Solar PV Feasibility at UIUC

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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. The application of renewable energy technologies is becoming more prevalent as current, prospective, and past students engage universities and encourage participation in national programs addressing climate change and the 'greening' of campuses.

The University of Illinois' Student Sustainability Committee commissioned a solar photovoltaic study to determine viable buildings for the installation of solar arrays. The new solar arrays would complement the existing 3,700 square foot Solar PV array located atop the Business Instructional Facility that produces approximately 55,000 kWh/year and help define the University of Illinois Urbana Champaign as a leader in the greening of campuses nationwide.

The University of Illinois' Business Innovation Services (BIS) was the organization selected to manage the project. Throughout the project, BIS solicited input from the following organizations on campus:

- Student Sustainability Committee (SSC)
- Facilities and Services (Planning, Sustainability Coordinator and Utilities and Energy Services)
- University Housing
- Urban and Regional Planning
- Independent Experts on solar system design and implementation

Identifying appropriate locations to install the solar technologies was completed according to the following criteria: visibility to members of the university community, building/constructability characteristics, and net energy benefit to the university. Initially building rooftops with proper north-south orientation were investigated for the solar arrays. However, as the project moved forward, it was determined that additional solar powered structures would be considered as well, including:

- Parking structures
- Solar awnings on south-facing buildings
- Solar kiosks/gazebos

Based on the selection criteria described previously, the following five buildings should be considered for solar photovoltaic installations:

1. Nugent Hall
    - Perhaps the easiest installation possible
    - High visibility/education opportunities
2. Florida Avenue Residence Hall -Solar awnings
    - Costliest installation, but greatest potential value
    - Potential for significant teaching opportunity-solar awning case study
3. Siebel Center for Computer Science (ribbed metal roof)
    - Lowest cost due to ease of racking system installation (no roof penetrations)

4. Institute for Genomic Biology - North section
   - High visibility/education opportunities
5. Illinois Street Residence Hall –Townsend
   - High visibility/education opportunities

Other structures and locations that should be considered for installation of solar PV arrays include:

- Parking Garages at B4 (Goodwin and University) and F29 (Dorner and Gregory)
- Parking Lots at D22 (Illinois and Lincoln), D5 (Krannert), D1 (Illinois St.), F12, F8, & E11 (all on Lincoln), and E24 (ARC)
- Solar kiosks at various locations throughout campus to provide shade, shelter and power (a kiosk or solar gazebo was disqualified for the engineering quad, though quads and other areas frequented by students are good locations for consideration of solar powered structures.)

Outreach and dissemination of renewable energy technologies on campus is also a key element of this project. Currently the UIUC is working with the US Department of Energy (DOE), National Science Foundation (NSF) and others to establish a Clean Energy Education Center on campus. If this project moves forward, the solar PV system installations will become a key component of the Clean Energy Education Program.

About The University of Illinois Urbana Champaign, Business Innovation Services' (BIS) - Energy Management and Sustainability Services:

Organizations are rapidly discovering that environmental and business performance are intricately linked. Wasteful practices are not sustainable and are not only bad for the environment; they are bad for the bottom line. BIS works with organizations to improve both their environmental performance and overall competitiveness by reducing wastefulness associated with energy, materials, and water utilization.

Emerging climate change policies, volatile and upward trending energy prices, universal pressure on businesses to reduce costs, and increased public and investor awareness of environmental issues all demand prudent management of energy and materials use at the organizational level. BIS's strategic approach to energy management and sustainability addresses both managerial and engineered solutions to reduce wastefulness and improve sustainability.

Solar Feasibility Study

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. The application of renewable energy technologies is becoming more prevalent as current, prospective, and past students engage universities and encourage participation in national programs addressing climate change and the 'greening' of campuses. This has even reached into various independent organizations now rate campuses regarding how they incorporate sustainability into their everyday operations.

Both the Princeton Review Green Guide and College Sustainability Report Card provide grades for universities and their incorporation of sustainable or 'green' practices on campus. According to a survey of 12,000 college applicants by The Princeton Review, "64 percent of respondents said they would value having information about a college's commitment to the environment. Moreover, of that cohort, 23 percent said such information would 'very much' impact their decision to apply to or attend the school" (The Princeton Review, 2011). In this guide, that includes 311 universities, the University of Illinois – Urbana/Champaign campus is noted for its efforts to fund current and future green initiatives through the Student Sustainability Committee fees: one, a Clean Energy Technology fee ($2 per student per semester), and the other, a Sustainable Campus Environment fee ($5 per student per semester). The University of Illinois was one of 120 universities identified as a Campus Sustainability Leader for 2011, for those schools that achieved an average of A- or better across the six campus categories in the College Sustainability Report Card.

Sustainability and green practices, including the adoption and implementation of renewable energy as a means to reduce the campus carbon footprint, are becoming increasingly important in not only the selection of colleges for prospective and entering students, but also in current student's desire to participate in reducing our reliance on electricity from the grid. Colleges educate and train the next generation of leaders who will influence and impact what technologies are implemented and put into practice. Solar photovoltaic applications are an educational tool, community outreach, and demonstration of the University's dedication to sustainability now and in the future.

The goals of this project were to assess the feasibility for solar photovoltaic (solar PV) applications at the University of Illinois campus at Urbana-Champaign Illinois (UIUC), to estimate corresponding energy and environmental benefits at UIUC and to demonstrate education and outreach opportunities for UIUC students and staff. The study included investigating potential applications where solar PV technology could be successfully implemented on the UIUC campus. Key considerations regarding the various sites and applications investigated included: -visibility of the potential installation sites, physical characteristics and surroundings of the prospective locations, and input from key University personnel and organizations.

Solar PV at Other Universities

Solar-PV projects have been implemented at numerous universities across the United States. Solar PV has commonly been implemented in a variety of configurations, including:

- Incorporated onto roofs
- Installed as carports providing shelter for vehicles
- Installed as solar shades over windows thereby reducing interior solar gain, and
- Installed on light poles that provide power to exterior lights.

Descriptions of several examples of solar PV installations at public institutions similar to the University of Illinois are provided below. These include applications at: Penn State University, University of Texas, University of Indiana, University of Iowa, Northwestern University, Michigan State University, and UIUC's sister campus at the University of Illinois at Chicago. The solar PV projects are summarized in the following table.

Table 1 Summary of Solar PV Arrays in Several Universities

University	Size of Solar PV	Generation Potential
Penn State University	2 - 2kW	n/a
University of Texas	n/a	406,000 kWh
University of Indiana	2kW	n/a
University of Iowa	38kW	70,000 kWh
Northwestern University	16.8kW	20,000 kWh
Michigan State University	10kW	n/a
University of Illinois - Chicago	51.52kW	59,000 kWh +
University of Illinois – Urbana/Champaign	30kW	55,000 kWh

Penn State has installed two-2,000 Watt Solar PV systems; one on the roof of the Main Building at Penn State - Delaware Valley and one on the roof of the Physical Plant Building at University Park. The systems were donated to Penn State by Conectiv Energy and the Solar Schools program. The electricity generated is fed into the electrical distribution system of the buildings and reduces the amount of power purchased from the utility.

The University of Texas at Austin has installed two grid-tied solar cell power systems at the J.J. Pickle Research Campus (PRC) in north Austin. The university received almost $1.6 million through a grant from the State Energy Conservation Office (SECO) for this project. The systems together can produce nearly 406,000 kilowatt hours (kWh) of renewable energy per year, or about 3 percent of PRC's total energy consumption.

Figure 1 University of Texas PV Array

Indiana University has installed eight solar panels, capable of producing two kilowatts, on the roof of the Indiana Memorial Union. The panels are each 250 watts and are located on the left side of the Whittenberger Auditorium entrance. The system is monitored and data describing the energy produced is available to the community through a website. A sample screen shot of the monitoring system is captured and presented here.

http://www.mannplumbinginc.com/IndianaUniversitySolarEnergy.html

The University of Iowa currently employs solar panel technology on two facilities, the Solar Electric Vehicle Charging Station and the Cambus Maintenance Facility. The south-facing 180-foot solar photovoltaic (PV) array generates an estimated 70,000 kWh of energy annually. The surplus power generated by the station is distributed back to the UI power grid. The solar project was funded by a coalition including the Office of Energy Independence, Department of Energy, UI Facilities Management, UI Office of Sustainability, and UI Parking & Transportation.

Northwestern University recently installed the Centennial Solar Panel System; a solar photovoltaic array covering nearly the entire available roof of the Ford Engineering Design Center. The 16.8 kW system is connected to the building's electric grid and expected to generate approximately 20,000 kWh per year. The system was a product of two groups - Students from Engineers for a Sustainable World (ESW) and the Northwestern Sustainability Fund (NSF) – to achieve the implementation of this renewable energy project on campus. It is Northwestern University's first onsite renewable energy source and a new educational tool for the University and the community.

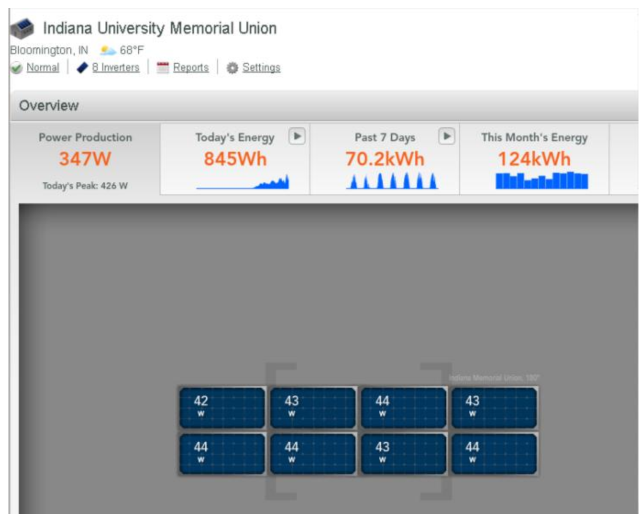

Figure 2 PV Screen Shot-Indiana University

Figure 3 University of Iowa PV Station

Michigan State University installed a 10kW solar photovoltaic system on its East Lansing Campus. Located at the Pavilion, the 72 module system was funded in part by a grant from the Energy Office of the state of Michigan's Department of Consumer and Industry Service. The system provides light to the interior of this 171,415 sq ft building that hosts hundreds of events throughout the year.

Figure 4 Michigan State University PV Array

At the University of Illinois Chicago Campus (UIC), the recently renovated Lincoln Hall became the first UIC project to earn LEED Gold certification. It uses both a multi-building geothermal heating/cooling system and its own solar photovoltaic panels. A 51.52 kW array of 224 solar panels were installed on the roof of Lincoln Hall. The solar panels are predicted to produce over 59,000 kWh over the next year. The system is tied to an on-line tool that monitors and graphically displays the current and past performance of the solar PV system, as shown in the snap shot below.

Figure 5 Lincoln Hall-UIC PV Array

Figure 6 Lincoln Hall PV Statistics (Screen Shot)

The entire Lincoln Hall PV array information can be monitored at the following URL: http://enlighten.enphaseenergy.com/public/systems/akcT2917

Existing Solar PV at UIUC

The University of Illinois at Urbana-Champaign has incorporated a solar photovoltaic array on the roof of the Business Instructional Facility (BIF) as part of the building's original design. The 3,700 square foot Solar PV array produces approximately 55,000 kWh of electricity per year, or 5% to 7% of the annual consumption of the new facility.

Solar Energy

Harnessing energy from the sun through solar photovoltaic technology is one of the most promising renewable energy sources that are commercially available. Photovoltaics (PV) convert the solar energy of sunlight into electricity. The physics of solar cells is based on the same semiconductor principles as diodes and transistors, which form the building blocks of the entire world of electronics. The technology is stable and fully commercialized. Solar panels are made from a collection of individual cells, typically made out of mono-crystalline silicon. A chemical reaction occurs when the cells are introduced to direct sunlight. The chemical reaction excites the electrons within the silicon, creating electricity in the form of direct current (DC) power. Solar PV modules do not have moving parts, operate silently without emissions, and require minimal maintenance. Solar PV modules generate direct current (DC) electricity (current), which when fed through an inverter will produce alternating current (AC) that can be used to power equipment within a building. The main barrier to widespread use of solar PV technology is the initial high equipment cost.

There are several types of solar photovoltaic technologies that fit in to one of two categories. They can be produced in many ways and have widely varying efficiency and costs per panel. The two groups are: discrete cell technology and integrated thin film technology. Discrete cell technology is comprised of single- or multi-crystalline silicon. Commercial single-crystal silicon cells can achieve 20 percent or more efficiency, while multi-crystalline silicon cells are typically near 15 percent efficiency. Integrated thin film technology uses amorphous silicon that can be integrated into building systems, such as replacing tinted glass with semi-transparent thin-film modules. Thin-film modules have an efficiency of over 10 percent in commercial systems; therefore they require more surface area to produce the same amount of energy as the discrete cell technology.

Power inverters are necessary for any solar power system that will be used for a grid-tied system. Inverters convert the solar panel DC output into alternating current (AC) power commonly used for equipment within a building. Grid-connected PV systems must have an inverter designed to produce a similar voltage of the electric utility provider (e.g. 240-volt AC output). Grid-tied inverters automatically use solar power when available, and use grid power when the solar power is insufficient to meet the building needs. Conversely, if the connected solar PV system is producing excess power, that power is fed back into the grid. The power company then gives a credit for the power provided to the grid. Net metering and interconnection standards are becoming increasingly common throughout the United States by utilities as consumers look to use renewable energy sources. There is no current national standard for net metering; states and utilities have developed policies and rate structures to account for customer-sited generation.

How the solar PV array is installed and where it is mounted affect not only the generation potential for the system, but also the installation costs. Solar PV arrays are typically mounted on a roof, on a pole, or as part of a shading device or car port. For roof mounted applications, such as those proposed for UIUC it is best to minimize the amount of additional roof penetrations needed to secure the solar array to the building or roof structure. The type of existing roof of the building is critical to determining how to mount the solar array, and the costs associated with the installation. Sloped, standing seam metal roofs offer a mounting solution that attaches to the elevated or standing portion of the roof, thereby minimizing any roof penetrations. Flat built-up roof or membrane roofs require a structure that can be attached to the building structure if the solar array is planned for an optimal angled installation. This requires investigating the existing building structure and the new structure for the solar array, to accommodate the added weight and loads (wind, snow, etc.) attributed to the solar array system.

A typical solar power support structural design should withstand wind gusts from 80 to 120 miles per hour. Prefabricated structures that are specifically designed for solar power applications are available from a number of manufacturers/installers. Prefabricated solar power support structures, are usually designed to withstand higher wind loads although they are typically more expensive since they are usually manufactured from stainless steel, aluminum, or galvanized steel materials. Typical roof mounted detail is shown in the figure below and is applicable to wood and concrete roof installations. Roofing contractors are typically consulted to ensure all roof-penetrations are properly sealed following rack installation. In order to prevent water leakage resulting from roof penetration, both wood and concrete standoff support pipe anchors should be thoroughly sealed with waterproofing compounds. Each standoff support is fitted with thermoplastic boots that are in turn thermally welded to roof cover material, such as single-ply PVC.

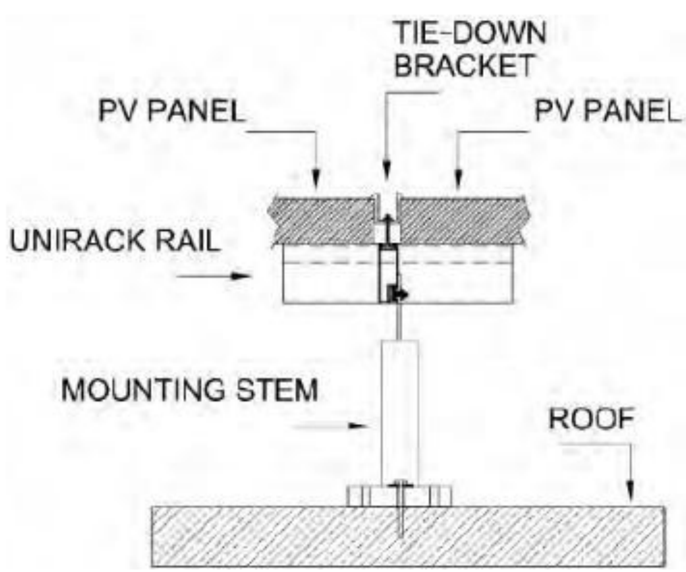

Figure 7 Roof Mounting Detail (Courtesy of Vector Delta Design Group)

Benefits of Solar PV

Solar PV technology-offers a number of benefits when compared to other commercially available renewable energy technologies. PV modules can be added to existing buildings, allowing power to be generated at point of use. Fixed solar PV modules do not have moving parts that can break down, do not require significant maintenance, or create noise. Solar PV systems that use tracking systems achieve higher efficiency, but also have moving parts that add to system complexity and maintenance requirements. Current funding and grant opportunities reduce the initial cost of installing solar PV systems. Solar PV systems are renewable technologies that are environmentally friendly, there are no emissions associated with their operation, and can be independent applications or semi-independent and connected to the utility grid. These systems are virtually maintenance free, last for decades (installers cite estimated useful lives for PV systems of 20-40 years), and do not have recurring operating costs. In many cases, solar PV systems can be supplemented with additional capacity in the future, depending on installation location.

The initial cost of installing solar PV systems can be a deterrent from implementing this renewable technology. Installation costs are comprised primarily of the panels themselves, the inverter required, wiring, mounting systems, and the labor to install the system. Costs for the materials have reduced over the past 5-10 years, and the systems continue to become more cost effective and more efficient. Solar PV systems require a large area for installation in order to generate substantial energy and a location with good exposure to the sun. The production efficiency is influenced by the amount of clouds, obstructions, and the surrounding environment. Energy is only produced by solar PV systems during the daylight hours, when in direct sunlight.

Maintenance Costs

As mentioned previously, one of the benefits of solar PV systems as a renewable energy technology is that they do not have moving parts (excluding solar tracking systems). From a maintenance standpoint, this is a tremendous advantage. Typically, most PV panel manufacturing companies recommend washing the panels that make up the array at least once a year to keep the panels clean and remove any buildup of dirt that can reduce the efficiency and energy output of the system by up to 5 percent. This is especially true for horizontally mounted PV systems. The panels and associated equipment should be visually inspected on a regular basis to spot any damage, particularly after major weather events. Though total maintenance costs for PV systems are not widely available in the literature, local installers have stated annual maintenance costs in the range of $0.005-$0.015/kWh produced ($600 to $1,000 per year for a 30kW array installed in Central Illinois).

Many solar PV installation companies typically provide one to three years of maintenance visits as part of the installation contract, with options for extensions. During these visits, the technician will verify that the system's electrical connections are intact and working efficiently. This inspection may also include voltage readings performed on the individual panels to confirm maximum performance and to spot problems not visible to the naked eye from the ground, like problems with the seals around the individual panel frames. Ongoing monitoring of solar PV panels can provide the real-time voltage readings on individual panels, depending on how the monitoring system is set up.

Study Methodology

Identifying appropriate locations to install the solar technologies was completed according to the following criteria: visibility to members of the university community, building/constructability characteristics and net energy benefit to the university. Each of these criteria was investigated as part of this opportunity assessment.

Visibility

Sustainability initiatives achieve greater support when the installed technologies are visible to the community: both the students and staff and the larger community at the University. Though this may be difficult for some of the buildings, some buildings have visibility either from the ground (preferable) or from adjacent buildings. Another mechanism for visibility that can be addressed for future consideration perhaps during the implementation planning stages is the monitoring of the generation of the installed solar photovoltaic system and providing that information to the public through a website, newsletter, or kiosk in a high traffic area (e.g. the host building or the Illini Union).

Building Characteristics

The physical building characteristics were also considered in the opportunity assessments. Issues such as roof structure and construction, visibility of the building, surrounding environment, electrical system condition, and building loads were evaluated when determining the initial buildings for consideration. How the solar technologies will be installed and accessibility to the proposed installation locations ~~are~~ were key factors. This included evaluating potential mounting mechanisms, orientation, mounting angle, and other installation issues. All of these factors impact the location and size of the solar technologies to be proposed. Solar technologies rely on ready access to the sun in order to effectively and efficiently turn the sun's energy into useable AC power. The surrounding buildings, trees, and other obstructions were considered during the building assessment. The potential for efficiency reduction will be considered when revising the building list.

Energy Benefit

The principal benefit of a solar PV array is electricity. At the outset of this project, it was anticipated that as many as 5 buildings would be selected for solar feasibility analysis based on the usefulness of solar energy technologies to be applied to the building. Efforts were made to understand each building's major energy using systems, overall electricity requirements of the facility and potential interface points for solar arrays. PV array size optimization was not a consideration since virtually all of the buildings have electricity requirements much larger than even the most efficient PV arrays can provide economically.

Phase One-Initial Building List

Throughout this project, The University of Illinois' Business Innovation Services (BIS) engineers obtained background information, input and feedback from key UIUC personnel regarding building operations and access, construction policy and protocols, building drawings, etc. Key personnel that contributed to this project effort include:

- Suhail Barot, Chairman, Student Sustainability Committee (SSC)
- Amy Allen, Student Sustainability committee
- Helen Coleman, Director of Planning, Facilities and Services
- Kent Reifsteck, Director of Utilities and Energy Services, Facilities and Services
- Morgan Johnston, Sustainability Coordinator, Facilities and Services
- Rick Gallivan, Architectural Draftsman, Facilities and Services
- Beth Leitz, Records Information Management Specialist, Facilities and Services
- John Humlicek, Associate Director for Housing
- Jeff Riddle, Assistant Director for Housing
- Brian Deal, Professor, Urban and Regional Planning
- Ty Newell, Professor Emeritus, Mechanical Science and Engineering
- Tim Lindsey, Principal Investigator, BIS
- Michael Chimack, Project Manager, BIS

BIS began the process of evaluating the feasibility of installing solar PV systems at the University of Illinois Urbana-Champaign by having a kickoff meeting with the stakeholders of the project. Meeting goals, objectives and timeline were discussed. Following the meeting, SSC and BIS created an initial list of the portfolio of buildings on campus where PV installations could be 'easily' installed. All architecturally protected buildings, buildings whose roofs are shaded for any reason, buildings with roofs that did not have the proper north-south orientation or where installations might be difficult were excluded from evaluation. The initial buildings list was then refined to a list of buildings that have reasonable visibility to the student population, can provide significant energy impact to the existing building loads, and whose physical structure could support the proposed installations. The types of buildings range from laboratories, to performing arts centers, libraries, and academic buildings.

The UIUC building database was also used to identify potential building locations. Additionally, Google Earth was used for aerial views of the potential buildings, the surroundings, and orientation. The initial list of buildings considered for solar PV is listed in Table 2.

Table 2 Initial Building List for PV Installation

Initial Building List	
Krannert Center	Undergraduate Library
Timothy J. Nugent Hall	Campus Recreation Center East
Swanlund	Illini Union Bookstore
Activities & Recreation Center	Agricultural Engineering Sciences
Alice Campbell Alumni Center	Allen Hall
Engineering Sciences Building	Illini Union (center of roof)
Temple Buell	Plant Sciences Lab
Institute for Genomic Biology	Everitt Lab
Labor and Employment Relations	

Following the development of the initial buildings list and elimination of inappropriate buildings through the Google Earth evaluation, BIS visited the campus to tour the identified buildings with Mr. Rick Gallivan, Architectural Draftsman. Each building on the principal list was evaluated during the site visit. The information collected included building use, size (square feet, stories, etc.), construction details, age of the buildings, roof size and condition, description of existing equipment on roof, access to electrical panels (potential electric interconnection points) and an 'ease of installation' ranking based on building characteristics. These steps assisted with identifying electric interconnections, potential structural issues, and overall constructability questions. From those site visits, some buildings were eliminated, while others were added. The building list was reduced to the top 5 potential building installation sites based on the evaluation criteria. They are listed in the Table 3. In addition, three alternate buildings were identified for consideration.

Table 3 Post-evaluation Building List for PV Installation

Final Proposed Building List	Alternate Buildings to Consider
Illinois Street Residence Halls	Psychology Building
Florida Avenue Residence Halls	Illini Union Bookstore
Grainger Library	NCSA Petascale
Institute for Genomic Biology	
Enterprise Works (Research Park)	

In general, the Champaign-Urbana area receives an average of 4.74 $kWh/m^2/day$ of solar radiation. This varies throughout the year, with the highest solar radiation occurring during the summer months, as shown in Figure 8.

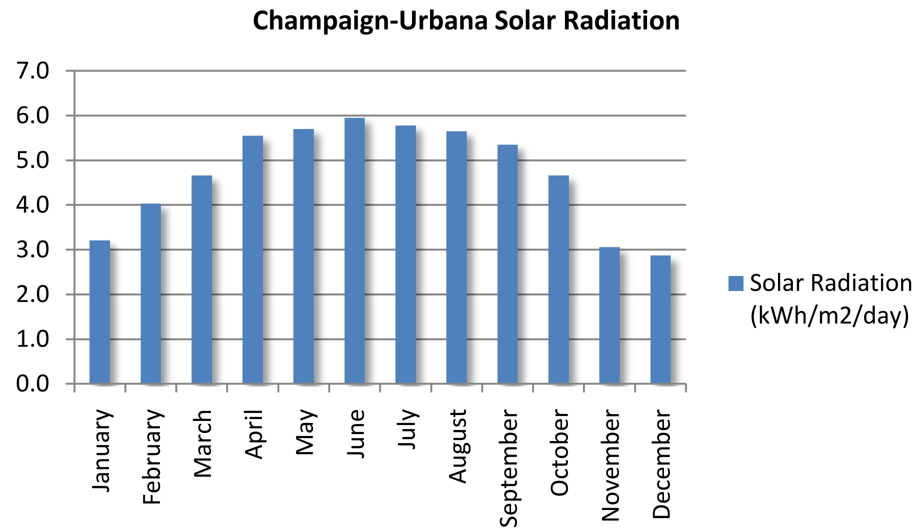

Figure 8. NREL Average Solar Radiation by Month for Champaign-Urbana

Potential solar PV system array options for the initial list of buildings were modeled using the SolOpt program provided by the National Energy Renewable Laboratory (NREL). SolOpt is an Excel-based modeling tool that predicts energy generation/cost avoidance from user defined solar PV arrays. Further, the program presents economic analyses based on the type of array installed, geographic location and local cost of electricity. This was done to determine the potential for generating energy from the solar panels for each building, the associated avoided electric costs, and the avoided greenhouse gas emissions. This assumes the optimal angle for the installation and directional location are utilized.

The results from the initial optimization modeling using the SolOpt software are presented in the table below. The annual system production is based on the angle of installation and solar characteristics for the area.

Table 4. NREL SolOpt Optimal Solar PV System by Proposed Location

Output Table		Genomic Biology	Illinois Street Residence	Florida Avenue Residence	Grainger Library	Enterprise Works
Optimal PV System Size	ft^2	3,000	1,000	1,000	5,000	3,800
Optimal PV System Capacity	kW	37.4	11.8	11.8	58.9	44.8
Number of PV Panels	-	214.4	71.5	71.5	357.3	271.6
Annual System Production	kWh	38,860	12,269	12,269	61,343	46,621
CBECS Energy Use	kWh	2,475,000	2,235,000	2,385,000	920,000	969,000
Cost Savings	$/yr	$3,109	$981	$981	$4,907	$3,730
System Cost with Incentives	$	$280,165	$88,410	$88,410	$442,051	$335,958
Greenhouse Gas Reduction (GHG)	tonnes CO2e	20	6	6	31	24

The potential electric energy generated by the solar PV system equals between 1-7 percent of building loads, as predicted by the Energy Information Agency Commercial Building Energy Consumption Survey (CBECS) electrical consumption data. Based on the system costs (without consideration of potential grant funds that may be available) and the current costs of electricity for the area, the simple payback for the solar systems for each building is greater than 100 years. A budget number of $7,500/kW was used as a cost for installation for the solar PV systems.

The final proposed building list and the identified alternate buildings, all met some or all of the selection criteria. All of the buildings have direct south-facing roofs or capacity to mount solar panels facing to the south to maximize the potential for renewable energy generation. The identified buildings have minimal or no shading that might negatively impact the efficiency of the proposed solar PV systems. In each case, there is at least some visibility and, in some cases, high visibility potential of the PV systems to current students, faculty, staff, alumni, and visitors for the buildings selected in the narrowed down list. Additionally, 4 out of 5 buildings have high student utilization. From an application standpoint, all of the buildings had high single-phase loads, which helps in the offsetting of current electric energy usage in the specific building. Note, Illinois Street Residence halls and Florida Avenue Residence halls could not be evaluated during the initial campus building evaluation trip because of policies restricting access.

Phase Two-Final Solar PV Concepts for UIUC

A second site visit was necessary to evaluate additional potential locations for the solar PV installations, particularly the residence halls and parking structures. During the second site visit to campus, BIS invited a local solar PV installation expert, Mr. Tom DeBates, Owner of Habi-Tek, Inc. to join BIS in assessing the Illinois Street Residence Halls and Florida Avenue Residence Halls. Moreover, Mr. DeBates provided pertinent commentary regarding the installation of solar PV on the various UIUC buildings. He is eminently qualified to provide input as he has commissioned dozens of solar PV projects on building and ground mounted solar systems and is an advisor to UIUC's Solar Decathlon team.

During the site visit, many solar configurations were discussed for Illinois Street Residence Halls and Florida Avenue Residence Halls. Because Florida Avenue Residence Halls have 8-foot parapet walls, solar PV was deemed infeasible for the tower building. However, Florida Avenue Residence Halls are an ideal location for considering solar awnings. This application will be discussed in the next section.

The roof of Nugent Hall was inspected and assessed as a very good location for a PV array. Nugent is located in the southwest part of campus in an area where older residence halls are being razed and replaced by new halls over approximately the next 10 years. This area has significant and consistent presence of students and, since Nugent is only five stories tall, a PV array would be visible to pedestrians. Further, the roof is new and has an unabated southerly view.

Other Solar Configurations

Based on the concerns expressed by various F & S and Housing department staff regarding roof installations, alternative solar PV configurations were investigated. The idea for structures not directly on top of buildings was explored for the increased visibility by the students, faculty, staff, and community to further educate on renewable energy technologies on the UIUC campus.

Solar Awnings

Solar awnings attach to the existing building structure over doorways and windows, thereby providing both shelter and shade, while generating renewable energy. By shading the windows, the solar awnings serve a secondary purpose in reducing the amount of solar heat gain and glare for the interior spaces. A conceptual example of solar awnings is shown in Figure 9.

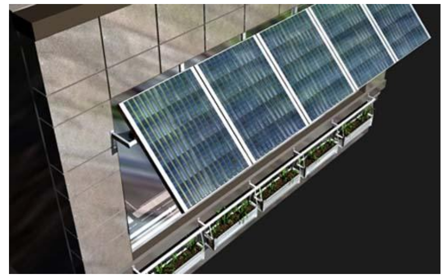

Figure 9 Example of Solar Awnings

An example of solar awnings currently used in a building located in Chicago is shown in Figure 10. The Chicago Center for Green Technology uses solar PV integrated into the window awnings. The entire array provides 10kW of usable electricity for the building.

Figure 10. Chicago Center for Green Technology Solar Awnings

Following the second site visit, the Florida Avenue Residence Halls were assessed for the possibility of installing solar awnings to not only generate energy from the solar array, but also provide shading to the existing windows. The Florida Avenue Residence Halls walls are ideally oriented for solar PV and would be excellent sites for visible solar PV demonstration projects. One potential design could involve selecting a number of floors on the tower of Florida Avenue Residence Halls, installing solar awnings, then monitoring energy use and power generated by the PV awnings. Simultaneously, energy use on the floors not covered with solar awnings can be monitored and a comparison can be made to the energy use on the floors with solar awnings.

Michael Chimack, Dr. Ty Newell, UIUC College of Engineering Professor Emeritus and Tom DeBates had a meeting following the walk-through of the residence halls to discuss other potential solar applications at UIUC. Dr. Newell emphasized the potential benefits of installing solar PV on Florida Avenue Residence Halls or any south-facing dormitory. Though beyond the scope of this project, Dr. Newell, developed a basic energy model demonstrating how installing solar awnings on the Florida Avenue Residence Halls would be beneficial and could move the dormitories toward net-zero energy buildings[1]. This model was intended to demonstrate how solar awnings can simultaneously offset electric load directly by generating power and indirectly by reducing the cooling load of the floors during the summer months. Assumptions of the model include:

[1] A net zero energy building (NZEB) essentially has zero net energy consumption and zero carbon emissions annually. In theory, a NZEB could be removed from the utility grid.

- Single floor (results will scale with increased or decreased area)
- Directly south facing windows with an area of 40square meters
- Wall area of 200square meters (insulation value assumed to be ~R13)
- No reflective film on the windows
- Solar heat gain factor of 0.5
- Electric energy requirements to condition a typical floor of rooms is 5700kWh per year
- Solar PV panels are mounted above the windows as overhangs (assuming panels are oriented to cut off solar from spring equinox to fall equinox)
- Coefficient of performance of air conditioning system = 3.0

Based on the model, the solar awning panels properly placed as overhangs would produce approximately 5,700kWh of electricity and reduce cooling demand by another 2,700kWh for a total of 8,400kWh net electric benefit per year per floor. In addition, the solar PV system could generate excess power during the summer months (if building is not used), helping reduce the campus peak power demand.

Solar Parking Structures

Covered parking structures are highly visible, and offer additional benefits of added shelter, shading, and weather protection for those visiting or driving to campus. Most people will choose to park in a covered area verses a parking spot exposed to the elements- rain, snow, and the summer heat. Therefore, adding solar carport structures provides additional perceived value beyond renewable energy generation. Additional opportunities to implement solar technologies on campus include bus shelters, with the same idea as a carport; provide shade and shelter from the weather. Most solar PV carport structures can be sized to fit standard and complex parking lots. As part of the carport structure, lighting and security cameras can also be added as an option. Carport structures with solar PV can also be used as docking and charging stations for hybrid and electric vehicles. A solar powered parking structure can power lighting for the covered parking structure, as well as other ancillary loads in proximity to the parking facilities.

The installation costs for parking structures can be 10-20% greater than a standard roof mounted system since the mounting systems are larger and installation requires more time.

Typical UIUC open parking lots and examples of solar canopies used in covered parking lots are shown in Figure 11 and Figure 12 below. A parking lot map demonstrating good applications for solar canopies is shown in Figure 13

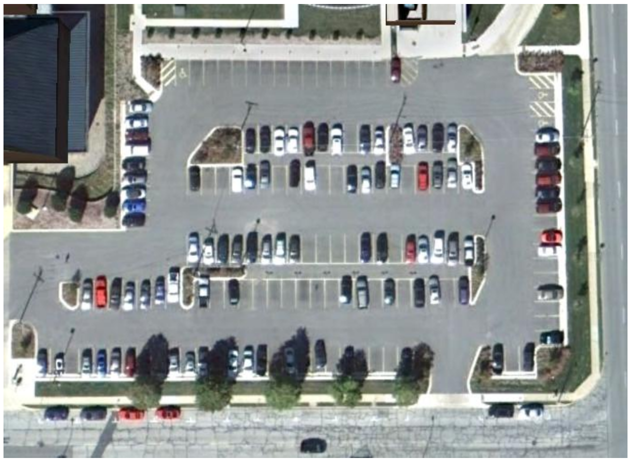

Figure 11. Typical UIUC Open Parking Lot

Figure 12. Solar Canopies for Open Parking Lots

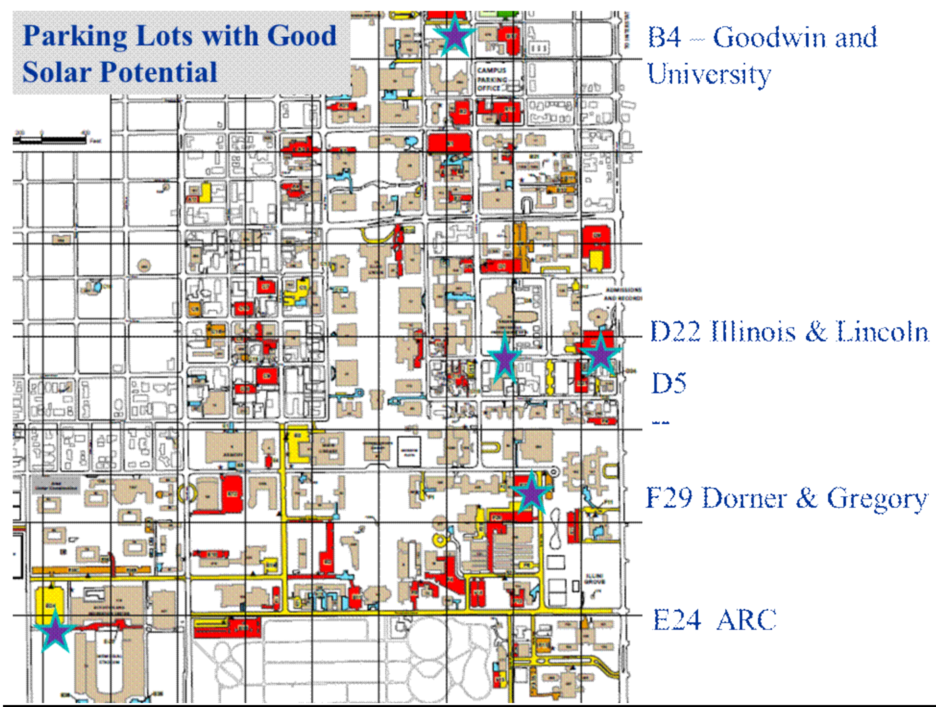

Figure 13 UIUC Potential Solar PV Parking Lot Locations

Other Solar Structures

Kiosks and gazebos are structures that provide short-term shelter for a variety of reasons. Installing solar kiosks on campus can provide sheltered areas for students to study while providing power for computers, electric vehicles, or other peripherals.

Kiosks and gazebos do not require changes in the roofing that other roof-mounted systems may require, are relatively easy to install, and provide sheltered and shaded locations for students to gather in areas with high volume of student, faculty, staff, and visitor traffic. Examples of solar gazebos and kiosks are shown in the images below.

Figure 14 Solar Powered Kiosks

Educational Opportunities

Outreach and dissemination of renewable energy technologies on campus is also a key element of this project. Currently the UIUC is working with the US Department of Energy (DOE), National Science Foundation (NSF) and others to establish a Clean Energy Education Center on campus. If this project moves forward, the solar PV system installations will become a key component of the Clean Energy Education Program.

As part of any installation of solar PV technologies on campus, the performance of installed solar arrays should be monitored, not only for maintenance purposes, but also from an educational view point. A web-enabled monitoring system, such as the one installed at the UIUC sister campus at the University of Illinois at Chicago, would allow the remote monitoring of any installed solar PV systems that could then be used not only in the classrooms and laboratories, for research, but also to educate past, current, and prospective students to the renewable energy technologies and the associated impact on greenhouse gas emission reductions and carbon footprint of the campus. Figure 15 shows a snapshot of the UIC website demonstrating various power statistics and daily, monthly or seasonal load patterns.

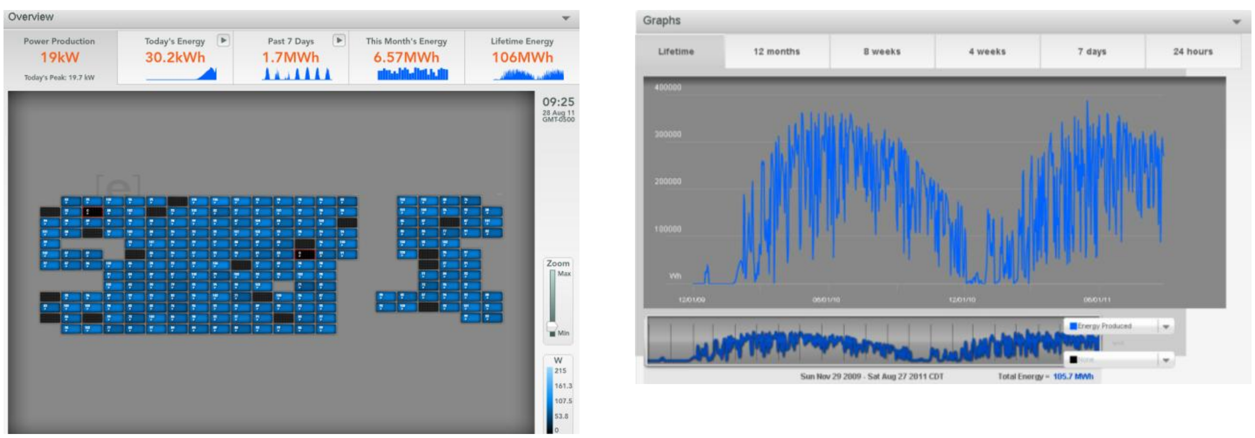

Figure 15. UIC Lincoln Hall Solar PV Real Time Energy Website: Solar Array and Energy Generation

Recommendations

The goal of this project was to identify potential locations for the installation of solar PV systems across the UIUC campus through working with the SSC and UIUC F&S. Five buildings were identified, as well as other structures and locations (kiosks, gazebos, and parking covers) based on the criteria of visibility, constructability, and surrounding environment. The next steps for the realization of installing more renewable energy technologies and system on the UIUC campus is to obtain approval from affected parties and to complete an engineering study that will include developing detailed specifications for all potential solar PV systems.

Based on the selection criteria demonstrated previously, the following five buildings should be considered for the solar photovoltaic installations:

1. Nugent Hall
    - Perhaps the easiest installation possible
    - High visibility/education opportunities

2. Florida Avenue Residence Hall -Solar awnings
    - Costliest installation, but greatest potential value
    - Potential for significant teaching opportunity-solar awning case study

3. Siebel Center for Computer Science (ribbed metal roof)
    - Lowest cost due to ease of racking system installation (no roof penetrations)

4. Institute for Genomic Biology - North section
    - High visibility/education opportunities

5. Illinois Street Residence Hall –Townsend
    - High visibility/education opportunities

Other structures and locations that should be considered for installation of solar PV arrays include:

- Parking Garages at B4 (Goodwin and University) and F29 (Dorner and Gregory)
- Parking Lots at D22 (Illinois and Lincoln), D5 (Krannert), D1 (Illinois St.), F12, F8, & E11 (all on Lincoln), and E24 (ARC)
- Solar kiosks at various locations throughout campus to provide shade, shelter and power (a kiosk or solar gazebo was disqualified for the engineering quad, though quads and other areas frequented by students are good locations for consideration of solar powered structures.)

Nest Steps: Design and Cost Considerations

The decision to install solar PV on the UIUC campus is multifaceted. If this initiative moves forward, the next step required is to conduct an engineering study, which is necessary for establishing an actual project design. The essence of the engineering study is to design the actual solar installation, evaluate and estimate the power generation, and determine the cost and benefits of the installation for the life span of the project. Results of an engineering study should include design scope and financial cost derivations including, but not limited to:

- Solar PV module cost (dollars per dc watts)
- Engineering design, which includes electrical, architectural, and structural disciplines
- Support structure hardware
- Electric devices, such as inverters, isolation transformers, and lightning protection devices; and hardware such as electric conduits, cables, and grounding wire
- Material transport and storage

- Labor wages (prevailing or nonprevailing) and site supervision (project management)
- Construction drawings and reproduction
- Permit fees
- Maintenance training manuals and instructor time
- Maintenance, casualty insurance, and warranties
- Spare parts and components
- Testing and commissioning
- Overhead and profit
- Construction bond and liability insurance
- Mobilization cost, site office, and utility expenses
- Possible federal taxes and state sales taxes
- Insurance/liability considerations

A licensed structural engineer should design all solar power installation platforms and footings.

An industry endorsed budget number for solar systems is $7,500 per kW installed. This is an average number from a number of sources[2] in the literature for all types of solar installations. The Student Sustainability Committee (SSC) has $200,000 available for implementation of the solar demonstration systems. Additionally, the Illinois Department of Commerce and Economic Opportunity (DCEO) may be able to match the SSC funds on a 3 to 1 basis, resulting in an additional $600,000 for solar system installations. The funding from DCEO requires completing a grant application and meeting minimum financial criteria for the proposed system.

With the available funds from the SSC and managing costs effectively to minimize cost overruns approximately 25 kW of solar arrays can be installed on the UIUC campus. Acquiring funding from DCEO would allow for much larger solar arrays or more importantly leveraging the new solar arrays with ancillary equipment required to ensure educational opportunities are created for the benefit of the UIUC students.

[2] Government, research, manufacturer, installation contractors, etc.

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