2012

Feasability [sic] of implementing alternative energy technology on a high school campus

Mackensey Ann Farmer

FEASABILITY OF IMPLEMENTING ALTERNATIVE ENERGY TECHNOLOGY ON A HIGH SCHOOL CAMPUS

A Project

Presented to the

Faculty of

California State University,

San Bernardino

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

in

Environmental Sciences

---

by

Mackensey Ann Farmer

June 2012

FEASABILITY OF IMPLEMENTING ALTERNATIVE ENERGY

TECHNOLOGY ON A HIGH SCHOOL CAMPUS

A Project

Presented to the

Faculty of

California State University,

San Bernardino

---

by

Mackensey Ann Farmer

June 2012

Approved by:

[redacted]

Dr. James Noblet, Chemistry and Biochemistry

6/6/12

Date

[redacted]

Dr. Brett Stanley

[redacted]

Jeremy Owens

ABSTRACT

This study examines ways in which wind turbine and solar panel alternative energy technologies can be utilized on high school campuses. Information collected on how wind turbines and solar panels operate, the size, structure, power output, cost, advantages and disadvantages, was used to determine which specific wind and solar systems would best serve campus needs. A Skystream 3.7 unit manufactured by Southwest Windpower was determined be the best choice for a wind turbine to be placed on a typical high school campus. The solar panels selected are constructed of polycrystalline solar cell technology, which generates more solar power per square foot. The system chosen for the new classroom building at Beaumont High School is manufactured by Sanyo and Unirac. Case studies have shown that the school cannot reach 100% sustainability, but can reduce the electrical need during peak usage periods. This approach results in an estimated savings of approximately $23,000 per year. The calculated time for reaching the return on investment break-even point for these systems is 25 years and 20-30years (depending on incentives) for the wind and solar systems, respectively. Comparison of the payback period to the estimated lifetime of the systems shows that

cost savings is probably not a significant benefit of these technologies. Rather, the main benefits to campuses and society are reductions in peak energy demand to the existing power grids, reducing dependence on fossil fuels and the associated green house gas emissions, and the opportunity to educate students about energy and sustainability.

ACKNOWLEDGEMENTS

I would like to thank my committee members Dr. James Noblet, Dr. Brett Stanley, and Jeremy Owens, for their support and constant help through this process. I am thankful for the Inland Empire Resource Conservation District, Redlands USD, and Beaumont USD for providing me the information needed in this project.

A special thanks to my family for their continuous support and inspiration.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

CHAPTER ONE

INTRODUCTION

Reasons for Using Alternative Energy

Energy has become an indispensable resource, and its cost and availability affects most of the people in the modern industrial society. Since the industrial revolution there has been a dramatic increase (Siddiqui, 2010) on the consumption of fossil fuel (oil, octane, diesel, natural gas and other use with increasing concerns of: waning fossil fuel reserves (Siddiqui, 2010) and their impact on climate change, an increase in greenhouse gas emissions e.g. CO_2, CO, NO_x, and other (Siddiqui, 2010) which has lead to an investment in alternative energy technologies. Implementing the use of alternative energy technologies that do not rely on fossil fuels will promote a process for the reduction of greenhouse gas emissions. By using various alternative energy sources, such as those that are beneficial to particular regions in the United States and around the world, could begin to stabilize CO_2 (carbon dioxide) concentrations in the atmosphere (Siddiqui, 2010). With an understanding that the current energy crisis is not going away due to population growth and a projected energy use from countries around the world, societies have the opportunity to become more educated in implementing alternative energy sources that would be most beneficial e.g. wind, solar, nuclear, hydro and tidal. Sustainable energy is a great concept, but education is a key factor in developing a sustainable society (Jennings, 2009).

This study compiled currently available and acceptable data on the use of sustainable/renewable energy sources. Specifically, information was obtained from utilizing literature reviews in relevant technical publications such as Renewable Energy Journal and Energy Economics Journal, feasibility reports and case studies, internet sources i.e. the Department of Energy (DOE) and National Renewable Energy Laboratories (NREL). The available information was collected on specific horizontal axis wind turbines, vertical axis wind turbines, photovoltaic cells and passive thermal solar panels for the purpose of assessing how these currently available technologies might fully or partially meet the electrical needs of a typical high school campus.

Motivation of the Study

The purpose of this study is to examine ways in which wind turbine and solar panel alternative energy technologies can be obtained, utilized, and feasibly incorporated in sustainable energy programs at high school campuses. Also, strategies can be developed on how to implement alternative energy conservation education into the science curriculum. In order to incorporate alternative energy technologies among high school campuses in a given area, i.e. wind and solar technology, decisions need to be made with respect to funding, target costs, and education (Siddiqui, 2010). This needed education on wind and solar alternative energy technology will be achieved through research, development, actual installation, and operation.

Using renewable energy on the high school campus will help reduce the use and reliance on non-renewable energy sources. An additional benefit is it will educate the student body on the significance of renewable energy and its positive impacts on the environment, and its role in developing possible sustainable energy resources for the future. For example at Beaumont High School in Beaumont, California the average daily energy use is approximately 5,843 kWh (a kilo watt per hour (kWh) is a unit of energy equal to 3600 kJ or 3.6 million Joules). For comparison, one kWh is the amount of energy required to operate ten

100-watt incandescent light bulbs for one hour. In a thirty one day month this high school is averaging 180,693 kWh for its electrical needs, which is approximately 2.2 million kWh per year. When a high school begins to take the initial steps in becoming a self-sustaining campus they soon realize that solar and wind technologies are becoming more economically feasible as possible school improvement projects. There are considerable financial incentives available through federal and private grant and loan programs that provide financial assistance to schools applying for these energy conservation projects on their campus. The ultimate, long term goal would be to provide enough energy so electricity would no longer need to be purchased on a regular basis therefore providing a low cost and sustainable energy source for the school. For this case study this could be achieved through the use of wind turbines and solar panels.

First and foremost, a horizontal-axis wind turbine has a rotor and electrical generator located at the top of the tower where the rotor is parallel to the ground. Conversely, the vertical axis wind turbines are constructed with the same components, but their rotational axes are perpendicular to the ground. The propellers rotational velocity increases proportionally to the wind speed; electricity is then generated as direct current or alternate current depending on the design.

Secondly, photovoltaic cells (PV) and passive thermal solar panels are similar due to no moving parts and are stationary when collecting solar energy. This energy collection is managed through a semiconducting material or a dark material that absorbs the sunlight, respectively (Aldous, 2011).

In reference to sustainability and costs; the money saved accumulated from these sources could be applied to the schools' budget and curriculum rather than an electrical bill.

CHAPTER TWO

SOLAR AND WIND POWER TECHNOLOGY

In accordance with the data that has been collected in providing an adequate perspective on what a school such as the state of California's Beaumont High School (the author's current employer) may need, there are three types of data that will be discussed. One, with respect to California State University San Bernardino's (CSUSB) use of implementing alternative resources, i.e. solar energy, data provided by CSUSB will be used to show the output and input of energy used. Data will also be utilized to compare, on a smaller and more comparable scale, on how the Los Angeles Unified School District and Redlands Unified School District has utilized solar power including information pertaining to savings, costs, and energy produced. Lastly, this data will be utilized in explaining how much energy versus costs a school the size of Beaumont High School can expect to incur as a result of implementing these alternative energy technologies.

Advantages and Disadvantages of Wind Turbines

Wind energy is a clean fuel source; there are no emissions that contribute to acid rain or greenhouse gases. Wind is a renewable resource and is regionally abundant throughout the world and especially abundant at Beaumont High School. Wind energy is one of the lowest-priced renewable energy technologies available today, costing between four to six cents per kWh, depending upon the wind resource and projected financial cost. Any excess power that is produced and not consumed by the school may be redirected into the local energy grid (Shamp, 2011). This would contribute energy regionally during times of high wind energy production and furthermore credit can be given to the school district (U.S. Department of Energy, 2011).

Some disadvantages of wind power are that it must compete with conventional energy generation sources on a cost basis. The intermittency of wind posses a major challenge to using it as a source of power therefore is not a reliable electric source during peak energy consumption (Tavner, 2008).

How Wind Turbines Work

The kinetic energy of moving air is converted into rotational energy through the use of blades that are attached to an axle which in turn runs into a gearbox. When the wind flows over the blades, a lift similar to the effect of air current flowing across an airplanes wing is created which causes the blades to rotate. The faster the drive shaft, or axle, spins inside the generator ,the more DC electricity is produced. The direct current is sent to a converter box located at the place of use and converted to alternate current. An inverter needs to be present in order to convert the direct current produced by the wind into alternate current.

Types of Wind Turbines

There are various types, sizes, and configurations of wind turbines, so in order to narrow the choices for this study information was collected through the U.S. Department of Energy website (DOE). The U.S. Department of Energy's National Renewable Energy Laboratory (NREL) has done research and tested large scale turbines, mid-size turbines, and small scale turbines.

This study focused on small scale horizontal and vertical axis wind turbines that would best suit a high school's energy needs and available space. The reason in choosing small scale wind turbines is most high school campuses in the Southern California region are located in urban areas where open land space is limited and often expensive, and the noise produced by larger turbines could be an issue. The National Renewable Energy Laboratory has testing capabilities that are accredited by the American Association of Laboratory Accreditation (NREL.gov, 2011). NREL tests for acoustic noise emissions, the turbine's performance over long periods of time, power performance, power quality, and lastly, safety and design function (NREL.gov, 2011). In this study it was found that horizontal axis wind turbines are approximately 10% more energy efficient than vertical axis wind turbines (NREL.gov, 2011). The vertical axis wind turbines that were tested by NREL were not considered for this study because they are not a part of the "Wind Powering America" program initiated by the DOE. The horizontal axis wind turbine that best suits this study (see below) is from a company by the name of Southwest Windpower. Southwest Windpower are the producers and engineers of the Skystream 3.7, which is a new small wind generator designed in partnership with the U.S. Department of Energy's National Renewable Energy Laboratory (Skystreamenergy.com, 2010).

The overarching reason the Skystream 3.7 was chosen for this project was because more than one unit can be constructed and built on a reasonable lot size, for example a professional field sports complex, i.e. football or baseball. Other reasons include, but are not limited to simple installation, cost effectiveness, aesthetic design, and no need for batteries (Skystreamenergy.com, 2010). Since these units would be installed on or near a high school campus they will promote education. They will be able to demonstrate an active renewable energy for students to see while providing a real time monitoring data system that can be incorporated into the curriculum (Skystreamenergy.com, 2010).

The Skystream is able to convert energy from the wind into utility grade electricity through an integrated inverter. This means it takes the direct current (DC) provided by the wind and inverts it to alternate current (AC), that is then sent down the tower to a hollow tube that contains electrical wiring, for immediate use. Any excess energy would be sent to the local or regional electrical grid. Excess energy causes the meter to spin backwards which is used at a later date at retail value (Skystreamenergy.com, 2010).

This Skystream setup is convenient for a high school campus because all components, motor and inverter, are built directly into the wind turbine unit therefore less significant maintenance costs. Depending on your installed cost, cost of electricity, and average wind speed, it is estimated that the wind turbine can pay for itself in five to seven years (Skystreamenergy.com, 2010). In order for a Skystream to be most effective there needs to be an average daily wind speed of 12MPH (miles per hour) or more. In determining the installation site location, views and local zoning should allow for structures to be at least forty two feet tall; this will assist in gaining the optimal average wind speed (Skystreamenergy.com, 2010).

Field experimental results have shown that the towers should be at a height of sixty to seventy feet tall in order to maximize optimal energy collection from the wind. There are several types of towers available, which will be chosen to meet the load specifications determined by Southwest Windpower (Skystreamenergy.com, 2010).

The Skystream 3.7 is a certified and reliable design based on national and international testing and safety standards. The Skystream has been designed for a twenty year life span, while also including a five year warranty in case of improper installation, periodic upgrades through remote software, and technical support for all systems (Skystreamenergy.com, 2010).

Their ability as company to provide remote display and web based monitoring concepts makes Skystream a great choice in order to integrate alternative energy projects into the school curriculum. Also the wireless remote provides real time data from the wind turbine that can be connected to a classroom computer or integrated to a webpage. This would allow the teachers and students to learn, observe, and monitor the system performance along with understanding local/regional wind dynamics.

Advantages and Disadvantages of Photovoltaic Cells

Some of the major advantages to PV cells is they can be retro fitted to existing buildings/structures as well as designed and built directly to new buildings/structures. In its simplicity there are no moving parts with the PV cells, installation is easy, and no greenhouse emissions are produced with its use. "Despite the growth in the market, photovoltaic installations are still very expensive. By selecting the right mix of system type and size, financing, and ownership, the PV payback period can be reduced by half" (Shamp, 2011, p. 9), although this would take a coordinated effort among district employees.

The major disadvantages would include the fact that the solar radiative flux at the Earth's surface is not constant and depends on many variables which include weather changes, location and position of panel, and lastly, time of day and year (NASA.gov, 2010). These disadvantages are the main contributions to the large inefficiencies in solar panels, which is approximately 60% due to solar energy inconsistencies and energy/heat lost from the actual solar panels (EERE, 2011).

How Solar Power Works

There are more companies present in the Southwest region of the United States producing and installing photovoltaic cells (PV) on buildings, than those for wind turbines. School districts have a greater opportunity to research and find the best PV product for their needs and costs. Through the U.S. Department of Energy the Energy Efficiency and Renewable Energy program provides information on products and services. This program provides a list of certified solar PV installers based on the region the school is located. These installers are the North American Board of Certified Energy Practitioners (EERE, 2011). Through this study it was discovered that the average pay back for the installation of a solar technology system would be three to six years (U.S. Department of Energy, 2011). "All photovoltaic arrays abide by the same general set of rules:

1. Solar-to-electric conversion efficiency decreases as the temperature of the array increases.
2. Solar-to-electric conversion is the most efficient when the surface of the array is perpendicular to the sun's rays.
3. Solar-to-electric conversion is most efficient when sunlight is direct and unobstructed.
4. PV systems lose power output with time. The system will continue to produce power for possibly twenty to thirty more years, but at a steadily decreasing output" (Shamp, 2011, p. 15).

Through this project it was discovered that all PV cells are similar in construction. Solar cells convert electromagnetic radiation from the sun into useable electricity. Simple PV cells are comprised primarily of three materials, silicon, and a couple of doping agents (Aldous, 2010). Here the term "doping" refers to the addition of a small amount of another substance to a material in order to change or enhance its properties. The reason two doping agents are used is due to the fact that silicon cannot produce electricity on its own. Doping agents need to be able to change the oxidation-reduction states to allow for the flow of electricity. With the use of phosphorus as a doping agent on the silicon crystalline structure a free valence electron will be produced. This type of material is then called n-type material. This n-type material helps with the flow of electricity, but electricity has to have two points to flow through. In order to solve this problem a second doping agent is introduced to the process (Bates, 2010). The second doping agent will have fewer than four valence electrons. This second doping agent produces vacancies or so-called holes in the silicon crystalline structure, which is produced by the absence of an electron. This hole produced by the second doping agent is capable of being filled by the free electron from the phosphorus doping agent. This material is called p-type material. The solar panel is comprised of n-type and p-type material that are compressed together to produce a p-n junction. This two-layered material that contains silicon and the two doping agents has a positive electrode on one side and a negative electrode on the other side of the cell (NASA.gov, 2010). When the cell is struck by solar rays (or any light of sufficient energy) the electrons are promoted to an excited state and are then able to flow from the n-type layer to the p-type layer of the semiconductor material (NASA.gov, 2010). The free flowing electrons therefore produce a current that is proportional to the amount of light absorbed. The more light that impinges on the surface of the solar cell, the more electricity generated (Aldous, 2010). If electrical conductors are attached to the positive and negative sides of the cell an electrical current is formed (NASA.gov, 2010). The energy collected from the PV cells is direct current (DC), which would have to be sent through an inverter to be changed to alternate current (AC). Then the alternating current can be usable electricity for the needs of the building or returned to the main grid.

Types of Photovoltaic Cells

There are several types of PV cells but the two major types of crystalline silicon produced are mono-crystalline and poly-crystalline. Mono-crystalline cells are made by pouring melted silicon into rod molds. Once the rods are solid, small silicon circular wafers are cut with a diameter of approximately 150mm and a thickness of 350 microns. "These tend to be the most expensive PV cells due to the considerable material waste lost in sawing and trimming" (Shamp, 2011, p. 15). "However, they are the most efficient at converting light to electricity" (Shamp, 2011). The efficiency of mono-crystalline PV cells producing electricity is 15% (Aldous, 2010). Poly-crystalline cells are similar to mono-crystalline, because the end product is a small silicon wafer. These are created by pouring molten silicon into blocks and in turn multiple large crystal structures may be formed and then sliced into small rectangular wafers. "With polycrystalline PV cells there is very little silicon waste in the manufacturing process, which reduces the cost" (Shamp, 2011, p. 17). The efficiency of poly-crystalline producing electricity is 14% (Aldous, 2010).

Despite effective production processes, one of the largest problems that plague crystalline silicon cells is the limits of their efficiency (Bates, 2010). For more power, cells are connected to form larger units called modules and are connected in series and/or parallel circuits to produce higher voltages (NEED.org, 2010). A PV array is the complete power generating unit, consisting of any number of modules and panels.

Advantages and Disadvantages of Solar Thermal Collectors

The advantages of installing solar thermal collectors are that the systems can be mounted to the roof which would better facilitate the fluid being heated by the Sun. Based on the hot water needs most standard size panels, which are $4m^2$, can contribute approximately 80% of energy based on the quantity of hot water required and the timing of that requirement. The disadvantages of these solar thermal collectors are practically the same as those for the PV cells mentioned earlier.

Active Solar Collector Construction

Solar thermal collectors produce heat and are different from photovoltaic (PV) modules, which produce electricity (SEIA.org, 2010). Solar water heating is the most cost effective and environmentally responsible method to heat water for residential, commercial, and industrial needs by using the Sun's energy to heat water rather than using electricity or natural gas (SEIA.org, 2010). There are several types of solar thermal collectors, but the two types that are most widely used are flat plate collectors and evacuated or otherwise known as vacuum tube collectors. Flat plate collectors are the most common type of collectors in the United States; typically copper pipes are affixed to an absorber plate contained in an insulated box covered with a tempered glass or polymer cover plate (SEIA.org, 2010).

There are two types of flat plate collectors, glazed and unglazed. Glazed flat plate collectors are insulated weatherproofed boxes that contain a dark absorber plate under one or more glass/plastic (polymer) covers. Unglazed flat plate collectors have a dark absorber plate, made of metal or polymer without a cover or enclosure (EERE.gov, 2010).

The evacuated tube collector features parallel rows of transparent glass tubes. These tubes consist of a glass outer tube and a metal absorber attached to a fin. The fin's coating absorbs solar energy but inhibits radiant heat loss. These collectors are used more frequently for U.S. commercial applications (EERE.gov, 2010).

Direct circulation systems pump water through the collectors and into the building. These active solar water heating systems are constructed with a collector, an insulated heat transport piping unit, heat storage unit, electric controls, and for colder climates, a freeze protection system (SEIA.org, 2010).

CHAPTER THREE

DATA

An Overview of the Data

Due to the relatively recent nature of applying sustainable energy technologies to educational institutions, collecting data on the subject of high schools in the United States that have implemented solar and wind power as an alternative energy source is quite scarce. This is primarily due to the fact that our state, not to mention the rest of the nation, is hindered by a severe budget crisis that makes funding for these types of progressive and innovative projects problematic to obtain. Most schools interested in alternative energy within the United States are in the research and development stages of executing small wind and solar panel projects. This thesis, in respect to alternative energy research, i.e. wind and solar, has revealed that there is not only an interest, but also a growth in regards to the alternative energy concepts discussed. Although we, the United Stated of America, are suffering from a poor economy there is optimism for the future in regards to obtaining appropriate funding for projects such as this. These incentives can be acquired by way of the formulation and development of *The American Recovery and Reinvestment Act of 2009* drafted by the United States government. This *American Recovery and Reinvestment Act* entails that interested parties are provided an uncapped dollar amount which includes a 30% investment tax credit for those programs that are eligible (EERE.gov, 2011). In addition to Federal support for sustainable energy project, there are a variety of individual state incentive programs to encourage the use of alternative energy. Overall, the United States has increased our installed wind energy per capita by 14 times, and our solar energy production, has quadrupled since the year 2000 (EERE.gov, 2011).

Solar Data

California State University San Bernardino (CSUSB) consumed a total of 27 million KWh per year of electricity for the 2009/2010 school year. The CSUSB campus has installed 1,300 KW of various solar panel array systems. These systems have generated approximately 18% of energy needed to operate the CSUSB campus over the contracted expected performance output. The solar energy production from these arrays accounts for about 6% of the total campus usage with an expected average of 28% during monthly peak demands. The total PV production should provide 1.7 million kWh per year.

Redlands Unified School District (RUSD) built a new high school in the North area of Redlands named Citrus Valley High School, with energy efficiency in mind. A software application, Energy Pro v4.0, was able to calculate baseline energy consumption for Citrus Valley High School. "This software application provides projected energy consumption and costs, both electrical and gas, based on several different criteria" (Shamp, 2011, p. 3).

The primary concern for RUSD in sizing a PV system for the school was to reduce peak usage during mid-to-late daytime hours. RUSD had a photovoltaic assessment conducted, which provided them with data in choosing the optimal PV system components for their needs. The consulting company that provided RUSD with their assessment calculated that Citrus Valley High School should have a tilted self-ballasted polycrystalline roof tile installed. The brand of panel was the Sharp ND-216U2 polycrystalline with a size of 64.4" x 39.1". At peak power each panel would generate 216 watts. The panels should be installed with a 10 degree tilt and the inverter chosen is Xantrex PV15 (Shamp, 2011). Based on Citrus Valley High School assessment 56 Sharp ND-215U2 polycrystalline panels will be installed on the school building roof tops. The projected daily total output is 12 kW with an annual output of 18,709 kWh (Shamp, 2011). The estimated total system cost for RUSD is $103,541, but the cost per kWh over a 25 year lifespan is $0.22 (Shamp, 2011).

Los Angeles Unified School District (LAUSD) has made a goal to reduce its energy use by 10% by the year 2012. In December of 2010 3,200 kW of solar power were installed at seven schools in LAUSD. The district is planning to have 60 solar power systems district wide that will generate approximately 21,000 kW by the year 2014. Canoga Park High School, which is part of LAUSD, has plans for 896 solar panels to be installed on top of a school building that will generate 273 kWh per day. The estimated saving is $65,000 a year on electricity with this system. The district as a whole consumes 455,000 kWh of electricity each year. With this solar power initiative, LAUSD is expected to lower the utility expenses by $112 million over a 20 year time frame.

Referencing CSUSB, LAUSD, and RUSD as guidelines to determine if solar power is appropriate for Beaumont's energy need is appropriate in regards to projecting potential energy produced, and the associated costs. Through collected data from Southern California Edison it has been determined that Beaumont High School consumed approximately 2,168,315 kWh in 2009. If a high school such as Beaumont High School was able to obtain funding for a solar panel project it would be expected that, through the information obtained from LAUSD and RUSD, savings would also be substantial given that they were able to save $65,000 dollars in one year by installing 896 solar panels. There are currently eight buildings located on the campus of Beaumont High School. Given these data it would be recommended, if funding was available, to utilize all eight buildings to incorporate solar energy, making the savings to actually be figured near $520,000 dollars. Since there is limited data to be used in regards to high school campus alternative energy collection, the data used are simplistic in nature.

Since the beginning of this study Beaumont Unified School District has conducted a feasibility report for solar installation at the high school campus. The feasibility study analyzed what PV system would best benefit the need of the school if built on the newly constructed two story classroom building. The PV panels would be installed on the roof of the building and over the stairs as an awning. PJHM Architects projected the electrical and gas energy cost per year of the building to be $64,000, based upon the calculations of the software application EnergyPro v5.0 (PJHM, 2011). Two systems where chosen based on their location on the building. The first system would be a polycrystalline silicon based system with a fixed flat mounting system manufactured by Unirac (PJHM, 2011). This system would consist of 330 panels installed on the roof of the classroom building. The second system would be polycrystalline silicon based system bifacial PV module by Sanyo and would be located about the stairwell to act as an awning (PJHM, 2011). This system would consist of 96 panels. The total installation cost of both systems is approximately $410,000, which includes a California Solar Initiative (CSI) deduction of approximately $200,000 or $610,000 without the CSI credit (PJHM, 2011). The proposed PV system, which includes the stairs and roof, provides for 32.2% of the estimated yearly energy usage on the campus. Solar panels would not be the sole resource recommended for a school such as Beaumont High School, therefore wind energy will also be included in reference to achieve 100% sustainability. Wind data will be included in respect to recommendations to achieve 100% sustainability at Beaumont High School further along in this paper. The following chart and figures can be utilized to determine whether solar power would be the appropriate choice to implement considering the two types of energies discussed, i.e. solar and wind power. Using figure 1. and figure 2. located on the below as a guideline, the areas colored red, orange, and yellow (in decreasing efficacy) are the areas where solar panels could be best utilized in order to maximize energy savings and ultimately reduces greenhouse gas emissions.

Table 1. Usage Comparison for January '09-December '09 Beaumont High School Beaumont, California. Source: Southern California Edison. Beaumont Unified School District Electrical Bill. 2009.

	Jan'09	Feb'09	Mar'09	Apr'09	May'09	Jun'09
Total kWh used	161,137	174,456	158,030	159,572	191,824	193,330
Number of Days	33	30	29	32	29	30
Appx. Average kWh used/day	4,882	5,815	5,449	5,267	6,614	6,444

	Jul'09	Aug'09	Sep'09	Oct'09	Nov'09	Dec'09
Total kWh used	168,407	137,749	239,863	226,452	192,011	165,484
Number of Days	32	29	30	32	30	30
Appx. Average kWh used/day	5,262	4,749	7,995	7,076	6,400	5,516

Average kWh per Month	180,693
Appx. kWh per Year	2.1×10^6

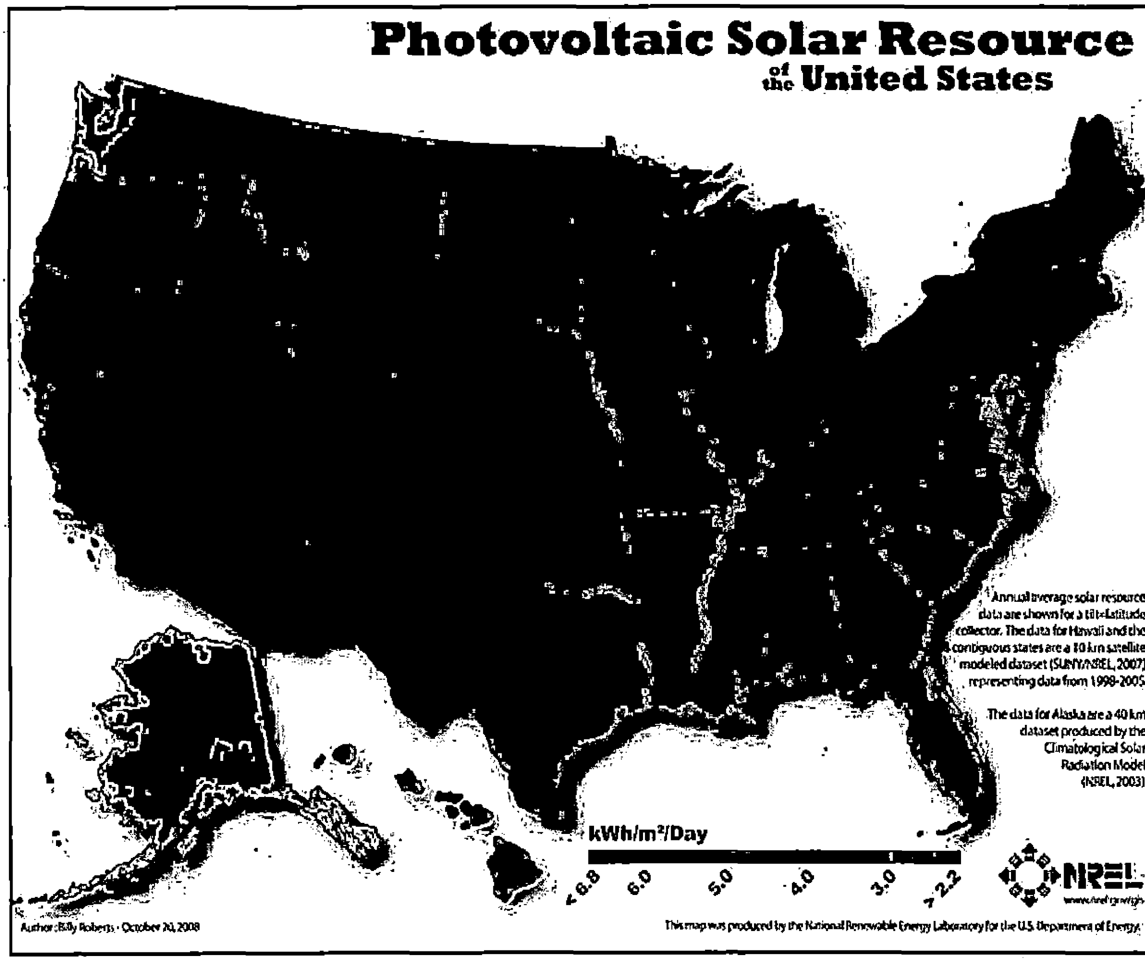

Figure 1. Photovoltaic Solar Resource of the United States. Provides an image of where PV resources would be most utilized. Source: National Renewable Energy Laboratories (NREL). http://www.NREL.gov (accessed March 2011).

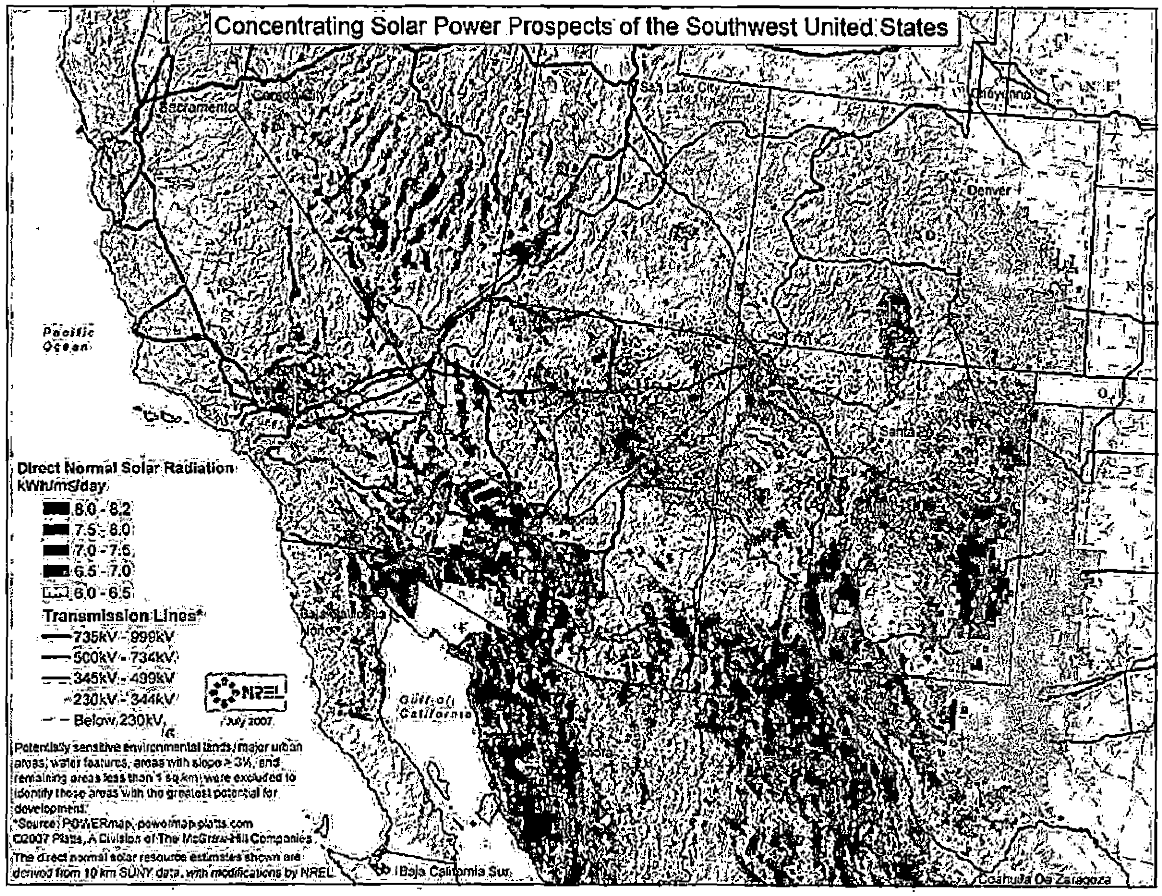

Figure 2. Concentrating Solar Power Prospects in the Southern United States. Source: National Renewable Energy Laboratories (NREL). http://www.NREL.gov (accessed March 2011).

Wind Data

Data was collected on California State University San Bernardino wind turbine installation project, which is new and still in the testing stage. There were two 10 KW turbines installed among the two sites on the campus in the winter and spring of 2011. The school is projecting a total energy output of 14,480 kWh per year. The campus of CSUSB was chosen as a comparison in order to assess whether Beaumont High School would benefit from wind power due to their similar geographical region and topography. Even though both schools are located in different areas of Southern California they were both constructed at the base of the San Bernardino mountain range and have a consistent wind pattern that blows across the base of the mountain range and therefore across campuses. According to figure 3. and figure 4., the Midwestern portion of the United States benefits the most from utilizing wind turbines as an alternative resource due to the increased amount of wind and/or wind velocity. Although, the map does provide evidence that there are small pockets i.e. along the San Bernardino mountain range located along the map in which wind speeds are high. Geographically the maps show that wind is also being utilized along the San Bernardino mountain ranges. As stated before the optimal wind speed and areas are located in the Midwestern portion the U.S. and are represented by color shades of purple and orange. Looking closely at the figures below those colors are also located within base of the San Bernardino mountain pass regions. This data further provides evidence that wind speeds are strong enough to utilize wind turbines as a resource. Geographically these mountain ranges, in regard to wind power class and illustration of the colors pink and purple, rate this area of Southern California to be at the class level of good to excellent i.e. Palm Springs wind farms.

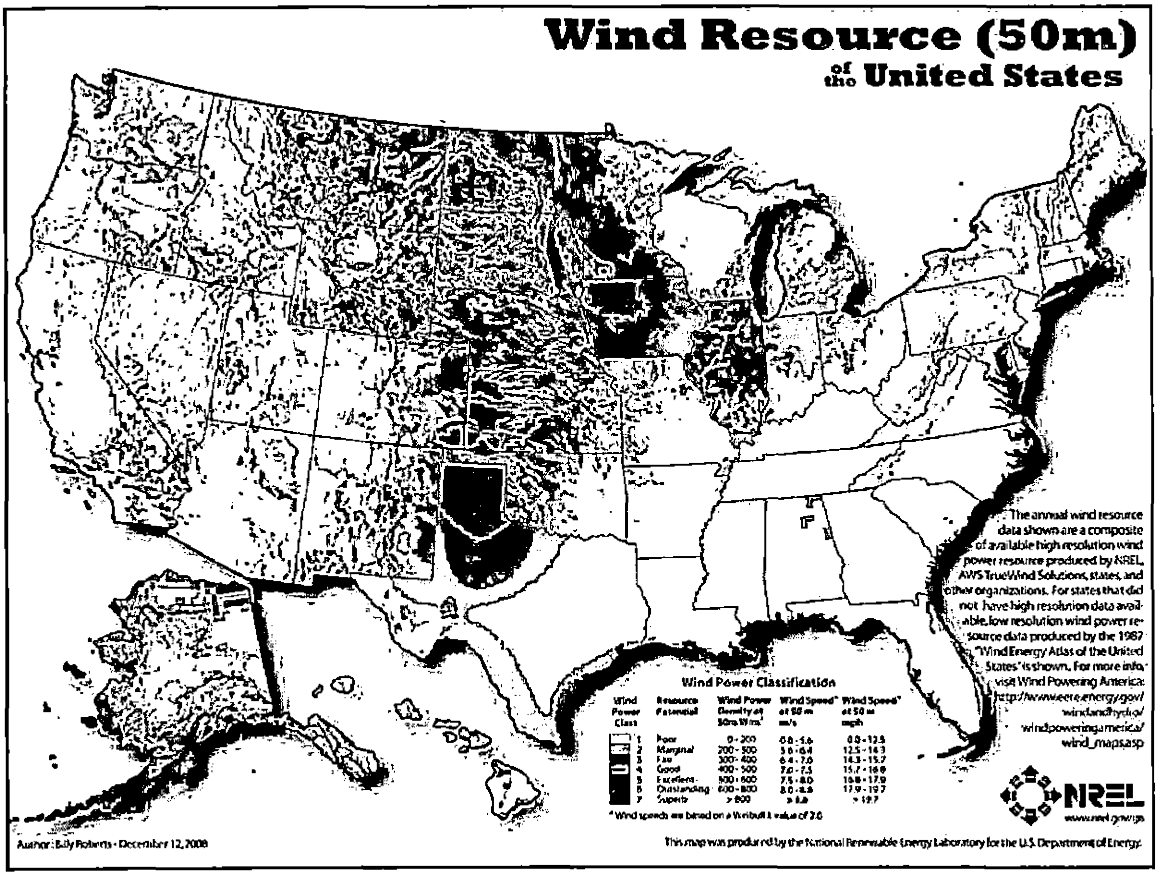

Figure 3. Wind Resource (50m) of the United States. Wind map for turbines at 50m in height. Source: National Renewable Energy Laboratories (NREL). http://www.NREL.gov (accessed March 2011).

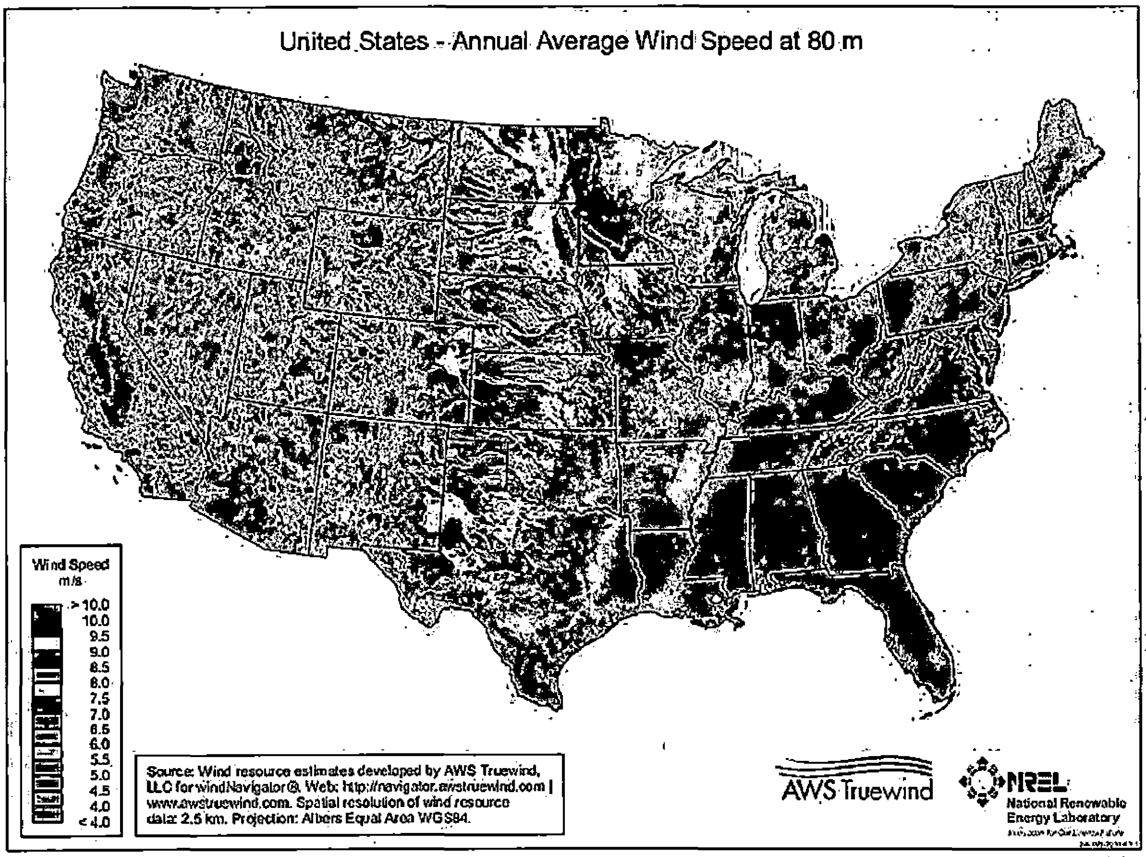

Figure 4. Annual Average Wind Speed at 80m. Wind map for turbines at 80m in height. Source: National Renewable Energy Laboratories (NREL). http://www.NREL.gov (accessed March 2011).

CHAPTER FOUR

IMPLEMENTING ALTERNATIVE ENERGY

Wind Turbine Case Study

A research effort was begun on the basic systematic of wind power and what type might be installed on a high school campus. In order for this to be implemented there are site considerations that a school must take into account first. These include wind pattern charts, necessary requirements for electrical generation to power the facility, turbine design (vertical or horizontal), energy conversion details, site preparation details, wind turbine height, and overall costs involved (Emanuel, 2010). Information investigated for a preliminary study will determine if wind turbines are feasible for any particular campus through a feasibility report. When considering the installation of a wind turbine, there are two predominant areas of concern:

1. The economic feasibility of installing a wind turbine.
2. Fulfillment of local, state and federal regulations regarding the construction and operation of a wind turbine (Emanuel, 2010).

In one case study, that of which involved Holy Name Central Catholic Junior/Senior High School in Worcester, Massachusetts, the projected electricity generated from the turbine was calculated using a statistical model called a Weibull distribution (Emanuel, 2010). A Weibull distribution model predicts the percentage of time a certain wind speed can be expected. These data were compared to the electrical usage of Holy Name Central Catholic Junior/Senior High School. With the data collected from the Weibull distribution method it was recommended that the High School install a 600kW wind turbine a top a 50 meter tower (Emanuel, 2010). The feasibility report for this case study calculated the school spending amount to be approximately $4.5 million on their electricity bill over twenty years if the wind turbine was not installed. By installing a 600kW wind turbine the estimated cost savings over twenty years on electricity through the implementation of the wind turbine came to be $300,000 dollars (Emanuel, 2010).

Beaumont Case Study

There are many turbine configurations available which can produce power from 1kW to over 600kW. Table 2. is a wind turbine manufacturer sample that displays a sample set of manufacturers and the models they produce. The figure is simply meant to show the rotary size, power generation and minimal wind requirements in order to understand and decide what would be most beneficial.

Table 2. Wind Turbine Manufacturer Sample. Source: National Renewable Energy Laboratories (NREL). http://www.NREL.gov (accessed March 2011).

Manufacturer	Model	Span Diameter (m)	Nominal Power (kW)	Cut-in Wind Speed (m/s)
Southwest Windpower	Skystream 3.7	3.7	1.9	3.5
	Air Whisper H200	2.7	0.2	5.4
	H500	4.5	0.5	5.4
	AirX	1.15	0.6	3.5
Bergey	BWC XL 1	2.5	1	4.5
	BWC Excel-R	7	7.5	8.9
	BWC Excel-s	7	10	8.9
DeWind	DW600 kW	46	600	6.7
Fuhrlaender	FL30	13	30	6.7
	FL100	21	100	6.7
	FL250	29.5	250	6.7

Based on the findings for wind resources presented earlier and in the figure below it has been determined that there are sufficient steady winds in the Beaumont area to power a 5kW or larger turbine. There is an abundant amount of suitable wind in the Inland Empire along interstate 10, which Beaumont is located adjacent to. Since this area is located relatively close to a coastal Mediterranean climate which leads to a rather constant wind flow and a desert climate there is intense heating during the day that generates strong winds. Due to the lack of vegetation and located in an open valley between the San Bernardino and San Jacinto Mountains the wind funnels through the area with little abatement. This area may experience a wind power of class III or higher consistently throughout the year, refer to figure 5. Once the turbine size has been chosen the next option to consider is the tower height. Since the site location of the turbines would be relatively close to other structures turbulence needs to be considered. To reduce the amount of wind turbulence from the surrounding structures it is necessary to find the optimal height of the turbine, this will be located on a stand-alone tower. Figure 5. categorizes the wind power classes based on a 50 m tower and information collected by NREL.

Wind Power Classification

Wind Power Class	Resource Potential	Wind Power Density at 50 m W/m ^{2}	Wind Speed[a] at 50 m m/s	Wind Speed[a] at 50 m mph
1	Poor	0 - 200	0.0 - 6.0	0.0 - 13.4
2	Marginal	200 - 300	6.0 - 6.8	13.4 - 15.2
3	Fair	300 - 400	6.8 - 7.5	15.2 - 16.8
4	Good	400 - 500	7.5 - 8.1	16.8 - 18.1
5	Excellent	500 - 600	8.1 - 8.6	18.1 - 19.3
6	Outstanding	600 - 800	8.6 - 9.5	19.3 - 21.3
7	Superb	> 800	> 9.5	> 21.3

[a] Wind speeds are based on a Weibull k of 2.4 at 500 m elevation.

Figure 5. Wind Power Classification Diagram. Source: National Renewable Energy Laboratories (NREL). http://www.NREL.gov (accessed March 2011).

Noise seems to be an additional issue when installing wind turbines in a residential area. All turbines produce some noise which is a function of rotation speed from the turbines. In order to reduce the noise pollution it is important to consider blade material construction when selecting the proper wind turbine for the site. The Skystream 3.7 blade design and material is constructed with noise reduction in mind and is a reason for choosing this product.

Large turbines were not considered in this study, due to cost and the overall size large turbines are not conducive to the current school property schematics. County regulations need to be considered for Beaumont High School due to Riverside County ordinances. As mentioned earlier in the limitations of this study any wind turbine constructed near a school or "habitable" dwelling need to follow certain ordinances. The wind turbine structure needs to be 1.25 times the height of the tower away from any public road. All horizontal-axis turbines need to be at least 25 feet from the ground. The turbine needs to have a foundation clearing that has a 10 foot radius. The tower and the compatibility of all the equipment needs to comply with these Uniform Building Codes. The noise level for these wind turbines need to be at or below 55 dB if they are constructed near a school or "habitable" dwelling. One can find these regulation/zoning ordinances at the Riverside County Planning Department or their local counties planning department. Based on the lot size, only wind turbine units with a blade span less than 10m were investigated. The smaller turbines that produce less than 5kW would be feasible at this site. For this reason small turbines produced by Southwest Windpower and Bergey (1kW) models were considered, as shown in figure 5. The projected sites for the turbines are likely to reside in proximity to building, trees, and the football stadium, therefore the size of the turbines is a critical factor. The smaller turbine size is likely a better option for Beaumont High School, in that it affords more flexibility in where the turbine can be located.

Cost Analysis of Wind Turbines

Skystream 3.7 by Southwest Windpower was chosen to be the best option for Beaumont High School in terms of performance, specifications, and cost. The reason is the unit is compact with the controls and has an integrated inverter built-in, and therefore the purchase of a separate inverter is not necessary with this unit. The Skystream 3.7 is known as a "turnkey system" meaning that when purchased from the manufacturer, they charge a rate that includes all parts to run the unit, installation, and warranty. The other two systems of wind turbines considered for Beaumont High School that are manufactured by Southwest Windpower are the Whisper and AirX, which are a piece by piece system. With these systems the turbine, tower, a controller, and the inverter must be purchased individually and the consumers must install the unit.

Table 3. Wind Turbine Implementation Costs. Source: Southwest Windpower. http://www.skystreamenergy.com (accessed September 2010).

	Skystream 3.7	Whisper 500	Air X
Turbine	$5,400	$6,045	$749
Tower	$4,500-9,000*	$800	$222
Installation	$6,000	$6,000**	$6,000**
Inverter	N/A	$1,757 (approx.)	$1,757 (approx.)
Total	$15,900-20,400*	$14,602	$8,728

*Price varies depending on height of tower.
**Buyer has to intall themselves or find a contractor.

Even though the Skystream 3.7 would be the most expensive unit of the three options listed above for BUSD, it would be the best choice for power output for the school's needs. The manufacturer criteria states that each unit needs 0.5 acres of unobstructed land for operation. The most optimal area for the Skystream 3.7 to be located is at the entrance of the sports complex facing in a west by southwest direction. This location should provide ample unobstructed room to install four turbines with a height tower of 70 feet. With an average wind speed above 12mph or 5.4m/s in this area the estimated energy production of one turbine unit is 400kWh per month (Skystream.com, 2011).

Each turbine has the potential to generate approximately 4800kWh for the year. If four turbine units are installed there is the potential of generating 19,200kWh per year that can offset the electrical demand for the stadium/school.

Table 4. Recommended System Summary For Wind Turbines. Source: Southwest Windpower. http://www.skystreamenergy.com (accessed September 2010).

Number of Skysteam 3.7 Turbines		4
Cost		
Turbine Units	$	21,600.00
Tower (70 feet)	$	36,000.00
Installation	$	24,000.00
Total System Costs	**$**	**81,600.00**
Electricity Costs		
25-year Average Virtual Rate		$0.17/kWh
Environmental Benefits		
Yearly Energy Savings		19,200kWh
Yearly Energy Savings Cost		$3,264
CO_2 emission offset		28,321lbs./yr.

Solar Configuration and Selection

Referencing CSUSB, LAUSD, and RUSD as guidelines to determine if solar power is appropriate for Beaumont's energy need is appropriate in regards to projecting potential energy produced, and the associated costs. Through collected data from Southern California Edison it has been determined that Beaumont High School consumed approximately 2,168,315 kWh in 2009. Data collected from NOAA stated that the Inland Empire region of Southern California receives on average 325 days of clear sunny skies per year. If a high school such as Beaumont High School was able to obtain funding for a solar panel project it would be expected that, through the information obtained from LAUSD and RUSD, savings would also be substantial given that they were able to save $65,000 dollars in one year by installing 896 solar panels.

There are currently eight buildings located on the campus of Beaumont High School. Given these data it would be recommended, if funding was available, to utilize all eight buildings to incorporate solar energy, in order to achieve a savings that was figured to be near $520,000 dollars per year. The data in table 5 was calculated for one newly constructed building on the Beaumont High School campus, not all eight building were included in table 5. Since there is limited data to be used in regards to high school campus alternative energy collection, the data used are rough approximations based on the best available information.

Since the beginning of this study Beaumont Unified School District has conducted a feasibility report for solar installation at the high school campus. The feasibility study analyzed what PV system would best benefit the need of the school if built on the newly constructed two story classroom building. The PV panels would be installed on the roof of the building and over the stairs as an awning. PJHM Architects projected the electrical and gas energy cost per year of the building to be $64,000, based upon the calculations of the software application EnergyPro v5.0 (PJHM, 2011). Two systems were chosen based on their location on the building. The first system would be a polycrystalline silicon based system with a fixed flat mounting system manufactured by Unirac (PJHM, 2011). This system would consist of 330 panels installed on the roof of the classroom building. The second system would be polycrystalline silicon based system bifacial PV module by Sanyo and would be located about the stairwell to act as an awning (PJHM, 2011). This system would consist of 96 panels. The total installation cost of both systems is approximately $410,000, which includes a California

Solar Initiative (CSI) deduction of approximately $200,000 (PJHM, 2011). The proposed PV system, which includes the stairs and roof, provides for 32.2% of the estimated yearly energy usage on the campus. The payback for these solar panels is approximately 20 years or approximately 30 years without CSI credit. Solar panels would not be the sole resource recommended for a school such as Beaumont High School, therefore wind energy will also be included in reference to achieve 100% sustainability.

Table 5. Recommended System Summary for Solar Panels at Beaumont High School. Source: Shamp, E. Photovoltaic Assessment for Citrus Valley High School. Redlands Unified School District. April 2009.

Number of PV Panels		
Roof PV Panels		330
Stair Awning PV Panels		96
Total PV Panels		**426**
Cost		
Roof Mounted Panels	$	473,550.00
Stair Mounted Panels	$	131,040.00
Estimated Total System Cost	$	604,590.00
Estimated CSI Incentive	$	(195,038.00)
Total Installed Costs	**$**	**409,552.00**
Electricity Costs		
25-year Average Virtual Rate		$0.17/kWh
Environmental Benefits		
Yearly Energy Savings		121,899kWh
Yearly Energy Savings Cost		$20,722
CO_2 Emissions Offset		105,233lbs./yr.

The laudable goal of achieving 100% sustainability, is difficult at the present time due to the fiscal instability of the local, state, and federal government. Beaumont High School should make a more reasonable goal of off-setting only the grid source electric energy that is most expensive, during peak times, rather than trying to off-set all grid source electric energy and strive for having 25% of their electrical needs met.

Areas of Most Usefulness

Several renewable energy sources are currently being used for the production of energy in the industrialized world. These renewable energy sources include biomass, biodiesel, ethanol, landfill gas, municipal solid waste, geothermal, solar, hydropower, wind, wood and wood waste. In regards to these renewable energy sources, geothermal, hydropower, solar, and wind do not directly give off greenhouse gases. For these reasons solar and wind power would be the most beneficial renewable energy sources to place on a high school campus in geographical regions of the United States that produced efficient amounts of wind and solar power annually, BHS certainly meets these criteria.

There are many possible locations that wind turbines and solar panels can be installed to optimize energy input and output on a high school campus. The locations that would be most beneficial are near or around football stadiums and on the roofs of the school buildings. The reason the football stadium would be an excellent location to install horizontal or vertical wind turbines is due to the open space, not to mention that most football stadiums are located in open areas where the wind turbines and solar panels are a safe distance from people, which would meet state safety regulations. The energy collected from these two types of wind turbines could run enough power to operate the sports fields for sporting events. Photovoltaic electric solar panels could be installed on the roof of the concession stands and the restrooms. The goal is to have the majority of the stadium's electricity needs obtained from energy collected through the use of wind turbines and the energy collected from the solar panels could sustain all the amenities for the concessions and restrooms.

As for campus classrooms, photovoltaic solar panels would work best on classroom building roofs for schools with minimal land space. Solar panels located on the roofs would provide an adequate distance for safety concerns from the students and faculty. "This is largely in part due to ground mounted systems being too vulnerable to vandalism and theft" (Shamp, 2011, p. 20). Energy collected from the photovoltaic solar panels electricity can be utilized to operate lights, computers, televisions, heating and air conditioning for the school day. If the high school campus has a swimming pool thermal photovoltaic solar panels would be optimal because the solar energy collected could be used to heat the pool.

Any excess production of energy collected by the wind turbine(s) and solar panels that happens to not get utilized during hours of operation could possibly be bought back by the local energy company or stored in batteries for later use. If possible, through budget and technology, any excess energy could be delivered to and used at a local elementary or junior high school within the campuses corresponding district.

Alternative Energy Education

Providing education to students through the utilization of alternative energy technologies is crucial in hopes that it will foster awareness in youth of the relationship between energy sustainability and environmental stewardship. This could be implemented through incorporating energy conservation classes into high school science curriculum. Strategies on implementing these alternative energy conservation concepts to the high school science curriculum are based on the California content standards. Having the students and teachers work with a local energy conservation organization will provide hands on experience through guest speakers, field trips, and classroom/campus projects. If the high school is located in the Inland Empire, i.e. Riverside and San Bernardino counties, certain resources and amenities could be utilized to establish environmental education permanence. Such as conservation agency located in inland Southern California the Inland Empire Resource Conservation District (IERCD). The IERCD offers many environmental education programs for the schools located within the agencies district boundaries. These programs offered by IERCD vary depending on the environmental science subject and can be adapted for students from kindergarten through 12th grade to meet the California content standards. The programs offered by the IERCD on energy conservation will introduce the students to the importance of energy and our natural resources. The students will understand where energy comes from and how it can be conserved at home, school, and in the greater community. When students have shown comprehension on alternative energy sources and conservation they could then begin working with the wind turbine(s) and solar panels on a regular basis for class curriculum. In the end, students would better understand the engineering behind these alternative energy sources and in return could assist in research by collecting data on wind speed, energy output and energy input.

CHAPTER FIVE

CONCLUSION

In order for high school campuses to become self sustaining they need to manage their energy consumption and use of renewable energy resources. It was discovered that there were few types of limitations that may occur for school districts in regards to installing wind turbines or photovoltaic panels. Typical limitations include: regulatory issues, budgetary constraints, undesirable length of payback period, and possible vandalism and theft. Regulatory issues could include ordinances involving height limits, safety setbacks, scenic setbacks, and noise standards. These types of ordinances can affect the construction of renewable resources in an area considered a "habitable" dwelling or school.

In this study it was found that alternative energy resources such as solar and wind power are capable of being implemented successfully at a high school campus similar to that of Beaumont High School. Not all high school campuses are located in areas with sufficient wind and solar power availability and would have to utilize other alternative energy sources mentioned earlier to reduce their energy consumption. Data in regard to installation of such technologies at high school campuses were scarce. In large part this is due to the high costs associated with such projects, as well as the limited funding available. Given the fact that this country at large, and specifically the State of California is facing economic hardship, it is easy to understand why funding for these types of forward thinking but non-essential projects is in limited supply. At the present time Beaumont High School is able to move forward in the development of alternative energy resources for one classroom building on the campus which is an important first step but due the expansion to the other building is limited to the lack of state funding. The alternative energy resources currently being implemented at Beaumont High School are solar panels, hopefully in the near future wind turbines will be installed. With that said it is obvious that when resources are available, implementing alternative energy will be possible on this campus which will greatly benefit the school and community in the long term. From the data obtained in this study, the calculated payback period for the Skystream 3.7 wind turbine is approximately 25 years, and the solar panel systems on the new classroom building is approximately 20 years (30 years without government incentives) if the price stays at the current rate of $0.17 per kWh. Since these are the approximate estimated functioning lifetimes for these systems, the school would probably break even on the cost of the alternative energy systems versus conventional energy consumption. Considerable cost savings could be achieved if the rates for conventional energy were to increase over the next 20-30 years. Since energy rate increases over the next three decades is likely, it is anticipated that some cost savings will be achieved. However, cost savings achieved from these systems would have to be balanced against any maintenance costs over time, and thus energy cost savings does not appear to be a primary benefit of installing such systems. The goal for Beaumont Unified School District in installing alternative energy systems should not be attaining 100% sustainability, but rather the campus and societal benefits including, but not limited to, the following:

Off-set only the grid source electric energy that is most expensive, during peak times, rather than trying to off-set all grid source electric energy.

Focus on job creation, and environmental education for students.

A reduction in the use of and dependency on fossil fuels for our energy needs and the corresponding CO_2 emission off-set per year resulting in a decreased carbon footprint.

These aspects will ultimately make these technologies not only feasible but absolutely necessary for meeting our future energy needs.

REFERENCES

Aldous, S. *How Solar Cells Work.* http://www.howstuffworks.com/solar-cell.htm (accessed September 2010).

Bates, B. B. *Solar Panel Feasibility Study At Wesley United Methodist church, Worcester.*http://www.wpi.edu/Pubs/E-project/Available/E-project-030509-215732/unrestricted/IQPReport.pdf (accessed August 2010).

Bird, L. B. (2005). Policies and market factors driving wind power development in the United States. *Energy Policy* , 33:1397-1407.

Emanuel, A. F. *Interdisciplinary and Global Studies: Global Perspective Program.* http://www.wpi.edu/Images/CMS/GPP/summary.pdf (accessed September 2010).

Energy Efficiency and Renewable Energy (EERE). http://www.eere.energy.gov (accessed September 2010), Energy Savers.

Energy Kids: Energy Information Administration. http://www.eia.doe.gov/kids/ (accessed January 2010).

Jenning, P. (2009). New direction in renewable energy education. *Renewable Energy* , 34: 435-439.

Johnston, D. (2010). Functional requirements for component films in a solar thin-film photovoltaic/thermal panel. *Solar Energy* , 84: 384-389.

NASA. http://www.NASA.gov (accessed January 2011).

National Energy Education Development Project (NEED). http://www.NEED.org (accessed September 2010), Schools Going Solar.

National Renewable Energy Laboratories (NREL). http://www.NREL.gov (accessed March 2011).

PJHM Architects. Beaumont High School Classroom Expansion Renewable Energy Study. Beaumont Unified School District. April 2010.

Rehman, S. B.-M. (2007). Cost of solar energy generated using PV panels. *Renewable and Sustainable energy* , 11: 1843-1857.

Shamp, E. Photovoltaic Assessment for Citrus Valley High School. Redlands Unified School District. April 2009.

Siddiqui, A. F.-E. (2010). How to proceed with competing alternative energy technologies: A real options analysis. *Energy Economics* , N/A.

Solar Energy Industries Association (SEIA). http://www.seia.org (accessed September 2010).

Solarserver. http://www.solarserver.de/wissen/photovoltaik-e.html (accessed September 2010).

Southern California Edison. Beaumont Unified School District Electrical Bill. 2009.

Southwest Windpower. http://www.skystreamenergy.com (accessed September 2010).

Tavner, P. (2008). Wind power as a clean energy contributor. *Energy Policy* , 36: 4397-4400.

U.S. Department of Energy (DOE). http://www.doe.gov (accessed August 2010).