Texas Renewable Energy Resource Assessment

Prepared by Frontier Associates, LLC

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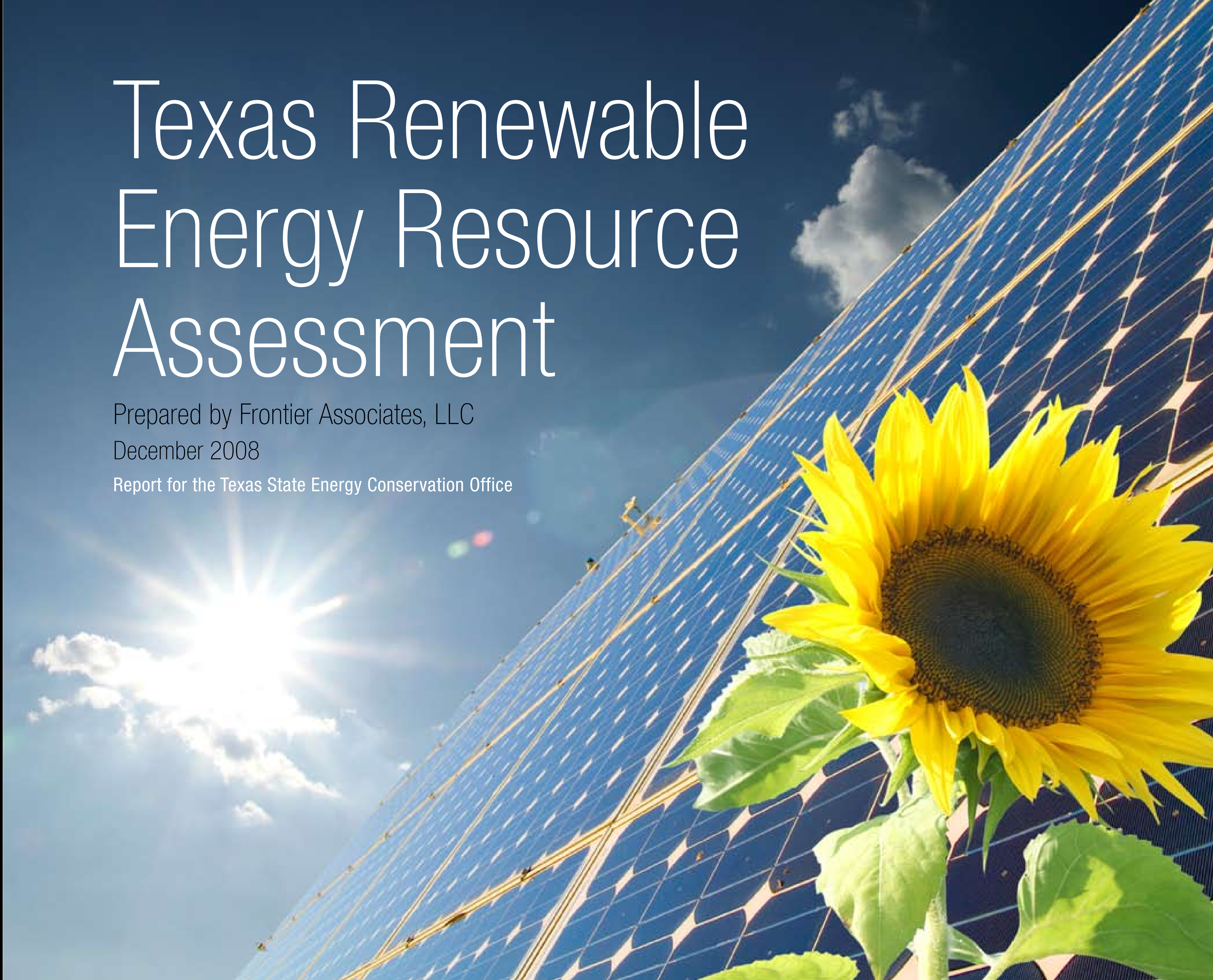
Report for the Texas State Energy Conservation Office



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SECO through the Innovative Energy Demonstration Program promotes the use of renewable energy and sustainable building practices through technology demonstration, hands-on instruction and renewable energy education.

Renewable energy can have significant economic development, security and reliability benefits and opportunities for Texas communities and individuals in the development of these resources.

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SUMMARY AND CONCLUSIONS

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EXECUTIVE SUMMARY

Overview

Texas leads the nation in non-hydropower renewable energy potential, being rich in wind, solar, biomass and geothermal resources. Wind resource areas in the Texas Panhandle, along the Gulf Coast, and in the mountain passes and ridge tops of the Trans-Pecos offer Texas some of the greatest wind power potential in the United States. Texas, in fact, leads the nation in wind-powered generation capacity, having surpassed California as the country's largest wind energy producer in 2006. Solar power potential is also among the highest in the country, with high levels of solar radiation suitable for distributed generation applications throughout the state, and direct sunshine capable of fueling large-scale solar power plants concentrated in west Texas. Due to its large agricultural and forestry sectors, Texas has an abundance of biomass energy resources. Texas' unused oil and gas wells provide access to a major geothermal resource. These renewable energy resources are available throughout the state and can be utilized in a variety of ways, from producing electricity through small, distributed systems or at large-scale central power plants, to providing liquid fuels for transportation.

Due to its large population and energy-intensive economy, Texas leads the nation in energy consumption, at 11.556 quadrillion Btu (2005),[1] up from about 10 quads in 1995, accounting for 11.5 percent of total U.S. energy use. Texas' per capita energy consumption ranks fifth in the U.S. at 506 MMBtu per year (2005).[2] Texas residential electricity consumption is significantly higher than the national average, due to high demand for air conditioning and the widespread use of electricity for home heating. Energy-intensive industries in Texas include aluminum, steel, chemicals, forest products, glass, and petroleum refining.

What has changed since the last report?

Texas' population and energy consumption is growing. Since the previous Renewable Energy Resource Assessment was written in 1995:

- The population of Texas has increased by approximately 28 percent, from 18.7 million to 24 million.
- ERCOT peak demand has increased by 33.6 percent, from 46,668 MW[3] to 62,339 MW.[4]
- Retail sales of electricity in Texas have increased by 30.2 percent, from 263,278,592 MWh to 342,724,213 MWh in 2006.[5]
- Texas retail electricity cost has increased by 221.8 percent, from $16.0 billion in 1995 to $35.5 billion in 2006.[6]
- The average retail price of electricity in Texas has increased by 70 percent, from $0.061 per kWh in 1995 to $0.104 per kWh in 2006.

As a result of our growing demand for energy and the increased cost of providing energy through fossil fuels, renewable energy has become an increasingly important source of energy. Over the last decade, the cost of renewables has been declining, while fossil fuel energy prices have been generally increasing. The U.S. Natural Gas Electric Power Price increased from $2.78 per MCF in 1997 to $7.31 in 2007.[7] For comparison, the cost of solar photovoltaics has decreased from an estimated cost of $0.40 per kWh in 1995 to $0.25/kWh in 2005, and is projected to continue to decrease, to approximately $0.10/kWh in 2015 and $0.05/kWh in 2025.[8]

Over this same time period, wind power, in particular, has grown dramatically. Worldwide wind generating capacity has increased by 1,439 percent, from less than 6,100 MW in 1996 to 93,864 MW in 2007.[9] U.S. wind power has increased by 1,152 percent, from less than 1,612 MW in 1995[10] to 20,152 MW in 2008.[11] Texas wind power has increased by almost 5,000 percent, from 116 MW in 1999 to 5,871 MW in 2008.[12]

Resource Quantification

In theory, Texas has the potential to satisfy all of its demand for energy with renewable energy resources. In fact, wind, solar, and geothermal energy each have the potential to provide more energy than Texas currently consumes. **Exhibit 1** provides estimates of the state's potential renewable energy resource base. The total physical resource is the amount available within the whole state per year, while the accessible resource is the amount that can feasibly be extracted each year with current technologies. The energy density for a good Texas site has been shown in Megajoules (MJ) per square meter per year.

Since the 1995 Renewable Energy Resource Assessment, there have been significant changes in the methods used to determine each quantity. For this reason many of the values have increased or decreased and in some cases changed by several orders of magnitude.

High-quality data for estimating the total solar resource for the state of Texas have been available since the 1970s. Updated data is now available from both ground stations and satellite observations. These enable greater precision in quantifying the state's solar resource at any given location, but do not significantly change the overall findings presented in the 1995 resource assessment. The energy density for a good Texas site was determined using monthly solar irradiation data from El Paso due to its ideal location. The data yielded approximately 8,000 Megajoules of energy per square meter over the span of a year, which gives it the highest energy density of any Texas site.

Estimates of the state's maximum wind resource capacity is based on 1 MW wind turbines spread out in alternating rows throughout Texas, with 7 diameter spacing for the first row and 9 diameter spacing for the second row. In practice, the spacing of wind turbines is often closer and the calculation would, therefore, yield an even larger wind resource. The accessible wind resource estimate is based on Wind Class 3 (14.3 to 15.7 mph at a height of 50 meters) and above, excluding urban land, highways, parks, wetlands, wildlife refuges, rivers and lakes, and slopes greater than 10 degrees. The main differences from the 1995 estimate are that in the previous report, the land considered useable had to be within a ten mile radius of transmission lines, spacing was 10 diameters apart and offshore wind generation was not taken into account. Based on current wind generation data, a good site produces 15 MW/km2, which equates to 500 MJ/m2 per year.

Exhibit 1 Estimates of the potential renewable energy resource base for Texas

RESOURCE	TOTAL PHYSICAL RESOURCE (quads/yr)	ACCESIBLE RESOURCE (quads/yr)	ENERGY DENSITY: GOOD TEXAS SITE (MJ/m^2/yr)	PRIMARY ENERGY USES				NON-ENERGY USES
				ELEC.	HEAT	MECH.	TRANS.	
SOLAR	4,300	250	8,000	X	X			
WIND	22	7	500	X		X		
BIOMASS	9	1	500	X	X		X	Food, feed, and fiber
WATER (as electricity)	0.10	0.02	10	X	X	X		Water supply; flood control
GEOTHERMAL	400,000	81,000	600	X	X			

Biomass is an important part of Texas' total renewable energy resource potential, consisting of energy from several different sources. The total physical biomass resource is made up of a combination of agricultural, forest, urban, animal waste, and algae production sources. Of these diverse sources, standing biomass, animal waste and algae production make up the majority of the total energy resource. Once algae production becomes financially viable, one acre of algae production is expected to produce about 15,000 gallons of biodiesel per year. Biomass is comparable to the other renewable resources because of the tremendous opportunity it provides for producing so much fuel on such a small amount of land. As a result, the production of biodiesel could considerably reduce the state's and the nation's dependence on oil.

Water has been harnessed to produce electricity for many years, but compared to other renewable resources it has the smallest future potential for additional development. Hydropower is currently the biggest contributor to the total water-to-energy resource base, but salinity-gradient solar ponds and pressure retarded electrodialysis may become considerable resources in the future. Estimates of Texas' hydropower resource were taken from federal studies, which found the total water resource for electricity production to be approximately 0.1 Quads per year, although only 20 percent of that is accessible. When looking at a site in Texas with good energy density, the total annual energy output can be found with respect to the area utilized. The number from the 1995 assessment, 10 MJ/m^2 per year, is still an accurate indication of a good Texas site for electrical production from water.

Geothermal energy potential is determined from four main sources: hydrothermal, geopressured, enhanced geothermal systems (EGS), and coproduced, of which EGS and geopressured make up about 98 percent of the total physical resource. The accessible resource is based on a percentage of the total, where the technology, geologic setting, and current economic threshold determine the percentage, which is 100 percent for hydrothermal, 70 percent for geopressured, 13 percent for EGS, and 25 percent for coproduced. The recently updated values for total and accessible resources are several orders of magnitude higher than the 1995 values because the new values were derived using different methods to approximate the energy potential from the four main geothermal sources.

While the state's recent efforts to promote energy efficiency through building construction energy codes and utility programs have proven quite successful, many opportunities to reduce energy use through cost-effective efficiency measures remain. Energy efficiency can be viewed as an energy resource, since the need for supply-side energy resources can be displaced by the adoption of more efficient equipment at homes and businesses or through changes in energy consumption patterns or practices. Avoiding the consumption of energy through energy efficiency measures provides a clean energy resource that is immediately available. There is abundant energy savings potential available at a low cost through energy efficiency measures in all economic sectors in Texas. Further energy efficiency can be realized through public education efforts, commitments to sustainable development and climate change mitigation by businesses and other organizations, more stringent building codes, accelerated research and deployment of new technologies, utility demand-side management programs, and equipment efficiency standards.

Resource-Specific Issues and Opportunities

Texas has the best renewable energy resource in the nation. From the sunny deserts in the west to the windy regions in the north, the state's geographical diversity provides an immense renewable energy resource. While many of Texas' renewable energy resources offer significant potential for further development, each provides specific opportunities and creates unique challenges. In evaluating the potential of these varied resources, it is important to consider the individual resources together, rather than separately, as they offer promising synergies for complementing each other, for example, through providing energy at different times. Renewable energy resources can also complement traditional energy resources, for example, through reducing or eliminating additions to the electrical transmission and distribution network.

Solar

Solar energy is a vast resource in Texas and is generally synchronized with daily and seasonal energy demand. Solar has the potential for large scale (central) production and for smaller scale (distributed) production and the latter has major advantages to our infrastructure. The most promising large scale solar technologies utilize solar thermal concentrators and thin-film photovoltaics (PV), while the most promising small scale, distributed technologies are passive applications, solar hot water, and photovoltaics (PV).

Solar energy is a vast resource for Texas, capable of supplying many times the state's total energy needs. It is environmentally benign and closely matches Texas' daily and seasonal energy demands, as noted above. Many solar electric applications are already cost-effective while the costs of others continue to decrease.

Several barriers to widespread utilization of solar energy exist: 1) solar energy requires relatively large amounts of collection area; 2) costs of large-scale solar generation are still relatively high; and 3) the intermittent nature of solar energy poses a challenge for integrating large-scale solar into the existing energy infrastructure.

Considerations for the large-scale utilization of solar energy include land use, water use, the availability of adequate electricity transmission, and the availability of feasible back-up power sources and/or storage technologies. The use of small-scale solar facilities can mitigate or eliminate these concerns but utility interconnection and net metering policies will greatly influence the degree to which these systems are installed.

Texas' best solar resource is located a considerable distance from large urban areas where energy demand is the highest, but the solar resource is adequate throughout the state for most distributed applications. Like wind resources, large-scale solar generation located in far west Texas requires an adequate electricity transmission system and imposes unique challenges on the grid. However, because solar and wind generation in west Texas generally occur at different times (solar during the day, wind generation at night), combining solar power plants with wind farms has the potential to result in more efficient utilization of transmission capacity and improved matching of generation to utility loading, including peak loading conditions.

Variations in solar energy tend to coincide with much of the demand for energy in Texas, with summer days representing the state's highest energy demand as well as the greatest abundance of solar energy.

Several different solar energy technologies have been developed to generate electricity at large-scale central power stations. Parabolic trough concentrators, that reflect solar radiation onto a fluid-carrying tube, have been the most common application, including the world's largest solar power plant in California's Mojave Desert, which has electrical generation capacity of 354 megawatts (MW).

Distributed solar applications are becoming increasingly common, and include solar electric (PV) systems, solar thermal water heaters, and passive solar design incorporated into buildings. Residential PV systems ranging from one to five kW and commercial/institutional PV systems of several thousand kW or more are becoming more prevalent as utilities offer their customers incentives for installation. PV systems are interconnected to the utility grid, enabling customers to meet all or a portion of their energy needs through self-generation and to export excess power to the utility distribution system for use by others. The use of stand-alone PV systems installed where it is expensive or impractical to extend a utility distribution line, passive solar applications and solar thermal water heating systems, largely reduces or eliminates many of the infrastructure challenges associated with large central power systems, including land use, water use and transmission adequacy. More than 1.7 MW of grid-connected PV has been installed in Texas.[13]

The current cost effectiveness of solar technologies varies widely. Passive solar architectural designs are very cost-effective. The cost of electricity from central solar power stations ranges from 12 to 18 cents per kWh. The cost of energy from photovoltaics has dropped dramatically during the last two decades and currently ranges from 20 to 35 cents per kWh. Based on current electricity rates, electricity from solar PV has a payback of 30 to 40 years. However, the cost of PV continues to decline, while conventional energy costs continue to rise, making electricity from PV increasingly attractive economically. The cost of installed PV systems is expected to decrease dramatically in the near future as production volumes increase and new producers come on line.

The solar energy industry, and in particular the photovoltaics industry, has grown in direct response to federal, state and local tax policies and subsidies. An obstacle to expanding the solar energy industry in Texas is the lack of a qualified workforce for installation and maintenance and the lack of equipment certification. Expanding the use of solar energy in Texas can have a significant positive impact on employment.

Wind

Wind is abundant and can be developed rapidly at competitive prices. However, wind power must have more transmission capacity to continue growing in windy areas of the state but wind generation can be constructed much more quickly than major expansions of the transmission system. Wind can deliver significant benefits (rural economic development, improved air quality, no water to generate electricity) but has challenges (large penetration into utility system, need for increased transmission, aesthetic/siting concerns).

Texas has the largest wind energy potential of any state in the country. Capturable wind power is estimated at 223,000 MW, which is several times the total electrical demand of the state. Texas is number one in the nation in installed wind capacity (estimated at 57 wind farms with 5,877 turbines providing 8,786 MW total capacity by the end of 2008), having surpassed California in 2006. Thirty-three percent of the new wind capacity in the U.S. in 2007 was installed in Texas and 2008 will be a record year, with an estimated 4,300 MW of additional wind capacity being installed in Texas. Texas' Renewable Portfolio Standard, approved by the state Legislature in 2005, set a goal of 5,000 MW of capacity from renewable energy by 2015, which was exceeded in 2008.

The major challenge to wind power in Texas is that most of the windy areas of the state are not close to the major urban load centers, so the transmission system needs to be upgraded and expanded in order to utilize the resource. Five Competitive Renewable Energy Zones (CREZ) have been designated by the Texas PUC for future wind development. The Commission ultimately chose a mid-level transmission expansion scenario which would accommodate 18,456 MW of wind-generated capacity in ERCOT.

ERCOT and the Texas PUC have been doing extensive research on the issues and operational risks associated with large-scale integration of wind power into the ERCOT transmission network. Variations in wind generation become more significant for system operation as the penetration of wind increases and wind forecasting will be increasingly important.

With federal production tax credits, wind is competitive with other new electric generation plants. Wind may become competitive without production tax credits if carbon regulation is implemented in the future and/or the "external costs" of fossil fuels are reflected in their price.

The development of wind energy provides important and diverse economic benefits to Texas. Wind farms provide important rural economic development, with both job creation and long-term stable royalty income to landowners. Texas could also benefit from expanding employment through increasing the manufacturing and assembly of wind turbines in the state. Wind energy can also provide significant sources of revenue for the State, including school taxes and royalty income for the General Land Office resulting from the installation of offshore wind farms.

Biomass

Texas has the potential to produce a significant amount of biomass for conversion to energy without conflicting with food or feed production. For example, biomass could provide approximately 15 percent of Texas' liquid fuel needs. Dedicated energy crops such as energy cane, grasses, and sorghums could support the operation of up to 15 cellulosic conversion plants within ten years. Residues such as crop residues, wood wastes, and municipal solid waste can also provide a large amount of biomass for energy production.

Texas has significant potential for diverse biomass production and bioenergy. Forest resources, municipal solid waste; construction residue; dedicated energy crops; crop residue; oilseed crops; grain; and algae are important potential sources of energy. This biomass can be converted into Generation II biofuels ranging from ethanol to green gasoline and diesel. However, Texas would require significant increases in grain production and/or importation to experience increased grain-based ethanol production.

Over 19 million tons of biomass could be used for biofuels production in Texas each year. Some of this might be used for thermal conversion for process heat or electricity production but it would be difficult for a power producer to compete with ethanol production for the feedstock. Feedlot biomass, forest/wood byproducts, poultry litter, cotton gin trash, and sugar cane bagasse are examples of biomass that are more appropriate for the thermal route.

Biomass represents a significant energy resource in East Texas and is primarily an unutilized resource. The demand for lower value woody biomass is currently low. House Bill 1090, *Agricultural Biomass and Landfill Diversion Incentive Program,* was passed in 2007 to encourage the construction of facilities that generate electrical energy using logging residue and urban woody biomass. Utilizing these resources for an array of bioenergy and bio-based products has several advantages including: year-round supply; complementary with existing sustainable forest management practices; and low energy and water input.

Municipal Solid Waste is an excellent source of biomass for energy recovery. In 2006, total waste disposal in Texas amounted to 30.45 million tons, an energy resource of approximately 365 trillion BTUs per year, or the equivalent of 6.3 million barrels of oil.

Algae have great potential as a feedstock for biofuels and bioproducts because they can regenerate in 5 to 72 hours. The potential for algae biodiesel production would be close to ten times the potential of palm oil and 100 times that of soy oil, the two most commonly used feedstocks for biodiesel production today.

Challenges for researchers, producers, equipment manufacturers, and end-users will be to develop production systems that are sustainable and efficient. A critical element in the success of biofuels production will be the linkage between biomass feedstock development, production, harvesting, transporting, storing, and processing into biofuels/bioproducts and/or energy. A key issue in the development of biorefineries will be the ability to continuously deliver biomass to the facility, which is significantly different than other agricultural commodities that tend to be seasonal in nature.

Water is potentially one of the more limiting inputs of biomass energy production. Other infrastructure considerations for biomass include: availability of land for dedicated energy crops; and production, harvest, storage and transport systems. The preferred areas will be those areas, such as those along the Gulf Coast, that have adequate rainfall, high quality available land, a long growing season, ability to provide just-in-time delivery, and strong producer networks.

Biofuel production can be an important force in the economy. The establishment of bioenergy production capability in Texas would have significant positive economic and energy implications. The utilization of biomass can provide rural development opportunities due to the numerous small facilities that would be required.

Energy from Water

Texas has limited potential for generating significant amounts of additional power and energy from water resources. Most good hydropower generation sites in Texas have already been developed. There are numerous sites for new hydroelectric sites, some with a potential of greater than 10 MW, but the hurdles related to siting and low generation potential will prevent most of them from development. Saline gradient solar ponds could prove to be a beneficial energy resource for the western region of Texas if there is a need for low grade hot water to assist in desalination or aquaculture temperature regulation.

Texas currently has 675 MW of conventional hydroelectric power, less than one percent of the state's total electric generating capacity. A 2006 assessment by the U.S. Department of Energy estimated that Texas had 18,000,000 MWh/yr of potential new hydropower generation although only 2,900,000 MWh/yr of this electricity is actually considered feasible. Much of this additional hydropower may never be developed due to economic and environmental constraints. Texas' existing hydropower plants could act as "pumped storage" facilities using inexpensive off-peak electricity to pump water behind the dam, then used later to generate power during high cost peak demand periods. This small, but possibly valuable, peaking resource capacity could complement intermittent wind power output

The total cost of hydropower production is low because there is no fuel cost. The average production cost in the US is less than 0.9 cents per kWh. Hydropower does not directly produce air pollution although it can result in other environmental impacts. Hydropower development may face regulatory impediments, including environmental protection, economic regulation of water and electricity, safety, and land use.

Texas has very limited potential to extract energy or electricity from ocean waves, ocean thermal gradients, currents, and tides. Wave energy systems require relatively large installations along the shoreline that could pose obstacles to development by interfering with marine animals, as well as boating and shipping traffic. Viable electricity costs have been estimated for wave farms along the California and Oregon coasts, however, Texas' offshore wave power densities are typically well below those considered to desirable. Power can also be produced from the ocean as the temperature differences between the surface and depths below 100 meters can drive a heat engine to produce electricity. Texas' ocean thermal energy potential is limited because the ocean depth near the Texas Gulf Coast is less than what is optimal for its development. Tides and ocean currents have also been explored for their energy potential but have not proven to be viable energy resources in Texas.

Useful energy can be produced using salinity gradients, through pressure retarded osmosis (PRO) and reverse electrodialysis (RED), or salinity gradient solar ponds (SGSP) that capture and store solar thermal energy. PRO and RED systems could be used at the saline gradient between Texas river mouths and bays, but only for very limited quantities of electricity. SGSP has the advantage of providing energy on demand and being able to use reject brine, often considered a waste product. Research has established the technical viability of using SGSP technology for electricity and water desalination, particularly in desert areas or where freshwater is not otherwise abundant. However, the demand for increased volumes of freshwater might promote the development of technologies that could reduce their cost for electric generation.

The potential for additional energy production from water resources in Texas is minimal and a substantial economic benefit is not anticipated for the state. However, some technologies, such as the use of SGSP for desalination or aquaculture enhancement, could prove beneficial to specific projects and locales.

Geothermal Energy

Geothermal resources are everywhere in Texas and are just waiting to be tapped. This source of energy has been used in some areas for over 50 years. Geothermal energy can be used to generate significant amounts of electricity from many oil and gas wells. In another geothermal application, using the constant temperature of the Earth's surface for cooling and heating in buildings can reduce energy use by up to 50 percent.

Geothermal energy consists of the natural, internal heat trapped within the rock and fluid found within the Earth. Geothermal energy is not dependent upon cyclical forces, as wind and solar energy are, but is available 24 hours a day, 365 days a year and, as such, can be considered a "baseload" energy technology. There are a number of promising geothermal applications in Texas.

Geothermal energy can be divided into electric and non-electric applications. One of the simplest non-electric ways to use geothermal energy is through a geothermal heat pump, which can work anywhere and represents the lowest cost application of the geothermal resource. Studies have shown that 70 percent of the energy used by a geothermal heat pump is renewable energy from the ground; the remaining 30 percent is electrical energy used to concentrate and transport the geothermal energy. More than 10,000 residential geothermal heat pumps have been installed in Texas. These systems cost approximately $3,000 to $5,000 per ton of cooling, compared to $2,000 to $2,500 for conventional HVAC systems. School districts and commercial buildings are increasingly utilizing geothermal energy. Over 160 schools in Texas have installed geothermal HVAC systems.

There are a number of other promising geothermal applications in Texas. Geothermal energy manifests itself in four distinct forms: 1) hydrothermal resources (hot steam or water), 2) geopressured-geothermal energy, 3) hot dry rock, and 4) magma. Space heating represents the largest potential use of low temperature (120° to 170°F) hydrothermal energy in Texas. Geothermal heat in the low to moderate temperature range can be extracted from subsurface hot water and used in various industrial and commercial processes, including district and space heating, greenhouses, and aquaculture facilities. Many hydrothermal resources, with low grade heat suitable for such applications, are distributed through Central Texas and the Trans-Pecos region.

Geothermal electric power can be generated using geothermal and geopressure fluids with temperatures of 200°F and higher. Temperatures in this range correlate with some of the oil and gas production in Texas, especially the East and South Texas fields. The most efficient way to develop this aspect is through coproduction of fluids. Other direct uses of the geothermal resource are enhanced oil recovery in south Texas, desalination, agriculture/aquaculture projects, and supercritical fluid processing for water and remediation. The geopressured-geothermal resources located along the Texas Gulf Coast provide higher temperatures, but are much deeper and more expensive to exploit and, therefore, may be most valuable for electric power production.

Issues related to hydrothermal and geopressure development include water availability, extraction, and disposal. The economics associated with utilizing high temperature geothermal resources depend on: 1) the quality of resource, principally its temperature, depth, and fluid characteristics; and 2) the ease and rate with which geofluids can be extracted and disposed of. The price of electricity will be important in determining whether geothermal electricity production in Texas remains economical until it becomes routine for oil and gas wells with fluid temperatures of over 200*F to be converted to geothermal energy production rather than simply plugged and abandoned. For increased applications of geothermal heat pumps and direct use, education and marketing will be important for giving potential users the knowledge that this resource even exists.

End-Use Energy Efficiency

Avoided energy use resulting from energy efficiency is the most immediately available clean energy resource in Texas and is as clean as any energy supply resource. There is abundant energy savings potential ("untapped reservoir") available through energy efficiency in Texas' residential, commercial, industrial, and transportation sectors. Some energy efficiency will arise naturally as fuel prices rise and carbon concerns increase, but much more can be realized through public education efforts, organizational initiatives, and building code enhancements, increased utility demand-side management programs, and other efficiency standards, incentives and programs.

Energy efficiency can be viewed as an energy resource, since the need for supply-side energy resources can be displaced by the adoption of more efficient equipment or through changes in energy consumption patterns. Avoiding the consumption of energy through energy efficiency measures provides a clean energy resource that is immediately available. Abundant energy savings potential is available through low cost energy efficiency measures in all economic sectors in Texas.

Some energy efficiency will arise naturally in response to high fuel prices and concerns about air pollution and climate change. Further energy efficiency can be realized through public education efforts, commitments to sustainable development, more stringent building codes, accelerated research and deployment of new technologies, utility demand-side management programs, and equipment efficiency standards.

In this report, energy efficiency is defined as the level of energy usage associated with performing a task at a minimum cost. Technologies that use more energy may be regarded as energy efficient if they are less expensive. Demand response, for example, changes the timing of energy use, lowering the cost of energy, but does not necessarily lower the overall consumption of energy.

Energy efficiency programs have been effective. U.S. energy consumption per dollar of economic output has been reduced to half of what it was in 1970. Texas has developed policies, rules, programs, and infrastructure to exploit the state's energy efficiency potential by establishing goals for energy efficiency, implementing goals for peak demand reduction via energy efficiency programs, and adopting statewide building codes. Programs administered by the state's investor-owned utilities have proven to be a particularly effective source of efficiency improvements, consistently exceeding their goals of meeting 10 percent of the projected growth in electrical demand through energy efficiency.

A state-of-the-art energy efficiency program at Texas A&M has produced energy savings in excess of $50 million at a cost of only $9.3 million. The LoanSTAR program, administered by the State Energy Conservation Office, the largest State-run building energy conservation program in the United States, has achieved energy savings of over $212 million. The revolving loan program will allow LoanSTAR to continue indefinitely and benefit generations of future Texans.

Some studies have argued that ambitious energy efficiency actions can eliminate over 80 percent of forecasted electric load growth at substantially lower costs than new electric supply. Market imperfections are thought to be responsible for the failure of consumers to achieve an optimal level of energy efficiency. Consumers may be unaware of opportunities to reduce energy consumption and cost or be unaware of the payback periods associated with energy efficiency investments. Consumers may lack the capital to purchase energy efficient products or the availability of energy efficient products may be limited. Homebuilders and homeowners and landlords and tenants may have competing interests concerning investments in energy efficiency. Environmental costs associated with energy use may not be adequately reflected in energy prices, leading to over-consumption of energy resources.

Summary and Conclusions

Texas' vast size, abundant resources, favorable business and political climates, and innovative, hard working citizens have helped to make Texas a national and international leader when it comes to energy. Texas' native energy resources and the success of industries built around them fueled Texas' economic growth for the past hundred years and has enabled the state to play a large role in shaping national and even international energy policies.

Among the contiguous 48 states, Texas has the highest potential for generating renewable energy from its solar, wind, biomass and geothermal resources[14] and these available renewable energy resources are almost entirely untapped. Texas' installed wind capacity comprises only about 4 percent of the state's estimated developable wind capacity, so there is plenty of potential for additional growth.[15] Likewise, Texas has only scratched the surface of the state's enormous developable potential solar, biomass, and geothermal capacity.

Texas possesses current energy demand and future growth rates that suggest the need to encourage development of the state's renewable energy resources. But this will not happen automatically. Capitalizing on the opportunities presented by Texas' renewable energy resources will require careful consideration of long-term strategies, formulation of shorter-term priorities, and identification and removal of barriers to development. Renewable energy cannot solve all of our energy problems, but have an important role in a diverse, stable energy supply and are certain to play a growing role in this century's energy supply. Yet the development of these vast resources hinge upon our ability to successfully address a variety of technical, economic, and policy challenges:

- Accommodating Intermittency
- Delivering Renewable Energy to Markets
- Valuing Distributed Generation
- Incorporating Energy Storage
- Economics of Renewable Energy Investments
- How Carbon Changes the Picture
- Government Subsidies
- Jobs and Economic Development
- Resource Allocation Consequences and Tradeoffs

Accommodating Intermittency

Resource intermittency is a significant issue for some renewable energy resources. Wind and solar resources are intermittent over short time periods and their intermittency poses unique challenges for integrating them into the electricity system at a large scale. Wind generation has achieved sufficient penetration on the Texas power grid that intermittency is beginning to emerge as an operational issue.

Strategies for accommodating intermittent resources include better short-term resource forecasting, geographical and technological diversification among intermittent resources, and utilization of demand response, storage, and backup generation.

Delivering Renewable Energy to Markets

Some renewable energy resources are located far from major energy markets, posing unique challenges in delivering renewable energy to customers. Wind energy is a prime example, with most Texas wind energy development to date being distant from load and population centers. Concentrating solar power plants face a similar electricity transmission challenge, while biomass must be transported to centralized production facilities and then to retail outlets. Energy transmission is an intra-state as well as an inter-state issue.

Valuing Distributed Generation

Small renewable energy generation systems can provide benefits of renewable energy while reducing utility costs. In addition to providing additional capacity and energy, distributed generation provides value through transmission and distribution cost deferrals, reduction in line losses, increased reliability, electricity price protection, and pollutant and greenhouse gas emission reductions.[16] Each of these benefits should be compensated at a fair value. Strategies may include the development of incentive programs to support adoption of distributed renewable generation and the adoption of fair and consistent interconnection and net metering practices by all Texas electric utilities.

Incorporating Energy Storage

Energy storage refers to wide range of technologies that can be used to store energy and release it later to perform some useful task. Development of economical storage is useful to intermittent energy resources, in particular, because it enables intermittent resources to comprise a larger portion of available capacity without compromising grid operations. Oil fields could be used for compressed-air energy storage. Market participants are exploring other options for compressed air storage or large-scale batteries.[17]

Economics of Renewable Energy Investments

Renewable energy projects tend to be even more capital intensive than traditional energy projects and lack ongoing fuel costs. As a result, up-front costs tend to be greater but financial returns on capital investments in renewable energy tend to more stable and predictable over the life of the project. The stability and predictability of renewable energy investments creates value that can be passed on to consumers of renewable energy through long-term, fixed price energy sales contracts. However, the higher initial cost and longer payback term does not always align with the interests of home- and building-owners who may not own the property long enough to reap the financial reward. As a result, some cost-effective distributed renewable generation projects will not be built without an up-front financial incentive.

How Carbon Changes the Picture

Regulation of greenhouse gases by the federal government could have a pronounced impact on Texas' energy future. Federal regulation of carbon dioxide and other greenhouse gases will have a large and disproportionate effect on Texas, due to the state's abundance of fossil fuel resources and the industries which have developed around them. In the U.S., mandatory carbon regulation has been considered but not adopted by the federal government. Some voluntary and regional efforts have taken hold, however. By increasing the cost of fossil fuel-derived energy, carbon regulation will make non-carbon emitting energy resources, such as many renewable energy resources, more cost-competitive. Texas' abundance of renewable energy resources means the state has a natural hedge against potential carbon regulation.

Government Subsidies

The abundance and diversity of subsidies for certain energy resources make a comparison of the relative costs and benefits of each energy resource a formidable task but some conclusions can be reliably drawn by examining incentives provided at the federal and state/local levels. More than three quarters of federal renewable energy subsidies, about $4.7 billion, went to ethanol production. Wind, solar, hydroelectric and biomass technologies together received $1.3 billion. Texas' state and local level government provided approximately $1.4 billion in direct financial subsidies to energy sources in 2006; however, 99.6 percent went to oil and gas production. The remaining $6.2 million, was split between solar, biodiesel, wind, and geothermal. Over $2 million of the solar subsidy was provided by Austin Energy.

Jobs and Economic Development

Expanding the use of renewable energy in Texas may have a significant positive impact on employment. Research has shown that renewable energy creates more jobs in the construction and manufacturing sectors than fossil fuel generation.[18] And because renewable energy resources are dispersed throughout the state, developing renewable energy can create new economic opportunities in rural areas of Texas. Renewable energy jobs are diverse and involve manufacturing, sales, construction, maintenance, service, and other skills.

Resource Allocation Consequences and Tradeoffs

Utilization of energy sources can impact air and water quality, land and water use, and wildlife, requiring decisions concerning competing uses of associated land and water. For example, many energy production technologies require vast amounts of water. Allocation of water between competing energy, agricultural, industrial, commercial and domestic demands will become a more important issue as each of these demands continues to grow. Certain distributed renewable energy generation technologies can help reduce water consumption by power plants, freeing water resources for other uses.

Barriers to Renewable Energy Development

The U.S. Department of Energy recently conducted a study of "non-technical barriers" to renewable energy use.[19] The study identified impediments that are holding back the acceptance of renewable energy technologies. Barriers identified included:

- Lack of government policy support,
- Lack of information dissemination and consumer awareness,
- High up-front capital cost,
- Difficulty overcoming established energy systems,
- Inadequate financing options,
- Failure to account for all costs and benefits of energy choices,
- Inadequate workforce skills and training,
- Lack of adequate codes, standards, and interconnection and net-metering guidelines,
- Poor perception by the public of renewable energy system aesthetics, and
- Lack of stakeholder/community participation in energy choices and renewable energy projects.

The U.S. is one of the world's major energy producers and consumers, and Texas is at the epicenter of U.S. renewable energy development. Texas' success in developing its wind resource, coupled with its enormous solar, geothermal and biomass potential, lead one study to conclude in mid-2008 that Texas was the most attractive U.S. state for long-term renewable energy development, ranking first among the states in wind and infrastructure, second in solar, and third in biomass and geothermal.[20]

As renewable energy sources emerge as a dominant contributor to future energy supplies, benefits will accrue to those regions with abundant renewable energy resources and policies that successfully encourage their development. With the right focus, Texas can be well-situated to benefit from its renewable energy resources and to maintain and expand its leadership role in energy well into the next century.

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