

**University of Montana**

**Photovoltaic Feasibility Report:**

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## **Section 1: General Overview**

### 1.1-Introduction:

This Report is intended as a reference guide for funding, designing, evaluating and implementing a grid-tied photovoltaic (PV) system on the University of Montana (UM) campus. It is my hope that this report can serve as a general reference for the future utilization of PV on campus, but it is specifically tailored toward assisting the Native American Studies (NAS) Design Team in their efforts to make use of a PV system in their upcoming application for Leadership in Energy and Environmental Design (LEED) certification. This report is the result of a Solar Feasibility Internship position that was initially developed to advise the now defunct, Think Tank Design Team in implementing PV for that project. The Think Tank project was ended due to budgeting issues and the internship responsibilities evolved into the production of this reference document. The internship position was partially funded by the nonprofit organization, Northwest Sustainable Energy for Economic Development (NW SEED). UM partnered with NW SEED's Green Campus Initiative Program to provide funding and technical guidance for the internship position and this report.

### 1.2-Overview:

As a public institution of higher education with multiple funding and labor resources, that is riding a groundswell of sustainable sentiment, the UM is in a unique position to lead by example in our pressing societal need to develop and implement responsible and sustainable building design and energy use practice. This report is intended to help create a realistic expectation of production capacity and rough expense in implementing PV, as well as provide useful information on potential funding sources and some basic technical guidelines and considerations in designing a PV system for on-campus use. Because of the extensive and detailed, existing PV installation and design literature available, this report focuses on general aspects of PV siting and design, rather than on the huge depth of technical detail required to install a well-designed PV system. See the Reference Section at the end of the paper for some excellent PV technical resources. For the purposes of this report, I have chosen to design a theoretical, example PV system that has a capacity of 2 kW (which would be quite small given the size and scope of the NAS building) and I have conducted an example solar site analysis on the recently completed Skaggs building roof-top, which is adjacent to the proposed location of the NAS building. The size and location of the example system is arbitrary and the example is intended to help with basic design considerations and processes that will remain relevant, no matter the size and location of the PV system that is ultimately settled upon for your project. In reviewing the sample system production numbers, please keep in mind that PV productivity is extremely site specific and it is important to understand that the example system is an example of process and not an accurate indicator for production capacity of a system that is located elsewhere, even an adjacent rooftop.

### 1.3-Rationale In Support of PV:

I found in my participation with the now defunct, Think Tank Design Team, that the role of the renewable energy (RE) consultant often times goes beyond the technical aspects of PV design and that the reality of renewable energy implementation in an institutional setting is that money will always be tight and the natural tendency of a design group is to cut costs where the cutting is easy. Grid tie PV electrical generation, more often than not, has poor return on investment (ROI) and simple payback (SP) figures and because of the complexities of budgeting and prioritizing projects in an institution, design decisions are often based solely on ROI or SP calculations (see section 3.2.7 for brief explanations of ROI and SP). It is not my intention to discount ROI and SP as one of a multitude of viable methods of prioritizing limited energy reducing expenditures, but it is important to be aware of the fact that there are other important considerations involved in implementing clean and renewable energy technologies and that ROI and SP figures tend to oversimplify and not fully account for a broad range of energy related, decision making criteria. If broader criteria for valuation and judgment cannot be applied in practice in an academic institution that is actively engaged in supporting, discussing and developing the tenants of sustainability, then how will our society move forward in acting on the clear requirement to “do something about Green House Gas (GHG) emissions”? I see the role of the RE consultant as a knowledgeable and reasonable advocate for dispersed, small-scale, RE production and the not so abstract benefits realized through sustainable societal action and a reduced carbon footprint that can result from its use. The problems with and reasons for looking beyond ROI and SP matrices are beyond the scope of this paper, but see the Reference Section at the end of this paper for relevant websites and resources for a more thorough discussion of alternative value systems.

In addition to sometimes unaccounted for benefits realized through utilization of RE generation, it is worth appreciating the fact that there is much potential for educational use of a PV installation on campus. The educational value of an installed PV system could be realized through its use as a demonstration project in PV technology/energy technology courses and this educational value serves to increase the benefit to public purpose that is so critical in demonstrating during the awards process of several state, federal and quasi-governmental grant distributing agencies. Other value added features of an on campus PV installation are that a visible use of PV, through web-based inverter displays, building operation information kiosks, visible placement of arrays or through building integrated panels, can serve to demonstrate and increase awareness of UM’s commitment to sustainability, increase the likelihood of procuring outside funding and generally increase the appeal of UM to potential and current students of a sustainable mind-set. The benefits listed here are simply the tip of the iceberg but, without going into excessive detail, a brief list of additional benefits realized through RE generation are: increased energy security through a reduced need for imported fossil fuels, peak load reductions on grid supplied electricity (and subsequently, infrastructure capacity required), elimination of transmission losses through onsite generation, capacity to net meter systems and a reduction in the amount of money exported from the community for grid-supplied energy. See the Reference Section at the end of the paper for links and references to learn more about the benefits of PV.

## **Section 2: Funding**

### 2.1-Funding Source Overview:

Because of our often professed need to move toward reduced GHG emissions through increased efficiency and renewable energy production, there are numerous state and federal agencies that provide grants and low to no interest loans intended to encourage the implementation and development of renewable energy technologies. Before implementing any RE generation installations, it is critical to have exhausted (within financial and practical constraints) the energy efficiency and conservation measures for a given building. The LEED process helps ensure that a high level of attention to energy conservation and efficiency has been applied and this demonstrable commitment can only serve to strengthen the position of any grant or loan application that is undertaken by UM. The following sections provide an overview of some of the funding resources that I have explored. This overview is by no means an exhaustive discussion of funding options, but it does cover the ins and outs of some of the more readily available resources for funding PV in an institutional setting. See the Reference Section at the end of the paper for funding resource websites.

An often overlooked issue that is pertinent in seeking funding for UM projects, is the fact that typically, all grants and grant proposals must be run through the UM Office of Research and Sponsored Programs (ORSP) (See the Reference Section for a website). There are exceptions that can be made to this requirement when the funding source is from an organization with an existing UM funding arrangement, if the total grant is less than \$25,000, or if the involvement of the ORSP would be detrimental to the award. Involvement of the ORSP is judged on a case-by-case basis and it should be assumed that all paperwork would be channeled through that office. ORSP involvement can decrease the likelihood of success in certain types of grants or loans, because a significant portion (up to 45%) of the final award is often deducted as an administrative expense by the ORSP. This sometimes discourages awards because this off-the-top administration fee is often perceived as lowering the “bang for the buck” of an award and award-administering organizations often seek grant and loan arrangements where the maximum dollar amount ends up in use, for the project. If the ORSP is involved in the funding process, it is critical to allow a minimum of two to three weeks for processing of the completed documentation before any submission deadline and ideally, the ORSP should be involved from the early grant writing stages due to the use of specific, fund procuring protocol out of that office.

### 2.2-Rough Funding and Engineering Timelines:

Because of the various requirements in project specificity stipulated by RE grant and loan administering organizations, the orchestration of a timely funds disbursement and PV installation will vary considerably depending on the grant or loan program being pursued. This section will provide rough timelines for funding and engineering of RE systems on campus. Please keep in mind that the individual programmatic requirements of each funding source will ultimately dictate the final sequence of activities and each

program will need to be reviewed in detail to determine the best approach to attaining a timely disbursement of funds and the most effective engineering sequence.

The following is an extremely rough approximation of a possible funding and engineering timeline:

- 1- Determine the capacity and type of system that is appropriate for the project.
- 2-Determine the optimum location for the array.
- 3-Work up rough estimates for site-specific system production, space requirements and cost in order to ensure that realistic expectations are in place within the design group.
- 4-Determine a context relevant funding source and establish programmatic requirements for that source, as well as sequential requirements for securing the funds. Make a time-line.
- 5-Contact the ORSP to determine documentation requirements and its level of involvement.
- 6-Write a detailed request for proposal (RFP) or bid request and submit it for installed cost bids from PV installers. The purpose of this initial RFP is not so much to allow for a public, service provider bidding process, but more to establish a professional and detailed, line item expense sheet, which may or may not be required from the selected funding organization. This initial RFP is critical for identifying potential engineering, insurance and permitting issues, as well as getting a precise estimate on installed cost (beyond your initial, rough estimates).
- 7-Facilitate communication between architects, engineers and PV system designers to ensure that the PV site will have:
  - A-Unrestricted solar access (no shading etc.)
  - B-Appropriate array mounting structure for the intended mounting method (pre-installed mounting is ideal in a membrane roof that is sensitive to mounting penetrations, see section 4.2).
  - C- PV wire conduit runs pre-installed to electrical service access points.
  - D- Easy and safe access for educational purposes
- 8- Write and submit an RFP or grant proposal (terminology will vary based on the issuing organization).

### 2.3-Funding Resources:

2.3.1- Montana Department of Natural Resources and Conservation (DNRC), Conservation and Resource Development Grant. The DNRC has been broadly directed by the legislature to administer monies that help with the “conservation, development, protection and management of states resources.” To that end, the Conservation and Resource Development Grant program is available for funding RE projects that

demonstrate a quantifiable benefit to “public purpose.” When applying for this grant or speaking with Pam Smith, who administers the program on behalf of the DNRC, it is critical to emphasize that a UM PV project would be beneficial to public purpose because of the clear educational value, reduction in carbon footprint/building energy requirements and because it would provide for a visible demonstration of RE technology in an institutional setting. The DNRC will send out a legislative report upon request that details the point allocation (awards are made based on a point system) for past projects, so it would be extremely useful to model any application off of past successful attempts. Past years have seen high success rates of applications as the program is fairly new and is still gaining momentum. Because of high past success rates, this is one of the more promising funding prospects (as promising as is possible in a rather uncertain, grant funding world).

2.3.2- Montana Department of Environmental Quality (DEQ), Public Buildings and Renewable Energy Section. The DEQ has, in the past, been able to work on administering grants to help finance RE projects for new construction. There has been a recent change in the awards process that prohibits the DEQ from administering grant monies for new construction RE projects. However, the DEQ does have a renewable energy loan program that could be applicable for a PV system with educational value in a setting that would provide for visible, institutional implementation of RE generation technologies. The DEQ loan has a 10 year pay-back @ 5 % interest. There is a potential for augmenting low interest loan payments with money saved through the “avoided cost” of not having to pay the utility rate for the electricity generated by a PV system. Because of the elevated cost of PV electricity and the current, relatively low cost of grid supplied electricity, you will not have sufficient avoided cost income to pay all of the loan in 10 years and complications can arise with monitoring and directing avoided cost dollars, but nevertheless, avoided cost figures could be helpful in offsetting the strain of repayment in the eyes of the UM administration.

2.3.3- Federal Clean Renewable Energy Bonds (CREBS). The CREBS program arose out of the Federal Energy Policy Act of 2005 and is intended to help finance RE generation through authorizing the issuance of tax-exempt bonds to finance interest free, RE loans. Bond issuance is an extremely complex and involved process and the project size would need to be substantial to warrant the amount of paper shuffling required to initiate a loan through the CREBS program. The program is worthy of mention here, because large PV array financing could be feasible through the program (if warranted by the project) and because of the way that CREBS are administered (smaller projects are funded first), small to medium programs (like the NAS project) would have an increased likelihood of receiving funds, provided that the design team has sufficient resources to move through the project with respect to the time and expertise needed to satisfy due diligence research requirements, underwriting and issuance of bonds. As of the date of this report, continuation of the CREBS program is suspect, so be sure to verify the programs continuance before investing too much time or research.

2.3.4-Northwestern Energy (NW Energy) Universal System Benefits (USB) Program. One of the more promising but delicate avenues for securing funds could be through the

NW Energy Universal System Benefits program. USB funds are collected from all Montana NW Energy customers as required by law. USB funds are administered through NW Energy and various sub-contracting agencies to help fund renewable energy, energy efficiency and low-income energy assistance projects around the state. The University of Montana does not participate directly in the USB program as it applies to most Montana NW Energy customers. Instead, UM pays for electricity on its own fee schedule (roughly 7.5 cents/kWh) from which USB funds are proportioned. UM is awarded yearly, lump sum allocations from the USB program and is responsible for self-administering these funds as it sees fit. UM allocates self-administered USB funds to various campus energy efficiency improvement measures, based on SP and ROI calculations. Because of PV's relatively poor performance (for now) under these assessment criteria, it is unlikely that UM will allocate any of their limited, efficiency improving, self-administered funds for PV. That being said, there are other avenues for qualifying UM PV projects for access to the larger pool of NW Energy USB funds. **One avenue that has seen success in other state educational institutions, is an arrangement whereby the University could partner with a Montana non-profit, who could use the campus PV installation as a demonstration site toward their stated mission (see the list of organizations and web addresses at the end of the paper for some ideas on potential partners).** By partnering a university project (with unavailable/limited, self-administered USB funds) with a Montana non-profit (that pays into and is eligible for NW Energy, USB funds) one could potentially tap into USB funds beyond the self-administered funds available through the UM. Another, perhaps simpler approach to qualifying for USB funds is to contact John Cambell (contact at end of paper), who is in-charge of the USB program and see how and if UM could qualify for these funds outside of semantic exercises. Because the UM, technically has an existing funding relationship with NW Energy for its self-administered USB program, it is less likely that the ORSP would need to be involved with any award received from this program. The USB program is quite organized and has an excellent PDF document available ("Bright Ideas in Alternative Energy") that clearly lays out timeline and content requirements. USB funds are awarded on a rolling basis every calendar year. Once the funds have been distributed for that year, there are no more USB funds available. So, it is ideal to get USB proposals in during the earlier part of the calendar year. Another quick side note on the application of USB funds to campus renewables, is that USB funded projects are restricted from selling Renewable Energy Certificates (RECs) or Green Tags that are created as a result of the USB funded system. RECs or Green Tags generated as a result of USB funded installations can be donated back to NW Energy as a means of recharging the pool of USB funds.

2.3.5-National Resource Conservation Service (NRCS), Conservation Innovation Grant. The NRCS offers up grant monies that are awarded through a fairly lengthy application process (which may exclude this as an option for the NAS building). NRCS grants have a strict requirement that 50% of the total project funds must come from a non-federal funding source. This funding requirement could be achievable, but it increases the complexity of attaining funds and creates a rather sticky "chicken or the egg" problem of locking in funds from various federal and non-federal sources in their appropriate proportions. Another potential problem with this program for UM PV is that it is intended as a funding source and incentive for "Innovative Conservation Measures."

Benefits to this purpose from a UM PV array can certainly be argued, but from a conservation innovation standpoint, grid-tied PV could be construed as “yesterday’s news” and the program may lean toward other, newer RE generation technologies.

2.3.6-Another extremely worthy funding prospect is the Bonneville Environmental Foundation (BEF). The BEF is a fairly nebulous nonprofit that promotes reputable community oriented, RE generation and RE education programs through financing secured by the sale of RECs (or Green Tags) and through the marketing of Environmentally Preferred Power (EPP) to government agencies, public utilities, businesses and individual customers. The BEF is a partner with NW SEED and is instrumental in funding NW SEED’s efforts to educate the public and facilitate visible implementation of dispersed, clean, RE generation throughout the Northwest. Because of the pre-existing relationship with NW SEED and BEF, I relied heavily on Leslie Moynihan (my main contact and technical advisor at NW SEED) to pursue funding opportunities at that organization, so I must admit a general lack of capacity to advise on the most advantageous approach for funding. I mention BEF here because it is active in providing resources and funding to increase the economic viability and likelihood of implementation of RE generation installations region-wide. BEF is well deserving of further investigation for funding of the NAS project and or purchase of Renewable Energy Certificates (or Green Tags) to help the NAS building lessen its carbon footprint, promote renewables across the region and gain LEED “Green Power” credits.

If funding is not materializing in your efforts to implement PV in your project, performance contracting (or some similar derivative, where installation costs are recovered by a third party through energy savings or net-meter surpluses realized as part of a separate, dispersed generation purchase arrangement with NW Energy) and the purchase of RECs could be excellent options for financing PV, gaining LEED points, or reducing the carbon footprint of new and existing structures.

### **Section 3: System Design**

#### *3.1-General PV Design Guidelines and Considerations:*

Because of the extensive PV design reference materials available online and in detailed design and installation manuals, I will not spend too much time on the technical intricacies of PV design here, but will instead focus on UM relevant design factors and provide some rough estimators for establishing approximate system parameters in the **early design phases**. This section largely describes a methodology for estimating design parameters. It is intended as a starting process and it is assumed that design parameters can and will be adjusted as design details evolve and come to light.

One of the major first steps in PV design is to determine what size, production capacity, cell technology and mounting system is appropriate for the project. Several criteria need to be evaluated in order to attain a happy equilibrium between system expectations, available funds and maximized benefits based on a broad continuum of desired outcomes. One method of determining appropriate system size and production capacity is through the LEED process. LEED provides a numeric, RE generation scoring

system that allocates credits based on the percentage of total building energy use that is generated onsite. The LEED credit breakdown is as follows: one LEED credit is allocated if 2.5 % of the total building energy needs are generated onsite. Two credits are allocated if 7.5% of the building energy needs are met with onsite RE generation. Three points are awarded for 12.5% production onsite. The determination to pursue LEED credits through RE generation is complicated by the fact that the RE generation points are some of the more expense-intensive points in the LEED program. Because of the high expense of onsite RE generation credits, other LEED points are available for green power purchases through RECs or other clean energy programs. The percentage of total building power generated onsite is determined by the level of LEED designation being sought (gold, platinum etc.), availability of funds, energy use intensity of the building, available space on the building and the desired level of carbon footprint reducing measures implemented in the building. Percentage of total building energy use, is a convenient way of thinking of PV systems, because it enables easy manipulation of production capacity to accomplish production goals and also provides for an easy conceptualization of benefits without the need for a firm grasp on sometimes confusing electrical units of measure.

Other design decisions worthy of consideration at this stage are the cell technology and mounting approach. The cell technology is typically determined by the type of mounting that will be utilized and the space available for the array. One of two main cell technologies are used in the vast majority of systems, amorphous thin film or mono and polycrystalline. Thin film PV is typically less productive per square foot of cell (lower cell efficiencies) than mono or polycrystalline cells. Thin film can be encapsulated on a flexible backing or encased in metal and glass. They are generally more durable, slightly less expensive and are used more often in building integrated PV (BIPV) designs, where cells or panels can be laid into metal roof troughs, integrated into tiles and shingles or used in window overhangs or to provide shading. Poly and monocrystalline cells can also be utilized in structural PV applications in overhangs, parking structure roofs, or in shading of usable outdoor space. Mono and polycrystalline cells are generally the most productive per area of cell, they are brittle and inflexible and are usually encased in glass and metal.

Another option for mounting (usually crystalline cell panels) is some form of tracker technology that enables the panels to follow the sun across the sky and thereby increases the daily production of panels at a given capacity, especially during longer days in summer months (performance increases are typically 15% in winter months and up to 40% in summer months). There has been much excitement surrounding building integrated and tracker technologies and this excitement is warranted, but excitement should be tempered a bit by a few issues surrounding their use. First, building integrated PV can be an extremely clean option and can enable the arrays to serve multiple purposes in addition to generation. However, BIPV is a fairly new application and the record of a given system should be examined closely before using it, especially tile or shingle integrated systems, where the complexity of the system and potential for problems is increased drastically by the volume of electrical interconnections needed to commission the system. Secondly, while tracker technologies can offer increased production for a given array capacity, there are increases in cost and complexity, where you are taking an elegant, solid state, low or no maintenance piece of technology and placing it on a

complex, sometimes maintenance intensive, moving rack. There are several interesting new motive methods used in trackers and their reliability is improving. However, trackers are not typically compatible with rooftop applications, there are often concerns with ground/pole mount aesthetics, potential for vandalism and added upfront cost and complexity. These factors should be weighed against increased PV production when considering the use of tracker technologies.

### 3.2- General UM Relevant PV Design Estimators and Sizing Factors:

The design of a PV system must start somewhere and it is generally best to start with broad estimations of expense, production capacity, size and percentage of building energy produced, in order to align system expectations with reality and begin to narrow down design parameters. The following section provides some rough guidelines for estimating size and array production that I found helpful in this process.

3.2.1-A few basic but useful definitions:

**PV Cell:** Refers to the individual unit of energy generating material. Can be one of a multitude of technologies including polycrystalline, monocrystalline, amorphous silicon thin film etc.

**PV Panel or Module:** Refers to the collection of cells that is interconnected by a grid of conductive material and usually encased in metal and glass. Usually has external wires or terminals for connecting with other modules in parallel or series.

**PV Array:** Refers to the collection of panels (or modules) wired in series or parallel.

**Array Capacity:** This is an expression of the capacity for energy production of a PV system under standard test conditions (STC) and is given in Watts (W) or kilowatts (kW). Array capacity is an indication of potential power production under standardized conditions at a given moment in time and is useful in discussing expense (panels are sold by \$ per Watt of array capacity) and the mounting method and space requirements of the array.

**Standard Test Conditions:** Because actual PV array energy production will vary considerably based on temperature of the array and the level of solar irradiance hitting the PV cells, standard test conditions for PV panel productivity were established in order to accurately compare the performance of modules of various type and manufacture. STC figures are an indicator of the power generated by an array while at 25 degrees Celsius, with a solar irradiance of 1,000 Watts per square meter.

**Array production:** Production differs from Capacity in that it is a measure of actual energy produced by an array, given real life and site-specific operating conditions, over a given amount of time. It is expressed in Watt hours (Wh), or kilowatt hours (kWh).

3.2.2-Estimation process: Because of the extreme variability of PV production based on site and region specifics, it is necessary to account for at least some of the variables that are likely to affect production when estimating for a given site. For the purposes of our initial system estimates, we will account for regional and micro-climate weather effects, estimated angle of the array and the positioning of the array with respect to due south. Because of the number of existing technical documents available for detailed explanations, I will simply walk through the estimation process as I performed it.

3.2.3-Establishing a baseline building energy use estimate: I used some rough figures provided by the Think Tank Project Engineer to approximate building energy use based on average annual kWh usage per square foot of building space on campus. A reasonable estimation for average campus wide, building energy use is 12 kWh/sf/year. It is quite important to appreciate that this could vary significantly for the NAS building, as the energy use per square foot for LEED buildings is typically significantly lower than buildings that have not had the same level of energy conservation and efficiency measures applied. For our example purposes, we will use the campus average building energy use (until detailed and building specific, energy model generated, energy use numbers are available) and a building of 5,000 square feet. We can extrapolate that our example building will use 60,000 kWh/year. The University pays roughly 7.5 cents/kWh for electricity, which would calculate out to a yearly building energy expense of approximately \$4,500. If we were to pursue one LEED onsite generation point at 2.5% of building energy use, we could calculate that we would need to produce approximately 1,500 kWh annually from our PV array (2 points at 7.5 % of bldg use= 4,500 kWh annually, 3 points @ 12.5% of bldg use= 7,500 kWh annually).

3.2.4-Calculating PV capacity needed to satisfy real-life, annual production requirements: This step requires some data collection and the manipulation of several, site specific variables in order to achieve accurate estimations of productivity. Because readers may want or need various levels of detail in the explanation of steps, the short version is that, given weather correlated and site specific data, you can expect to produce roughly 1,226 kWh per year, per kW of array capacity, **if the system is sited and designed well.**

The first step in calculating site-specific PV productivity is to look up the number of full sun hours per day for our location, taking microclimate and regional weather data into consideration. Full sun hours are an indication of how many hours per day, on an annual average, that you are likely to receive 1000 Watts per square meter (which is our STC solar irradiance). Daily full sun hour data for any site in the US is found by going to the National Renewable Energy Laboratory (NREL), PV Watts calculator website and entering in the Latitude and Longitude of your location. For our example, I will use Long. of -114.254 Degrees and Lat. of 46.893 Degrees, which is approximately the location of the Skaggs building rooftop. The PV Watts calculator will also let you enter the tilt angle and cardinal direction of your PV array in order to achieve full sun estimates for various PV placements, tilt angles and aspects. For our estimate purposes, we will assume a tilt angle at latitude (which typically achieves the best year-round average production for fixed angle, grid-tied PV) and a due South facing array (usually the best aspect for grid tie PV). The PV Watts site indicates that for the specified array placement, we can expect an annual average of 4.48 full sun hours per day. Because we know the STC rating of our array under these solar irradiance conditions, we can extrapolate that an array that has a capacity of 1 kW will produce 4.48 kWh per day, on average throughout the year. Because PV systems do not operate at 100% efficiency (due to voltage drops in wiring, inverter losses, reduced production in hot weather etc.) it is an industry standard to estimate production at about 75% efficiency. So, if we have a calculated production of roughly 4.48 kWh per day, then we could expect to see actual array production at 3.36 kWh/day when system inefficiencies are factored in. If we are

generating 3.36 kWh per day, per kW of array capacity, then we can expect to see a yearly average of roughly 1,226 kWh per kW of array capacity. For our theoretical, 2 kW capacity example system, we could expect approximately 2,452 kWh produced annually. It is important to keep in mind that this estimate is for a prime solar location with no shading and if we are expecting to see real life production at these levels, then we will need an optimal solar site.

3.2.5- Area requirements estimator: While in our rough estimation mode, it is helpful to have some idea of the area that will be required to accommodate an array of the desired capacity. An extremely rough rule of thumb is that you will need 100 square feet of space per kW of array capacity. So again, for our 2 kW capacity, poly or monocrystalline cell, example system, we would require roughly 200 square feet of roof space for fixed (non tracking), roof mounted panels as well as a small (less than 10 square feet) wall space in or near the control room for the inverter and AC/DC disconnect switches. While this is a decent method for rough estimation of space requirements for traditional PV arrays, various factors ranging from the type of cell technology (poly or monocrystalline vs. thin film etc.) to the mounting mechanism (building integrated mounts on overhangs, tilted ballasted mounting, pole mounted tracker, etc.) could affect space requirements considerably.

3.2.6-Cost estimator: Estimating installed cost of PV systems is an extremely sticky prospect because of the huge number of variables in system design, installation and availability of PV components. It is critical to get detailed, current, installed cost estimates from PV installation professionals for the system being considered for a multitude of reasons. However, an extremely rough estimation number of \$10,000 per kW of array capacity is a fairly conservative rule of thumb and can help narrow down a range of extremely rough, anticipated installed system costs. It is worth considering that this would be the full retail, high-end estimate and that substantial savings could be realized through distributor or manufacturer discounts, or through the use of supervised student labor for a portion for the install.

### 3.2.7-Overview of ROI, SP and CO2 Reduction Calculations:

ROI:

Return on investment is generally given as a percentage or a ratio and is a method of evaluating investments based on the percent of return on you initial investment. ROI for efficiency improvements and RE generation is calculated by dividing the energy savings realized, by the expense of the energy saving measure or RE system. For example, if our 2 kW capacity sample system produces 2,452 kWh per year at a savings of \$184 per year (@ 7.5 cents per kWh) and costs \$20,000 installed, then the ROI would be roughly 1% per year. ROI is a rough indicator of performance and does not account for non-monetary benefits, maintenance, inflation, energy cost increases or the expected life of the improvement

SP:

Simple payback is a method of evaluating how long it will take to make-back the initial cost of an energy saving measure. It is calculated by dividing the initial cost of the efficiency improvement by the annual energy savings realized through the improvement, to give a simple payback period in years. SP is helpful in rough estimations but is lacking in that it does not account for time value of money, maintenance costs, inflation, increased energy costs and the life of the improvement. The SP on our example 2 kW system would be \$20,000 divided by \$184 and would come to a simple payback of around 108 years. (Keep in mind the limitations of this figure in conveying non-monetary benefit and that any rebates, increases in energy rates, changes in peak-demand/time of use pricing structures and any system discounts or incentives could effect this figure drastically!)

CO2 Footprint Calculations:

Performance of some basic, ballpark estimations of reduced GHG emissions due to RE use is an effective and tangible way to highlight the benefits of a PV system. An additional side-note here, is that GHG reduction calculations can sometimes detract from the motivation for RE generation, because there are other, less expensive and perhaps simpler, energy efficiency improvements that can serve to reduce GHG emissions at a lower cost. However, because RE generation has other, value-added benefits ranging from educational value, to offsetting peak grid demand (and a reduction in the associated infrastructure needed to satisfy those loads), there is a strong argument remaining in support of dispersed RE as an effective means of reducing GHG emissions while accomplishing other, critically important tasks. (See section 1.3 for a more detailed discussion on additional, value-added benefits of PV).

There are a considerable number of online, carbon footprint calculators that base projected CO2 and other GHG emission reductions off of various levels of specificity and depth. See the Reference Section at the end of the paper for a range of CO2 footprint calculator websites. Most footprint calculators are intended to help quantify reductions in GHG emissions realized through improvements in energy efficiency, green materials selection, RE generation and a multitude of other criteria. Because calculations range from extremely detailed analysis of GHG relevant variables, to generalized, “back of napkin” calculators, there can be a large discrepancy between projected GHG savings from various sources. For purposes of our example, I will use the interactive energy calculator available at [www.infinitepower.org](http://www.infinitepower.org). First, I selected “Western Coal” as our predominant grid electricity generating fuel (various grid electricity fuel types will change the GHG reductions based on the pollution causing characteristics of that fuel). Second, I entered in our yearly estimated production for our sample 2 kW PV system at 2,452 kWh. The calculator figured reductions of the following GHG types: 4,904 lbs of CO2/year, 8.53 lbs SO2/year, 14.22 lbs NOx/year, 0.5 lbs of particulate mater smaller than 10 microns and 0.3 lbs of VOC/year. It is important to consider that this is a fairly simplified calculator that does not account for the life cycle GHG costs of manufacture, transportation or installation of the PV system. But, it is a good starting point and is quite useful in providing a concrete demonstration of the GHG reducing benefits of RE. As a general rule of thumb, most PV panels “make back” the CO2 used in their manufacture in 4-5 years of use.

## Section 4: Example System Site Analysis

### 4.1- Siting Concerns and Tool Setup:

Because of the fact that you will ultimately need a detailed and site specific professional design/quote for funding, engineering and permitting processes and because of the various and detailed PV design references available, I will not go into much detail on system design or selecting system components. Instead, I will go through the process of performing a site analysis, as this is a critical skill in determining the suitability and production capabilities of a proposed site. An initial site analysis should be performed prior to seeking any quotes or designs from a professional PV installer because a site review shows installers that there is at least a basic understanding of system requirements and that realistic expectations as to system capabilities are in place. This perception is important in encouraging detailed quotes and demonstrating that installers will not be wasting time educating would be RE implementers as to PV system basics, or fighting an uphill battle against unrealistic expectations from a PV system.

The example system site analysis was performed with a Solar Pathfinder, Solar Site Analysis Tool. The tool is owned by the College of Technology and Ashley Preston (Energy Technology Dept. Head- See Reference Section for contact info) would be your contact for checking out the tool for use. The Pathfinder has detailed instructions that need to be followed closely for an accurate site assessment. I will not discuss tool basics at length here (see the tool reference manual in its case) but will walk through the site analysis process for our example system and provide a few photos of the sample site assessment as an example of how to orient and read the tool.

The Pathfinder is an effective and relatively simple tool used to get solar resource information on a given site. The tool operates by reading the reflection of potential shading obstacles in the tool's glass bubble top and examining how the shade causing obstacles will cast a shadow on the PV array during every hour of every day throughout the year. In performing a site assessment, it is critical to keep in mind that even a minor shadow, including partial shadows from power lines or handrails, creates a highly resistive area within the panel and drastically reduces panel productivity. So, it is important to be aware of even seemingly inconsequential, shadow casting objects and the fact that appropriate setbacks from all obstacles is critical for good PV productivity. This is not to say that if a site has even minimal shading, that it is of no use. Instead, it is simply important to design for as shadow-free a circumstance as is possible (especially during prime, peak sun hours between 9 AM and 3 PM) and especially critical that any shading of the panels is accounted for in your projections of panel productivity, as shading effects power production drastically. The Pathfinder has several paper charts in the case that are used to most closely match your latitude and the corresponding arc that the sun follows at that latitude. For UM site assessments, there are sun path diagrams intended for 43-49 degrees latitude. Once you have found the appropriate sun chart and placed it on the tool surface below the glass dome, the next set-up step is to adjust the tool for magnetic declination, so that you can orient the tool to true solar South using the integrated tool-compass. Our magnetic declination in Missoula is roughly 17 Degrees East. The tool can be adjusted by rotating the flat plate of the tool so that the small declination indicator arrow points to 17 Deg. East, on the latitude-specific paper sheet.

After the tool is set for a reading, the next step is to establish a rough outline of the array that corresponds to the square footage requirement of whatever capacity system that you are working with. For our example 2 kW system, we would be looking at roughly 200 square feet, or an area 20' X 10". Once you have the location of the array outlined, you would want to position the tool facing South (using the compass which has been adjusted from magnetic to solar south by your previous adjustment) at the height of the intended array (depending on the mounting system), at all four corners of the outlined area. The four corners method is effective at identifying shading issues across the array, which is necessary for accurate production calculations. If you are dealing with a large array, or have multiple shade causing variables, you may need to take readings scattered throughout the array in addition to the four corners. It is important to keep in mind that large equipment or large steel structural masses beneath the surface that you are placing the Pathfinder tool on may deflect the compass and give a false cardinal reading. To guard against error, it is a good idea to pick an object that is roughly South relative to your site and make sure that the compass is not giving you a false bearing. Another magnetic deflection safe-guard could be to consult building plans for general building orientation. Once you have a good compass reading and a visible reflection in the tool, take a digital photo 12-18" above the dome looking straight down on the tool. The digital photo will record the reflection of any potential shade sources and the solar chart below the reflective bubble will show at what time on what day the sun will be obstructed by a shading source. Production numbers can be adjusted based on the amount and frequency of full or partial shading. This shading data also allows several design adjustments as needed. One could be a slight offset to either East or West to make optimal use of your available solar window. Another could be an adjustment to height, type of mounting, or location of the array. It is a good idea to take several photos of the surrounding area to help visualize and identify any safety, shading or access issues around the site.

4.2-Example Site Photos:

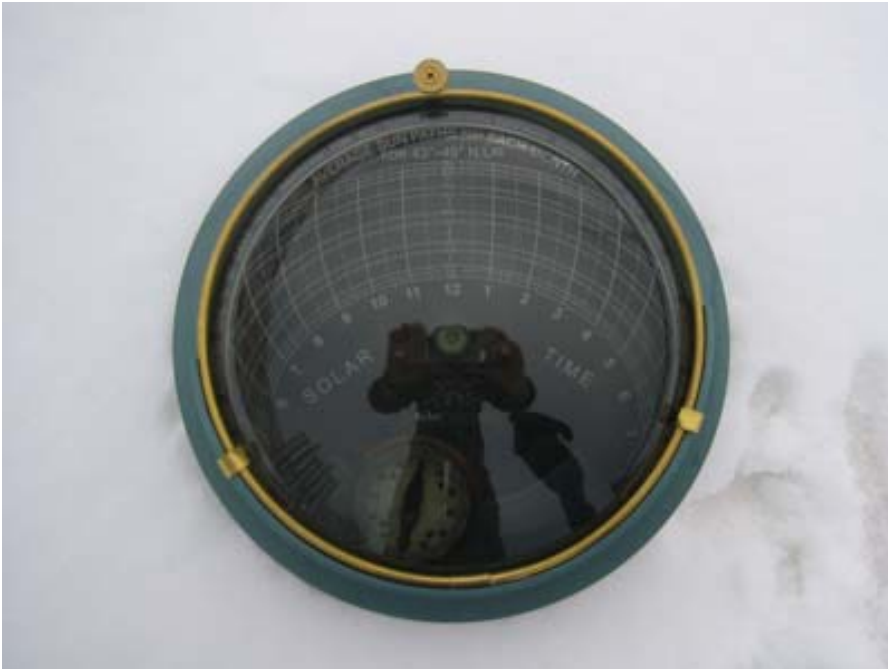


Photo #1: Corner #1- SW corner.



Photo #2: Corner #2- SE corner



Photo #3: Corner #3-NE corner



Photo #4: Skaggs rooftop with 20' on the tape.

#### 4.3-Example Solar Site Review:

There is no photo for the 4<sup>th</sup> corner of our array because I was getting an inadvertent compass reading due to massive steel supports beneath the corner. The example site on top of the Skaggs mechanical room is an excellent solar site. The Solar window is totally clear except for very small shading possibilities before 9 AM from Mt. Sentinel in December and January (little to no practical effect likely). Because the building control/mechanical room is located directly beneath this site, wire runs (and subsequently, conduit runs, wire gauge and voltage drops) would be held to a minimum. The roof is a membrane roof, which can raise concerns with mounting penetrations because membrane penetrations can cause leaks and can sometimes void roof warranties. The Think Tank Project Engineer said that penetrations were not a large concern in her mind and did not see a problem with well-sealed mounting holes. However, the type of roof may dictate the type of mounting that is used (non-penetrating ballasted or weighted roof mounts are available) and could increase the importance of designing in PV mounts and conduit runs before the membrane is applied in order to keep roof warranties intact.

A few practical concerns with the site would be: 1- Difficulty of access. This rooftop is up a level from the main roof and requires climbing a fairly exposed ladder to access it. This could be of concern if the array is to be used as an educational tool, because students would need to climb up to the rooftop and permission/liability concerns could limit the practicality as an educational tool. 2- Code requirements for “rooftop systems requiring maintenance” (which an array would most likely be described as), indicate that a handrail may need to be installed at the rooftop edge if the system is within ten feet of an edge of the roof. I was aware of this and drew my array outline 10 feet away from the edge but, if a handrail were required, it would most definitely create a shading issue on the array and would need to be accounted for in the system production calculations.

### **Section 5: Conclusion**

My experiences with the Feasibility Study project have been very much an eye opener to the logistical, ideological and technical challenges that are an inextricable part of the building design process. Negotiating the nuance of an integrated design approach and deciphering the seemingly coded process of procuring funds in an institution has provided much insight into the realities, challenges and potential rewards of working in Renewable Energy Technologies. It is my hope that this document finds some practical use as a technical reference for future internship positions and that the document can be helpful in conveying the motivation for and importance of incorporating renewable energy technologies and sustainable building practice on the UM campus. I firmly believe that the UM Administration has a professional and ethical responsibility to enable, encourage and support the efforts of agents and employees of the University to be leaders with respect to on the ground action toward a sustainable end. I hope that this document can be useful in presenting potential solutions to our often articulated energy quandary and that it can be helpful in readying the University to assume a position of sustainable leadership that the gravity of our collective societal situation demands.

## Reference and Contact Section:

Relevant Section:	Contact/Reference Info:	Title/Purpose:
1.1/1.3 General	<a href="http://www.nwseed.org/">http://www.nwseed.org/</a>	Northwest Sustainable Energy for Economic Development (NW SEED)/General reference and resource
1.1	<a href="http://www.nwgreencampus.org/">http://www.nwgreencampus.org/</a>	NW SEED Green Campuses Program
1.2	<a href="http://www.ulsf.org/programs_talloires.html">http://www.ulsf.org/programs_talloires.html</a>	The Talloires Declaration/Collegiate sustainability action plan
1.2/ General	Solar Energy International. <u>Photovoltaics Design and Installation Manual</u> . BC, Canada: New Society Publishers, 2004.	PV Design and installation technical reference. <b>The</b> PV reference bible.
1.2/ General	Sunelco PV manual (new edition pending)	Excellent resource from a local PV distributor/installer.
1.2/ General	<a href="http://www.sunelco.com/">http://www.sunelco.com/</a>	Sunelco website/Local PV installer resource for quotes and bids
1.3	Hawken, Paul et. all. <u>Natural Capital</u> . US: Little Brown and Company, 1999.	Natural Capital/ Thorough discussion on sustainable valuation, ROI and SP
1.3	<a href="http://www.natcap.org/">http://www.natcap.org/</a>	Natural Capital website/Downloadable excerpts from the book and general info.
1.3	Cook, David. <u>The Natural Step Towards a Sustainable Society</u> . Bristol, UK: J.W. Arrowsmith Ltd. 2004	General framework and rationale for sustainable action.
1.3/ 3.2.7	<a href="http://www.rprogress.org/about_us/about_us.htm">http://www.rprogress.org/about_us/about_us.htm</a>	Redefining Progress/Discussion and info on Sustainable Economics and Ecological Footprint Calculator.
1.3/ 2.3.6	<a href="http://www.b-e-f.org/index.shtm">http://www.b-e-f.org/index.shtm</a>	Bonneville Environmental Foundation (BEF)/All around informational and funding resource.
2.1	<a href="http://www.dsireusa.org/library/includes/map2.cfm?CurrentPageID=1&amp;State=MT&amp;RE=1&amp;EE=1">http://www.dsireusa.org/library/includes/map2.cfm?CurrentPageID=1&amp;State=MT&amp;RE=1&amp;EE=1</a>	Database of State Incentives for Renewables and Efficiency/ Montana funding resource database
2.1	<a href="http://www.umt.edu/research/orsp/orspoverview.htm">http://www.umt.edu/research/orsp/orspoverview.htm</a>	Office of Research and Sponsored Programs (ORSP)/ UM grant administering office.
2.3.1	Pam Smith <a href="http://dnrc.mt.gov/cardd/default.asp">http://dnrc.mt.gov/cardd/default.asp</a>	Montana department of natural resources (DNRC), conservation and resource development grant
2.3.2	Gorgia Brensdaal	Montana Department of

	<a href="http://www.deq.state.mt.us/Energy/Renewable/altenergyloan.asp">http://www.deq.state.mt.us/Energy/Renewable/altenergyloan.asp</a>	Environmental Quality (DEQ), Public Buildings and Renewable Energy Section
2.3.3	<a href="http://www.nwoasis.org/documents/NWMT/GenConnect.html">http://www.nwoasis.org/documents/NWMT/GenConnect.html</a>	Clean Renewable Energy Bonds (CREBS)/ Miscellaneous MT links
2.3.4	<a href="http://www.northwesternenergy.com/display.aspx?Page=Renewable_Energy_Program">http://www.northwesternenergy.com/display.aspx?Page=Renewable_Energy_Program</a>	Northwestern Energy USB Program/Information and USB relevant links
2.3.4/ General	<a href="http://www.ncat.org/websites.php">http://www.ncat.org/websites.php</a>	National Center for Appropriate Technology (NCAT)/ RE related non-profit links and general resource
2.3.5	<a href="http://www.nrcs.usda.gov/">http://www.nrcs.usda.gov/</a>	National Resources Conservation Service (NRCS)/Grant information
2.3.6/ 1.3	<a href="http://www.b-e-f.org/index.shtm">http://www.b-e-f.org/index.shtm</a>	Bonneville Environmental Foundation/See 1.3 reference above
3.1	<a href="http://www.usgbc.org/DisplayPage.aspx?CMSPageID=220">http://www.usgbc.org/DisplayPage.aspx?CMSPageID=220</a>	Leadership in Energy and Environmental Design (LEED)/ Points allocation breakdown and general reference
3.2.4	<a href="http://www.nrel.gov/rredc/pvwatts/version2.html">http://www.nrel.gov/rredc/pvwatts/version2.html</a>	National Renewable Energy Laboratory (NREL) PV Watts Calculator/ Site specific and weather data correlated, solar irradiance data
3.2.7	<a href="http://www.infinitepower.org">http://www.infinitepower.org</a>	Infinite Power Texas site from Texas State Energy Conservation Office/CO2 footprint and ecological footprint calculator
3.2.7/ 1.3	<a href="http://www.rprogress.org/about_us/about_us.htm">http://www.rprogress.org/about_us/about_us.htm</a>	Redefining Progress/ Ecological footprint calculator
General	<a href="http://www.montanagreenpower.com/mrea/">http://www.montanagreenpower.com/mrea/</a>	Montana Renewable Energy Association (MREA)/Excellent general PV reference and statewide database of PV Installers
General	<a href="http://www.solarplexus1.com/">http://www.solarplexus1.com/</a>	Solar Plexus/ Local PV installer and resource
General	Brian Kerns/ (406) 532-3228 <a href="mailto:Brian.Kerns@mso.umt.edu">Brian.Kerns@mso.umt.edu</a>	Excellent UM Campus savvy, RE resource
General	Dr. Paul Williamson/ (406) 532-3227	University RE resource
General	Ashley Preston/ 243-7915 <a href="mailto:Ashley.Preston@mso.umt.edu">Ashley.Preston@mso.umt.edu</a>	Energy Technology Program Coordinator
General	<a href="http://www.aeromt.org/">http://www.aeromt.org/</a>	Alternative Energy Resources Organization (AERO)/Excellent MT specific, RE resource