BENEFITS AND OBSTACLES TO INSTALLING WIND AND SOLAR ENERGY SYSTEMS ON UNIVERSITY CAMPUSES: A TEXAS STUDY

BY

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DISSERTATION

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Jerimiah 29: 11: “For I know the plans I have for you, declares the LORD, plans to prosper you and not to harm you, plans to give you hope and a future.

ABSTRACT

There is much known about renewable energy, including solar and wind. However, there is little information available regarding the use of wind and solar energy on college and university campuses. As educators and shapers of the next generation of society, colleges and universities can be important leaders in transitioning to renewable energy, and in educating their students about renewable energy. In addition, college and university campuses are in an economic downfall now, with the high cost of education and decreased state funding. Institutions of higher education must find ways to save money and decrease costs; utility bills could potentially be reduced by using cutting-edge technologies of renewable energy.

The overall goal of this research was thus to identify benefits and obstacles to installation of wind and solar energy on college and university campuses. Specific objectives were:

1. To conduct interviews with officials at several colleges and universities in Texas with renewable power already installed, to learn more about the factors that influenced their decision, and identify any issues with implementation.

2. Using themes that emerge from the interviews conducted as part of Objective 1, to develop a survey to administer to a larger sample of colleges and universities in Texas to see whether they use solar/wind power, identify factors that influenced their decision, and identify any issues with implementation.

Texas was selected not only because the University of Texas at Arlington is located in Texas, and thus traveling to other universities in Texas for the case studies was convenient, but also because Texas is the leading state in production of wind power, and also has large potential for production of solar power. In addition, Texas has a large number of colleges and universities to survey.

This research study can help a college or university that is considering using solar or wind power to make a sound decision. This study will be of value to various university personnel, including sustainability directors, physical operations personnel, and faculty members.

This study used an exploratory sequential mixed methods approach. In the first phase, interviews were conducted with the Sustainability Directors from 3 universities in Texas that have already installed solar and/or wind power: the University of North Texas in Denton, Texas A&M University at Corpus Christi, and the University of Texas at Arlington. The themes identified from these interviews were then used to develop quantitative survey questions regarding potential benefits and obstacles to installation of solar and wind power on university campuses. The surveys were then sent to 59 colleges and universities across Texas. Twelve survey responses were received.

Important themes that emerged from the interviews were 1) the importance of renewable energy for the environment, 2) green publicity, 3) opportunities for teaching and research, 4) the need for financial savings, and 5) the need for grant funding. Selected findings from the quantitative survey were:

- Most respondents agreed or strongly agreed that installing wind or solar power on campus would make for good publicity for the college or university (92%), would attract students to the school (83%), and would be good teaching tools for students on campus (100%).
- The colleges and universities surveyed were more likely to think that that solar power would save them money (83%) compared to wind power (58%).
- Large schools (> 10,000 students) and 4-year schools were more likely to believe that renewable power could be a useful research tool at their university.
- The primary obstacle to installing solar panels and wind turbines on university campuses is up-front costs. Providing additional grant funding and incentives is critical in overcoming this hurdle. Secondary concerns include availability of wind power and the potential for both solar panels and wind turbines to be eye-sores.

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Chapter 1

INTRODUCTION

1.1 Background

Humans have reached a point where it is time to look beyond fossil fuels for our energy needs. Fossil fuels are those fuels formed by natural processes of heat and pressure acting on decomposing buried organisms over time. The global population on Earth reached beyond 7 billion people in 2011. Fossil fuels are non-renewable to the extent that we are using fossil fuels quicker than they can be replenished. They take millions of years to develop (Liu, 2012).

Fossil fuels have the ability to harm the environment. Issues include climate change, air pollution, water and land pollution, and thermal pollution. Fossil fuels impact the climate when they are burned. One major gas, carbon dioxide, is given off and can be trapped in the earth's atmosphere. Statistics show that over the last 150 years, burning fossil fuels has increased the carbon dioxide concentration more than 25% in the atmosphere. Each year, burning fossil fuels adds 3.2 billion tons of additional carbon dioxide to the atmosphere (Union of Concerned Scientists, 2017).

Burning of fossil fuels affect the air we breathe. There are several pollutants that are produced: carbon monoxide, nitrogen oxides, sulfur oxides, and hydrocarbons. Nitrogen oxides and hydrocarbons combine in the atmosphere to form tropospheric ozone, a major component of smog which affects many populated cities across the world. The pollutants mentioned above can affect a person with underlying health issues such as heart and respiratory problems as well as affecting the healthy person with irritations.

Water and land pollution can result from the use of fossil fuels. Production, use, and transportation of oil can affect water. Oil spills can leave the water polluted for lengthy amounts of time. This can result in loss of animal and plant life. Land pollution can occur from coal mining such as strip mining, which leaves the land barren and not healthy for new growth unless good topsoil is used when replanting occurs.

Thermal pollution can occur when burning fossil fuels to produce heat energy. Much of the heat produced reaches the atmosphere or can be released to the water that is used as a coolant. The heated

water when it returns to a lake or river can be an issue. The warm water could upset the aquatic ecosystem (Union of Concerned Scientists, 2017).

The United States is very dependent on fossil fuels, using nearly 20 million barrels of oil per day, importing 55% of it. We spend more than $20 billion each year on oil from the Middle East. It is projected that twenty years from now, the United States will be consuming 28.3 million barrels of oil per day, with 70% of it being imported, as the dependence continues to grow, as shown in Figure 1.1 below. Relying so heavily on foreign oil makes America dependent on some countries that are very unstable (Natural Resources Defense Council, 2004).

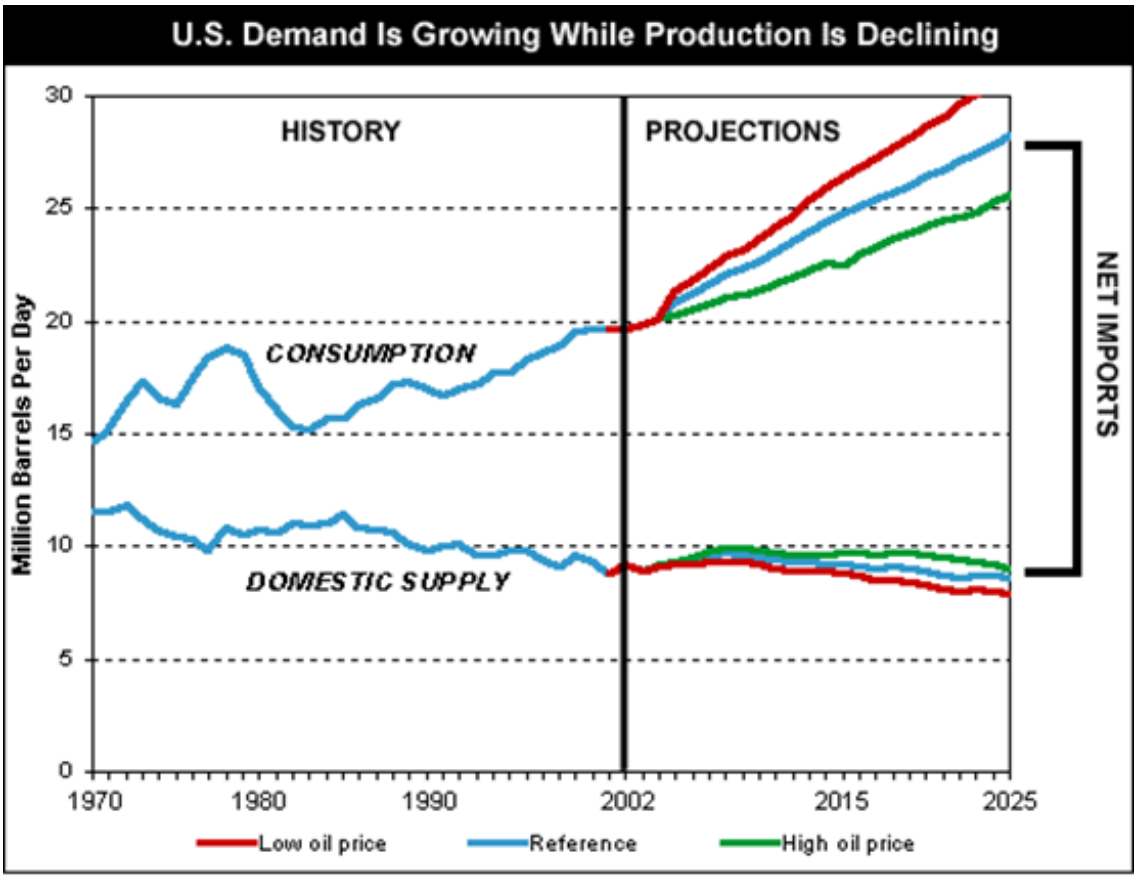

Figure 1.1 U.S. Oil Consumption (Our Finite World, 2013)

Humans must look for new forms of energy to be better prepared for a growing population that some say may reach 11 billion by the year 2100. Renewable forms of energy just may be the cutting-

edge solution we are looking for. These types of energy can be replenished in a much shorter time than the millions of years it takes to form fossil fuels. In addition, renewable forms of energy are cleaner to use. They are more friendly to our atmosphere and in turn, healthier for the human population.

Renewable types of energy include wind, solar, hydropower, and biofuels to mention a few. These forms of energy are getting much attention at this current time due to the fact they renew themselves at a much faster pace than fossil fuels which can take millions of years. In this study, two forms of renewable energy will be studied closely.

As educators and shapers of the next generation of society, colleges and universities can be important leaders in transitioning to renewable energy, and in educating their students about renewable energy. Installation of renewable energy technologies like wind and solar on campuses in particular can provide valuable teaching and research tools at colleges and universities.

In addition, college and university campuses are in an economic downfall of profit now with the high cost of education and some students are not being able to afford the cost of attending. Institutions of higher education must find ways to save money and decrease costs such as in utilities; this could potentially be done by using cutting edge technology using the renewable energy sources of wind and solar.

1.2 Research Goal and Objectives

The overall goal of this research is to identify benefits and obstacles to installation of wind and solar energy on college and university campuses.

Specific objectives include:

1. To conduct interviews with officials at several colleges and universities in Texas with renewable power already installed, to learn more about the factors that influenced their decision, and identify any issues with implementation.
2. Using themes that emerge from the interviews conducted as part of Objective 1, to develop a survey to administer to a larger sample of colleges and universities in Texas to see whether they use solar/wind power, identify factors that influenced their decision, and identify any issues with implementation.

Texas was selected not only because the University of Texas at Arlington is located in Texas, and thus traveling to other universities in Texas for the case studies was convenient, but also because Texas is the leading state in production of wind power, and also has large potential for production of solar power. In addition, Texas has a large number of colleges and universities to survey.

This research study can help a college or university that is considering using solar or wind power to make a sound decision. This study will be of value to various university personnel, including sustainability directors, physical operations personnel, and faculty members. The information provided about perceived benefits and drawbacks of installation of solar and wind power on college/university campuses will help them make a more informed decision.

1.3 Organization of Dissertation

Table 1.1 lists the dissertation organization.

Table 1.1 Dissertation Organization

Chapter	Content
2	This chapter provides background information and contains a literature review of similar studies.
3	This chapter deals with the methodology that was employed in collecting and analyzing the data.
4	This chapter includes the results and discussion of the data.
5	This chapter lists conclusions and recommendations for future research.

Chapter 2

LITERATURE REVIEW

2.1 Introduction

Fossil fuels are being used at an alarming rate with the world's population now over 7 billion people. The projected availability of fossil fuel supplies is important to look at. Oil will continue to account for the largest share in the world's primary energy supply up to the year 2030 at least. Demand is expected to growth by about 57% from 2002 to 2030. It is expected to be only a marginal drop in today's share of the global energy mix, from 36% in 2002 to 35% in 2030. Proved reserves (those amounts of fossil fuels that have been "discovered and defined") of oil in the United States totaled 21.317 billion barrels in 2007. Undiscovered oil reserves (projected quantities of oil and natural gas that are estimated to exist in unexplored areas) for the U.S. totaled 145.5 billion barrels. Total proved and undiscovered oil reserves for the U.S. were estimated at 166.7 billion barrels (Agricultural Marketing Resource Center, 2009). World energy consumption is expected to increase by 50% to 180,000 GWh/year by 2020 (Fernando et al., 2006), due primarily to increases in demand from rapidly developing Asian countries such as China and India (Khanal, 2009). According to the Intergovernmental Panel on Climate Change (IPCC, 2007), fossil fuel combustion already contributes 57% of emissions that cause global warming. Fossil fuel combustion also produces substantial amounts of traditional air pollutants, including carbon monoxide, particulates, nitrogen oxides, sulfur oxides, and volatile organic compounds. We must look for new ways to produce energy that can replenish themselves at a faster rate than fossil fuels and are less toxic which reduces air pollution. Renewable energy is one type of energy being considered.

Types of renewable energy continue to be used and researched due to the increased demand on fossil fuels. The diagram below shows the renewable energy as share of total primary energy consumption in 2010:

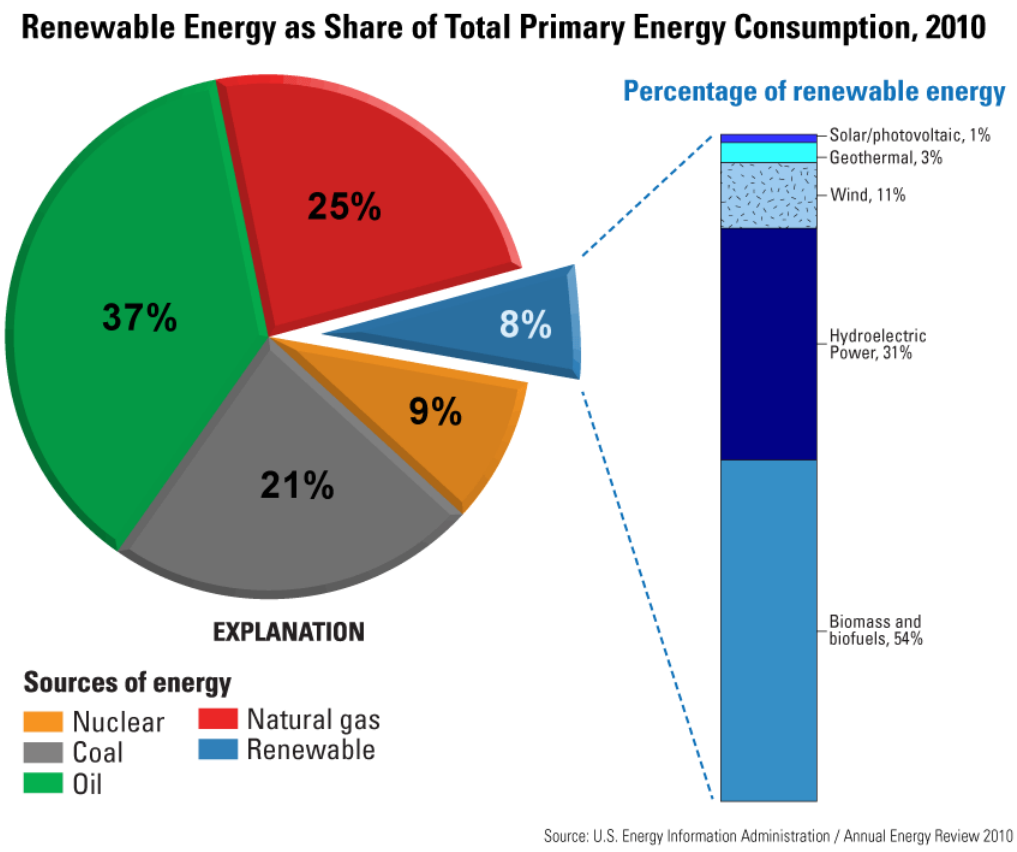

Figure 2.1 Renewable Energy Consumption (U.S. Energy Information Administration, 2010)

The study of renewable energy has a rich history. The United States Energy Legislative History goes back to the 1970s. Renewable energy legislation and policy gained interest by many after the oil crisis in the 1970s and the potential environmental concerns that could result. Wind energy was among the renewable energy options that were included in the U.S. energy policy starting in the 1970s. During this time frame, the Public Utility Regulatory Policies Act of 1978 was passed. This particular policy mandated increased electricity production from renewable energy facilities. (Loiter and Norber-Bohm, 2011)

Later in 1989, the Renewable Energy and Energy Efficiency Technology Competitiveness Act was instated. The purpose of this policy was to set specific goals for the U.S. in relation to wind, photovoltaics, and solar thermal energy programs. For wind energy, the specific goals set included,

improving design methodologies and developing more reliable and efficient wind turbines to increase the cost competitiveness of wind energy.

2.2 Overview of Types of Renewable Energy

Solar and wind energy are two types of renewable energy that are receiving much attention. These two types of renewable energy create electrical power in a much cleaner manner than do fossil fuels when they are burned. This is very important in helping to reduce the air pollution, waste pollution, and toxic pollution which can be attributed to the burning of fossil fuels. It should be kept in mind, however, that ll kinds of renewable energy have some kind of risk. Wind energy, for example, can be bad for birds and bats that fly into the spinning blades of the wind turbine. Toxic chemicals such as hydrochloric acid and sulfuric acid are used to clean the surface of the semiconductors during PV cell production. This section will provide an overview of advantages and disadvantages of different types of renewable energy, including solar, wind, hydropower, and biomass. (http://www.education.seattlepi.com)

2.2.1 Solar Energy

Solar energy is the radiant light and heat from the sun. The Earth receives 174 petawatts (PW) of incoming solar radiation at the upper atmosphere. Approximately 30% is reflected back to space while the rest is absorbed by clouds, oceans, and land masses, as shown in Figure 2.2 below. The total solar energy absorbed by Earth's atmosphere, oceans, and land masses is about 3,850,000 exajoules (EJ) per year. It can be harnessed using several different types of technology including solar heating, solar photovoltaics, solar thermal electricity, and solar architecture. Solar energy technologies can be either active or passive depending on the way they capture, and convert and distribute solar energy. Active solar techniques include the use of photovoltaic panels, pumps, and fans and solar thermal collectors to capture the energy from the sun. Passive solar techniques include constructing a building towards the Sun and selecting materials with favorable thermal properties, and designing spaces that naturally circulate the air. Solar energy is not new. It spans from the 7th Century B.C. to today. Its beginning was concentrating the sun's heat with glass and mirrors to light fires. The discovery of photovoltaics occurred

in 1839 when French physicist Edmond Becquerel demonstrated photovoltaic activity. Today, we have everything from solar-powered buildings to solar-powered vehicles (U.S. Department of Energy, 2013).

Benefits to using solar energy include: (Clean Energy Ideas, 2007)

- The power source of the sun is free.
- The production of solar energy produces no pollution.
- The technological advancements in solar energy systems have made them cost effective, particularly in certain applications.
- Most systems do not require maintenance during their lifespan, which means no maintenance costs.
- Most systems have a life span of 30 to 40 years.
- Most systems carry a full warranty for 20 to 30 years or more.
- Unlike traditional big panel systems, many modern systems are sleeker such as Uni-Solar rolls that lie directly on the room like regular roofing materials.
- In 35 states, solar energy can be fed back to the utilities to eliminate the need for a storage system as well as eliminating or drastically reducing electric bills.
- Solar systems of today are now designed for particular needs. An example would be converting outdoor lighting to solar. The solar cells are directly on the lights and cannot be seen by anyone. This helps to eliminate all costs associated with running outdoor lighting.

The advantages above clearly show solar energy has its positive aspects. However, there are disadvantages to using solar energy.

- High upfront cost of the equipment used to harness the solar energy. Solar panels remain a costly alternative to the use of readily available fossil fuel. Even though the startup cost is expensive, solar panels will often pay for themselves over future years due to reduced energy bills.
- A large surface area is required. Residential and commercial solar energy systems require a large surface area of solar panels in order for the system to be efficient in

providing a source of reliable electricity. This could be a disadvantage in areas where space is at a premium such as inner cities.

- Using solar energy technology requires reliable amounts of sunshine to work efficiently. Weather plays into this situation. In areas of the country where there are many partly or mostly cloudy days annually, panels would not be efficient.
- Solar energy is only useful during the daylight hours. At night, solar panels are unable to generate electricity due to lack of solar energy. Some polar panel systems use solar battery chargers that are able to store varying amounts of solar electricity for use during the night
- Another disadvantage of solar energy is that it does not provide power continuously. As mentioned above, on consecutive cloudy days, it is difficult to generate continuous power for generating electricity. (Clean Energy Ideas, 2007)

Figure 2.3 A Solar Panel Harnessing the Sun's Energy at Texas A&M-Corpus Christi

2.2.2 Wind Energy

Wind energy is a form of solar energy in that the uneven heating of the atmosphere by the sun, produces the pressure gradients that cause wind, with its magnitude and direction modified by the irregularities of the earth's surface, and the rotation of the Earth. Wind patterns and speeds vary greatly across the United States. Wind energy is a term that describes the process by which the wind is used to generate electricity. Wind turbines convert the kinetic energy in the wind to mechanical power. A wind

turbine works the opposite of a fan. A fan uses electricity to made wind, whereas wind turbines use wind to make electricity.

As with all forms of energy including renewable, there are pros and cons to using wind. Advantages of wind energy include:

- It is environmentally friendly, as no fossil fuels are burned to generate electricity from wind energy.
- Wind turbines take up less space than the average power station. They only have to occupy a few square meters for the base, this allows the land around the turbine to be used for other purposes, such as agriculture.
- Newer and more advanced technologies are making the extraction of wind energy more efficient. The wind is free.
- Wind turbines are a great resource to generate energy in remote locations, such as mountainous areas and remote countryside. Wind turbines can be various sizes in order to support varying population levels.
- Combining wind energy with solar electricity provides a steady, reliable source of electricity, for developed and developing countries.
- The use of wind turbines to generate electricity via a generator produces no on-site air pollution, although a small amount of emissions is produced during manufacture of the turbines. One life cycle assessment found that off-grid wind turbines reduce greenhouse gas emissions by 93%. The use of wind turbines to generate electricity via a generator produces no on-site air pollution, although a small amount of emissions is produced during manufacture of the turbines compared to off-grid diesel power generation systems. An additional advantage is that wind turbines are simple mechanical systems that can be easily maintained and repaired. (Glinzak, 2011)

Wind energy is not without some disadvantages:

- Wind can be unreliable. In many areas, the winds strength is too low to support a wind turbine.

- Wind turbines may produce substantially less electricity than the average fossil fuel power station. This factor would require multiple wind turbines to be built in order to make an impact.
- Wind turbine construction can be very expensive for startup capital costs.
- The initial construction of a wind farm could impact the surrounding wildlife during the building process. In addition, there is concern about bird deaths due to wind turbine operation.
- Wind energy does not provide continuous power. Speaking meteorologically, some days the wind speeds are low to calm and that will not produce energy for electricity.
- Noise pollution from commercial wind turbines is sometimes similar to a small jet engine.
- Sometimes protests and or petitions confront proposed wind farm development. People feel the countryside should be left in its natural beautify to be enjoyed. (Clean Energy Ideas, 2007)

2.2.3 Hydropower

There are other renewable energy options. Hydropower is creating electricity using energy of water in motion. Hydropower is not a new form of energy. The first hydroelectric power plant was built at Niagara Falls in 1879. Hydroelectric power provides almost one-fifth of the world's electricity. China, Canada, Brazil, the United States, and Russia were the five largest producers of hydropower in 2004. The largest hydropower plant in the United States is located at the Grand Coulee Dam on the Columbian River in northern Washington. It is estimated that more than 70% of the electricity made in Washington State is produced by hydroelectric facilities. (Northwest Power & Conservation Council, 2008) Figure 2.2 shows hydropower at work.

There are some advantages to using hydropower. Research has shown that hydropower is the cheapest way to generate electricity today. There is capital cost to build a dam and install the equipment, but once installed, flowing water is free. It is a clean fuel source that is renewable yearly by precipitation falling. Another advantage of using hydropower is that it is readily available due to engineers being able to control the flow of water through the turbines to produce electricity on demand.

Figure 2.4 Hydropower Dam (Clean Energy Ideas)

There are some disadvantages to using hydropower. Damming the rivers my alter wildlife and other natural resources. Hydroelectric dams can change fish migration patterns and hurt fish populations. These plants can also cause low dissolved oxygen levels in the water, which can be harmful to river habitats. Hydropower plants can be impacted by drought. When there is a shortage or lack of rainfall, the hydropower plant cannot produce electricity.

2.2.4 Biomass

Another renewable energy option is biomass energy. Some think of this as just garbage. It can include dead trees, tree branches, left-over crops, wood chips. It can eve include used tires and livestock manure. Trash contains some types of biomass that can be reused. When recycling of biomass occurs for fuel, it cuts down on the need for "landfills" to hold garbage (National Geographic, 2012). Figure 2.5 show materials that can be used to create biomass.

California produces more than 60 million bone dry tons of biomass per year. Of this total, five million bone dry tons is now burned to make electricity. This 60 million tons of biomass could make close to 2,000 megawatts of electricity for California's growing population.

Biomass can help reduce global warming compared to a fossil-fuel powered plant. Plants use and store carbon dioxide when they grow. CO_2 stored in the plant is released when the plant is burned or decays. When the crops are replanted, new plants can use the CO_2 produced by the burned plants. Using

the biomass and replanting helps close the carbon dioxide cycle. If the crops are not replanted, then biomass can emit carbon dioxide that will contribute toward global warming.

The use of biomass can be environmentally friendly due to the biomass being decreased, recycled and then reused. Biomass is a renewable resources because plants to make biomass can be grown over and over (California Energy Commission, 2012).

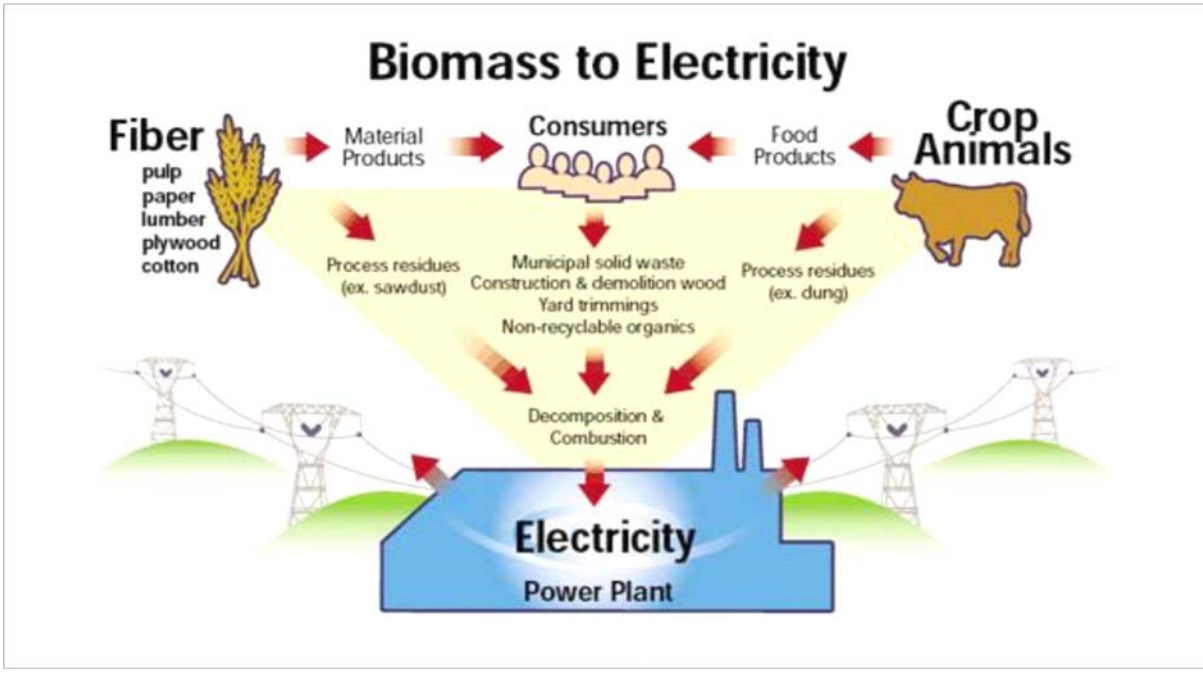

Figure 2.5 Components of Biomass (Biomass Examples, 2015)

2.3 Specific Background Information on Solar and Wind Energy

Different types of renewable energy have been discussed. The remainder of this work will focus on two different types of renewable energy, wind and solar. The number of universities that could use hydropower is limited, since hydropower requires a location near a large river that has not already been tapped for hydropower. Dams are expensive and often meet with public resistance. Biomass from a university's waste could provide a small portion of its electricity on the order of 1% (Sattler, 2013). Wind and solar could provide much larger percentages. Both solar and wind energy are renewable and generate fewer harmful emissions such a sulfur and nitrogen compounds, particulate matter, mercury, and greenhouse gases. As the costs continue to increase to operate colleges and universities, they must

discover and utilize other energy options that could be cheaper to use to help lower operating costs including energy bills. The question for this research to answer is: what are benefits and drawbacks of using wind and solar energy on college and university campuses? (Oklahoma State University, 2008)

2.3.1 Detailed Background Information on Wind Energy

Wind power has been available as long as humans have put sails into the wind. It is growing at a rate of 30% annually, with a worldwide installation capacity of 282,482 megawatts (MW) as of 2012. The U.S. wind industry now totaled 60,007 MW of combined wind capacity through the end of December 2012. There are over 45,100 wind turbines in the U.S. During 2012, wind energy reached the number one ranking of the new U.S. electricity generating capacity for the first time, providing some 42% of all new generating capacity. (American Wind Energy Association (AWEA), 2013)

Wind energy is continuing to grow in Texas. At the present time, research shows a total installed capacity of 26,637 MW (Dallas Morning News, 2016). Figure 2.6 below illustrates Texas wind generation capacity by year in megawatts. Texas produces the most wind power of any U.S. state at the present time. Wind power accounted for 9.2% of the electricity generated in Texas during 2012. The increase in wind generation in Texas is due partly by the expansion of the state's Renewable Portfolio Standard (regulation that requires the increased production of energy from renewable energy sources), use of designated Competitive Renewable Energy Zones (designated geographical areas throughout the state where financial resources, land areas, and renewable energy technologies can create energy that will join with traditional energy sources, expedited transmission construction, and help from the Public Utility Commission rule-making policies. (AWEA, 2012) This expanding wind power market is projected to help Texas meet its 2015 renewable energy goal of 5,000 new megawatts of power from renewable sources.

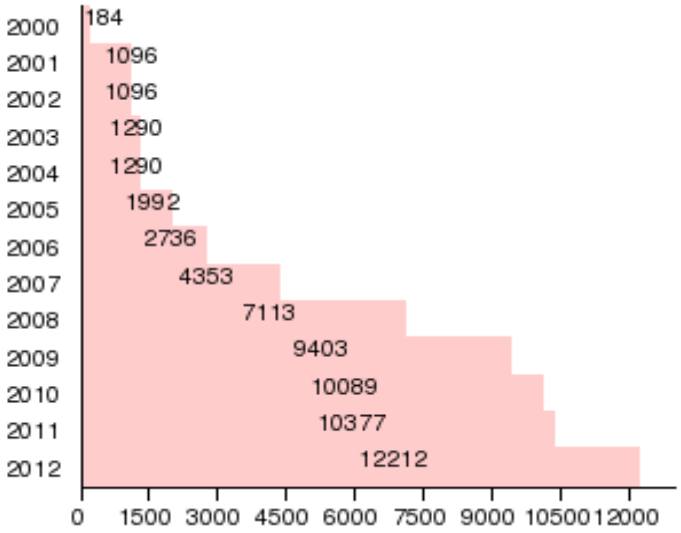

Figure 2.6 Texas Wind Generation Capacity by Year (MW) (Howling Pixel, 2016)

There are many wind farms in Texas. Several factors are driving the growth of wind power in Texas: the wind resources in many areas of the state are very large, large wind farms are relatively easy to site, and the market price for electricity is set by natural gas prices and so is relatively high. Wind resource areas lie in the Texas Panhandle, along the Gulf Coast south of Galveston, and in the mountain passes and ridge tops of the Trans-Pecos. The majority of them are located in West Texas due to the topography of the land being rather flat and the lack of tall trees. Figure 2.7 is a map of Texas showing large wind farm locations.

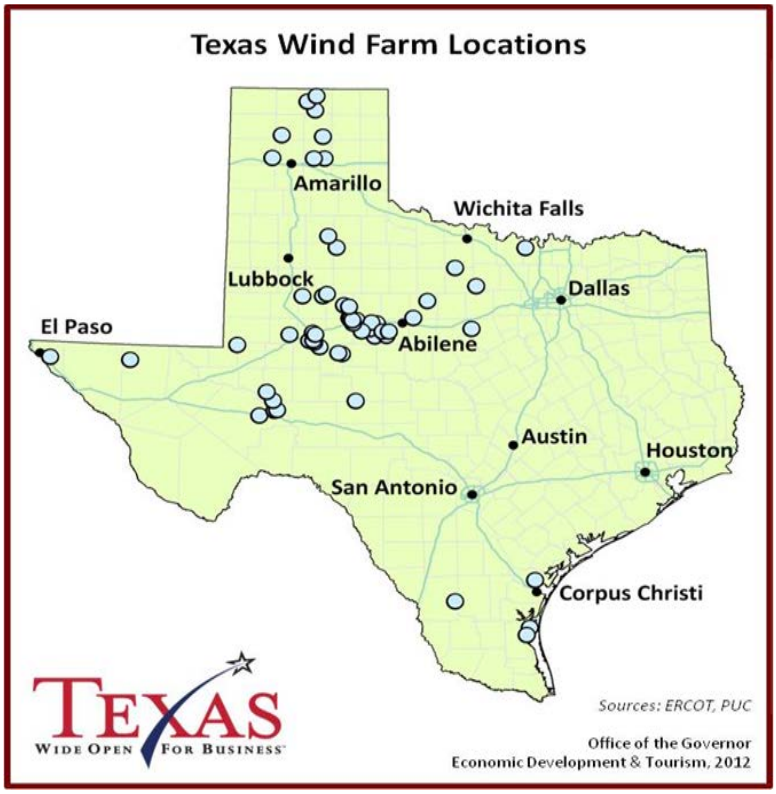

Figure 2.7 Locations of Large Wind Farms in Texas (ERCOT)

The wind power industry is creating thousands of jobs for the communities where they are located in Texas and globally. Statistics show that jobs in the wind industry increased 70% in 2012. With 35,000 jobs created in 2008, the wind industry now employs more people than the coal industry. According to the AWEA (American Wind Energy Association), an estimated 85,000 Americans are currently employed in the wind power industry and related fields. (AWEA, 2010)

The Roscoe Wind Farm in Roscoe, Texas which is located west of Abilene, Texas in West Central Texas, was the largest wind farm in the world when it was completed with 627 wind turbines and a total capacity of 781MW, which is enough energy to power more than 250,000 Texas homes sources. (Power Technology, 2007)

Table 2.1 is a summary of the five largest wind farms in Texas based on the installed capacity in megawatts (Power Technology, 2013).

Table 2.1 Largest Wind Farms in Texas

Wind Farm	Installed Capacity(MW)	Turbine Manufacturer	County
Roscoe Wind Farm	781	Mitsubishi	Nolan
Horse Hollow Wind Farm	735	GE/ Siemens	Taylor/ Nolan
Capricorn Ridge Wind Energy Center	662	GE Energy /Siemens	Sterling/ Coke
Sweetwater Wind Farm	585	GE Energy/Siemens/ Mitsubishi	Nolan
Buffalo Gap Wind Farm	523	Vestas	Taylor/ Nolan

Figure 2.8 below shows the total installed wind capacity of 89, 078 MW. This data proves the fact that Texas is one of the leading states in the United States in wind production.

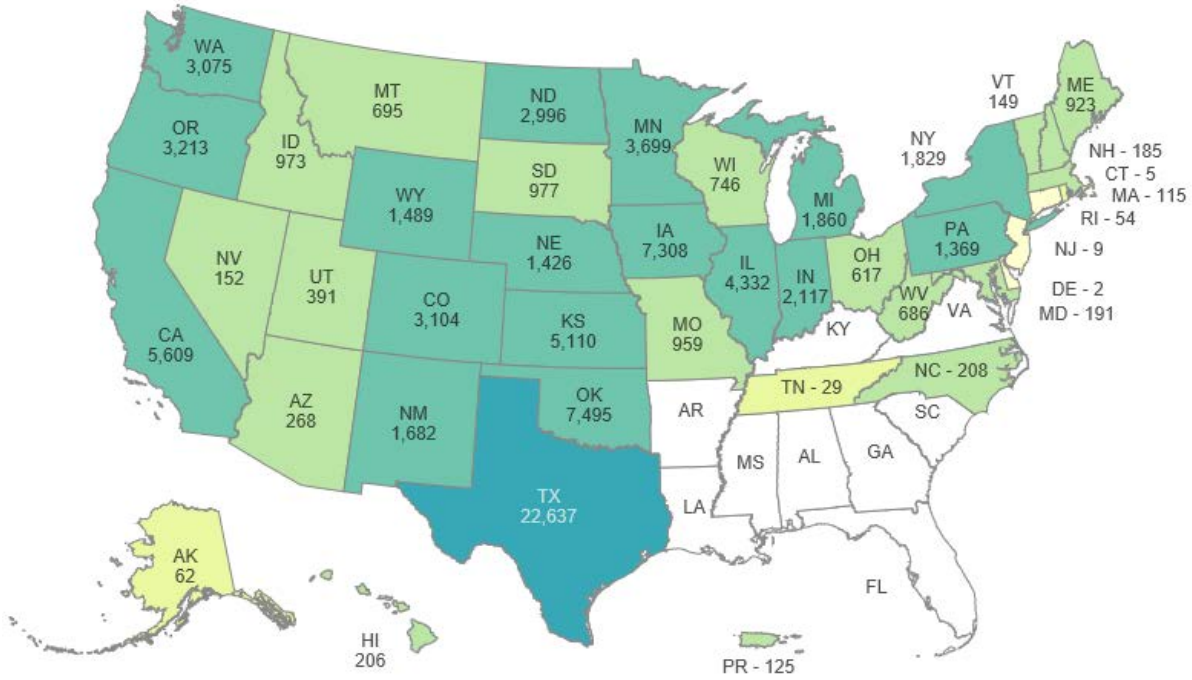

Figure 2.8 Total Installed Wind Capacity: 89,078 MW

Wind velocity, the horizontal direction and speed of air motion, is a very important factor when it relates to wind power created from operational wind turbines. As shown in Figure 2.9, wind power is a proportional to the wind velocity cubed.

$$P = \frac{1}{2} C_p \rho A V^3$$

where

C_p - Power Co-efficient

ρ - Air density (kg/m^3)

A- A is the area of the turbine blade in m^2

V- Wind velocity in m/sec

Figure 2.9 Equation for Wind Power as Function of Wind Velocity

2.3.2 Detailed Background Information on Solar Energy

The solar electricity capacity in the U.S. has increased in recent years from 334,244 kilowatts in 1997 to 1,488,500 kilowatts in 2011. Even with this increase, it still only accounts for 0.1% to 0.2% of net electricity generated in the United States (Institute for Energy Research, 2013).

Much research has been done on using solar energy for solar cars, solar panels for home and building roofs, and generation of electricity. For example, a study was administered at the United States Marine Corps Base Camp Pendleton in 2007 involving using SHW (solar hot water) and PV (photovoltaic) systems at training pools on the base (U.S. Department of Energy, 2009).

Turning now to solar energy as a renewable type of energy to be used on a college or university campus, the use of solar energy produces no on-site air pollutants (although pollutants are typically generated in the process of manufacturing PV cells). Solar energy can be utilized in two ways: direct heat energy for various purposes (heating water, heating space) and direct current electricity generation using photovoltaics (PV).

The U.S. solar industry achieved substantial growth in 2012. According to the Solar Foundation, it is projected that the U.S. will add approximately 3.9 GW of new solar capacity and continues increasing the installation rates for both residential and utility-scale PV systems. Use of solar energy produces no on-site air pollutants (although pollutants are typically generated in the process of manufacturing PV cells).

It is important to look at the energy storage for solar power that is now being researched, developed, and utilized. The increasing share of solar power is changing the grid. This is the focus why energy efficient storage systems will play a vital role in overcoming the current challenges by integrating stationary energy storage systems in private homes and in commercial buildings. Storage systems allow more solar power to be consumed on site helps to lower feed-in tariffs which in turn will make electricity prices more attractive option for consumers.

One challenge facing the widespread use of solar energy is reduced or curtailed energy production when nighttime occurs or when the sun is blocked by clouds during the daytime.

One solution may be thermal energy storage. In a concentrating solar power (CSP) system, the sun's rays are reflected onto a receiver, which then creates heat that is used to generate electricity. If the

receiver contains oil or molten salts as the heat-transfer medium, then the thermal energy can be stored for later use. This helps the CSP systems to be cost-competitive for providing clean, renewable energy. Solar thermal systems use mirrors to focus sunlight, generating temperatures high enough to produce steam to drive a turbine. One of the advantages of the solar thermal approach, versus conventional photovoltaics that convert sunlight directly into electricity, is that heat can be stored cheaply and used when needed. (Solar Energy Storage Pro, May 2013)

Figures 2.10 and 2.11 show photovoltaic and concentrated solar power resources, respectively, across the United States.

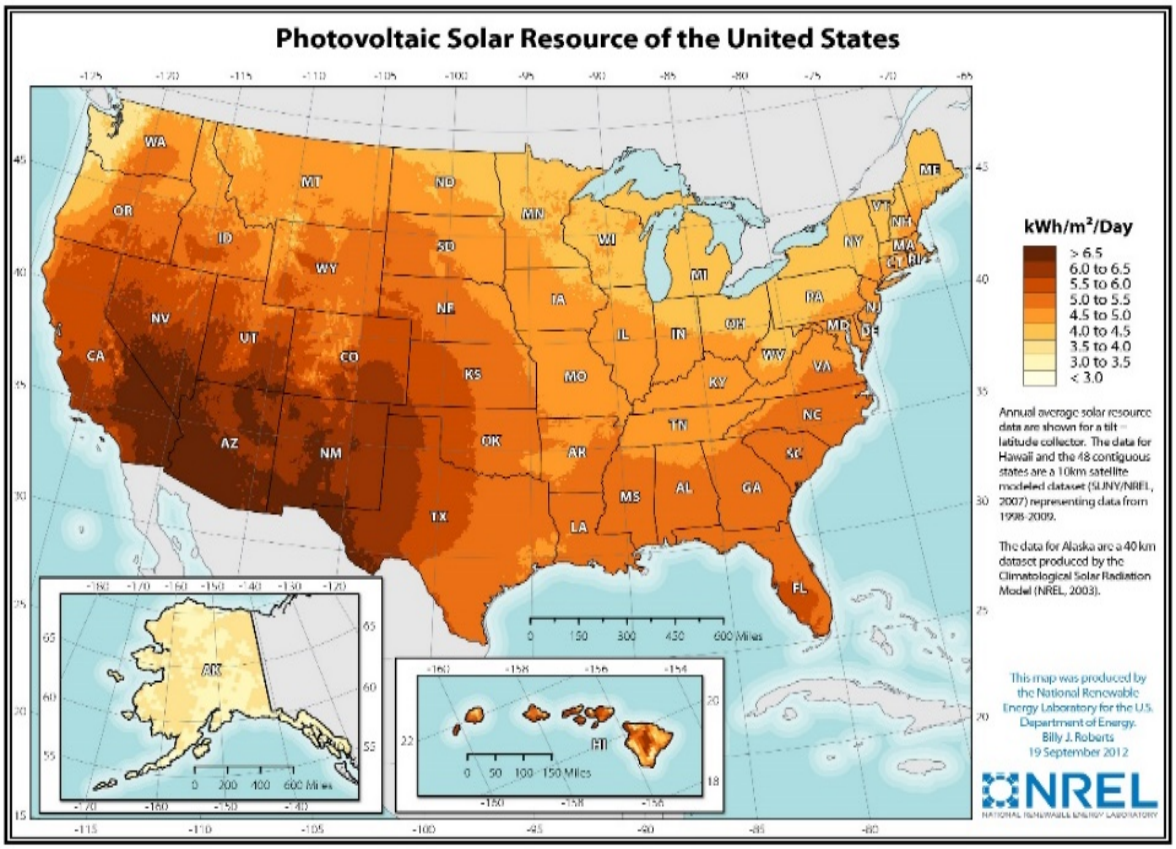

Figure 2.10 Photovoltaic Solar Resources of the United States (NREL)

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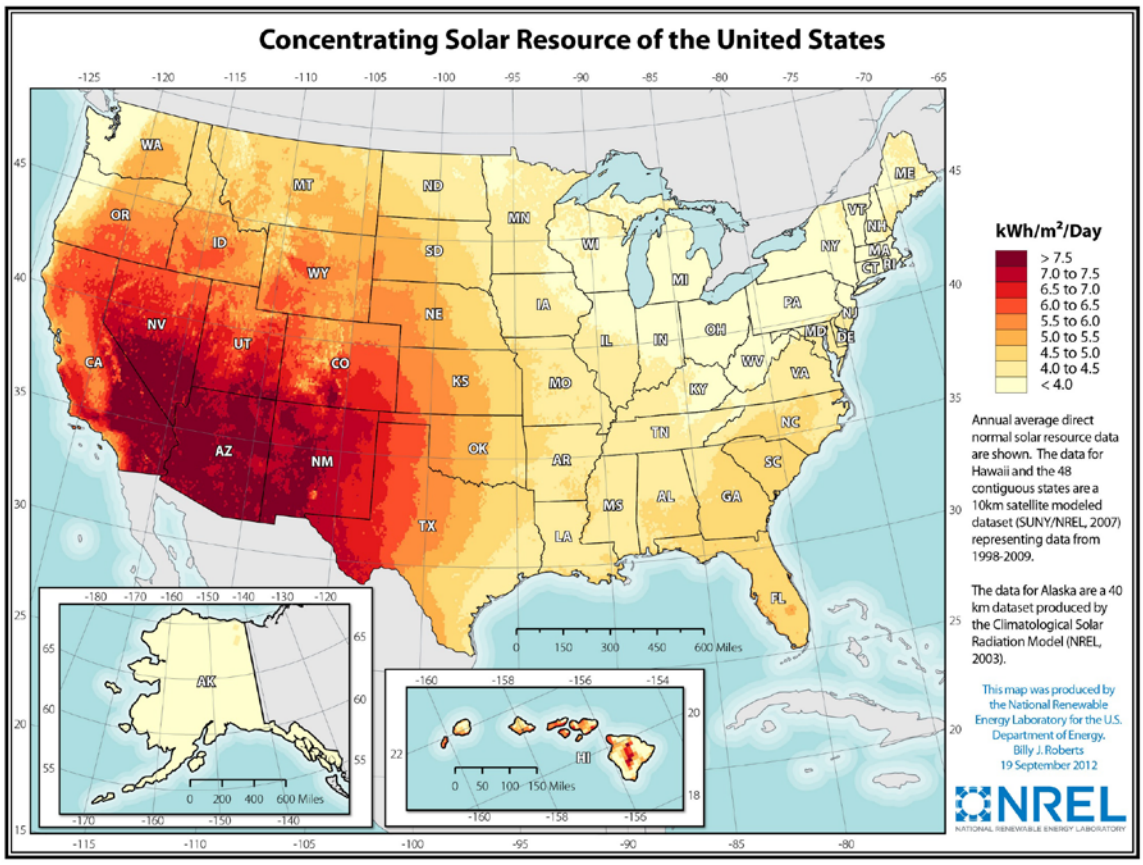

Figure 2.11 Concentrating Solar Power Resources of the United States (NREL)

There is new research being done currently on thermal storage. Bright Source Energy, based in Oakland, California, is building one of the world's largest solar thermal power plants with planned capacity of 392-megawatts. Their primary goal is to develop a system for generating power when the sun is not shining. The company believes the technology can lower the cost of solar power and make it more reliable. (Bright Source, 2017)

Bright Source is using an approach to storage that has been used for ten years. This approach includes heating up molten salt, a combination of sodium and potassium nitride, then storing it in a tank. To make electricity, the molten salt is pumped through a heat exchanger to generate steam. The CEO for Bright Source, John Woolard states that one big factor in making this technology economically attractive

is the use of power towers, in which mirrors focus sunlight on a central tower that generates higher temperatures than other solar thermal designs.

Storage allows a thermal power plant to run more hours in the day. By running more hours in the day, it allows for quicker recovery for the cost of expensive steam turbines and generators. It is projected that while a solar thermal plant without storage can generate electricity about 2,700 hours a year, Bright Source's storage system increases that to 4, 300 hours. The increased output more than offsets the added cost of storage. A study from the National Renewable Energy Laboratory (NREL) in Golden, Colorado, estimates that storage in a power tower system could cut costs per kilowatt hour by 25 to 30 percent. (MIT Technology Review, 2011)

Depending on the type of storage, there are several requirements that must be considered to ensure optimal storage dynamics and longevity.

- High energy density in the storage material.
- Good heat transfer between the heat transfer fluid and the storage medium.
- Mechanical and chemical stability of the storage material.
- Chemical compatibility between the heat transfer, heat exchanger, and storage medium.
- Complete reversibility for a large number of charging/discharging cycles.
- Low thermal losses.
- Low cost.
- Lower environmental impact. (Kuravi et al., 2012)

2.4 Previous Studies of Use of Wind and Solar Power at Colleges and Universities

As discussed previously, wind and solar energy are very important and key forms of renewable energy. Much research has been done on the uses of each. In examining research that has been done, however, ***none is found on the feasibility of using wind and solar energy on college and university campuses***. Several data bases and governmental websites were researched. These include EPA (Environmental Protection Agency), Department of Energy, National Renewable Energy Laboratory, California Energy Commission, American Wind Energy Association, American Solar Energy Society,

Texas Solar Energy Society, data bases including Science Direct, EBSCO, Environmental Sciences and Pollution Management, and Science Collection. This study will help address this gap in the literature.

2.5 Research Goal and Objectives

After having done much research on my topic, there is very little information available on the feasibility of using wind, solar, or both on higher education campuses. This fact supports the need for this research to be done. My personal experience as a professor at Dallas Baptist University also leads me to believe that this research is needed in the realm of renewable energy use at colleges and universities.

The **overall goal** of this research is to identify benefits and obstacles to installation of wind and solar energy on college and university campuses. **Specific objectives** include:

1. To conduct interviews with officials at several colleges and universities in Texas with renewable power already installed, to learn more about the factors that influenced their decision, and identify any issues with implementation.
2. Using themes that emerge from the interviews conducted as part of Objective 1, to develop a survey to administer to a larger sample of colleges and universities in Texas to see whether they use solar/wind power, identify factors that influenced their decision, and identify any issues with implementation.

This research study can help a college or university that is considering using solar or wind power to make a sound decision. This study will be of value to various university personnel, including sustainability directors, physical operations personnel, and faculty members. The information provided about perceived benefits and drawbacks of installation of solar and wind power on college/university campuses will help them make a more informed decision.

Chapter 3

METHODOLOGY

3.1 Introduction

This study uses an exploratory sequential mixed methods approach (Creswell, 2014). In this approach, the researcher begins with a qualitative phase and explores the views of participants. The data are then analyzed, and the information used to build a second, quantitative phase. In the case of this research, interviews from the qualitative first phase were used to build the quantitative survey instrument used in the second phase.

In particular, in the first phase, interviews were conducted with representatives from 3 universities in Texas that have already installed solar and/or wind power. The themes identified from these interviews were then used to develop quantitative survey questions regarding potential benefits and obstacles to installation of solar and wind power on university campuses. The surveys were then sent to a larger sample of universities across Texas.

3.2 Qualitative Case Study Method

3.2.1 Selection of Universities

Three Texas Universities were chosen for case study: the University of North Texas in Denton, Texas A&M Corpus Christi, University of Texas in Arlington. These were selected due to each of them already using some form of renewable energy. The University of North Texas is currently operating 3 wind turbines for generating electricity, Texas A&M in Corpus Christi is currently operating 11 wind turbines and is also using solar photovoltaic panels on the rooftop of the engineering building to harness the sunlight and create renewable energy, and the University of Texas at Arlington has solar panels on their parking garage.

3.2.2 Interview Personnel, Questions, and Process of Conducting Interviews

At each university, an interview was conducted with the Director of Sustainability. Names and titles of persons interviewed are provided in Table 3.1. A list of questions asked during each interview is provided in Figure 3.1 for universities with wind power, and in Figure 3.2 for universities with solar power.

Additional follow-up questions were used to clarify responses and allow the interviewees to expand upon comments. Interviews were conducted in person at the interviewee's university, and were audio recorded with permission from the interviewees. The interviews lasted approximately 1-2 hours each.

Table 3.1 University Personnel Interviewed

Person Interviewed	**University**	**Title**	**Date of Interview**
Lauren Helixon	University of North Texas	Assistant Director of UNT Sustainability	July 12, 2013
Stephen Baxter	Texas A&M University Corpus Christi, Texas	Sustainability Director	July 31, 2015
Terry Tatum	Texas A&M University Corpus Christi, Texas	Sustainability Facilitator	July 31, 2013
Meghna Tare	University of Texas In Arlington	Director of UTA's Institute for Sustainability and Global Impact	August 17, 2013

1. What were the primary factors leading your college to install wind power?
2. Did you consider any other sources of alternative power besides wind?
3. What were the costs of construction, purchasing, and maintenance for the wind turbine project?
4. What factors were used to determine the location for the working turbines?
5. What components were specified as part of the turbine model: type of motor, types and sizes of blades?
6. What criteria were used to select the site for the turbines to be built?
7. Have you identified any biological or environmental effects from using wind turbines?
8. Looking at the meteorological aspects, what is the average wind speeds per month and average wind gusts, where the wind turbines are located?
9. How do you archive your daily and monthly data produced from the wind turbines?
10. Do you have any foreseeable plans to use solar energy or any other renewable types of energy on your campus?
11. How does your university view the use of renewable energy on your campus?

Figure 3.1 Questions Asked at University Case Study Visits Regarding Wind Energy

1. What were the primary factors leading your university to install solar panels?
2. Are the solar panels used as an educational tool for students?
3. How economic is it to use solar panels on the roof tops?
4. What is the upstart cost to purchase and install the solar panels?
5. How much of an expense is the upkeep and repair of the panels?
6. In your opinion, what is the ROI, Return on Investment?
7. Did installing the solar panels bring public support?
8. What lead to your selection of the types of solar panels you installed?

Figure 3.2 Questions Asked at University Case Study Visits Regarding Solar Panels

3.2.3 Analysis of Interview Transcripts

Once the three interviews were conducted, the information from the audio recordings was transcribed into a word processor. Recordings were reviewed two times to make sure that any important points had not been missed. Next, printed copies of the transcripts were evaluated to identify themes using several different methods. First, themes were highlighted using the pawing method, which involves color-coding themes with different colored markers or highlighter pens (Bernard, 2006). Key phrases were underlined to identify patterns in the qualitative data. An example theme was using renewable energy to show the local citizens that the university is using green technology to help the environment, called "publicity advertisement." Repetitions of themes by interviewees at multiple universities were identified.

A second method used to identify themes was to compare and contrast based on the idea that the themes represent the ways in which texts are closely related or different from one another between each of the three universities interviewed. Finally, a third unique method used to identify themes was searching for missing information. This works in reverse from other theme identification methods. Instead of discovering themes that come from the text, I searched for themes that were missing from the text that I thought would be there.

3.3 Quantitative Survey Method

Based on the qualitative interviews, a quantitative survey was developed and administered to colleges and universities across regions of Texas to determine potential benefits and obstacles to installing wind and solar power.

Statistical analysis could not be conducted due to the small number of surveys returned. Only 12 surveys were returned out of 59. The number of respondents needed depends on the survey goals and desired confidence of results. The rule of thumb is the higher degree of confidence needed, the lesser margin of error should be accepted. In this case, the population size was 59. For an 80% confidence level with a margin of error of 10%, a sample size of 25 respondents would be needed. Only 12 out of 59 responded, so the sample size was too small for a typical statistical analysis, and an advanced analysis was beyond the scope of the project. (Survey Monkey, 2018)

3.3.1 Survey Development

Figure 3.1 shows the survey questions. Rationale behind groups of survey questions will now be discussed in more detail.

3.2.1.1 Questions # 1-9

Survey Questions # 1-9 were developed from the qualitative interviews from University of North Texas in Denton, Texas, Texas A& University-Corpus Christi, Texas, and University of Texas in Arlington. As discussed in more detail in Chapter 4, a theme that emerged from the interviews with the three universities was how important each school thought renewable energy was now and in the future. How beneficial would it be for the university in helping the environment? Questions # 1 and 2, as shown in Fig. 3.1, were developed from this theme.

UNIVERSITY/COLLEGE WIND/SOLAR SURVEY

Please select the number below that best represents how you feel about the following statements.

	Strongly disagree (1)	Disagree (2)	Neutral (3)	Agree (4)	Strongly Agree (5)
1) My school is concerned about environmental issues and sustainability.	1	2	3	4	5
2) Has your school ever thought about green or renewable energy as an alternative to our current campus's energy supply.	1	2	3	4	5
3) Installing wind or solar power on campus is/would be good publicity for my school.	1	2	3	4	5
4) Installing wind or solar power on campus would help attract students to my school.	1	2	3	4	5
5) Wind turbines or solar panels are/would be an effective **teaching** tool at my campus.	1	2	3	4	5
6) Wind turbines or solar panels are/would be an effective **research** tool at my campus.	1	2	3	4	5
7) Wind energy is saving/could save my school money over the long-term.	1	2	3	4	5
8) Solar energy is saving/could save my school money over the long-term.	1	2	3	4	5
9) Availability of government subsidies for wind/solar would influence my school's decision to install them.	1	2	3	4	5

Please answer the following questions:

10) My campus has already installed:
- ____ Wind turbines
- ____ Solar panels
- ____ Neither

11) If your campus does not have wind turbines installed, what are the main reasons why? Rank the following in order (# 1 main reason to # 7 least reason)
- ____ Start-up cost
- ____ Maintenance cost
- ____ Space availability for turbines
- ____ Availability of wind on campus
- ____ Eye-sore on campus
- ____ Noise
- ____ Biological concerns

12) If your campus does not have solar panels installed, what are the main reasons why? Rank the following in order (# 1main reason to # 6 least reason)
- ____ Start-up cost
- ____ Maintenance cost
- ____ Space availability for panels
- ____ Too many trees on campus
- ____ Not enough sunny days

____ Eye-sore on campus

13) If your campus has wind turbines installed, what has been the biggest advantage and biggest disadvantage you have discovered?
Advantage-
Disadvantage-

14) If your campus has solar panels installed, what has been the biggest advantage and biggest disadvantage you have discovered?
Advantage-
Disadvantage-

15) Is your school a two or four-year institution?
_____ 2-Year

_____4-year

16) What is your student population at your College/University?
_____<5,000
_____>5,000
_____<10,000
_____>10,000

17) What is your role at the college/university?
_____Sustainability Director

_____Physical Operations

_____Faculty

_____Other (please specify) _____

18. If your school is using solar or wind energy or both, what percentages of your campus' energy is supplied by renewable energy?
Solar _____%
Wind_____%

19) Does your school purchase renewable power for an electric company?

_____Yes, then what company?

_____No

20) If your school has already installed wind/ solar, or both, did your school receive grants to finance the project?

_____Yes

_____No

Figure 3.4 Quantitative Survey Questions

One of the themes identified in the interviews was that all three schools wanted to appear to the public that the university was using “green” techniques. In other words, it was a way to demonstrate a publicity advertisement of using practices to help the environment. Questions # 3 and 4 were included in the survey to ask about the above theme.

An important theme to all three universities was using wind energy and solar energy as educational tools for their students. This would include teaching as well as research tools. As more and more wind turbines and solar panels are being installed and used, comes the need to train and offer a degree to students on how to do maintenance on the wind turbine and solar panel. Each of these two types of renewable energy devices, will require the knowledge of a mechanic that can work on them as routine maintenance is needed. Survey Questions # 5 and 6 correlate to this theme.

Now is a time in the life of colleges and universities where the operating budget is very tight with money. Schools are searching for ways to cut back and to save money. This was a common theme between the three universities in my case study in research for qualitative data. Survey Questions # 7 and 8 were developed to correlate to this important theme.

The start-up cost for installing wind turbines and solar panels is very expensive. With the rising costs to keep a college and university operating, it was nearly impossible for my three case studies of Texas A&M-Corpus Christi, University of North Texas in Denton, and University of Texas in Arlington to even consider using one of these types of renewable energy. A unifying theme was all three looked for federal government subsidies/grants to help finance their renewable energy project. This theme relates to survey Question # 9 on the survey.

3.2.1.2 Questions # 10 – 14

Survey Question #10 asks whether the college or university has installed wind or solar power. Questions # 11 and 12 are then targeted at universities that <u>have not</u> installed either, to find out why. Questions # 13 and 14 are targeted at universities that <u>have</u> installed renewable power, to find out advantages and disadvantages experienced.

3.2.1.3 Questions # 15 – 17

Questions #15-17 ask some basic information about the school and survey respondent: whether the school is 2- or 4-year, size of school, and position of the respondent. These questions were asked in view of analyzing the survey responses to determine whether differences exist for 2- vs. 4-year schools, by size of school, or by identity of survey respondent.

3.2.1.4 Questions # 18 – 20

Finally, Questions # 18 – 20 gather additional potentially useful information:

- percent renewable power supplied for schools that have installed wind and solar,
- whether the school purchases renewable power (instead of or in addition to generating their own on campus), and
- whether the school received grants for installation of their wind turbines or solar panels

3.2.2 Sample

For my sample, college and university campuses were used from each region of the state of Texas, as shown in Figure 3.3: Panhandle Plains, Big Bend Country, Hill Country, South Texas Plains, Gulf Coast, and the Prairies and Lakes. The Piney Woods area of East Texas was not surveyed, as this area has too many trees for solar and wind energy. Surveys were not sent to the three universities interviewed in the qualitative part of the research.

Figure 3.4 Regions of Texas (Texas Parks & Wildlife)

The list of Texas' universities by dividing up Texas into regions, as shown above in Figure 3.4, and then using an internet site called "Community Walk," which displays a map of Texas and identifies the universities by region with yellow markers (www.community.com/texas_colleges_and_universities_map). This produced a list of 45 schools: 30 four-year universities and 15 two-year colleges. Obtaining information from both 4-year universities and 2-year colleges was desired, in order to be able to compare renewable energy use at each kind of institution. A complete list of the schools to which the survey was sent is provided in the appendix.

3.2.3 Process of Administering Surveys

The person to whom the survey should be sent was obtained via each school's web site, and varied from school to school. The larger universities typically had a Sustainability Director. The smaller two-year colleges were mostly sent to the Physical Operations Director. In some instances, a phone call was made to the school to obtain the contact name and email address.

Survey Monkey was used to develop the survey (shown in Fig. 3.3), along with the introduction, shown in Fig. 3.5. A link to the survey was sent via email to all schools on one calendar date. At the end of week 2, a follow-up email with the survey was sent again just in case they had deleted or could not find the original survey. In round two of sending them out, I strongly mentioned again that I was a Ph.D. student at the University of Texas at Arlington and that the data they could send me, would be very important in my dissertation. That helped as more surveys came in. At the end of week 3, a final email

was sent asking for participation. This helped to get a few more. So total, the survey was sent out twice, along with three reminder emails. Phone call reminders were attempted but were not that helpful, as the person would frequently not be in their office, and voicemail messages were not returned.

My name is Andrew LaFavers and I am a current Ph.D. student in the Earth and Environmental Program at the University of Texas in Arlington, Texas. I am also a Professor of Geosciences and Environmental Science at Dallas Baptist University in Dallas, Texas.

The goal of this survey is to inquire about types of renewable energy that your college/ university might be using or would consider using with a focus on solar and wind. I will be using this data in my dissertation which is titled “Benefits and Obstacles to Installing Wind and Solar Energy Systems on University Campuses: A Texas Study).

The survey consists of 20 questions and should take about 5-10 minutes. In order to progress through the survey, please use the following navigation links:

Click the Next>> button to continue to the next page.
Click the Previous >> button to return to the previous page.
Click the Submit>> button to submit your survey.

Figure 3.5 Survey Introduction

Chapter 4

RESULTS AND DISCUSSION

4.1 Qualitative Interviews Results and Discussion

4.1.1 General Information about Use of Renewable Energy at each University

4.1.1.1 University of North Texas Wind Turbines

The contact person at the University of North Texas in Denton, Texas, was Ms. Lauren Helixon, Assistant Director of Operations and Research. The operating wind turbines, as shown in Figure 4.1, were visited on June 20, 2013. The operation of the 3 turbines helps to power the stadium lights, concession stand lights, and other electrical needs. It is estimated that the 3 turbines will offset energy consumption of Mean Green Village, the area of campus surrounding the stadium, by 6%, and keep 323 metric tons of carbon dioxide from being emitted annually. A web-based monitoring system provides details on energy production, carbon dioxide reduction, and other data that can be used for education and research purposes at UNT. Designed for low wind conditions, the community-scale 100 kW turbines are well-suited to the North Texas region, which has an average wind speed of approximately 12 mph. Unlike the tall turbines usually found at wind farms, community-scale turbines are small and ideal for municipalities, schools, neighborhoods, and universities. The approximate noise levels of the turbines is 55 decibels at 40 m (131 ft.), which is equivalent to that of a normal conversation between 2 people.

Figure 4.1 Operating Wind Turbines, Football Stadium, University of North Texas

4.1.1.2 Texas A&M University – Corpus Christi Wind Turbines and Solar Panels

An interview with Stephen Baxter, S&E Operations Supervisor at Texas A&M University (TAMU), Corpus Christi, was conducted on July 15, 2013. Figure 4.2 shows several of the 11 TAMU Corpus Christi wind turbines, which provide a combined total of 92 kilowatts (3 20-kW turbines, and 8 4-kW turbines). Taking advantage of the high-speed afternoon winds on Corpus Christi Bay, the turbines produce 218,000 kWh of electricity each year, which displaces 300 tons of carbon dioxide emissions. It also saves the university $18,000 to $25,000 in utility costs each year. Mr. Baxter commented on his school's important accomplishment: "the 20-kilowatt vertical axis wind turbines are the largest of this type in the continental United States."

The design of the wind turbines at Texas A&M-Corpus Christi allows the turbines to take advantage of the high-speed afternoon winds on Corpus Christi Bay. The vertical axis enhances this process. (Texas A&M University, Corpus Christi)

(a)

(b)

Figure 4.2 (a) and (b) Operating Wind Turbines: Texas A&M University-Corpus Christi

When comparing the special vertical axis turbines at Texas A&M-Corpus Christi to more conventional wind turbine designs, Texas A&M-Corpus Christi are shorter in height and as already discussed, they have a vertical axis of rotation. Conventional wind turbines are much taller with a range in height from 300 to 325 feet and have a horizontal axis of rotation.

Texas A&M-Corpus Christi also has installed solar array atop of the Engineering Building on campus, as shown in Figure 4.3. The solar array consists of 100 photovoltaic panels which are converting sunlight into pollution-free electricity to reduce utility bills and the University's carbon footprint.

Figure 4.3 Operating Solar Array: Texas A&M University-Corpus Christi

4.1.3.3. University of Texas at Arlington – Solar Panels

The University of Texas at Arlington views renewable energy as a very important aspect of showcasing the university of "being green" to help the environment. Currently solar panels are being used atop UT Arlington's Park North and Park Central parking garages, shown in Figure 4.4. In fact, UT Arlington's College Park garage is the largest car garage installation of solar panels in Texas. The solar panels harness enough sun to offset approximately 30% of the energy used by the mixed-use College Park development.

Figure 4.4 Operating Solar Array on Parking Garages: University of Texas at Arlington

In terms of research, a Materials Science and Engineering team at UTA as helped the renewable research by developing a new energy cell that can maintain and store large amounts of solar energy. This cell is an all-vanadium photo-electrochemical flow that allows the sun's energy to be stored at night and on cloudy days. In addition, the Center for Renewable Energy and Science Technology (CREST) at UTA is dedicated to research on the development of renewable and alternative energy sources. Examples of their research includes fabrication or the making of solar cells, techniques to harvest energy, biodiesel fuel processing, and decreasing the costs of coal liquefaction.

Furthermore, UTA purchase renewables energy credits (RECs). RECs are trading of kilowatt hours. These green credits represent electricity produced using environmentally friendly renewable energies, such as solar and wind.

UTA has also utilized "green roofs" around the campus. Examples would be a cool roof, which is a roof system that can reflect solar radiation and thus reduce heat transfer to the building; a roof with solar thermal collectors; or roofs where plants are cultivated. The goal of cool roofs is to lessen building cooling loads, and thus save electrical energy, and also reduce the heat island effect.

4.1.2 Themes Identified in Interviews

4.1.2.1 Importance of Renewable Energy for the Environment

A theme among the three universities was how important each school thought renewable energy was now and in the future. How beneficial would it be for the university in helping the environment? All three universities (University of North Texas, Texas A&M-Corpus Christi, and University of Texas at Arlington) mentioned in my interviews with each school, that renewable energy was very important in helping the environment and reducing environmental issues.

Ms. Lauren Helixon, Assistant Director of Operations and Research at University of North Texas, stated that "their university wanted to show the community they were attempting to make a difference in the environment by developing their Office of Sustainability." This led to the development and installation of their (4) wind turbines to help power the athletic complex including the football field.

Stephen Baxter, S&E Operations Supervisor at Texas A&M University (TAMU), Corpus Christi, was given the task to help reduce the university's carbon footprint. Mr. Baxter said "the university wanted to show it was doing its part in reducing carbon dioxide emissions and to show the local area of South Texas and the entire country, it was doing research on renewable energies and helping the environment."

Meghan Tare, UT Arlington Office of Sustainability, said "helping the environment and reducing the carbon footprint was very important to UTA, which helped lead to the development of the Office of Sustainability." "Teaching students about renewable energy practices and how they can help make a difference in the environment and educating the public on taking care of the environment, are main goals at UTA," Ms. Tare reported.

4.1.2.2 Green Publicity

One theme that emerged from the interview with Ms. Lauren Helix at University of North Texas in Denton was "**Green Publicity**," or how the wind turbines are being used to demonstrate to the public that the university is making the efforts to use renewable types of energy such as the wind turbines they have operating at their athletic complex, including their football field. She stated how the university realized that they needed to demonstrate to the city of Denton that they are making efforts to become "green" using renewable types of energy. Once the turbines were erected, they saw immediate attention from the city

via newspaper articles, television reports, and people just stopping by the university to see the turbines and inquire about why the turbines were installed, and how much did the university think it would help with electric expense. Many also asked whether it would lead to other forms of renewable energy being implemented in the future at the University of North Texas.

The above theme on “Green Publicity” was also common at Texas A&M University in Corpus Christi, Texas. Meeting with Sustainability Facilitator Terry Tatum, he stated this was a big game winner in the Coastal Bend of Texas, that region of South, Texas where Texas A&M-Corpus Christi is located.

4.1.2.3 Opportunities for Teaching and Research

Turbines create opportunities for learning, research, and innovation to apply engineering principles to real-world wind power generation. Representatives from each school – Texas A&M - Corpus Christi, University of North Texas in Denton, and the University of Texas in Arlington – reported that new courses were created to use the wind turbines and or solar panels on campus to teach students about renewable energy.

Two of the universities found it very important not just in helping the environment using renewable types of energy such as solar and wind, but also in training and teaching students about solar and wind energy. Ms. Lauren Helixon, Assistant Director of Operations and Research at University of North Texas, had much to say about using the wind turbines for teaching and research opportunities. “Having the turbines on campus, gives professors in the engineering department the opportunity to teach students how a wind turbine generates electricity. Their classroom is out in the field at the sports complex on campus to learn the mechanics of wind energy and also the maintenance on how to fix a wind turbine when mechanical issues occur.”

Stephen Baxter, S&E Operations Supervisor at Texas A&M University (TAMU), Corpus Christi, said “having solar and wind energy on our campus helps in our engineering program to teach students about these two renewable energy types, as well to do research to further the study of solar panels and wind turbines.” “The university is challenging the engineering department to discover better and more

efficient solar panels that will increase the amount of energy output as well as possibly new blades for wind turbines that would be more effective and efficient in producing electricity from wind."

As more and more wind turbines and solar panels are being installed and used, comes the need to train and offer a degree to students on how to do maintenance on wind turbines and solar panels. Classes have been created at Texas A&M-Corpus Christi to help students learn how to work on the mechanics of wind turbines and solar panels.

4.1.2.4 Need for Financial Savings

Now is a time in the life of colleges and universities where the operating budget is very tight with money. Schools are searching for ways to cut back and to save money." Need for financial savings" was a common theme between the three universities in my case study in research for qualitative data. They are looking at their expense list to find areas where money can be saved. One large monetary expense for colleges and universities is energy, specifically speaking, electric bills. This would include lighting across campus such as classroom lighting, street lights on campus, and lights around entrances to buildings for safety measures; heating; and air conditioning. Administrators are searching for ways to lower these types of expenses.

Ms. Lauren Helixon, Assistant Director of Operations and Research stated that "we had to find a savings method to lower our electricity bill on the campus of University of North Texas… Our research group turned to renewable energies for help…. That is when we discovered we could generate electricity to part of the campus mainly being the Athletic Complex including the football field, and that would in turn would give us some relief on our electricity bill while at the same time, help the environment."

Stephen Baxter, S&E Operations Supervisor at Texas A&M University (TAMU), Corpus Christi, said "colleges and universities are now at a time where they have to look for sources to reduce their electric usage and electric bill…. September 12, 2012 was a big day at our campus as we flipped the switch to begin operating our wind turbines on campus and to begin making a difference with electricity costs."

Meghan Tare, UT Arlington Office of Sustainability, stated that, “Here at our campus, we are trying to find renewable energy methods to also help with energy usage and costs of electricity. By installing solar panels on the two parking garages, we are seeing over time a difference being made.”

4.1.2.5 Need for Grant Funding

The start-up cost for installing wind turbines and solar panels is very expensive. With the rising costs to keep a college and university operating, it was nearly impossible for my three case studies of Texas A&M-Corpus Christi, University of North Texas in Denton, and University of Texas in Arlington to even consider using one of these types of renewable energy. A unifying theme was the “need for grant funding,” as all three looked for federal government subsidies/grants to help finance their renewable energy project. All three people interviewed said there is money out there to help get subsidies and grants, but it is a long and hard process to find them. This theme of relates to survey question number nine on the survey.

University of North Texas in Denton received a $2 million grant from the State Energy Conservation Office to install three wind turbines that will generate electricity to power their football stadium and other building athletic building in the general area of the stadium. This stadium was the first collegiate stadium to be built using onsite renewable energy. (University of North Texas, https://news.unt.edu/news-releases/wind-turbines-generate-power-new-unt-football-stadium)

Continuing with the discussion of how these three universities were able to find the start-up cost money to begin the renewable project at their school, we look at Texas A&M University in Corpus Christi, Texas. They received a federal grant called Distributed Renewable Energy Technology Stimulus Grant from the State Energy Conservation Office of $955,000, which was matched by the university with $265,000 in funds, for a total of $1.2 million for the project. (Texas A&M University-Corpus Christi, http://windenergy.tamucc.edu)

The University of Texas at Arlington installed solar panels on their Park North and Park Central parking garages. UTA received a $1.8 million grant from the American Reinvestment and Recovery Act. The university also provided $368,000 for the project. This money is expected to be recovered soon through a promised grant from Oncor in the amount of $ 390,000. (University of Texas in Arlington,

https://www.uta.edu/news/releases/2012/08/solar-monitoring.php and through face to face interview with Ms. Meghna Tare, Director of the Institute for Sustainability and Global Impact)

4.2 Quantitative Survey Results and Discussion

Of the 59 surveys sent, 12 responses were received, representing a 20% response rate. Table 4.1 summarizes number of responses received from 2 vs. 4 year schools, schools of different sizes, and person who responded (sustainability director, faculty member, etc.), as indicated in survey Questions #15-17. Most responses were received from 4-year schools, compared to 2-year schools, and from faculty members, compared to sustainability directors or facility operations managers. Responses were fairly evenly split between small, medium, and large schools.

Table 4.1 Summary of Survey Respondents (Questions # 15-17)

	Number (Percent) of Responses		
Category	**Category 1**	**Category 2**	**Category 3**
Type of School	2-year 3 (25%)	4-year 9 (75%)	N/A
Size of School	Small (< 5000) 5 (42%)	Medium (between 5000 and 10,000) 4 (33%)	Large (>10,000) 3 (25%)
Type of Respondent	Faculty member 9 (75%)	Sustainability Director 2 (16.7%)	Facility Operations 1 (8.3%)

Table 4.2 shows the number of survey responses by regions of Texas. The Prairie and Lakes Region had the most completed surveys returned. The topography of this region is more of a flat plain of land which makes a good geographic area for wind turbines. The Gulf Coast region and the Panhandle Plains region came in second, with 3 surveys completed per region. Although surveys were not sent to schools in the Piney Woods region of Texas, because there are too many trees for wind and solar energy to be successful, one survey was returned from Stephen F. Austin University in this region. Unfortunately, no responses were received from the Big Bend Country, Hill Country, and South Texas Plains.

Table 4.2 Number of Survey Responses by Region of Texas

Region of Texas	Number of Responses
Panhandle Plains	3
Prairies and Lakes	5
Piney Woods	1
Big Bend Country	0
Hill Country	0
South Texas Plains	0
Gulf Coast	3
TOTAL	12

Due to the small number of responses, statistical analysis of the data was not conducted. Trends in the responses are discussed below. An additional survey, perhaps nationwide, with a larger number of responses would be needed to confirm whether the trends are statistically significant.

4.2.1 Results for Questions #1-9

4.2.1.1 Results for All Schools - Questions #1-9

Table 4.3 tabulates survey responses for all schools for Questions #1-9.

Table 4.3 Compilation of Survey Responses to Questions #1-9 – All Schools

	Number of response (percent)					
Question	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**Total**
1. My school is concerned about environmental issues and sustainability.	0 (0%)	0 (0%)	4 (33.3%)	7 (58.3%)	1 (8.3%)	12
2. My school has thought about renewable energy as an alternative to our current campus's energy supply.	1 (8.3%)	0 (0%)	4 (33.3%)	5 (41.7%)	2 (16.7%)	12
3. Installing wind or solar power on campus is/ would be good publicity for my school.	0 (0%)	0 (0%)	1 (8.3%)	9 (75%)	2 (16.7%)	12
4. Installing wind or solar power on campus would attract students to my school.	0 (0%)	0 (0%)	2 (16.7%)	7 (58.3%)	3 (25%)	12
5. Would turbines or solar panels be an effective teaching tool at my school?	0 (0%)	0 (0%)	0 (0%)	10 (83.3%)	2 (16.7%)	12
6. Would turbines or solar panels be an effective research tool at my campus?	0 (0%)	1 (8.3%)	4 (33.3%)	5 (41.7%)	2 (16.7%)	12
7. Wind energy is saving/ could save my school money over the long-term.	1 (8.3%)	1 (8.3%)	3 (25%)	6 (50%)	1 (8.3%)	12
8. Solar energy is saving/ could save my school money over the long-term.	0 (0%)	1 (8.3%)	1 (8.3%)	9 (75%)	1 (8.3%)	12
9. Availability of government subsidies for wind/solar would influence my school's decision to install them.	0 (0%)	0 (0%)	3 (25%)	4 (33.3%)	5 (41.7%)	12

Questions related to "Importance of Renewable Energy for the Environment." According to Question #1, 67% of the schools responded that they either agree or strongly agree that they are concerned about environmental issues and sustainability. This indicates a widely held view that sustainability is important to universities. The positive results show that the schools that responded on the survey were able to identify environmental issues and realized that attention must be given to this aspect.

According to Question #2, over (58%) of the schools responded that they had at least thought about renewable energy to help with their school's energy needs. However, it was a little surprising that 33.3% of those schools that responded were neutral in their response to Question #2. One strongly disagreed, indicating that the school is likely adamantly against installing renewable power, for some reason.

Questions related to "Green Publicity." In an almost unanimous response to Question #3, 92% agreed or strongly agreed that installing wind or solar power on campus would make for good publicity for the college or university. Only one survey was neutral. This is an important area for any college or university to show the city where the campus is located, that the school is doing their part to help the environment

In Question #4, the combined total of those who agreed and strongly agreed that renewable power would attract students to their school was 83%. The kinds of students attracted could be several types. Students who are interested in engineering or renewable energies would be very interested from an educational or research viewpoint. Seeing the turbines turning on campus and seeing solar panels on rooftops would be inviting for a student to come to the college or university if this was their interest for a major and career. In addition, having the wind turbines operating on campus, as well as the solar panels harnessing the sun's energy, shows another group of potential students that the university is very aggressive and innovative with technology. This could help a student to decide to go to school that was progressive and trying new things, and committed in terms of environmental protection and sustainability.

Questions related to "Opportunities for Teaching and Research." In Question #5, all respondents (100%) agreed or strongly agreed that renewable power would be an effective educational tool at their campus. However, in Question #6, only 58% of survey participants viewed having the renewables as valuable in helping students get involved in research. Four responses were neutral, but one disagreed. This may be because the focus of some institutions is more on education than research. Another reason may be that a number of the survey respondents may be personally involved in education but not research.

Questions related to "Need for Financial Savings**."** For Question #7, 58.3% of respondents either agree or strongly agree that over a long-term period, using wind energy could help cut their energy costs.

However, 41.7% of the respondents either strongly disagreed (8.3%), disagreed (8.3%), or were neutral (25%). Thus, there was considerable disagreement on this question.

Comparing Question # 7 with Question #8, it was very interesting that more respondents of my survey felt that using solar energy would save them more money over the long-term rather than using wind energy. 83.3% agree or strongly agree that solar energy would save their university money over the long-term, but only 58.3% of respondents agree or strongly agree that wind energy would save money. From having done some research, it appears that installing solar panels requires somewhat less start-up cost than does installing wind turbines. This could be one factor that is reflected in the above percentages. In addition, solar panels can be on the rooftops of the buildings, as they are at Texas A&M-Corpus Christi. They are not as easily seen located on a rooftop. On the other perspective, wind turbines are much more visible to the human eye as they stand rising from the ground upward. Some see wind turbines as an "eye sore."

Question related to the "Need for Grant Funding." 75% of respondents agreed or strongly agreed that receiving government subsidies or grants would influence their school's decision to install wind or solar energy. Combining the response to this question with the positive responses to the preceding questions shows the desire or interest is there, but with the economy as it is today, the school would have to receive some type of financial help.

Summary. In summary, responses to most questions were overwhelmingly positive, with the exceptions of whether renewable power would be an effective research tool, and whether wind power would save the school money. Responses to these questions were still net positive, but with more dissention compared to other questions.

4.2.1.2 Results for 2- vs. 4-year Schools - Questions #1-9

Table 4.4 separates survey responses for Questions #1-9 for 2- and 4-year schools.

Table 4.4 Compilation of Survey Responses to Questions #1-9: 2-Year and 4-Year Schools

	Type of School	Number of response (percent)					
Question		**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**Total**
1. My school is concerned about environmental issues and sustainability.	2-year	0 (0%)	0 (0%)	1 (33%)	2 (67%)	0 (0%)	3
	4-year	0 (0%)	0 (0%)	3 (33%)	5 (56%)	1 (11%)	9
	All	0 (0%)	0 (0%)	4 (33.3%)	7 (58.3%)	1 (8.3%)	12
2. My school has thought about renewable energy as an alternative to our current campus's energy supply.	2-year	0 (0%)	0 (0%)	1 (33%)	2 (67%)	0 (0%)	3
	4-year	1 (11%)	0 (0%)	3 (33%)	3 (33%)	2 (22%)	9
	All	1 (8.3%)	0 (0%)	4 (33.3%)	5 (41.7%)	2 (16.7%)	12
3. Installing wind or solar power on campus is/ would be good publicity for my school.	2-year	0 (0%)	0 (0%)	0 (0%)	3 (100%)	0 (0%)	3
	4-year	0 (0%)	0 (0%)	1 (11%)	6 (67%)	2 (22%)	9
	All	0 (0%)	0 (0%)	1 (8.3%)	9 (75%)	2 (16.7%)	12
4. Installing wind or solar power on campus would attract students to my school.	2-year	0 (0%)	0 (0%)	2 (67%)	1 (33%)	0 (0%)	3
	4-year	0 (0%)	0 (0%)	2 (22%)	6 (67%)	1 (11%)	9
	All	0 (0%)	0 (0%)	4 (33.3%)	7 (58.3%)	1 (8.3%)	12
5. Would turbines or solar panels be an effective teaching tool at my school?	2-year	0 (0%)	0 (0%)	0 (0%)	3 (100%)	0 (0%)	3
	4-year	0 (0%)	0 (0%)	0 (0%)	7 (78%)	2 (22%)	9
	All	0 (0%)	0 (0%)	0 (0%)	10 (83.3%)	2 (16.7%)	12

6. Would turbines or solar panels be an effective research tool at my campus?	2-year	0 (0%)	0 (0%)	2 (67%)	1 (33%)	0 (0%)	3
	4-year	0 (0%)	1 (11%)	2 (22%)	4 (44%)	2 (22%)	9
	All	0 (0%)	1 (8.3%)	4 (33.3%)	5 (41.7%)	2 (16.7%)	12
7. Wind energy is saving/ could save my school money over the long-term.	2-year	0 (0%)	0 (0%)	1 (33%)	2 (67%)	0 (0%)	3
	4-year	1 (11%)	1 (11%)	2 (22%)	4 (44%)	1 (11%)	9
	All	1 (8.3%)	1 (8.3%)	3 (25%)	6 (50%)	1 (8.3%)	12
8. Solar energy is saving/ could save my school money over the long-term.	2-year	0 (0%)	1 (33%)	0 (0%)	2 (67%)	0 (0%)	3
	4-year	0 (0%)	0 (0%)	1 (11%)	7 (78%)	1 (11%)	9
	All	0 (0%)	1 (8.3%)	1 (8.3%)	9 (75%)	1 (8.3%)	12
9. Availability of government subsidies for wind/solar would influence my school's decision to install them.	2-year	0 (0%)	0 (0%)	1 (33%)	1 (33%)	1 (33%)	3
	4-year	0 (0%)	0 (0%)	2 (22%)	3 (33%)	4 (44%)	9
	All	0 (0%)	0 (0%)	3 (25%)	4 (33.3%)	5 (41.7%)	12

Both 2-and 4-year schools were concerned about environmental issues and sustainability, as tabulated in Question # 1 (67% agreed or strongly agreed, for both 2- and 4-year schools), as expected. Colleges and universities can observe and understand the environmental issues that exist today and they desire to do their part. However, not all schools have the financial ability to use types of renewable energy such as solar and wind on their campus because of start-up costs. For Question #2, it was not surprising that ***a higher percent of 4-year universities strongly agreed that their school had considered the possibility of using wind energy or solar energy*** (22% for 4-year schools vs. 0% for 2-year schools). Four year universities may have a better opportunity to find grants or financial assistance from large corporations, to help them fund their renewable energy project due to larger research projects that they may have on their campus, compared to a 2-year college.

As noted in Question #3, one similar theme from both 2-year and 4-year schools was that most agreed or strongly agreed that using solar and or wind energy on their campus would be great publicity

for their school (100% for 2-year schools, and 89% for 4-year schools). It would show that the school was doing its part to reduce the carbon footprint and help the environment.

Although all schools agreed or strongly agreed that having wind turbines and solar panels on their campus would be both a good teaching tool (Question #5), ***a substantially larger percent of 4-year schools (67%) agreed or strongly agreed that turbines and solar panels would be a good research tool for their university***, compared to 2-year schools (33%). This is not surprising, given that 4-year universities are more likely to conduct research.

Question # 7, which states that wind energy is saving or could save my school money in the long term, was an interesting question between how respondents responded from 2-year schools versus 4-year schools. All two year colleges agreed, strongly agreed, or were neutral that wind turbines could save money on their respective campuses. However, there were two 4-year universities which disagreed or strongly disagreed that using wind energy on their campuses would save them money. One school stated that using wind turbines was more of a publicity factor for their city than saving money on their electricity bill and helping the environment. This could lead to future research on this topic by examining the schools that felt it was more for public relations than helping the environment by finding out their reasoning behind this view.

Similar to Question #7, Question # 8 asked whether solar energy is or could save my school money over the long-term. 67% of 2-year schools and 89% of 4-year schools agreed or strongly agreed. ***Of particular note is that more 4-year schools thought that solar energy could save them money than wind energy***. There were no schools of either size that disagreed that using solar energy could save them money. This was different from Question # 7, where two 4-year schools disagreed that using wind energy could save their schools money. This would also be a good further research topic, to find out why more 4-year colleges and universities favor solar energy over wind energy at their campus.

In summary, 4-year schools were more likely to have considered using renewable power, and to regard it as a potentially important research tool, compared to 2-year schools. Between wind power and solar power, 4-year schools were more likely to think that solar power could save them money.

4.2.1.3 Results by Size of School – Questions #1-9

Table 4.5 divides survey responses for Questions #1-9 by size of school.

Table 4.5 Compilation of Survey Responses to Questions #1-9 by Size of School

Question	Size of School	Number of response (percent)					
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total
1. My school is concerned about environmental issues and sustainability.	<5000	0 (0%)	0 (0%)	2 (40%)	2 (40%)	1 (20%)	5
	>5000 & <10,000	0 (0%)	0 (0%)	1 (25%)	3 (75%)	0 (0%)	4
	>10,000	0 (0%)	0 (0%)	1 (33%)	2 (67%)	0 (0%)	3
	All	0 (0%)	0 (0%)	4 (33.3%)	7 (58.3%)	1 (8.3%)	12
2. My school has thought about renewable energy as an alternative to our current campus's energy supply.	<5000	1 (20%)	0 (0%)	1 (20%)	2 (40%)	1 (20%)	5
	>5000 & <10,000	0 (0%)	0 (0%)	1 (25%)	2 (50%)	1 (25%)	4
	>10,000	0 (0%)	0 (0%)	2 (67%)	1 (33%)	0 (0%)	3
	All	1 (8.3%)	0 (0%)	4 (33.3%)	5 (41.7%)	2 (16.7%)	12
3. Installing wind or solar power on campus is/ would be <u>good publicity</u> for my school.	<5000	0 (0%)	0 (0%)	0 (0%)	5 (100%)	0 (0%)	5
	>5000 & <10,000	0 (0%)	0 (0%)	1 (25%)	2 (50%)	1 (25%)	4
	>10,000	0 (0%)	0 (0%)	0 (0%)	2 (67%)	1 (33%)	3
	All	0 (0%)	0 (0%)	1 (8.3%)	9 (75%)	2 (16.7%)	12
4. Installing wind or solar power on campus would <u>attract students</u> to my school.	<5000	0 (0%)	0 (0%)	2 (40%)	3 (60%)	0 (0%)	5
	>5000 & <10,000	0 (0%)	0 (0%)	1 (25%)	2 (50%)	1 (25%)	4

	>10,000	0 (0%)	0 (0%)	1 (33%)	2 (67%)	0 (0%)	3
	All	0 (0%)	0 (0%)	4 (33.3%)	7 (58.3%)	1 (8.3%)	12
5. Would turbines or solar panels be an effective teaching tool at my school?	<5000	0 (0%)	0 (0%)	0 (0%)	5 (100%)	0 (0%)	5
	>5000 & <10,000	0 (0%)	0 (0%)	0 (0%)	2 (50%)	2 (50%)	4
	>10,000	0 (0%)	0 (0%)	0 (0%)	3 (100%)	0 (0%)	3
	All	0 (0%)	0 (0%)	0 (0%)	10 (83.3%)	2 (16.7%)	12
6. Would turbines or solar panels be an effective research tool at my campus?	<5000	0 (0%)	1 (20%)	3 (60%)	1 (20%)	0 (0%)	5
	>5000 & <10,000	0 (0%)	0 (0%)	0 (0%)	2 (50%)	2 (50%)	4
	>10,000	0 (0%)	0 (0%)	1 (33%)	2 (67%)	0 (0%)	3
	All	0 (0%)	1 (8.3%)	4 (33.3%)	5 (41.7%)	2 (16.7%)	12
7. Wind energy is saving/ could save my school money over the long-term.	<5000	1 (20%)	0 (0%)	1 (20%)	3 (60%)	0 (0%)	5
	>5000 & <10,000	0 (0%)	0 (0%)	1 (25%)	2 (50%)	1 (25%)	4
	>10,000	0 (0%)	1 (33%)	1 (33%)	1 (33%)	0 (0%)	3
	All	1 (8.3%)	1 (8.3%)	3 (25%)	6 (50%)	1 (8.3%)	12
8. Solar energy is saving/ could save my school money over the long-term.	<5000	0 (0%)	0 (0%)	1 (20%)	4 (80%)	0 (0%)	5
	>5000 & <10,000	0 (0%)	0 (0%)	0 (0%)	3 (75%)	1 (25%)	4
	>10,000	0 (0%)	1 (33%)	0 (0%)	2 (67%)	0 (0%)	3
	All	0 (0%)	1 (8.3%)	1 (8.3%)	9 (75%)	1 (8.3%)	12
9. Availability of government subsidies for wind/solar would influence my school's decision to install them.	<5000	0 (0%)	0 (0%)	1 (20%)	3 (60%)	1 (20%)	5
	>5000 & <10,000	0 (0%)	0 (0%)	1 (25%)	1 (25%)	2 (50%)	4
	>10,000	0 (0%)	0 (0%)	1 (33%)	0 (0%)	2 (67%)	3
	All	0 (0%)	0 (0%)	3 (25%)	4 (33.3%)	5 (41.7%)	12

There were some interesting trends and things to see in examining survey responses by size of school. Fortunately, in Question # 1 that most all schools, no matter the size of the school, were concerned about environmental issues and sustainability. 60% of small schools, 75% of medium schools, 67% of large schools, and 67% of schools overall either agreed or strongly agreed that their school was concerned and aware of environmental concerns.

Surprisingly, although 60% of small schools and 75% of medium schools reported having considered renewable power (Question #2), only 33% of large schools had. This is not consistent with responses to Question #10, however, in which all 3 large schools report having installed solar power. Perhaps the respondents thought that the question referred to purchase of additional renewable power, supplementing what was already produced on campus.

It was mostly unanimous (100% of small schools, 75% of medium schools, and 100% of large schools agreed or strongly agreed) that installing wind turbines and or solar panels would be good publicity for their school, as noted in Question # 3. Having a type of renewable energy used on a college or university campus, shows that the school is doing their part in reducing the carbon footprint and trying to help the environment.

In Question # 5, overwhelmingly 100% of the respondents from all 3 size categories think wind and solar energy could be very good tools in <u>teaching</u> students, either in renewable energy courses or just making the students aware of how renewable energy can help reduce the carbon footprint and help the environment.

Question # 6 asked respondents if wind and or solar panels could be good <u>research</u> tools at their schools. It was interesting, but not too surprising, that ***colleges with student populations under 5,000, were not too supportive of this idea*** (only 20% agreed). This could be from the fact that smaller schools would have a harder time even having the startup cost for wind turbines or solar panel infrastructure. In addition, smaller schools may be less active in research. From the opposite perspective, larger schools with student populations between 5,000 and 10,000 (100%) and greater than 10,000 (67%) seem to have a stronger stance that wind turbines and solar panels could be used for research tools. One of their thoughts of reasoning may be that a larger school might have an easier way to obtain grants and financial

assistance to help with the startup costs. Larger universities tend to have stronger engineering department than smaller populated schools and tend to be much more research oriented.

For Question # 7***, respondents from large schools were less optimistic about wind power saving their school money***. 33% of respondents from large schools agree on strongly agree on Question #7, vs. 60% and 75% for small and medium schools respectively. The reason for this is not clear, but it may explain the fact that for Question #2, only 33% of respondents from large schools say their university had considered installing renewable power. The larger schools would be less likely to consider installing wind power if they think it will not save their schools money.

In summary, larger schools were more likely to believe that renewable power could be a useful research tool at their university. Larger schools were also more likely to believe that solar power (as opposed to wind power) would save their university money.

4.2.1.4 Results by Type of Survey Respondent – Questions # 1-9

Table 4.6 splits survey responses for Questions # 1-9 by type of respondent.

Table 4.6 Compilation of Survey Responses to Questions # 1-9 by Type of Respondent

		Number of response (percent)					
Question	**Type of Respondent**	**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**Total**
1. My school is concerned about environmental issues and sustainability.	Sustainability Director	0 (0%)	0 (0%)	0 (0%)	2 (100%)	0 (0%)	2
	Physical Operations	0 (0%)	0 (0%)	0 (0%)	1 (100%)	0 (0%)	1
	Faculty	0 (0%)	0 (0%)	4 (44.4%)	4 (44.4%)	1 (11.1%)	9
	All	0 (0%)	0 (0%)	4 (33.3%)	7 (58.3%)	1 (8.3%)	12
2. My school has thought about renewable energy as an alternative to our current campus's energy supply.	Sustainability Director	0 (0%)	0 (0%)	1 (50%)	0 (0%)	1 (50%)	2
	Physical Operations	0 (0%)	0 (0%)	0 (0%)	1 (100%)	0 (0%)	1
	Faculty	1 (11%)	0 (0%)	3 (33%)	4 (44%)	1 (11%)	9
	All	1 (8.3%)	0 (0%)	4 (33.3%)	5 (41.7%)	2 (16.7%)	12
3. Installing wind or solar power on campus is/ would be <u>good publicity</u> for my school.	Sustainability Director	0 (0%)	0 (0%)	0 (0%)	2 (100%)	0 (0%)	2
	Physical Operations	0 (0%)	0 (0%)	1 (100%)	0 (0%)	0 (0%)	1
	Faculty	0 (0%)	0 (0%)	0 (0%)	7 (78%)	2 (22%)	9
	All	0 (0%)	0 (0%)	1 (8.3%)	9 (75%)	2 (16.7%)	12
4. Installing wind or solar power on campus would <u>attract students</u> to my school.	Sustainability Director	0 (0%)	0 (0%)	0 (0%)	2 (100%)	0 (0%)	2
	Physical Operations	0 (0%)	0 (0%)	1 (100%)	0 (0%)	0 (0%)	1
	Faculty	0 (0%)	0 (0%)	3 (33.3%)	5 (55.5%)	1 (11.1%)	9
	All	0 (0%)	0 (0%)	4 (33.3%)	7 (58.3%)	1 (8.3%)	12
5. Would turbines or solar panels be an	Sustainability Director	0 (0%)	0 (0%)	0 (0%)	2 (100%)	0 (0%)	2

effective teaching tool at my school?	Physical Operations	0 (0%)	0 (0%)	0 (0%)	1 (100%)	0 (0%)	1
	Faculty	0 (0%)	0 (0%)	0 (0%)	7 (78%)	2 (22%)	9
	All	0 (0%)	0 (0%)	0 (0%)	10 (83.3%)	2 (16.7%)	12
6. Would turbines or solar panels be an effective research tool at my campus?	Sustainability Director	0 (0%)	0 (0%)	0 (0%)	2 (100%)	0 (0%)	2
	Physical Operations	0 (0%)	0 (0%)	0 (0%)	1 (100%)	0 (0%)	1
	Faculty	0 (0%)	1 (11%)	4 (44%)	2 (22%)	2 (22%)	9
	All	0 (0%)	1 (8.3%)	4 (33.3%)	5 (41.7%)	2 (16.7%)	12
7. Wind energy is saving/ could save my school money over the long-term.	Sustainability Director	0 (0%)	0 (0%)	1 (50%)	1 (50%)	0 (0%)	2
	Physical Operations	0 (0%)	0 (0%)	0 (0%)	1 (100%)	0 (0%)	1
	Faculty	1 (11%)	1 (11%)	2 (22%)	4 (44%)	1 (11%)	9
	All	1 (8.3%)	1 (8.3%)	3 (25%)	6 (50%)	1 (8.3%)	12
8. Solar energy is saving/ could save my school money over the long-term.	Sustainability Director	0 (0%)	0 (0%)	0 (0%)	2 (100%)	0 (0%)	2
	Physical Operations	0 (0%)	0 (0%)	0 (0%)	1 (100%)	0 (0%)	1
	Faculty	0 (0%)	1 (11%)	1 (11%)	6 (67%)	1 (11%)	9
	All	0 (0%)	1 (8.3%)	1 (8.3%)	9 (75%)	1 (8.3%)	12
9. Availability of government subsidies for wind/solar would influence my school's decision to install them.	Sustainability Director	0 (0%)	0 (0%)	1 (50%)	0 (0%)	1 (50%)	2
	Physical Operations	0 (0%)	0 (0%)	0 (0%)	0 (0%)	1 (100%)	1
	Faculty	0 (0%)	0 (0%)	2 (22%)	4 (44%)	3 (33%)	9
	All	0 (0%)	0 (0%)	3 (25%)	4 (33.3%)	5 (41.7%)	12

On Question #1, overall, all three categories of respondents were very favorable that their school was concerned about environmental issues and sustainability (67%); however, it was surprising that 44% of the faculty members were neutral on this question.

For Question #3, most respondents agreed or strongly agreed that renewable energy served as a good publicity measure. The only neutral response was from the physical operations director, who is less likely to be engaged in publicity than the other respondents. Sustainability directors want to show good relationships with the community in which the school is located, and one major way to do this is to visibly show the school is doing its part in helping the environment. Faculty members are also concerned about publicity, primarily from the standpoint of recruiting students. In Question #4, however, 33% of the faculty members were neutral about whether renewable power would actually attract students to their school.

On Questions #7 and 8, the ***sustainability directors and facility operations personnel were more positive about wind and solar power saving their university money***. Between the two questions, 5 out of 6 responses (83%) were agree or strongly agree for sustainability directors and facility operations personnel. For faculty members, only 12 out of 18 responses (67%) were agree or strongly agree. Sustainability directors and facility operations personnel likely have more influence over whether wind turbines or solar panels are actually installed on their campus; hence, their positive responses are likely to have an impact.

In summary, there were not large differences when responses were broken out by type of respondent. The physical operations director seemed less concerned about publicity compared to the sustainability directors and faculty members. The sustainability directors and facility operations personnel were more positive about wind and solar power saving their university money.

4.2.1.5 Results by Whether School Has Already Installed Wind/Solar Power – Questions # 1-9

Table 4.7 breaks out survey responses according to whether the school has already installed wind/solar power or not. The percentages for “all” are different in this table from preceding tables, because one university had installed both wind and solar power, so its responses were counted in both categories, and because one university did not respond to the question of whether it had already installed renewable power.

Table 4.7 Compilation of Survey Responses to Questions #1-9 by Renewable Power Installation

Question	Type of Renewable Power Installed	Number of response (percent)					
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total
1. My school is concerned about environmental issues and sustainability.	Solar			1 (20%)	3 (60%)	1 (20%)	5
	Wind				2 (100%)		2
	Neither			2 (40%)	3 (60%)		5
	All	0 (0%)	0 (0%)	3 (25%)	8 (66.7%)	1 (8.3%)	12
2. My school has thought about renewable energy as an alternative to our current campus's energy supply.	Solar			2 (40%)	1 (20%)	2 (40%)	5
	Wind			1 (50%)	1 (50%)		2
	Neither	1 (20%)		2 (40%)	2 (40%)		5
	All	1 (8.3%)	0 (0%)	5 (41.7%)	4 (33.3%)	2 (16.7%)	12
3. Installing wind or solar power on campus is/ would be <u>good publicity</u> for my school.	Solar				4 (80%)	1 (20%)	5
	Wind				2 (100%)		2
	Neither			1 (20%)	3 (60%)	1 (20%)	5
	All	0 (0%)	0 (0%)	1 (8.3%)	9 (75%)	2 (16.7%)	12
4. Installing wind or solar power on campus would <u>attract students</u> to my school.	Solar			1 (20%)	4 (80%)		5
	Wind				2 (100%)		2

	Neither			2 (40%)	2 (40%)	1 (20%)	5
	All	0 (0%)	0 (0%)	3 (25%)	8 (66.7%)	1 (8.3%)	12
5. Would turbines or solar panels be an effective teaching tool at my school?	Solar				5 (100%)		5
	Wind				2 (100%)		2
	Neither				3 (60%)	2 (40%)	5
	All	0 (0%)	0 (0%)	0 (0%)	10 (83.3%)	2 (16.7%)	12
6. Would turbines or solar panels be an effective research tool at my campus?	Solar			2 (40%)	3 (60%)		5
	Wind				2 (100%)		2
	Neither		1 (20%)	1 (20%)	1 (20%)	2 (40%)	5
	All	0 (0%)	1 (8.3%)	3 (25%)	6 (50%)	2 (16.7%)	12
7. Wind energy is saving/ could save my school money over the long-term.	Solar		1 (20%)	3 (60%)	1 (20%)		5
	Wind				2 (100%)		2
	Neither	1 (20%)			3 (60%)	1 (20%)	5
	All	1 (8.3%)	1 (8.3%)	3 (25%)	6 (50%)	1 (8.3%)	12
8. Solar energy is saving/ could save my school money over the long-term.	Solar		1 (20%)	1 (20%)	3 (60%)		5
	Wind				2 (100%)		2
	Neither				4 (80%)	1 (20%)	5
	All	0 (0%)	1 (8.3%)	1 (8.3%)	9 (75%)	1 (8.3%)	12
9. Availability of government subsidies for wind/solar would influence my school's decision to install them.	Solar			2 (40%)	1 (20%)	2 (40%)	5
	Wind				1 (50%)	1 (50%)	2
	Neither			1 (20%)	1 (20%)	3 (60%)	5
	All	0 (0%)	0 (0%)	3 (25%)	3 (25%)	6 (50%)	12

In Question # 1, a larger percentage of respondents from schools that had already installed solar or wind power reported that their schools were concerned about environment and sustainability, compared to schools that had installed neither (80% and 100% for solar and wind, respectively, vs. 60% for neither). Having installed solar or wind power would provide concrete evidence that the school was concerned about sustainability, so this makes sense.

Responses to Question #2 were puzzling. Two respondents from schools that had already installed solar power, and one respondent from a school that had already installed wind power, were neutral about whether their school had thought about renewable power, despite the fact that it was already installed on their campus. Perhaps they interpreted the question to mean purchase of renewable power from an electric company.

Several subsequent questions did demonstrate more positive responses from schools that had already installed renewable power compared to those that had not, as would be expected. On Question # 3, 100% of respondents from schools that had already installed solar or wind power thought it was good publicity, compared to 80% of respondents from schools that had installed neither. On Question #4, 6 of 7 respondents (86%) from schools that had already installed renewable power thought it would attract students to their school, compared to 3 of 5 (60%) for schools that had installed neither. Similarly, on Question #6, 6 of 7 respondents (86%) from schools that had already installed renewable power thought it would be a valuable research tool at their school, compared to 3 of 5 (60%) for schools that had installed neither.

Responses to Questions #7 and 8 were surprising. On Question #7, even though 100% of schools that had installed wind power thought that wind power could save schools money, only 20% of schools that had installed solar power thought wind power could save schools money. Perhaps the schools that installed solar power had done so because they thought wind power would not save their schools money. However, on Question #8, 100% of the schools that had installed wind power or neither thought that solar power would save schools money, compared with only 60% of schools that had actually installed solar. One possible explanation for this is that the schools that had already installed solar had data to show that it did not, in fact, save their schools money.

***In summary, generally, respondents from schools that had already installed solar or wind power were more positive about it than respondents from schools that had installed neither, as would be expected. One notable exception was that schools that had installed solar were considerably more negative about its potential to save their schools money than other respondents**, **indicating that perhaps solar did not live up to its potential for cost savings**.*

4.2.1.6 Results by Region of Texas – Questions # 1-9

Table 4.8 represents survey responses by location of school.

Table 4.8 Compilation of Survey Responses to Questions 1-9 by Location of School

Question	Location of School	Number of response (percent)					
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	Total
1. My school is concerned about environmental issues and sustainability.	Panhandle Plains	0 (0%)	0 (0%)	1 (33%)	2 (67%)	0 (0%)	3
	Prairies and Lakes	0 (0%)	0 (0%)	1 (20%	3 (60%)	1 (20%)	5
	Piney Woods	0 (0%)	0 (0%)	1 (100%)	0 (0%)	0 (0%)	1
	Gulf Coast	0 (0%)	0 (0%)	1 (33%)	2 (67%)	0 (0%)	3
	All	0 (0%)	0 (0%)	4 (33.3%)	7 (58.3%)	1 (8.37%)	12
2. My school has thought about renewable energy as an alternative to our current campus's energy supply.	Panhandle Plains	0 (0%)	0 (0%)	1 (33%)	2 (67%)	0 (0%)	3
	Prairies and Lakes	1 (20%)	0 (0%)	1 (20%)	2 (40%)	1 (20%)	5
	Piney Woods	0 (0%)	0 (0%)	1 (100%)	0 (0%)	0 (0%)	1
	Gulf Coast	0 (0%)	0 (0%)	1 (33%)	1 (33%)	1 (33%)	3
	All	0 (0%)	0 (0%)	4 (33.3%)	5 (41.7%)	2 (16.7%)	12

3. Installing wind or solar power on campus is/ would be good publicity for my school.	Panhandle Plains	0 (0%)	0 (0%)	0 (0%)	2 (67%)	1 (33%)	3
	Prairies and Lakes	0 (0%)	0 (0%)	1 (20%)	4 (80%)	0 (%)	5
	Piney Woods	0 (0%)	0 (0%)	0 (0%)	0 0(%)	1 (100%)	1
	Gulf Coast	0 (0%)	0 (0%)	0 (0%)	3 (100%)	0 (0%)	3
	All	0 (0%)	0 (0%)	1 (8.3%)	9 (75%)	2 (16.7%)	12
4. Installing wind or solar power on campus would attract students to my school.	Panhandle Plains	0 (0%)	0 (0%)	0 (0%)	2 (0%)	1 (0%)	3
	Prairies and Lakes	0 (0%)	0 (0%)	3 (60%)	2 (40%)	0 (0%)	5
	Piney Woods	0 (0%)	0 (0%)	0 (0%)	1 (100%)	0 (0%)	1
	Gulf Coast	0 (0%)	0 (0%)	1 (33%)	2 (67%)	0 (0%)	3
	All	0 (0%)	0 (0%)	4 (33%)	7 (58%)	1 (11%)	12
5. Would turbines or solar panels be an effective teaching tool at my school?	Panhandle Plains	0 (0%)	0 (0%)	0 (0%)	1 (33%)	2 (67%)	3
	Prairies and Lakes	0 (0%)	0 (0%)	0 (0%)	5 (100%)	0 (0%)	5
	Piney Woods	0 (0%)	0 (0%)	0 (0%)	1 (100%)	0 (0%)	1
	Gulf Coast	0 (0%)	0 (0%)	0 (0%)	3 (100%)	0 (0%)	3
	All	0 (0%)	0 (0%)	0 (0%)	10 (83.3%)	2 (16.7%)	12
6. Would turbines or solar panels be an effective research tool at my campus?	Panhandle Plains	0 (0%)	0 (0%)	0 (0%)	1 (33%)	2 (67%)	3
	Prairies and Lakes	0 (0%)	1 (20%)	2 (40%)	2 (40%)	0 (0%)	5
	Piney Woods	0 (0%)	0 (0%)	1 (100%)	0 (0%)	0 (0%)	1
	Gulf Coast	0 (0%)	0 (0%)	1 (33%)	2 (67%)	0 (0%)	3

	All	0 (0%)	1 (8.3%)	4 (33.3%)	5 (41.7%)	2 (16.7%)	12
7. Wind energy is saving/ could save my school money over the long-term.	Panhandle Plains	0 (0%)	0 (0%)	0 (0%)	2 (67%)	1 (33%)	3
	Prairies and Lakes	1 (20%)	0 (0%)	2 (40%)	2 (40%)	0 (0%)	5
	Piney Woods	0 (0%)	1 (100%)	0 (0%)	0 (0%)	0 (0%)	1
	Gulf Coast	0 (0%)	0 (0%)	1 (33%)	2 (67%)	0 (0%)	3
	All	1 (8.3%)	1 (8.3%)	3 (25%)	6 (50%)	1 (8.3%)	12
8. Solar energy is saving/ could save my school money over the long-term.	Panhandle Plains	0 (0%)	0 (0%)	0 (%)	2 (67%)	1 (33%)	3
	Prairies and Lakes	0 (0%)	1 (20%)	1 (20%)	3 (60%)	0 (0%)	5
	Piney Woods	0 (0%)	0 (0%)	0 (0%)	1 (100%)	0 (0%)	1
	Gulf Coast	0 (0%)	0 (0%)	0 (0%)	3 (100%)	0 (0%)	3
	All	0 (0%)	1 (8.3%)	1 (8.3%)	9 (75%)	1 (8.3%)	12
9. Availability of government subsidies for wind/solar would influence my school's decision to install them.	Panhandle Plains	0 (0%)	0 (0%)	0 (0%)	2 (67%)	1 (33%)	3
	Prairies and Lakes	0 (0%)	0 (0%)	1 (20%)	1 (20%)	3 (60%)	5
	Piney Woods	0 (0%)	0 (0%)	1 (100%)	0 (0%)	0 (0%)	1
	Gulf Coast	0 (0%)	0 (0%)	0 (0%)	2 (67%)	1 (33%)	3
	All	0 (0%)	0 (0%)	3 (25%)	4 (33.3%)	5 (41.7%)	12

Table 4.8 shows some interesting trends and areas worthy of discussion. In particular, for Question #7, the respondent from the Piney Woods strongly disagreed that wind turbines would save the campus money, which makes sense given that winds are blocked by trees in this region. On the other hand, 100% of the Panhandle Plains respondents and 67% of the Gulf Coast respondents agreed or strongly agreed that wind turbines would save their schools money. Both of these regions, the Panhandle Plains in particular, have high wind speeds good for wind turbine operation. Similarly, for Question #8, 100% of respondents from the Panhandle Plains and Gulf Coast thought solar power could save their schools money. For Question #2, 67% of schools in each of these two regions had thought about renewable energy as an alternative source of power at their school. For Question #6 67% of schools in

each of these two regions had felt wind and solar power would promote good research work for their students. Percents for these two regions for Questions # 2, 6, 7, and 8 were higher than for the Prairies and Lakes region.

Results for most of the other questions were similar regardless of region. Question # 3 refers to installing wind, solar, or both would be good public relations for the school. All regions supported this idea. For Question # 5, overwhelmingly, the respondents that yes, wind and/or solar would be great teaching tools. For Question #9, most all regions of Texas felt if they received subsidies or grants, they would be more in favor of using renewable energy such as solar or wind on their campus.

In summary, two regions with the high potential for wind and solar power in Texas, the Panhandle Plains and the Gulf Coast, were overall more positive about potential use of wind and solar power on their campuses, compared to regions with less potential.

4.2.2 Results for Questions # 10, 18-20

4.2.2.1 Results for All Schools - Questions # 10, 18-20

Table 4.9 tabulates survey responses for all schools for Questions # 10, 18-20.

Table 4.9 Compilation of Survey Responses to Questions # 10, 18-20: All Schools

Question	Response option, number of responses (percent)			Total Responses to Question
10. My campus has already installed:	Wind turbines 2 (18%)	Solar 5 (45%)	Neither 5 (45%)	11 (one school installed both)
18. Average percent of power supplied by:	Wind N/A	Solar Avg. 3.25%		4
19. Does your school purchase renewable power from an electric company?	Yes 3 (50%)	No 3 (50%)		6
20. If your school has already installed wind/ solar, or both, did your school receive grants to finance the project?	Yes 5 (83%)	No 1 (17%)		6

Question #10 shows that 6 schools out of 11 that responded to the question (54%) have installed a type of renewable energy (one school has installed both solar and wind, so appears in 2 columns). One standout piece of data is that more schools (45%) installed solar panels for solar energy rather than wind turbines (18%). This variation could result from the fact that through my research, it seems more schools install solar energy due to the fact that it is somewhat cheaper than the start-up costs of the infrastructure of wind energy installing the wind turbines.

Question #18 shows that for the schools with solar panels installed, the average percent power supplied for their campus is 3.25%. Several schools that had not installed solar panels on their campus responded to this question. They were likely reporting the percent of their campus energy purchased from power companies that was renewable. Since this was not the intent of the question, these responses were ignored.

An interesting question and corresponding percentage above is Question # 19, referencing does your school purchase renewable power from an electric company. This was split down the middle of the 6 respondents that replied. 50% of schools surveyed do purchase renewable energy from an electric company and 50% do not. Six of the schools did not respond to this question, likely because the respondent did not know.

In Question #20, the need for financial assistance, such as grants or other financial help, was seen as important. ***83% of the respondents that have wind, solar, or both on their campus, did receive grants***, which is understandable. With the high costs for a college or university to operate in today's times, grants would be needed to get a renewable energy such as wind or solar off the ground and started. Responses to this question from schools that had not actually installed wind or solar power were disregarded.

The following sections break out responses to Questions #10, 18-20 by 2-year vs. 4-year schools and by size of school. These questions were not broken out by type of respondent, because they are factual rather than opinion questions. In addition, these questions are not broken out by whether the school has already installed wind or solar power, because that is what the questions are asking.

4.2.2.2 Results for 2- vs. 4-year Schools - Questions # 10, 18-20

Table 4.10 separates survey responses by 2- vs. 4-year schools for Questions # 10, 18-20.

Table 4.10 Compilation of Survey Responses to Questions # 10, 18-20: 2-year vs. 4-year Schools

Question	Type of School	Response option, number of responses (percent)			Total Responses to Question
10. My campus has already installed:	2-year	Wind turbines 0	Solar 1 (50%)	Neither 1 (50%)	2
	4-year	Wind turbines 2 (22%)	Solar 4 (44%)	Neither 4 (44%)	9 (one school installed both)
	All	Wind turbines 2 (18%)	Solar 5 (45%)	Neither 5 (45%)	11 (one school installed both)
18. Average percent of power supplied by:	2-year	Wind N/A	Solar 4% Avg. 4%		1
	4-year	Wind N/A	Solar 1%, 1%, 7% Avg. 3%		3
	All	Wind N/A	Solar Avg. 3.25%		4
19. Does your school purchase renewable power from an electric company?	2-year	Yes 0 (0%)	No 2 (100%)		2
	4-year	Yes 3 (75%)	No 1 (25%)		4
	All	Yes 3 (50%)	No 3 (50%)		6
20. If your school has already installed wind/ solar, or both, did your school receive grants to finance the project?	2-year	Yes 1 (100%)	No 0 (0%)		1
	4-year	Yes 4 (80%)	No 1 (20%)		5
	All	Yes 5 (83%)	No 1 (17%)		6

Table 4.10 above separates the respondents of 2-year vs. 4-yr schools. Most responses were similar for 2- and 4-year schools. The percent of schools that have installed renewable power is comparable for 2- vs. 4-year schools (50% and 55%, respectively). The average percent power supplied by solar panels is also analogous for 2- vs. 4-year schools (4% and 3%, respectively). In Question # 20, 80% of 4-year schools and 100% of 2-year schools received funding support for renewable power installation. A smaller two-year school in particular would need financial assistance to install renewable types of energy due to the fact that smaller schools operate usually on a smaller budget than a large four-year university.

However, responses to Question #19, does your school purchase renewable power from an electric company, were markedly different for 2- and 4-year schools (0% positive for 2-year schools, vs. 75% positive for 4-year schools). Perhaps if purchasing renewable power is more expensive, 4-year schools may have more funds available to purchase it.

In summary, responses to Questions #10, 18-20 were similar for 2-year and 4-year schools, with the exception of the fact that 4-year schools were more likely to purchase renewable power from an electric company than 2-year schools.

4.2.2.3 Results by Size of School - Questions 10, 18-20

Table 4.11 divides survey responses by size of school for Questions 10, 18-20.

Table 4.11 Compilation of Survey Responses to Questions 10, 18-20 by Size of School

Question	Size of School	Response option, number of responses (percent)			Total Responses to Question
10. My campus has already installed:	<5000	Wind turbines 1 (25%)	Solar 1 (25%)	Neither 2 (50%)	4
	>5000 & <10,000	Wind turbines 0	Solar 1 (25%)	Neither 3 (75%)	4
	>10,000	Wind turbines 1 (33%)	Solar 3 (100%)	Neither 0	3
	All	Wind turbines 2 (18%)	Solar 5 (45%)	Neither 5 (45%)	11
18. Average percent of power supplied by:	<5000	Wind N/A	Solar 1%		1
	>5000 & <10,000	Wind N/A	Solar 7%		1
	>10,000	Wind N/A	Solar 1%, 4%		2
	All	Wind N/A	Solar Avg. 3.25%		4
19. Does your school purchase renewable power for an electric company?	<5000	Yes 1 (50%)	No 1 (50%)		2
	>5000 & <10,000	Yes 2 (67%)	No 1 (33%)		3
	>10,000	Yes 0 (0%)	No 1 (100%)		1
	All	Yes 3 (50%)	No 3 (50%)		6
20. If your school has already installed wind/ solar, or both, did your school receive grants to finance the project?	<5000	Yes 2 (100%)	No 0 (0%)		2
	>5000 & <10,000	Yes 0 (0%)	No 1 (100%)		1
	>10,000	Yes 3 (100%)	No 0 (0%)		3
	All	Yes 5 (83%)	No 1 (17%)		6

In Question # 10, the smallest school population category of <5,000 students show half of the survey respondents use renewable energy on their campus already, either wind or solar. The other half of the respondents use neither. This split down the middle could be a result of some smaller schools just not having the finances for the start-up costs to have wind turbines or solar energy panels on their campus. It was somewhat surprising that in the size category of >5,000 students and < 10,000, as only one school (25%) had solar, and 3 schools (75%) have neither wind nor solar on their campus. One might conclude that the schools are just not interested in renewable forms of energy. Another hypothesis to explain the lack of renewable energy mid-size schools is that the money is not readily available for start-up costs for wind or solar energy.

When looking at Question # 10 for schools with student populations >10,000, all three schools surveyed (100%) were using solar. In addition, one of the three schools had installed both wind and solar. This is consistent with Questions # 7 and 8, in which larger schools clearly thought that solar panels were more likely than wind turbines to save their schools money. It is not consistent, however, with responses to Question #2, in which 2 of the large schools were neutral about whether their school had considered renewable power.

Trends by school size for Questions #18 and 19 were difficult to discern. For Question # 20, all small schools and all large schools received some type or form of financial assistance to start the project. The only school that did not receive assistance was the one medium-sized school.

In summary, large schools were more likely to have installed renewable power on their campus. Trends for the other questions were either difficult to discern or did not vary by size of school.

4.2.2.4 Results by Region of Texas - Questions # 10, 18-20

Table 4.12 compiles survey responses to Questions 10, 18-20 by location of school.

Table 4.12 Compilation of Survey Responses to Questions 10, 18-20 by Location of School

Question	Location of School	Response option, number of responses (percent)			Total Responses to Question
10. My campus has already installed:	Panhandle Plains	Wind turbines 1 (33%)	Solar 0 (0%)	Neither 2 (67%)	3
	Prairies and Lakes	Wind turbines 0 (0%)	Solar 2 (40%)	Neither 3 (60%)	5
	Piney Woods	Wind turbines 0 (0%)	Solar 1 (100%)	Neither 0 (0%)	1
	Gulf Coast	Wind turbines 1 (50%)	Solar 2 (100%)	Neither 0 (0%)	2 (one school installed both)
	All	Wind turbines 2 (18%)	Solar 5 (45%)	Neither 5 (45%)	11 (one school installed both)
18. Average percent of power supplied by:	Panhandle Plains	Wind N/A	Solar N/A		0
	Prairies and Lakes	Wind N	Solar 4%, 1%		2
	Piney Woods	Wind N/A	Solar 1%		1
	Gulf Coast	Wind N/A	Solar 7%		1
	All	Wind N/A	Solar Avg. 3.25%		4
19. Does your school purchase renewable power for an electric company?	Panhandle Plains	Yes 1 (100%)	No 0 (0%)		1
	Prairies and Lakes	Yes 1 (25%)	No 3 (75%)		4
	Piney Woods	Yes N/A	No N/A		0

	Gulf Coast	Yes 1 (100%)	No 0 (0%)		1
	All	Yes 3 (50%)	No 3 (50%)		6
20. If your school has already installed wind/ solar, or both, did your school receive grants to finance the project?	Panhandle Plains	Yes 1 (100%)	No 0 (0%)		1
	Prairies and Lakes	Yes 2 (100%)	No 0 (0%)		2
	Piney Woods	Yes 1 (100%)	No 0 (0%)		1
	Gulf Coast	Yes 1 (50%)	No 1 (50%)		2
	All	Yes 5 (83%)	No 1 (17%)		6

Some interesting trends were that a higher percentage of schools in the Gulf Coast region have installed wind energy. Speaking meteorologically, wind is greater or stronger near bodies of water. This makes having wind turbines closer to the water more efficient in producing electricity with the availability of wind being greater.

4.2.3 Results for Questions # 11-14

Responses to these questions were not split by 2-year vs. 4-year school, size of school, or type of respondent, due to the small number of responses, especially for Questions # 13 and 14.

According to responses to Question #10 above, 2 schools have installed wind power, 9 have not, and one did not respond to the question. Of the 9 that have not installed wind power, 8 responded to Question #11, indicating why they have not installed wind power. Responses for these 8 schools are shown in Table 4.13. Only the top response to why each school has not installed wind power was compiled: all respondents provided reason #1, but many respondents did not rank all of the responses from 1-7.

Table 4.13: Compilation of Survey Responses to Question #11: Top Reason for Not Using Wind Power

Primary Reason not Installed	Number of Responses (Percent)
Start-up cost	3 (37.5%)
Maintenance cost	0 (0%)
Space availability for turbines	1 (12.5%)
Availability of wind on campus	3 (37.5%)
Eye-sore on campus	1 (12.5%)
Noise	0 (0%)
Biological concerns	(0%)

From the data in Table 4.13, start-up cost and lack of availability of wind on campus were the primary reasons for not installing wind turbines. Installation of wind turbines would be an expensive cost for a college or university if they did not receive financial incentives such as a grant. Research shows that wind speeds greater than 9 mph are required for small wind electric turbines. Larger wind turbines require a minimum average wind speeds of 15 mph. (Department of Energy (DOE), https://windexchange.energy.gov/small-wind-guidebook#intro). A substantial number of schools reported not having sufficient wind speeds to support turbines on campus.

From Table 4.13, other reasons for not installing wind turbines on campus are space availability and the fact that some see them as an eye-sore. Being an eye-sore relates to the acronym “NIMBY” which means Not in my Backyard.” Some believe it takes away the natural aesthetic beautify of nature if wind turbines are turning in the background.

According to responses to Question #10 above, 5 schools have installed solar power, 6 have not, and one did not respond to the question. Of the 6 schools that have not installed solar power, all responded to Question #11, indicating why they have not. Responses are compiled in Table 4.14. Only the top response to why each school has not installed solar power was compiled: all respondents

provided reason #1, but many respondents did not rank all of the responses from 1-6. A response from a school that had already installed solar power was disregarded.

Table 4.14 Compilation of Survey Responses to Question #12: Top Reason for Not Using Solar Power

Primary Reason not Installed	Number of Responses (Percent)
Start-up cost	5 (83.3%)
Maintenance cost	0 (0%)
Space availability for panels	0 (0%)
Too many trees on campus	(0%)
Not enough sunny days	(0%)
Eye-sore on campus	1 (16.7%)

Table 4.14 shows that, similar to wind turbines, number one reason for not installing solar power is the start-up cost. At first glance, these responses seem to be in conflict with responses to Question #8, in which schools were optimistic about solar power saving their schools money. When one distinguishes between up-front capital and long-term operating costs, however, the responses are not in conflict. Although the up-front cost of solar panels is high and may be cost-prohibitive, there is long-term potential for the panels to save the universities money on their electric bills. This underscores the importance of the college or university receiving some kind of grant to finance the project up-front. Similar to wind turbines, one respondent listed eye sore as the top reason for not installing solar power (it was actually the same respondent).

As mentioned previously only 2 of schools surveyed have wind turbines installed. One of the schools did not respond to Questions #11-14. Responses to Question #13 for the other school with wind power are listed below. Responses to Question #13 from schools that did not have wind power installed were disregarded.

Biggest Advantages of Wind Turbines:

- None at this point. Turbine is used for demonstration only.

Biggest Disadvantages of Wind Turbines:

- Maintenance

As mentioned above, five of the schools surveyed are using solar power. Only two of these responded to Question #14, which asks campuses with solar panels about their biggest advantages and disadvantages. Responses for these two schools are listed below. Reponses to Question #14 from schools that did not have solar installed were disregarded.

Biggest Advantages of Solar Panels:

- Supplemental energy
- Almost zero marginal cost for electrons produced.

Biggest Disadvantages of Solar Panels:

- They do not create enough power and are too expensive.
- Upfront cost of solar panels.

Based on these responses, a benefit of solar panels is the almost-free energy they provide once installed, but up-front capital costs are high. This is consistent with the responses to Question #8, in which schools were overall positive about its potential to save their schools money, and Question #12, in which 83% of respondents listed cost as the primary reason that their university had not installed solar panels.

In summary, up-front costs of solar panels are a primary concern for schools that have installed them as well as for schools that have not. Installation costs for wind turbines are also a barrier, as well as availability of wind.

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 Findings and Conclusions

Findings from Qualitative Interviews

- Important themes that emerged from interviews with the 3 Texas universities with wind turbines and/or solar panels already installed were importance of renewable energy for the environment, green publicity, opportunities for teaching and research, the need for financial savings, and the need for grant funding.

Overall Findings from Quantitative Surveys

- Most respondents agreed or strongly agreed that installing wind or solar power on campus would make for good publicity for the college or university (92%), would attract students to the school (83%), and would be good teaching tools for students on campus (100%).
- There was also consistency between the colleges and universities surveyed (75%) that the school would need financial assistance such as grants to be able to install wind, solar energy, or both. Of the colleges and universities that installed renewable energy on their campus already, 83% did receive grants to cover start-up costs to begin their renewable energy project.
- The colleges and universities surveyed were more likely to think that that solar power would save them money (83%) compared to wind power (58%).
- The primary reason that colleges and universities have not installed solar and wind power is up-front costs. Secondary concerns include availability of wind power and the potential for both solar panels and wind turbines to be eye-sores.

Quantitative Survey Findings by 2- vs. 4-year Schools, Size of School, Type of Respondent, and Location of School

- Large schools (> 10,000 students) and 4-year schools were more likely to believe that renewable power could be a useful research tool at their university.

- Large schools and 4-year schools were also more likely to believe that solar power (as opposed to wind power) would save their university money.
- Large schools were more likely to have installed renewable power on their campus.
- 4-year schools were more likely to purchase renewable power from an electric company than 2-year schools.
- When looking at responses by type of respondent, the physical operations personnel seemed less concerned about publicity benefits than the sustainability directors and faculty members. Sustainability directors and physical operations personnel were more positive about wind and solar power saving their university money, compared to faculty members.
- Two regions with the high potential for wind and solar power in Texas, the Panhandle Plains and the Gulf Coast, were overall more positive about potential use of wind and solar power on their campuses, compared to regions with less potential.

Conclusions

- Reported benefits of installing solar and wind power on university campuses include helping the environment, green publicity, opportunities for teaching students about renewable energy practices and how they can make a difference in the environment, engaging students in research, and financial savings.
- The primary obstacle to installing solar panels and wind turbines on university campuses is up-front costs. Providing additional grant funding and incentives is critical in overcoming this hurdle.

5.2 Recommendations for Future Research

- Extend the surveys to other states outside of Texas where wind and solar energy are prevalent. This would give more data and also see the thoughts from other states regarding the use of renewable energy.
- Build a tool such as a computer program to help a college or university which is considering using wind, solar, or both, to be able to input different parameters into the computer program to give the school an idea of whether using wind, solar, or both would be pragmatic at their school.

- More research needs to be done to see why more respondents think solar energy could save their school more money than wind energy.
- Identify federal government programs that would help finance the start-up costs for schools installing wind, solar, or both.
- Add other types of renewable energy to the surveys.
- Conduct similar surveys for other business or non-profit sectors, including corporate office campuses.
- Survey other stakeholders at universities, including students from engineering, environmental science, economics/business, and architecture.
- Determine whether the university being public vs. private affects results.
- Determine whether the presence of an environmental science program at the university affects results.

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APPENDIX: LIST OF UNIVERSITIES & COLLEGES TO WHICH SURVEY WAS SENT

West Texas A&M: Canyon, Texas

Texas Tech University: Lubbock

Sam Houston State: Huntsville

Texas A &M- College Station

Baylor University

University of Houston

University of Texas –Austin

Rice University

Tarleton State University: Stephenville

Sul Ross State University

Lamar University-Beaumont

Stephen F. Austin University

Texas Christian University

Southern Methodist University

Texas State Technical College-Sweetwater

El Centro-Dallas

Texas A&M-Kingsville

University of Texas-El Paso

Austin College: Sherman

Cisco Jr. College

Midland College

Southwestern University: Georgetown

University of Texas at Austin)

University Of Houston-Clear Lake

University of Texas-El Paso

University of Texas Pan American

Hardin Simmons University

Abilene Christian University

McMurray University

Embry Riddle Aeronautical University Dyes AFB Abilene, Texas

Angelo State University

Dallas Baptist University

University of North Texas

University of Texas at Arlington

Texas A&M University-Corpus Christi

East Texas Baptist University

Howard Payne University

Houston Baptist University

Texas A&M University-Commerce, Texas

Jarvis Christian College

Lubbock Christian University

Letourneau University

Midwestern State University

St. Edward's University

Texas State University

Texas A&M University-Galveston, Texas

Prairie View A&M University

Texas A&M International University

Texas Lutheran College

Texas Woman's University

University of Dallas

University of Mary Hardin-Baylor University

Wayland Baptist University

Wiley College

BIOGRAPHICAL INFORMATION

Andrew LaFavers graduated with a Bachelor's Degree in Broad Field Social Science from Texas A&M University in Commerce, Texas, formerly known at that time as East Texas State University. He was a high school science teacher for 13 years and tennis coach. He received a Master's Degree in Earth Science in August 1988 from Texas A&M - Commerce. Andrew continued teaching high school until January 1997.

In January 1997, he began a Master's Degree in Meteorology at Mississippi State University. The second Master's Degree was completed in December 1999.

He began his television meteorology career as a "weatherman" in Corpus Christi, Texas, from 1998-2001 at the CBS Affiliate, KZTV. Next, Andrew moved up the Texas coast to the NBC Affiliate, KBTV, located in Beaumont Texas, from 2001-2002. His last television market was KTXS located in Abilene, Texas. Andrew worked there from 2002 to 2007.

After several years working in his "dream job" as a television meteorologist, he knew it was time to return to his first love, teaching. He began as a professor at Dallas Baptist University in 2007, where he continues teach. His teaching areas are physical geology, meteorology, astronomy, and environmental science. He began his Ph.D. degree at the University of Texas in Arlington, Texas in 2009 in Environmental Science. Andrew will graduate with his Doctorate Degree on May 11, 2018. He will continue his full-time teaching at Dallas Baptist University in Dallas, Texas, where he is the Director of the Environmental Science Department.