Planning and Engineering for a Large Campus Solar Installation

Department of Electrical and Computer Engineering

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PROJECT DESCRIPTION

The new electrical and computer engineering building (ECE building), which began construction on January 13, 2012, will be a unique green building on our campus. It is designed to be *the most energy efficient engineering building in the world*. With the full planned solar energy complement, the building is likely to even achieve Net Zero Energy status. The facility would be the largest net-zero energy building in the United States. The goal of this project is to prepare a major solar energy component to support this building.

This proposal seeks seed funding from the Student Sustainability Committee (SSC) to initiate work on the solar energy components of the new structure, as a way of participating in this spectacular green building. The SSC support will help make the facility and its solar resources unique educational living energy laboratories. Students in energy-oriented classes will be able to work hands-on with the energy system and the solar generation plant. Students in other programs on campus would be exposed to one of the largest solar energy installations in Illinois, and will be able to track its operation and view its components from a web site as well as inside the new building.

The working definition of *sustainability* in the context of this project is to create a facility that supports all its own energy needs —leaving no carbon or fossil extraction footprint. The ECE building design itself is intended to achieve LEED Platinum certification, although the energy objectives go far beyond this rating to true energy sustainability. The building will be the first large structure in Illinois to target this type of sustainability. This is especially significant in a comprehensive combined classroom/research/office facility that includes, among many advanced features, an energy-intensive instructional clean room.

The solar energy system under discussion for the new ECE building includes two major elements:

1. Solar photovoltaic (PV) panels on the roof of the building itself. Estimated peak capacity is approximately 300 kW (about four times the size of the BIF array).
2. Solar PV panels mounted above the top level of the North Campus Parking Structure at the corner of Goodwin Ave. and University Ave. in Urbana. This structure will serve as the parking area for the new building. It should accommodate at least 1000 kW of solar PV panels (more than 25 times the College of Business Instructional facility [BIF] array size).

The funding need is immediate: the parking structure solar project can be carried out with target completion and power connection by the end of 2012. This will jump-start major solar energy systems on the campus, and gives us renewable energy resources at a substantial level well in advance of completion of the building itself (scheduled for July 2014).

We request a sustainability grant in the amount of $150,000 to help with the new ECE building. These funds will be used specifically to provide seed funding for the large solar energy system for the North Campus Parking Structure. Costs to be covered include:

- Complete structural studies and comprehensive engineering plans.
- Drawings and detailed plans and specifications for the project.
- Support for a portion of the major equipment, notably the inverters that convert energy from the PV panels and connect to the campus and utility electricity grid and special metering that will allow the system to be monitored by anyone on campus.
- Support for educational elements, include monitoring, metering, web site, and interconnection into campus laboratory facilities.

Longer term, the requested funds will initiate broader work on the green energy system for the new building. Some of the special features are as follows:

- The building roof solar energy system will be directly accessible from research and teaching labs on the fourth floor of the building.
- About 10% of the building PV panels will be allocated for use by students in both undergraduate and graduate projects.
- The PV panels will support Smart Grid test bed activities, now in the planning stages from the Illinois

Center for a Smarter Electricity Grid (ICSEG).

- We anticipate that the solar system will provide a demonstration site for at least two major solar power conversion technologies invented at the University of Illinois. It may also provide a test bed for two or three solar cell technologies invented here.
- Electric power data, webcams, and various data tracking methods will be featured in kiosks in the main public areas of the new ECE building, and will also be available generally on the web.
- The systems will be monitored, controlled, and applied in at least five engineering classes taught in the College of Engineering.
- The industry collaborator is seeking to include a 500 kWh storage battery component. This offers important advantages in terms of cost recovery, and helps address needs of the Smart Grid test bed.

Feasibility

The North Campus Parking Structure has a top deck area of about 84,000 square feet (about 7800 m^2). The PV panels would be pointed at about 40°, the local latitude. To avoid self-shading, PV panels pointed at this angle can cover no more than 64% of the roof area. With state-of-the-art 20% efficient solar cells, this provides peak production very close to 1000 kW, particularly if a small portion of the south façade of the structure augments the solar installation. The parking structure has two added advantages: proximity to campus electrical infrastructure, and proximity to local utility electrical infrastructure. An electrical vault at ground level directly south of the parking structure leads into electrical support equipment in the North Campus Chiller Plant, while another vault has access to a utility feed. These advantages offer research benefits, as the proposed solar installation can be integrated into either system (or, with switches, into both).

Although engineering studies (to be covered with the proposed funds) need to be carried out, a suitable solar structure should be possible above the parking structure. Meetings with the Parking Department have established the basic working objectives: tie a solar framework into structural members, away from parking spaces; avoid encroaching on parking capacity; and provide suitable snow and water management. A structure meeting these objectives, shown below, has been built at Colorado State University. Other similar projects have been installed at Arizona State University, a city lot in Long Beach, California, at York University in Ontario, and in Bergen County, New Jersey. Although such installations are increasing, it is still rare to find them in the Midwest.

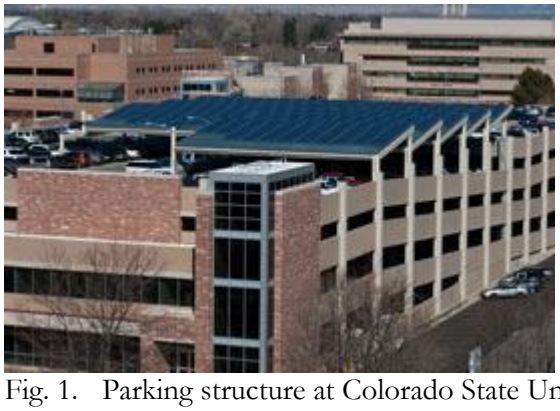

Fig. 1. Parking structure at Colorado State University

The design and components will be selected for a target 40-year total system life. PV panels typically achieve 40 year life, and generally have 25 year warranties. Other system components, such as inverters, require regular maintenance to achieve these extended lifetimes; this is included in project plans. Since the installation effectively becomes a permanent feature of these buildings, the project will support large-scale solar output for many decades.

Communications with relevant campus entities

Formal planning for the new ECE building now under construction began in January 2008. Over the four-year time span as the project ultimately entered the construction phase in January 2012, the full array of campus administrative entities and facilities offices has been involved. The solar concepts for the new building have been presented to all of them, including discussions with the F&S Executive Director, Jack Dempsey. The project concepts have been vetted with the F&S utilities leaders, and they have been closely involved in preliminary feasibility analysis. There have been meetings with the Parking Department to establish ground rules for the parking structure aspects of the project. Research elements of the project will be led by the Coordinated Science Lab (CSL) faculty on campus; discussions are underway for micro-grid-related research. Structural elements to support solar panels are part of the base new ECE building design, and are included in the drawings and construction documents.

BUDGET, FUNDRAISING, AND TIMELINE

I. Detailed Budget

Summary:	
Student Sustainability Committee	$150,000
Illinois Center for a Smarter Electricity Grid	$500,000
ECE Department and Grainger Center funds	$100,000
Industry Collaborator	$3,000,000
Other funds to be raised	$1,750,000
TOTAL	$5,500,000

Total initial cost:	$5.5 million
Modeled power production:	1752 MWh per year (average)
Energy value at $0.08/kWh:	$140,160 per year
Storage value, estimated based on 0.5 MWh and valued at $100/MWh:	$18,250 per year
Maintenance cost (based on 4 hrs per week average plus an allowance of $3,000 per year for hardware maintenance):	$10,000 per year
Simple net annual income:	$148,410
Simple payback period:	37 years

II. Fundraising and budget commentary:

The SSC support for this project provides key initial funds to support the engineering studies and plans for the parking structure solar PV array. Even though SSC funds are a modest portion of the total (less than 3%), they provide the essential "first funds" to set up plans and kick off the project. Many of the active and potential participants are seeking these planning details before making a full commitment. The SSC funds are vital to get this activity underway. They also establish a firm student commitment to sustainability that will be emphasized and featured in the new ECE building. We need these funds to get started.

Although the payback period appears very long, this is misleading, since research and educational activities associated with this PV installation have substantial value. In effect, the payback should be judged against the

$2.5 million campus support and fundraising, with the additional $3 million representing investment by an industry collaborator. A $2.5 million cost represents a simple payback of less than 17 years. Notice that the income is computed based on campus electricity costs ($0.08 per kWh) rather than on the effective avoided peak rate (which is at least 50% higher).

Illinois Center for a Smarter Electricity Grid support is directed at inverters and electrical infrastructure to establish the complete working system. The ICSEG support also helps make the system "microgrid ready" to support long-term research objectives.

The ECE Department and Grainger Center for Electric Machinery and Electromechanics (CEME) funds will mainly be from the CEME. The CEME is an endowed program that supports energy conversion and advanced energy initiatives. As much as $100,000 will be available during project development for the complete building, including some department funds that will help support educational components.

Other funds to be raised will be sought with leveraging grant proposals to the Illinois DCEO based on this proposal, through the Department of Defense in support of programs on microgrids, through the Department of Energy, and through interested alumni supporters.

Both CSL and the ECE department are in discussions with Acciona, a major renewable energy provider with U.S. headquarters in Illinois. Acciona has identified several project benefits and provided cost estimates that are the basis for the budget.

III. Timeline

Start date:	May 1, 2012
Engineering study; prepare plans	May, June 2012
Prepare site; begin solar mount preparation	July – September 2012
Solar panel procurement and installation	June – October 2012
Inverter procurement and installation	June – November 2012
Interface to campus and utility grids	November-December 2012
Commissioning and first power	December 15, 2012
Storage system installation and connection	November 2012 – January 2013
End date:	January 31, 2013

Follow-up activities:
Data collection and operation of research activities will proceed throughout 2013 and into the future. During summer 2014, data collection will be integrated into the new ECE building for educational purposes.

ENVIRONMENTAL, SOCIAL, AND ECONOMIC IMPACTS

I. Renewable Energy Projects

Energy generation: The project seeks to install a nominal 1 MW (peak) solar PV system above the upper deck of the North Campus Parking Structure on University Avenue. Based on federal data from the National Renewable Energy Laboratory, this PV system is expected to generate an average of 4.8 MWh per day, amounting to 1752 MWh per year. The average energy production rate is 200 kW. This system will be the largest building-installed PV system on the campus, and will be a major component to help the new ECE building achieve possible zero-net-energy status. The allocated project lifetime is 40 years, representing production of more than 70,000 MWh over the project life.

Energy inputs: In addition to conventional energy inputs to manufacture the PV panels, inverters, and hardware to interconnect to the utility grid, the project involves the preparation of steel or aluminum trusswork. Additional hardware will be used to tie the truss structure to existing structural risers in the garage.

Other effective generation aspects: The project is expected to provide effective covering for the garage top deck, eliminating most snow removal energy and cost. The gain from this benefit will offset much of the implied energy associated with installation. Maintenance will emphasize regular inspection, remote sensing, and repair or replacement of parts as necessary. The project, as envisioned by our industry partner, will also include a modest energy storage component. While this does not by itself "generate" energy, the flexibility associated with energy storage leverages a PV system to provide greater benefits for the campus and grid.

III. All Projects

Greenhouse Gas Impact
Effect on greenhouse gases: Based on average CO_2 production of 1.672 lb/kWh, the energy generated by this project will offset more than 8000 lb of CO_2 daily on average, or almost 3 million lb per year. Over the 40-year project life, the total avoided CO_2 value is almost 120 million lb.

Other Environmental Impact and Metrics
We believe the snow and water management attributes of the PV array offer substantial cost and environmental savings on the parking structure top deck: reduced wear and tear, no need to use fuel-driven snow removal vehicles, and a more attractive shaded area for parking. The Parking Department will be able to show cost savings from snow removal reduction and from decreased exposure of the top deck to snow and ice. In addition, we intend within the scope of this project to provide a few electric vehicle parking spaces throughout the structure, with chargers drawing energy from the solar array or its storage resources.

As the project is completed, and data and sensing ultimately integrated into the new ECE building, the educational benefits will be substantial. We plan to have interactive displays showing the PV array, detailing its energy production, and showing how it contributes over time to the zero-net-energy objectives of the combined project.

Social Impact
This project provides a large-scale PV system in an active campus location. The scale is much larger than other campus arrays – at least 25 times the size of the array at BIF, for example. By going beyond just a commitment to solar energy, all the way to a commitment to zero-energy buildings, campus sustainability objectives will be highlighted. This project will play a major role in making our campus the Midwest energy leader. It is impossible to overstate the social impact of a zero-net-energy building here on campus. We have a challenging climate, and a large demonstration building on our campus suggests that energy-sustainable buildings can be prepared nearly anywhere.

Economic Impact

The economic impact on energy is clear, as there is a payback time interval within the project's lifetime, even given the modest electricity rates paid by the campus. The larger implications, however, are much more significant. A large net-zero structure on campus will be effective in helping to attract industry and academic leaders. It will be leveraged for many other funding activities. More to the point, the large PV facility will be a test bed that can support millions of dollars in annual research. Smaller economic benefits, such as reduced costs because of reduced parking snow removal, will benefit campus indirectly, although they do not factor into project budgets. The economic benefits to campus could reach more than $500k annually, based on a conservative estimate of facilities expenses for related advanced research endeavors.

OUTREACH AND EDUCATION

The ECE Department intends to publicize the building project widely and recognize supporters. This will go far beyond the conventional permanent plaque: recognition in the new ECE building will take the form of permanent interactive displays that detail the nature of the support, show those portions of the overall project, and place the support in context. In the context of this project, the SSC efforts will be highlighted in the overall zero-net-energy context. The zero-net efforts will include extensive energy metering and interactive educational exhibits and displays. These displays will be in the main lobby of the facility. The objective is to keep the energy sustainability front-and-center for generations of students, and to link the outcomes to investments first made in 2012, with an impact lasting for decades.

This proposal was motivated and, in many ways, instigated by ECE students. There is growing interest in energy and sustainability issues everywhere on campus, and the ECE department is one of the most active units in this arena. Many of our students, for example, have participated in the past three Solar Decathlon projects. The leaders among these students realized that aggressive energy goals are possible on our campus. They had a role in pushing the building design team toward the zero-net goal. As the project unfolds, students will be involved in its research components, and will also be part of the planning teams. It is especially important to us that students be the primary designers of user interfaces and interactive displays: they are the best people to determine how to get the message across to the public.

This PV project will have direct classroom and curriculum impact in three ways:

- A portion of the building solar array will be accessible from a laboratory on the fourth floor. This part of the array will be used in power-grid interactive experiments. Courses include ECE 464 and ECE 469.
- The accessible portion of the building array will be available for student project activities, ranging from tests of new power conversion to tests of solar PV technologies. Courses include ECE 445 and independent study.
- The array will support study in the existing Green Electric Energy course, ECE 333.

Media opportunities for the new ECE building are extensive, as at present it is the largest zero net energy project in the United States. We have been fielding press inquiries, and this will grow as the project proceeds. Campus publicity resources are available to help.