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Texas Offshore Wind Power and Water Desalination Potential

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Texas Offshore Wind Power and Water Desalination Potential

by

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Thesis

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This work is dedicated to my parents,

José Ramon and Josefa Maria,

as well as my siblings,

Anna, Carlos, and Cristina.

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Texas Offshore Wind Power and Water Desalination Potential

by

Jose Daniel Beceiro, MA

The University of Texas at Austin, 2015

CO-SUPERVISORS: David Spence, Michael Webber

Texas leads the nation in oil and gas production as well as renewable energy production. Texas also leads the nation in installed wind power and is the 6th largest wind market in the world. Over the past decade, Texas has gone from nearly zero megawatts of installed wind to now over 14,000 megawatts. Texas has an immense onshore wind resource that has been exploited. However, another of Texas' large untapped energy resources has yet to be explored – offshore wind.

Texas is also experiencing one of the most severe and longest sustained drought cycles in the state's history. Texas is blessed with a vast supply of ocean water and brackish groundwater trapped in aquifers, but energy-intensive water desalination plants are required to purify the water to potable standards. Offshore wind has the ability to turn large-scale water desalination into an economical solution.

This thesis focuses on offshore wind and water desalination technology development, cost competitiveness with competing renewable energy and thermo electric generation resources on the ERCOT nodal grid, and the opportunity to couple water desalination facilities with offshore wind farms to enhance overall project economics, reduce the cost of electricity, and increase the supply of fresh water. An economic model evaluating offshore wind-powered water desalination is utilized to demonstrate the viability of implementing these technologies across the state.

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Chapter One: Introductory Remarks

Texas has enormous potential in offshore wind energy and water desalination development to satisfy future energy and water demand. If developed, offshore wind in Texas would have the unique advantages of peak demand coincidence, close proximity to load centers, a state-operated nodal electric grid to deliver power to energy-intensive facilities, cost competitiveness with conventional forms of power generation, existing deep industry knowledge base of offshore energy production, and the possibility to scale faster than onshore wind projects if offshore transmission lines were constructed proactively to encourage development.

Texas is also facing one of the longest and most severe drought cycles in the history of the state (Everything You Need to Know About the Texas Drought, National Public Radio (NPR); The National Drought Mitigation Center; LCRA, Texas Drought). With Texas' booming population and resource-intensive industrial economy, energy and water challenges are pressing. Texas has substantial brackish water aquifers, access to ocean water along the Texas Gulf Coast, an energy sector that already extracts and injects large volumes of groundwater for oil and gas production, and an industrialized economy statewide that can accommodate large-scale water desalination facilities. Texas has existing water desalination plants online, but will need substantially more capacity to satisfy future water demand. The ability to develop offshore wind generation and couple the technology with energy-intensive water desalination technologies is an opportunity that Texas is uniquely positioned to develop and pioneer.

This thesis focuses on offshore wind and water desalination technology development, the opportunity to couple water desalination facilities with offshore wind farms to enhance overall project economics, and the opportunity to supply a new and reliable source of peak power generation that can increase the supply of fresh water. An economic model evaluating offshore wind-powered water desalination is utilized to demonstrate the viability of implementing these technologies across the state. The economic model will analyze a variety of municipal water rates and offshore wind contract prices to demonstrate the viability of offshore wind-powered water desalination across Texas. The economic model demonstrates that offshore wind-powered water desalination is viable in cities across Texas, but offshore wind transmission line infrastructure is a limiting factor that is impeding development.

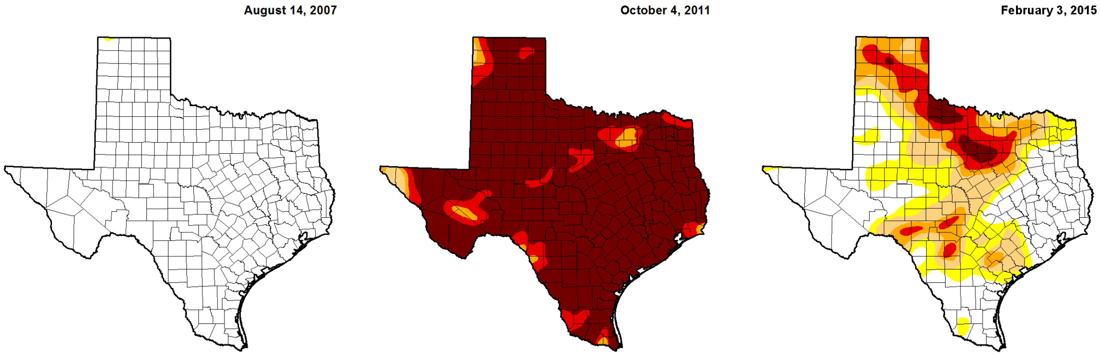
Additionally, this thesis addresses Texas water rights and takings regulation as it relates to the tragedy of the commons theory. Innovation theories are applied to demonstrate how offshore wind and water desalination technologies can be further advanced to lower implementation costs. The principal-agent model is used to explain whether offshore transmission line construction can help accelerate offshore wind development as was observed with Texas' Competitive Renewable Energy Zone (CREZ) projects for onshore wind. Other topics that are covered include Texas' advantage of owning more than ten miles of offshore submerged lands that can be developed for offshore wind energy projects, the hurricane frequency in the Gulf of Mexico, and the economic development impact that offshore wind development and large-scale water desalination facilities could have on the Texas economy.

Chapter Two: The Texas Drought

Texas is currently experiencing one of the worst and longest sustained drought cycles in the state's history (Everything You Need to Know About the Texas Drought, National Public Radio (NPR)), which is currently in its 8th consecutive year. The current drought cycle began in August of 2007 when only 835 out of 26 million Texas residents were experiencing "abnormally dry" weather conditions across the state, which is the least severe category of drought according to the U.S. Drought Monitor (The National Drought Mitigation Center; LCRA, Texas Drought). The three drought maps depicted in Figure 2.1 show how the entire State of Texas was impacted prior to the onset of the drought in August of 2007, during the peak month of the drought in October 2011, and the current conditions as the state begins to emerge from the drought.

The Texas drought peaked in September and October of 2011 after a summer of no rain, 90+ days of triple digit temperatures, and the most devastating wildfires the state has ever experienced (Mashhood, 2011 Was Austin's Hottest Year on Record, Austin-American Statesman). It is estimated that the 2011 Texas wildfires cost Texans over $500 million in property damage (Castellon, Texas Wildfires). The Bastrop County Complex fire alone burned over 34,000 acres, destroyed 1,700 homes, and caused $325 million in damages (Castellon, Texas Wildfires). In October of 2011, almost 100% of the state's population experienced drought conditions, and almost 19 million of 26 million Texas residents experienced the most severe "exceptional drought" category. The National Oceanic and Atmospheric Administration (NOAA) declared Texas' 2011 summer the hottest summer on record in U.S. history with an average summer temperature of 86.8 degrees F (NOAA, U.S. Experiences Second Warmest Summer on Record). The most recent drought conditions data suggests that Texas is steadily recovering. Currently, over 12 million of 26 million Texans are not experiencing any drought conditions. However, 13 million of 26 million Texans are still experiencing some level of drought and over 750,000 are still experiencing the most severe "exceptional drought" category.

Figure 2.1



Source: The National Drought Mitigation Center,
http://droughtmonitor.unl.edu/MapsAndData/DataTables.aspx?TX

Despite the positive signs of the 8-year Texas drought subsiding, fresh surface water resources remain at historic lows in Texas. According to the Lower Colorado River Authority (LCRA), Central Texas lake levels have fallen with Lake Travis at almost 60 feet below its full capacity level of 681 feet and Lake Buchanan over 30 feet below its full capacity level of 1,020 feet (LCRA, Texas Drought). According to the

Texas Water Development Board's 'Water for Texas 2012 State Water Plan' report, the current fresh water supply for Texas cities, farms, and industry totals about 17 million acre-feet annually and the projection is that by 2060 only 15.3 million acre-feet per year of water will be available to Texans (Vaughan, Water for Texas 2012 State Water Plan, Texas Water Development Board). Population growth in Texas is expected to increase 80% from 26 million currently to 46.3 million by 2060, and water demand is expected to increase 22% from 18 million acre-feet per year currently to 22 million acre-feet per year by 2060 (Vaughan, Water for Texas 2012 State Water Plan, Texas Water Development Board). Due to increasing population, increasing demand for water, and decreasing fresh water supplies, Texas will need to supply an additional 8.3 million acre-feet of water annually from new sources by 2060 to satisfy water demand if projections prove to be correct (Vaughan, Water for Texas 2012 State Water Plan, Texas Water Development Board).

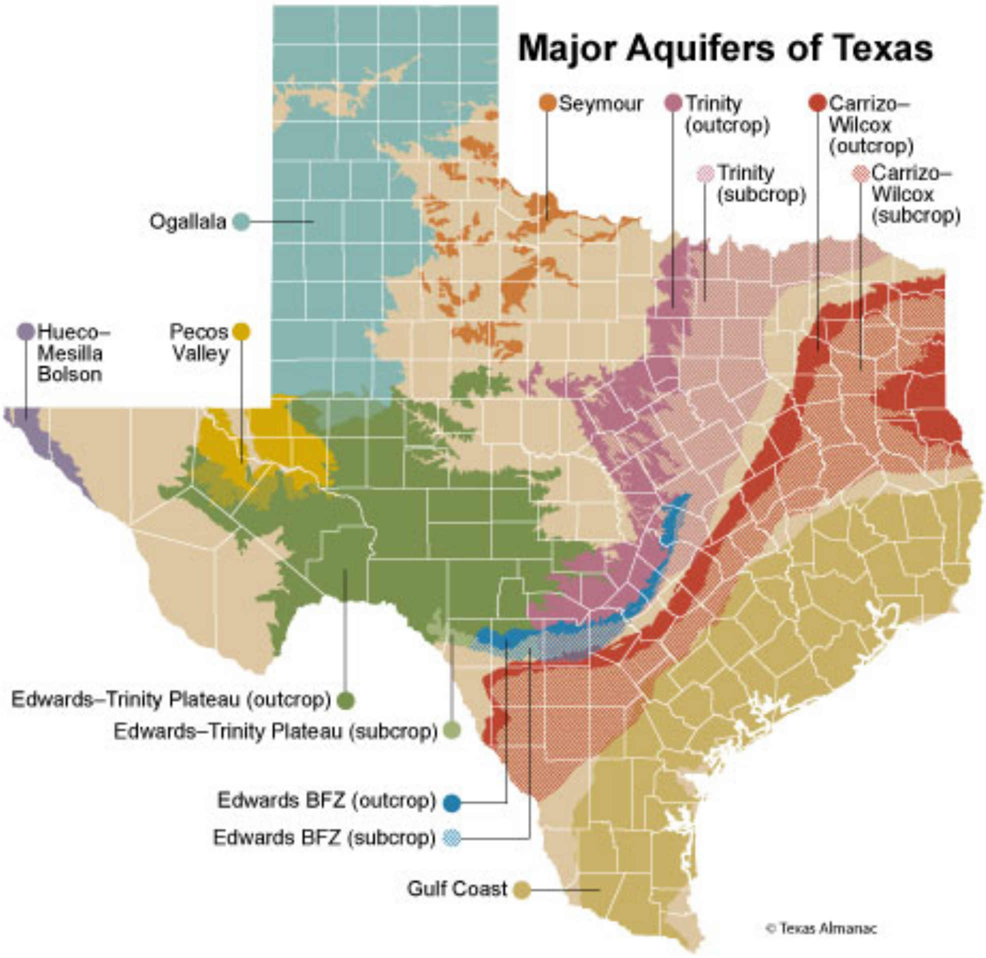
One important aspect of Texas water resources is how water rights and takings regulation have evolved in Texas since its inception (Vaughan, Water for Texas 2012 State Water Plan, Texas Water Development Board). Texas' water rights laws were first developed over 200 years ago, and were modeled after both Spanish and English common law conventions. This convention is known as the riparian doctrine and essentially states that all water resources in the state are owned by the state, but are made available to landowners, municipalities, and industry under the Rule of Capture. The Rule of Capture states that any landowner in Texas who had accessible water on or adjacent to their land such as a river, reservoir, or groundwater was allowed to make reasonable use of the water resources without restrictions so long as the water pumping of any landowner is not deemed malicious towards a neighbor, wasteful, or cause subsidence of the land.

In 1840, Texas made the decision to change its water laws to follow a new system known as the prior appropriations system. This new system was designed to restrict water use across the state in order to conserve dwindling water resources. Due to the prevailing Rule of Capture law and subsequent tragedy of the commons impact to Texas water resources, the state was forced to restrict water use to just 200 acre-feet per year for domestic and livestock purposes throughout the state. Today, the State of Texas manages water permits and pumping through the Texas Commission on Environmental Quality (TCEQ), Regional Water Planning Areas, Groundwater Conservation Districts, River Authorities, and Aquifer Authorities.

Despite Texas' efforts to better control its fresh water resources through regulation, TCEQ still recognizes the doctrine of priority, which stipulates that superior water rights are given to users who first used the water. Current Texas water regulations still prioritize water rights based on when the permit was approved and not necessarily based on the purpose of use. The one exception TCEQ makes is during times of drought when municipalities and industry are given priority over irrigation users (Vaughan, Water for Texas 2012 State Water Plan, Texas Water Development Board). Since Texas is a drought prone state, regulations to create more structure and restrictions on water usage were adopted with the goal to more effectively manage state water supplies. Despite these policy changes, Texas still faces a significant water crisis going forward and water desalination technologies might satisfy future water demand.

One potential new source for additional fresh water in Texas could come from the implementation of utility scale water desalination facilities to purify Texas' vast supply of underground brackish water stored in aquifers and also ocean water along the Texas Gulf Coast. Figure 2.2 depicts the 9 major aquifer systems distributed across the State of Texas. The Ogallala Aquifer system located in the Texas Panhandle region is one of the largest and most productive aquifer systems in the world supplying fresh water to municipalities, farms, and industry. The Hueco-Mesilla Bolson Aquifer in the El Paso region along with the Edwards, Carrizo-Wilcox, and Gulf Coast Aquifers are also considered to be highly productive aquifers. However, major challenges exist for the implementation of water desalination plants across Texas such as the high capital cost of implementation and also the energy intensity of operating a water desalination facility. Offshore wind could be a viable solution to power water desalination plants, which will be investigated in this thesis.

Figure 2.2



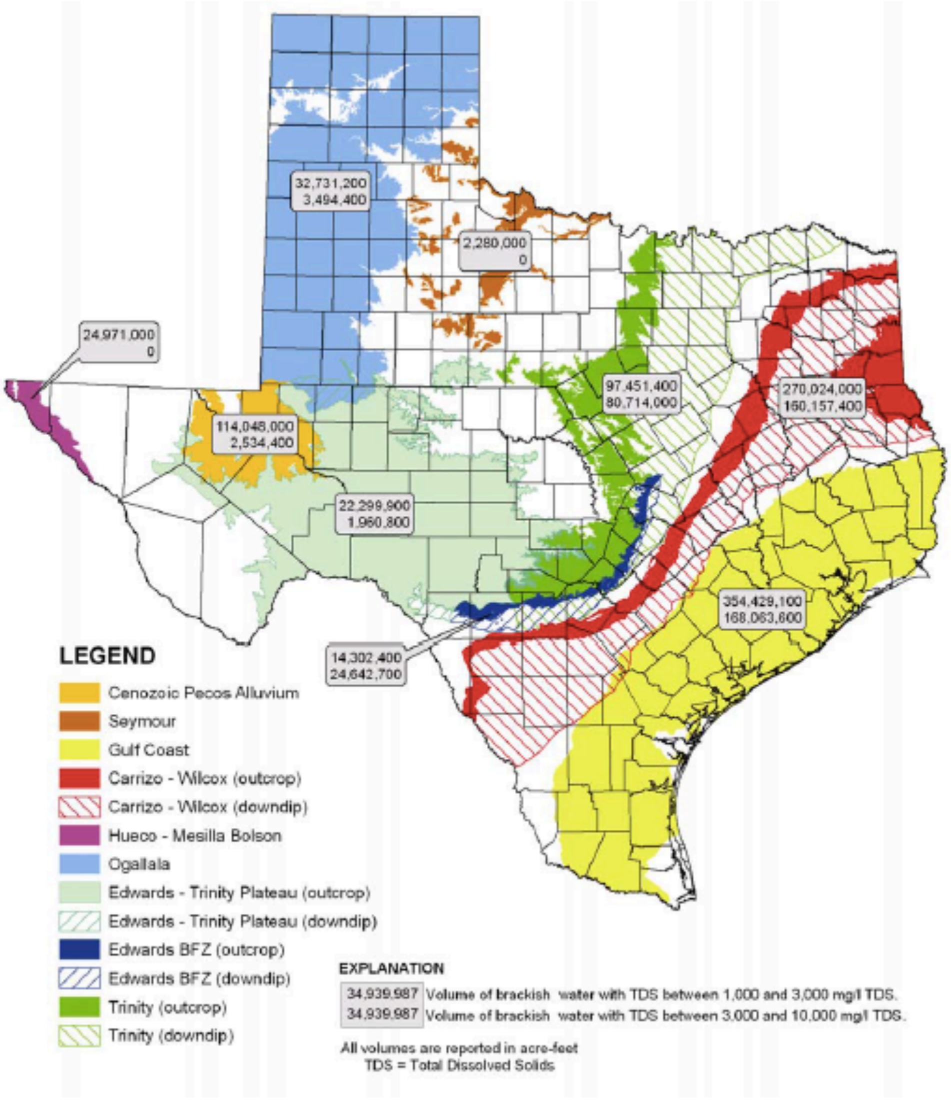
Source: Texas State Historical Association, Texas Almanac, *http://www.texasalmanac.com/topics/environment/aquifers-texas*

Chapter Three: Texas Water Desalination

Despite declining supplies of fresh surface and ground water with low salinity below 1,000 mg/l, Texas still has substantial underground brackish water resources available stored in aquifers stretching across the entire state (Figure 3.1). Texas is home to 9 major aquifers and 21 minor aquifers available with varying grades of water quality from fresh to saline. About 60% of Texas' annual water supply comes from the state's aquifers. About 80% of the water used for farming and 35% of the water used for cities comes from underground aquifers. According to the Texas Water Development Board, Texas has a total of about 2.7 billion acre-feet of water stored underground with 1.8 billion acre-feet classified as moderate salinity between 1,000 mg/l to 3,000 mg/l and about 1 billion acre-feet classified as heavy salinity between 3,000 mg/l to 10,000 mg/l. Some of the underground water is fresh water, which means that it does not have to be treated significantly for use and is less energy-intensive to produce. The remaining water in the ground has higher salinity content and requires more energy-intensive treatment processes, which adds to the overall costs of implementing water desalination.

According to the Texas Water Development Board, Texas Aquifers had approximately 12.7 million acre-feet per year of water available in 2010. The largest aquifer system in North America is located in the Panhandle of Texas called the Ogallala Aquifer. The Ogallala in Texas has about 6 million acre-feet per year of water available followed by the Gulf Coast Aquifer at 1.8 million acre-feet per year (George, P. et al., Aquifers of Texas, pg. 15). Figure 3.1 depicts the location and hydrogeological structure of the major and minor aquifer systems in Texas. Figure 3.1 also provides data on the amount of available water resources for each aquifer and the quality of the water.

Figure 3.1

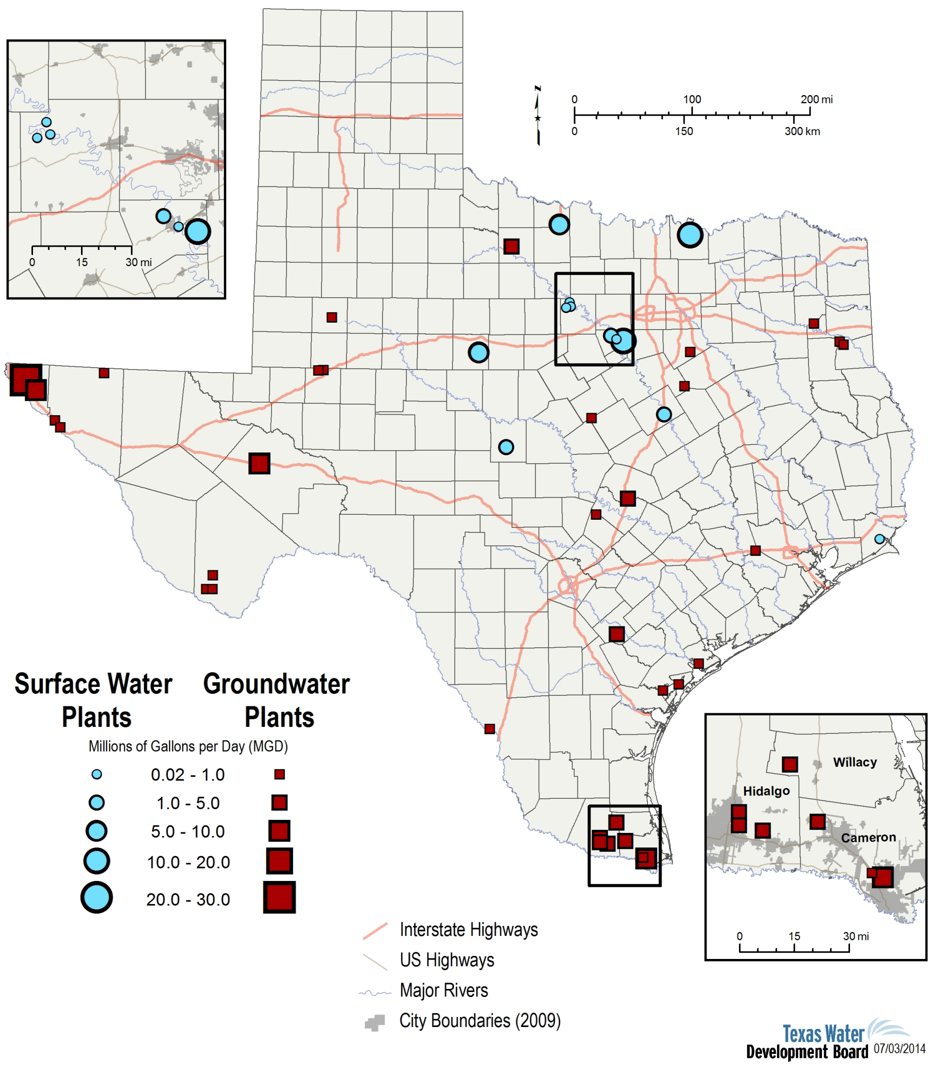


Source: Kalaswad, S. et al., Brackish Groundwater in Texas, Texas Water Development Board, pg. 7, http://www.twdb.state.tx.us/publications/reports/numbered_reports/doc/R363/B2.pdf

The available aquifer data suggests that Texas could solve its water challenges by extracting and treating brackish water to make up for the expected shortfall of 8.3 million acre-feet per year by 2060. With the application of advanced innovation models, Texas could pioneer an effort to develop new innovative water desalination technologies that are scalable and cost competitive. Texas could further establish itself as a world leader in energy/water innovation with the support of major energy/water research activities at the University of Texas at Austin, Pecan Street, Inc.'s smart water and grid infrastructure research, and with the presence of the Texas oil and gas industry and its expertise in water extraction, treatment, re-injection, and hydraulic fracking.

Advanced innovation models are also seen in Texas with large-scale implementation of water desalination technology. For example, the City of El Paso recently implemented the world's largest inland water desalination facility called the Kay Bailey Hutchison Desalination Plant. The facility has the capacity to produce almost 31,000 acre-feet of fresh water annually from underground brackish water. The El Paso facility cost $91 million to construct, which translates into $2,900/acre-foot. There are currently more than 40 water desalination plants online across Texas, and several new plants are scheduled to come online soon including San Antonio's $225 million, 30,000 acre-feet per year plant, which will be the largest inland water desalination plant in the state (Galbraith, K., Texas' Water Woes Spark Interest in Desalination, The Texas Tribune). Figure 3.2 shows the location of water desalination plants across Texas and also the water production capacity of each facility.

Figure 3.2



Desalination Plant Capacities

Source: Texas Water Development Board, *http://www.twdb.texas.gov/innovativewater/desal/doc/maps/Desal_Capacity_sw_gw_20140703.jpg*

Advanced innovation models in Texas are also being applied in technology commercialization efforts. Austin-based Omni Water Solutions (OWS) is a venture-backed startup that is pioneering water membrane filtration technology. OWS has raised nearly $20 million in funding to date to develop an innovative mobile water treatment platform that can be used to purify brackish water, treat drinking water in remote locations, or even treat used fracking fluid for oil and gas production.

Lastly, an advanced innovation model that is unique to Texas is that offshore wind's economies of scale and cost competitiveness in the ERCOT market could serve as the most efficient method to power large-scale, energy-intensive water desalination facilities. It is estimated by the Texas Water Development Board that water desalination will cost Texas approximately $267 million to implement in order to produce 92,212 acre-feet per year by 2060. If we extrapolate the implementation cost estimate of water desalination and forecast that Texas can economically produce the projected water supply shortfall of 8.3 million acre-feet per year by 2060, then the total cost of implementing water desalination in Texas will be on the order of $2,896/acre-foot per year or $24 billion. However, if Texas fails to implement advanced innovation models to identify new sources of fresh water, the economic impact could be devastating to the state. It is estimated that if Texas does not invest in new water resources, then Texas could lose $115.7 billion annually in income and a million jobs by 2060. As a result, Texas' ability to continue leveraging its energy/water research capabilities, advanced and highly scalable energy economy, and incubating new startup companies in the energy/water sector will be key to pioneering offshore wind and water desalination innovation.

Chapter Four: Texas Gulf Coast Geology

The first step in understanding offshore wind's potential in the Texas Gulf coast and how Texas' aquifer systems developed is first to understand the geology of the Gulf Coast region. The Gulf of Mexico Basin is a gravity fed depositional system that dates back to the mid-late Cretaceous and early Tertiary periods. This basin is one of the most prolific in the nation in fossil fuel resources including lignite coal, oil, and natural gas. As a result, Texas is the largest producer of oil and gas in the nation and one of the largest in the world.

The sedimentary process in the Gulf of Mexico Basin began over 65 million years ago when the Texas coastline was 100 miles farther inland than it is today. Through the process of regional uplift and volcanism, new sedimentary layers were deposited farther towards the southeast. Also, Texas' large river systems including the Red River, Trinity, Brazos, Colorado, Guadalupe, and Rio Grande Rivers contributed greatly to the depositional process by transporting minerals and clastic sedimentary rocks from Colorado and West Texas down into the Gulf of Mexico Basin (Galloway et al., 2011, p. 942) (Figure 4.1).

Figure 4.1

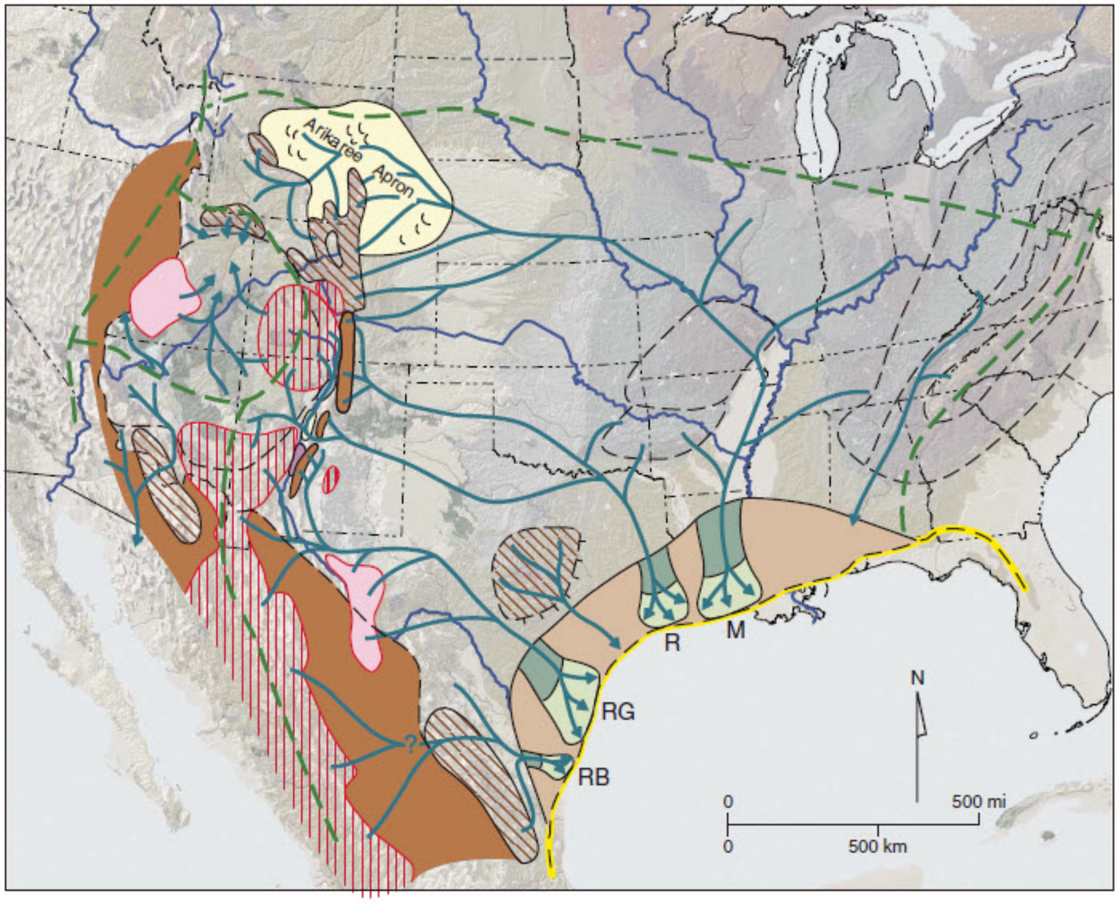


Figure 14. Early Miocene paleogeography. Compiled from Bart (1975), Scott (1982), Cather et al. (1994), Chapin and Cather (1994), Pazzaglia and Kelley (1998), Connell et al. (1999), Holm (2001), Buffler (2003), Cather et al. (2008), McMillan et al. (2006), and Flowers et al. (2008). For explanation see Figure 6.

Source: Galloway et al., 2011, p. 959

Beginning in the early Cretaceous period, the Gulf of Mexico Basin's depositional environment formed limestones, shales, and marine sandstones. During this depositional period, plant and animal fossils were also transported into the basin where they were subjected to increasing temperature and pressure under new depositional layers. This process is largely responsible for the formation of modern day lignite coal deposits such as the Sandow Lignite Coal Mine near Rockdale, TX, the oil and gas shale deposits such as the Eagle-Ford, Permian Basin, and Barnett Shales, as well as the offshore oil and gas reservoirs in the shallow and deep waters off the Texas Gulf Coast.

Subsequent sedimentary layers deposited in the Gulf of Mexico Basin during the late Cretaceous period produced dolomite, marine chalk, and shales. The early Tertiary period produced marine shales, clays, marine sands, and silts. Through the late Tertiary period and into the Quaternary period, the Gulf of Mexico Basin experienced a depositional environment that produced marine sands, shales, and clays. The current sea floor of the Gulf of Mexico is comprised mostly of sand and clay, which is the foundation that all shallow and deep-water offshore oil platforms are anchored today (Fails, 1990, p. 225).

This depositional process that created the Texas Gulf Coast is also the same process that developed all of Texas' major and minor aquifer systems. Figure 4.1 shows how the Texas coastline has expanded southeast towards the Gulf of Mexico to its current position and formation today. The Texas coastline and aquifer systems were formed through the help of Texas' major river systems depositing water, soils, and organic materials along watersheds, riverbanks, basins, and downstream into the Gulf of Mexico.

Chapter Five: Texas Offshore Energy History

Texas began offshore energy exploration in 1938, and the technology used in constructing offshore oil and gas platforms is easily adaptable for offshore wind. Since the 1930's, offshore oil and gas production platforms in Texas have undergone considerable design changes and technological advancements.

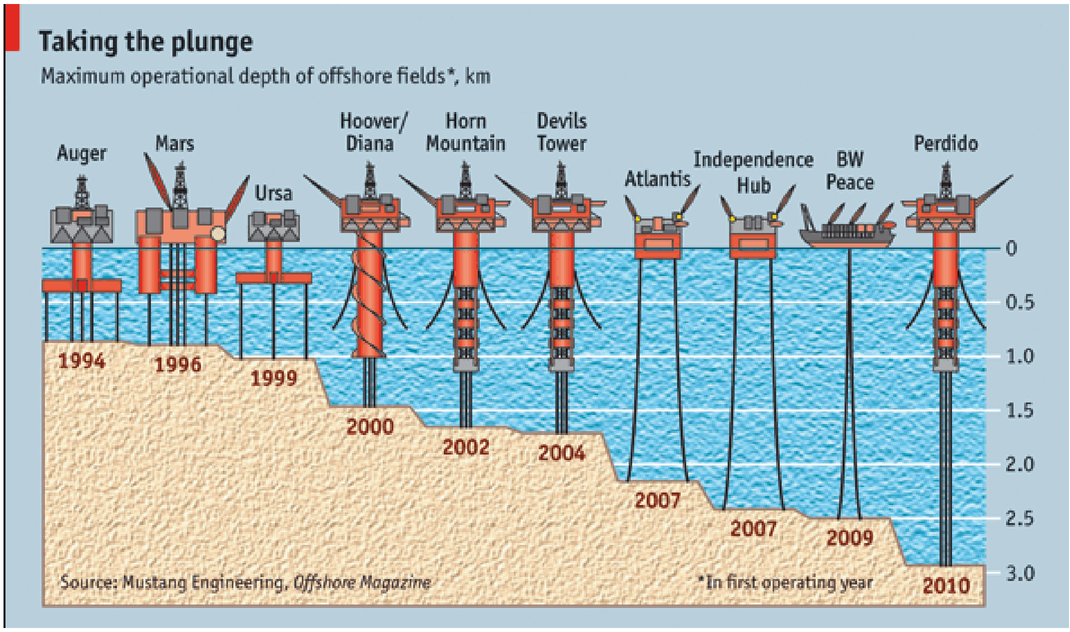
Offshore platform technology was largely limited to 1-kilometer (3,000 feet) depths from 1938-1999. From 2000-2004, design advancements allowed for deep-water platforms to operate in water depths as deep as 1.75 kilometers (5,775 feet). Modern day offshore platform technology that was developed and deployed from 2007-2010 reached an all-time record depth of 2.42 kilometers (8,000 feet).

First generation fixed platform technology was designed to support the entire drilling structure from the seafloor using a scaffolding support structure. Fixed platform technology was viable in water depths to .534 kilometers (1,754 feet). The deepest fixed platform in operation today is ChevronTexaco's Petronius platform that was deployed in 1998. Vertically moored tension leg platform technology was developed to float in place while anchored to the sea floor using weights and tension lines. Vertically moored tension platforms can operate at depths of 1.4 kilometers (4,674 feet). The deepest operating vertically moored offshore platform is ConocoPhillips' Magnolia platform deployed in 2004. Spar platform technology also is a floating platform technology design that is anchored to the sea floor. Spar platform technology is what is used in the deepest waters and can operate at depths as far down as 2.42 kilometers (8,000 feet) or deeper

(NOAA, Types of Oil/Gas Structures). The deepest operating offshore platform in the world today is Shell's Perdido platform that was deployed in 2010 (Shell.com, Perdido).

Figure 5.1 shows the advancement in technology of offshore oil and gas platforms. As the technology advances, oil and gas production has been able to reach deeper and deeper depths, which has unlocked some of the largest oil and gas fields in the world. Similarly, this offshore technology will enable offshore wind's deployment farther offshore in order to capture the optimal wind resource.

Figure 5.1



Source: Mustang Engineering, Offshore Magazine

Chapter Six: Texas Offshore Wind Energy

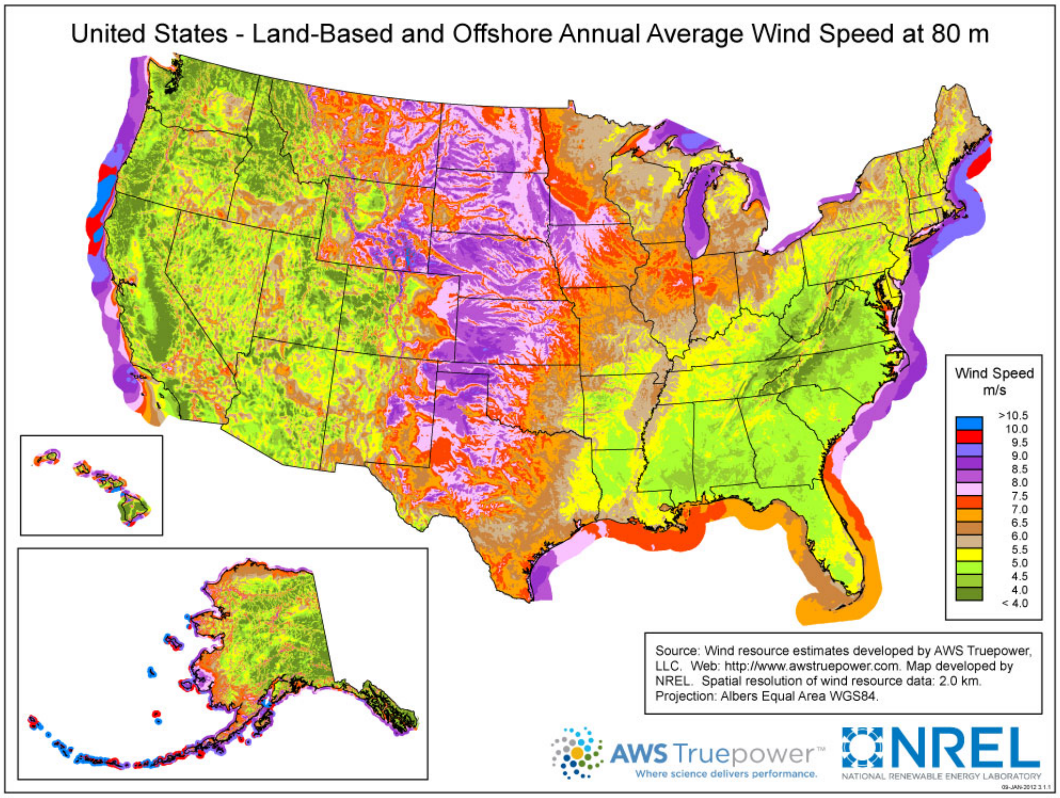
Offshore oil and gas platform technology is a key enabler to implementing offshore wind at scale. Texas is in an advantageous position when it comes to offshore wind deployment due to the availability of industry expertise located within the state. Additionally, Texas is also the largest wind market in the nation with 14,098 megawatts of wind capacity installed (AWEA, State Wind Energy Statistics: Texas). Texas has more than double the installed wind capacity of California and Iowa, the 2nd and 3rd largest U.S. wind markets, respectively. Texas ranks as the 6th largest wind market globally after China, United States, Germany, Spain, and India (AWEA.org, Industry Statistics).

When it comes to offshore wind capacity, the United States still does not have a single installed wind turbine. There are plans to develop offshore wind projects off the coasts of Massachusetts and Rhode Island, but regulatory hurdles and coastal communities concerned with ecosystem and aesthetical impacts have prevented these projects from moving forward. The world leaders in offshore wind deployment include the United Kingdom followed by Denmark (AWEA.org, Offshore Wind). It is estimated that there are approximately 2,500 turbines and 8,000 megawatts of offshore wind deployed in the world today mostly in European waters (Corbetta, G., European offshore wind industry - key trends and statistics 1st half 2014).

Texas' offshore wind potential is one of the best untapped energy resources in the country. Texas has already proven itself as the national leader in onshore wind development with 14,098 megawatts installed. It is estimated that West Texas' wind resource potential ranges from class 2 to class 4 wind. Class 2 wind ranges from 12.5 to 14.3 miles per hour. Class 3 wind ranges from 14.3 to 15.7 miles per hour. Class 4 wind is considered to be very economical and ranges from 15.7 to 16.8 miles per hour. Much of the Texas Panhandle features class 4 wind, which has been one of the primary drivers of West Texas and Texas Panhandle wind development.

Texas also has a robust potential with its offshore wind resource. In fact, offshore wind potential in Texas is substantially greater than onshore wind. Offshore wind potential off the Texas Gulf Coast ranges from class 4 to class 6 wind. The Texas Gulf Coast features class 4 wind potential from approximately Matagorda Bay, TX to the north to the Texas-Louisiana state border. A small area of class 5 wind ranging from 16.8 to 16.9 miles per hour exists from approximately Corpus Christi, TX to the north to Matagorda Bay. Finally, the best offshore wind potential exists along the southern most stretch of the Texas Gulf Coast from approximately Brownsville, TX to the north to Corpus Christi. This southern most stretch features class 6 wind potential with average wind speeds in the 17.9 to 19.7 mile per hour range (DOE, EERE). Figure 6.1 shows the onshore and offshore wind resource available across the entire country. Figure 6.2 zooms in on the Texas Gulf Coast region and depicts the robust wind resource available offshore in Texas.

Figure 6.1

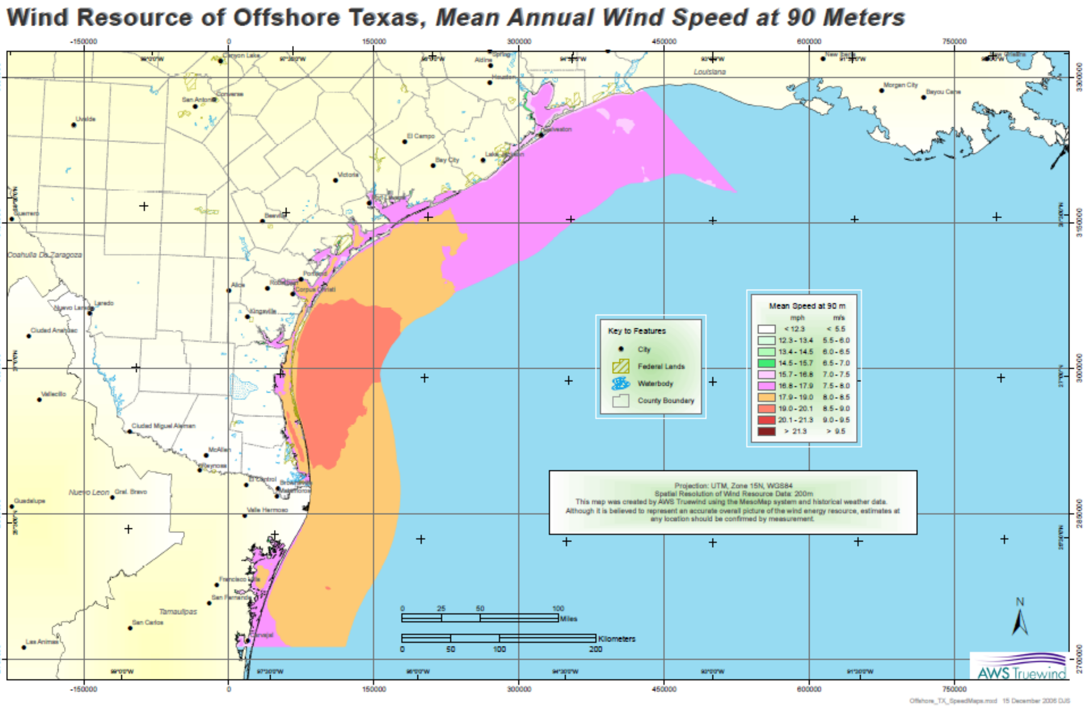


United States - Land-Based and Offshore Annual Average Wind Speed at 80 m

Source: Wind resource estimates developed by AWS Truepower, LLC. Web: http://www.awstruepower.com. Map developed by NREL. Spatial resolution of wind resource data: 2.0 km. Projection: Albers Equal Area WGS84.

Source: U.S. Department of Energy (DOE), Energy Efficiency & Renewable Energy, http://www1.eere.energy.gov/wind/resource_assessment_characterization.html

Figure 6.2



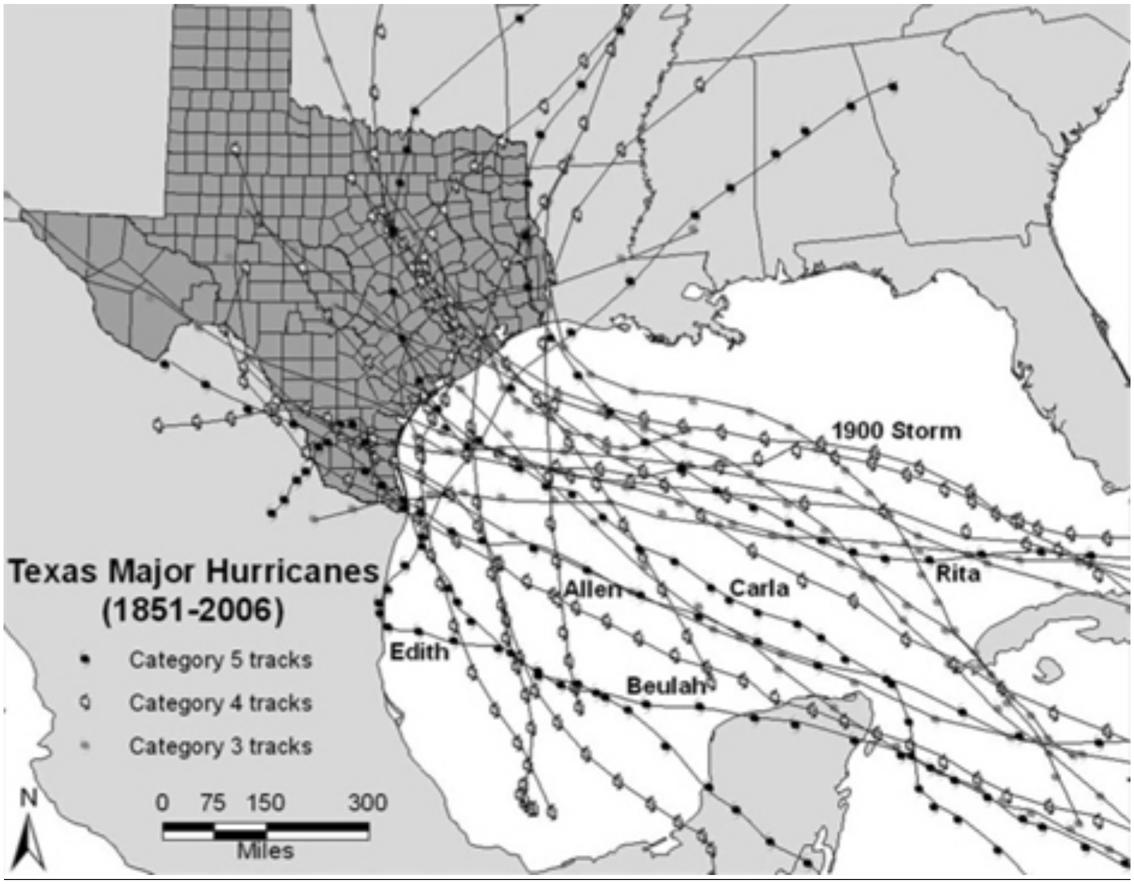
Source: U.S. Department of Energy (DOE), Energy Efficiency & Renewable Energy, http://apps2.eere.energy.gov/wind/windexchange/windmaps/offshore_states.asp?stateab=tx

Chapter Seven: Texas Gulf Coast Hurricane Frequency

According to the National Weather Service, the Texas Gulf Coast is a frequent target for hurricanes and inclement weather that can affect offshore oil, gas, and wind production. Since 1527, it is estimated that the Texas Gulf Coast has suffered a direct hit by a major hurricane at least 122 times (Roth, National Weather Service, Texas Hurricane History,). This translates into a hurricane frequency of approximately one hurricane every 4 years. However, this frequency is not the same for the entire Texas coastline. There is a higher chance of a hurricane strike near Matagorda Bay versus Sabine Pass. The probability of a hurricane making landfall at Matagorda Bay is 41% versus at Sabine Pass is 31%. Additionally, there have been entire 10-year stretches where the Texas Gulf Coast did not experience any hurricane activity like from 1989 to 1999. There have also been stretches where the Texas Gulf Coast has been affected by a hurricane each year and in some cases multiple times per year, as was the case from 1885 to 1888. Four hurricanes struck the Texas Gulf Coast in 1886 alone. The most active decades for hurricane activity since records were kept include the 1880's with 8 hurricanes and 3 tropical storms, the 1940's with 8 hurricanes and 6 tropical storms, and the 2000's with 5 hurricanes and 5 tropical storms.

Hurricane frequency is high enough on the Texas Gulf Coast that it must be factored into the overall project cost and risk assessment when deciding whether to deploy offshore wind and coastal water desalination projects. Figure 7.1 shows the historical storm tracks of hurricanes that have impacted the Texas Gulf Coast region.

Figure 7.1

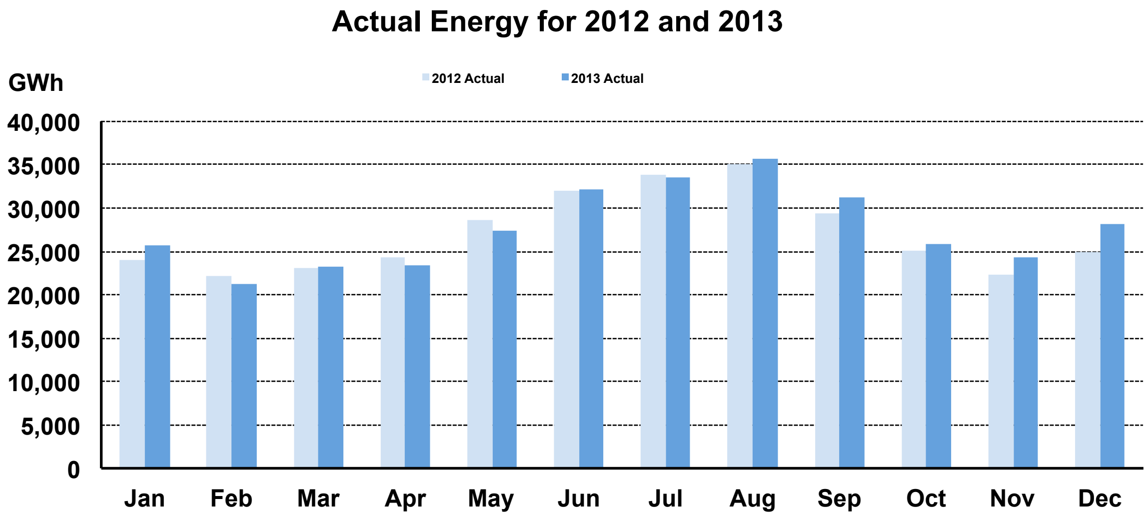


Source: Houston Advanced Research Center, *http://www.harc.edu/AirQualityClimate/TexasClimateInitiative/tabid/1044/Default.aspx*

Chapter Eight: Texas Wind Energy on ERCOT

One major advantage that offshore wind has in Texas is its ability to produce energy during peak demand times for electricity. In Texas, peak demand for energy occurs from 3pm to 7pm from June to September each year according to the Electric Reliability Council of Texas (ERCOT). Figure 8.1 shows the total load for ERCOT by month for 2012 and 2013. The chart shows that peak demand occurs during the hot summer months on ERCOT primarily due to air conditioning load.

Figure 8.1

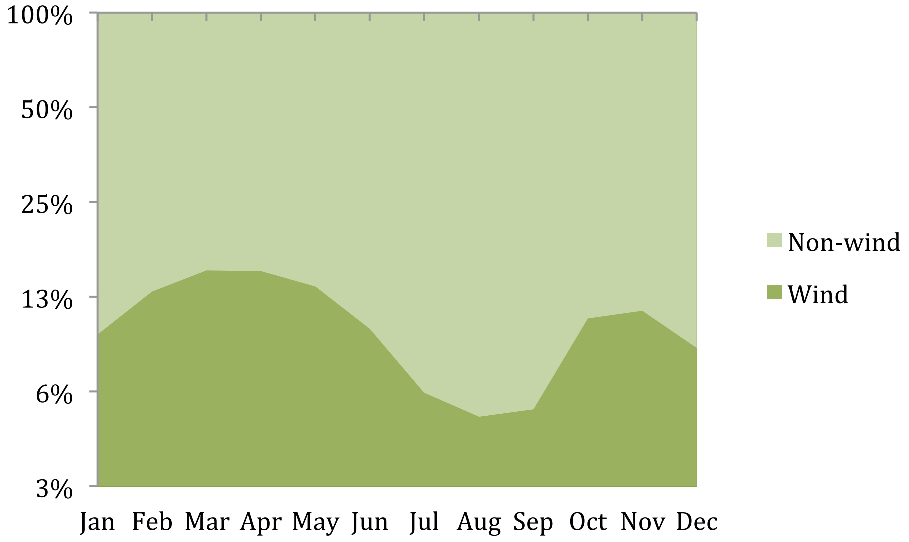


Source: Electric Reliability Council of Texas (ERCOT), 2013
http://www.ercot.com/news/presentations/

Figure 8.2 shows that the 14,098 megawatts of onshore wind installed in Texas makes up approximately 15% of our state's total generation capacity in 2013. However, only between 5%-10% of our state's power needs are satisfied by wind power during peak demand times during the summer months. The primary reason is due to the characteristics of West Texas wind power. West Texas wind peaks during off-peak times at night and during cold weather. As a result, the state's share of power met by wind is the highest during the coldest months of the year. For example, the all-time record peak for wind power in Texas occurred on November 2, 2014. On this day, the total output from Texas wind farms topped out at 10,301 megawatts, which accounted for 33.4% of the state's total power generation. Looking more closely at Texas' record peak wind power output, almost every new record was set during cold weather months or during off-peak times. The record that was set in November 2014 occurred at 10:39 AM. Figure 8.3 shows the wind power record statistics for Texas. The chart provides details for each wind output record event including total megawatts of wind generated, the date and time of the event, and the percent of the total ERCOT load that wind power satisfied.

Figure 8.2

Electric Reliability Council of Texas
Energy By Fuel Type, Percent



Source: Electric Reliability Council of Texas (ERCOT), 2013
[*http://www.ercot.com/news/presentations/*](http://www.ercot.com/news/presentations/)

Figure 8.3

ERCOT: Wind Record Stats

MWs	Date	Time	Percent of Load
10,301	11/2/14	10:39 AM	33.4
10,296	3/26/14	8:48 PM	29
9,481	2/9/13	7:08 PM	28
8,521	11/10/12	10:21 PM	26
7,599	3/7/12	8:41 PM	22
7,403	3/6/12	6:55 AM	24
7,400	10/7/11	3:06 PM	15
7,355	6/19/11	10:26 AM	15
7,227	12/11/10	7:16 AM	26

Source: Electric Reliability Council of Texas (ERCOT),
[*http://www.ercot.com/news/press_releases/show/495*](http://www.ercot.com/news/press_releases/show/495)

On average, wind power output in Texas ranges from 8%-15% of total power generation during off peak months. Offshore wind has the potential to boost the state's share of wind power generation to higher levels especially during critical peak demand times for energy. ERCOT states that in the summer of 2011 when Texas experienced over 90 straight days of 100+ degree temperatures, coastal wind helped the state avoid involuntary rolling blackouts. ERCOT President Trip Doggett said in an interview in August 2011, "We would love to have more development of coastal wind. The diversity of coastal wind versus West Texas wind is an advantage to us in operating the grid" (Carol, C., August 2011). Offshore wind could be an invaluable resource for Texas water desalination facilities due to its peak coincidence, competitiveness on ERCOT, long-term fixed-priced contracts, reliability, and scalability.

Chapter Nine: Offshore Wind Technology Innovation

A major advantage that offshore wind has in Texas is its ability scale faster and larger than onshore wind if offshore transmission line infrastructure were installed proactively to encourage development. Onshore wind turbine technology has ranged from 1.5 to 3.0 megawatts over the past decade. Despite technological advancements in utility wind turbine design, one major limiting factor for onshore turbine design has been the size and weight constraints of existing transportation infrastructure for wind turbine components. The only means of transporting onshore wind turbines is by conventional methods such as rail or truck. The 3-megawatt wind turbines that are being transported to West Texas today have reached a critical limit point with truck towing capacities and highway overpass clearances. Therefore, offshore wind turbine designs have the ability to exceed both onshore wind turbine capacity and performance.

Offshore designs are not limited by conventional transportation methods since offshore wind turbines can be assembled at facilities on the coast and then shipped or barged out to the project site. The advantage of shipping or barging wind turbines out to the offshore project site is that it allows offshore turbines to be scaled substantially larger than onshore wind turbines. Offshore wind turbines can be designed from 3 to 10 megawatts in size with virtually no weight limitations, and can be designed to feature 1.5 to 2 times the tower heights and blade lengths of onshore wind turbines. These economies of scale can be achieved due to the elimination of conventional transportation-related constraints associated with onshore wind project development.

Chapter Ten: Offshore Wind CREZ Policy

Another major advantage of offshore wind in Texas is its close proximity to the Texas Triangle. The Texas Triangle is the geographic area comprised of Dallas, San Antonio, and Houston, which also includes the Austin metro region. The Texas Triangle is where approximately 80% of the state's population resides and where the greatest demand for peak power exists. Onshore and specifically West Texas wind farms are located on average 200 miles away from the Texas Triangle.

The State of Texas developed a strategic initiative and committed significant financial resources to connecting wind farms to the ERCOT grid. The Texas State Legislature enacted a policy known as CREZ (Competitive Renewable Energy Zones) in 2005, which allowed for the construction and extension of new transmission lines from the ERCOT grid into the high wind resource areas of the state including West Texas, the Texas Panhandle, and South Texas along the coast. These CREZ transmission line projects have cost the state billions of dollars to complete with a total price tag of approximately $7 billion or $2,000,000 per mile for 3,600 miles of new transmission lines (Malewitz, $7 Billion CREZ Project Nears Finish, Aiding Wind Power, The Texas Tribune).

The Renewable Portfolio Standard (RPS) and Renewable Energy Credit (REC) market that were implemented since 1999 and then the CREZ transmission lines constructed since 2005 helped accelerate the wind energy economy in Texas. The initial rapid build-out of wind projects in West Texas from 1999 to 2005 quickly exceeded the

ERCOT grid’s design limits and forced many wind farms into curtailment by ERCOT due to transmission line congestion issues. Therefore, the Texas Public Utility Commission (PUC) made a strategic decision in 2005 to enhance these congested areas by increasing the transmission line capacity by 18.5 gigawatts. This additional expansion of the ERCOT grid has allowed more wind power from West Texas, the Texas Panhandle, and South Texas to reach the energy-intensive load centers in the Texas Triangle. As a result, Texas has seen wind farm development grow exponentially from nearly zero megawatts of wind power in 1999 to now over 14,098 megawatts in 2015.

Texas’ CREZ policy is a policy model that can be examined through a principal-agent theory analysis. The rationale behind CREZ involved the state, acting as the principal, encouraging wind project developers, acting as agents, to build out utility-scale wind farms across the state with the goals of diversifying Texas’ power generation portfolio, exploiting Texas’ vast renewable energy resources, and creating jobs and economic impact in rural and urban areas across the state. The negotiation around CREZ began when the Texas Legislature made the decision to deregulate the Texas utility market in 1999. To get bipartisan support, the Texas Legislature included a RPS policy that included a REC program. Later in 2005, a CREZ program was implemented to help expand the wind market in Texas. One of the biggest expenses of building large-scale wind and solar farms is the transmission line infrastructure required to transport the electricity from rural windy and sunny areas back to the load centers. Texas has substantial wind and solar resources across the state, but unfortunately not where there was existing transmission line infrastructure already built or near the energy-intensive load centers within the Texas Triangle. As a result, the state succeeded, acting as the principal, in providing adequate market incentives and infrastructure investment to spur project developers, acting as agents, to quickly ramp up wind development across the state. Because of the execution of a principal-agent policy model, the State of Texas was able to successfully fulfill the requirements of the RPS policy, increase reliability on the ERCOT electric grid by adding West Texas, Texas Panhandle, and South Texas wind power, and also create a booming wind energy economy that has created thousands of jobs for Texas. The project development companies have also succeeded by following the state's transmission infrastructure build-out to economically deploy wind projects across the state.

Building out offshore CREZ infrastructure utilizing a similar policy model could be done to accelerate offshore wind development. If Texas implements a principal-agent policy model to proactively build out offshore CREZ transmission line infrastructure, it might encourage wind developers to deploy offshore wind farms. This could also bring a second agent into the mix with water desalination developers who might be able to take advantage of offshore wind's peaking power to support large-scale water desalination plants. Offshore wind could help the state minimize congestion line issues similar to what has been experienced in West Texas, the Texas Panhandle, and South Texas. Additionally, offshore wind in Texas is located much closer to the load centers within the Texas Triangle than West Texas wind. Instead of the state building over 200 miles of new transmission lines to connect a wind farm in West Texas, an offshore wind farm could only require 7 miles of underwater transmission lines to interconnect with the existing ERCOT grid along the Texas Gulf Coast. Underwater transmission is more expensive per mile than onshore transmission, but the order of magnitude difference in overall distance to the load centers and larger scale of offshore wind turbines could make offshore wind's long-term economics attractive compared to onshore wind.

Chapter Eleven: Texas General Land Office

A major advantage that Texas has over most coastal states is in its offshore land rights. Since Texas used to be its own country, one right Texas maintained after joining the United States union was its ownership of its infrastructure including its offshore land and mineral rights. Most coastal states only control up to 3 miles offshore whereas Texas controls up to 10 miles offshore.

The state agency that manages all of Texas' public lands including offshore submerged lands is the Texas General Land Office (GLO). The GLO's primary responsibility is to manage all of the public lands in Texas and exploit the minerals and resources available on these lands to generate revenue for the state. The revenue that the GLO produces from public lands is used to fund public education in the state through two separate funds. The GLO supports the Permanent University Fund, which funds higher education institutions in the state. The GLO also supports the Permanent School Fund, which funds kindergarten through 12th grade education in Texas. The GLO was established shortly after Texas was founded in 1837, and owns approximately 5% of the land in Texas. This translates into approximately 13 million acres of land that is distributed all across the state. The GLO generates revenue from these acres by leasing the land for mineral and energy production. The majority of the land is leased for oil, gas, and mineral production, but more recently, the GLO has been leasing land in West Texas and South Texas for renewable energy projects. The GLO currently has renewable energy leases in its portfolio for wind farms, geothermal plants, solar farms, and offshore wind farms.

Until recently, an Austin-based company called Baryonyx had 67,000 acres of GLO offshore land under lease to develop Texas' first offshore wind farms (Henry, T., NPR.org, January 2012). The company had been evaluating offshore wind patterns in the Gulf of Mexico for 2 years and was awaiting the completion of an environmental impact study by the Army Corps of Engineers. The preliminary data collected by met towers installed in the Gulf of Mexico suggested that the ideal location for offshore wind farms in Texas would be between Corpus Christi and Brownsville. This data aligns perfectly with DOE and SECO maps that identify the Corpus Christi-Brownsville offshore corridor to have a class 6 wind resource potential. The offshore wind turbines would be located 7 miles offshore, which places the turbines farther from the coast than many of the offshore oil platforms.

A major issue that has arisen in offshore wind farm development policy is the "Not In My Backyard" or NIMBY opposition where communities along the coast are actively opposing offshore wind projects because of the perceived aesthetic and environmental impacts that would presumably occur. However, in Texas, offshore wind development will most likely take place at a distance far enough from shore where the wind turbines will not be visible from the coast. From a public policy standpoint, this is a major advantage that Texas has when it comes to approving offshore wind farm development projects.

Chapter Twelve: Price Competitiveness of Wind Energy

Despite all the advantages that wind power has in Texas, one factor above all has proven to be the main driving force behind wind power's success. In Texas, wind power is a highly competitive source of energy that competes against conventional forms of energy on price. Like all renewable energy technologies, wind power has faced sharp criticism for being too expensive and not ready for large-scale deployment because of the perception that it will increase overall electric rates in the state. However, quite the opposite effect has occurred with Texas energy prices due to wind power. Wind energy is a perpetually advancing technology and similar to Moore's Law in semiconductor technology, new advancements in wind power technology brings higher efficiencies at lower costs. Additionally, the way the ERCOT market is structured allows cheap wind power generated in West Texas to be sold into higher energy cost areas of the state where no wind power is produced. The ability to sell zero or negative-priced wind into more expensive nodes in Texas has actually caused a drop in wholesale energy prices where wind power is purchased.

Wind is an intermittent resource and still requires base load reserves to step in when wind resources unexpectedly decline. However, when the wind resource is strong, wind has the ability to sell into different nodes on the ERCOT system at the lowest available marginal price or even negative prices. Negative wind prices occur when congestion on ERCOT occurs forcing ERCOT to curtail wind production to alleviate the congestion issues. To avoid curtailment by ERCOT, wind farm operators will offer their power at zero or negative prices as long as they can still recoup revenue from the federal Production Tax Credit (PTC) and REC sales. Once ERCOT enforces curtailment, the wind farm operator will switch off their turbines and cease generating until the congestion issues are resolved (Brattle, 2012, p. 20). As a result, wind energy in Texas has put significant downward pressure on overall energy prices in Texas, which is contrary to conventional perceptions regarding the cost and electric rate impact of renewable energy.

An example of how wind power has become cost-effective for electric utilities in Texas is seen in Austin Energy's recent purchase of 291 megawatts of coastal wind (Toohey, July 2011). Austin Energy recently signed long-term power purchase agreements (PPA's) with two wind farm developers for 25-year periods. The wind farms will be constructed onshore along the Texas Gulf Coast in the Corpus Christi-Brownsville corridor. The PPA contracts signed by the utility further demonstrate wind power's competitiveness and positive impact on the state's economy. Austin Energy's landmark PPA contracts guarantee the utility 291 megawatts of clean, renewable, carbon-free, and water-free energy for 25 years at a price that is competitive with natural gas and other conventional forms of energy. Austin Energy will spend $50 million per year on wind power from the Texas Gulf Coast, which will translate into an unprecedented low price of 3.5 cents/kwh.

A key advantage to Austin Energy's PPA for 291 megawatts of coastal wind is that these wind farms will produce the majority of their power during critical peak times for energy. The Texas Public Utility Commission (PUC) announced that the market cap for peak power purchases increased to $7,000/MWh on June 1, 2014 and will increase again to $9,000/MWh on June 1, 2015. The goal of the PUC in raising the peak power market caps is to encourage generators to build additional generation capacity by allowing them to charge higher prices during peak times. These higher peak prices help generators improve the economics of installing additional natural gas peaking units. In the summer of 2011, electric utilities across Texas paid on average $850/MWh for additional peaking power off the spot market. During peak times, utilities that need to purchase additional peaking power almost always lose money. Austin Energy will be able to more effectively avoid additional peak power purchases by engaging in PPA contracts that offer power when it is most needed and at a low price that is fixed for 25 years.

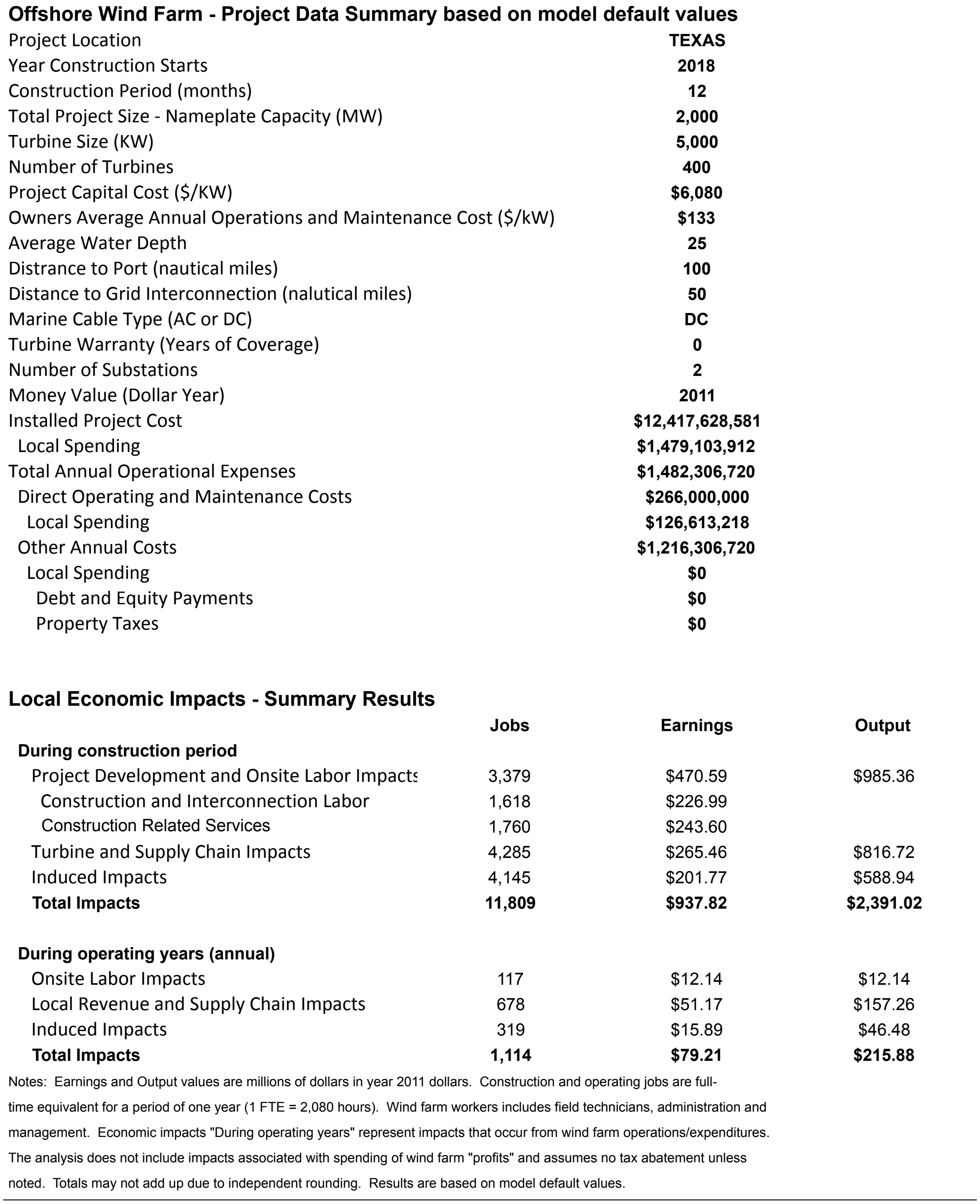
Chapter Thirteen: Economic Impact

According to the American Wind Energy Association (AWEA), Texas has 14,098 megawatts of wind installed with 7,000 megawatts of wind currently under construction and another 25,000 megawatts of wind projects in the planning stages. AWEA also estimates that the Texas economy has gained approximately 9,000 jobs over the past decade from wind energy alone. These jobs include operations and maintenance, construction, manufacturing, project development, legal, PR/marketing, and financial services (Anonymous, AWEA, October 2012).

The U.S. Department of Energy recently released a series of economic impact tools designed to estimate the economic impact for a state, county, or region based on the deployment of renewable energy projects. The DOE refers to these economic impact tools as Jobs and Economic Development Impact tools or JEDI. Using DOE's JEDI tool for offshore wind development makes it possible to estimate the economic impact of 2,000 megawatts of offshore wind projects to the Texas economy. The results of the JEDI analysis are provided in Figure 13.1. Assuming Texas successfully develops 2,000 megawatts of offshore wind projects, the State of Texas stands to gain 11,809 jobs during the construction phase of these projects and 1,114 full time permanent jobs during the operating years of these projects. The total capital investment associated with 2,000 megawatts of offshore wind in Texas is estimated at $12.4 billion. By moving forward with offshore wind development to power large-scale water desalination plants, Texas stands to double its wind power and clean energy workforce over the next decade.

Figure 13.1

Jobs and Economic Development Impact Model (JEDI) – Texas Offshore Wind



Offshore Wind Farm - Project Data Summary based on model default values

Project Location	**TEXAS**
Year Construction Starts	**2018**
Construction Period (months)	**12**
Total Project Size - Nameplate Capacity (MW)	**2,000**
Turbine Size (KW)	**5,000**
Number of Turbines	**400**
Project Capital Cost ($/KW)	**$6,080**
Owners Average Annual Operations and Maintenance Cost ($/kW)	**$133**
Average Water Depth	**25**
Distrance to Port (nautical miles)	**100**
Distance to Grid Interconnection (nalutical miles)	**50**
Marine Cable Type (AC or DC)	**DC**
Turbine Warranty (Years of Coverage)	**0**
Number of Substations	**2**
Money Value (Dollar Year)	**2011**
Installed Project Cost	**$12,417,628,581**
Local Spending	**$1,479,103,912**
Total Annual Operational Expenses	**$1,482,306,720**
Direct Operating and Maintenance Costs	**$266,000,000**
Local Spending	**$126,613,218**
Other Annual Costs	**$1,216,306,720**
Local Spending	**$0**
Debt and Equity Payments	**$0**
Property Taxes	**$0**

Local Economic Impacts - Summary Results

	Jobs	Earnings	Output
During construction period			
Project Development and Onsite Labor Impacts	3,379	$470.59	$985.36
Construction and Interconnection Labor	1,618	$226.99	
Construction Related Services	1,760	$243.60	
Turbine and Supply Chain Impacts	4,285	$265.46	$816.72
Induced Impacts	4,145	$201.77	$588.94
Total Impacts	**11,809**	**$937.82**	**$2,391.02**
During operating years (annual)			
Onsite Labor Impacts	117	$12.14	$12.14
Local Revenue and Supply Chain Impacts	678	$51.17	$157.26
Induced Impacts	319	$15.89	$46.48
Total Impacts	**1,114**	**$79.21**	**$215.88**

Notes: Earnings and Output values are millions of dollars in year 2011 dollars. Construction and operating jobs are full-time equivalent for a period of one year (1 FTE = 2,080 hours). Wind farm workers includes field technicians, administration and management. Economic impacts "During operating years" represent impacts that occur from wind farm operations/expenditures. The analysis does not include impacts associated with spending of wind farm "profits" and assumes no tax abatement unless noted. Totals may not add up due to independent rounding. Results are based on model default values.

Source: DOE, Jobs and Economic Development Impact Models (JEDI), http://www.nrel.gov/analysis/jedi/download.html

Chapter Fourteen: Public Policy

According to The Brattle Group report released in June of 2012, one potential threat to the future of wind development and especially offshore wind development in the United States is the expiration of the Production Tax Credit (PTC) (Newell, The Brattle Group, June 2012,).

The PTC was introduced in 1992 and has helped the wind industry expand at a more accelerated pace than it otherwise would have without the federal subsidy. The PTC functions as a performance-based incentive by compensating wind farm operators on a per kilowatt-hour basis. The incentive supplied by the PTC has been set at $23/MWh or 2.3 cents/kwh. This incentive allows wind energy to compete against conventional forms of power generation more aggressively. A major issue with the PTC is that it has never been extended for long periods of time. Instead, due to political maneuvering by both political parties in Congress, the PTC has been extended for only one or two year increments at a time. The lack of market certainty created by short-term extensions of the PTC has resulted in inconsistent growth cycles in the U.S. wind industry. A long-term extension of the PTC could help the U.S. grow its wind energy economy more consistently and become the largest wind market in the world.

One possible negotiation tactic on the PTC could be for Congress to agree to incremental step-downs of the payout rate in exchange for a longer extension period. The wind industry has matured to a point where it is quickly becoming cost-competitive with conventional energy generation with little or no subsidies. The PTC has been a helpful policy, but will eventually be phased out since it has already served its purpose of jumpstarting the U.S. wind energy economy.

From a water rights policy perspective, municipalities across the state are looking for long-term solutions to satisfy their future water needs. With dwindling availability of fresh surface water resources, cities across the state are looking for fresh and brackish groundwater resources that can be produced economically. With groundwater policy in Texas controlled at the local level by groundwater conservation districts, municipalities are facing significant challenges in securing future water rights, which is spurring new innovative approaches. For example, the City of San Antonio recently signed a long-term contract for groundwater rights located nearly 150 miles away in Burleson County, Texas. San Antonio Water System's Vista Ridge Pipeline project will pump water via pipeline to the City of San Antonio's water inlet facility where it will be treated and then distributed across the city. At a projected cost of $3 billion, it is estimated that the Burleson County water well field and Vista Ridge Pipeline will provide 50,000 acre-feet of fresh water to San Antonio each year (SAWS, Vista Ridge Pipeline). Likewise, cities across the state are also looking to implement large-scale water desalination facilities. The costs associated with constructing water desalination plants are significant, and a more innovative approach to plan, finance, and power large-scale water desalination facilities is needed. With this in mind, coupling offshore wind projects with water desalination plants is a promising solution.

Chapter Fifteen: Economic Model

Considering the major challenges that Texas faces going forward in solving its energy and water crises, the deployment of utility scale water desalination facilities powered by offshore wind energy is a concept that has promise especially when examined using an economic model analysis. For the purposes of this economic model, we will explore five unique scenarios that will help demonstrate the feasibility of water desalination and offshore wind in Texas for a range of municipal water rates and offshore wind Power Purchase Agreement (PPA) contract prices.

All scenarios will look at the economic model of constructing a utility scale water desalination facility in Far West Texas where the population and water demand are high, surface water is scarce yet underground brackish water is plentiful and has low salinity content. We will evaluate the desalination plant by calculating its operational profitability using:

- Scenario 1 – low municipal water prices and low offshore wind PPA prices
- Scenario 2 – average municipal water prices and average offshore wind PPA prices
- Scenario 3 – high municipal water prices and high offshore wind PPA prices
- Scenario 4 – low municipal water prices and high offshore wind PPA prices
- Scenario 5 – high municipal water prices and low offshore wind PPA prices

Each of these five scenarios will be examined using an operational profitability calculation that is represented by the following formula:

Annual Operating Profit of Offshore Wind-Powered Water Desalination Facility

Annual Operating Profit = Annual Water Revenue
– Annual Capital Expenditure Costs
– Annual Operating Expenses
– (Annual Offshore Wind Power Purchase Agreement (PPA) Contract Price x Annual Energy Consumption)

The Annual Operating Profit formula will measure whether the water desalination facility will be able to cover its annual operating costs including the cost of signing a PPA contract for offshore wind. Applying the same formula and economic model analysis to each of the five scenarios will demonstrate whether the concept of offshore wind-powered water desalination is feasible across the entire state of Texas. For the analysis, we will assume that municipal water rates in Texas range from approximately \$250/acre-foot to \$2,800/acre-foot (Clayton, M. et al., Implementation of Brackish Groundwater Desalination Using Wind-Generated Electricity), and current offshore wind PPA contract prices range from 12 cents/kWh to 20 cents/kWh with a 2020 target range of 5 cents/kWh to 9 cents/kWh (Roland Berger Strategy Consultants, Offshore Wind Towards 2020).

Before examining the five Annual Operating Profit scenarios, we must first calculate a baseline Annual Operating Profit to compare the five scenarios. The baseline Annual Operating Profit will be calculated using the City of El Paso's Kay Bailey Hutchinson (KBH) Desalination Plant. The KBH facility produces a maximum capacity of 31,000 acre-feet of water annually at a capital cost of $91 million. The brackish water that is being treated at the El Paso facility is considered to be low salinity with total dissolved solids (TDS) between 1,000 mg/l to 3,000 mg/l, so the energy required to treat the brackish water is higher than treating fresh surface water, but still cheaper than desalinating ocean water. It is estimated that the El Paso facility currently produces water at a cost of $489/acre-foot (Arroy, J. and Shirazi S., Cost of Brackish Groundwater Desalination in Texas).

If we assume that the facility is operating at full capacity, the total annual production costs for the KBH plant will total $15,159,000. Breaking down the annual production costs of the KBH plant in more detail shows that annual electricity usage operating at full capacity is 19,680,000 kilowatt hours (kWh) (Anonymous, Request for Proposal Solar Photovoltaic System Procurement RFP 62-11), and the average electric rate for the KBH plant is 8.35 cents/kWh. So, the annual electricity cost for the KBH plant is $1,643,280. The total capital investment of the KBH plant is $91,000,000, and the typical timeline to pay off the capital expense is 20 years. This means that the annual capital cost for the KBH plant is $4,550,000. The remaining costs are other operating-related costs, which total $8,965,720 annually. Adding all of these production costs together yields a total annual production cost of $15,159,000 assuming an average electric rate of 8.35 cents/kWh. If the facility produced 31,000 acre-feet of water annually and sold the water at the average municipal price of water in El Paso, TX, which is $855/acre-foot (Anonymous, Comprehensive Annual Financial Report), then total operating profitability for the KBH facility would be as follows:

<u>Baseline Scenario</u>: Avg. El Paso Municipal Water Rate; Avg. El Paso Electric Rate

Annual Operating Profit (KBH Plant) = $855/acre-foot (31,000 acre-feet) water revenue
- $4,550,000 capital costs
- $8,965,720 operating costs
- 8.35 cents/kWh (19,680,000 kWh) electricity costs

Annual Operating Profit (KBH Plant) = $11,346,000

From this calculation, it is estimated that the KBH plant will earn over $11 million each year at the average municipal water rate of $855/acre-foot and average electric rate of 8.35 cents/kWh in El Paso, TX. This analysis establishes a baseline Annual Operating Profit that we can use to compare our five scenarios.

For Scenario 1, we will run the Annual Operating Profit calculation assuming a low municipal water rate and a low offshore wind PPA contract price to see how the KBH plant's Annual Operating Profit compares to the baseline scenario. If the KBH plant operated at full capacity producing 31,000 acre-feet of water annually, but instead sold the water at a low municipal water rate of $250/acre-foot and contracted for offshore wind power to provide 100% of the facility's electricity at 5 cents/kWh, then the Annual Operating Profit of the KBH plant would be as follows:

Scenario 1: Low Municipal Water Rate; Low Offshore Wind PPA

Annual Operating Profit (KBH Plant) = $250/acre-foot (31,000 acre-feet) water revenue
- $4,550,000 capital costs
- $8,965,720 operating costs
- 5 cents/kWh (19,680,000 kWh) electricity costs

Annual Operating Profit (KBH Plant) = -$6,749,720

In Scenario 1, using a low municipal water rate and low offshore wind PPA contract price yields an Annual Operating Profit of negative $6.7 million. This scenario demonstrates that water desalination facilities need to have a sufficiently high enough municipal water rate in order to cover the costs associated with operating the facility. Even with a very low offshore wind PPA contract price, the KBH plant would not be profitable and would therefore not be an economical investment for the El Paso region.

For Scenario 2, we will run the Annual Operating Profit calculation assuming an average Texas municipal water rate and an average offshore wind PPA contract price to see how the KBH plant's Annual Operating Profit compares to the baseline scenario. If the KBH plant again operated at full capacity, but instead sold the water at an average rate of $1,500/acre-foot and contracted for offshore wind power at an average price of 12 cents/kWh, then the Annual Operating Profit of the KBH plant would be as follows:

<u>**Scenario 2**</u>**:** Average TX Municipal Water Rate; Average Offshore Wind PPA

Annual Operating Profit (KBH Plant) = $1,500/acre-foot (31,000 acre-feet) water rev.
- $4,550,000 capital costs
- $8,965,720 operating costs
- 12 cents/kWh (19,680,000 kWh) electricity costs

Annual Operating Profit (KBH Plant) = $30,622,680

In Scenario 2, using an average municipal water rate and average PPA contract price for offshore wind yields a higher Annual Operating Profit of $30.6 million compared to the baseline scenario. This scenario demonstrates that even with an offshore wind PPA contract price that is more than twice Scenario 1, operating a water desalination plant in Texas is feasible if the facility can charge an average municipal water rate. This scenario shows that an offshore wind-powered water desalination facility like the KBH plant is a worthwhile investment for the El Paso region and most likely an economical solution for other regions in Texas

For Scenario 3, we will calculate the Annual Operating Profit for the KBH facility assuming a high municipal water rate and high offshore wind PPA contract price. Assuming that the KBH facility is operating at maximum capacity producing 31,000 acre-feet of water annually, but instead sold the water at a high municipal water rate of

$2,800/acre-foot and locked in a high offshore wind PPA contract price of 20 cents/kWh, then the Annual Operating Profit for the KBH plant would be as follows:

<u>Scenario 3</u>: High Municipal Water Rate; High Offshore Wind PPA

Annual Operating Profit (KBH Plant) = $2,800/acre-foot (31,000 acre-feet) water rev.
- $4,550,000 capital costs
- $8,965,720 operating costs
- 20 cents/kWh (19,680,000 kWh) electricity costs

Annual Operating Profit (KBH Plant) = $69,348,280

In Scenario 3, running the calculation using a high municipal water rate and high offshore wind PPA contract price yields an Annual Operating Profit of more than $69 million. This scenario shows that even with a high contract price for offshore wind, a water desalination plant can be a very profitable investment for a community that is located in a region of the state where water resources are scarce and the price for municipal water is very high. This scenario in particular bodes extremely well for the viability and opportunity of implementing offshore wind-powered water desalination plants across the State of Texas.

For Scenario 4, we will run the Annual Operating Profit calculation assuming a low municipal water rate and high offshore wind PPA contract price. Again assuming that the KBH plant is producing a maximum of 31,000 acre-feet of water per year, but instead sold the water at a low municipal water rate of $250/acre-foot and contracted offshore wind power at a high price of 20 cents/kWh, then the Annual Operating Profit for the KBH plant would be as follows:

__Scenario 4__**:** Low Municipal Water Rate; High Offshore Wind PPA

Annual Operating Profit (KBH Plant) = $250/acre-foot (31,000 acre-feet) water rev.
- $4,550,000 capital costs
- $8,965,720 operating costs
- 20 cents/kWh (19,680,000 kWh) electricity costs

Annual Operating Profit (KBH Plant) = -$9,701,720

In Scenario 4, using a low municipal water rate and high offshore wind PPA contract price yields an Annual Operating Profit of negative $9.7 million. This scenario is by far the worst outcome of the five scenarios evaluated for the KBH plant. Scenario 4 demonstrates that areas of the state where water is already cheap and plentiful will most likely not benefit from implementing an offshore wind-powered water desalination facility.

For Scenario 5, we will evaluate the Annual Operating Profit for the KBH facility using a high municipal water rate and a low offshore wind PPA contract price. In this scenario, we will again assume that the water desalination plant is producing at maximum capacity of 31,000 acre-feet of water annually, but instead selling the water at a high municipal rate of $2,800/acre-foot and powering the facility off of a low offshore wind

PPA contract price of 5 cents/kWh. The Annual Operating Profit of the KBH facility would be as follows:

<u>Scenario 5</u>: High Municipal Water Rate; Low Offshore Wind PPA

Annual Operating Profit (KBH Plant) = $2,800/acre-foot (31,000 acre-feet) water rev.
- $4,550,000 capital costs
- $8,965,720 operating costs
- 5 cents/kWh (19,680,000 kWh) electricity costs

Annual Operating Profit (KBH Plant) = $72,300,280

In Scenario 5, utilizing a high municipal water rate and a low offshore wind PPA contract price yields an Annual Operating Profit of over $72 million. Scenario 5 is the optimal profitability scenario for the KBH plant. This scenario demonstrates that water desalination facilities, though expensive and energy-intensive, can be implemented economically when coupled with a long-term, fixed-price offshore wind PPA contract. Areas of the state where water is scarce and costly to produce will be able to profitability implement offshore wind-powered water desalination to meet future water needs.

Figure 15.1 provides detailed municipal water rate and annual water consumption information for the largest cities in Texas. This data shows that municipal water rates among the largest Texas cities are within the range of the municipal water rates that were used for the economic model analysis. Also, each city is located on or near one of Texas' major aquifer systems that can supply large volumes of brackish water that is of low to moderate salinity. Therefore, offshore wind-powered water desalination is an economical option for Texas cities, which will help Texas solve its future water and energy needs.

Figure 15.1

Texas Municipal Water Rates and Consumption

City	Municipal Water Rate ($/Acre-Foot)	Annual Consumption (Acre-Feet)
Austin	$1,638	146,539
Dallas	$1,331	414,299
El Paso	$855	107,380
Houston	$755	662,004
San Antonio	$1,503	169,120

Source: Comprehensive Annual Financial Report, Cities of Austin, Dallas, El Paso, Houston, and San Antonio

Chapter Sixteen: Conclusions

In conclusion, Texas has abundant natural resources due to its unique geological history. The Gulf of Mexico Basin is a good location for offshore and deep-water energy production whether it is in the form of oil, gas, or wind. The required offshore industry expertise is already in place and capable of adapting offshore oil and gas platform technology to offshore wind projects. Prevailing offshore wind patterns position the Texas Gulf Coast as one of the major untapped energy resources in the nation. These offshore winds align with peak demand for energy, which allow offshore wind energy to compete directly with conventional forms of energy on the ERCOT grid. Texas' unique deregulated utility market allows wind power to thrive through a nodal market structure that rewards the cheapest marginal cost unit of energy available. Offshore wind due to its robust wind resource, federal subsidies, and RECs is positioned to out compete all forms of energy in Texas including cheap natural gas from the Permian Basin, Barnett, and Eagle-Ford Shales.

Texas is also facing one of the most severe droughts on record. Fresh water resources in Texas are continuing to decline as the state's population is expected to nearly double by 2060. Texas must find a way to produce an additional 8.3 acre-feet of fresh water annually in order to satisfy future demand. Large-scale water desalination plants are a promising solution to the Texas water crisis, and Texas has immense reserves of brackish water trapped in underground aquifers across the state. Coupling the economies of scale and peak power coincidence of offshore wind with large-scale water desalination plants could be a solution to solve Texas' future energy and water challenges. The Texas PUC could implement a principal-agent model offshore CREZ policy to build out offshore transmission line infrastructure in order to encourage the construction of offshore wind to power water desalination projects across the state. Because of the seamless integration of the ERCOT utility market, offshore wind could be contracted to power onshore and coastal water desalination plants across Texas. From the Annual Operating Profit economic model analysis, we have demonstrated how a range of municipal water rates and a range of offshore wind PPA contract prices can work in tandem to help make offshore wind-powered water desalination economical and profitable for Texas cities.

Offshore wind and water desalination development have the ability to create thousands of new jobs for the Texas economy and attract billions of dollars in new investment for new wind energy and water technology headquarters, manufacturing, project development, and R&D facilities. Texas' economic future is dependent on solving its energy and water challenges. Offshore wind development and large-scale water desalination facilities could enable Texas to thrive as the world's most advanced and innovative Energy and Water Capital.

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Vita

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