The Potential for Solar Panels to Power MSU: An Examination of the Existing Infrastructure at MSU and the Future of Photovoltaic Panels

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Introduction

As an institution of higher learning, MSU must lead by example. One of the most important problems facing our generation is climate change prevention and mitigation. Former MSU President, Geoff Gamble, signed the American College & University Presidents' Climate Commitment (ACUPCC) agreement in 2008 (Blacker, 2014). This is an institutional commitment to eliminate net greenhouse emissions from campus. Some actions have already been taken to reduce emissions and others are underway, like the development of new LEED standard buildings. However there remains an indefinite amount of research, planning and work to be done to continue progress towards the zero-net-emissions goal.

In Montana, the Net Metering Law effectively limits the amount of credit that renewable energy producers can receive for sending excess energy to the grid. This can prevent solar panels from being an economical renewable energy source for homes and businesses. The complex of buildings on campus allows MSU to share energy between buildings. Essentially no energy created from solar panels will have to go back to the grid, so MSU is not affected by the restrictions of the net metering law (Ray, 2014). This makes MSU a prime candidate to use solar power to help offset emissions. The MSU Student Union Building (SUB) currently has 22 solar panels in place above the south entrance. These panels are producing approximately 5,500 kWh per year (Ray, 2014), roughly 1% of the SUB power supply. While this seems insignificant compared to total power consumed, it still proves that solar panels work. It serves as a message of MSU's dedication to renewable energies, and as an educational tool. Knowing that, we wrote our paper on photovoltaic technology and the feasibility of implementing solar power in Bozeman.

Solar Power Feasibility in Bozeman, Montana

Photovoltaic (PV) technology is a proven energy source that can be used in a wide range of applications, scales, climates and geographic locations. All that is needed is open space with a south-facing aspect, to better catch the solar radiation. The commercial solar PV panel can convert 10-18% of sunlight energy into electricity, while the high-end models have more than 20% efficiency. With solar power and living a greener lifestyle becoming more popular, there has been an increase in PV manufacturing over the past 10 years (Renewable Energy for America, 2014). This has led to a decrease in cost and an increase in research on new PV technologies. Solar panels are now more affordable, cleaner, and efficient. Solar power is also more widely accepted by the public and has less geopolitical, environmental, and aesthetic concerns than other forms of renewable energy like nuclear, wind, or hydropower (Maehlum, 2014).

A study done by Dubey et al. (2012) looked at the photovoltaic potential of the world (Figure 1). Their study focused on two main variables: irradiance (flux of radiant energy per unit area) and temperature. Regions of high altitude have higher performance ratios due to low temperatures. The Himalayas’ potential is important due to the increase in energy demands from China and India. However, the problems with putting PV panels in a high altitude region include the transportation of the system and the increase in maintenance that goes along with the severe environmental conditions of these regions (Dubey et al., 2012).

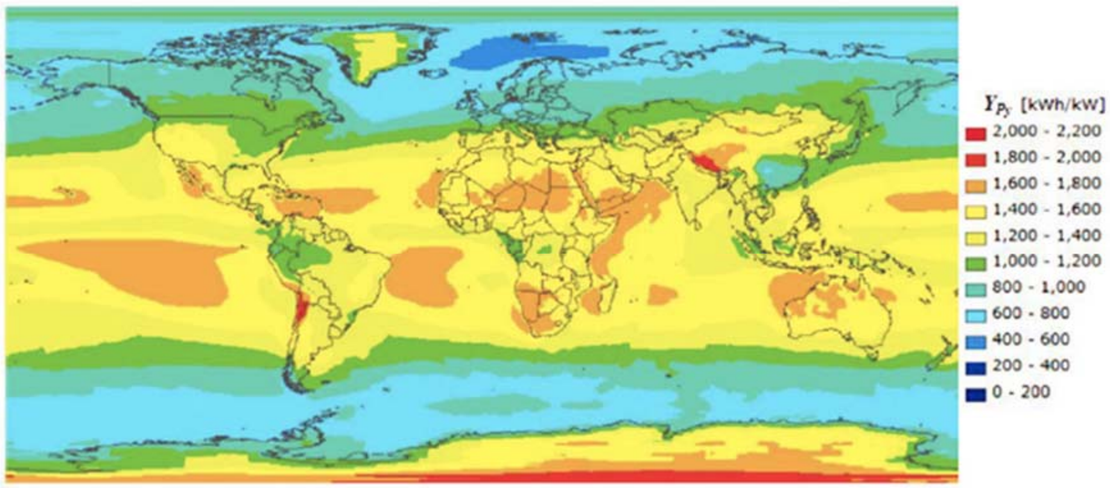


Figure 1: Global PV potential, with temperature and irradiance as the variables (Dubey et al., 2012).

Temperature plays an important role in PV systems because of its impact on their efficiency. The output of a PV module increases with a decrease in temperature (Dubey et al., 2012). This occurs because voltage generated by the panels comes from the difference between the electrons in their resting state versus electrons excited from photons (Renewable Energy for America, 2014). Therefore, when the resting electrons are excited from heat, there is not as much energy potential between the electrons- resting and photon-excited states.

When deciding whether PV panels are economically feasible for a resident of Bozeman, one must take into account the amount of solar radiation the area gets, what the efficiency is of the panels, how big of a solar system it is, and how much one is saving for not paying for energy from an energy company. The Renewable Energy Atlas from the National Renewable Energy Laboratory (Figure 2) shows that Montana gets 4.5-5.5 kWh/m^2/day, and Bozeman in particular gets on average 5.0 kWh/m^2/day.

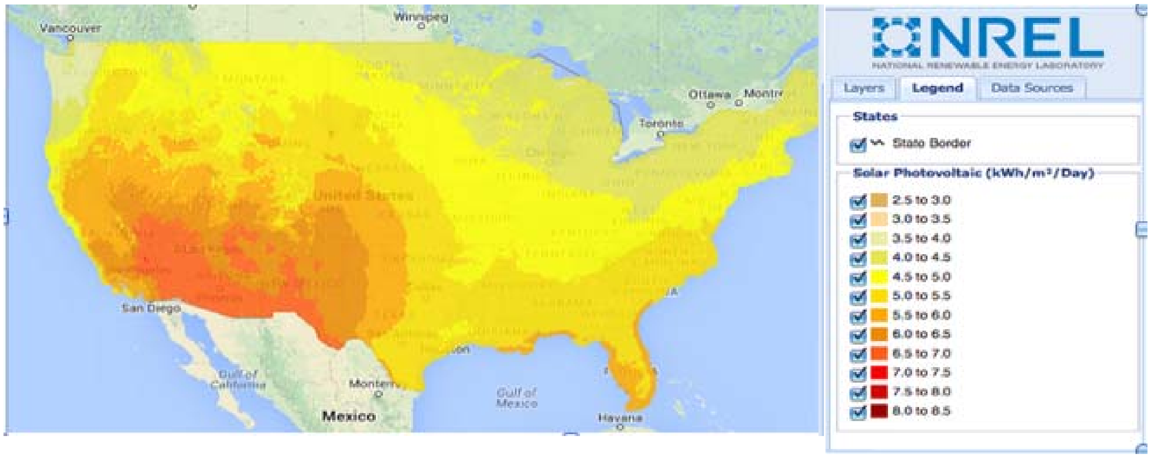


Figure 2. The solar radiation received by the continental United States in kWh/m^2/day.

An estimate of how much a PV system could cost can be calculated easily. A 10kWh system that is 100m^2 with a 10% efficiency would cost approximately $10,000 initially. Factoring savings from energy bills, approximately $0.60/kWh from Northwest Energy, and generating 5.0kWh/m^2/day solar radiation, the panels will pay for themselves 9.1 years.

Like any energy source, there are both economic and environmental advantages and disadvantages to solar energy. Even though the solar panels may be expensive initially, and energy storage is costly, the economic advantages are evident as seen in the calculations above. PV panels operate at 80% efficiency at year 25, so one can assume there will be years of having the panels paid off and reducing energy cost. Most governments also will give a 30% tax credit for solar power (Banoni, 2012).

Solar power is renewable, as long as we have the sun, we will have the ability to use solar power. This energy is also abundant; the Earth’s surface receives 120,000 tW of solar radiation, which is 20,000 times more power than what is needed to provide power for the entire world. It also generates no noise or chemical pollutants during use unlike other renewable energy sources. However, to make the PV cells and the batteries to store the energy, toxic chemicals and heavy metals are used. For example, nitrogen trifluoride and sulfur hexafluoride are greenhouse gases that are emitted in the manufacturing of the panels and are more toxic to the atmosphere and biosphere than carbon dioxide. Production, transportation, and installation have a high carbon footprint. They also have a relatively short life span of 25 years (Maehlum, 2014).

Despite what initially seem to be negative aspects to PV panel production and installation, there are tradeoffs to all sources of energy. No one energy source is perfect. The consumer must decide what they want out of their energy source and make compromises. The benefits with solar power is that there are not any greenhouse gases or toxic chemicals emitted after the panels have been set up, and while they are working, the consumer is getting clean energy and saving money. The industry will only improve with time and will produce jobs as the research and manufacturing increase.

Life Cycle Analysis for Current Photovoltaic Systems

Life cycle analysis (LCA) quantifies the environmental impacts associated with a product throughout its life. This analysis starts with raw materials that are used to create the product, including the environmental impacts of creating the product. Next, the cost of the installation of the system is assessed and the balance of system is taken into account, the balance of system referring to the support structure, cables and wiring, transformers, and inverters that are used during the installation. After this, any energy that is consumed while the panel is functioning and finally the environmental impact of recycling or disposing of the material is calculated. Life cycle analysis that is “cradle to the grave” accounts for all inputs and outputs to measure a product’s total environmental impact. Life cycle analysis makes it possible to directly compare similar products to determine which is the most environmentally friendly.

The units that will be used to compare the different photovoltaic panels are global warming potential (GWP), fossil fuel consumption (FFC), and energy payback time (EPBT). Global warming is caused by greenhouse gases that keep infrared light from radiating away from the earth, so the GWP is a measure of greenhouse gas emissions from the earth. For this paper, natural gas, crude oil, and coal are taken into account for FFC. EPBT is the period of time that a renewable energy system takes to generate the same amount of energy that was used to create it.

The types of photovoltaic panels that will be compared are CZTS (copper zinc tin sulfide), Zn_3P_2 (zinc phosphate), mono-Si (mono-crystalline silicon), Poly-Si (poly-crystalline silicone), a:Si (amorphous silicon), CdTe (cadmium telluride), CIGS (copper indium gallium diselenide), and DSSC (dye sensitized solar cells). While this seems like a lot of photovoltaic options, only five of these are commercially produced (Mono-Si, Poly-Si, a:Si, CdTe, CIGS) and the other three are possible future productions (CZTS, Zn_3P_2, DSSC). As you can see in Figure 3, the poly-crystalline silicon and mono-crystalline silicone are by far the most

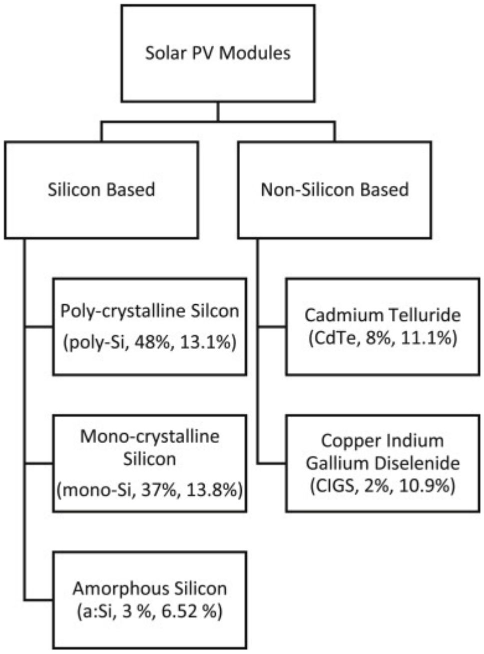


Figure 3- The global use (percent on the left) and efficiency of the currently used systems (percent on the right; Collier 2014).

commonly used solar energy systems. Two of the new products, CZTS and Zn_3P_2, have similar efficiencies to some of the non-silicon based solar panels at 10% efficiency, which means the system converts 10% of the sun's radiant energy to electrical energy. An advantage of CZTS and Zn_3P_2 is they are made from more abundant materials that are less toxic than their comparable photovoltaic systems. CZTS is comparable to CIGS and Zn_3P_2 is comparable to CdTe in manufacturing process and overall efficiency. The DSSC panels currently have efficiencies of less than 10%, but it is believed that if they are researched a little more and become commercially produced, they will easily be over ten percent in the coming years (Parisi, 2014). A few intriguing qualities for DSSC are that it creates energy from indirect light which is unlike any other type of solar panel, it has a much lower cost for production, the raw materials are more available, and its more flexible and lightweight nature create many options for architectural integration (Parisi, 2014).

Through researching different LCA's, CdTe is the most environmentally friendly option for a commercially manufactured photovoltaic system. Even with Cd, a toxic element, the CdTe panels have an overall lower ecological toxicity than all of the other commercial systems, CZTS, and its comparable alternative Zn_3P_2 (Collier, 2014). DSSC was the one exception to this. DSSC

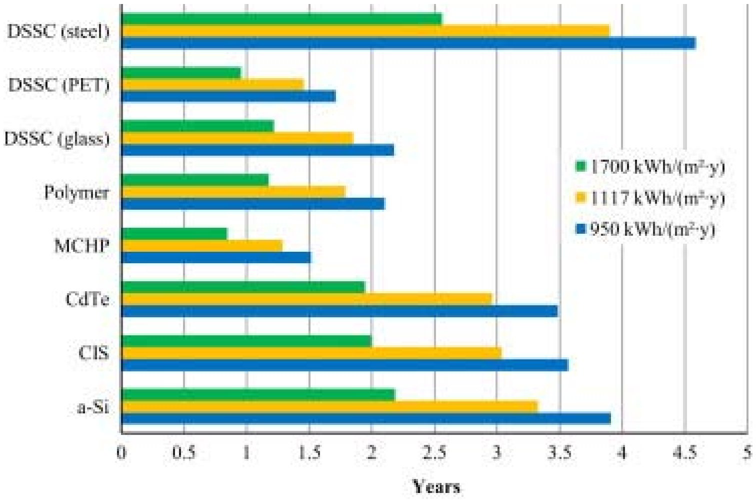


Figure 4 – This graph compares energy payback time of DSSC and other common photovoltaic systems.

had similar GWP and EPBT (Parisi, 2014). Also this study was conducted under production procedures that will be greatly improved once they are industrialized, which may make DSSC the most environmentally friendly photovoltaic system in the coming years. Currently the EPBT for DSSC is around 1 year (Figure 4), and this number is lower than CdTe, which is closer to 2 years. When DSSC becomes commercially produced, this product will change photovoltaic technology and its feasibility.

Case Studies

College campuses use a large amount of energy due to dormitories, computers and energy-intensive labs. Is it possible for these energy-demanding universities to produce enough of their own energy via solar to become net-zero? A study in 2011 was done to look at the financial feasibility for a community college campus in Los Angeles to becoming net zero solely using solar energy (Kwan and Kwan, 2011). Despite the local and federal tax incentives and energy rebates, solar PV still remained 30% higher in cost than electricity generated by fossil fuels (Kwan and Kwan, 2011). With approximately 9 hours of usable sunlight per day, these solar systems are non-performing for 62% of the day. This means that the solar panels, in order to be net-zero, would have to generate 100% of the university's energy needs in that 9-hour time frame (Kwan and Kwan, 2011). This lack of hours of sunlight required the university to either have a very large solar PV array or to tap into the existing grid-produced energy when energy use on campus exceeded the amount the solar panels could produce. Direct sunlight isn't the only factor to consider when looking at solar PV systems. Solar cells performance decreases with increasing temperatures (Dubey et al., 2012).

MSU is approximately twice the size of the LA community college. This size difference would make moving to a net-zero campus even less achievable due to the higher energy use associated with a larger university. As a state run university, MSU will not be able to utilize tax incentives and will have to find a source of private funding to help with the implementation of solar PV systems. As Figure 2 shows, MSU doesn't have quite as high of solar insolation as LA but the temperatures are significantly lower in Montana in comparison to Los Angeles. This bodes well for Montana with low temperatures and a high number of days of sunlight. Despite these factors, in order to be net-zero, a solar PV array covering an area greater than 12 football fields would have to be installed that can capture enough energy during the 9 hours of usable sunlight that can supplement all of MSU's energy needs.

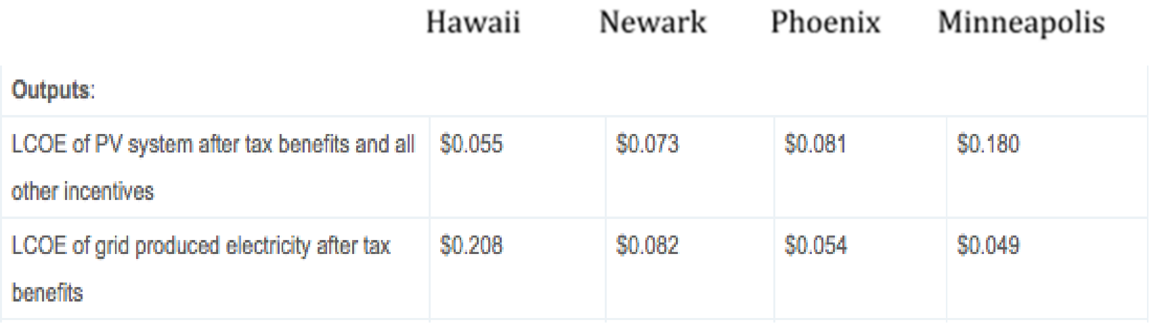
With current incentives and equipment costs, a net zero campus is not feasible (Kwan and Kwan, 2011). Alternatively, reducing energy use during peak demand hours helps lower costs and greenhouse gas emissions without the financial strain of going net-zero. This cost reducing tactic is coined peak shaving (Kwan and Kwan, 2011). Acknowledging that a net zero campus is not feasible, MSU can still strive towards the goal of lowering our greenhouse gas emissions by using solar energy during our peak demand hours.

Universities are not the only establishments that are making the shift to solar power. Many organizations have realized the potential that solar power holds and have begun to investigate whether or not it makes financial sense to make the switch. Comparing solar PV produced to grid-produced electricity is a very site-specific process. Four very differing geographic locations that made the switch to solar photovoltaic energy systems were investigated to compare the costs associated with solar PV versus grid-produced electricity (Swift, 2013).

Site-specific information regarding existing grid cost of electricity, available sunlight, PV system costs and performance, and financial incentives is necessary when considering the feasibility of installing solar power. The four sites that were analyzed—Honolulu, Hawaii, Newark, New Jersey, Phoenix, Arizona and Minneapolis Minnesota—had installed a 50-kW solar PV system. In 2012 a 50-kW system installation cost was $262,500 before any incentives or rebates (Swift, 2013).

Levelized cost of electricity (LCEO) allows a comparison of different energy systems on a price by kWh basis. The LCOE equation incorporates capital, financing costs, fuels costs, inverter costs and maintenance costs (Swift, 2013). Table 1 shows the LCOE of solar PV produced power and grid-produced power in each location.

Table 1: The LCOE of PV systems and grid produced electricity in each of the four locations (Swift 2013).



	Hawaii	Newark	Phoenix	Minneapolis
Outputs:				
LCOE of PV system after tax benefits and all other incentives	$0.055	$0.073	$0.081	$0.180
LCOE of grid produced electricity after tax benefits	$0.208	$0.082	$0.054	$0.049

Honolulu makes for an ideal location due to its high solar insolation and high price of grid produced electricity. For the 50-kW PV system installed in Honolulu, after the federal (30%) and state (35%) tax credits, the net cost was $96,009 (Swift, 2013). This is substantially cheaper than the initial $274,313. Even without the state tax credit, the solar PV system still would have a better rate of return than grid-produced electricity in Honolulu (Swift, 2013). Newark's average annual solar insolation was 4.5 hours per day, which is similar to Bozeman’s solar insolation of approximately 5 (Figure 2). Newark doesn’t have any state tax incentives. However Newark has a growing market for Solar Renewable Energy Certificates (SRECs; Swift, 2013). After all rebates and certificates, the PV LCOE, as shown in Table 1, was $0.073/kWh compared to the grid-produced LCOE price of $0.082/kWh.

Phoenix has high solar insolation, however the price of electricity in Arizona for commercial and industrial businesses was very low. The state income tax credit was also only 10% which is low, especially compared to Hawaii’s 35%. Phoenix however does have rebate programs that help with costs associated with PV systems. Despite the rebates and amount of sunlight, the grid-based electricity is still very inexpensive and the lack of tax incentives makes solar PV systems economically unviable. Minneapolis receives only 4.6 hours of solar insolation per day, again similar to Bozeman. The price of grid-produced electricity however was low ($0.076/kWh). The LCOE of the proposed 50-kWh solar PV system was $0.18/kWH and the LCOE from the grid-produced electricity is much lower at $0.049/kWh. The variability shown at these four locations is reason to have site-specific research done before installation (Swift, 2013).

Further information about the existing cost of grid-produced electricity, the amount of sunlight, PV systems costs and performance and financial incentives is necessary to decide whether installing solar power is feasible at MSU (Swift, 2013). A net-zero campus is clearly not feasible (Kwan and Kwan, 2011). However during peak demand hours, the use of solar PV arrays would help reduce costs and greenhouse gas emissions. MSU should take into consideration peak shaving because it helps towards our goal of eliminating net greenhouse emissions from campus at a fraction of the cost compared to going net-zero.

Conclusions

There are several inhibitors that prevent solar panels from being installed on university campuses such as MSU. One limiting factor is that buildings are not outfitted to support the infrastructure and weight of large panels. The University of Montana has experienced leaks in some of its buildings as a result of bolting solar panels onto roofs (Blackler, pers. comm.). The MSU Office of Sustainability has worked with design teams to ensure that all new buildings constructed on MSU, including the Jake Jabs College of Business, are capable of supporting solar panels, which can be installed once funding becomes available. In the next 5-10 years, solar panels are projected to become far more economically viable. This increases the likelihood of future panel installation.

The requirement of a large initial investment is the greatest barrier in installing solar panels on campuses. While MSU is prepared to invest in reducing its carbon footprint, solar energy is far from the easiest or most economical solution. Investment in improving building energy efficiency, geothermal energy and heat transfer between buildings will produce greater returns on energy savings and reductions in GHG emissions (Butler, 2014). Solar panels will pay themselves off eventually; but initially they require a large capital investment. The funding for the SUB solar panels came from a variety of sources, including: ASMSU, NECO, MSU Energy Research Institute and the Northwestern Energy Universal Systems Benefit grant (Bjornson, pers. comm.) Most of these organizations are limited in the amount they can invest into a program such as this; future funding must come from other sources.

Public-private partnerships (PPP’s) between universities and private companies have been effective in securing funding for solar panel installation. The University of California San Diego has partnered with AMSOLAR Corporation to obtain solar energy for their campus. The private company pays for the solar panels that are placed on university buildings. In return, the university pays a fixed price for the energy generated from the panels for a predetermined number of years. As energy prices generally increase, the university will begin to save money on energy bills. After the lease expires, the solar panels are gifted to the university, to be used until the ends of their lifespan. The private company receives tax rebates for the solar panels that the university, as a non-profit, is not eligible to receive. The private company generates profits from energy sales and receives further tax incentives when it gifts the solar panels to the university. At University of California San Diego, this partnership has proven to be a win-win scenario (Rescorla, 2010).

MSU has shown resolve in reducing its greenhouse gas emissions. Currently solar energy is not the most economical solution. In the near future, as other options are exhausted and solar panels become more cost-effective, MSU may decide to install more panels. The infrastructure is already in place for some panels, specifically all buildings built this year or in the future. PPP’s are one option to secure funding for solar panels. Solar panels are a visible manifestation of MSU’s dedication to the increasingly important task of GHG emission reductions. The panels on the SUB prove this, but they are just the start.

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