UW-SOLAR
FEASIBILITY STUDY

99% DRAFT: June 11, 2013

Contents:

Executive Summary

The UW Solar Team is a collaborative group of eleven students representing multiple schools and departments within the University of Washington system ranging from undergraduate to PhD level. Our goal is to support the growth of local, clean energy in Washington State based on the efficient use of renewable resources, with community participation in the stewardship of energy assets. We seek to empower future student-led, on-campus, clean energy projects through completion of a successful solar demonstration that combines project design, implementation, and evaluation. The UW Demonstration Solar project serves as a focal point for research and education about the use of renewable energy in the built environment. It's a project where students, faculty, and staff come together to share ideas and promote new ways of thinking about sustainability. It also provides the community with access to information and resources including interactive displays about the project including power production and how the system works.

Project participants include mission-aligned students, faculty, and staff that are deeply committed to sustainability and creating a vibrant academic environment. In an effort to address climate change, we wish to increase UW's use of local, renewable energy. This project will allow UW to offset fossil fuel use, address uncertain future energy costs, and reduce environmental impacts. The ultimate goal of the project is to speed the transition of UW solar energy projects from concept to implementation.

The ***Siting and Infrastructure*** portion of the feasibility study determines where the pilot solar array and SCADA system will be located. Based on our goals and research of three potential Housing and Food Service building sites, Mercer Court A is the most suitable for a solar-electric array. The UW Solar Team's second choice is Poplar Hall, and our third choice is Lander Hall. Mercer Court A provides the largest area for a solar array, with the least amount of shading from other roof structures or equipment. In addition, Mercer A's visibility meets UW Solar Team's education and outreach goals for both the university community and general public. We recognize that Poplar and Lander may provide more direct curriculum relationships than would Mercer, since the Mercer buildings are apartments, rather than residence halls. However, the UW Solar Team believes that the larger potential for power production and greater community visibility of Mercer Court are more important to our team's goals.

The ***Supervisory Control and Data Acquisition (SCADA)*** **system** portion of the feasibility study discusses the purpose of using an industrial control system (ICS) in order to monitor UW Solar power production. The purpose of the SCADA system is to remotely monitor and control the physical system and to collect data in real time from energy and weather-related sensors mounted on UW Solar. For the UW Solar project, the SCADA system will acquire energy and atmospheric data from sensors mounted on the solar panel array(s). The SCADA system will provide a large body of usable data for analysis by distinct groups of academics and professionals including those concerned with atmospheric sciences, energy, and informatics. The virtual SCADA "Lab" will be available for use in future coursework at the University in a vast array of academic specializations. These newly

opened research opportunities will consequently function to attract new students, faculty and professionals in the above-mentioned disciplined.

The ***Institutional Frameworks*** portion of the feasibility study establishes a UW Solar work-plan along with a timeline for each phase of the project (feasibility initial draft, revisions, including Advisory Group review, and final approval), the project design and implementation. This section also discusses the process for attaining stakeholder consensus, which included the Institutional sub-group establishing an Advisory Committee with key representatives from UW Solar sub-groups (Siting & Infrastructure, Financing & Policy, SCADA, and Education & Outreach), and with representatives from UW Office of Planning & Budgeting, Department of Housing & Food Services, and UW Facilities Services. The Institutional section also details the Advisory Committee process, which includes scheduling and keeping meeting minutes for regular bi-weekly meetings to allow participants to discuss important project issues and establish key action items for meetings. In addition, the Advisory Committee process includes regular weekly memo reports to all Committee members to document project progress.

The ***Financing, Policy, and Budget*** portion of the feasibility study examines cost effective methods for building and financing the UW Solar project and provides a body of research that aids in the wider development of solar technology on campus. As part of this process, the UW Solar Team is consulting with a wide range of solar vendor companies in the Seattle area and soliciting input regarding labor and equipment requirements. This section explores scenarios for financing UW Solar project implementation through different funding structures and potential partnerships with outside vendors including currently available programs and incentives to help encourage investment in solar. Utilizing the expertise of our advisors, vendors and stakeholders, we examine both initial upfront capital costs and long-term lifecycle costs, and set up financial models for the feasibility installation to forecast and track cost, and financial performance, through the life of the solar system. In addition, aligning all return on investment information with how the University of Washington evaluates capital investment should help decision makers compare and contrast different investment opportunities.

The ***Education and Outreach Plan*** is still being developed as part of the UW Solar project. This section discusses project signage, educational outreach plans, and the location decision tree for screening potential solar sites.

Siting and Infrastructure

The siting and infrastructure portion of the feasibility study will determine where the pilot solar array and SCADA system will be located. This study will provide the framework to examine and assess the entire University of Washington Seattle campus for the feasibility of solar installation. However, an initial pilot study will be performed on Housing and Food Services managed buildings: Lander Hall, Mercer Court, and Poplar Hall. For each of the buildings, the following components will be addressed:

- Stakeholder Input,
- Location Decision Criteria,
- Structural and Space Usage Considerations,
- Shading and Accessibility Concerns,
- Types of Solar Panels and Equipment,
- Expected Annual Energy Generation, and
- Solar Project Structural Support Needs and Options.

We have developed a fourteen-point process for completing the requisite analysis. The feasibility study begins with the definition of goals and objectives for the pilot project and ends with the presentation of the cumulative analysis and resulting recommendations. This analysis incorporates the requirements identified by each of the specialized teams in our working group (e.g., electrical engineers, cyber security, etc.) and ultimately results in a choice that best supports the objectives and values outlined in UW-Solar's mission statement.

> *UW-Solar is a multi-disciplinary student-led research project working to maximize the visibility of and potential for clean and renewable solar energy systems to promote awareness, research, and sustainability in our local community.*
>
> *Key Objectives:*
> *1. Conducting a feasibility study looking at the placement of solar panels on UW buildings.*
> *2. Installing a solar panel array on a Housing and Food Service Building.*

The fourteen points we have identified for the siting and infrastructure analysis are:

1. Determine goals for solar pilot project.
2. Identify potential sites.
3. Determine general roof characteristics.
4. Describe roof and provide design and specifications.
5. Research future development plans.
6. Develop solar-electric system equipment matrix.
7. Compare photovoltaic applications.

8 Determine site electrical use.
9 Determine spatial requirements for equipment.
10 Calculate system economics.
11 Re-evaluate site considerations based on goals and make recommendations.
12 Describe permitting requirements and project phasing for implementation.
13 Determine preferred vendors and equipment.
14 Make recommendations and seek stakeholder input.

We began the research to address these points during the winter quarter of 2012. In order to optimize resources, we pursued several sections of research and analysis simultaneously. It is important to note that some of these steps must be performed sequentially, while some may be pursued in tandem. The report that follows explains in prose what we were able to accomplish in this analysis and also notes limitations.

Location decision criteria

1. Determine goals for solar pilot project

As the first step of siting the solar array, the UW-Solar team articulated four goals for the pilot project:

- Producing solar electricity;
- Providing power for SCADA infrastructure;
- Integrating the solar array as a design feature; and
- Educating the university community, professional community, and general public about solar power in Seattle.

The team then developed minimum criteria for each goal.

The first goal is producing solar electricity. Specifically, the goal of this project is to maximize power production within a given budget of $85,000. To enable comparison to other existing and future solar-electric projects, we will articulate the power production as price per watt of peak capacity.

We recognize, however, that this project is unique because it is a pilot project, and other projects may have different objectives. Therefore, we developed additional objectives, articulated as questions, that may be more applicable to other projects:

- Should the array produce a specific kilowatt-hour output level? If a specific output target is desired, this leads to sizing requirements for the array.
- Should the array power a certain percentage of the building's energy use? If a percentage of energy use is deemed relevant, this also leads to sizing requirements for the array.

- Should the array power certain aspects or functions of the building's operations? If so, meeting this objective will dictate requirements for the design and installation of the array.

The second goal is providing power for SCADA infrastructure. In order to do this, the team determined how much power the SCADA operations will require. Similar to the considerations related to the first goal, SCADA power requirements will determine power output needs for the solar array. The team has determined the SCADA infrastructure will require very minimal power. Refer to the SCADA section of the feasibility study for further detail.

The third goal is integrating the solar array as a design feature. One of the team's stakeholders suggested exploring secondary uses for the solar array in terms of design features, e.g., sun shading. A number of the buildings under consideration for this pilot project are highly visible to neighboring residents and business, and the team expects that the extra efforts to install an attractive array will help mitigate any negative reaction from the public. The team decided to include perspectives of the proposed array design, showing the appearance of the array from street level when such views would be possible.

The fourth goal is educating the university community and general public about solar power in Seattle. Because this is a pilot project, education and outreach are important objectives. The team has determined that we will target University of Washington students and local professionals for education and students, professionals, neighbors, and the general public for outreach. Refer to the education and outreach section of the feasibility study for further detail.

In recognition of our relationship with the UW Campus Sustainability Fund (CSF), the team articulated our goals in relationship to CSF's goals of student leadership and involvement; education and outreach; environmental impact; and feasibility, accountability, and sustainability. Our project's main environmental impact addresses renewable energy. See Table 1 for further elaboration.

Table 1. Goal Compatibility between CSF and UW-Solar

CSF Goals	UW-Solar Response to Goals	
Student Leadership and Involvement	Student Volunteers	There are 14 students that are volunteering their time to perform the feasibility study, design, and implement the UW-Solar project.
	Teams	There are five UW Solar teams, including: Siting & Infrastructure, Financing & Policy, Information Systems, Institutional Frameworks, and Education & Outreach. Each team, made up of approximately 3-4 students, is responsible for a unique aspect of the project. Each team has an assigned leader who reports weekly to the larger UW Solar group. Each team is responsible for ensuring all necessary items are completed with appropriate timeliness and high standards.
Environmental Impact	Problem Statement	The long-term UW-Solar vision is for the installation of solar panels at multiple UW sites, with a model for finance and management that is easy to replicate; thus encouraging of expansion at UW and other public universities. The benefits to the expanded use of solar energy include reduced off-site energy resource consumption, reduced energy costs, community energy resilience and independence, environmental educational opportunities, and

		decreased environmental impacts.
	Impact Measurement	A component of the project is to track energy production through the industrial control system, which manages information and controls the function of the panels and flow of energy and data, showing the kWh of energy output daily, monthly, and seasonally. Solar energy displays at the project site will showcase the amount of clean power generated and tons of carbon emissions avoided, and will educate the student body about the UW-Solar project.
Education and Outreach	Student Volunteers	Student volunteers will conduct the feasibility study, design, and installation phases, including the solicitation of bids from firms to volunteer services and/or donated equipment. In the process of participating, the firms will educate and mentor participating students on the products, markets, and processes for developing solar and related smart systems. To establish financing and ownership arrangements for this and future installations, the UW-Solar team has included institutional and capital finance arrangements in the feasibility study, for approval by Housing and Food Services, and all appropriate UW administrators. These arrangements, perhaps the first of their kind on campus, will ease the replication of solar investments at UW and similar universities. Thus, our outreach includes contact with other public universities at conferences or special events attended by UW-Solar participants.
	Campus Community	Campus outreach will include the dissemination of information through UW student organizations devoted to sustainability and cyber-security. Should the project move from feasibility to design and installation – as planned in the Fall of 2013 – members of the UW-Solar team continuing their education the following fall will propose a freshman interest group on the subject of solar power, sustainability, the mitigation of greenhouse gases, and cyber-security.
	Curriculum	Furthermore, a curriculum is being developed for seminars on siting and funding solar panels, to be offered as a graduate student-led course for credit. The completion of this pilot study will impact the larger region by providing a framework for the application of these methods to similar projects across the region. This, in turn, will enhance the overall resilience of the Pacific Northwest.
	Wider Community	After installation, UW-Solar will position monitors and publish to the web current, real-time and historical energy production and savings information from the solar panel installations. These monitors will educate the community on the importance of environmental sustainability, the use of renewable resources, advantages of energy conservation, and overall savings in energy cost as an advantage of solar power.
Feasibility, Accountability, and Sustainability	Feasibility Study	The feasibility study will explore solar feasibility through the following sections: Siting and Infrastructure, Institutional Frameworks, Financing and Policy, Electrical Engineering, SCADA Systems, and Education and Outreach.
	Procurement	Procurement will be undertaken in May-June.
	Installation	Installation on the selected facility will occur in September.

2. Identify potential sites

Our pilot project focuses on priority sites as determined by HFS and UW-Solar. In the spring of 2013 it was determined that the pilot study would focus specifically on Lander Hall, Mercer Court, and Poplar Hall. For each building we considered:

- Current or future sustainability projects or programs in the building,
- Compatibility with the building's structural and electrical capacity, and
- Aesthetic impacts of the array on surrounding buildings and streets.

Sustainability Projects and Programs

The buildings under consideration all address sustainability in their overall development and design. As HFS has indicated on their website, the new west campus buildings have been conceived under the following sustainability framework:

- Reduce the carbon footprint through increased pedestrian usage and by creating a community where everything is easily accessible;
- Target a 90 percent diversion of construction waste from landfills;
- Target a minimum of a LEED Silver rating and use 30 percent less energy than similar buildings in similar climates;
- Increase quantity of daylight for building interiors;
- Use environmentally-friendly materials with low volatile organic chemicals;
- Improve the building envelope with insulation and reduction in infiltration;
- Target a 30 percent water reduction due to low-flow fixtures; and
- Plant 60 new street trees.[1]

HFS has set a target that these new buildings should, at a minimum, reach Silver certification in the Leadership in Energy and Environmental Design (LEED) rating system.[2] Possible certifications in order of increasing requirements are: Certified, Silver, Gold, and Platinum. The LEED rating system for New Construction requires the achievement of prerequisites and credits across seven criteria:

- Sustainable Sites,
- Water Efficiency,
- Energy and Atmosphere,
- Materials and Resources,
- Indoor Environmental Quality,
- Innovation in Design, and

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[1] West Campus faq, University of Washington Housing and Food Service website, last accessed April 21, 2013, https://www.hfs.washington.edu/housing/Default.aspx?id=2120.

[2] West Campus faq, University of Washington Housing and Food Service website, last accessed April 21, 2013, https://www.hfs.washington.edu/housing/Default.aspx?id=2120.

- Regional Priority.[3]

Mercer Court and Lander Hall are still under construction and, thus, are awaiting certification. Poplar Hall achieved Gold certification in September 2012 (received 41 of 69 possible points) under the New Construction v2.2 LEED criteria. Both Mercer Court and Lander Hall will need to meet the New Construction v2009 requirements.

At the time this analysis was undertaken, most information available is related to Poplar Hall, which has achieved LEED Gold certification and has exceeded the minimum standards outlined by HFS. The point allocations awarded to Poplar are shown by major category in Table 2. Notably, Poplar Hall received 0 of 4 possible points for on-site renewable power and green power.

Table 2. LEED Point Allocations for Poplar Hall

Design Criteria Categories	Possible Points	Points Awarded
Sustainable Sites	14	9
Water Efficiency	5	3
Energy and Atmosphere	17	8
Materials and Resources	13	4
Indoor Environmental Quality	15	12
Innovation in Design	5	5
TOTAL	69	41

Source: UW Poplar Hall LEED scorecard, available online at http://www.usgbc.org/projects/uw-poplar-hall-33w?view=overview.

Moving beyond design, Poplar Hall is also home to UW's Sustainable Living Community, which "offers residents opportunities to explore environmental impact and social equity topics on individual, local and global scales in a vibrant, social community."[4]

Under the LEED New Construction 2009 guidelines, between 1 and 7 credits can be obtained for on-site renewable energy. The requirements for this credit are to "use on-site renewable energy systems to offset building energy costs."[5] Performance scores are allocated based on the expression of the percentage of the building's annual energy cost obtained through the renewable system. See Table 3 for percentages and resulting credits.

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[3] U.S. Green Building Council, LEED 2009 for New Construction and Major Renovations, USGBC Member Approved November 2008 (Updated April 2013), available online at http://www.usgbc.org/sites/default/files/LEED%202009%20RS_NC_04.01.13_current.pdf.

[4] Sustainable Living Community, University of Washington Housing and Food Service website, last accessed April 21, 2013, https://www.hfs.washington.edu/housing/rh/sustainability/.

[5] U.S. Green Building Council, LEED 2009 for New Construction and Major Renovations, USGBC Member Approved November 2008 (Updated April 2013), available online at http://www.usgbc.org/sites/default/files/LEED%202009%20RS_NC_04.01.13_current.pdf.

Table 3. LEED-NC Point Allocations for Percent of On-Site Renewable Energy Production

Percentage Renewable Energy	Points
1%	1
3%	2
5%	3
7%	4
9%	5
11%	6
13%	7

Source: U.S. Green Building Council, LEED 2009 for New Construction and Major Renovations, USGBC Member Approved November 2008 (Updated April 2013), available online at http://www.usgbc.org/sites/default/files/ LEED%202009%20RS_NC_04.01.13_current.pdf.

Structural and Electrical Capacity

All three buildings have similar construction: wood-frame upper floors above concrete foundations and concrete ground floors. Notably, Mercer Court building A was originally designed for a solar hot water system, which was removed during the value engineering design stage. The system still appears on the construction drawings, and we expect that the building is structurally compatible with a solar-electric array on at least one part of the roof.

The building ultimately selected for the pilot project will require evaluation by a structural engineer in order to assess whether additional structural support is required for the proposed array. HFS has requested an array with no roof penetrations, which means the pilot project will use a ballasted roof mounting system. Ballasted systems have less wind load on the building's structure than do other penetrating attachment systems, so most of the structural capacity will be the dead load of the system.

We anticipate that the electrical systems of all three buildings are generally compatible with a solar-electric array. Refer to section 8, "Determine site electric use," below, for further details.

Aesthetic Impacts

The roofs of Mercer Court are moderately visible from surrounding roads, particularly the University Bridge. UW owns most of the buildings with roof views of Mercer. Similarly, the roofs of Poplar Hall and Lander Hall are visible only from buildings owned by UW.

3. Determine general roof characteristics

Mercer Court A has a flat roof. The long axis of the building runs roughly east-west. There is shading on the roof from two penthouses. Most of the equipment on the roof is clustered around the penthouses, leaving large open spaces for two or three arrays. Overall, Mercer Court A achieves an "excellent" rating. See Table 4 for rating scale.

Poplar Hall also has a flat roof. The building is C-shaped, with the long axis running roughly north-south and two smaller sections running east-west. There is shading on the roof from three penthouses. Equipment is distributed over the roof, not clustered, leaving moderate open spaces for one or two arrays. Overall, Poplar Hall achieves a “fair” rating.

Lander Hall also has a flat roof. The building is G-shaped, with the longest and shortest axes running roughly east-west, and the other two axes running north-south. There is shading on the roof from two penthouses and a cell tower equipment platform. Equipment is distributed over the roof, not clustered, leaving small open spaces for one or two arrays. Overall, Lander Hall achieves a “fair” rating.

Table 4. Rating Scale for Roof Suitability for Solar Electric Array

Rating	*Description*
Excellent	Site has an unshaded space suitable for installation of solar system sized to meet customer’s stated goals, appropriate and available location for balance of systems
Good	Site has some minimal shading, smaller space available for installation of solar system, and/or will require some modifications to accommodate equipment
Fair	Site has some moderate shading, small spaces available for installation of solar system, and/or will require significant modifications to accommodate equipment
Poor/Not Advisable	Site has very limited solar window or other physical characteristics that make it unsuitable for the installation of a solar-electric system

Source: Adapted from Wisconsin’s Focus on Energy Site Evaluation form, as published in Velcheck & Finger Roof Consulting, “Solar Electric Site Assessment Report: Solomon Juneau Business High School” (18 May 2009), available online at http://www4.eere.energy.gov/solar/sunshot /resource_center/sites/default/files/17_pv_juneau_high_school_.pdf

4. Describe roof and provide design and specifications

Mercer Court A has a new roof, constructed in 2013. The supporting structure of the building is wood framing, with a concrete foundation. The roof is in excellent/new condition. There are no electrical panels on the roof; therefore, connections into the building’s electrical system will have to take place on a lower floor, which may require roof penetration. The building originally was designed for a solar hot water system, so we do not anticipate any structural issues. The penthouses on the roof are low enough in temperature to house centralized inverters. The approximate area available for modules is estimated at 6,200 square feet. The building and roof are highly visible from the University Bridge, which provides opportunities to increase public awareness of the project, but may result in aesthetic objections from neighbors. Mercer Court A is well sited for solar with an east-west orientation and is one story taller than the other four Mercer buildings.

Poplar Hall has a new roof, constructed in 2012. The supporting structure of the building is wood framing, with a concrete foundation. The roof is in excellent/new condition. There are electrical panels located within the mechanical penthouse; however, the temperature is too hot to house any centralized inverters within the penthouse. The approximate area available for modules is estimated at 3,200 square feet. The roof of Poplar is not visible from street level, which reduces opportunities for public visibility. All the neighboring buildings that overlook Poplar's roof are University buildings, decreasing the risk of aesthetic objections from neighbors.

Lander Hall will have a new roof, which is not complete at the time of this report. The supporting structure of the building is wood framing, with a concrete foundation. We anticipate the roof will be in excellent/new condition when completed. The approximate area available for modules is estimated at 1,500 square feet. The roof of Lander is not visible from street level, which reduces opportunities for public visibility. All of the neighboring buildings that overlook Lander's roof are University buildings, decreasing the risk of aesthetic objections from neighbors. Notably, the roof is visible from some areas of surrounding HFS buildings, such as Poplar Hall.

Our team has the design and specifications (construction documents) for the buildings under consideration, and will use this during the system design phase in order to provide more specific information for the design of the array.

5. Research future development plans

All buildings under consideration for our pilot project are in the west campus portion of the University of Washington's Seattle campus. See Figure 1 below.

Figure 1. West Campus New Housing Locations (Image reproduced from University of Washington Housing and Food Services website, available online at https://www.hfs.washington.edu/assets/0/81/f4b88f50-9861-439e-bbe2-5fa9ab9362f3.jpg.)

The City of Seattle zoning overlay for the area is all Major Institutional with neighborhood commercial, commercial, and midrise designations. Height limitations in the area range from 65 to 105 feet.[6]

According to the 2003 Campus Master Plan, parcels surrounding the pilot study sites where future development is likely will range from 37 feet to 105 feet in height or between 3 and 8 floors. Mercer Court, Lander Hall, and Poplar Hall are 124 feet, 166 feet, and 194 feet, respectively, so shading from surrounding future development is not likely. It is possible that future zoning changes will

[6] website of the City of Seattle Department of Planning and Design, available online at http://www.seattle.gov/dpd/Research/gis/webplots/k23e.pdf.

allow for greater height in the area, but such uncertainties are always present in such projects. Please refer to Figure 2 and Table 5 below for more information.

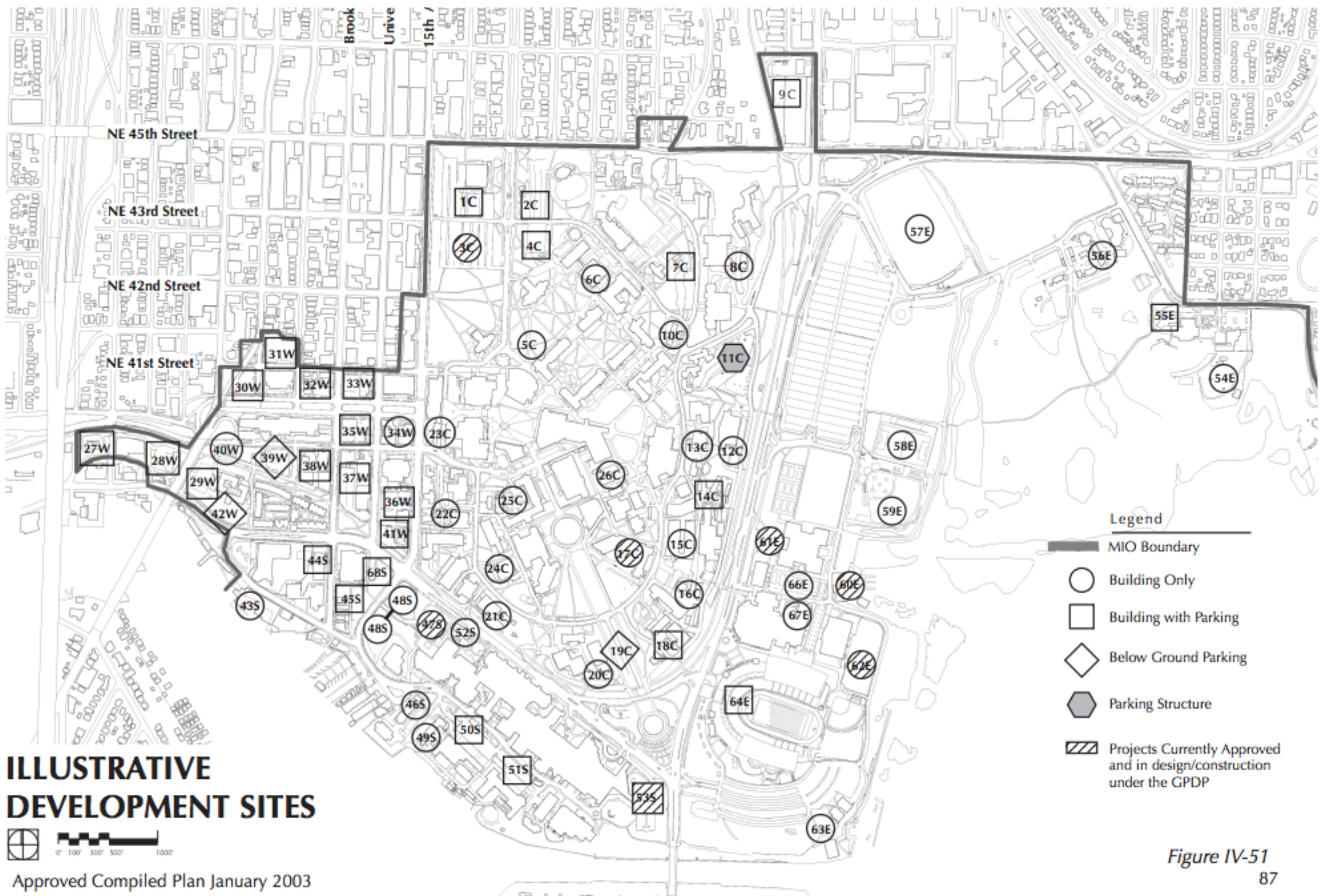

Figure 2. Illustrative Development Sites (Image reproduced from University of Washington Master Plan - Seattle Campus Development Program (2003), available online at http://www.washington.edu/community/files/2003/08/04B_Development_Program_FP.pdf.)

Table 5. UW Campus Plan - Potential Future Development Sites

Site Number	Maximum Height (feet)	Maximum Height (floors)
28	65	5
29 – Mercer Hall	124	8
30	105	5
31 – Cedar Apartments	Unknown	Unknown
32 – Elm Hall	Unknown	Unknown
33 - Poplar	194	7
34	65	5
35 - Alder	Unknown	Unknown
36	65	5

37	65	5
38	65	5
39	65	5
40	105	8
41	65	5
42 –Mercer Court	124	8
43	37	3
44	50	4
45	50	4

Source: University of Washington Master Plan - Seattle Campus Development Program (2003), available online at http://www.washington.edu/community/files/2003/08/04B_Development _Program_FP.pdf.

6. Develop solar-electric system equipment matrix

In order to compare various options for the solar array components (including photovoltaic [PV] modules and inverters), we developed an equipment matrix. At of the time of our research, there are over sixty manufacturers and 900 PV modules,[7] requiring some initial sorting criteria in order to create a manageable comparison. These criteria are:

- Equipment certified as made in Washington.
- Equipment certified as made in America.
- Equipment used in other Seattle-area projects. Performance information for these systems will be more relevant to UW-Solar's pilot project than out-of-area systems.

Based on these criteria, we included PV modules manufactured by iTek Energy, Silicon Energy, SolarWorld, and Sharp. Refer to Table 6. See Equipment Matrix Chart in Appendix of this report.

7. Compare photovoltaic applications

Two main options exist for solar-electric systems: grid-tied or standalone (also referred to as "off the grid"). Because all of the buildings under consideration in this study are connected to the grid, and because the solar-electric array will not produce sufficient power for the entire building load, we will use a grid-tied system. Even in a grid-tied system, however, there are other equipment and application considerations, particularly batteries, generators, and transfer switches.

[7] Based on HomePower, "2012-2013 PV Module Buyer's Guide" spreadsheet, accessed 3 March 2013, http://www.homepower.com/web-xtras.

While standalone systems require batteries, grid-tied systems can function without them. Batteries allow electricity produced to be stored for later use. However, they add cost to the system and long-term reliability can be an issue.

The team also considered including a generator in the system in lieu of batteries. In this application, the generator would begin to run in the event of a power outage, increasing the building's resiliency in instances of grid failure. However, a generator will add cost to the system, and most generators rely on fossil fuels for power production.

Another potential option is the inclusion of a transfer switch. Typically, decentralized power generation sources, such as solar arrays, automatically power off in the event of grid failure in order to protect utility workers from electrocution. A transfer switch allows the building to disconnect from the grid (also called "islanding") temporarily. Islanding permits the solar array to continue to function during grid failure events while protecting utility workers from any electrocution hazard. Transfer switches do add cost to the system, but compared to the cost of other components, the cost is negligible. Unfortunately, transfer switches seem most suited for small, residential applications: They generally require someone to manually throw the switch to disconnect from and reconnect to the grid.

Based on our analysis, the team elected to exclude batteries, generators, or transfer switches from the solar-electric system.

8. Determine site electrical use

For most solar installation projects it is prudent to conduct the following analysis before determining a preferred site and an optimal system:

- Examine past records of power consumption,
- Determine potential for conversion to renewable energy sources,
- Determine existing site electrical infrastructure, and
- Develop a conceptual model.

This pilot project is slightly different than many potential projects as two of the three buildings under consideration are still under construction, so past records of power consumption are not available. Also unique is that all of the buildings under consideration are connected to the same power grid and electricity production from a solar array on any of these buildings will provide power to the same grid, regardless of the chosen location. Because all buildings are grid tied and they have capable electrical panels on or near their roofs, they make excellent candidates for a solar photovoltaic system.

To determine whether these buildings will allow for a solar panel installation, we have inspected the electrical infrastructure on or near the roofs. There must be electrical panels suited for the amount of supplied current and voltage (208 or 480 volts), either on the rooftop, or in the main electrical room.

In the system design phase, we will determine the voltage needed from each string of solar panels, feed them into a combiner box, feed that into an inverter (if not using micro-inverters), and connect to one of the electrical panels to be tied into the grid. A production meter will only be required in the event that financial incentives being sought require power output tracking.

9. Determine spatial requirements for equipment

SCADA Equipment
The SCADA lab will be located off-site with capacity for remote access. It will not be located within any of the HFS buildings under consideration for the pilot project.

Solar Installation
The approximate areas listed above in section 4 include a 10-foot perimeter around the entire array in order to comply with safety and maintenance regulations. The specific layout of the array, including location and orientation of specific modules, will be designed at a later date.

10. Calculate system economics

PV installation projects are not all necessarily driven by the same goals, so this section may increase or decrease in overall importance depending on the goals of the project and the installation team. When determining system economics, the following factors should be addressed:

- Determine capital costs,
- Determine maintenance costs,
- Perform benefit-cost analysis and return on investment potential,
- Evaluate ownership and financing structures and incentives, and
- Estimate electrical production and savings.

Our PV project is largely budget driven. We hope to generate as much solar power as possible given the constraints of our budget. To this effect we have contacted installers to determine the costs of various solar panel modules, and we are working with them to determine the cost of maintenance annually over the life of the system.

The finance team is currently modeling benefit-cost and ROI potential and is also creating a matrix to evaluate ownership structures and incentives. The team is also working to create an excel tool to maximize the electrical production and savings based on panel characteristics and roof availability. This tool will be useful in our pilot project, but may prove to be more useful in projects where there is slightly more flexibility in the budget parameters.

11. Re-evaluate site considerations based on goals and make recommendations

Based on our goals and research, we understand **Mercer Court A** to be most suitable for a solar-electric array. Our second choice is **Poplar Hall**, and our third choice is **Lander Hall**.

Mercer Court A provides the largest area for a solar array, with the least amount of shading from other roof structures or equipment. Poplar has the next largest area, followed by Lander. Mercer A's east-west orientation provides ideal solar access. The large, connected area that is available for the array will help meet our goal of maximizing power on our budget. Poplar and Lander have smaller areas available with longer distances from each other, which will require a larger portion of the budget to be allocated to electrical conduit. The larger investment in conduit may reduce the budget available for modules, decreasing the amount of power the system will produce. In addition, Poplar and Lander have less ideal orientations, reducing the array's solar access.

Lastly, Mercer A's visibility will help meet our education and outreach goals for both the university community and general public. We recognize that Poplar and Lander may provide more direct curriculum relationships than would Mercer, since the Mercer buildings are apartments, rather than residence halls. However, we believe that the better siting, larger potential for power production, and greater community visibility of Mercer Court are more important to our team's goals.

12. Describe permitting requirements and project phasing for implementation

As the pilot project will be under the $90,000 threshold, it likely will not need to go through UW's Capital Projects Office (CPO). However, since Lander is still under construction, it may need to go through CPO. Should this building be selected, we will review requirements with CPO. We will also review requirements with UW's Design Review Board.

We anticipate this project will require a building permit and an electrical permit from the City of Seattle.

The installation process will include the following stages:

- Write specifications,
- Create and distribute Request for Proposals (RFP),
- Hold pre-bid meeting,

- Review bids and award project,
- Coordinate with selected contractor, and finalize design and engineering,
- Acquire permits and approvals from UW and the City of Seattle, and
- Install infrastructure and solar panels.

Because Lander is under construction, the installation process will not include an RFP. Instead, we anticipate this scope of work to be an add-on to their contract.

Regardless of which building is selected, we will ensure that consideration is given to construction activities that may affect the public, such as street closures and traffic officers.

13. Determine preferred vendors and equipment

As a demonstration project, our team feels it important to emphasize local power production. As part of this focus on local, we emphasize the use of local companies for the array equipment. Therefore, we recommend the following modules (listed in decreasing order of preference):

1. iTek
2. Silicon Energy
3. SolarWorld
4. Sharp

Similarly, we recommend inverters from local companies. At the time of this analysis, we are considering both centralized and micro-inverter options. Our current favored option is to design two smaller arrays, one with a centralized inverter and one with micro-inverters, in order to compare performance.

14. Make recommendations and seek stakeholder input

As noted in section 11, we recommend **Mercer Court A** as the best location for a solar-electric array. Our second choice is **Poplar Hall**, followed by our third choice, **Lander Hall**. We are finalizing our decision within our team and with HFS.

The SCADA System

Purpose & Scope

A Supervisory Control and Data Acquisition (*SCADA*) system, is a type of industrial control system (ICS). The purpose of such a system is to remotely monitor and control a physical system, and to collect data in real time from sensors mounted on said system. In the scope of the UW-Solar project, the SCADA system will acquire energy and atmospheric data from sensors mounted on the solar panel array(s).

SCADA systems typically consist of five or six primary components: The Human-Machine Interface (HMI), The Supervisory System, A Data/Operational Historian, Remote Terminal Units (RTUs) or Programmable Logic Controllers (PLCs), and a communications infrastructure (a network). The HMI is essentially the interface that the human operator interacts with in order to monitor and control the system. The supervisory system is the server and software that acquires data transmitted from the RTUs or PLCs and sends commands or controls to the mechanical portion of the system from the HMI. The Data or Operational Historian is database software which logs and records data for analyzing historical trends. The RTUs and PLCs are apparati which collect signals from physical sensors placed on the system, and translate those signals into digital data which is then transmitted to the supervisory system. PLCs are more complex than RTUs and will not be necessary for the scope and functionality of the UW-Solar system. One RTU from each of the selected SCADA vendors will suffice for the initial scope of the system. Finally, the last major component is a communications infrastructure, or network, for the remote systems to communicate with one another. Data must be collected by sensors, transmitted to RTUs, and then translated and transmitted to the supervisory system. This can be done via a number of potential options for connectivity including wired and wireless transmission.

For the scope of UW-Solar, several of these components will be virtualized, stored in a University data center, and accessed remotely. The HMIs, supervisory systems and data historians are all pieces of vendor-specific software which will be installed on virtual machines at a University data center. They will then be remotely accessible from any computer via authorized web login credentials. Physical aspects of the UW-Solar SCADA system will consist of four RTUs, each provided by a different vendor, sensors installed on the solar panels, and any cabling that is necessary for the communications infrastructure.

Parameters for Usability

System Design

Controls

The general consensus regarding solar panel usage in the Pacific Northwest states that fixed solar arrays are most useful because of particular climatic conditions inherent to our area. The region has significant annual cloud cover that causes scattering and energy absorption that makes solar tracking less effective than it is in other areas of the World. Fixed solar arrays are likely the most useful commercial or home solar energy applications but we feel that a movable array offers our project many benefits. A major portion of UW-Solar’s unique value proposition comes from the synergistic effects of combining Cyber Physical Systems (CPS) with sustainable energy. If our group elected to utilize a fixed array we would lose a key percentage of possible future stakeholders that have considerable vested interest in the use and security of applied Industrial Control Systems. For the aforementioned reasons, we elect to implement solar arrays that can be oriented along a single axis (east-west or north-south) despite conventional wisdom suggesting solar energy production in Seattle is only marginally improved through solar tracking. The movement along a single axis is controlled through our virtualized SCADA laboratory.

Sensors

The range of sensing capabilities is quite diverse. There are a number of considerations that will work to constrain our choices. Those considerations are elaborated hereafter. Firstly, many panels have built-in sensing units that are essential to monitoring the efficiency and health of the panel. These on-board sensors track a number of physical variables like panel temperature and energy output and will provide UW-Solar with useful data for later analysis. For our purpose, the use of a micro-inverter will offer the greatest value via its simplicity and inherent sensing capabilities. Secondly, panel vendors do offer cross-compatible plug-in sensor arrays that can track other variables. Thirdly, UW-Solar can use other sensor solutions mounted within the same physical area as the panels but separate from them.These arrays are diverse and will be used to track and calculate important climate variables that can affect solar energy production like ambient temperature, barometric pressure, wind speed and infrared or ultraviolet light. In sum, there will be sensing capabilities in the panels, plugged into the panels, and around the panels in order to generate a diverse data set that can be used by many disciplines for academic research.

Power

The system's RTU(s) will be connected in line with the solar panel array and will be powered by the solar panels. These units vary in power consumption but for the scope of UW-Solar's system, the units that will be used require a negligible amount of power--i.e. they are very energy efficient and many models exist that are explicitly made to be solar powered. Aligning with the goal of the UW-Solar project to provide uninterrupted power, directly connecting the RTUs to the solar array will also aid in ensuring availability and reliability of data acquisition. The remainder of the SCADA system will be software housed on a University data server and power consumption will not be a factor.

Networking

The SCADA system will be networked to provide two distinct areas of functionality. Firstly, SCADA control system instructions must be relayed from the virtualized lab to the Remote Terminal Unit to articulate the orientation of the panels. Therefore, an operator can access the control software through a virtual machine and give instructions to the RTU that will change the physical orientation of the solar panel(s). Secondly, as the RTU acquires data generated from the sensor components, it will require a means to transmit that data back to the supervisory system. The exact method of transmission varies between vendors but most RTU manufacturers include Ethernet ports on the RTU that can be hooked up to either a local area network or a wireless router for data transmission. The method utilized is largely dependent on the location of the panels and the

RTUs, as well as the existing IT infrastructure of that particular building. Most importantly, it is feasible to transmit the data over either cables or wirelessly.

Data Acquisition

The other primary function of our system will be the generation of useful data. The vendor specific Operating Systems offer services to be used as a "data historian" to track and compare changes over time. More importantly, we wish to generate a rich and varied data set that can be made available to other researchers and interested parties for the purpose of scholarship. The data sets can be provided upon request to academic researchers. The data acquisition functions are provided by vendor specific packages with proprietary software that will transmit, interpret, and store acquired data for the user.

Virtualization

The UW-Solar SCADA "lab" will be virtualized. What this means is that most of its components will be software rather than hardware, and will be installed on a server at one of the University's data centers. Each SCADA system vendor generally provides all components of the system, which all function with proprietary software. Taking this into account, we will be installing four different SCADA systems, which will all run as virtual machines on one of the University's servers. Each SCADA system's software will run on top of the operating system specified by its respective system requirements. Certain services will be opened on each virtual machine to allow for remote administration, data aggregation, and web access of the HMI and available controls. Access will be limited to authorized users with login credentials.

Controller

The Operating System (OS) is generally governed by the vendor that provides the SCADA system. The general thinking from people within industry is that proprietary Operating Systems are most feasible. Generally speaking, the SCADA system is tethered to a specific vendors particular OS. For our purposes we would like to utilize the SCADA solutions of four different vendors such that we can analyze and study issues of performance and interoperability. The currently discussed vendors are Siemens, Motorola, Wonderware, and Schneider (in-state). We are in the process of selecting and contacting vendors for further information to prioritize and compare costs and benefits.

Maintenance

Maintenance of the SCADA system and related components will be tied into the existing data center's maintenance infrastructure and policies. The Remote Terminal Unit (RTU) is designed to be rugged and weather resistant and does not require special maintenance. The only concern would be required repairs or troubleshooting the RTU, which would be exercised through the vendor. Outdoor RTUs are designed to be low maintenance.

Security & Privacy

Physical security controls will be synonymous with the UW data center within which the virtualized SCADA system(s) are housed. The primary technical access control that will be in place is a Single Sign-On (SSO) login ID and password that will be required to access the web API in order to monitor and control the virtualized SCADA systems. These login credentials will only be provided to select persons upon request, and will expire in a timely fashion corresponding with said person's need for access--i.e. if a student needs access for research purposes for a period of three months, their login credentials will expire 90 days after they are created. Only a limited number of authorized personnel will have administrator-level access to the virtualized SCADA systems. Auditable logs will also be generated on the system detailing who logged into the system and when for incident response and attribution purposes. Periodic snapshots of the virtual machines will be made and stored on a separate drive as backups for continuity and recovery purposes.

Education & Outreach

The SCADA system will provide a large body of usable data for analysis by distinct groups of academics and professionals including those concerned with atmospheric sciences, energy, and informatics. The virtual SCADA "Lab" will be available for use in future coursework at the University in a vast array of academic specializations. Specifically, it will provide a unique opportunity for supplementary education and focus in increasing vital academic concentrations such as: cyber physical systems (CPS), critical infrastructure protection, information assurance (including issues of data Confidentiality, Integrity, and Availability), data mining, data analytics, database management, cloud services (IaaS), renewable energy, and uninterrupted, distributed power systems. These newly opened research opportunities will consequently function to attract new students, faculty and professionals in the above-mentioned disciplined.

Data generated by the system will also serve to inform potential future publications in information systems and management as well as renewable energy research. Establishing the virtualized SCADA "lab" will also provide a legacy system for future students to learn about SCADA system maintenance, expansion, upgrading and repurposing in addition to the particular areas of academic research the system serves. Aside from individual research projects, the system will also function as an applied research tool for interdepartmental collaborative efforts, such as larger-scoped projects conducted between Information School and Urban Planning students. In this way, the system will provide an avenue for real-world interdisciplinary teamwork, project management and research experience.

Additional outreach efforts by the system will include data visualizations on display in the lobbies of the buildings upon which solar panels are installed. Monitors will display data such as: power consumption, power generated by solar panels, and weather/atmospheric data acquired by sensors on the solar array. These publicly displayed monitors will serve as outreach mechanisms to provide the public with a visual representation of what the UW-Solar system does.

Institutional Frameworks

Institutional Goals

Regulatory Frameworks

The Institutional sub-group is working with the Financing & Policy sub-group to develop a Vendor Matrix which will list and rank key UW Solar values and corresponding project design objectives (for example - working with a local vendor, sourcing locally manufactured products, working with a vendor with demonstrated solar community outreach experience).

In addition, the Institutional sub-group has created the following Implementation Process framework for the UW Solar project based on solar vendor feedback:

1) Request For Proposal – Vendor submits RFP & Proposal is accepted by UW Solar;

2) Google Earth – Vendor works with UW Solar to examine roof characteristics with Google visualization to examine shading (or future shading) which can have negative impact on power production;

3) Site Visit – Vendor works with UW Solar to take measurements including identifying any roof obstructions, safety buffer needs, measures solar path, and determines if any line loss/wiring issues;

4) CAD Drawing – Vendor works with UW Solar to create layout for module & inverter placement, including orientation of panels (if arrays move & tilt), identify if central string inverter versus micro-inverters (add 10% to cost for micro-inverters), electrical box, wiring, etc.;

5) Project Proposal – Vendor creates Full Proposal which typically includes 3 project alternatives (Silicon Energy, Itek, or Solar World system for example);

6) One-Line Drawing – Vendor works with UW Solar to craft a one-line drawing which will codify project elements including # of panels, inverters, expected system capacity (Drawing to be submitted to Seattle City Light with Permit Application);

7) Obtain Seattle City Light Electrical Permit & Interconnection Agreement and Dept. of Revenue certification – Vendor will work with UW Solar to obtain necessary permitting for project; building permit is responsibility of UW Solar;

8) Pre-Construction Meeting – Vendor will conduct Pre-Construction Meeting with UW Solar group and contractors on-site;

9) Installation – Vendor installs panels at project site;

The framework for Maintenance is discussed below.

Developing a UW Solar Stakeholder Timeline
The Institutional sub-group established a UW Solar work-plan with timeline for each phase of the project including the feasibility study (initial draft, revisions, including Advisory Group review, and final approval), the project plan & design, and project implementation. The feasibility study has been finalized and includes an exploration of the potential viability of solar energy on University of Washington's Seattle campus. The feasibility study addresses key project concerns including identifying appropriate site locations, solar equipment, and installation requirements. In addition, the study establishes:

- Regulatory and building code considerations;
- Project space usage & accessibility concerns;
- Establishes stakeholder advisory committee and regular reporting process;
- Fundraising and outreach plan;
- Cost/Benefit and return on investment analysis;
- Management plan for project maintenance;

Maps of potential solar install locations and a priority listing of project sites, pursuant to approval by key UW staff and administration, will also be included in the study. The UW Solar Team has engaged the enthusiastic participation of the UW Offices of Housing and Food Services, Budgeting and Planning, and Facilities for this purpose. In addition, UW Solar initiated project planning and design in the spring 2013 which will continue through this quarter.

Once the Advisory Committee has approved the UW Solar design plan, project implementation (tentatively scheduled to begin in September 2013) will commence. The design and implementation phases include solicitation of bids from firms to volunteer and/or donate services and equipment. We expect the participating firms to play a key role as mentors for participating students as part of this project. Participating firms will be assist students in learning about the technology, markets, and processes associated with developing solar systems.

The project seeks to install a solar array on a Housing and Food Service residence hall on the UW Seattle campus for shared use by the College of Built Environments. Energy production will be tracked through an industrial control system showing kilowatt output. UW Solar plans to use events and public displays to showcase information about the project on campus to communicate about the impact of local clean power. Consequently, we expect that showcasing this project on campus will help raise awareness among students about energy conservation and the advantages of solar power. Campus outreach will include information dissemination through UW student organizations devoted to sustainability, clean energy and green building. Several members of the UW Solar team will be continuing their education the following fall 2013 and plan to recruit new interested members to the UW Solar team. Furthermore, UW Solar plans to work with faculty at the School of Built Environments to develop a curriculum on designing, siting and funding solar systems to be offered as a graduate level course.

Creating a UW Solar Stakeholder Consensus Process
In order to set up a process for attaining stakeholder consensus, the Institutional sub-group first **established an Advisory Committee** with key representatives from UW Solar sub-groups (Siting & Infrastructure, Financing & Policy, SCADA, and Education & Outreach, and with representatives from UW Office of Budgeting & Planning, Office of Housing & Food Services, and Office of Facilities; UW Solar including each of the sub-groups, UW Office (JR Fulton, Lyndsey Cameron, Jan Whittington, Stefanie Young).

Next the Institutional sub-group established a **regular bi-weekly in-person meeting schedule** for the Advisory Committee; these bi-weekly meetings allowed participants to discuss important project issues and establish key action items for the next meeting; before each in-person Advisory Committee meeting, participants were able to review notes from the previous meeting, post reports for review, and add to the meeting agenda as needed prior to each meeting; one person was assigned each meeting to document Committee meeting minutes and highlight key action items and the associated point person; bi-weekly Advisory Committee meetings provide a regular venue for ongoing project feedback.

Next, the Institutional sub-group established **regular weekly memo reports** sent out to all Advisory Committee members to document project progress; in addition, these regular memos kept each of the sub-groups focused on key action items and assisted UW Solar in planning meeting agendas for the bi-weekly in-person meetings; Committee.

Lastly, project partners will be in regular contact via phone, email, and text, and be conducting regular in-person meetings with vendors including site visits; participants will have opportunities to raise concerns or issues with the Advisory Committee and among UW Solar Team members, who will in turn be able to offer suggestions or recommendations.

Assessing UW Solar power usage & payment process
The Institutional sub-group examined the UW Solar project power usage and payment process. The project site will be **located on the west-side of the UW campus** which is connected to the local utility (Seattle City Light) grid; in addition, UW currently contracts with the local public utility, Seattle City Light, to provide a majority of their electricity on campus (note – approximately 95% of

Seattle City Light's power generation comes from hydro-electric dams which produce electricity at relatively low rates).

Electric rates are priced at two levels - off-peak and peak rates (currently priced **at approximately 4-6 cents per kW/h**); prices fluctuate based on seasonal demand and changes in the energy market; UW also participates in Seattle City Light's Green Up program, which funds the purchase of Renewable Energy Credits (RECs) to support regional wind, solar, and other renewable projects in Washington, Oregon, and Idaho.

The power consumption associated with the selected UW Solar project site will be examined as part of the SCADA sub-group's data collection and monitoring process; in addition, UW Solar SCADA sub-group hopes to **integrate price paid per kW/h as a performance metric** for the purposes of monitoring the project's power usage and cost; the Financing & Policy section of this report explores benefit/cost scenarios associated with varying solar system size designs and expected power production.

Identifying UW Solar Operation & Maintenance Responsibilities

The Institutional sub-group plans to work with the Advisory Committee to draft an official Operations & Maintenance Agreement with Housing & Food Services (sponsoring unit) for this project; the **Operation & Maintenance Agreement will codify the process** for UW Solar project operation & maintenance and identify at least one UW Solar contact and one Housing & Food Services contact as responsible parties for the purposes of the Agreement.

The UW Solar project operation will include monitoring of the project system and power production to be **coordinated with personnel from Housing & Food Services** and the UW Solar SCADA project monitoring sub-group. Based on solar contractor feedback, solar system maintenance includes annual cleaning of solar panels with **recommended budget of $300-$500/year**.

In addition, there may be periodic equipment repairs and replacement of system components; the UW Solar budget will include **contingency cost allocations for periodic repair and maintenance**; the UW Solar identified responsible party to the Agreement (student participant) working in collaboration with Housing & Food Services personnel will be responsible for coordinating project maintenance as needed.

Financing, Policy, and Budget

The finance and policy portion of the feasibility study examines cost effective methods for building and financing solar panel projects on the University of Washington campus. The secondary goal of the study is to provide a body of research that aids in the wider development of solar technology, both on campus and regionally. The UW Solar team will work with industry experts, UW faculty, CSF, and UW HFS to research a wider array of financing methods and solar best practices.

Our group and future solar advocates will use this research to lobby for better city, state, and federal renewable energy permitting regulations and incentives. This section describes our ongoing research as of April 5, 2013 and outlines the framework that we will use going forward.

The main components of our work include:

- Developing partnerships
- Leveraging other projects
- Researching for potential solar advocacy
- Exploring available financing mechanisms
- Researching incentives
- Finding carbon credit opportunities
- Conducting a Cost-Benefit Analysis
- Brainstorming alternative options - including Value Engineering
- Calculating the financial return on researched investment models

Each of these steps is explained in further detail below.

Developing Partnerships
One important step in the financing and policy research involves developing partnerships with the University of Washington departments, solar consultants, and other key stakeholders. These relationships will help us pool resources and knowledge to develop a strong model for solar array development.

Moving forward, we plan to consult with a wide range of solar companies in Washington State, in addition to the potential contacts listed above. At this stage, we are soliciting all possible input on appropriate requirements to include in our array and the financing options. This information will be useful not only for the current array, but for our reporting on tools for future solar energy development as well.

Identified Finance and Policy Consultants and Partners (As of April 5, 2013)

Potential Contact Organizations	Organizations Contacted by the Finance and Policy Working Group
American Solar Energy Society (WA Chapter)	Keyes and Fox
Cascade Power Group	McKinstry and the Capital Strategy Group
Environmental Capital Partners	Vulcan
Mosaic	
NW SEED	
Puget Sound Energy	
Puget Sound Solar	
Seattle City Light	
Spectrum Energy Development, Inc.	
Sunergy Systems	

Leveraging Other Projects

The feasibility study scope includes identifying solar projects in Washington State that are either in the feasibility stage, underway or completed. By collaborating with other project teams, we hope to accelerate our learning and adopt existing best practices from other projects.

Vulcan, a large local developer with a focus on sustainable technology and McKinstry, a leading provider of energy retrofit programs, are already working with our team. With help from these two companies and other private sector partners, we hope to gain a comprehensive understanding of what has worked well in the past and what potential challenges lie ahead for UW-Solar.

We plan to reach out to project leaders at a number of other Universities that have researched solar array installation and completed renewable energy projects. One notable group includes the universities with the top ten highest energy capacity roof mounted solar projects, as submitted to the Association for the Advancement of Sustainability in Higher Education (AASHE): Arizona State University; California State - Fullerton; University of San Diego; University of California - San Diego; California Institute of Technology; Santa Clara University; California State - East Bay; and University of California- Irvine. While these projects occurred in other states, with different permitting and tax conditions, there is still much to be learned from their successes.

Potential Solar Advocacy

We will continue to investigate the requirements for and roadblocks to solar energy at various scales in the state. Our research has discovered that Washington State has certain legislative restrictions in place on Power Purchase Agreements for projects at a smaller scale. Potentially, our research and developed partnerships may be leveraged to lobby for a more widely applicable and streamlined process for power purchase agreements concerning renewable energy.

Through this study, we hope to identify potential incentives that would support solar implementation. Our policy team hopes to work with other lobby groups to identify potential incentives and legislative changes that further support future widespread solar adoption.

Exploring Available Finance Mechanisms
The team will explore financing the solar implementation through various financing structures and potential partnerships with outside vendors. These creative financing methods may not be viable for the pilot solar array set to be built in 2013, however our team will continue to evaluate all possible mechanisms for their potential to apply to future projects.

To fulfill one goal of the study, we are researching financing options and ranking them in terms of applicability to long-term solar implementation. A few of these mechanisms already being researched include:

Equity Flip: In this case, the vendor or investor provides capital for a PV solar implementation. After a set period where vendor/investor receives a set return on investment through tax incentives and/or energy savings, ownership of solar system switches back to UW.

Reverse Auction (Bid): Focusing on energy generation and payback period requirements when soliciting vendor bids for solar systems.

Power Purchase Agreement (PPA): Agreement to purchase power from a vendor or investor group who pay for and install a solar system.

501c(3): Creating or partnering with non-profit organizations. Non-profits may provide an alternative investment model for UW. Nonprofits may have access to a wider array of tax exemptions and credits than other models, but they come with certain restrictions. We are currently investigating the formation of a 501c(3) through the Husky Fund and continue to research all possible avenues of incorporating the 501c(3) model.

Real Estate Investment Trust, Investment Funds or Mosaic: Real Estate Investment Trusts (REITs) or other investment funds may provide capital for projects in exchange for long-term return on investment. Mosaic, a solar investment fund, works to fund solar projects by connecting individual investors with promising solar projects. It essentially creates a crowd-sourced network of funders and makes investors aware of tax and other incentives that make renewable energy projects financially feasible.

Other Mechanisms: We are using the contacts enumerated above, as well as all current available reporting on solar financing, to brainstorm options for financing both the feasibility installation and future solar installations.

Incentives

Our team has researched currently available programs and incentives to help encourage investment in solar. The team has identified a need for more incentives supporting larger installations. In addition, some of the incentives currently available will be negatively affected by the sequester. Through working with our advisors and partners, we will explore potential opportunities to utilize incentives from local, state and federal governments. Potentially applicable incentives that we are currently researching include:

Federal Renewable Electricity Production Tax Credit (PTC): a federal tax credit that lowers the income taxes of renewable energy project owners based on the kilowatt-hours that renewable energy facilities connected to the grid produce.

Investment Tax Credit (ITC): a federal tax credit that reduces income tax based on investment in capital for renewable energy projects.

Washington Administrative Code (WAC) 458-20-273: A renewable energy system cost recovery program that provides incentive payments of up to $1.08 per kWh for equipment manufactured in WA State.

Renewable Energy Credits (RECs): a mechanism for utilities to fulfill their Renewables Portfolio Standard commitment to obtain 15% of their electricity from new renewable resources by 2020. Utilities can produce the energy themselves, or purchase RECs. The Western Electricity Coordinating Council (WECC) has set up the Western Renewable Energy Generation Information System (WREGIS) to oversee REC trading.

We are continuing to cast a wide net as part of our studies, in order for our research to be useful for individuals looking to develop future solar projects at UW and in the region.

Carbon Credit Opportunities

Renewable energy projects such as this solar array have the benefit of replacing greenhouse gas emitting energy sources with sustainable, clean alternatives. There are a number of organizations out there that seek to incentivize this process of phasing out fossil fuels. We will continue to investigate how best to incorporate the issue of greenhouse gas mitigation in our finance and policy reporting. As a preliminary step, the electrical output of the solar array can easily be converted into carbon dioxide equivalents for reporting purposes.

Cost Benefit Analysis

Utilizing the expertise of our advisors, vendors and stakeholders, we are researching both the initial upfront capital costs and long-term lifecycle costs. We are in the process of setting up financial models for the feasibility installation to forecast and track cost through the life of the solar system. We hope to establish a long-term study of the financial performance of solar systems at UW.

Alternative Options - Value Engineering

While we will be installing one system, we will be looking at alternatives system configurations. The alternatives, which may include only slight modifications, will be measured in terms of power generation, initial upfront investment and long-term repair and maintenance costs. The goal is to explore alternatives that may provide a better overall value for the UW and other solar implementations.

Return on Investment Models

Financial returns can be measured in a variety of ways. One of the main deliverables from the study will be aligning all return on investment information with how the University of Washington evaluates capital investment. This will help decision makers compare and contrast different investment the opportunities. Our findings may be presented in a few ways, including IRR (Internal Rate of Return), total lifecycle costs discounting future values at the UW's preferred investment return rate, net present value, payback periods and other measures depending on direction from our partners.

Education and Outreach Plan

Education
Signage and educational outreach. Proposed signage design should go through our office if it is to be located on the exterior of the building. You will have a much better chance of having exterior signage approved if it is located in an interior courtyard. The interior of the building is under housings purview.

Outreach
Community Outreach. Be prepared to take the feasibility study before
CUCAChttp://www.washington.edu/community/cucac/ and
FCUFS http://www.washington.edu/faculty/committees/

Location Decision Tree for Screening for PV Sites
As a component of our outreach and education campaign, we hope to develop a tool that will aid in the screening of sites for solar arrays in similar institutional settings, particularly in the Pacific Northwest. The idea for this tool came from a joint effort of the United States Environmental Protection Agency (EPA) and the National Renewable Energy Laboratory (NREL). The EPA and NREL tool is useful, but it is geared toward larger development projects (i.e., rooftops with more than 30,000 square feet) in areas with greater solar resources.

We envision that this tool will take the form of a decision tree that will reduce the time and effort involved in establishing initial screening parameters for rooftop installations. We will include pre-screening, screening, financial, and equipment flowcharts that are predominantly geared toward institutional or commercial sites in western Washington State.

The decision tree will mirror our own feasibility study, but will provide generalized information and tips in a user-friendly format. At this time, we envision four separate flow charts to guide interested parties through the feasibility analysis, although this will likely change as we work through our own feasibility process. The components we envision consist of:

- Pre-Screening
  - Goal formulation
  - Site or study area identification
  - General roof characteristics
  - General PV potential
- Screening
  - Detailed roof specifications
  - General building characteristics
  - Detailed PV potential
  - Future development plans and tree canopy
- Equipment
  - Equipment type, specifications, and applications
  - Preferred Vendors
- Financial
  - System economics
  - Equipment cost and maintenance
  - Installation costs
  - Existing incentives or tax credits

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As a component of our outreach and education campaign, we hope to develop a tool that will aid in the screening of sites for solar arrays in similar institutional settings, particularly in the Pacific Northwest. The idea for this tool came from a joint effort of the United States Environmental Protection Agency (EPA) and the National Renewable Energy Laboratory (NREL). The EPA and NREL tool is useful, but it is geared toward larger development projects (i.e., rooftops with more than 30,000 square feet) in areas with greater solar resources.

We envision that this tool will take the form of a decision tree that will reduce the time and effort involved in establishing initial screening parameters for rooftop installations. We will include pre-screening, screening, financial, and equipment flowcharts that are predominantly geared toward institutional or commercial sites in western Washington State.

The decision tree will mirror our own feasibility study, but will provide generalized information and tips in a user-friendly format. At this time, we envision four separate flow charts to guide interested parties through the feasibility analysis, although this will likely change as we work through our own feasibility process. The components we envision consist of:

- Pre-Screening
  - Goal formulation
  - Site or study area identification
  - General roof characteristics
  - General PV potential
- Screening
  - Detailed roof specifications
  - General building characteristics
  - Detailed PV potential
  - Future development plans and tree canopy
- Equipment
  - Equipment type, specifications, and applications
  - Preferred Vendors
- Financial
  - System economics
  - Equipment cost and maintenance
  - Installation costs
  - Existing incentives or tax credits

Equipment Matrix - priority list

Company & Product	*Description*	*Type*	*Dimensions*	*Weight*	*Electrical Data & Parameters*								*Frame*	*Maintenance & Expected Lifetime*	*Additional Components & Considerations*
					Peak Power	*Voltage at max power*	*Open-circuit voltage*	*Max power current*	*Short-circuit current*	*Nominal operating cell temperature*	*Power tolerance*	*Module efficiency*			
itek Energy Solar Module 255w *certified Made in WA	Specifically designed for NW lighting conditions. Frames provide mounting holes for microinverters (compatible with APS microinverters, which are also made in WA).	silicon cell, monocrystalline 60 cells (3 strings of 20 cells, 3 bypass diodes)	39.1" x 64.8" x 2"	43#	255 W	30.4 V	38.4 V	8.7 A	9.0 A	48.20 C	3% +/-	18%	high strength, anodized aluminum. both top-down clamps and bottom flange mounting compatible.	25-year power output warranty	fully compatible with APS microinverters
Silicon Energy Cascade Series Next Generation 205w *made in WA	Silicon Energy's next generation Cascade module's integrated design delivers simplicity, beauty, and the flexibility to perform for all types of installations, including sunshades, canopies, awnings, shelters, carports and other overhead structural solutions benefitting from light passage. Can be roof- or ground-mounted.	crystalline 49 cells (7 x 7 series, 4 bypass diodes)	44" x 48"	55#	205 W	25.6 V	30.6 V	8.0 A	8.6 A						
SolarWorld Sunmodule Solar Panels 245w * made in USA	The mono-and polycrystalline products from SolarWorld come in variety of sizes, making them suitable for all applications – from a residential rooftop to a large-scale facility.	polycrystalline 60 cells	37.44" x 65.94" x 1.22"	46.7#	245 W	30.8 V	37.5 V	7.96 A	8.49 A	46 C	-0 / + 5	14.61%	clear anodized aluminum, compatible with both top-down and bottom mounting methods	25-year linear performance guarantee	SolarWorld also makes a Suntrol monitoring system
SolarWorld Sunmodule Solar Panels 270w * made in USA	The mono-and polycrystalline products from SolarWorld come in variety of sizes, making them suitable for all applications – from a residential rooftop to a large-scale facility.	monocrystalline 60 cells	37.44" x 65.94" x 1.22"	46.7#	270 W	32.1 V	38.3 V	8.42 A	8.90 A	46 C	-0 / + 5	16.1%	clear anodized aluminum, compatible with both top-down and bottom mounting methods	25-year linear performance guarantee	SolarWorld also makes a Suntrol monitoring system
Sharp 250w module * qualify as "Buy American"	This module uses an advanced surface texturing process to increase light absorption and improve efficiency.	polycrystalline 60 cells in series	39.1" x 64.6" x 1.8"	41.9#	250 W	29.8 V	38.3 V	8.40 A	8.90 A	47.5 C	-0 / + 5%	15.3%		25-year limited power output warranty	

DURABLE
SUSTAINABLE
BEAUTIFUL

THE SILICON ENERGY DIFFERENCE

CASCADE SERIES PV MODULE AND MOUNTING SYSTEM, NEXT GENERATION

Silicon Energy's next generation Cascade module's integrated design delivers simplicity, beauty, and the flexibility to perform for all types of installations, including sunshades, canopies, awnings, shelters, carports and other overhead structural solutions benefitting from light passage.

MADE IN USA · ETL US · ARRA COMPLIANT

CASCADE SERIES MODULE

Silicon Energy's Double-Glass Cascade Module is a US-made PV module with unmatched quality, durability, safety, appearance, and versatility.

SILICON ENERGY ADVANTAGE:

- Strength - 125psf design meets the demands of the highest wind and snow loads
- Durability - Double-Glass construction bonded with advanced laminate materials is built to last and backed by a 30-year warranty
- Power - High efficiency crystalline solar cells
- Suitable for overhead structures and integrated designs, allowing approximately 10% light passage.

CASCADE SERIES MOUNTING SYSTEM

Silicon Energy's integrated mounting system is engineered to optimize solar production and enable clean and safe installations.

SILICON ENERGY ADVANTAGE:

- Designed for 4' Centers, simplifying structural design for the US Market
- Mounting System protects and conceals wiring
- Modules are supported in a shingle-like pattern to optimally shed snow, dirt, debris, and increase air flow
- Custom colors available (Architectural bronze is standard)

ELECTRICAL CHARACTERISTICS MEASURED AT STC*	SiE190	SiE195	SiE200	SiE205
Rated Power (Pmax) Watts	190	195	200	205
Maximum Power Voltage (Vmp)	25.3	25.5	25.6	25.6
Maximum Power Current (Imp)	7.5	7.7	7.8	8.0
Open Circuit Voltage (Voc)	30.5	30.5	30.6	30.6
Short Circuit Current (Isc)	7.9	8.2	8.4	8.6
Maximum System Voltage (VDC)	600	600	600	600
Series Fuse Rating Amp (Amps-DC)	15	15	15	15

**Standard Test Conditions (STC) at 1000w/m², AM 1.5 spectrum, 77°F/25°C cell temperature*

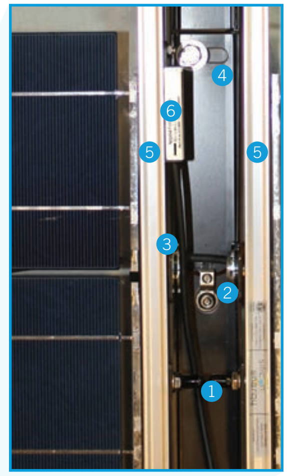
WARRANTIES AND CERTIFICATIONS	
Warranties	30-year limited power warranty 5-year limited product warranty
Certifications	UL 1703, (Canada and US) Class-A Fire Rating CEC
Qualifications	Made in Washington
	Made in Minnesota
	Made in USA

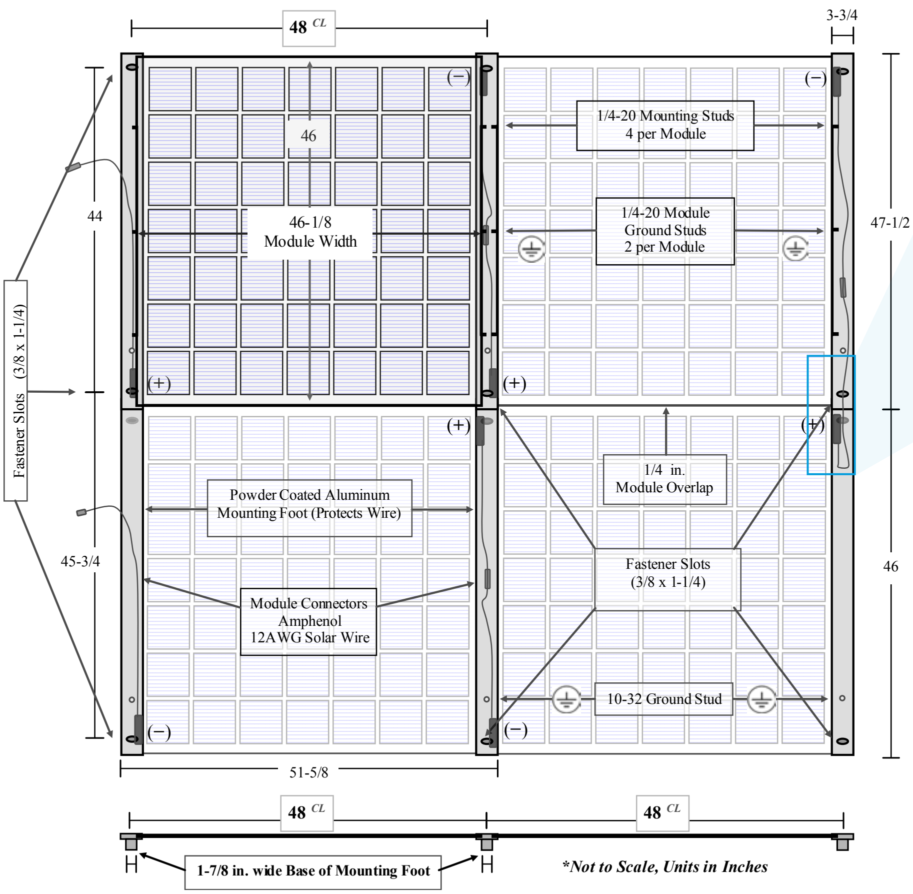
MECHANICAL SPECIFICATIONS	
Module Weight	55 lbs, (Module & mounting hardware weighs ~ 62 lbs or 3.9 lbs/ft²)
Cells	49 crystalline silicon cells wired in series (7x7)
Diodes	4 bypass diodes per module
Frame	Aluminum alloy 6063-T6 extruded ¼-20 stainless steel studs with flange nuts
Design Load	125 psf, front and back
Construction	**Front:** 0.125 in. high transmissivity tempered float glass with anti-reflective (AR) coating **Back:** 0.125 in. tempered glass **Encapsulant:** Advanced encapsulant
Mounting Foot	0.090 in. powder coated aluminum alloy 5052 H32
Slope of Module	1.85° (minimum mounting surface angle 5°)
Connectors (Wire)	Amphenol, (12AWG USE2 wire, length ~ 32 inches)

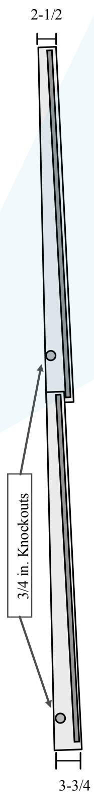
THERMAL CHARACTERISTICS	
Temperature Coefficients	Pmax: -0.566/°C Voc: -0.389%/°C Isc: 0.109%/°C
Temperature Range	-40 to 194°F (-40 to 90°C)

MOUNTING FOOT FEATURES

1. ¼-20 Mounting Studs
2. Ground Lug
3. Conduit Fittings
4. 3/8 x 1¼ Fastener Slot
5. Module Frame
6. Single Pole Junction Box







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Marysville, WA 98271 USA
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Mt. Iron, MN 55768 USA
Tel: 218-789-1710

silicon energy™

www.silicon-energy.com

SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE
ATTENTION: THOROUGHLY READ INSTRUCTIONS IN USER'S MANUAL BEFORE INSTALLING

Revision 01.18.2013

SHARP

solar electricity

250 WATT

MULTI-PURPOSE MODULE

ND-250QCS

MULTI-PURPOSE 250 WATT MODULE FROM THE WORLD'S TRUSTED SOURCE FOR SOLAR.

Using breakthrough technology, made possible by nearly 50 years of proprietary research and development, Sharp's ND-250QCS solar module incorporates an advanced surface texturing process to increase light absorption and improve efficiency. Common applications include commercial and residential grid-tied roof systems as well as ground mounted arrays. Designed to withstand rigorous operating conditions, this module offers high power output per square foot of solar array.

This module is ideal for large commercial applications, demonstrating financial astuteness and environmental stewardship.

ENGINEERING EXCELLENCE

High module efficiency for an outstanding balance of size and weight to power and performance.

5% POSITIVE POWER TOLERANCE

Count on Sharp to deliver all the watts you pay for with a positive-only power tolerance of +5%.

RELIABLE

25-year limited warranty on power output and 10-year limited warranty on materials or workmanship.

HIGH PERFORMANCE

This module uses an advanced surface texturing process to increase light absorption and improve efficiency.

Sharp multi-purpose modules offer industry-leading performance for a variety of applications.

Tempered glass, EVA lamination and weatherproof backskin provide long-life and enhanced cell performance.

SHARP: THE NAME TO TRUST

When you choose Sharp, you get more than well-engineered products. You also get Sharp's proven reliablity, outstanding customer service and the assurance of both our 10-year warranty on materials or workmanship as well as the 25-year limited warranty on power output. With over 50 years experience in solar and over 4.3 GW of installed capacity, Sharp has a proven legacy as a trusted name in solar.

BECOME POWERFUL

250 WATT

ND-250QCS

Module output cables: 12 AWG PV Wire (per UL Subject 4703)

ELECTRICAL CHARACTERISTICS

Maximum Power (Pmax)*	250 W
Tolerance of Pmax	+5%/-0%
PTC Rating	223.6 W
Type of Cell	Polycrystalline silicon
Cell Configuration	60 in series
Open Circuit Voltage (Voc)	38.3 V
Maximum Power Voltage (Vpm)	29.8 V
Short Circuit Current (Isc)	8.90 A
Maximum Power Current (Ipm)	8.40 A
Module Efficiency (%)	15.3%
Maximum System (DC) Voltage	600 V (UL)/1000V (IEC)
Series Fuse Rating	15 A
NOCT	47.5°C
Temperature Coefficient (Pmax)	-0.485%/°C
Temperature Coefficient (Voc)	-0.36%/°C
Temperature Coefficient (Isc)	0.053%/°C

*Illumination of 1 kW/m² (1 sun) at spectral distribution of AM 1.5 (ASTM E892 global spectral irradiance) at a cell temperature of 25°C.

MECHANICAL CHARACTERISTICS

Dimensions (A x B x C to the right)	39.1" x 64.6" x 1.8"/994 x 1640 x 46 mm
Cable Length (G)	43.3"/1100 mm
Output Interconnect Cable	12 AWG with *SMK Locking Connector
Hail Impact Resistance	1" (25 mm) at 52 mph (23 m/s)
Weight	41.9 lbs / 19.0 kg
Max Load	50 psf (2400 Pascals)
Operating Temperature (cell)	-40 to 194°F / -40 to 90°C

*Intertek recognized for mating with MC-4 connectors (part numbers PV-KST4; PV-KBT4)

CERTIFICATIONS

UL 1703, ULC/ORD-C1703, IEC 61215, IEC 61730, CEC, FSEC

WARRANTY

25-year limited warranty on power output
Contact Sharp for complete warranty information

Design and specifications are subject to change without notice.
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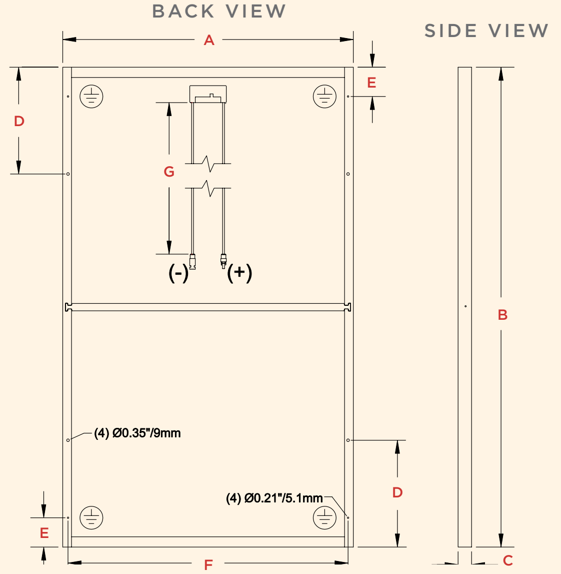
DIMENSIONS



A	B	C	D	E
39.1"/994 mm	64.6"/1640 mm	1.8"/46 mm	14.4"/365 mm	3.9"/100 mm

F	G
37.7"/958 mm	43.3"/1100 mm

Contact Sharp for tolerance specifications

ISO QUALITY & ENVIRONMENTAL MANAGEMENT

Sharp solar modules are manufactured in ISO 9001:2000 AND ISO 14001:2004 certified facilities.

"BUY AMERICAN"

Sharp solar modules are manufactured in the United States and Japan, and qualify as "American" goods under the "Buy American" clause of the American Recovery and Reinvestment Act (ARRA).

SHARP ELECTRONICS CORPORATION
5700 NW Pacific Rim Boulevard, Camas, WA 98607
1-800-SOLAR-06 • Email: sharpsolar@sharpusa.com
www.sharpusa.com/solar

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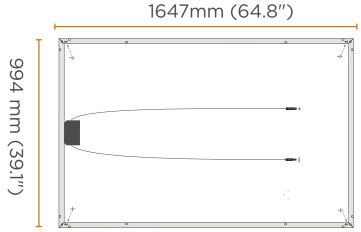
Itek Energy Solar Modules

The high performance, high quality and affordable solar solution

- High Efficiency Mono Crystalline Cells
- 25-Year Power Output Warranty
- 10-Year Workmanship Warranty

GENERAL DATA

Cell Type	60 Mono crystalline cells • 3 strings of 20 cells - 3 by-pass diodes
Glass	Ultra clear low iron tempered solar glass with anti-glare prismatic subsurface texture
Backsheet	Double layer highly resistant polyester
Frame	High strength anodized aluminum frame compatible for both top-down clamps and bottom flange mounting • Numerous flange mounting holes on inch dimension centers • Mounting holes specifically for micro-inverter applications
Cable	1M (39”) 90C 12AWG PV wire
Connector	MC4
Grounding	Certified for Wiley Electronics WEEB™ grounding clips • Eight standard grounding locations per module for reduced ground wire length
Wafers	200 microns thick



Backside of Solar Module

ELECTRICAL DATA*

ELECTRICAL DATA*	IT 225	IT 230	IT 235	IT 240	IT 245	IT 250	IT 255
Maximum Power - P_{MAX} (Wp)	225	230	235	240	245	250	255
Maximum Power Voltage - V_{MPP} (V)	29.7	29.8	29.9	30.0	30.1	30.3	30.4
Maximum Power Current - I_{MPP} (A)	7.8	7.9	8.1	8.2	8.4	8.5	8.7
Open Circuit Voltage - V_{OC} (V)	37.6	37.7	37.9	38.0	38.2	38.3	38.4
Short Circuit Current - I_{SC} (A)	8.4	8.5	8.6	8.7	8.8	8.9	9.0

** Electrical characteristics may vary within + / - 3% of the indicated values at Standard Test Conditions (STC): Irradiance of 1000W/m2, AM 1.5 spectrum, cell temperature 25C(77F)*

MECHANICAL DATA

Dimensions	39.1” X 64.8”
Weight	43 lbs

MAXIMUM RATINGS

Operational Temperature	-40...+90ºC
Maximum System Voltage	600V
Design Load (UL1703)	
Maximum Load (IEC 61215)	551 KG/M2 (5400 Pa) Target
Maximum Wind Speed	122 mph (safety factor 3) Target
Max Series Fuse Rating	15A
Max Reverse Current	15A

NOTE: Specifications subject to change without notice.

TEMPERATURE RATINGS

Nominal Operating Cell Temperature (NOCT)	48.20 C
Temperature Coefficient of P_{MPP}	-1.20 W/C
Temperature Coefficient of V_{OC}	-0.1323 Voc/C
Temperature Coefficient of I_{SC}	0.040 Isc/C

QUALIFICATIONS

UL Listing	UL 1703
Fire Rating	Class C

Made in Washington State

itek energy

360.647.9531 | itekenergy.com

Sunmodule® *SW 270 mono / 2.5 Frame*

TUV Power controlled:
Lowest measuring tolerance in industry

Sunmodule Plus:
Positive performance tolerance

-0/+5 Wp

25-year linear performance warranty and
10-year product warranty

WARRANTY

World-class quality
Fully-automated production lines and seamless monitoring of the process and material ensure the quality that the company sets as its benchmark for its sites worldwide.

SolarWorld Plus-Sorting
Plus-Sorting guarantees highest system efficiency. SolarWorld only delivers modules that have greater than or equal to the nameplate rated power.

25 years linear performance guarantee and extension of product warranty to 10 years
SolarWorld guarantees a maximum performance degression of 0.7% p.a. in the course of 25 years, a significant added value compared to the two-phase warranties common in the industry. In addition, SolarWorld is offering a product warranty, which has been extended to 10 years.*

*in accordance with the applicable SolarWorld Limited Warranty at purchase.
www.solarworld.com/warranty

Made in USA

- Qualified, IEC 61215
- Safety tested, IEC 61730
- Periodic Inspection

ISO 9001
ISO 14001
Certified

Intertek

SOLARWORLD

We turn sunlight into power.

Sunmodule SW 270 mono / 2.5 Frame

PERFORMANCE UNDER STANDARD TEST CONDITIONS (STC)*

Maximum power	P_{max}	270 Wp
Open circuit voltage	V_{oc}	38.3 V
Maximum power point voltage	V_{mpp}	32.1 V
Short circuit current	I_{sc}	8.90 A
Maximum power point current	I_{mpp}	8.42 A

*STC: 1000 W/m², 25°C, AM 1.5

PERFORMANCE AT 800 W/m², NOCT, AM 1.5

Maximum power	P_{max}	194.9 Wp
Open circuit voltage	V_{oc}	34.5 V
Maximum power point voltage	V_{mpp}	28.9 V
Short circuit current	I_{sc}	7.19 A
Maximum power point current	I_{mpp}	6.74 A

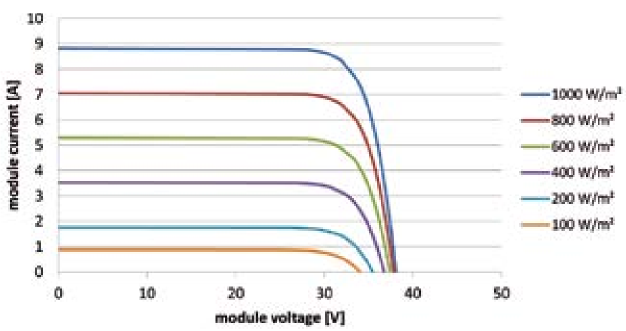
Minor reduction in efficiency under partial load conditions at 25°C: at 200 W/m², 95% (+/-3%) of the STC efficiency (1000 W/m²) is achieved.

THERMAL CHARACTERISTICS

NOCT	46 °C
TC I_{sc}	0.004 %/K
TC $_{Voc}$	-0.30 %/K
TC P_{mpp}	-0.45 %/K
Operating temperature	-40°C to 85°C

COMPONENT MATERIALS

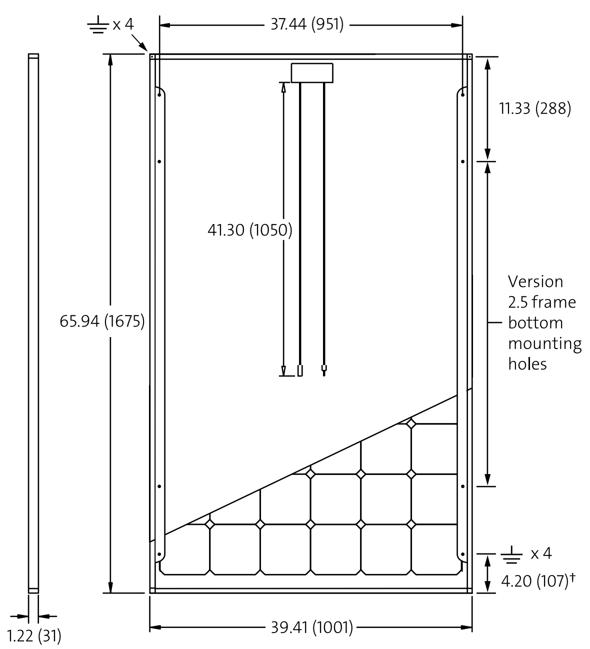
Cells per module	60
Cell type	Mono crystalline
Cell dimensions	6.14 in x 6.14 in (156 mm x 156 mm)
Front	Tempered glass (EN 12150)
Frame	Clear anodized aluminum
Weight	46.7 lbs (21.2 kg)



SYSTEM INTEGRATION PARAMETERS

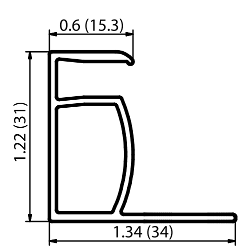
Maximum system voltage SC II		1000 V
Max. system voltage USA NEC		600 V
Maximum reverse current		16 A
Number of bypass diodes		3
*UL Design Loads**	*Two rail system*	113 psf downward 64 psf upward
*UL Design Loads**	*Three rail system*	170 psf downward 64 psf upward
*IEC Design Loads**	*Two rail system*	113 psf downward 50 psf upward

* Please refer to the Sunmodule installation instructions for the details associated with these load cases.



ADDITIONAL DATA

Power sorting[1]	-0 Wp / +5 Wp
J-Box	IP65
Connector	MC4
Module efficiency	16.10 %
Fire rating (UL 790)	Class C



VERSION 2.5 FRAME

- Compatible with both "Top-Down" and "Bottom" mounting methods
- ⏚ Grounding Locations:
  - 4 corners of the frame
  - 4 locations along the length of the module in the extended flange†

NEW! Black & Veatch validated PAN files now available. Ask your account manager for more information.

1) Measuring tolerance traceable to TUV Rheinland: +/- 2% (TUV Power Controlled).
All units provided are imperial. SI units provided in parentheses.

SolarWorld AG reserves the right to make specification changes without notice.