Third Report on the Installation of Shaded Parking Lot Structures with Integrated Photovoltaic Power System at Kansas State University

Kansas State University Chemical Engineering REU Students
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Introduction

In 2009, a group of students in the Research Experiences for Undergraduates program began work on a group project to investigate the concept of adding solar panels to parking lots to produce electrical energy and shade the parking spaces at the same time [1]. In 2010, a second group of students built upon that report [15]. This report builds on the work from the last two years [1][15] and provides additional information. In this white paper, the social value, environmental impacts, and economics of the proposed project are presented. The new information compiled by the student group is integrated into the previous year's [15] report.

Goals and Objectives [15]

The goals of this project are to:

A. Advance solar energy generation and applications through a demonstration research project;

B. Conduct research to investigate the science, technology, and societal acceptance of solar panels and electrical vehicle charge stations in parking lots;
C. Conduct research on the operation and maintenance of the equipment and disseminate the results to the manufacturers, public, and others;
D. Provide learning opportunities for students who participate in the project, and those who are in classes where the project is used for educational purposes;
E. Advance Kansas State University's score and image as a green university, and as a place to enroll to learn about sustainability;
F. Conduct social science research on the social value of the project.

Project Concept [15]

The basic idea of the project is to place solar panels over parking spaces in one or more parking lots at Kansas State University in order to:

1. Provide shaded parking spaces that enhance the value of the parking space;
2. Provide charge stations for plug-in electric vehicles;
3. Generate electrical energy for use at the charge stations and/or by K-State;
4. Collect data related to the project;
5. Provide a demonstration location in Kansas for the education of students and the public with respect to new solar energy technologies and charge stations for electrical vehicles;
6. Educate students through participation in this project as part-time employees;
7. Advance the public image of the university with respect to sustainability and renewable energy;
8. Advance the growth of solar industries and green jobs in Kansas and the mid-west.

There is significant interest in working with manufacturers, distributors, and local companies to put up individual solar collectors over each parking space. Each would be instrumented to provide information on the rate of electrical energy production and the amount of energy produced each day. Because of clouds, weather events, and geographical location, measuring the capacity factor (amount of energy produced in a year related to the maximum production) has value. The team will evaluate the impact of weather events on the solar panels and their maintenance needs. The change in the capacity factor over time due to deterioration of the panels will also be determined.

Proposed Activities [15]

The following core activities are envisioned for this project:

A. Design, construct, and operate the demonstration site, which would include the solar panels with their support system, electrical system, inverter, vehicle charge station, and connection to the K-State grid;
B. Collect data and evaluate it; data will include weather data (temperature, precipitation, wind speeds, hail, snow, ice), electrical energy and power data, efficiency data, maintenance events, and user satisfaction;
C. Communicate with manufacturers to obtain panels and discuss data collection needs and issues with them;
D. Develop a web site and public education program, including instrumentation and displays at the site;
E. Develop and implement a reporting process, including the preparation of educational materials for use in classes at K-State;
F. Work cooperatively with all of the potential partners in the program, including the Architectural Engineering and Construction Science faculty and students, Electrical and Computer Engineering faculty and students, marketing faculty and students, and social science faculty and students, the Director of Sustainability, Parking Services, and any manufacturers, suppliers and vendors.

Proposed Investigators and Partners [15]

Ruth Douglas-Miller, Ben Champion, Keith Hohn, and Larry E. Erickson will provide leadership for the project. Several units at K-State will be invited to be part of this project:

Parking Services to help with parking permits, financial aspects, and facility management from a parking space perspective; With leadership from Ruth Miller, electrical engineering students will help with the electrical aspects of the project, including design, data collection, and data analysis; With leadership from faculty in Architectural Engineering and Construction Science, students will help with the design and construction of the support system to hold the solar panels and associated equipment and wires in place; Other proposed partners that will be contacted include Administration and Finance, including Facilities, Advanced Manufacturing Institute, Chemical Engineering, Center for Hazardous Substance Research, Marketing, and K-State Research and Extension. Solar panel manufacturers, vendors, and installation professionals, charge station manufacturers and vendors, and electrical power companies will be invited to participate in the project. Diamond Solar Solutions, Decent Energy, National Renewable Energy Laboratory, and partner organizations of the Consortium for Environmental Stewardship and Sustainability (CESAS) will be included in the effort to build an effective working consortium as well.

Table 1 provides a partial listing of companies that provide solar panels that can be considered for this proposed project.

Table 1: Photovolatic Companies in the United States

Company	Website	Address	Phone	Email
Amonix Inc	amonix.com	1709 Apollo Court, Seal Beach CA 90740	562.200.7700	info@amonix.com
Atlantis Energy Systems	atlantisenergy.com	4517 Harlin Dr., Sacramento CA 95826	916.438.2930	info@atlantisenergy.com
BP Solar	bp.com	630 Solarex Ct., MD 21703	301.698.4200	
Canrom Photovoltaics	canrom.com	1654 Ontario Ave., Niagara Falls NY 14305	716.285.8508	info@canrom.com
DayStar Technologies	daystartech.com	7373 Gateway Dr., Newmark CA 94560	408.582.7100	media@daystartech.com
EPV Solar, Inc.	epv.net	8 Marlen Dr., Robinsville NJ 08691	609.587.5355	
Evergreen Solar, Inc.	evergreensolar.com	138 Bartlett Street, Malboro MA 01752	508.357.2221	info@evergreensolar.com
First Solar, Inc.	firstsolar.com	350 West Washington Street, Suite 600, Tempe AZ 85281	602.414.9300	
GE Energy	gepower.com		203.373.2211	
Global Solar Energy	globalsolar.com	8500 South Rita Road, Tucson AZ 85747	520.546.6313	info@globalsolar.com
Innergy Power Corporation	innergypower.com	9051 Seimpre Viva Rd., BLDG 6 Suite AB, San Diego CA 92154	619.710.0758	help@innergypower.com
PowerFilm, Inc.	powerfilmsolar.com	2337 230th Street, Ames IA 50014	888.354.7773	
Kyocera Solar, Inc.	kyocerasolar.com	7182 East Acoma Dr., Scottsdale AZ 85260	800.223.9580	infosolar@kyocera.com
Mitsubishi Electric	mitsubishielectricsolar.co m	Solar/Photovoltaic Division, 5665 Plaza Dr., Cypress CA 90630	714.220.0007	pv@meus.mea.com
Mitsui Comtek	mitsuicomtek.com	20300 Stevens Creek Blvd., Suite 300,	408.725.8525	dkaltsas@sjmcb.mitsui.com

Corp.		Cupertino CA 95014		
Pacific SolarTech	pacificsolartech.com	44843 Fremont Blvd, Fremont CA 94539	510.979.0112	
Schott	us.schott.com	5201 Hawking Dr. SE, Albuquerque NM 87106	888.457.6527	
SANYO Energy	us.sanyo.com	550 S. Winchester Blvd., Suite 510, San Jose CA 95128	408.557.4083	
Sharp	sharpusa.com	Sharp Plaza, Mahwah NJ 07495	800.765.2706	
Solar Power Industries	solarpowerindustries.com	440 Johnathan Willey Road, Belle Vernon PA 15012	724.379.6500	
Spire Corporation	spirecorp.com	One Patriot's Park, Bedford MA 01730	781.275.600	pvsales@spirecorp.com
SunPower Corporation	us.sunpowercorp.com	3939 North 1st Street, San Jose California 95134	408.240.5500	
SunWize Technologies	sunwize.com	1155 Flatbush Road, Kingston NY 12401	800.817.6527	
Terra Solar	terrasolar.com	45 Rockefeller Plaza, Suite 200092, New York NY 10111	212.332.1819	solarinfo@terrasolar.com
Tideland Signal	tidelandsignal.com	P.O. Box 52430, Houston TX 77052	713.681.6101	
United Solar Ovonic	uni-solar.com	2956 Waterview Drive, Rochester Hills MI 48309	248.293.0440	info@uni-solar.com

Social Value of the Proposed Project [15]

This array of photovoltaic cells will not only help the KSU campus become more green but will also have a great impact on the public and provide many social benefits.

Installing the solar cells on parking lots bordering campus will encourage the public in green practices. Written and verbal descriptions of green practices can introduce concepts to the community, but real life examples seen on a regular basis will make the idea of harnessing solar energy more tangible and, consequently, more acceptable to the public. People will be able to see it often as they drive by on their way to work, school, or play. The actual structures will be supplemented by electronic signs that will communicate to the public the panels' amount of power output. These signs can stand next to the panels as well as be dispersed throughout the campus. The output of previous days can be recorded and put into terms that are relevant to the public, such as energy in kWh, number of Chevy Volts charged, or 2,000 ft^2 houses powered. Another posting might be to compare the cost of kWh to prices in the past to demonstrate the advances in solar panels. This information will also be posted on a website so that people can access it in areas besides campus.

This array of solar panels will provide a great hands-on opportunity for KSU students. Mechanical engineering students can take part in planning and building the metal support that the solar cells will sit on. Once installed by trained technicians, electrical engineering students can study how different fixed angles of the panels result in different power output as well as compare output of stationary panels to sun-tracking panels. They can be responsible for collecting and analyzing the data and can present the data to the public through the electric signs and the solar website. Students can also be involved in maintaining the solar panels by cleaning them periodically to ensure optimal power output.

Integrated into the structure will be plug-ins for parked electric cars so that they can charge as they sit in the parking lot. Although plug-in vehicles are presently very scarce at KSU and in the United States, automakers such as Nissan, Ford, General Motors, and Volkswagen, have great plans in the works. There are currently two cars currently on the market. General Motors is selling the Volt, and Nissan has been selling the Leaf, a purely electric vehicle. Other companies also have electric cars and hybrids in the works. With federal tax credits, these vehicles will cost from $25,000- $33,000. Though these are relatively expensive compared to their gas powered counter parts, charging stations such as this one at KSU will provide more incentive for consumers to switch to electric.

The parking lot structure will also be a great source of shade to the vehicles parked beneath it. A study done by the Department of Pediatrics of the University of Oklahoma showed the great effect that shade has on the internal temperature of vehicles. The study was performed in Oklahoma during the summer with temperatures reaching 100 °F. The researchers found that while in direct sunlight, the temperatures inside small and large vehicles increased up to 172 °F and 149 °F, respectively. The temperature of small vehicles (large vehicles in shade were not studied) reduced significantly when the vehicles were under shade. The temperature dropped from 172 °F to 111 °F [2]. Cracked windows caused little decrease in temperature. These high temperatures are harmful to the body especially when accompanied by the lack of ventilation in the car and the humidity outside. Humidity and the lack of ventilation together can render the human body's main cooling mechanism, sweating, ineffective and heat stroke along with other ailments can result. Shading will not only provide relief from the heat while sitting inside parked vehicles, but will also save car owners from sun damage, such as cracked interiors and warped possessions.

The installation of the large array of solar panels will be contracted out to one or more private companies providing for green jobs in the community. This will also give the green companies more publicity as people see their job and their company signs on campus. This will make solar panels appear more feasible to the rest of the public and hopefully encourage them to someday contract out the companies to install their own home solar panels.

Environmental Value of the Proposed Project [15]

One aspect of the "triple bottom line" dealing with sustainable energy is the project's environmental advantage or impact. In addition to social and economic advantages, this project will have several major environmental advantages over commonly used fossil fuel and petroleum energy sources. Environmental advantages from this project include effective land use by providing charging spaces for electric cars, providing a sustainable source of energy, reducing Kansas State's carbon footprint, and promoting electric vehicles.

First and foremost, as a brainchild of the 2009, 2010 and 2011 Sustainability REUs at Kansas State University, this project offers a sustainable source of energy for electric vehicle charging stations. Sustainability is an ever-growing concern among researchers. However, spreading that concern beyond university walls can be challenging. This site will offer a publicly viewable site that will help increase environmental awareness in the community of Manhattan and the collegiate world. This project is just one aspect of sustainability being explored at K-State and we hope to spread the interest above and beyond.

As mentioned above, the parking cover will shade vehicles. This is a way to optimize the use of limited parking on campus. The stalls, instead of only a parking spot, will be a source of shade, a solar energy collector, and an electric vehicle charging station. This project also promotes the development of electric vehicles. While currently in development, electric vehicles will offer a reduced carbon option for transportation. This overall will reduce CO_2 emissions and K-State's carbon footprint.

A reduction in CO_2 emissions due to a reduced use of fossil fuels is a major benefit of this project. This advantage is seen in both the solar power production and electrical vehicle aspects of the project. Solar power utilizes energy from the sun instead of combusting a fuel. This energy can be harnessed and converted to electrical energy by a solar panel. An inverter will then convert the direct current (DC) into alternating current (AC), which can be used to charge electric vehicles. While electric vehicles are still in the development stage, their development over the next 2-5 years requires planning for a charging station infrastructure. This project, educational in nature, will be a potential research site for those interested in developing solar panels and charging stations for the community.

As outlined in the project goals, part of this project is to collect data on local weather, solar panel efficiencies, and social impact. Local weather readings, especially when displayed for public viewing, will be encouraging to community members looking into alternative energy options. Kansas offers a great location for wind and solar energy. Promotion through Kansas State University will only benefit the community by providing information to residents who are aware of, concerned about, or interested in being environmentally friendly.

Financial Value of Proposed Project

Along with the social and environmental value that comes with the proposed project, there will also be a financial value to K-State. The standard billing process for KSU, is to charge based on the peak demand. Weststar Energy, the provider for KSU, charges around $12.00 per kW used at that time. Specifically, KSU has three substations, Campus Sub, SW Substation/Coincid, and Bramlage Coliseum and the three areas charged by peak power demand are Demand Charge, Environmental Charge, and Transmission Delivery Charge. If the energy produced by the solar panels is tied into the grid, KSU could theoretically decrease its peak demand for the substation that the panels are tied to, since that time usually corresponds to time when there is high irradiance and the panels could be orientated to produce the maximum amount of power whenever needed. The energy produced could also be sold to the energy company, which will also help decrease the overall electric bill.

Regarding energy production, the amount of energy produced by the solar panels can also be estimated. Based on the original two solar panels on the roof, which are rated for 220V, each panel could produce 180W at the peak time. It three panels were used to cover each of the parking spaces, each space could produce a peak of 540W. The current plan involves installing two to five spaces, an estimated 1.08kW to 2.70kW on sunny days. This doesn’t make an overall difference in the overall energy bill, but it does make a small difference and the non-monetary benefits far outweigh the financial ones. This is a fact that may change if this project is expanded beyond a pilot project.

A second way in which this project will benefit the college is the added benefit of the shaded parking spaces. The shaded spaces could be zoned so that people pay more to park there. Once the number of electric cars on campus increases, the spots can be sold to people with electric cars. This will provide additional financial benefit to the campus. If a car does charge through the station, it will cost the college some money to pay for the electricity. Charging a car, for example the Nissan Leaf, will cost around $3.00. This is not an expense that KSU can charge directly to consumers, since it would cause the college to become a utility company, which has legal ramifications that make this option not worthwhile. The cost of electricity could be factored into the cost of the parking space. Also, very few cars will require the full charge when they plug in, so the amount of electricity that will be required, and the associated price, will be less than mentioned above. Also, depending on the charging station chosen, the amount of time the car is plugged in may not allow it to be fully charged. A Chevy Volt requires 10 hours to fully charge with 120V and the Leaf takes closer to 20 hours.

Overall, the monetary benefit of reducing the peak power demand and maybe putting energy onto the grid will benefit KSU. The fact that the college can charge for the parking spaces, for both the benefit of shade and for the electric charging station, adds to the financial value of this project.

Solar Potential in Manhattan, Kansas [15]

Manhattan, Kansas has a good solar resource. Insolation is the measure of solar potential in an area. Table 2 shows some basic weather data for Manhattan, KS. All information in the table is based on Latitude 38.5, Longitude -96.5. The monthly average direct normal radiation is defined as the monthly average amount of solar radiation incident on a surface oriented normal to the solar radiation for a given month, averaged for that month over the 22-year period (Jul 1983 - Jun 2005). The monthly average clear sky insolation incident on a horizontal surface is defined as the monthly average amount of the total solar radiation incident on a horizontal surface at the surface of the earth when the cloud cover is less than 10%, averaged for that month over the 22-year period (Jul 1983 - Jun 2005) [3]

Table 2: Weather Data for Manhattan, KS

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Avg.
Monthly Avg. Direct Normal Radiation (kWh/m^2/day)	3.84	3.89	4.71	4.90	5.25	5.95	6.59	5.79	5.78	4.89	3.99	3.70	4.95
Monthly Avg. Clear Sky Insolation Incident On A Horizontal Surface (kWh/m^2/day)	3.20	4.38	5.89	7.23	7.98	8.11	7.86	6.97	6.09	4.40	3.44	2.83	5.72
Monthly Avg. Daylight Hours (Hrs)	9.75	10.7	11.9	13.2	14.3	14.8	14.6	13.7	12.4	11.2	10.1	9.48	12.18
Monthly Avg. Air Temp 10 m Above Earth's Surface (°C)	-3.68	-0.83	4.99	11.60	17.30	21.90	24.50	24.00	19.00	12.70	4.38	-2.02	11.20

From this data and inefficiencies associated with solar panels, the power output of the panels can be estimated. Some inefficiencies include temperature, miss-matched module, dirt, and inverter inefficiencies.

Temperature Inefficiency, η_T (also known as the Temperature Rating Factor) is inefficiencies due to the ambient temperature being substantially different from the Nominal Operating Cell Temperature (NOCT), or the nominal temperature for panel output (varies with panel brand/model). It can be calculated as shown Equation 1below:

$$\eta_T = 1 - \frac{0.005}{°C}(T_{CELL} - 25°C) \quad (1)$$

Where η_T is the temperature rating factor and T_{CELL} is the solar cell temperature. T_{CELL} can be calculated as shown below in Equation 2:

$$T_{CELL} = T_{AMB} + \frac{(NOCT - 20°C)}{0.8\,\frac{kw}{m^2}}[S_{ACT}] \qquad (2)$$

T_{AMB} is the temperature of ambient air temperature (taken from the "Monthly Avg. Air Temp 10 m Above Earth's Surface" in Figure 1), S_{ACT} is the insolation seen by the panel ("Monthly Avg. Direct Normal Radiation" in Figure 1 converted to units of W/m^2), and NOCT is the Nominal Operating Cell Temperature, which a value from a panel specification sheet of 46 °C was used for calculations

Other inefficiencies associated with solar panels include miss-matched module, dirt, and inverter inefficiencies. The miss-module inefficiency, $\eta_{M\text{-}M}$, is an inefficiency due to faulty modules within the solar panel, a factor of panel manufacturing. An industry accepted value of 3.0% faulty modules within the panel yields a $\eta_{M\text{-}M}$ =0.97. This is the miss-matched module efficiency used in our calculations. The dirt inefficiency η_D, is an inefficiency due to dust/dirt collection across the face of the panel, a factor of panel maintenance. A dirt efficiency of .95 was used in calculations. Inverter inefficiency, η_I, is the inefficiency due to the inverter and converting electricity from DC to AC. Inverter efficiencies typically range from 85-98%. An inverter efficiency of .96 was used for calculations.

Power can then be calculated by the rated panel power and adjusting for the panel inefficiencies as shown below in Equation 3:

$$P_{ADJ} = (\eta_T)(\eta_{M-M})(\eta_D)(\eta_I)P_{NOM} \qquad (3)$$

For our calculations a panel rated as 215 W was used for all calculations [4].
A MATLAB m-script was used to do calculations for a panel over the course of a year. The MATLAB m-script can be seen in Appendix I. The results are shown below in Figure 1:

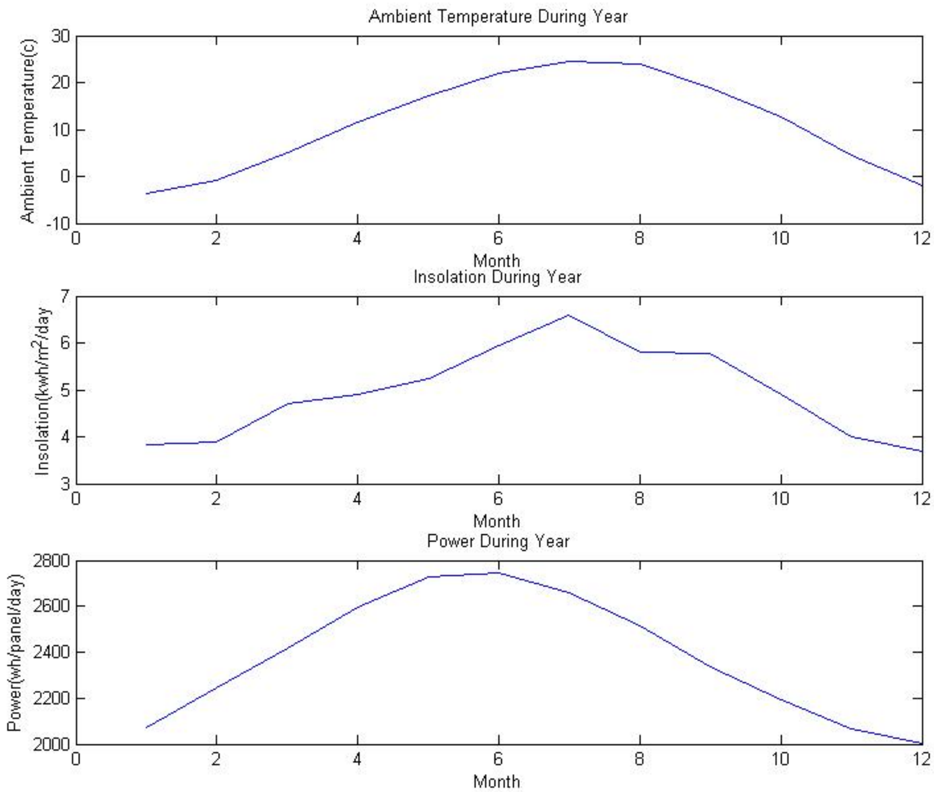

Figure 1: Ambient Temperature, Monthly Insolation, and Predicted Panel Output for Manhattan, KS

From this you can see that there is a lot of power potential for solar panels in Manhattan, KS.

Electric Vehicles [15]

When developed, this project would provide charging stations for plug in electric vehicles. As previously stated, one model of a recently released electric vehicle is the Chevrolet Volt. The Volt can be plugged into a 120 V household outlet or a 240 V charging station. There are no adaptors needed. It runs 40 miles purely on electricity stored in the batteries, and then uses a range extended gas generator to produce electricity for hundreds of miles on a single tank of gas. It takes 10 hours to fully charge the batteries and uses less gasoline then a typical IC engine [5]. This is a new technology in development and there will most likely be many more models of electric vehicles in the future.

Charging Stations

With the recent move toward electric vehicles, a standard charging connector was chosen for universal access of charging stations. The standard connector is the J1772. It is a five pin connector with two AC lines, one carrying 120 V and one carrying 240 volts, so the connector offers two levels of charging. Thanks to this standard charge stations can connect to most electric vehicles. The two most popular, the Nissan Leaf and Chevrolet Volt, are confirmed to be compatible with the J1772. These universal charge stations are available through different companies. A company that has installed stations in our region is Lilypad EV. They have installed 10 stations at hospitals and large businesses. Their charging stations can be managed through the internet. The users can also use the internet to find the nearest charging station. The stations can be mounted to poles, walls, or bollards. When using Lilypad EV tax credits are available that can cut the investment in half, thus making these stations affordable.

Location for Solar Panels and Charging Stations

The placement of the solar panels and charging stations is critical in determining the effectiveness of this project. To make sure we placed the panels in the optimum location, we looked at several variables. One of the issues we looked at was the amount of trees surrounding the parking lot. Tree coverage should be at a minimum to increase the amount of solar energy the panels produce. If shade from trees covers the panels, the amount of solar energy produced will be smaller than if the panels were in direct sunlight at all times. The amount of solar energy will be greater during the periods of the day where the sun is directly overhead and solar panels will produce the most energy when hit by direct sunlight. Another variable we looked into was the use of the actual parking lot. As a group, we decided to place the panels and charging stations in an existing parking lot. From there, we looked at which parking lot sees the most cars throughout the school year. This was done so that students, faculty, staff, or guests could recharge their electric cars in the most convenient spots on campus.

Based on the criteria stated above, we proposed placing the solar panels in the parking lot west of the old stadium. The tree coverage in this area is minimal which will allow for the most direct sunlight for the solar panels. The parking lot is also conveniently located and sees a lot of traffic throughout the school year. This is ideal when placing the charging stations. The group also talked about placing other charging stations in the parking lot behind and around Call Hall. These areas also see a lot of traffic throughout the school term and will be convenient for users in the north part of campus.

An additional option for charging stations is the new welcome center that is being renovated on campus. Having a charging station located here would help to increase awareness of the university's energy initiatives to those who are not students, faculty or staff. Anyone stopping by the welcome center would see the station and this placement would be very beneficial access for those visiting the university or traveling through Manhattan.

Sources of Funding and Proposed Budget [15]

Funding for a solar project on a college campus can be obtained through three main sources. These include: government funding, corporate funding, and bonds. All of these funding possibilities have been pursued by other universities with success in the past.

Government Funding

The majority of funding for renewable projects comes from the American Recovery and Reinvestment Act of 2009 ($8.5 billion to subsidize loans, and $28.4 billion for program funding). States were awarded funding through this program to dole out to projects throughout their districts. One such program was Project Sunburst in the state of Maryland [6]. Public Utilities and Authorities offer subsidies for projects aimed at reducing the load on the electricity grid [7]. In California, Pacific Gas & Electric has incentive programs that allow customers to obtain rebates for installing on-site generation, which can fund upwards of half the cost [8]. State Energy Offices offer programs that are less competitive than national programs. The Department of Energy offers grants for renewable projects, as well [9].

The National Science Foundation (NSF) frequently offers grants for research, and so including this project in a research proposal for educational purposes would be desirable. Specifically, the NSF has a grant program called Grant Opportunities for Academic Liaison with Industry (GOALI) (program solicitation NSF 10-580). Specifically, the grant cites example proposals, including, "University-based support for partnering university and industry scientists, or engineers, or both on a research project of mutual interest…" Potential to fund this project using a grant such as this is very high, and should be looked into in more depth.

Corporate Funding

Some companies, such as BP Solar, donate solar panels to schools for renewable projects [10]. Private companies can own the panels outright, and have the colleges buy the electricity from them. Chevron and Los Angeles Community College formed this type of partnership, though problems arose with the city prohibiting any entity but the power utility from selling electricity [11]. And so, local and state laws should be analyzed before such an agreement is made. Local retailers and distributors could also be contacted in aiding the funding of a project. Distributors could gain valuable publicity and advertising while benefitting the local university. Western Washington University was able to fund a project on their campus partly due to funds donated from local companies [12].

Bond Market

Colleges frequently resort to bonds to help finance large scale projects. Federal bonds, such as clean Renewable Energy bonds [13], as well as county bonds, have been successfully used to fund renewable energy projects on various college campuses. However, bonds are usually used when project costs are in the millions, such as Arizona Western College funding a $30 million project with $22 million in recovery zone facility bonds. And so, this would only be a practical source of capital for large scale projects, and not for a small-scale research projects such as the one being proposed here.

Economically speaking, the possibility of selling back electricity to the grid is a possibility, though only at large scales. This project will most likely start out very small, with a majority of the energy possibly going to charge vehicles, and so revenue from selling back to the grid would be initially small or nonexistent. However, at larger scales, there is great potential at Kansas State University. Currently, KSU has over 10,000 parking stalls, not including their parking garage [14]. The average parking stall conservatively is 25 m^2. Solar panels can average about 215 W at 1.25 m^2 in size, which amounts to roughly 20 such solar panels able to be put up to cover a stall. Ideally speaking, approximately 200,000 of said solar panels could be put up on campus, resulting in a combined power output of 43 MW. These panels currently cost on average $800, and so it is currently not feasible from a large-scale perspective.

In 2009, the campus used approximately 149,030,825 kWh. This is equivalent to approximately 17 MW, with peak power use potentially being on the order of 50 MW. And so, there is good potential for being able to provide a majority of the campuses electricity through this renewable energy source.

Cost

The cost of the project will include:

1. Cost of the solar panels
2. Cost of charge stations
3. Cost of supporting system
4. Inverter and electrical system
5. Installation and labor costs
6. Instrumentation and display equipment
7. Manpower for data collection, recording, analysis, and management
8. Web site development, upkeep, and management
9. Public education program

Items 1 through 5 above are associated with each parking space that is covered with panels and converted to a charge station. The estimated cost may be $10,000 to $20,000 per space depending on products supplied by vendors at cost or at reduced cost. This is a capital cost that can be paid for over time through parking fees and electrical energy produced. Items 6-9 are related to the research and demonstration elements of the project. If several part-time students work on the project, and some of the students participate without pay for credit projects, the direct costs of salaries would be about $15,000 to $30,000/year.

Year 3

The last two years focuses mainly on bonds, corporate funding, and government funding, but there are significant resources in tax incentives and partnerships as well. All of these areas were taken into consideration in our research, and all of them have tremendous opportunity. The next few paragraphs are specific funding opportunities that our group has located, but these are just a sample of what is out there.

The "Alternative-Fuel Fueling Station Tax Credit" is a good example but it passed Jan 1, 2009.). There is also the "business energy investment tax credit" which gives a tax credit of 30% when installing solar power, it was recently expanded by the American Recovery and Reinvestment Act of 2009 (originally a part of the Energy Improvement and Extension Act of 2008) The "Solar Photovoltaic Electricity Tax Credit" is a viable option, offering more than 2,000 being claimed in tax credits.

A potentially good partnership would be with SunEdison who partners with several companies from around the country. They will pay to put panels on rooftops and sell electricity at costs that are less than the public utility. This can potentially create a revenue stream for the university and make Kansas State a leader in using renewable energy effectively. Kansas State can be a front runner of college campuses to use renewable energy at a cost less than traditional power plant produced electricity. Although they have not partnered with anyone in Kansas, they have partnered with utilities, public sectors, and commercial sectors close by in Colorado. Partnering with SunEdison will not only make Kansas State University the first SunEdison client in Kansas, but among the first with respect to Universities across the United States.

Solar ABC might be another good option for a partnership along with/instead of SunEdison. It's funded by the Department of Energy and its goal is to expand the solar market by eliminating barriers to the adoption of solar technologies. They also help with connections among PV manufacturers, sellers, buyers, and users to foster the acceleration of the photovoltaic market. This partnership could potentially work really well if they would help fund so they can "foster growth of the solar energy market." There is also a pretty big focus on education along with this partnership which is one of the overall aims of our project.

To help transform the solar parking lot from a few test parking stalls to a large scale project, the USAID's Development Innovation Venture and other similar grant opportunities may be good options. The Development Innovation Venture aims to identify, develop, test, and scale innovative approaches to development challenges. It provides funding in a step-wise fashion, first for identification and development, and then for testing and going large scale if the project proves successful.

Kansas State University may also be a significant source of funding. The university facilities, parking services, and other departments that have a vested interest in the solar parking lot should be pursued. The NSF Earth Wind and Fire REU, whose participants have prepared this report, has funds that may be used toward a project on sustainability. Student led organizations, both specific to sustainability and not, could also be a major resource. Asking for funding on a project that no one has heard about can be difficult, but if student groups, clubs, government, newspapers, etc. get involved and get the student body interested, funds from both the university and the Manhattan community will be much easier to come by.

The above resources are good options for expanding the project beyond a few test spots, but a different strategy may be necessary to get the project going. Especially at first, the economics of the project should not be of great concern. The solar parking spot are being built primarily for their social value. While they may help reduce k-state's peak power, the effects will only be felt on a large scale project. For the pilot project educating the public about solar energy and the importance of sustainability will be much more valuable than the electricity produced by the solar panels. The DOE and NSF are possible organizations where funding might be found related to energy education. The wind for schools program is a good example, where funding is given to build wind turbines for educational use.

Case Studies

There are several college campuses across the nation who are pursuing solar parking lot projects and charging station installations, though few are integrating them in the same way as Kansas State University.

West Michigan University in Kalamazoo, Michigan, recently installed four charging stations on its campus. Each one has a Level 1 (120 V) and Level 2 (240 V) charger. The charging stations were situated near public bus stops, promoting West Michigan University's pledge for building a sustainable community. Using the charging station is free; electric vehicle owners must simply get a special card to swipe in. The cost of the electricity used by the charging stations should be offset by the wind and solar energy produced on campus; if demand becomes too high, this approach will be reevaluated. WMU received the stations free of charge from the manufacturers, Coloumb Technologies. The company is a part of a Department of Energy grant program called ChargePoint America. The program covers ten regions in the United States: Boston, MA; Bellevue/Redmond, WA; Sacramento, CA; San Jose/ San Francisco Bay Area, CA; Los Angeles, CA; Austin, TX; southern MI; New York City, NY; Washington, D.C/Baltimore; and Orlando/Tampa, FL . In return for handing out charging stations, Coloumb will collect data from them in order to conduct research.

The University of California San Diego finished installing solar parking shading a few years ago on the roofs on a couple of parking garages. The Solar Tree™, as dubbed by Envision Solar, consists of a photovoltaic canopy supported by branching arms and a solid trunk. Kyocera supplied the solar modules. The third party, who also owns and operates the solar structures via a Power Purchase Agreement (PPA), paid for the Solar Groves. As a third party, they are able to benefit from investment tax credits offered by California that are not available to institutions such as universities. Each Solar Tree™ can generate more than 17,000 hours of renewable energy annually, while avoiding 13.2 metric tons of carbon emissions. This leads to a yearly power production of 275,000 kWh. The Solar Trees™ also come with the option of installing an outlet for charging electric vehicles, though it has yet to be implemented by UCSD.

Lane Community College in Eugene, Oregon, finished its first phase of building the first of it's two solar electric and vehicle charging station during the fall of 2010. The station consists of 18 covered charging stations that produce around 40 kW of solar electricity (per year?). At least ten of the charging stations (five Level 1, five Level 2) have also been installed. The entire project was projected to cost $1.5 million dollars; the current station cost around $800,000 to implement. $100,000 of came from the Eugene Water & Electric Board Greenpower grant, while the college sold bonds to raise the remaining funds.

Looking into case studies such as these can help KSU prepare for its own implementation process. Learning from others examples will allow KSU to efficiently and effectively plan and complete the solar parking and charging station project.

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Appendix I: MATLAB m-script used for Figure 1 - Modified from Engineers without Borders Milwaukee School of Engineering Chapter

```
clear
clc
noct=46; %Nominal operating cell temp
mme=.97; %mismatched module efficiency
dl=.95;%dirt loss
ei=.96;%efficiency of inverter
ep=.171; %efficiency of panel
pp=215; %panel power(watts)
s=[3.84,3.89,4.71,4.90,5.25,5.95,6.59,5.79,5.78,4.89,3.99,3.70]; %insolation(kwh/m^2/day)
c=1;

while c<=12
   swm(c)=(s(c)*1000)/24; %converts insolation to w/m^2
   c=c+1;
end
ph=[9.75,10.7,11.9,13.2,14.3,14.8,14.6,13.7,12.4,11.2,10.1,9.48];%peak hours per month(NASA Data)
tamb=[-3.68,-0.83,4.99,11.6,17.3,21.9,24.5,24,19,12.7,4.38,-2.02];%Ambient temperature average per
month(NASA Data)
c=1;
while c<=12
   tcell=tamb(c)+((noct-20)/800)*swm(c);
   rt=1-(.005*(tcell-25));
   p=rt*mme*dl*ei*pp;
   eday(c)=p*ph(c)
```

```
    c=c+1;
end

%Temperature
subplot(3,1,1)
plot(1:1:12,tamb)
hold on
xlabel('Month')
ylabel('Ambient Temperature(c)')
title('Ambient Temperature During Year')
hold off

%Insolation
subplot(3,1,2)
plot(1:1:12,s)
hold on
xlabel('Month')
ylabel('Insolation(kwh/m^2/day')
title('Insolation During Year')
hold off

%power
subplot(3,1,3)
plot(1:1:12,eday)
hold on
xlabel('Month')
ylabel('Power(wh/panel/day)')
title('Power During Year')
hold off
```