Michigan Stadium Solar Project:

A Feasibility Study for Installation of a Photovoltaic System on Michigan Stadium

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EXECUTIVE SUMMARY:

The University of Michigan has a great opportunity to become a leader in renewable energy and serve as an example for institutions nationwide. The proposal at hand is to install a photovoltaic system on the roofs of the new additions to Michigan Stadium. These new additions are slated to be completed in August of 2010 and represent a way for the university to strengthen tradition through innovation. The slogan used for the renovation is "building our future... strengthening our tradition," and installation of solar panels atop these additions would do just that. Not only would the university save money from energy savings, but it would also become a leader in sustainability, mitigate environmental impacts, and serve as a recruitment tool by generating great publicity.

This report attempts to analyze the feasibility of a photovoltaic system atop these new additions. The tools used to create this report were energy analyses, cost-benefit analyses, environmental impact mitigation, social benefit analysis, and peer institution review. Most importantly, the payback period for each system was analyzed. Methodologies and calculations can be found in the appendices. The results show that a system of this size would be feasible, and would actually pay for itself over time.

New technology has allowed solar panels to be made at a much lower cost than in the past and operate with greater levels of efficiency. The three panels that are best suited for Michigan Stadium are the Sharp 224 Watt Module, the Evergreen Solar ES-A-210 210 Watt Module, and SolarWorld's 175-Watt SunModule. These three have the best energy output, energy displacement, efficiency, and cost-effectiveness. Their respective capital investments not including installation are $2,261,466.93, $2,136,182.01, and $1,804,848.00. Additional costs include installation ($2-3/Watt), the cost of the inverters ($75,000-$150,000), and optional maintenance. The money saved creates payback periods for each system.

In addition to energy cost savings, environmental impacts from buying energy from coal-fired power plants would be mitigated. A good deal of greenhouse gas emissions would be prevented, with the biggest impact coming from the 776 tons of carbon dioxide being prevented over the system's lifetime.

If completed, this solar system would be the first of its kind for football stadiums in America. The University of Michigan would be setting an example for collegiate and perhaps professional athletic programs in an effort to create a sustainable energy future. Solar technology has also been utilized at the university level as more and more schools strive toward sustainability.

This drive toward sustainability has taken hold at hundreds of universities across the nation including recognizable schools such as Harvard, the University of Virginia, the University of South Carolina, and Carnegie Mellon, as well as at smaller schools such as Oberlin College and Portland State University.

It is recommended that the University of Michigan install solar panels to the roof additions of the Michigan Stadium. The Sharp 224 Watt module is the best option for the project based on its efficiency and output capacity. The panel will displace 9.0256% of power per hour. The system should be online continuously throughout the year as this option provides the shortest payback period with little additional operational costs. With the Sharp 224 Watt module, the capital investment of solar panels would be paid back in 15.34 years. Including average installation costs, the payback period would increase to 26.34 years. The University also should hire maintenance personnel to clean the panels during winter months. By clearing off snow and ice, the panels will operate closer to maximum efficiency.

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SUMMARY OF FINDINGS:

Infrastructure

The renovations to the Michigan Stadium provide approximately 42,179 square footage of roof space. Approximately 4,000 square feet is required for already existing infrastructure, including ventilation units and maintenance walkways. Therefore, approximately 38,179 square feet of roof space is available for installation of photovoltaic modules.

Statewide Energy Potential

The state of Michigan recorded 61 fair days, 168 partly cloudy days, and 137 cloudy days during 2008.[12] There on average are 4.2 hours of peak sunlight per day in Michigan. In terms of solar radiation, the state of Michigan receives 4.4 kWh/m²/day in potential energy. The maximum state energy potential can increase to 6 kWh/m²/day during summer months and decrease to 2 kWh/m²/day during winter months. According to Exhibit 3, during summer months the energy potential of the state of Michigan is similar to that of southern states, such as Florida and Texas.[10]

Stadium Energy Demand

The energy needs of the Michigan Stadium will be 226,800 kWh for the 2010 season. The stadium will use approximately 5,400 kWh of energy per hour during each home game. The power used at the Michigan Stadium is purchased at a cost of fifteen cents per kWh from the DTE energy grid. Based on the 2010 estimated energy use after renovations, the Sharp, Evergreen, and Solarworld panels can displace between 8 and 9% of the stadium's energy load per hour under optimal conditions; with the Sharp 224 module being the best at 9.02%.[17]

Solar Energy

Solar energy is a clean and renewable form of energy used to produce electricity, heating, lighting and cooling. Electricity, in particular, is produced when photovoltaic cells are combined into silicon panels and become charged when subjected to sunlight.[18] Solar panels are becoming increasingly inexpensive to install and can help institutions cut energy costs and set an example in sustainability for future generations. The availability of free sunlight, local and state government incentives, and grid connections are helping the photovoltaic industry grow at rate of thirty percent per year.[22]

Solar Panel Technology

Third generation solar cells consist of flexible thin-film modules and rigid thin-film modules. These cells provide higher efficiency than those of the previous generation, increasing efficiency from 15-20% to more than 30%. This is accomplished while maintaining second-generation price levels.[26]

The most common types of solar cells utilize polycrystalline silicon, monocrystalline silicon, or wafer technology. Numerous solar panel manufacturers using the aforementioned technologies have a global presence such as Kyocera and Sharp.[17] Local companies such as Michigan-based United Solar Ovonic (Uni-Solar) and Evergreen are also capitalizing on the third generation technologies.[6, 23]

Types of Solar Panels

United Solar Ovonic produces a flexible thin-film panel known as a photovoltaic laminate. The unique panel is extremely lightweight and has an easy peel-and-stick application for rooftops. Photovoltaic laminates produce between 68 and 144 Watts of power per hour. This technology has been used in multiple U.S. locations as well as on the side of the ThyssenKrupp Stahl facility in Germany. This particular project produces between 20,000-25,000 kWh per year.[22, 23]

Evergreen Solar manufactures panels using state-of-the-art string-ribbon wafer technology. This particular technology is extremely environmentally friendly and Evergreen Solar claims to have the smallest carbon footprint of all manufacturers. These panels have been installed on rooftops and as stand-alone units in northern states such as Massachusetts and New Jersey. The Evergreen Solar ES-A 210 Watt panel is well fit for installation on the Michigan Stadium.[6]

SolarWorld manufacturers the Sunmodule line of panels using monocrystalline silicon technology. The company demonstrates a commitment to the environment by offering end of life recycling of all Sunmodules. This sustainable recycling program reduces landfill waste and lowers production costs. The three types of Sunmodules range in size from 155 to 175 Watts. The 175 Watt model is one of the three best fit panels for the Michigan Stadium.[18]

Sharp produces polycrystalline silicon solar panels that offer a high power output per square foot. The line of solar modules ranges in size from 80 to 224 Watts per panel. The 224-Watt module has the greatest energy potential for the Michigan Stadium.[17]

The three panels of best fit for installation on the Michigan Stadium are the Evergreen Solar ES-A 210 Watt module, the SolarWorld 175 Watt Sunmodule, and the Sharp 224 Watt module. It was determined that the Sharp 224 Watt module is the best option for the project based on efficiency.

Engineering Viability

Solar systems can be very heavy with individual panels weighing as much as 40 pounds. Since the roof of the Michigan Stadium was built to sustain additional construction, roof weight capacity is not an issue. Additional weight support for a roof-mounted photovoltaic system would not be necessary for installation.

The installation of a photovoltaic system necessitates the purchase and installation of a power inverter to change the direct current generated by the system into alternating current, which is required to use the power. Inverters do not take up very much space, and could be located off of the roof if needed. High-Wattage inverters, which would be required for a project this size, generally weigh 1.5-3 tons and take up an area of 2 x 2 x 1.5 m (dimensions taken from Xantrex GT250-480 Grid Tie Commercial Inverter).[18]

Most solar systems include a 10-year warranty from the manufacturer, and some warranties extend to 20 years. In general, photovoltaic systems require little maintenance, are very durable and are unlikely to break during any sort of maintenance activity. This is due to the fact that the systems have few, if any, moving parts. Rainwater is sufficient to keep the panels clean.[6, 17, 19]

To generate an optimal amount of energy, the solar panels must be completely free of debris. Solar panels can be cleaned off manually using a tool such as a broom or roof rake. However, maintenance is optional - it is not necessary to keep the panels completely free of snow and ice. The University of Michigan's S.T. Dana Building, for example, does not perform any maintenance on its rooftop solar panels. During winter months, snow will accumulate on the panels, generating less than optimal energy, but there are no additional maintenance costs.[14]

Cost/Benefit Analysis

The following is a cost benefit analysis of the three types of panels that are determined to be the best fit for installation on the Michigan Stadium. The analysis is based on 2010 estimated energy use after renovations. The following panels are made for commercial use and were selected as best fit based on their potential to displace the greatest amount of energy per hour.

- Sharp 224-Watt Module
- Evergreen Solar ES-A 210-Watt Module
- SolarWorld Sunmodule 175-Watt Module

Capital Investment:

The capital investment of the solar panels would be the greatest cost incurred during the project. This cost excludes the cost of installation. Both the number of cells needed to cover the roof and price per Watt vary per panel. Price per Watt was discovered on the Alt E Store. See Exhibit 4 for specific formulas used in the calculation. Based on calculations, the SolarWorld 175 Watt module is the least expensive for installation purely based on capital investment costs.[6, 17, 18]

Panel Type	Price per Watt	Number of Cells	Capital Investment
Sharp (224-Watt)	$4.64	2176	$2,261,466.93
Evergreen (210-Watt)	$4.51	2255	$2,136,182.01
SolarWorld (175-Watt)	$4.74	2719	$1,804, 848.00

Payback Period:

The payback period was calculated based on the following three solar system options: online for home games only, online for 6 months of the year (April-September), and online for the entire year. This calculation does not include cost of installation. Based on payback period calculations, the Evergreen 210 Watt panel provides the fastest payback period of 14.91 years when the system is online throughout the entire year.

Panel Type	Capital Investment	Payback Period: On for home games only (years)	Payback Period: On for 6 months (years)	Payback Period: On for 12 months (years)
Sharp (224-Watt)	$2,261,466.93	736.51	30.60	15.34
Evergreen (210-Watt)	$2,136,182.01	715.87	29.83	14.91
SolarWorld (175-Watt)	$1,804, 848.00	752.38	31.35	15.67

If the system was online only during the football games, the amount of power produced and money saved does not warrant installation of solar panels. Using the Sharp module as an example, the amount of power generated for the entire season would only total 20,454 kW. This is roughly 9-10% of the power consumed by the stadium for the entire season. Considering the output level in terms of money saved, with fifteen cents per kWh being standard, the Athletic Department would only save roughly $3,068.10 for the entire season. The results for the other two modules are similar and give a clear indication of the infeasibility of using the system only during football games.

If, instead, the system was online for the warmest six months of the year (April through September) the amount of energy produced would be much more significant. The payback period of roughly 30 years would be on par for solar installations nationwide.

As exhibited in the above chart, the best option is clearly to keep the system online continuously throughout the year. The payback period is significantly lower while the additional operation costs are minimal.

Installation Costs:

The above calculations do not account for installation costs. Solar panel installation costs $2 to $3 per Watt on average. The installation at Michigan Stadium would cost an estimated $1.5 million dollars. Including installation costs, the payback period is estimated to increase by 10 years to 26.3 years in total. Note that installation costs can vary greatly between bidders and this estimate could therefore be unrepresentative of actual costs.

Inverter Costs:

As mentioned earlier, the project would require one 500 kW power inverter. The single inverter would cost approximately $150,000. Inverters of lesser power are available but the University would most likely to be required to purchase two of these. These inverters range in price from $75,000 to $150,000 each.[18]

Environmental Offset:

Outside of the money saved in energy costs, the solar installation has the added benefit of reducing the environmental impact of purchasing energy from DTE's coal-fired power plants. The installation itself produces no greenhouse gas emissions and would offset carbon dioxide, nitrogen oxides, sulfur dioxide, and mercury releases. The table below illustrates the amount of pollutant emissions that would be prevented by installing the photovoltaic system. [9, 28, 31]

Emissions Prevented	**CO_2 (lbs)**	**NO_x (lbs)**	**SO_2 (lbs)**	**Mercury (mg)**
Per Hour	770.00	3.75	11.16	5.85
Per Year	1,553,458.07	7,566.00	22,501.00	11,791.00

Net Metering:

Net Metering, also known as selling back to the grid, occurs when electricity consumers have a renewable energy source, such as wind or solar power, and use their own energy source to power their needs. If one produces more energy than they actually use, the excess energy can be sold back to the grid at the market price.[1]

Each state has its own rules and regulations regarding net metering. In Michigan, a bill was passed allowing people to sell energy back to the grid for profit. Systems that are 20 kW and smaller are eligible for true net metering, and systems between 20 kW and 150 kW are eligible for modified net metering. For both, this will be okay until the aggregate net-metered capacity is 0.5% of a utilities peak.[5]

While DTE accepts systems up to 150kW in size, the proposed system on the Michigan Stadium would be 3-4 times that size and therefore ineligible for net metering. However, the University represents a large amount of DTE's business and if the University wanted to arrange for net metering with the proposed system, DTE would most likely work with the University in fear of losing their business.[1]

Similar Stadium Projects

There are no professional or college football stadiums in America that use solar energy; however, there are a few professional baseball stadiums, similar to the Michigan Stadium in influence and fame, who have installed solar panels on their roofs. These include the San Francisco Giants, Boston Red Sox, Cleveland Indians and Colorado Rockies.

The San Francisco Giants play in AT&T Park, which is a much newer stadium than the Michigan Stadium. The Giants worked with their energy provider, PG&E, to install 590 Sharp solar panels to their stadium roof. The panels are connected to the San Francisco grid and will generate 120 kilowatts/hr. The project took about two months to complete and cost between $1 million to $1.5 million. However, the Giants are not paying for these costs. Since the panels are connected to the San Francisco grid, the price will be distributed among the 15 million customers of PG&E and these costs will be less than a dollar for customers. They chose to install 590 Sharp panels on their roof facing the port walk, a famous location where the home runs go splashing into the bay. It was a conscious decision to place the solar panels at this signature location on the waterfront so the Giants could send a message to fans, television viewers and larger community about the importance of using renewable energy. The Giants are also using this opportunity to run a five-year public awareness campaign to educate their fans about responsible energy use.[14]

Fenway Park is using solar technology to heat water as opposed to electricity generation; while those are different, it is still important to note that Fenway Park in Boston is very similar to the Michigan Stadium. Fenway Park houses one of the oldest and most vibrant sporting cultures in the U.S., which is very similar to the football culture at the Michigan Stadium. The stadium owners in Boston recognize their influence on fans, Boston and professional sports in general; therefore, they see that they are in the position to lead the clean energy movement by example.[2] Fenway Park has claimed they are committed to preserving the integrity and tradition of the building, while leading the way to a cleaner future.[2] Boston's mayor said that the aim of this ballpark project was to "'make clean, abundant, and affordable solar energy the norm and no longer an alternative source of energy'". With the solar panel installations, they will be replacing 37% of the natural gas previously used to heat water and will reduce carbon emissions by 18 tons annually.[16]

Additionally, the Cleveland Indians are using 8.4 kilowatts/hr of solar energy to power all 400 television sets in the stadium and the Colorado Rockies are utilizing 616 square feet of their roof space to produce more than 14,000 kilowatt hours of energy annually, which is enough to offset the energy needed to power their LED scoreboard.[8, 21]

Social Benefits

Based on the four examples from San Francisco, Boston, Cleveland and Colorado, the stadium owners found that roughly six social benefits came from installing solar panels on their buildings. As a stadium, one can:

1. Create, reinvent or maintain a good image of being environmentally conscious

   Boston, for example, is a city once famous for their manufacturing - they are literally trying the "clean up" their image by installing clean energy systems throughout the city. Fenway Park is just one site where they have installed solar panels. San Francisco on the other hand, is already seen as an environmentally conscious city, and by installing solar panels to AT&T Park, they are reinforcing their "green" image.

2. Lead the solar power movement by example

   In many cases it takes some key influential leaders in order to take a movement off the ground. These stadiums decided that if clean energy is important to them, then they have to walk the talk and become leaders for solar energy.

3. Create positive media coverage

   With the onset of global climate change, institutions of all kinds have received a lot of pressure from the general public to reduce their "carbon footprint". In that light, the media has taken interest in climate change issues and has reported that the stadiums are doing their part to reduce their carbon footprint.

4. Educate fans about solar energy

   By installing solar panels, these stadiums found that they could educate their fans about their renewable energy systems by giving tours, interviews and making information accessible to people interested in knowing more about it.

5. Assist the solar power industry by making it appear more mainstream and accessible

   Often, renewable energy is seen as the expensive alternative to existing sources of energy. However, by installing solar panels on highly influential stadiums, it provides fans with a concrete example of how solar power can be reliable, functional and eventually cheaper than our existing sources of energy.

6. Promote innovation while still upholding tradition

   Fenway Park made the conscious decision to update their energy systems while still maintaining the integrity of their ballpark.

In the context of the University, the Michigan Stadium would be the first football stadium in the United States, collegiate and professional, to install solar panels. The Michigan Stadium is a sports icon and arguably the most famous college football stadium in the world. The University of Michigan would be demonstrating their commitment to renewable energy and setting an example for how collegiate and professional athletic programs can decrease their carbon footprint.

A solar panel system on the roof of the Michigan Stadium would generate a lot of positive publicity for Michigan football and the University as a whole, especially if we are the first football stadium in the nation to achieve this. Each season, several home games are televised nationally and there are typically several overhead shots of the stadium to show the famous crowd of 107,501 Michigan fans. The channel broadcasting the games could do a piece on these solar panels and then show a panoramic view of the new stadium, the solar panels and the crowd. Additionally, the capacity of the Michigan Stadium will exceed 108,000 after the renovations are complete and word-of-mouth could also generate even more excitement about the solar panels. The University of Michigan could feature this project on the umich.edu website and The Michigan Daily could write an article about the project to inform students. It is important to note that these are all forms of free publicity.

The installation of solar panels would also provide the chance to educate a wide audience about solar energy. For example, the announcer currently states the attendance and recycling records during each home football game. Similar to these announcements, the announcer could state how much energy the stadium solar panels have produced or how much carbon has been offset during that football Saturday. The stadium could also provide informational pamphlets to interested fans or educational boards around the stadium that provide a simple explanation of their solar energy system. An example of educational boards can be seen on campus in the S.T. Dana Building about their green building renovation.

Solar panels would reinstate the progressive image of the University of Michigan as an environmentally conscious and forward-thinking university. The project would also demonstrate that the University of

Michigan could promote the high technology innovation of today, while still upholding over-a-century old tradition.

Similar University Projects

Solar technology has also been utilized at the university level as more schools strive toward sustainability. The drive toward sustainability has taken hold at hundreds of universities across the nation including recognizable schools such as Harvard, the University of Virginia, the University of South Carolina, and Carnegie Mellon. Smaller schools including Oberlin College and Portland State University are also promoting sustainability. Numerous northern schools have also demonstrated this drive through the installation of solar panels.

The University of Vermont installed solar panels on the roof of the heating plant several years ago. While the panels do not provide a substantial amount of power, its output of 19 kWh per day can power 95 energy efficient light bulbs for 10 hours, or 9 TVs for 10 hours, or 9 desktop computers for 10 hours. The solar panels serve as a symbol for the university's commitment and reflect the environmentally conscious reputation of the school.[27]

Princeton University has installed 5,000 solar panels atop of their storage library. The panels produce 370 kWh and provide a good amount of the energy required to power the building.[20]

Georgetown University first installed solar panels atop the Intercultural Center during the 1980s. The collection was the largest solar panel collection in the world as recently as 2001. The energy produced by the panels offsets approximately $45,000 in energy costs annually.[11]

In addition to these Universities, other northern schools employing solar energy include Harvard, SUNY at Buffalo, Yale, Bowling Green University, and the University of Michigan, who operates a solar array atop the central power plant and the S.T. Dana Building. These installations set an example for other universities worldwide as sustainability efforts continue at a rapid pace.

Student Response

To begin to assess student support of this project, a survey of 100 University of Michigan students was conducted. The results below indicate an overall positive student response to the installation of solar panels on Michigan Stadium.

- 83% of students believed that environmental issues are somewhat important or important.
- 61% of students stated that it is either somewhat important or important to them to install solar panels on the Michigan Stadium.
- 80% of students responded "yes" when asked if they would be willing to pay an extra $2 per home football game for the installation of solar panels.
- 84% of students stated that it is either somewhat important or important to them that the University of Michigan be a leader in renewable energy.

See Exhibit 7 for a copy of the survey questions and results.

Funding

There are several opportunities for funding renewable energy systems in the state of Michigan. A small number are applicable to the installation of a photovoltaic system at the Michigan Stadium. According to Andrew Brix, the Ann Arbor Energy Coordinator, the Michigan Energy Office offers a state grant that pays up to $50,000 toward a 10kW or larger photovoltaic system for nonprofit institutions. Additionally, the Michigan Public Service Commission (PSC) Energy-Efficiency Grant Program offers an annual state grant of $5.5 million for renewable energy investments by schools. Although specifics have not been worked out yet, it appears likely that there will also be funding available through President Obama's stimulus plan.[5, 6]

In addition, it is possible that the Michigan Legislature will enact a law that allows people to earn money by returning energy back onto the grid. This feed-in tariff would set the price for grid-returned power at a much higher level, providing money to independent energy producers, therefore lowering the payback period.[7]

The Michigan Stadium could also attempt to do something similar to the San Francisco Giants by working with DTE to pay for the photovoltaic system. The electric company in San Francisco plugged the Giants solar panel system into the grid that powers the Bay area. Therefore, they were able to distribute the $1.5 million dollar project costs to their 15 million customers, making the cost per person negligible. It might be possible for Michigan to set up a similar system with DTE - there is a strong demand in Ann Arbor for renewable energy. Another idea could be to raise ticket prices by a very small amount to cover some of the costs of the solar panels; however, that, of course, is up to the Athletic Department. Private donors could also contribute to offsetting the costs.[14]

Next Steps

In order to install the solar panels on the roof of the Michigan Stadium, there are some crucial next steps that must be taken. First, gaining the approval of Bill Martin and the Athletic Department will be necessary in terms of moving this proposal forward. They will need to approve the project idea, the project costs, and the aesthetics of installing the solar panels. Second, it is a good idea to complete the installations of the solar panels before the renovation construction is completed in August 2010. While the system could be installed post-construction, any new construction after the renovation could mitigate the allure of an August 2010 final completion. However, this does not have to be the case - the San Francisco Giants installed their solar panels after the construction of their new stadium and it took about two months for the installation to be completed.

Recommendations

The University of Michigan should install solar panels to the roof additions of the Michigan Stadium. The Sharp 224 Watt module is the best option for the project based on its efficiency and output capacity. The panel will displace 9.0256% of power per hour. The system should be online continuously throughout the year as this option provides the shortest payback period with little additional operational costs. With the Sharp 224 Watt module, the capital investment of solar panels would be paid back in 15.34 years. Including average installation costs, the payback period would increase to 26.34 years. The University also should hire maintenance personnel to clean the panels during winter months. By clearing off snow and ice, the panels will be able to operate closer to maximum efficiency.

The University should work directly with DTE regarding net metering. Currently, the University does not qualify for net metering, but Michigan is a large enough customer and with the University's influence, they might be able to persuade DTE to come to an agreement in order to sell excess energy back to the grid. Michigan should also work with DTE to see if the costs of this project could be spread across the bills of DTE customers in the surrounding area, in exchange for connecting the Michigan Stadium onto the grid. However, if DTE is unaccommodating to these ideas, then Michigan should investigate rerouting the energy generated to other athletic facilities or buildings on campus. Crisler Arena is a likely facility to reroute the power to, as it is adjacent to Michigan Stadium, hosts' daily basketball practices and several events throughout the year. Providing power to Crisler Arena would offset their energy costs and as well as decrease their carbon footprint.

The University should promote the solar panels and make the benefits known to fans. Simple actions such as announcing the amount of energy saved per game would garner goodwill and generate a great deal of free publicity. Finally, the solar panels should be installed before the August 2010 construction date in order to optimize the construction schedule.

APPENDIX:

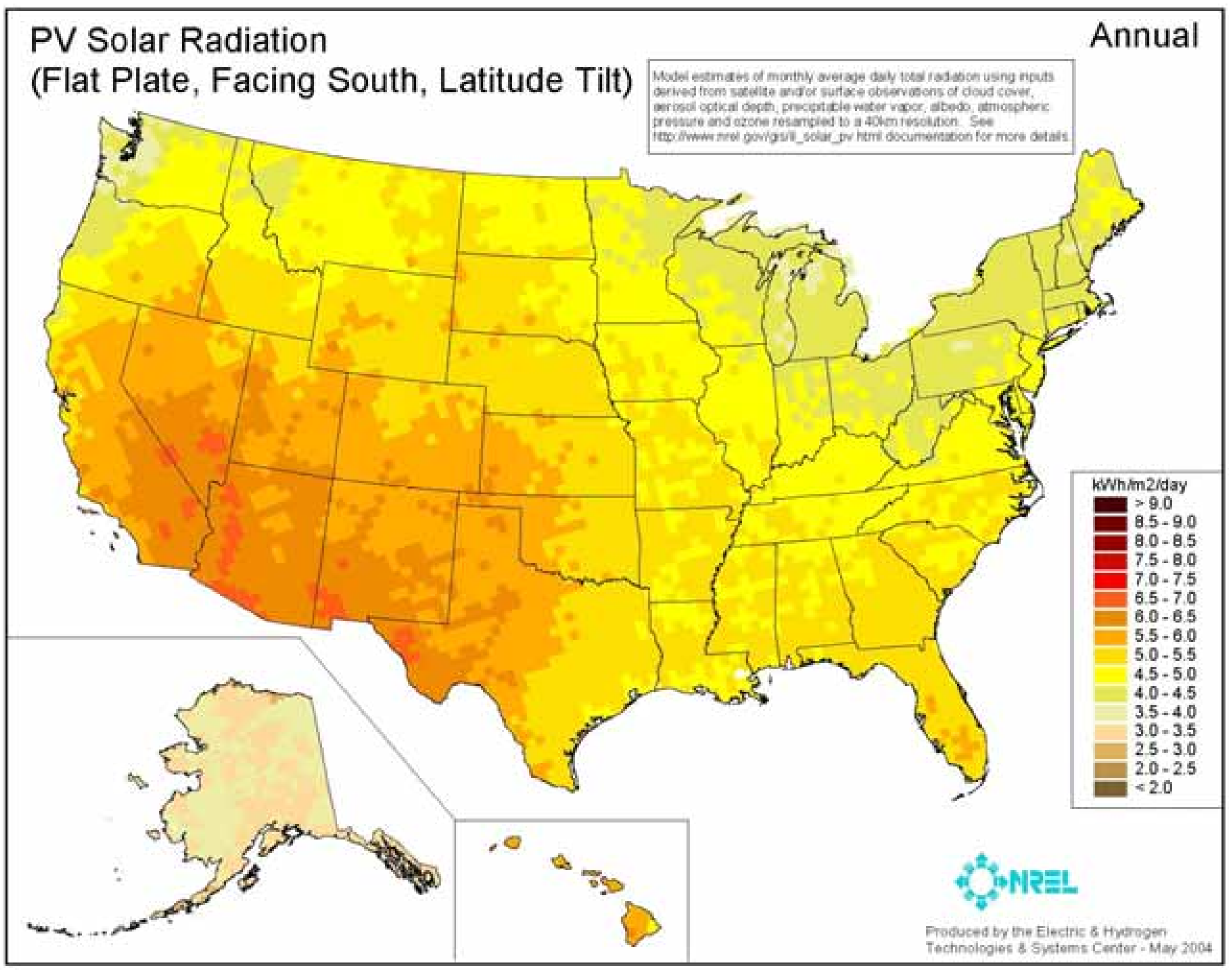
<u>Exhibit 1:</u> Monthly and Annual Solar Radiation for Detroit, Michigan

Solar Radiation for Flat-Plate Collectors Facing South at a Fixed Tilt ($kWh/m^2/day$), Uncertainty ±9%

Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	1.6	2.5	3.4	4.6	5.6	6.2	6.1	5.3	4.1	2.8	1.7	1.3	3.8
	Min/Max	1.3/1.9	2.1/3.2	3.1/4.0	3.6/5.2	4.6/6.5	5.5/7.3	5.7/6.8	4.6/6.1	3.5/4.7	2.2/3.4	1.3/2.1	1.1/1.5	3.6/4.0
Latitude -15	Average	2.4	3.3	4.1	5.0	5.7	6.1	6.1	5.6	4.8	3.7	2.4	1.9	4.3
	Min/Max	1.8/2.9	2.7/4.6	3.5/5.1	3.7/5.8	4.6/6.7	5.4/7.2	5.6/6.8	4.8/6.6	3.9/5.6	2.6/4.7	1.5/3.3	1.4/2.5	4.0/4.5
Latitude	Average	2.7	3.6	4.2	4.9	5.4	5.6	5.6	5.4	4.8	3.9	2.6	2.1	4.2
	Min/Max	1.9/3.3	2.8/5.1	3.6/5.3	3.6/5.7	4.3/6.2	4.9/6.6	5.2/6.3	4.5/6.3	3.9/5.7	2.7/5.1	1.6/3.7	1.5/2.8	4.0/4.5
Latitude +15	Average	2.8	3.7	4.1	4.5	4.8	4.9	4.9	4.9	4.6	3.9	2.6	2.2	4.0
	Min/Max	2.0/3.5	2.8/5.4	3.5/5.2	3.3/5.3	3.8/5.5	4.3/5.7	4.6/5.5	4.1/5.8	3.7/5.5	2.6/5.1	1.5/3.8	1.6/3.0	3.7/4.2
90	Average	2.6	3.3	3.2	3.0	2.8	2.7	2.8	3.1	3.3	3.2	2.3	2.0	2.9
	Min/Max	1.8/3.4	2.5/5.0	2.7/4.1	2.2/3.6	2.3/3.1	2.5/3.0	2.6/3.0	2.6/3.6	2.6/4.0	2.1/4.2	1.3/3.5	1.4/2.9	2.7/3.1

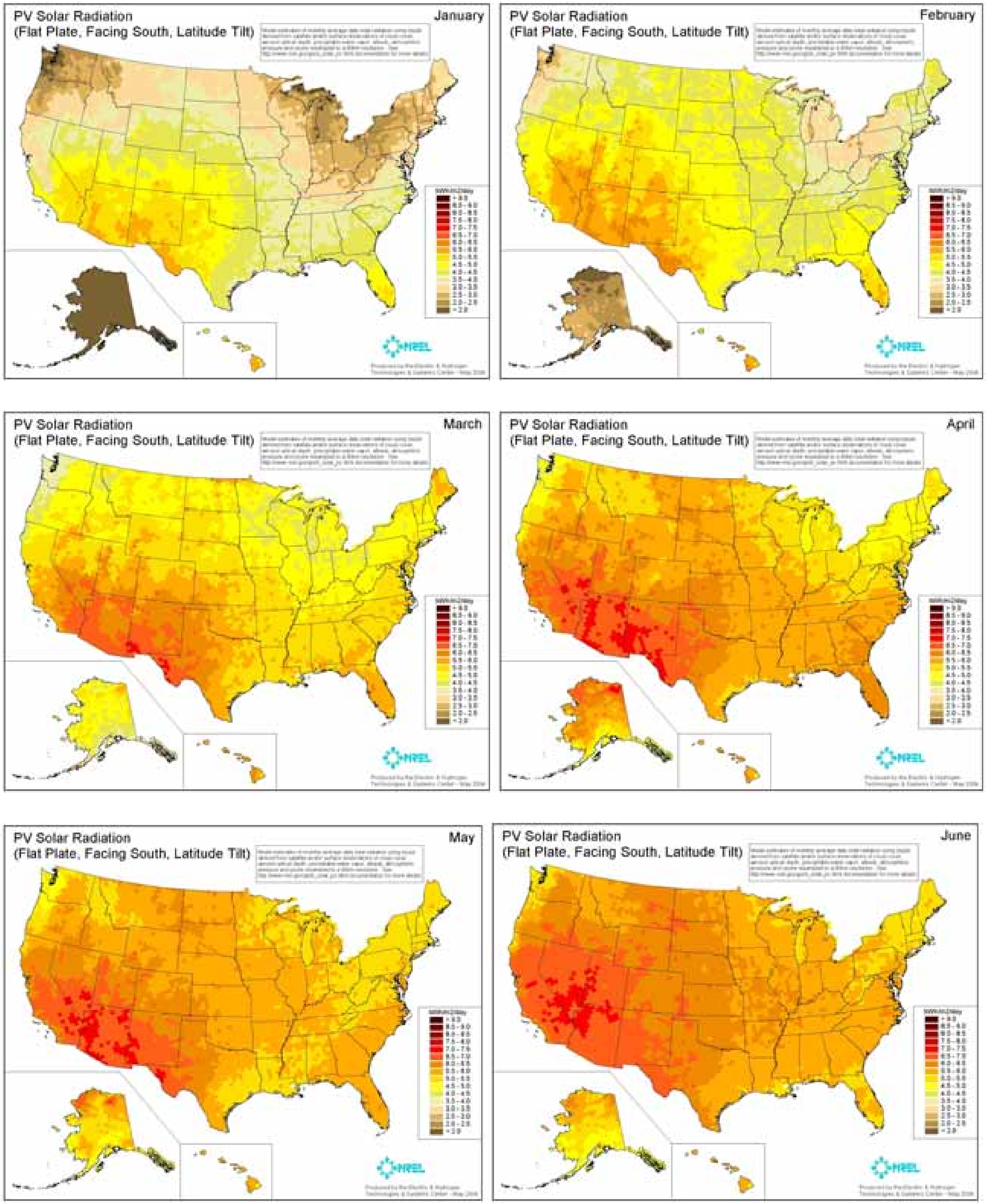
http://rredc.nrel.gov/solar/pubs/redbook/

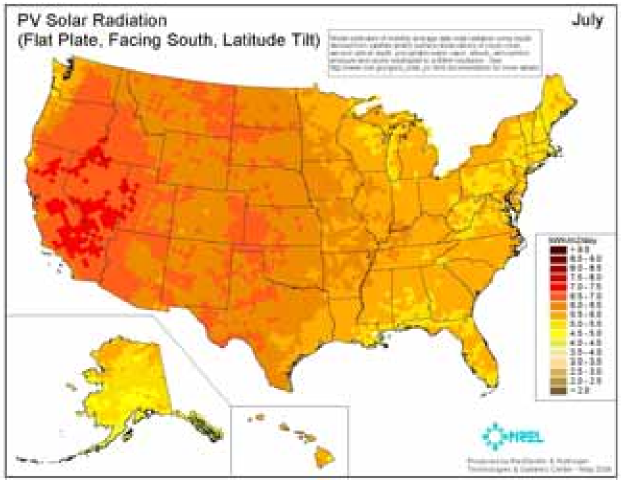
<u>Exhibit 2:</u> Map of Annual Photovoltaic Solar Radiation in the United States

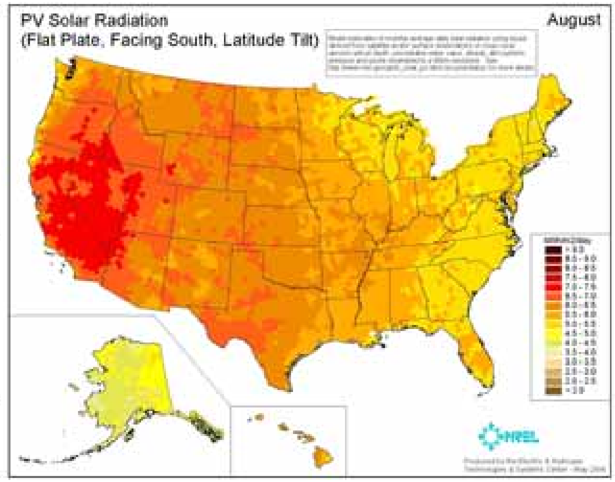


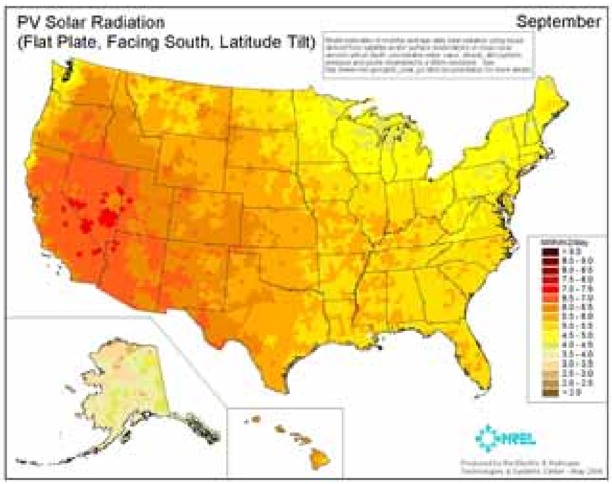
http://www.nrel.gov/gis/solar.html

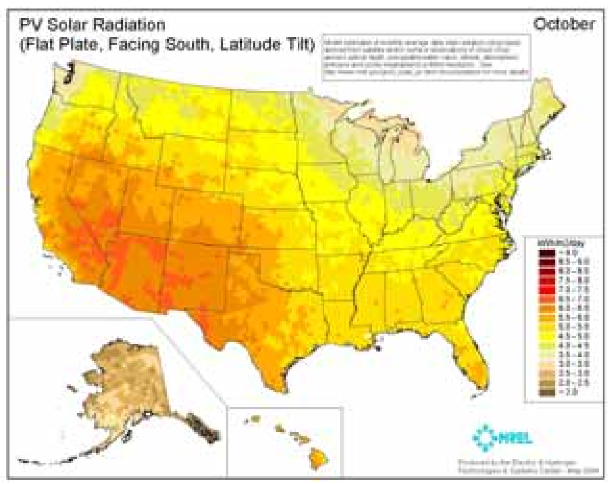
<u>Exhibit 3:</u> Map of Monthly Photovoltaic Solar Radiation in the United States

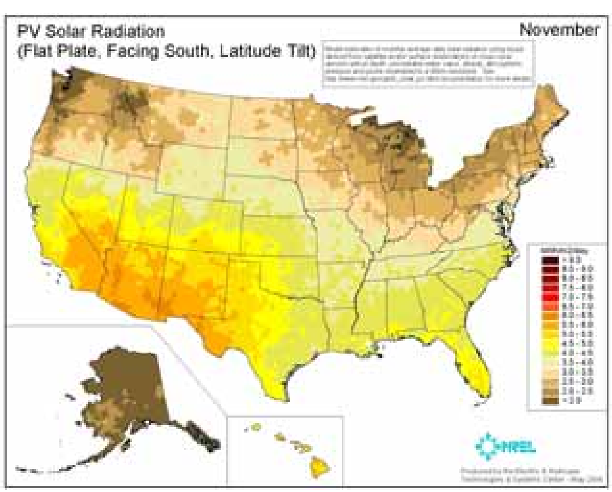


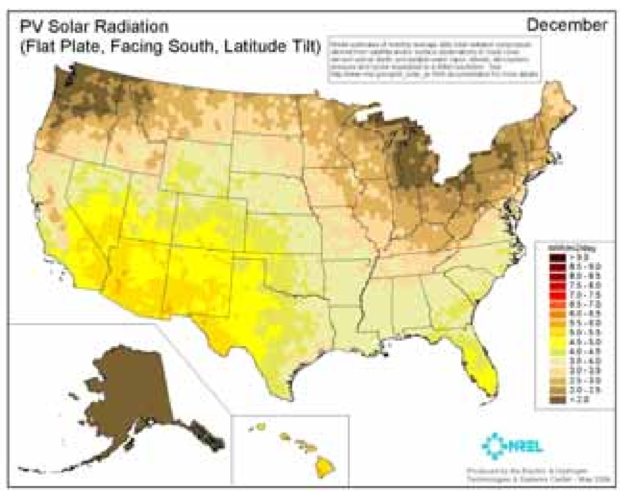












http://www.nrel.gov/gis/solar.html

<u>Exhibit 4:</u> Calculation used in Cost/Benefit Analysis

- Convert Power to kWh (per module) = Module Power/1000
- Number of Cells Needed = Roof Area/Module Area
- Output Per Hour = (Number of Cells)*kWh/module
- % Displaced power/hour = [(Output per hour)/(power needs per hour)]*100
- Output Per Game = (Output per Hour)*6
- Output Per Season = (Output per game)*7
- Cost of System = (Output per Hour)*($/W)*1000
- Savings per Season = (Output per hour)*0.15*6*7
- Savings per 6 months = (Output per Season)*24
- Pay off Period (season only) = (Cost of System)/(Savings per Season)
- Pay off Period (running 6 months) = (cost of system)/[Savings per 6 months)
- Pay off Period (running 12 months) = Pay off Period (running 6 months)/2

<u>Exhibit 5:</u> Graph of Payoff Period with Solar System Online for 6 Months (April-September)

<u>Exhibit 6:</u> Graph of Payoff Period with Solar System Online for 12 Months

Exhibit 7: Survey Questions and Results

1. How important are environmental issues to you?

	Not at all important	Somewhat unimportant	Neutral	Somewhat important	Important	Response Count
Please choose one of the following.	2.0% (2)	6.0% (6)	9.0% (9)	38.0% (38)	**45.0% (45)**	100

2. How important to you would it be to put solar panels on the Big House?

	Not at all important	Somewhat unimportant	Neutral	Somewhat important	Important	Response Count
Please choose one of the following.	9.0% (9)	7.0% (7)	23.0% (23)	29.0% (29)	**32.0% (32)**	100

3. Would you want solar panels on the Big House even if it meant paying an extra $2 per home football game?

	Response Percent	Response Count
Yes	**80.0%**	**80**
No	20.0%	20

4. How important is it to you that the University of Michigan be a leader in renewable energy?

	Not at all important	Somewhat unimportant	Neutral	Somewhat important	Important	Response Count
Please choose one of the following.	4.0% (4)	4.0% (4)	8.0% (8)	23.0% (23)	**61.0% (61)**	100

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