Powering Up E-14

A Feasibility Study on Implementing Solar Panels as Parking Coverage

Douglas Klein, Jack Morrissey, Nana Ochiai

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Executive Summary

Sustainability is a growing area of interest for many universities across the United States. How the issue of sustainability is addressed depends on the preferences and priorities of the individual university and community. Solar energy is a great way to introduce sustainability to the University of Illinois community. Solar energy is one of the few completely “clean” power sources known today. Quite simply, solar energy production does not produce any pollution whatsoever. Solar energy also saves money. The average 20 year savings for Americans using solar energy in 2011 was 20,000 dollars and solar panel efficiency has only increased since then (Solar Power, 2013).

Solar energy does not come without a cost, however. Solar energy has an extremely high initial cost due to the fact that solar panels and all associated construction is still extremely expensive. Depending on the size of the associated construction, solar energy can take anywhere between a few years and a few decades to pay off. Another downside of solar energy is that large areas are required to make their implementation worthwhile (Solar Power, 2013).

We have identified parking lot E-14 as an ideal location to place a solar parking lot as it has a large surface area (18.75 acres) that is largely unshielded by overhanging trees or buildings. While there are other areas on University of Illinois’ expansive campus that are large enough to house such a large solar canopy, not many of them have the same ideal conditions.

This study is dedicated to determining whether putting a solar canopy at parking lot E-14 is feasible for the University of Illinois. With this goal in mind, it was ultimately determined that a solar canopy of this magnitude would cost the university around $30 million while producing slightly over $1 million dollars worth of energy per year (Pvwatts). Therefore, it would take the University about 28 years to see returns on their large initial investment. At the same time, University of Illinois students stated very definitively that they would be in favor of this project even if it meant that they had to pay slightly more for parking or tuition. All of this means that a solar canopy at lot E-14 would likely be feasible if the University could find investors to help with some of the initial costs.

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Introduction and Background

Society is looking to renewable resources like solar power to provide electricity for the future because it produces clean energy without leaving behind waste and emissions. Installing solar panels on a house, however, is expensive and requires a great deal of experience. The costs are generally relatively high for the average homeowner; therefore, it is more beneficial to construct solar farms where professionals can install solar panels in bulk. Recent trends have involved solar roofs being installed on large parking lots around places such as schools and large office buildings (Solar Power, 2013). This allows for a much larger area to be covered and thus more energy produced.

With this in mind, we have found campus parking lot E-14 to be an ideal location for a solar roof because it consists of a very large area (18.75 acres). We also like this location because of its proximity to Memorial Stadium. During football season fans frequently use parking lot E-14 as a place to hold their tailgates. The addition of solar panels would not only provide for protection from bad weather, but would also allow for tailgaters to connect to the electricity source for all of their power needs during their stay. This would likely turn parking lot E-14 into the premium spot for tailgaters allowing the University to charge patrons extra for the use of electricity. With this in mind, however, a potential obstacle arises in any construction involving lot E-14. Due to the fact that State Farm Center was recently added to the list of top ten endangered historic places in the State of Illinois ("Statewide"), it has become much harder to make changes to the surrounding area. Thus, the Illinois Landmarks Organization must first approve any changes. The addition of solar panels, however, has the potential to have a positive effect on the surrounding aesthetics of this building in addition to its main purpose, which is producing energy.

Lot E-14/University of Illinois/Champaign County:

Based on the scale provided by Google Maps as can be seen in Figure 1, parking lot E-14 is approximately 18.75 acres (76,000m^2) with 2,330 parking spots to accommodate its many patrons. This is closely comparable to the 21 acres of land for the proposed South Campus Solar Farm Project (University, 2012). This can be seen in the following Figure 2 with two areas outlined in red. The top red area is the entire State Farm Center area and the bottom shows the proposed Solar Farm Project location. The fact sheet for the Solar Farm Project stated that the proposed project would "Produce an estimated 7.86 million kilowatt-hours (kWh) the first year or 1.8% of the electricity usage for the campus based upon the fiscal year 2012 usage of 432.45 million kWh; however, the percentage increases to 2.1% based upon usage projections for fiscal year 2015 of 368 million kWh (University, 2012)." With the grand scale of Lot E-14, it is most likely also possible to produce a significant percentage of the campus' electricity usage.

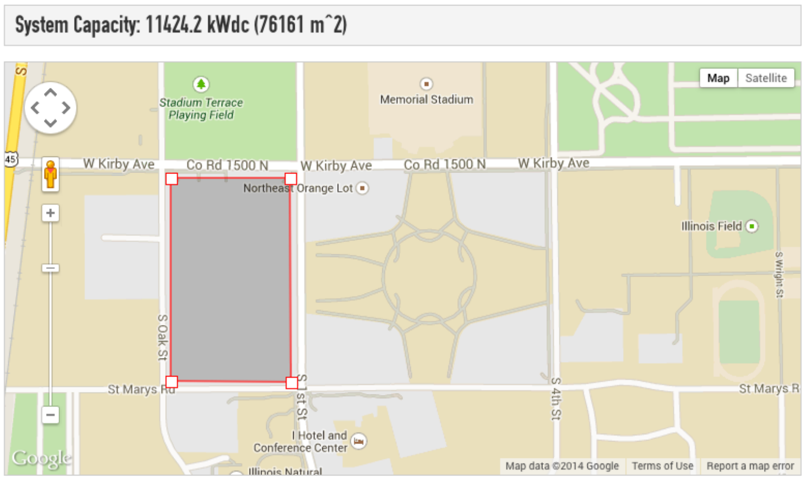

Figure 1. Lot E-14 - Proposed Solar Canopy Site

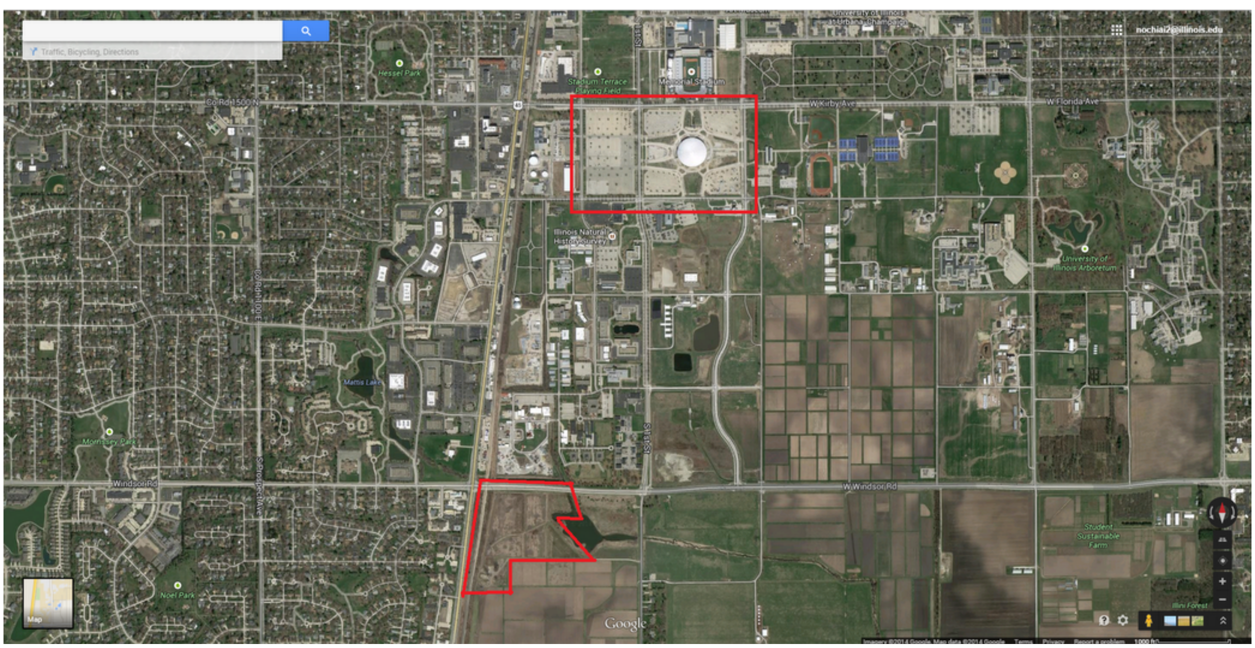

Figure 2. Proposed South Campus Solar Farm Project and State Farm Center/Lot E-14

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Location: W088 15, N40 07

CHAMPAIGN, ILLINOIS
Central Standard Time

Astronomical Applications Dept.
U. S. Naval Observatory
Washington, DC 20392-5420

Duration of Daylight for 2014

Day	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.
	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m	h m
01	09:23	10:10	11:18	12:40	13:55	14:50	14:58	14:16	13:04	11:46	10:28	09:32
02	09:24	10:13	11:21	12:43	13:57	14:51	14:58	14:14	13:01	11:43	10:26	09:31
03	09:25	10:15	11:24	12:46	14:00	14:52	14:57	14:12	12:59	11:41	10:23	09:30
04	09:25	10:17	11:26	12:48	14:02	14:53	14:56	14:10	12:56	11:38	10:21	09:29
05	09:26	10:19	11:29	12:51	14:04	14:54	14:56	14:07	12:54	11:35	10:19	09:28
06	09:27	10:21	11:32	12:54	14:06	14:55	14:55	14:05	12:51	11:33	10:17	09:27
07	09:28	10:24	11:34	12:56	14:08	14:56	14:54	14:03	12:48	11:30	10:15	09:26
08	09:30	10:26	11:37	12:59	14:10	14:57	14:53	14:01	12:46	11:28	10:12	09:25
09	09:31	10:28	11:39	13:01	14:12	14:58	14:52	13:59	12:43	11:25	10:10	09:24
10	09:32	10:31	11:42	13:04	14:14	14:58	14:51	13:57	12:41	11:22	10:08	09:23
11	09:33	10:33	11:45	13:06	14:16	14:59	14:50	13:54	12:38	11:20	10:06	09:22
12	09:35	10:36	11:47	13:09	14:18	14:59	14:48	13:52	12:36	11:17	10:04	09:22
13	09:36	10:38	11:50	13:12	14:20	15:00	14:47	13:50	12:33	11:15	10:02	09:21
14	09:37	10:40	11:53	13:14	14:22	15:00	14:46	13:48	12:30	11:12	10:00	09:21
15	09:39	10:43	11:55	13:17	14:24	15:01	14:45	13:45	12:28	11:10	09:58	09:20
16	09:40	10:45	11:58	13:19	14:26	15:01	14:43	13:43	12:25	11:07	09:56	09:20
17	09:42	10:48	12:01	13:22	14:28	15:01	14:42	13:41	12:23	11:05	09:54	09:20
18	09:44	10:50	12:03	13:24	14:30	15:01	14:40	13:38	12:20	11:02	09:52	09:19
19	09:45	10:53	12:06	13:27	14:31	15:02	14:39	13:36	12:17	11:00	09:50	09:19
20	09:47	10:55	12:09	13:29	14:33	15:02	14:37	13:34	12:15	10:57	09:49	09:19
21	09:49	10:58	12:11	13:32	14:35	15:02	14:36	13:31	12:12	10:55	09:47	09:19
22	09:50	11:00	12:14	13:34	14:36	15:02	14:34	13:29	12:09	10:52	09:45	09:19
23	09:52	11:03	12:17	13:36	14:38	15:01	14:32	13:26	12:07	10:50	09:44	09:19
24	09:54	11:05	12:19	13:39	14:40	15:01	14:31	13:24	12:04	10:47	09:42	09:19
25	09:56	11:08	12:22	13:41	14:41	15:01	14:29	13:21	12:02	10:45	09:40	09:20
26	09:58	11:11	12:25	13:44	14:42	15:01	14:27	13:19	11:59	10:42	09:39	09:20
27	10:00	11:13	12:27	13:46	14:44	15:00	14:25	13:16	11:56	10:40	09:37	09:20
28	10:02	11:16	12:30	13:48	14:45	15:00	14:23	13:14	11:54	10:38	09:36	09:21
29	10:04		12:33	13:51	14:47	15:00	14:22	13:11	11:51	10:35	09:35	09:21
30	10:06		12:35	13:53	14:48	14:59	14:20	13:09	11:48	10:33	09:33	09:22
31	10:08		12:38		14:49		14:18	13:06		10:30		09:22

Figure 3. Duration of Daylight for 2014 in Champaign, IL

It has also been determined that Champaign County receives an average of 195 days of sunlight per year. With an average of 12 hours of sunlight per day that gives 2340 hours of sunlight at parking lot E-14 per year (Duration) estimated from the information shown in Figure 3. This is just slightly below the United States average (2460 hours of sunlight per year) but is still a very significant amount (Climate). Figure 4 from the National Renewable Energy Laboratory (NREL) shows the average solar resource of the entire United States and compares it with other countries. One of the countries shown is Spain, the current world leader in solar power generation. The figure shows that our Midwest region actually receives a comparable amount of sunlight to part of the Spanish region, fortifying why implementing more solar arrays in our area could make a significant difference.

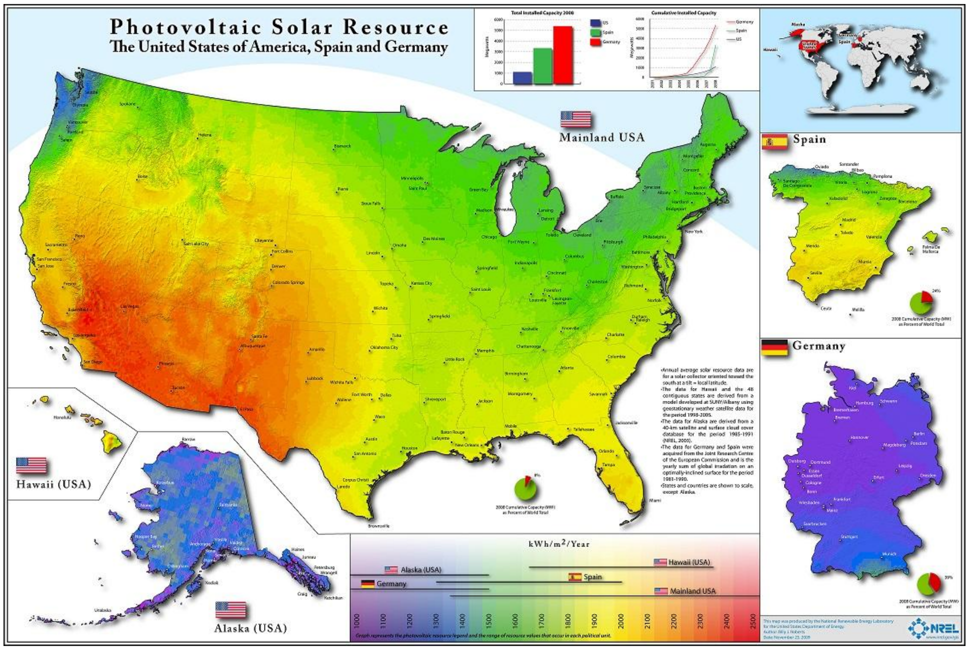

Figure 4. Photovoltaic Solar Resource

The UIUC Energy Report of fiscal year 2014 explicitly states the energy usage of the past year and compares it with the year before. "During 2014, the Urbana-Champaign campus used a total of 4,831,255 Million BTU's (MBTU) for the entire campus served by campus utilities. Over the utility service area of 21,003,246 gross square feet, this factors out to 230,024 BTU's per square foot, also known as the Energy Utilization Index or EUI." One British Thermal Unit (BTU) converts to 2.931 E-4 kilowatt-hours, so in this past year, our campus has used approximately 1.416 billion kWh, with an EUI of 67.41 kWh/ft^2 (2014).

The State of Illinois also has a rebate program to provide incentive for solar and wind energy usage. Three different brackets make up this incentive program. Residents can receive up to 30% of eligible project costs, Commercial 30%, and Nonprofits and Public Sectors 40% (Solar, 2014). As a public university, we would fall under the Nonprofits and Public sector and have the highest rate of return from the state in the incentive program.

Similar Projects:

One well-known urban solar array is located in Cincinnati, Ohio. In 2011, the Cincinnati Zoo constructed a 1.56 MW solar canopy, with 6400 monocrystalline panels, on one of their parking lots (Boyer, 2011).

Another similar implementation of solar panels over a parking lot was built on the campus of Arizona State University (ASU) in 2011 and can be seen in Figure 5. ASU partnered with NRG solar to cover a parking lot next to one of its athletic stadiums. The array completely covers an area of 5.25 acres and outputs 2.1 MW of electricity. Arizona State University currently pays NRG for the power output, as NRG was the one to provide the capital and funding for the project. The total cost of the solar parking lot was $11.55 million and it is expected to lead to energy-cost savings within three to four years while also providing an extra source of income via advertising banners that are hung from the structure (Craft, 2011).

Figure 5. ASU Solar Canopy

In a much larger scale, Rutgers University also built a solar canopy at one of their parking lots as can be seen in Figure 6. This solar canopy project, which was completed in 2011, is approximated to cover around 32 acres. The project cost a total of $40.8 million project and generate up to 8 MW. Similar to the project at ASU, Rutgers University did not pay the upfront costs of construction but they rather pay the company that financed the project for the electricity they receive. After a 15-year period, the University will be able to purchase the system at the full fair market price estimated at $3.6 million (Rugers, 2011).

Figure 6. Rutgers University Solar Canopy

We were also able to contact Melink Corporation, which developed a 600,000 square foot, roof-mounted solar array in Indiana. This is about 1/3 of the size of lot E-14. The array consists of approximately 12,000 monocrystalline silicon panels and produces 3.18 MW. The system, only recently put into commission, is estimated to produce up to 4.4 million kWh per year (Melink, 2014).

Most recently, Ford Motor Company in a joint project with DTE Energy began construction on what will be the second largest solar carport in the Midwest in Dearborn, MI. This solar canopy will provide over 400 covered parking spaces and 30 charging stations for electric vehicles. It will "have the capacity to generate 1.038 MW of electricity--enough to power 158 average-sized homes" (Ford, 2014).

Solar Panels:

Two types of solar panels are commonly used today: amorphous and monocrystalline silicon panels. Both operate in fundamentally similar ways in the fact that both harvest solar radiation and convert it to energy. Monocrystalline panel technology has been around for decades. It is made of thin crystalline silicon disks with metal conductors aligned in a grid and then covered by a thin layer of glass. It is still the better of the two in terms of energy output and efficiency; however, monocrystalline panels are more likely to overheat. This lowers their ability to function in higher temperatures (Dirjish, 2012). Amorphous panels on the other hand are still an emerging technology, but are more consistent under variance in temperature. They are created through the laying of multiple thin layers of silicon. Each of these layers specializes in the absorption of different layers of the solar spectrum. This process helps significantly lower the materials costs and results in a thinner and lighter panel. Some amorphous panels also come with multiple circuits so some output can still be gained under partial breakage. There are obviously advantages and disadvantages to both types of solar panels. One thing that is not a distinguishing factor, however, is cost. Both panels cost about the same per kWh of energy produced (How, np).

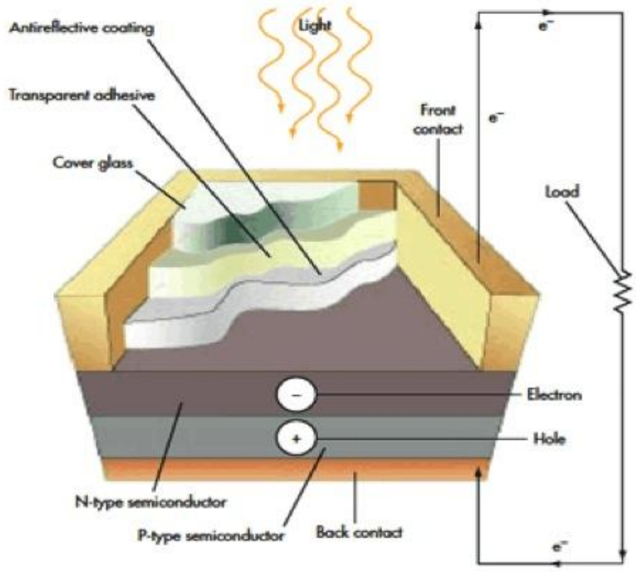

Figure 7. Monocrystalline Panel

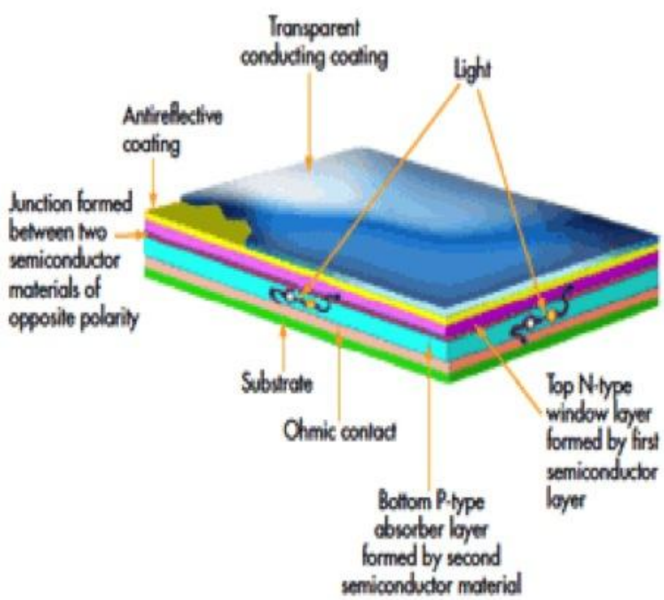

Figure 8. Amorphous Panel

Extreme seasonal weather in the Champaign-Urbana area is the main concern when choosing solar panels. Several studies have been done to evaluate the effects of snow and differing surface coatings on solar panel functionality. R.M. Fillion et al. of University of Windsor (2014) ran tests on super-hydrophobic coatings across five properties: ice resistance, transparency, self-cleaning, antireflection, and mechanical robustness. The study begins by looking into the origin of hydrophobic surfaces, which was first observed in nature via a phenomena called the "Lotus effect" which refers to the ability of the flower to stay clean of dirt and pollution even while growing in muddy waters. It was established that the water repellent properties of a super hydrophobic coating can "prevent and reduce the accretion of ice" (p807). On top of this, the transparency and antireflective effect can be optimized to ensure a maximization of light transmission and efficiency, and the coating would allow for minimal maintenance thus increasing the overall useful life of a solar panel. Another study done by Yao and He of the University of Chinese Academy of Sciences (2014) focuses not on hydrophobic coatings but rather a purely anti-reflective coating in order to maximize efficiency. This study also looks into the transparency and self-cleaning properties of this coating. The conclusion that was reached, however, does not show simple anti-reflective coating for solar panels to be useful in their current state as they are still extremely sensitive to mechanical wear. They do, however, express hope in the advancement of the technology to achieve a durable antireflective surface, which will be "beneficial for practical applications in large areas" (p134). Finally, a study conducted based on data from south-eastern Ontario by Rob Andrews et al. (2013) evaluated various variables, such as yield loss, time to clear panels, and the Albedo effect (the reflecting power of a surface), against panel angles and temperatures of both crystalline and amorphous panels separately. They concluded that losses deeply depended on the angle and panel type, however, correlation between time and changes in time or humidity were quite insignificant. They emphasize the importance of the proper assessment of snow related losses will most likely improve the performance and maintenance of the system and influence better systems optimization.

Construction Location and Type:

Solar parking lot roofs are constructed in many different forms as can be seen in Figure 9 below. Some of these provide full coverage to protect from weather, while others have more gaps, which allow for more sunlight to get through to the pavement below. While both have their own unique set of advantages and disadvantages, an optimal system often depends on the local climate as well as the goals of the project.

Figure 9. Several Types of Solar Canopies

Top Left: EEPRo, Offshoot for German Company EEPro GmbH in NC (Casey, 2010)

Top Right: Almaden Campus Solar Port for the Santa Clara Valley Water District (Almaden)

Bottom Left: Solar Canopy at Cincinnati Zoo Parking Lot (Bates, 2011)

Bottom Right: "Solar Tree' (solar powered canopy) at UCSD (LaMonica, 2008)

Over the past few years, solar panels have become significantly easier to install as well. The steps in implementing solar panels are simply stated as follows: Obtain a permit, determine location and tilt, physically install the panels allowing for space for airflow beneath the system, and connect the system to the electrical grid. The simplification of these four steps has led to a decrease in man hours required for implementation, which translates into lower construction costs.

The University of Illinois would benefit from this project in the following ways:

- Financially: After the initial cost of construction is paid off, solar energy is essentially free. On top of this, covered parking can be charged at a higher rate. During tailgates a covered solar parking lot not only provides shade and rain cover, but could also provide electricity for those who are willing to pay premium rates. University advertisements could also be hung from the solar canopy as was done at Arizona State University.

- Visibility to visitors and alumni that the University of Illinois is committed to sustainability and green energy: Often, people coming to campus park at lot E-14. With this being the case, parking lot E-14 is often the first thing that people see when coming to the campus. How better to show that the University is committed to being green than to welcome people to campus with an expansive solar parking lot?
- By implementing solar roofing, the urban heat island effect caused by surfaces such as blacktop commonly used in parking lots can be greatly reduced: The United States Environmental Protection Agency defines heat islands to be a phenomena that "can affect communities by increasing summertime peak energy demand, air conditioning costs, air pollution and greenhouse gas emissions, heat-related illness and mortality, and water quality" (Heat Island Effect). With solar panels soaking up the sun's radiation above the blacktop, the heat island effect can be minimized.
- Clean energy: Approximately 2% of the campus' electricity usage can be generated from these solar panels, based on the estimation given by the Solar Farm Project back in 2012 (University, 2012). This is 2% that does not need to be produced by methods that are more financially and environmentally burdensome.

Project Objectives

Our overall objective is to determine the financial feasibility of putting a solar panel parking structure at parking lot E-14. This entails selecting both a structure for the solar panels to sit on and a type of solar panel with the ultimate goal of determining a price estimate for construction and an estimate for how much energy the solar parking lot will produce on a monthly and annual basis. Finally, we will also evaluate the student body's response to our proposed project.

Methodology

Throughout this semester our group worked to fulfill the following general tasks: Preliminary Research, Brainstorming, Selection, and Communication. Each one of these tasks is detailed as follows:

- **Task 1: Preliminary Research** - This step was broken down into two sections, "internet-based" and "field-based" research. We started by looking into parking lot E-14. We both visited the site and looked at maps and aerial photographs to determine if the location was feasible and to find the exact size of the parking lot. We then conducted research on and compiled a list of solar energy companies that could provide solar panels solar panels for this project. This included contacting several local representatives to ask them about previous solar efforts on the University of Illinois campus (such as the Solar Farm Project, Solar Decathlon Team, the Business Instructional Facility, etc.) and researching other parking-related solar canopies in around the United States. While we conducted research on the implementation of solar canopies nation-wide, we maintained a focus on the Midwest area and similar areas where the climate is relatively consistent with that of the Champaign-Urbana area.

  On top of visiting the proposed project site, our "field-based" research also consisted of observing the maintenance and current state of our particular lot, and extrapolating an estimate of average sunlight via weather data. We also spoke with company representatives relating to projects such as the Business Instructional Facility and the recent Electrical and Computer Engineering Building, as well as personnel at the University of Illinois Facilities & Services Office to look into the details of connecting our solar array back into the power grid for the campus to best take advantage of the output.
- **Task 2: Brainstorming** - This task entailed using all of our compiled research to weigh the several options that we had. Our group deliberated several times on the type of structure we wanted to build, the type of solar panels that we wanted to use, the overall cost estimate for the entire project, and the estimated amount of energy that the campus will receive from the project. During this step of the process, we also reached out to several University of Illinois faculty, staff, and students to see

whether or not they would support the implementation of a solar canopy at lot E-14 and how they thought it could best be implemented.

- **Task 3: Selection -** This was the final and most simple step in the process of bringing this project tog ether. Once we had all of our research and received opinions from several faculty, staff, and students, the process of selecting final designs and estimates was fairly straightforward

Alternative Solutions:

Solar energy is likely viable in multiple locations in the Champaign-Urbana area. Outside the University, a program could subsidize and assist residents with putting solar panels on the roofs of their homes. On campus, many buildings with viable roofs for solar panels are available but they would not likely cover enough area to provide useful energy savings. The main alternative the University has already considered is the Solar Farm Project, which would be a solar array near the intersection of First Street and Windsor Road in Champaign. The project had an initial proposed completion date of Fall 2013 but has yet to be implemented due to the delayed approval for beginning the contract by the State Purchasing Officer and for contract clarifications about the complex financing structure.

Schedule

Our group approached this project according to the following schedule:

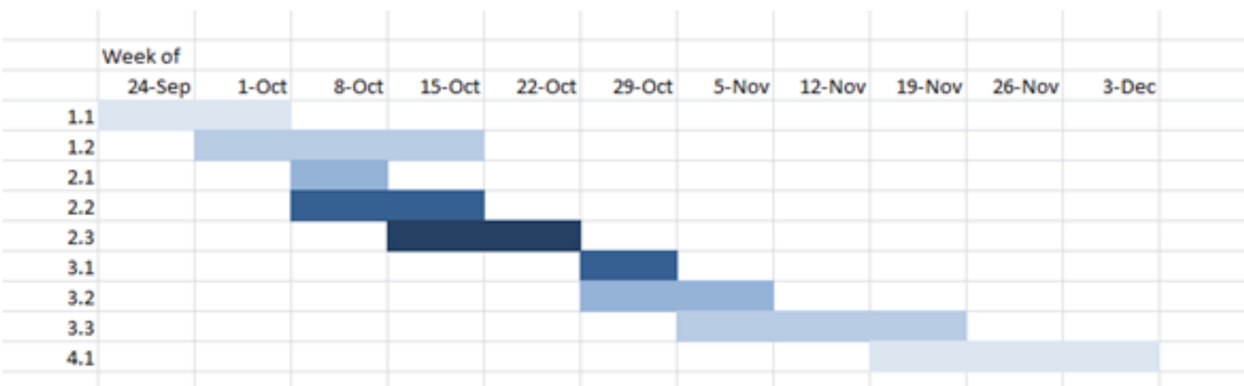

Figure 10. Semester Schedule

- [1.1]: “Internet-based” research
- [1.2]: “Field-based” research
- [2.1]: Compare different types of solar panels

- [2.2]: Compare designs
- [2.3]: Decide on designs
- [3.1]: Gather opinions on design proposals
- [3.2]: Decide on final design
- [3.3]: Calculate final costs and benefits

Results and Discussion

We split up our results into five sections: Structure, Solar Panel Type, Construction Cost Estimate, and Energy Production Estimate, and Social Aspect to accurately answer each part of our objective.

Structure:

It was decided that combining the designs from the Arizona State University and Rutgers University solar canopy projects would provide the largest benefits. As was described in the "Introduction and Background" section, the solar canopy that we would like to construct is somewhere right between these two projects in terms of size. The ASU solar canopy project is 5.25 acres and is completely covered by a solar canopy. The Rutgers University solar canopy project is 32 acres but has driving lanes that are not covered by the solar canopies. Our design combines these two ideas into a solar canopy that would cover a total area of 16 acres. It would involve four, four-acre solar canopies that would be completely covered as in the ASU design (see Figure 11). While we do have 18.75 acres to work with at lot E-14, this would leave room for two intersecting driving lanes between the four canopies as well as landscaping on the perimeter. We like this design for several reasons. First, it provides a very large coverage area, which would provide a significant amount of energy throughout the year. Second, this design would allow for landscaping around the perimeter, which would not only make the parking lot look nicer but may also be necessary as the State Farm Center is now on the State of Illinois' list of top endangered buildings and changes to surrounding areas would likely need to be approved by an appearance commission. Finally, by constructing four separate solar canopies, the entire parking lot would not have to be under construction at once. Parking lot E-14 is used every day of the week and it may not be feasible to close the entire area down for construction at once. By constructing four separate solar canopies, only one section of the parking lot would be closed at a time, allowing for people to still park in the rest of the lot.

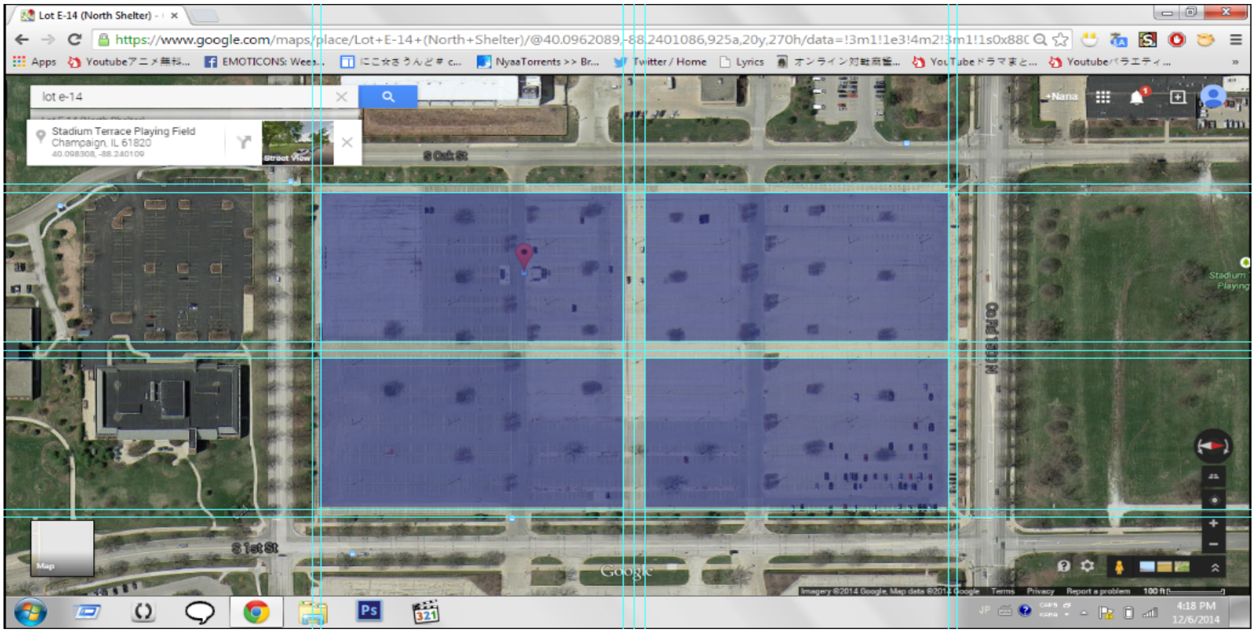

Figure 11. Proposed Design for Solar Array

Solar Panel Type:

Due to the fact that extreme heat is very unlikely in the Champaign-Urbana area, we have chosen to use monocrystalline panels for their superior efficiency and cost effectiveness over amorphous panels. Monocrystalline panels have also been around for a longer period of time and are therefore a more proven technology.

Construction Cost Estimate:

In order to make our cost estimate we conducted background research on several similar projects around the United States over the last few years. While the costs of several projects were considered, the ASU and Rutgers University projects took precedence as our design was modeled off of them. If we simply scale the ASU construction costs, the relative cost of our project considering the increase in size would be $35.2 million. This is our high estimate. At the same time, if we simply scale the Rutgers construction costs, the relative cost of our project considering the decreased size would be $20.4 million. This is our low estimate. Based on this information, as well as the costs of the several other projects outlined in the "Introduction and Background" section, we settled on a construction cost estimate of $30 million. We believe that this is a good if not slightly high estimate considering both size of project and decrease in price of solar panels over the past few years.

Energy Production Estimate:

We used the solar energy calculator at http://pvwatts.nrel.gov in order to create our energy production estimate for the proposed solar canopy on a monthly and annual basis. Pvwatts uses the projected weather from your location as well as the criteria laid out in Figures 12 and 13 below to give an extremely accurate energy production estimate.

Location and Station Identification

Requested Location	61820
Weather Data Source	(TMY3) UNIV OF ILLINOIS WI [BONDVILLE - SURFRAD], IL 7.8 mi
Latitude	40.06° N
Longitude	88.37° W

PV System Specifications *(Residential)*

DC System Size	11424.2 kW
Module Type	Standard
Array Type	Fixed (roof mount)
Array Tilt	20°
Array Azimuth	180°
System Losses	14%
Inverter Efficiency	96%
DC to AC Size Ratio	1.1

Figure 12. Location and System Specifications

Initial Economic Comparison

Average Cost of Electricity Purchased from Utility	0.09 $/kWh
Initial Cost	3.30 $/Wdc
Cost of Electricity Generated by System	0.15 $/kWh

Selected Incentives

Capacity Based Incentives (CBI)	DCEO - Solar and Wind Energy Rebate Program Rate: $0.00 - Maximum Amount: $50,000.00
Production Based Incentives (PBI)	Illinois Solar Energy Association - Renewable Energy Credit Aggregation Program Rate: $0.2/kWh

Figure 13. Economic Details and Incentives

RESULTS 11,480,623 kWh per Year *

Print Results

Month	Solar Radiation ($kWh / m^2 / day$)	AC Energy (kWh)	Energy Value ($)
January	2.57	668,962	60,608
February	2.42	562,701	50,981
March	4.12	997,205	90,347
April	4.16	957,033	86,707
May	5.01	1,167,134	105,742
June	5.96	1,288,889	116,773
July	6.57	1,425,677	129,166
August	5.48	1,217,579	110,313
September	5.06	1,097,732	99,454
October	3.62	863,553	78,238
November	2.58	611,656	55,416
December	2.44	622,503	56,399
Annual	4.17	11,480,624	$ 1,040,144

Figure 14. Final Estimated Energy Output and Economic Value

Figure 14 details the total estimated energy output for our 16-acre solar canopy. It states that the total energy production will likely be near 11.5 million kWh per year, which is worth slightly over 1 million dollars.

Social Aspect:

With any construction, the necessity of evaluating ethics and incentives plays an extremely large role. We created a brief survey using "SuperSimpleSurvey" to collect 150 responses within the University of Illinois students community to see if students who currently pay for a parking permit would be willing to pay an additional fee to utilize the covered parking that the implemented solar arrays would offer. The current rates for student parking are $660 for a 12-Month permit and $127 for the shuttle lot. We made sure to establish that the covered parking was due to a potential implementation of solar canopies. The options offered were "Absolutely Not", "Probably Not", "Yes at a Reasonable Fee", and "Definitely Yes" in response to whether they'd be willing. The results heavily favored "Yes at a Reasonable Fee," with 113 responding in favor of this category. While this survey only consisted of a very small pool of students, it is fair to extrapolate that a significant percent of people would be willing to pay the additional fee for covered parking due to a solar canopy.

Conclusions

The main reason for this study was to evaluate the financial feasibility of putting a solar panel parking structure at parking lot E-14. This entailed selecting both a structure for the solar panels to sit on and a type of solar panel with the ultimate goal of determining a price estimate for construction and an estimate for how much energy the solar parking lot will produce on a monthly and annual basis. A design that combined the best aspects of the Arizona State University solar canopy project and the Rutgers University solar canopy project was selected at an estimated construction cost of $30 million. This solar canopy, which consists of four separate four-acre canopies, will cover a total area of 16 acres and will produce about 11.5 million kWh annually. This comes out to slightly over $1 million worth of energy per year. With the high initial cost of implementing solar panels on such a large scale, the University of Illinois would likely have to find outside funding in order to make this solar canopy worthwhile. Using the above estimates, it would likely take 25-30 years in order for this solar project to pay for itself.

Reflections

The most useful part of the project experience for the members of our group was the experience that was gained in writing somewhat technical reports. While we have all taken English and Rhetoric classes previously we have not had much experience in writing a technical report of this length. The skills we gained in technical writing over the course of the semester will be invaluable in any future engineering projects we take on in the future as students or professionals.

Throughout this project we ran into several obstacles, some of which turned out better than expected and some of which proved incredibly hard to resolve. One example of this is our experience with Pvwatts. Prior to finding the Pvwatts website, we were really struggling to provide an accurate estimate as to how much power our solar farm would be able to output. Pvwatts proved to be an incredibly useful website in which we could input all of the information about the solar canopies that we planned to build and it provided an accurate estimate. Another example of an obstacle we faced was that most companies we contacted either did not respond or were not able to provide small-scale costs that we could utilize to calculate our own projections.

If we were to do this project again we would be more aggressive in reaching out to those who might be able to help us with our project. Our group reached out to several individuals both within the University of Illinois community and those in corporate America who had knowledge of solar panels and their implementation. While we reached out to several individuals, we heard back from relatively few and this caused us to have to do much more internet-based research.

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Appendix and Budget

The focus of our group's project was to determine the feasibility of solar panel implementation through research and communication with personnel about past projects, efficiency, and costs. For this reason, no budget was needed.