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Research article

Implementation of a large-scale solar photovoltaic system at a higher education institution in Illinois, USA

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Abstract: Solar energy has several environmental, economic, and educational benefits for college campuses, but it is difficult for state schools to find funding for these projects. This study shows that a solar photovoltaic (PV) system on Illinois State University's (ISU) campus is technically and financially feasible. While there have been several solar feasibility studies of higher education institutions in USA, there has been a lack of in depth financial analysis. We conducted solar site assessments on five potential locations on campus, used a solar energy performance model to analyze the technical feasibility of each location, and performed a financial assessment using a professional PV financial modeling tool to compare different financing options. Our results show that three sites on campus can be used to develop a combined solar PV system of one megawatt. Both direct and third-party ownership models are financially feasible for this combined system. Our findings can be replicable as a case study for future solar PV system development on college campuses.

Keywords: photovoltaics; renewable energy; energy modeling; feasibility study; sustainability; higher education

1. Introduction

College and university campuses use enormous amount of energy on a daily basis to operate buildings and facilities used by students, faculty, staff, and visitors. Due to the large energy needs of these higher education institutions, and the increasing concerns of consuming conventional fossil fuel sources, many institutions in the US are now trying to actively implement renewable energy projects such as solar photovoltaic (PV) systems on their campuses.

The need for sustainable change and transition to a low-carbon emitting society is a widely held view at higher education institutions as shown in the American College and University Presidents' Climate Commitment [1]. This program was created in an effort to address climate change, reduce greenhouse-gas emissions by colleges and universities, as well as to drive research and promote education. Many colleges and universities in Illinois are currently experiencing difficult economic situations as well as fierce competition in attracting prospective students. Installing a commercial scale solar photovoltaic system on campus can be a great opportunity for universities and colleges to highlight their commitment toward sustainability. From an aesthetic point of view, a solar PV system on campus creates an impression of a forward thinking and green institution for students, faculty, and visitors. Although solar panels look progressive and innovative, whether installing a large solar PV system can generate substantial savings on electricity bills is still in question and this is not well understood by investment offices at the universities and colleges. Therefore it is critical to assess reduced energy costs and carbon footprint, increased education and research opportunities, and enhanced reputation which can support this sustainable energy initiative as a good investment for academic institutions.

A number of colleges and universities were reviewed that have applied photovoltaic systems in order to gain insight and learn from their experience of developing PV systems at academic institutions. In particular, we looked at the University of Colorado at Colorado Springs that installed a 14 kW PV system on their Science and Engineering Building in 2010 [2]. The project informed us how an academic institution planned, financed, and installed a moderately sized photovoltaic system. Another institution reviewed was Smith College that installed a 29 kW PV system in 2010 [3]. Their experience taught us how to structure a Power Purchase Agreement (PPA) to maximize benefits to the institution. We also looked at schools that chose a direct ownership strategy. A case study of Libertyville Highland Middle School demonstrated how schools in Illinois can take advantage of a grant from the Illinois Clean Energy Community Foundation in order to directly own their PV system [4]. The Libertyville School received a $1.8 million grant to help finance their 900 kW installation in 2014. Finally, we looked at Agnes Scott College who used a green revolving loan fund to finance a 6 kW PV system on their observatory [5]. Their projects showed us that incorporating creative financing strategies is crucial in assessing the financial feasibility of renewable energy projects. Some other studies developed and validated the methodological framework to assess the optimum capacity and benefits of statewide grid-connected renewable energy options in Illinois [6,7].

Although the previous case studies showed how their solar PV systems were implemented, none of them suggested how we should select an appropriate solar PV system size considering different financing options. Here we report that choosing the right system sites, and matching financing strategies to the institutional culture can maximize the solar energy system's potential for value creation.

2. Materials and Method

2.1. Site Assessment

The site assessment was performed to evaluate the suitability of potential solar sites, subsequently used to estimate the solar energy generation potential of the selected sites at Illinois State University in USA using a solar energy performance model. The structural integrity of the targeted buildings were evaluated and the advantages and drawbacks of each roof were identified. We assessed a variety of sites suitable for solar installation including rooftops, parking lots, and open fields based on the availability of space and future development plans on campus. After consulting with the university's facilities department, a total of eleven sites were selected for detailed site assessment. Once initial sites were selected, an on-site solar assessment was conducted using Solar Pathfinder. This device was utilized to perform a shading analysis at various points to assess solar access of each site which can be used to determine solar resource availability throughout the year. These sites were measured, using a measuring wheel, to determine the correct space available for the solar PV system. Rooftop measurement was based on satellite imagery as access to some roof structures was not permitted.

2.2. Energy Performance Model

Once a solar site assessment was completed for 11 sites on campus, a number of solar developers were contacted for system cost estimates based on the gathered site data. We used the suggested solar PV system components and system size specifications from a local solar developer to model the system using System Advisor Model (SAM) developed by National Renewable Energy Laboratory (NREL) for each location. SAM is an energy performance modeling software that contains weather data from the National Solar Radiation Data Base (NSRDB), as well as solar module and inverter performance data. After inputting various components, the software can estimate a potential annual energy production based upon the system size, equipment used, and annual solar resource availability from the local weather station. The annual energy production can then be used to perform a financial analysis based on the cost of the electricity produced and other economic variables including energy escalation rate, inflation rate, and discount rate.

2.3. Financial Analysis

Following the technical analyses of all potential sites, their financial performance was modeled using the PV finance model developed by the Midwest Renewable Energy Association (MREA). This PV finance model was utilized to calculate system cost, available incentives, payback period, return on investment, and cash flow. The model also calculated various environmental benefits of the PV systems, such as coal and gasoline offsets, miles driven in an electric vehicle charged by the system, and acres of forest required to offset an equivalent amount of CO_2. We modified the MREA model to include operations and maintenance costs, and revenues from selling solar renewable energy credits (SRECs). We also changed the weather data to utilize Typical Meteorological Year

(TMY) 2 instead of TMY3. We determined the TMY3 dataset to be inaccurate for this location as some sections of the data were incomplete.

The prices for the Solar Renewable Energy Credits (SREC) in Illinois were taken from the November 2015 procurement results. Sub 500kW systems had an SREC price of $115/SREC, and systems over 500kW rated at $130/SREC [8]. These prices were for a five year contract, but since re-bidding is allowed, we assumed a $100/SREC price for 10 year contracts. Even though 10 year SREC contracts are not unrealistic, we made our investment recommendations based on five year contracts in order to follow the fiscally conservative nature of the university. A comparison of financial results with either SREC term is shown in Table 1. Operation and Maintenance (O&M) cost of $5/kW per year for roof mounted systems and $10/kW per year for parking canopies and ground mounted systems were applied based upon the local PV system installers' system cost estimates.

Table 1. Comparison of financial results under a five year and a ten year SREC contract in a direct ownership model.

System	Payback Period (years)		IRR (%)		Lifetime Savings ($)	
	5 year SREC	10 year SREC	5 year SREC	10 year SREC	5 year SREC	10 year SREC
CRE (110 kW)	9.6	5.3	11.71	20.94	450,556	515,258
CRE (1MW)	8.4	5.0	13.29	21.85	4,402,272	4,886,672
Gregory St.	13.3	8.0	8.09	14.06	2,372,631	2,864,781
CPA	6.0	6.0	18.47	18.47	346,675	346,675
McCormick	10.6	10.6	10.47	10.47	133,526	133,526
SSB	10.6	10.6	10.47	10.47	125,968	125,968
Kingsley St.	10.2	7.1	10.93	15.77	338,426	424,552
School St.	19.5	16.4	5.13	6.21	431,533	603,785
Main St.	19.2	12.6	4.91	8.62	595,668	789,165
Ropp	22.1	15.6	3.82	6.66	604,095	833,765
N. University Garage	70.9	64.3	-3.23	-2.74	-318,758	-252,728
S. University Garage	59.5	52.9	-2.33	-1.70	-815,033	-550,913

To maximize potential financial benefits, each system was modeled with both direct ownership and third-party ownership scenarios. State universities do not pay taxes, and so tax credits themselves are not useful to these universities. As Illinois State University does not have a tax appetite, we used a power purchasing agreement (PPA) in order to utilize the 30% federal investment tax credit. For direct ownership exclusively, the Illinois Clean Energy Community Foundation offers a grant of up to 60% of the system cost, but it is conditional on retiring all SRECs [9].

After analyzing preliminary financial modeling results, further detailed calculations were done for the selected sites. For parking canopy systems, a $200 increase per parking pass, and a $10 increase for tailgating permits were added to the revenue stream (Table 2). These covered parking fees were assumed to escalate at a rate of 1% per year. A probable power purchase agreement rate was estimated for each system with 2% annual escalation. The current electrical rates were assumed to escalate at 2% per year. Finally, lifetime savings for the university were determined based on the calculated costs and revenues for each system.

Table 2. Parking canopy savings for the university over a 25 year PPA.

Parking Lot	Current Cost of Electricity ($)	PPA Cost of Electricity ($)	Net Cost of Electricity ($)	Parking Spaces	Parking Revenue ($)	Net Savings ($)
Kingsley St.	395,500	790,999	-395,500	70	499,199	103,699
Ropp	1,054,666	2,109,332	-1,054,666	160	912,820	-141,846
Main St.	888,556	1,777,112	-888,556	150	855,769	-32,787
School St.	790,999	1,581,999	-790,999	132	753,077	-37,923

3. Results and Discussion

Considering all the potential benefits from each site, as well as the current financial status of the university, three sites were selected that can be utilized for campus PV development in two phases. In order to select the top three sites, a stakeholders meeting was held with staff members from the offices of the University Architect, Energy Management, Sustainability, Facilities, Parking & Transportation, University Marketing, Admissions, and Alumni Board, as well as two faculty representatives. The Kingsley Street parking lot (Lot G53) (Fig. 2.), roof of the Center for Performing Arts (CPA) (Fig. 3.), and the Center for Renewable Energy (CRE) (Fig. 4.) were selected. The first phase recommends the most financially realistic options that maximize publicity, recruitment, and educational benefits. The second phase serves to develop a whole one megawatt system that can generate substantial economic gains.

Figure 2. 3D rendering of Kingsley (G53) parking lot PV canopy system.

A ground mounted system will be located at the Center for Renewable Energy (CRE) because that is one of only two large and open university owned spaces. It can provide educational and research opportunities at the CRE, and the adjacent Shelbourne apartments have a very high electricity rate between $0.08/kWh and $0.12/kWh depending on the season. The system will be sized as 110 kW, which will be enough to cover the electricity needs of university staff apartments at the adjacent complex. It is sized to fit the apartments' demand in order to allow for direct university ownership without losing financially from net metering an oversized system. Nevertheless, we recommend a PPA as the university would most likely be currently reluctant to make a $231,000 investment. Assuming a 20 year PPA with a rate of $0.075/kWh (2% annual escalation) and a five year SREC contract, the university would save $98,473 over the term of the PPA. This would also serve as a learning experience for the university to be familiar and comfortable with PPA contracts before making agreements on larger systems.

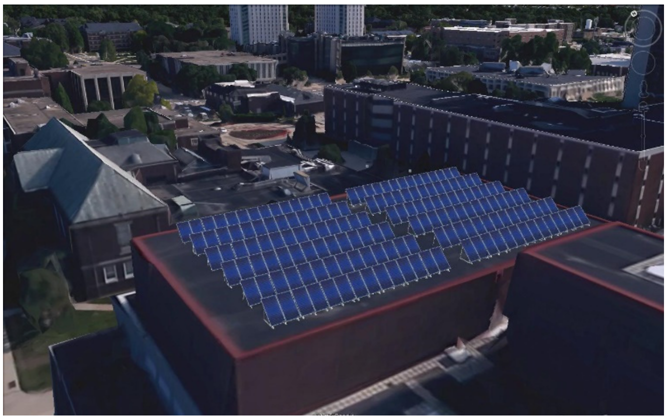

Figure 3. 3D rendering of Center for Performing Arts rooftop PV system.

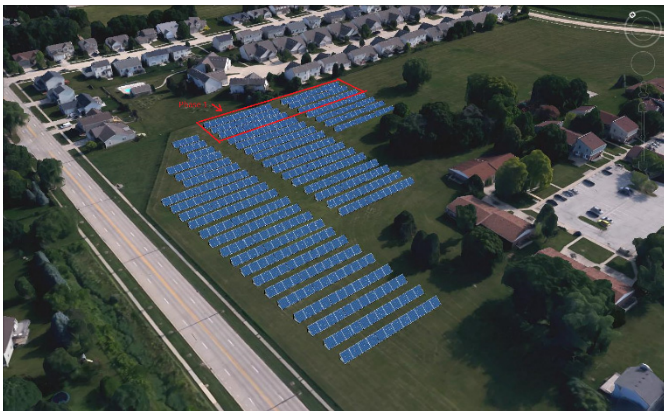

Figure 4. 3D rendering of Center for Renewable Energy ground mounted PV system (phase one system size outlined in red color).

The rooftop PV system will be located on top of the Center for Performing Arts. The system is sized at 67 kW to utilize all available rooftop area. This site was chosen because of great potential for financial gains as well as recruitment and marketing value. The CPA currently pays a very high $0.115/kWh for electricity, which leaves a lot of room for savings. The building is also located at the central quad area, with visibility from a lookout on the top floor of the Watterson Towers residential hall. The lookout is currently being developed into a major stopping point on campus tours, and information about the CPA PV system as well as other campus PV development could be prominently displayed. In order to finance the $156,110 system, we recommend direct ownership as it offers greater returns than a PPA, and the initial investment is affordable. Applying to the Illinois Clean Energy Community Foundation grant would cover 60% of the cost. This would leave $62,444 for the university to fund from the Student Sustainability Fund, and/or with donations to set this up as the first project in the school's green revolving loan fund. Over 30 years, this PV system will save ISU $346,675.

The last system in the first phase is suggested to install a parking canopy PV system on the Kingsley Street parking lot (Lot G53). This system would provide a great amount of visibility as it is located on the main road that goes through the town and campus. Financially, the canopy system will be expensive with 150 kW costing $750,000, and a $0.065/kWh electricity rate does not provide a lot of potential for savings. In order for the university to be able to afford it, it would need to assign the 70 parking spaces under the system as covered parking spaces, with a more expensive parking pass than they currently have. The current price difference between a covered parking permit and a regular permit is roughly $200 [10]. In addition, this parking lot is also a main public tailgating lot that currently charges $10 [10] per football game with an average of five games a year. This fee can be doubled to $20 for covered tailgating spots. Assuming these increases in parking fees, with a 1% annual escalation, ISU could make extra parking revenue of $499,199 over 25 years. We recommend a PPA ownership strategy again due to high initial investment requirements. Assuming a $0.13/kWh PPA rate with 2% annual escalation over 25 years, the university would end up saving $103,699 over that time frame. This system is expensive and requires the creation of extra revenue with a change of parking permits, but its high visibility makes it a valuable investment.

For the second phase of campus PV deployment, we recommend to install a full one megawatt system at the CRE site in order to take advantage of economies of scale. This system would cost $2,100,000. The CRE is located off of the main campus area, with no ISU owned grid connection to the main campus, and a load that is not big enough for the 1,384,00 kWh/year output of this system. This is one of the reasons, in addition to the high initial cost, why we recommend a third-party ownership model. Assuming a 20 year PPA with a rate of $0.075/kWh escalated 2% annually, the PV system would cumulatively save the university $895,206. However, if the university decided to invest directly and negotiate a transmission agreement with the utility, it could generate savings of over four million dollars.

Table 3. Comparison of results for selected sites.

	Location	System Size & Type	Annual Production	Total Cost	Ownership Model	Initial Investment	Lifetime Savings
Phase 1	CRE	110 kW Ground Mounted	152,240 kWh/year	$231,000	Third-Party	$0	$98,473
	CPA	67 kW Roof Mounted	90,517 kWh/year	$156,110	Direct	$62,444	$346,675
	Kingsley Parking Lot	150 kW Parking Canopy	202,650 kWh/year	$750,000	Third-Party	$0	$103,699
Phase 2	CRE	1,000 kW Ground Mounted	1,384,000 kWh/year	$2,100,000	Third-Party	$0	$895,206

4. Conclusion

Relevant case studies and previous research allowed us to create an in-depth methodology for calculating the technical and financial feasibility of installing a combined one MW solar PV system on different locations at ISU. By using various technical and financial modeling tools, we were able to develop a database of 12 different systems, with system size, annual production, cost estimates, and financing options for each. After analyzing all the data collected, we narrowed it down to the top three sites that would generate the most economic, environmental, educational, and reputational benefits for the university. Our most valuable sites on campus included the Center for Performing Arts, the Kingsley Street parking lot, and the Center for Renewable Energy. Our research concluded that these top three sites on campus have the technical potential to develop a combined one MW PV system, and both direct and third-party ownership models are financially feasible options for generating savings for the university.

In addition to finding that the PV system at ISU is feasible, this study can also serve as an educational tool for potential projects in the near future. The research performed in this study is a representation of a successful pathway for other universities to implement a large scale solar system. Splitting up the system into multiple sites could maximize the potential for aesthetic visibility, financial gains, and power output. Our financial models can be replicated and applied to other colleges and universities that want to embrace sustainability and optimize their investment decisions.

Conflict of Interest

All authors declare no conflicts of interest in this paper.

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