.1
	Recirc (Wet Tower)	1.2	1.1
Nuclear	Once-Through	46.2	0.1
	Recirc (Wet Tower)	1.5	1.5

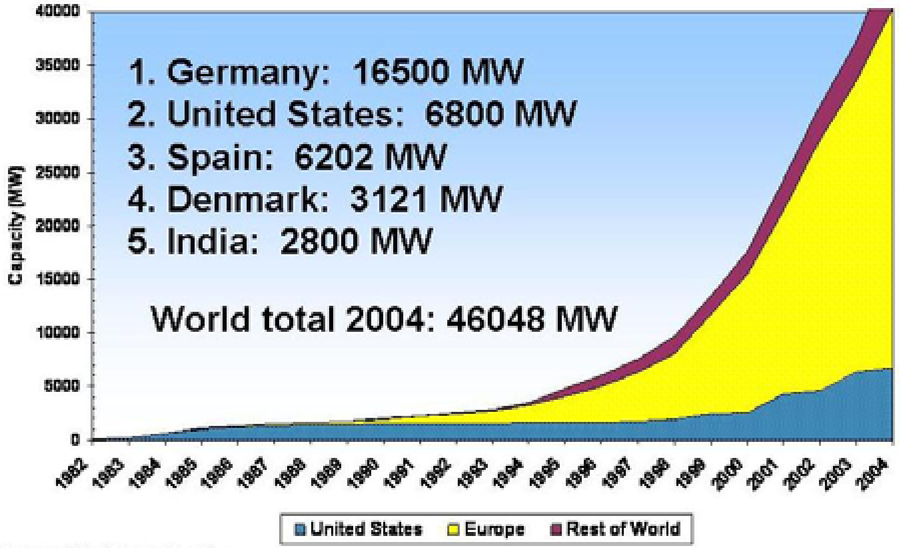
3. WIND ENERGY TECHNOLOGY PROGRESS

The U.S. has a rich history of employing wind energy to mechanically pump water. Without the water-pumping windmill, for example, it would have been much more difficult to establish rail transportation across the Great Plains. At the end of the nineteenth century, there was a boom in water pumping across the big cattle ranches and farms of the West, further facilitating westward expansion. Today, led by manufacturers such as General Electric, wind energy is a $3 billion annual industry in the U.S.

3.1 Wind Energy Market

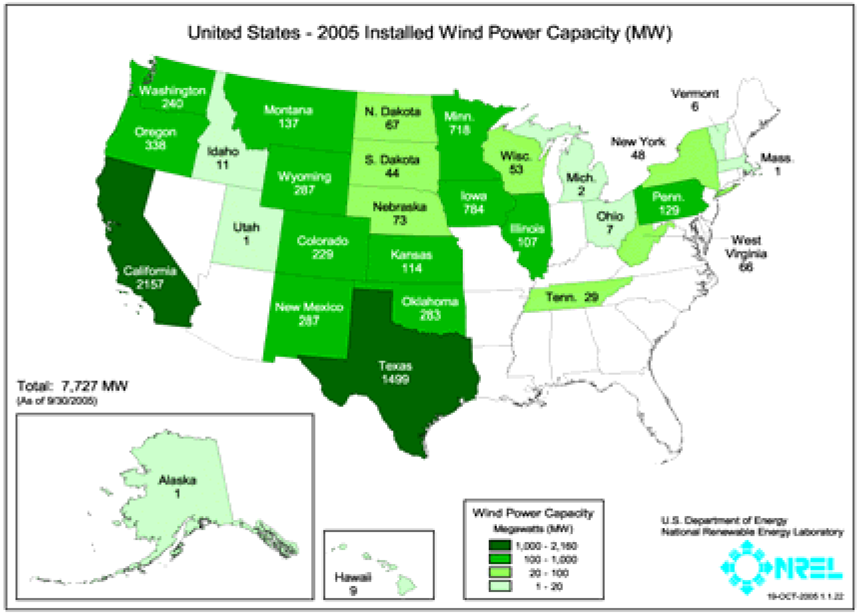
Wind energy is the fastest-growing bulk energy source in the world (Figure 8) and has become a significant commercial enterprise. At the end of 2004, the United States had about 6.4 gigawatts (GW) of installed capacity. By the end of 2005, with a) more than 50,000 megawatts (MW) installed worldwide (Global Wind Energy Council, 2005), b) more than 9 GW installed in the United States (U.S. Department of Energy, 2005b), and c) more than 30% annualized growth over the past 5 years, wind power worldwide generates enough energy to supply the needs of more than 9 million U.S. homes (American Wind Energy Association, 2005). Twenty-four states have significant operating utility-scale wind projects, and 16 of those states have more than 100 MW installed (Figure 9).

Figure 8 – Installed Wind Power Capacity Worldwide (end of 2004)



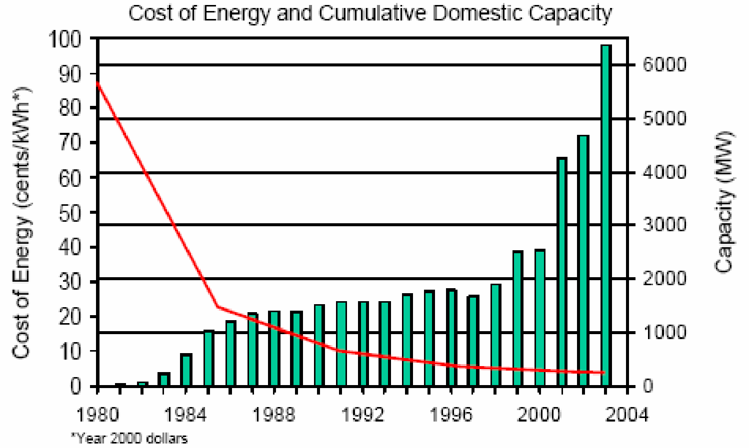
Source: *WindPower Monthly*

Figure 9 – Installed Wind Power Capacity U.S. by State (September 30, 2005)



The technology for utility-scale applications has come a long way since its commercial beginnings in the early 1980s in California. The average utility-scale turbine is now 1.5-2.0 MW in capacity (compared to 50 kW in 1980) and operates more than 98% of the time when the wind is blowing (the availability factor), compared to less than 60% of the time in 1980. These two factors, along with the strong growth in market demand, have resulted in a drastic decline in the cost of utility-scale wind energy (from more than 20 cents/kWh in the early 1980s to 4-6 cents/kWh in good U.S. wind regimes today. As the cost of wind energy for bulk power applications has decreased, the number of installations has increased. (Refer to Figure 10.)

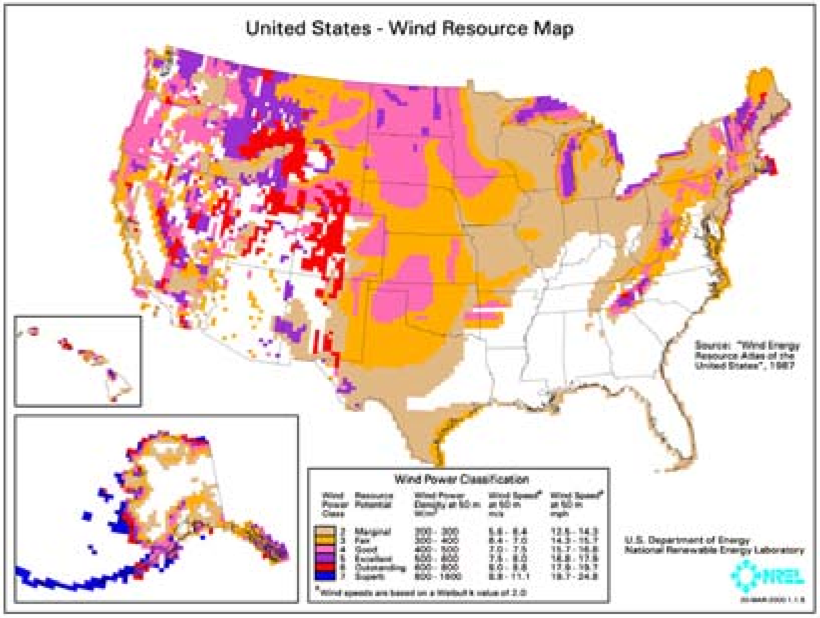
Figure 10 - U.S. Overall Growth and Cost Reduction since 1980 (Flowers, 2005)



3.2 Market Drivers

The drivers for this rapid expansion of wind energy include declining wind costs, fossil fuel price increases and uncertainty, federal and state policies, economic development impacts, the growth of the green power market driven by customer preference for clean energy, and energy/economic security. While costs of wind energy have declined over the years, so have prices. Figure 11 shows the range of wind resources across the country. Currently, wind energy in good wind regimes is the lowest-cost form of new sources of bulk generation, in part because of the recent sharp increase in the cost of natural gas. Additionally, wind is a stable-priced product because it is not subject to fuel price variations and uncertainty. No other energy or commodity can be predicted 20 years in advance. The uncertainty associated with the future costs of other bulk electricity sources (natural gas, coal, nuclear) makes wind particularly attractive to institutional electricity buyers and self-generators.

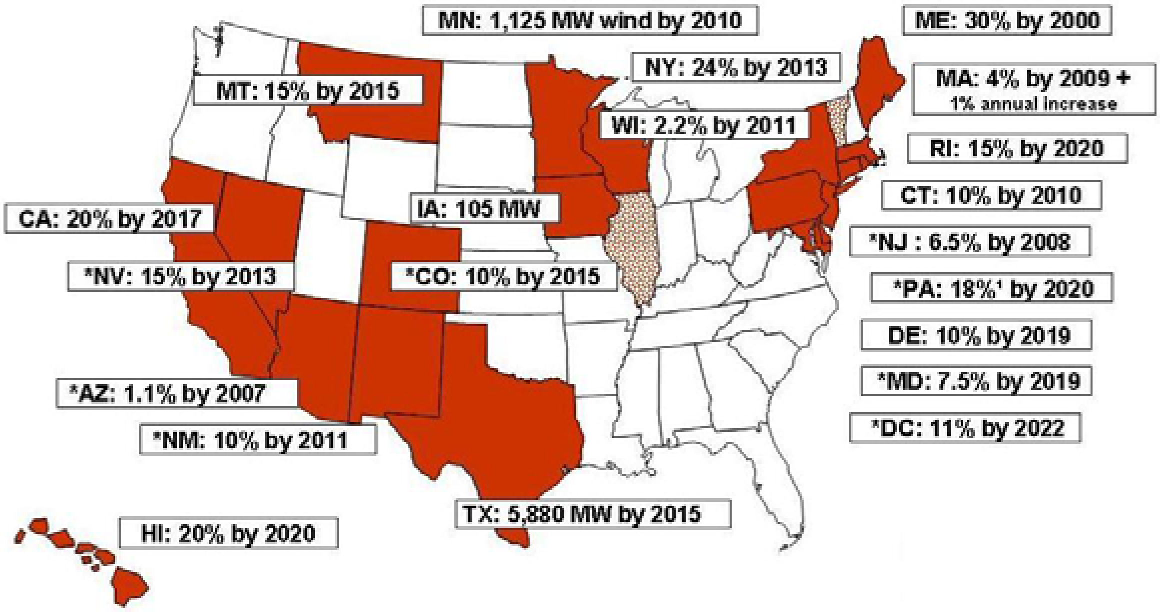
Figure 11 - Annual Average Wind Resource Estimates in the U.S. (U.S. Department of Energy, 2005a)



The federal production tax credit (PTC), an incentive of 1.5 to 1.9 cents per kWh, and accelerated depreciation for wholesale wind energy facilities are important financial enticements to wind developers and investors. The Energy Policy Act of 2005 (EPAct) extended the PTC until the end of 2007. For entities without federal tax liability, EPAct established a bonding instrument, Clean Renewable Energy Bonds (CREBs), for co-ops, municipalities, and a number of other non-profit institutions.

On the market demand side, 20 states and the District of Columbia have established Renewable Portfolio Standards (RPSs) (Figure 12) to require the utilities to include a predetermined amount of renewables in their future generation portfolios. For example, Texas passed an RPS that mandates 2.28 GW by January 1, 2007, and 5.88 GW by January 1, 2015.

Figure 12 - States with Renewable Portfolio Standards



A number of states have also established a Systems Benefit Charge (SBC) fund, based on a small per-kWh charge, to (for example) buy-down the first cost of small renewable energy projects that are otherwise non-competitive (see www.dsireusa.org for more information).

The economic development benefits of wind energy development to rural economies are substantial. For conventionally developed, third-party-financed projects, the local and state economic development benefits include lease payments to landowners, county and state property and sales tax revenues, and construction and operations and maintenance job income. The large majority of these income streams remain in the rural community that hosts the wind project, with multipliers that include indirect and induced income on the order of 2 to 2.5.

For example, 40 MW of wind development in Hyde County, South Dakota, resulted in $400,000 - $450,000/yr (not including the multiplier effect), including:

- More than $100,000/yr in annual lease payments to farmers ($3,000 - $4,000/turbine/yr)
- $250,000/yr in property taxes (25% of Highmore’s education budget)
- 75 -100 construction jobs for 6 months
- 5 permanent O&M jobs
- Increased sales taxes of more than 40%.

The 8000-plus MW of wind installed in the rural United States represent more than $9 billion in invested capital which – with the multiplier effect – will have results on the order of $4.5 - $9 billion in rural economic development over the 20-year project life. If the 2020 installed capacity goals (200 GW) of the American Wind Energy Association are met, the result will be $100 - $200 billion of rural economic development. When the projects are locally owned, the resulting economic development is even greater— hence the emerging interest in community wind concepts. According to David Benson, farmer and county commissioner of Nobles County, Minnesota, “Wind is a homegrown energy that we can harvest right along side our corn or soybeans or other crops. We can use the energy in our local communities or we can export it to other markets. We need to look carefully at wind energy as a source of economic growth for our region" (personal communication, 2002).

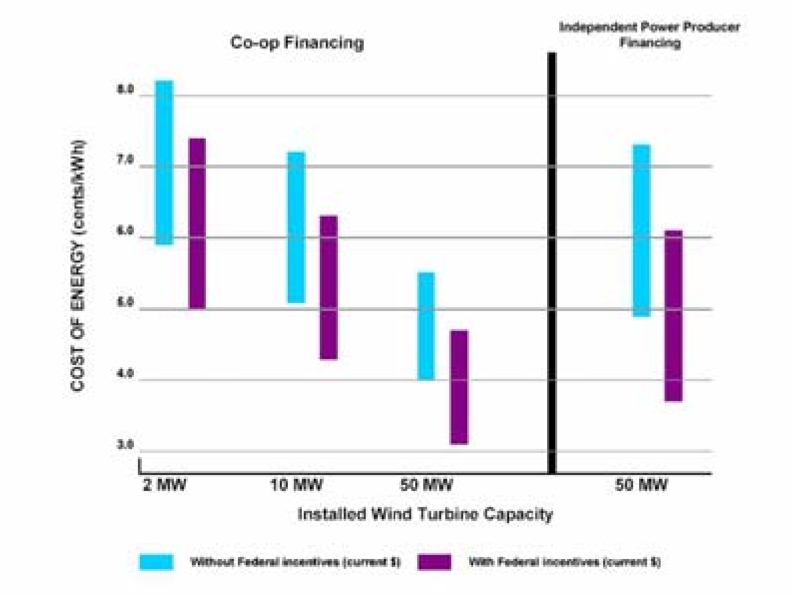
In a number of surveys, electricity consumers have overwhelmingly supported an increased amount of renewables in their electricity providers' portfolios to reduce the environmental impacts of conventional generation, and they have stated that they are willing to pay a modest premium for clean energy. Approximately 600 U.S. utilities now offer green power products, which include 2050 MW of wind energy. Originally, green pricing programs were offered to provide an opportunity for customers to pay a small premium to purchase renewable energy. Reflecting the cost advances of wind turbines and recently increasing costs for fossil-powered generation, customers enrolled in "green pricing" programs in some utility service areas are paying less than "traditional" customers. After the Denver Post reported in October 2005 that subscribers to Xcel Energy's Windsource program were paying less for energy, the number of new applications for the program soared. Xcel reports that Windsource is fully subscribed with 33,265 Colorado customers and a waiting list of 1,100 (Raabe, 2005).

The concept of energy and economic security is currently in national and global discussions. Wind energy represents an important player in this field because it is an inexhaustible, stably priced, economically competitive, environmentally preferred, indigenous resource that often provides greater economic development impacts to rural communities than conventional generation alternatives.

3.3 Market Economics

In the United States, most investment decisions in electricity generation are based on the comparative economics of generation options and fuel costs and projected demand. A basic understanding of the key elements that determine the cost of wind power is important. The four major drivers for the economics of wind are wind resource, project size, financing, and policy incentives (Figure 13).

Figure 13 – Major Drivers for Wind Economics



Because the energy in the wind is proportional to the cube of the wind's velocity, the wind resource is the most important parameter in the cost of wind. For example, a 1-mph difference in the average wind velocity can have a 1 cent/kWh impact on the delivered wind energy cost. The sensitivity and importance of this variable make it crucial to measure the wind speed for at least 1 year at the site (preferably at hub height).

There are important economies of scale in the development, manufacturing, construction, and operation of wind projects. Thus, a 100-MW project will have significantly lower capital cost/MW, and for the same wind resource, a lower cost of energy (the critical parameter in competitively bid projects) than a 1-MW to 10-MW project. The third important element is the financing parameters; since wind projects use no fuel, they are more capital intensive (not necessarily more costly per installed kilowatt) than conventional generation. Thus, the project cost of capital is important; e.g., a conventional loan of 8%-10% for 10 years will have a significantly higher per/kWh cost than a 5% U.S. Department of Agriculture Rural Utility Services loan for 20 years, for the same project; this aspect will highlight the energy cost benefit of the newly enacted CREBs (which will lower the interest rate on renewable energy projects to near zero). The fourth parameter is policy incentives. The current federal PTC is 1.9 cents/kWh for the first 10 years of the project; in an excellent wind resource, this incentive could exceed 35% of the net worth of the project. Some states have instituted their own state PTC. Some have instituted production-based payments, some have reduced property and sales taxes, and some have designed power purchase agreements (PPAs) to be front-end loaded. It should be noted that all forms of electricity generation have incentives/subsidies, often not directly reflected in the energy cost. The PTC was instituted by Congress to somewhat level the "subsidy playing field" with conventional electricity generation sources.

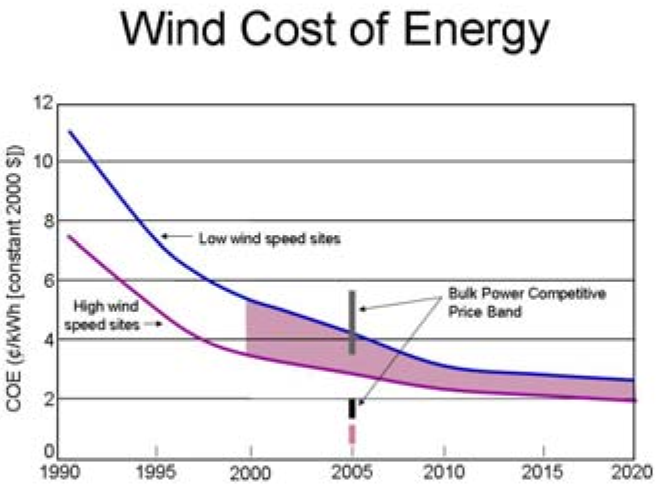
Additionally, several studies have characterized the cost of utility ancillary services needed to integrate intermittent wind power into major utility grids (Interwest Energy Alliance, 2004). *Wind Power Impacts on Electric Power Systems Costs: Summary and Perspective on Work Done to Date* summarizes various studies of incremental cost, with results varying from 0.147 cents to 0.550 cents per kWh. Included in the report is an Xcel Energy ancillary cost of 0.185 cents/kWh in Minnesota, and a Bonneville Power Authority (BPA) ancillary cost at 7% wind penetration of 0.147 cents/kWh to .227 cents/kWh. These results indicate that the additional costs for today's level of wind penetration in utility grids is in the range of .25 cent/kWh to .50 cent/ kWh. The November/December 2005 issue of *IEEE Power and Energy Magazine* (refer to www.uwig.org) is devoted to the integration of wind energy into the electric power system and addresses ancillary services among other integration issues.

A final note on the economics of wind relates to what it is compared to: as previously noted, in good wind regimes new wind energy projects are usually lower (energy) cost than new conventional sources, as demonstrated by recent Integrated Resource Planning (IRP) processes in Minnesota and Colorado. According to Mark Kapner, manager of conservation and renewable energy at Austin Energy, "We at Austin Energy found that large wind energy projects are the least expensive new electric generation source. Not only is the price lower than other renewable sources, it's even lower than the fuel cost of our natural-gas-fired units. We're learning how to handle the non-dispatchable and somewhat unpredictable nature of wind energy" (personal communication, 2002).

In minimal-load-growth, energy-export markets (e.g., the Dakotas), new wind projects compete with older coal plants that have been fully amortized and whose marginal cost only includes the variable cost of the next shovel of coal; this "avoided cost" of the next kilowatt-hour of energy that the wind project would offset is often less than 1.5 cents/kWh. Therefore, new wind costs more than old coal. However, once the wind plant is fully depreciated and the loan is repaid, its O&M cost is less than 1 cent/kWh, and since there is no fuel, it costs less and is more economically certain than old coal.

The bottom line: new wind is less expensive than new coal (or natural gas), old wind is less expensive than old coal (or natural gas), but new wind is more expensive than old coal. Also, beware of comparisons of new wind projects to average generation portfolio avoided costs, which often include substantial amounts of fully amortized, older facilities (Figure 14).

Figure 14 - Wind Cost of Energy



3.4 Implementation Issues

The modern wind energy industry is slightly more than 25 years old, and during that time it has addressed many issues associated with integrating wind onto the grid. Modern wind turbines have evolved to be highly reliable, grid-friendly, remotely operated and monitored, serviceable, and environmentally preferred electricity generators. Because the output of wind generators is not dispatched by the utility control center, they are different from conventional generators. Until penetrations of wind power exceed 10% to 15% of the utilities' instantaneous load, the utility dispatcher sees wind energy much like a negative load, varying in time. While wind energy is not perfectly predictable, there have been significant technical advancements in both 24-hour and 1-hour ahead forecasts, thus minimizing the cost of integration, mostly in the areas of load following and unit commitment.

Another utility concern has been limited transmission availability. Certainly if AWEA is to achieve its goal of 200 GW by 2020, significant investments in transmission will be required. A number of regional groups are investigating strategic transmission upgrades and additions, depending on load growth and future generation portfolio scenarios. However, in the meantime, the Federal Energy Regulatory Commission (FERC), which oversees interstate electricity transmission rules, is investigating means of using the existing grid more efficiently, including tariffs to allow wind to supply during unconstrained periods (a large fraction of the time, even on constrained paths). Additionally a number of regional transmission organizations have relieved wind projects from the punitive imbalance penalties of FERC Order 888 that were designed to discourage energy market manipulation. Often, especially in community-sized projects (less than 10 MW), utility-scale turbines can be interconnected to the distribution system, thus minimizing the need for transmission upgrades. A number of such projects have been implemented in Minnesota and Iowa with low-cost, safe, reliable, and code-compliant interconnection procedures.

Siting of wind energy projects requires permits from local authorities, and in some cases, state and federal agencies. Working with the local community to fully disclose the project impacts and benefits early and often has proven useful in getting community support and permitting authority approval (National Wind Coordinating Committee, 2005). Often, issues of wildlife interactions, noise, and visual impacts arise during the permitting process. All are important issues, and with established guidelines and practices, can be addressed effectively. The National Wind Coordinating Committee (NWCC) is a multi-stakeholder group that has studied both wildlife and other siting practices. It has published case studies and held workshops on these aspects. One of the findings is that, of the 100 million to 1 billion birds killed in collisions with manmade structures every year, researchers estimate that 10,000 to 40,000 fatalities can be attributed to collisions with wind turbines (Erickson et al., 2001). Noise from wind turbines has been dramatically reduced in modern wind turbines, and at 1000 ft (normal minimum setback), the noise is less than 40 dB (American Wind Energy Association, 2004), which is equivalent to refrigerator noise from an adjoining room. Computer simulations are routinely done to demonstrate the visual impacts from various vantage points in the community. Ultimately, however, permitting authorities need to weigh the benefits and the impacts of wind energy.

3.5 Wind-Powered Water Service Applications

Wind turbines are interconnected to the grid at the transmission and distribution levels or are off-grid. Transmission-level interconnections are designed for bulk-power generation involving up to several hundred-MW-scale facilities connected to utility substations feeding long-distance transmission operating at over 100 kiloVolts (kV). Distribution-level interconnections involve a smaller number of turbines feeding a local distribution feeder operating at less than 100 kV. Off-grid systems range from dedicated electric water pumping for home or livestock use, to battery-based residential systems, to sophisticated wind-diesel hybrid village power systems.

The top five potential applications for water utilities using wind energy generation have been identified as:

1. Transmission or distribution-connected wind generation providing low-cost, price-stable bulk power to water utilities,
2. Customer-side interconnected wind generation providing demand-side energy cost reductions to water utilities
3. Distribution-connected rural wind installations meeting both wind electric pumping for agricultural irrigation and other local loads.

4. Wind-electric heating for supplanting propane (and in coming years, natural-gas) fired thermal applications.
5. Wind-powered off-grid power for water utility operations where loads and distance to conventional electric service is uneconomic.

4. PROJECT OBJECTIVES

The main objective of this research is to characterize general opportunities in the municipal water sector for wind energy; specifically, to identify locations that may be constrained in water services due to several parameters. These parameters are presented in a matrix (Table 2) that is intended for use by energy and water analysts and providers. Though for this report, case studies were pre-selected, completion of the matrix has identified new locations for wind-water applications. The overall approach for this research is represented by Figure 15.

Figure 15 - Wind-Water Matrix and GIS Approaches Leading to Screening for Promising Case Study Candidates

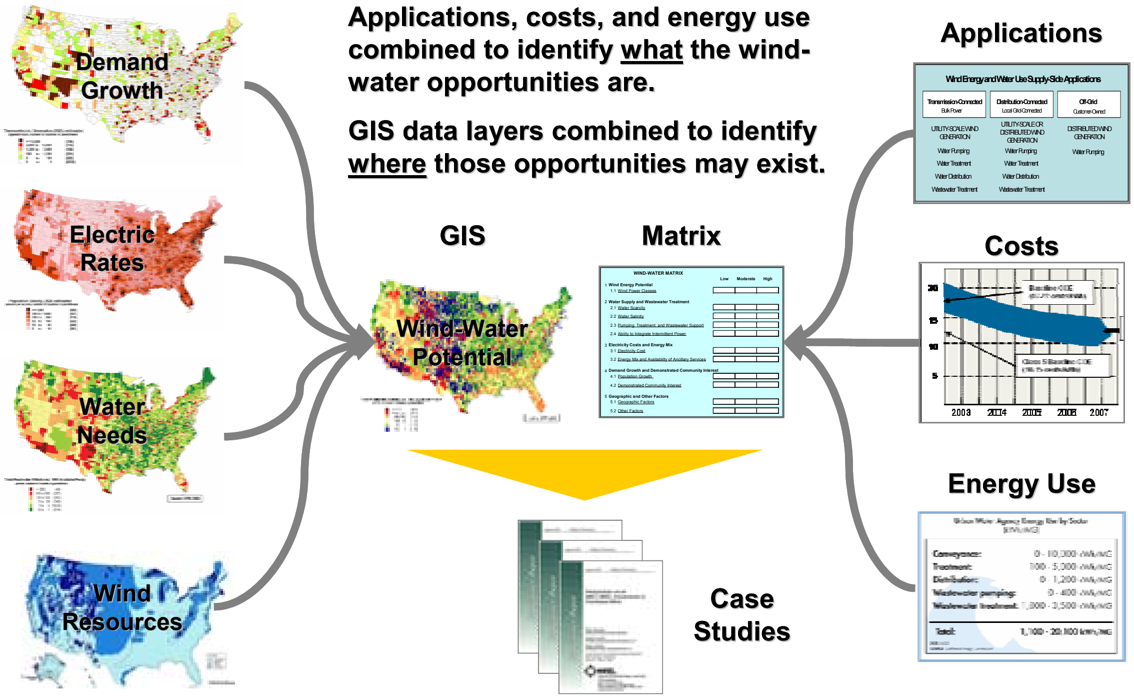


Table 2. Matrix of Wind-Water Opportunities

WIND-WATER MATRIX		**Low**	**Moderate**	**High**
1.0	**Wind Energy Potential**	1.1.1	1.1.2	1.1.3
1.1	Wind Power Classes			
1.1.1	Wind Class 1-2 (Low)			
1.1.2	Wind Class 3-4 (Moderate)			
1.1.3	Wind Class 5-7 (High)			
2.0	**Water Supply and Wastewater Treatment**	2.1.1	2.1.2	2.1.3
2.1	Water Scarcity			
2.1.1	Low Scarcity			
2.1.2	Moderate Scarcity			
2.1.3	High Scarcity	2.2.1	2.2.2	2.2.3
2.2	Water Salinity			
2.2.1	High Salinity (30,000 - 45,000 ppm tds)			
2.2.2	Moderate Salinity (15,000 - 30,000 ppm tds)			
2.2.3	Low Salinity (5,000 - 15,000 ppm tds)	2.3.1	2.3.2	2.3.3
2.3	Pumping, Treatment, and Wastewater Support			
2.3.1	Little Need for Support			
2.3.2	Moderate Need for Support			
2.3.3	High Need for Support	2.4.1	2.4.2	2.4.3
2.4	Ability to Integrate Intermittent Power			
2.4.1	Low Ability to Integrate Intermittent Power			
2.4.2	Moderate Ability to Integrate Intermittent Power			
2.4.3	High Ability to Integrate Intermittent Power			
3.0	**Electricity Costs and Energy Mix**	3.1.1	3.1.2	3.1.3
3.1	Electricity Cost			
3.1.1	Low Retail Rates			
3.1.2	Moderate Retail Rates			
3.1.3	High Retail Rates	3.2.1	3.2.2	3.2.3
3.2	Energy Mix and Availability of Ancillary Services			
3.2.1	Low Availability of Ancillary Services			
3.2.2	Moderate Availability of Ancillary Services			
3.2.3	High Availability of Ancillary Services			
4.0	**Demand Growth and Demonstrated Community Interest**	4.1.1	4.1.2	4.1.3
4.1	Population Growth			
4.1.1	Low Population Growth			
4.1.2	Moderate Population Growth			
4.1.3	High Population Growth	4.2.1	4.2.2	4.2.3
4.2	Demonstrated Community Interest			
4.2.1	Low Community Interest			
4.2.2	Moderate Community Interest			
4.2.3	High Community Interest			
5.0	**Geographic and Other Factors**	5.1.1	5.1.2	5.1.3
5.1	Geographic Factors			
		5.2.1	5.2.2	5.2.3
5.2	Other Factors			

4.1 Screening for Water Service Opportunities in Windy U.S. Areas

To identify locations well suited for both wind energy and clean water supply, a matrix was developed. Nine major sets of parameters are characterized in the matrix, plus several sub-level descriptive parameters (Table 2). For each of the major parameters (described in more detail below), one of three levels is assigned, running from least- to most-attractive for wind-water opportunities.

Wind Energy Potential

For this study, wind power potential is divided into three major categories of recognized U.S. wind speed/power classes that define wind resources in the United States: Low (Classes 1 and 2), Moderate (Classes 3 and 4, often associated with small, distributed-application wind turbines or larger utility-scale turbines built to Low Wind Speed Turbine design parameters), and High (Classes 5 and higher, which are excellent wind resources).

Refer back to Figure 11 for the map of U.S. wind energy potential; however, for more detailed data in the matrix, state-based maps were downloaded and reviewed. An example of a state wind map is the Nevada map in the case study below (Figure 21). Validated, high-resolution wind resource maps for 34 states and the District of Columbia can be found at http://www.eere.energy.gov/windandhydro/windpoweringamerica/state_activities.asp.

Water Supply and Wastewater Treatment

Water issues have been divided into water scarcity; salinity; pumping, treatment, and wastewater support; and ability to integrate intermittent power sources. Water scarcity is defined as the ratio of 2004 withdrawals divided by long-term annual average precipitation (refer back to Figure 2). Water salinity is disaggregated into three classes that can be addressed by wind energy; for salinity, the order of salinity categories follows from highest to lowest. For pumping, treatment, and wastewater support, the levels simply address the need for electric power supplies from new sources. The ability of the water supply and wastewater treatment provider to integrate intermittent power is important in estimating the likelihood of successful adoption of wind generation support by the provider.

Electricity Costs and Energy Mix

Along with wind resources and water needs, the cost and mix of electricity are critical factors in estimating the success of a wind-water application. The principal determining factor is the cost of electricity; in this study, costs are represented by the residential rate. Figure 16 presents statewide average electric utility costs, gathered from the EIA October 2005 utility rate report, in three categories: less than \$.07/kWh (low), \$.07-\$.10/kWh (medium), and over \$.10/kWh (high). The mix of energy resources also comes into play; if the mix can comfortably accommodate wind added for water applications, or the electric system can provide ancillary services that enable wind interconnections, then a significant hurdle has been overcome.

Demand Growth and Demonstrated Community Interest

Figure 17 shows population growth centers, with calculated county population growth rates from 2003-2004, based on U.S. Census estimates. The map highlights the current and future population pressure zones within three growth categories: 0% or less (no or negative growth), 0-2.5% (normal growth), and over 2.5% (high growth).

Demonstrated community interest is scored based on membership in a regional, national, or an international environmental organization. Some examples include the International Council for Local Environmental Initiatives (ICLEI), Federal Clean Cities, National League of Cities, and U.S. Mayors Climate Protection Agreement.

Figure 16 - Statewide Average Electric Utility Costs

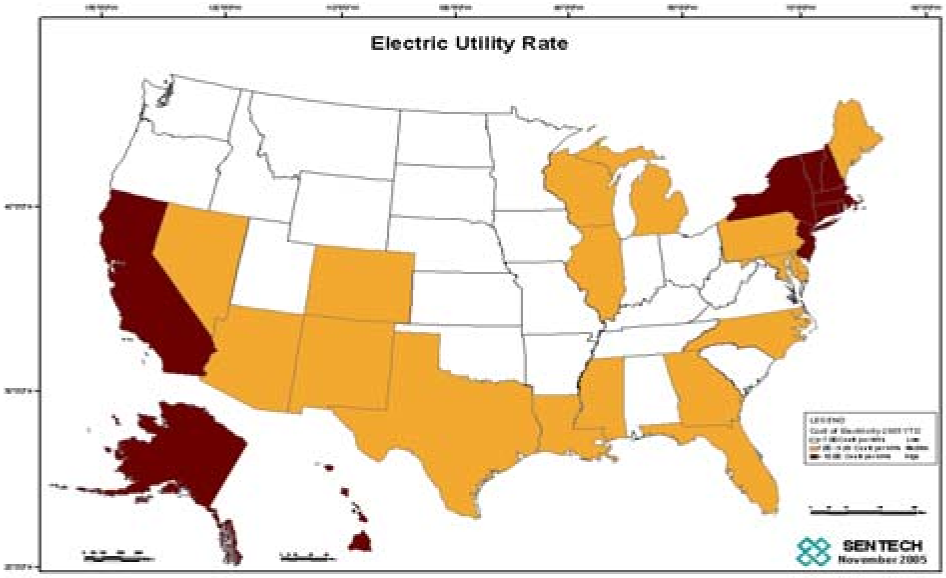
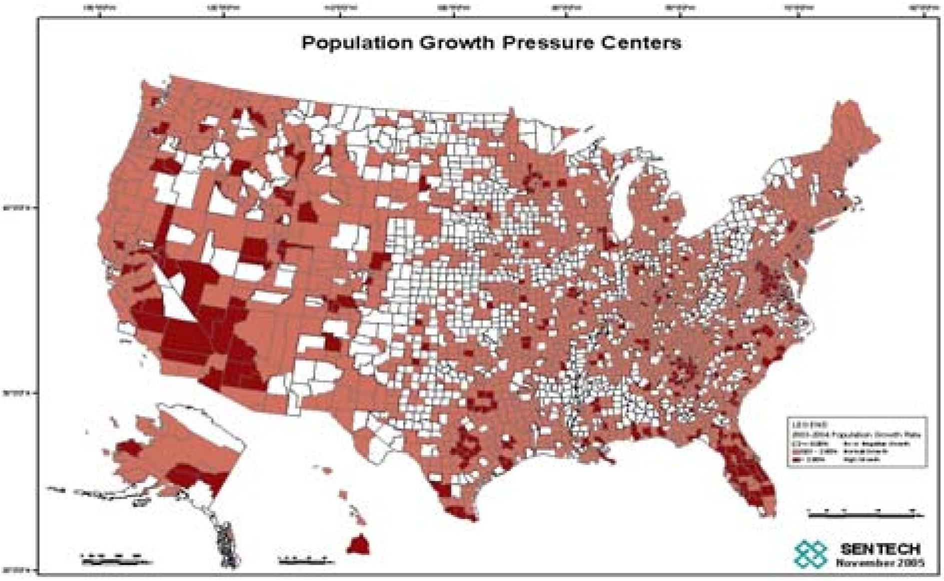


Figure 17 – County Population Growth Pressure Centers



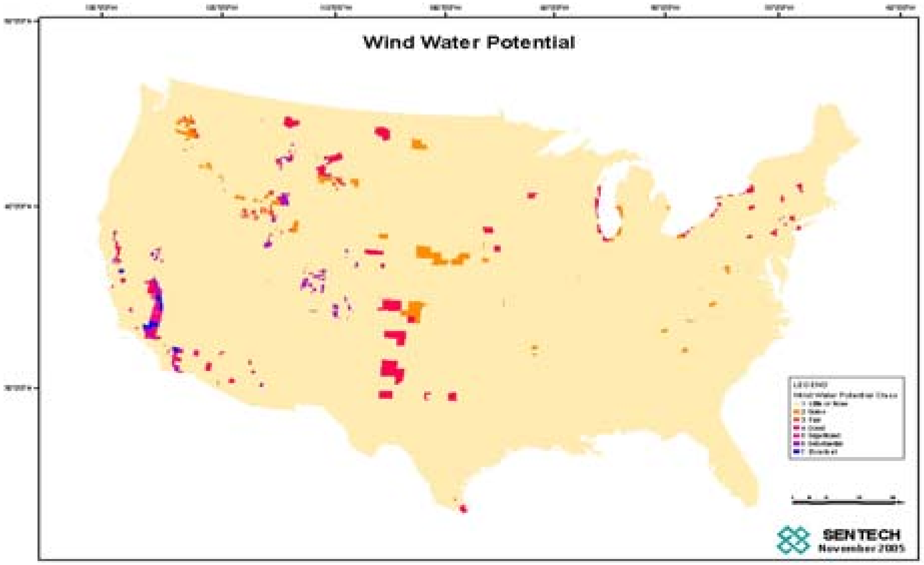
Geographic and Other Factors

In particular cases, there may be unique factors that should be highlighted.

4.2. Analysis

The results of this research will be used in subsequent reports to highlight locations with conditions favorable to wind energy use by water providers. Initial findings show promising areas scattered around the U.S (refer to Figure 18). In the meantime, energy and water analysts and providers are invited to consider the parameters outlined above in their respective municipalities. Two case studies are outlined below as examples.

Figure 18 – Initial findings for U.S. locations with wind-water potential



5. CASE STUDIES

5.1 Austin, Texas

5.1.1 Wind Energy Potential

Austin is located in a relatively low wind energy potential area (Class 2) and lies approximately 250 miles from good land-based wind sources in western Texas and the Texas panhandle to the north. However, if recent proposals for off-shore wind development near Galveston come to fruition, this resource would be 150 miles distant.

5.1.2 Water Supply and Treatment

Water is currently used in and around the Austin area for municipal uses (residential, non-residential, and urban irrigation) and industrial uses (cooling, turf, and other uses). The Austin Water Utility (AWU) supplies water to customers within and outside the corporate city limits of Austin, as well as the communities of Rollingwood, Sunset Valley, Pflugerville, and Round Rock, one water control and improvement district, five water supply corporations, seven municipal utility districts, and three private utilities.

The total utility service area is 457 square miles. The water demand for each of these sectors in 2004 was calculated using information from the AWU. In 2004, AWU served almost 800,000 people, with 93% being retail population. The total demand for 2004 was 41.4 billion gallons

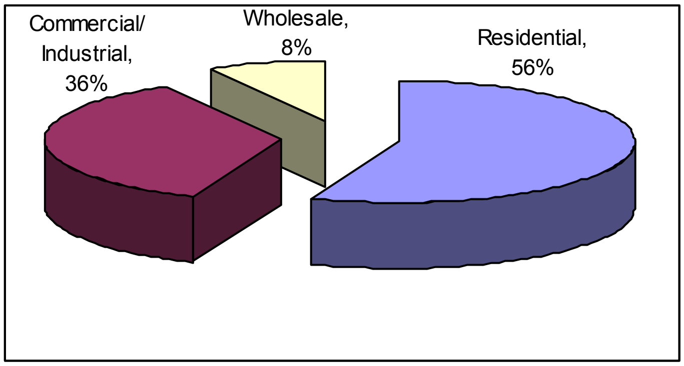
(127,000 AF), distributed among different water use sectors (Figure 19). This reflects a system-wide water demand of approximately 140 gallons/person/day. Residential is the most significant water use, followed by commercial/industrial demands.

5.1.3 Electricity Costs and Energy Mix

One hundred percent of Austin's water is derived from local surface sources: the Colorado River, including Lake Austin and Town Lake. As a result, there is very little pumping (or electricity use) prior to treatment.

AWU operates three raw water treatment plants (WTPs): Green, Ullrich, and Davis. Two of the WTPs (Green and Davis) are located on the Colorado River, while water is pumped 2,800 feet horizontally to the Ullrich WTP. The city maintains 34 distribution reservoirs with an effective storage capacity of 250 million gallons (768 AF). The city also maintains 47 pump stations and local booster stations.

Figure 19 - Austin Water Utility Normal Year Supplies



Total energy use related to treatment, distribution, and post-use treatment was 185,600 megawatt-hours (MWh) in fiscal year 2004. This equates to an average hourly demand of 21 MW/hr. Costs are listed in Table 3.

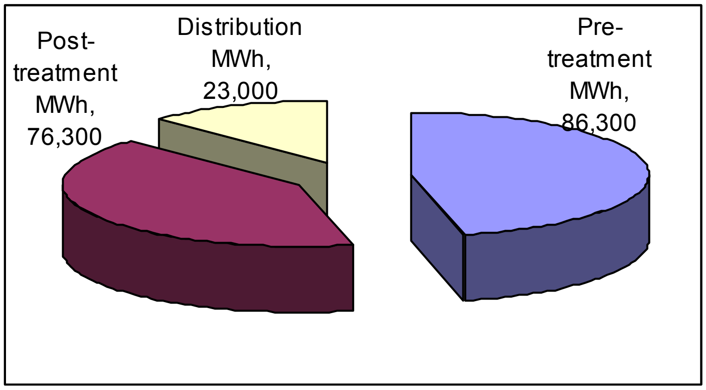
Table 3 - Austin Energy Residential Service Rates (over 500 kWh)

Billings Months	Energy Rate (cents/kWh)
May - Oct	7.82
Nov - April	6.02

A breakdown of electricity usage by water system segment is shown in Figure 20. Fiscal year 2004 energy use data includes:

- Treatment: 86,300 MWh (1780 kWh/million gallons for treatment of 48.5 billion gallons) [The demand for capturing water and getting water to treatment is included with water treatment.]
- Distribution: 23,000 MWh (557 kWh/MG for distribution of 41.4 billion gallons)
- Post-treatment (wastewater collection and treatment use): 76,300 MWh (2,439 KWh/Mgal for 31.3 billion gallons wastewater effluent treated).

Figure 20 - Austin Water System Energy Requirements, 2004



5.1.4 Demand Growth and Demonstrated Community Interest

Texas is growing at a rapid pace; the U.S. Census Bureau reports that it added 4 million residents state-wide from 1990-2000. Austin's projected 2030 service area population is 1.3 million, which is more than a 50% increase from the 2004 population. At current per-capita use rates, projected water demand will be 64.7 billion gallons/year (~200,000 AF). Austin projects meeting future water demand through its existing supply, the locally named Colorado River, where it has a water right to use 325,000 AF/year. Based on the answer to our survey, the AWU does not know all of its future needs at this time. Furthermore, it reports that all facilities in the water system need a constant and reliable source of power and that there is not enough wind in the local area to provide a reliable supply.

As for community interest, Austin Energy, the city's electrical utility, has contracts with wind generation fields in other parts of the state to provide a portion of the city's power needs. In fact, the utility just entered a 12-year contract for 128 MW from wind sources in western Texas. Furthermore, the City of Austin has its own renewable portfolio standard: 20% by 2020, with potentially 6.5% of this coming from wind power.

5.1.5 Geographic and Other Factors

Despite being located at a fair distance from good wind resources, several other factors may contribute to greater wind development related to municipal water needs such as: the transmission "bottleneck" related to wind sources from western Texas is improving, and there may be an opportunity for a pumped-hydro project, making use of the elevation difference between Lake Austin and Town Lake.

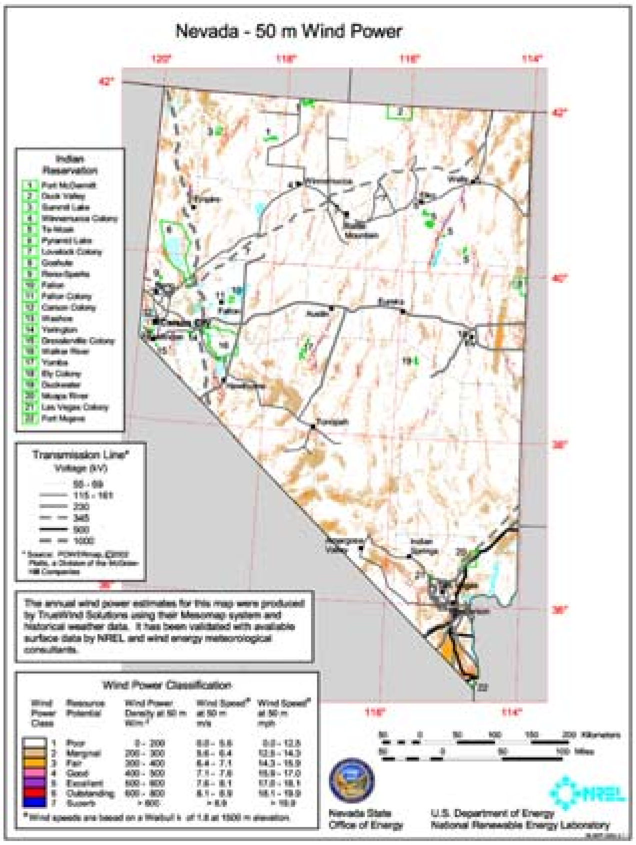
In summary, Austin is a fairly good prospect for applying wind to water-related energy demands. Although wind resources are not close by (and not close to the load), rapid growth, high rates for electricity from other fuel sources, and strong local support suggest that wind may have a good opportunity.

5.2 Las Vegas, Nevada

5.2.1 Wind Energy Potential

Although not pictured here (Figure 21), some of the good wind resource immediately around Las Vegas may be wind west of the city in California, or south of the city.

Figure 21 – Wind Energy Potential in Nevada



5.2.2. Water Supply and Treatment

Water is currently used in and around the Las Vegas area for irrigation, municipal uses (residential, non-residential, and urban irrigation), and industrial uses (cooling, turf, and other uses). Southern Nevada Water Authority (SNWA) is the water wholesaler for member agencies, which include the Cities of Las Vegas, Henderson, Boulder City, North Las Vegas, and portions of Unincorporated Clark County, Nevada. The water demand for each of these sectors in 2003 was calculated using information from the SNWA.

The SNWA provides wholesale water service to its member agencies. The SNWA's member agencies provide retail water and wastewater service to customers in their service areas. The population residing in their service areas was estimated to be about 1.58 million in 2003.

The SNWA's member agency normalized 2003 water use, including potable and non-potable water use, was about 169.5 billion gallons (520,000 AF) distributed among three sectors. Residential was the most significant water use, followed by commercial and industrial demands.

The SNWA and its member agencies currently obtain about 90 percent of its water from the Colorado River. In addition, the SNWA members use groundwater resources to meet the remaining roughly 10 percent of their water needs.

The SNWA owns and operates the Southern Nevada Water System (SNWS), which provides a majority of the water to the SNWA's member agencies. The SNWS consists of two intake structures, two water treatment plants, and a transmission system with a current combined delivery and treatment capacity of about 750 million gallons/day. The source water for SNWS is the Colorado River at Lake Mead. There is a limited distance between the SNWS intakes and its water treatment facilities. The farther of the two water treatment facilities is less than 5 miles from Lake Mead.

5.2.3 Electricity Costs and Energy Mix

SNWA's wholesale delivery of water includes pumping from the treatment facilities to several storage reservoirs prior to delivery to its member agencies. The SNWA's member agencies are responsible for distribution of water, since they are retail water providers. Total SNWA electricity usage for delivering water to the SNWA member agencies during 2003 was about 646,000 MWh. This equates to an average hourly demand of about 70 MW/hr.

5.2.4 Demand Growth and Demonstrated Community Interest

The SNWA anticipates that the Colorado River will continue to provide a majority of its water resource for meeting water needs of its member agencies. The SNWA is currently planning to develop surface and groundwater resources to deliver water to its member agencies and diversify its water resource portfolio. This plan is intended to result in a greater share of water needs being met from non-Colorado River sources in the long term.

The SNWA is pursuing a host of conservation programs. An advisory committee report summarizing a series of recommendations, including recommendations on water conservation, was presented to the SNWA Board in November 2005. The conservation recommendations included reducing the SNWA's system-wide per capita water use to 245 gallons by the year 2035 from a current per capita use of 294 gallons.

In July 2005, the University of Nevada Las Vegas - Center for Business and Economic Research forecast that Clark County, Nevada would grow from an estimated population of 1.64 million in 2003 to a forecast population of about 3.41 million in the year 2030. A majority of this forecast population is expected to reside in the SNWA's member service areas.

The SNWA is currently working on plans to develop surface and groundwater resources to deliver water to its member agencies and diversify its water resource portfolio. These projects together are anticipated to have an average hourly demand of between about 80 to 90 MW/hr. SNWA is currently meeting approximately 13% of its needs using hydropower from Hoover Dam.

5.2.5 Geographic and Other Factors

Wind power may be a future option to supply a portion of the SNWA's power needs. However, the intermittent nature of wind power must be considered. For example, SNWA has plans to build a solar generating facility and trade the non-firm power to Nevada Power Company for firm power to use for SNWA load. Perhaps wind energy could be used to offset peak power times to produce clean energy for the region.

6. RESULTS AND RECOMMENDATIONS

The growth in the U.S. population and the related economic growth will require additional energy and water. There are a number of regions and communities in the United States, especially in the West, that there are already non-sustainable withdrawals and consumptions of water resources. As water and energy demands grow with time, these areas will grow in number and intensity; additional, but uncertain, stress on the water systems will result from extended drought cycles. Therefore, growth in water demand (from all sources) combined with a finite, and possibly diminishing, resource creates a compelling need for consideration of alternatives to business as usual, especially for growing urban areas in the West. While not a focus of this paper, wind energy offers an energy source that uses limited water compared to thermoelectric generation (Clean Air Task Force and The Land and Water Fund of the Rockies 2003).

Wind energy can play a role in this context by supplying energy for municipal water supplies and processes. This can be in the form of pumping energy, water treatment, desalination, and, in some cases irrigation pumping. Because wind energy has low and predictable costs and is non-polluting, indigenous, renewable, and a minimal water user, it is an attractive alternative to conventional energy sources for supplying municipal water needs. However, the ability to apply wind energy to municipal water needs may be limited by the proximity of the wind resource to the load and the intermittent nature of the wind resource. At the same time, in certain cases the municipal water system storage capabilities and opportunities may somewhat mitigate wind's intermittency.

The DOE Wind program is in the process of characterizing the opportunity for wind energy in supplying energy for municipal water supplies. The opportunity will depend on each municipality's characteristics of wind resource, water supply and treatment requirements, energy costs and types, demand growth, community interest, and other geographic factors. Case study opportunities are being developed for a variety of municipalities based on these parameters. Following the development of the case studies, the opportunity for pilot projects will be explored with municipalities that have both a good opportunity and reasonable replicability of the application to other communities.

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As communities grow, greater demands are placed on water supplies, wastewater services, and the electricity needed to power the growing water services infrastructure. Water is also a critical resource for thermoelectric power plants. Future population growth in the United States is therefore expected to heighten competition for water resources. Many parts of the United States with increasing water stresses also have significant wind energy resources. Wind power is the fastest-growing electric generation source in the United States and is decreasing in cost to be competitive with thermoelectric generation. Wind energy can offer communities in water-stressed areas the option of economically meeting increasing energy needs without increasing demands on valuable water resources. Wind energy can also provide targeted energy production to serve critical local water-system needs. The research presented in this report describes a systematic assessment of the potential for wind power to support water utility operation, with the objective to identify promising technical applications and water utility case study opportunities. The first section describes the current situation that municipal providers face with respect to energy and water. The second section describes the progress that wind technologies have made in recent years to become a cost-effective electricity source. The third section describes the analysis employed to assess potential for wind power in support of water service providers, as well as two case studies. The report concludes with results and recommendations.

15. SUBJECT TERMS

wind energy; wind turbines; water; municipal water supplies; water conservation; municipal water; energy-water nexus

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