Feasibility Study of Economics and Performance of Solar Photovoltaics at the Sky Park Landfill Site in Eau Claire, Wisconsin

A Study Prepared in Partnership with the Environmental Protection Agency for the RE-Powering America's Land Initiative: Siting Renewable Energy on Potentially Contaminated Land and Mine Sites

Joe Simon and Gail Mosey

Produced under direction of the U.S. Environmental Protection Agency (EPA) by the National Renewable Energy Laboratory (NREL) under Interagency Agreement IAG-08-0719 and Task No. WFD3.1002.

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Work for Others Report
NREL/TP-7A30-56995
January 2013
Contract No. DE-AC36-08GO28308

NATIONAL RENEWABLE ENERGY LABORATORY

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Executive Summary

The U.S. Environmental Protection Agency (EPA), in accordance with the RE-Powering America's Land initiative, selected the Sky Park Landfill site in Eau Claire, Wisconsin, for a feasibility study of renewable energy production. The National Renewable Energy Laboratory (NREL) provided technical assistance for this project. The purpose of this report is to assess the site for a possible photovoltaic (PV) system installation and estimate the cost, performance, and site impacts of different PV options. In addition, the report recommends financing options that could assist in the implementation of a PV system at the site. This study did not assess environmental conditions at the site.

The Sky Park Landfill is a 26-acre site located on the southwest side of Eau Claire, Wisconsin, near Highway 37 and I-94. The site operated as a municipal waste facility from 1948 until closure in 1965. The present site is capped and unused, except for a small area used for excess snow and storm damage vegetation storage. A majority of the site has dense vegetation, including trees, which would need to be removed should the entire site be developed for a solar array. The site is located in an industrial district with adjacent manufacturing, offices, and municipal facilities.

The feasibility of a PV system is highly impacted by the available area for an array, solar resource, distance to transmission lines, and distance to major roads. In addition, the operating status, ground conditions, and restrictions associated with redevelopment of a closed and capped landfill site can impact the feasibility of a PV system. Based on an assessment of these technical factors, the Sky Park Landfill is suitable for deployment of a large-scale PV system, should a reasonable power purchase agreement (PPA) be secured for the electricity produced.

There are approximately 3 acres available for installation of a PV system without the removal of significant vegetation and with minimal concern regarding ground settlement. The areas laden with excess vegetation following city-wide storms is less ideal due to the potential for differential settlement. Depending on interest in the system, the City of Eau Claire has indicated that it would be possible to remove the existing vegetation and develop the entire site. As this cost would be separate from the developer's necessary work, this preparation cost is not considered in this analysis. For the purposes of this report, 23 acres, representing approximately 92% of the site is considered feasible for development. Calculations for this analysis use the entire feasible area.

The economic feasibility of a potential PV system on the Sky Park Landfill site depends greatly on the purchase price of the electricity produced. The economics of the potential system were analyzed using the current Xcel Energy policies, net-metering options, the city's average blended commercial electric rate of $0.08/kWh, and incentives available to the site. Current incentives considered include the federal tax credit, Xcel Energy standard policies, and the State of Wisconsin tax incentives. Table ES-1 summarizes the system performance and economics of a potential system that would use the assumed 23-acre feasible area surveyed at the Sky Park Landfill site. The table shows the annual energy output from the system along with the number of average American households that could be powered through such a system, as well as estimated job creation.

For this analysis, two distinct scenarios were considered, the first using virtual net metering (VNM) to offset other city energy use and the second assuming energy produced would be sold under a PPA.

Table ES-1 summarizes the estimated production, feasibility, and payback of potential systems installed at the site. This analysis considers the current cost of energy, expected installation cost, site solar resource, and existing incentives for the proposed PV system. While the net present value for this system is negative, the value to the community associated with meeting its 25% by 2025 renewable energy generation goal, public perception, and community support for renewable energy development may justify the net cost of the system.

Table ES-1 also indicates the results for potential systems developed under a PPA arrangement and assumes that the project would be developed by a third party on land leased from the City of Eau Claire and that electricity would be either sold to the utility or to an adjacent energy consumer. The analysis calculates the estimated required PPA price to allow for an overall project internal rate of return (IRR) of 8%. If a PPA at the rate associated with each type of system, approximately $0.10/kWh increasing at 3.5% annually, could be developed, the system would be an attractive investment for the city as well as the solar developer.

Table ES-1. Sky Park Landfill PV System Summary

System Type	Financial Model	PV System Size[a] (kW)	Array Tilt (deg)	Annual Output (kWh/year)	Number of Houses Powered[b]	Construction Period Jobs[c]	Jobs Sustained[d]
Crystalline Silicon (Fixed Tilt)	VNM	4,007.52	LAT	4,837,763	438.2	n/a	n/a
Crystalline Silicon (Single-axis Tracking)	VNM	3,506.58	n/a	5,337,797	483.5	130.9	1.4
Crystalline Silicon (Dual-axis Tracking)	VNM	3,005.64	n/a	4,572,138	414.1	n/a	n/a
Crystalline Silicon (Fixed Tilt)	PPA	4,007.52	LAT	4,837,763	438.2	130.9	1.4
Crystalline Silicon (Single-axis Tracking)	PPA	3,506.58	n/a	5,337,797	483.5	n/a	n/a
Crystalline Silicon (Dual-axis Tracking)	PPA	3,005.64	n/a	4,572,138	414.1	n/a	n/a

System Type	Financial Model	Annual Output (kWh/year)	Cost of Electricty/PPA Price[e] (¢/kWh)	System Cost ($/watt)	Total System Cost	1ST Year Savings/Revenue ($/year)	After-tax NPV
Crystalline Silicon (Fixed Tilt)	VNM	4,837,763	8	$ 2.79	$ 11,179,632	$ 387,021	$ (1,007,989.90)
Crystalline Silicon (Single-axis Tracking)	VNM	5,337,797	8	$ 3.35	$ 11,688,105	$ 427,024	$ (807,095.57)
Crystalline Silicon (Dual-axis Tracking)	VNM	4,839,482	8	$ 3.68	$ 10,979,756	$ 387,159	$ (900,799.34)
Crystalline Silicon (Fixed Tilt)	PPA	4,837,763	10.61	$ 2.79	$ 11,179,632	$ 513,066	$ 96,991.21
Crystalline Silicon (Single-axis Tracking)	PPA	5,337,797	9.94	$ 3.35	$ 11,688,106	$ 530,635	$ 101,219.94
Crystalline Silicon (Dual-axis Tracking)	PPA	4,839,482	10.35	$ 3.68	$ 10,979,756	$ 500,767	$ 95,158.14

a Data assume a maximum usable area of 23 acres was used for all arrays. Array size determined by energy density indicated in Table 1.
b Number of average American households that could hypothetically be powered by the PV system assuming 11,040 kWh/year/household.
c Job-years created as a result of project capital investment including direct, indirect, and induced jobs.
d Jobs (direct, indirect, and induced) sustained as a result of operations and maintenance (O&M) of the system.
e Assumes a utility rate that increases at 2% per annum and a PPA that increases at 3.5% per annum. Inflation assumed to be 1.5%/year.

U.S. Energy Information Administration. http://www.eia.doe.gov/ask/electricity_faqs.asp#electricity_use_home. Accessed November 2, 2010.

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1 Study and Site Background

The U.S. Environmental Protection Agency (EPA), in accordance with the RE-Powering America's Land initiative, selected the Sky Park Landfill site in Eau Claire, Wisconsin, for a feasibility study of renewable energy production. The National Renewable Energy Laboratory (NREL) provided technical assistance for this project. The purpose of this report is to assess the site for a possible photovoltaic (PV) system installation and estimate the cost, performance, and site impacts of different PV options. In addition, the report recommends financing options that could assist in the implementation of a PV system at the site. This study did not assess environmental conditions at the site.

The Sky Park Landfill is a 26-acre site located on the southwest side of Eau Claire, Wisconsin, near Highway 37 and I-94. The site operated as a municipal waste facility until closure. The present site is capped and unused, except for a small area currently being used for excess snow and storm damage vegetation storage. A majority of the site has dense vegetation, including trees, which would need to be removed should the entire site be developed for a solar array. The City of Eau Claire, Wisconsin, currently owns and maintains the site. Located in western Wisconsin, approximately 90 miles from Minneapolis, Minnesota, the site experiences an average annual solar resource of 4.49 kWh/m^2/day.

Under the RE-Powering America's Land initiative, EPA Region 5 provided funding to NREL to support a feasibility study of solar renewable energy generation at the Sky Park Landfill site in Eau Claire, Wisconsin. The site is surrounded by a light industrial park zoned for industrial and office uses. Adjacent functions include offices, manufacturers, municipal facilities, and a local operations and call center for the utility, Xcel Energy.

As previously indicated, the site operated as a municipal waste facility from 1948 and was ultimately closed in 1965. The site was capped and since that time, significant vegetation has grown throughout a majority of the site. Due to the time elapsed, all differential settlement of the landfill is assumed to be complete. A small, approximately half-acre portion of the site, however, has been used for removal and storage of storm-damaged vegetation from throughout the city after a 1980 significant storm event. This area still experiences significant differential settlement and is not being considered feasible for a solar installation.

Approximately 3 acres of the site is clear of vegetation and reasonably flat, such that it could be developed with minimal site preparation work. The remainder of the site would require removal of vegetation and basic grading, which would be undertaken by the site owner, the City of Eau Claire. As such, approximately 92%, or 23 acres, of the site is considered feasible for a solar installation. As the site owner would be responsible for the removal of vegetation and initial grading of the site, the cost of this initial site preparation work is not considered in this analysis for the virtual net metering (VNM) scenerio.

As this site is a historical landfill, all its site contaminants are not known. However, the site is considered contained and successfully capped. Long-term ground monitoring is in place throughout the perimeter of the site and has not indicated any areas of concern. The depth and construction of the landfill cap is mainly 12–18 inches of granular soils, so a ballasted system is recommended for this feasibility study, but upon further evaluation of this site, it may be possible to develop alternate mounting solutions and the estimated installed cost can be reduced accordingly.

Alternative solutions could include a shallow spread footing foundation or, after investigation is completed as to the exact location of the system and ground conditions, a more traditional foundation system could be used. All information relating to the history of the site and contaminants was provided to the authors and is not independently verified. The purpose of this report is not to analyze the contaminants or history but to analyze the potential for a solar development.

The site is not directly served by any utility infrastructure, but it is located in a developed industrial park within the City of Eau Claire. The adjacent site occupants are significant energy users and the available utility services, including transmission lines, are assumed to be capable of supporting up to a 4-MW solar installation, depending on system type. Zoning restrictions for the site are minimal and should not affect the implementation of a successful solar development. Site access is sufficient, with an existing gravel access road that begins at the adjacent public street and ends at the center of the site. The site is surrounded to the south and east by industrial properties and is bounded to the north and west by Hamilton Avenue.

Feasibility assessment team members from NREL, the City of Eau Claire, the State of Wisconsin, and EPA Region 5 conducted a site visit on May 30, 2012, to gather information integral to this feasibility study. The team considered information including solar resource, transmission availability, community acceptance, and ground conditions.

2 Development of a PV System on Landfill

Through the RE-Powering America's Land initiative, the EPA has identified several benefits for siting PV facilities on closed municipal waste landfills, noting that they:

- Can be developed in place of limited greenfields, preserving the land carbon sink
- May have environmental conditions that are not well-suited for commercial or residential redevelopment and may be adequately zoned for renewable energy
- Generally are located near existing roads and energy transmission or distribution infrastructure
- May provide an economically viable reuse for sites that may have significant cleanup costs or low real estate development demand
- Can provide job opportunities in urban and rural communities
- Can advance cleaner and more cost-effective energy technologies and reduce the environmental impacts of energy systems (e.g., reduce greenhouse gas emissions).

By taking advantage of these potential benefits, PV can provide a viable, beneficial reuse, in many cases, generating significant revenue on a site that would otherwise go unused.

The Sky Park Landfill site is owned by the City of Eau Claire, which is interested in potential revenue flows on the site. The city is also interested in opportunities for public outreach and demonstration associated with the installation of renewable energy on the Sky Park site. For many closed landfill sites, the local community has a significant interest in seeing such land be brought into some form of productivity. Thus, community engagement is critical to match future reuse options to the city's vision for the site.

Understanding studies performed at similar sites demonstrates the potential for PV system development. Municipal solid waste landfills such as the Sky Park site in Eau Claire are particularly well-suited for solar development because they are often located near critical infrastructure, adjacent to a significant population base, are constructed with large areas of minimal grade, and have a lower land cost due to limitations on alternative uses. Large-scale solar developments have been successfully completed on closed landfills in the past, using PV integrated into a geomembrane and ballasted system. As a landfill constructed before the 1960s prior to legislation requiring particular construction methods, the engineering design, siting criteria, lining, and implementation is relatively unknown. As the Sky Park Landfill is already closed, and considering its construction, using a ballasted system to minimize impact of the system is expected.

The subject site may have potential to be used for other functions beyond the solar PV systems proposed in this report. Any potential use should align with the community vision for the site and should work to enhance the overall utility of the property. A solar facility on the site represents a significant opportunity for development.

Beyond the financial benefits of installing a solar facility and selling the electricity produced, there are additional non-financial benefits to consider. There are many compelling reasons to consider moving toward renewable energy sources for power generation instead of fossil fuels, including:

- Renewable energy sources offer a sustainable energy option in the broader energy portfolio.
- Renewable energy can have a net positive effect on human health and the environment.
- Deployment of renewable energy bolsters national energy independence and increases domestic energy security.
- Fluctuating electric costs can be mitigated by locking in electricity rates through long-term power purchase agreements (PPAs) linked to renewable energy systems.
- Generating energy without harmful emissions or waste products can be accomplished through renewable energy sources.

3 PV Systems

3.1 PV Overview

Solar PV technology converts energy from solar radiation directly into electricity. Solar PV cells are the electricity-generating component of a solar energy system. When sunlight (photons) strikes a PV cell, an electric current is produced by stimulated electrons (negative charges) in a cell layer designed to give up electrons easily. The existing electric field in the solar cell pulls these electrons to another layer. By connecting the cell to an external load, this current (movement of charges) can then be used to power the load (e.g., light bulb).

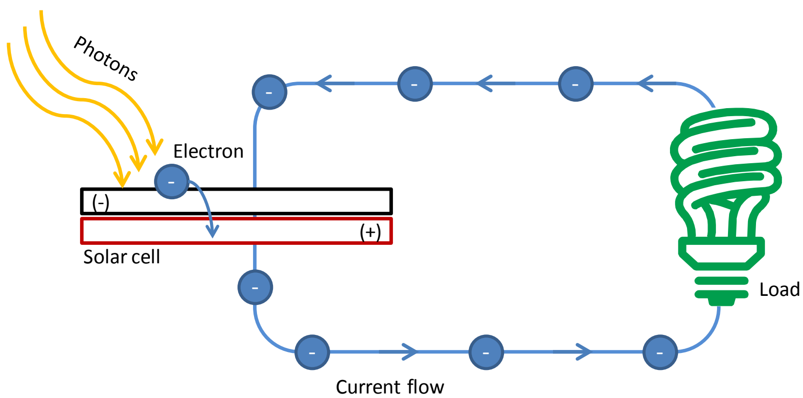

Figure 1. Generation of electricity from a PV cell

Source: EPA

PV cells are assembled into a PV panel or module. PV modules are then connected to create an array. The modules are connected in series and then in parallel, as needed, to reach the specific voltage and current requirements for the array. The direct current (DC) electricity generated by the array is then converted by an inverter to useable alternating current (AC) that can be consumed by adjoining buildings and facilities or exported to the electricity grid. PV system size varies from small residential (2–10 kW), to commercial (100–500 kW), to large utility scale (10+ MW). Central distribution plants are also currently being built in the 100+ MW scale. Electricity from utility-scale systems is commonly sold back to the electricity grid.

3.2 Major System Components

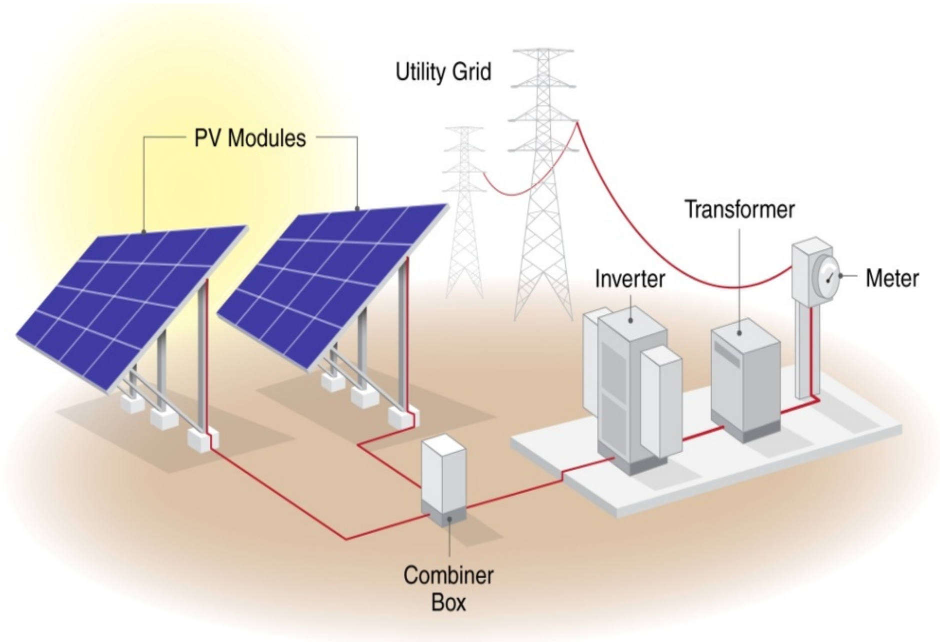

Figure 2. Ground-mounted array diagram

Source: NREL

A typical PV system is made up of several key components, including:

- PV modules
- Inverter
- Balance-of-system components.

These, along with other PV system components, are discussed in turn below.

3.2.1 PV Module

Module technologies are differentiated by the type of PV material used, resulting in a range of conversion efficiencies from light energy to electrical energy. The module efficiency is a measure of the percentage of solar energy converted into electricity.

Two common PV technologies that have been widely used for commercial- and utility-scale projects are crystalline silicon and thin film.

3.2.1.1 Crystalline Silicon

Traditional solar cells are made from silicon. Silicon is quite abundant and nontoxic. It builds on a strong industry on both supply (silicon industry) and product side. This technology has demonstrated consistent and high efficiency for over 30 years in the field. The performance degradation (reduction in power generation due to long-term exposure) is under 1% per year. Silicon modules have a lifespan of 25–30 years but can keep producing energy beyond this range.

Typical overall efficiency of silicon solar panels is between 12% and 18%. However, some manufacturers of mono-crystalline panels claim an overall efficiency nearing 20%. This range of efficiencies represents significant variation among the crystalline silicon technologies available. The technology is generally divided into mono- and multi-crystalline technologies, which indicates the presence of grain-boundaries (i.e., multiple crystals) in the cell materials and is controlled by raw material selection and manufacturing technique. Crystalline silicon panels are widely used based on deployments worldwide.

Figure 3 shows two examples of crystalline solar panels: mono- and multi-silicon installed on tracking mounting systems.

Source: SunPower, NREL PIX-23816

Source: NREL PIX-13823

Figure 3. Mono- and multi-crystalline solar panels

3.2.1.2 Thin Film

Thin-film PV cells are made from amorphous silicon (a-Si) or non-silicon materials such as cadmium telluride (CdTe). Thin-film cells use layers of semiconductor materials only a few micrometers thick. Due to the unique nature of thin films, some thin-film cells are constructed into flexible modules, enabling applications like solar energy covers for landfills, such as a geomembrane system. Other thin-film modules are assembled into rigid constructions that can be used in fixed-tilt or, in some cases, tracking system configurations.

The efficiency of thin-film solar cells is generally lower than crystalline cells. Current overall efficiency of a thin-film panel is between 6% and 8% for a-Si and 11% and 12% for CdTe. Figure 4 shows thin-film solar panels.

Source: NREL PIX-18068

Source: NREL PIX 14726

Source: NREL PIX 17395

Figure 4. Thin-film solar panels installed on (left) solar energy cover and (middle and right) fixed-tilt mounting system

Industry standard warranties of both crystalline and thin-film PV panels typically guarantee system performance of 80% of the rated power output for 25 years. After 25 years, they will continue producing electricity at a lower performance level.

3.2.2 Inverter

Inverters convert DC electricity from the PV array into AC and can connect seamlessly to the electricity grid. Inverter efficiencies can be as high as 98.5%.

Inverters also sense the utility power frequency and synchronize the PV-produced power to that frequency. When utility power is not present, the inverter will stop producing AC power to prevent "islanding" or putting power into the grid while utility workers are trying to fix what they assume is a de-energized distribution system. This safety feature is built into all grid-connected inverters in the market. Electricity produced from the system may be fed to a step-up transformer to increase the voltage to match the grid.

There are two primary types of inverters for grid-connected systems: string and micro-inverters. Each type has strengths and weaknesses and may be recommended for different types of installations.

String inverters are most common and typically range in size from 1.5 kW to 1,000 kW. These inverters tend to be cheaper on a capacity basis, as well as have high efficiency and lower operations and maintenance (O&M) costs. String inverters offer various sizes and capacities to handle a large range of voltage output. For larger systems, string inverters are combined in parallel to produce a single point of interconnection with the grid. Warranties typically run 10 years, which is currently the industry standard. On larger units, extended warranties up to 20 years are possible. Given that the expected life of the PV panels is 25–30 years, an operator can expect to replace a string inverter at least one time during the life of the PV system.

Micro-inverters are dedicated to the conversion of a single PV module's power output. The AC output from each module is connected in parallel to create the array. This technology is relatively new to the market and is in limited use in larger systems because of the potential increase in O&M associated with significantly increasing the number of inverters in a given array. Current micro-inverters range in size between 175 W and 380 W. These inverters are typically a more expensive option per watt of capacity than string inverters. Warranties range from 10–25 years. Projects with irregular modules and shading issues usually benefit from micro-inverters.

With string inverters, small amounts of shading on a solar panel will significantly affect the entire array production. Instead, it impacts only that shaded panel if micro-inverters are used. Figure 5 shows a string inverter.

Figure 5. String inverter

Source: NREL PIX 07985

3.2.3 *Balance-of-System Components*

In addition to the solar modules and inverter, a solar PV system consists of other parts called balance-of-system components, which include:

- Mounting racks and hardware for the panels
- Wiring for electrical connections.

3.2.3.1 Mounting Systems

The array has to be secured and oriented optimally to maximize system output. The structure holding the modules is referred to as the mounting system.

3.2.3.1.1 Ground-Mounted Systems

For ground-mounted systems, the mounting system can be either directly anchored into the ground (via driven piers or concrete footers) or ballasted on the surface without ground penetration. Mounting systems must withstand local wind loads, which range from 90–120 mph for most areas or 130 mph or more for areas with hurricane potential. Depending on the region, snow and ice loads must also be a design consideration for the mounting system. For landfill applications, mounting system designs will be primarily driven by these considerations coupled with settlement concerns.

Typical ground-mounted systems can be categorized as fixed tilt or tracking. Fixed-tilt mounting structures consist of panels installed at a set angle, typically based on site latitude and wind conditions, to increase exposure to solar radiation throughout the year. Fixed-tilt systems are used at many landfill sites. They have lower maintenance costs but generate less energy (kWh) per unit power (kW) of capacity than tracking systems.

Tracking systems rotate the PV modules so they are following the sun as it moves across the sky. This increases energy output but also increases maintenance and equipment costs slightly. Single-axis tracking, in which PV is rotated on a single axis, can increase energy output up to 25% or more. With dual-axis tracking, PV is able to directly face the sun all day, potentially increasing output up to 35% or more. However, depending on underlying soiling conditions, single- and dual-axis trackers may not be suitable due to potential settlement effects, which can interfere with the alignment requirements of such systems.

Settlement concerns combined with the higher cost typically limits the economic feasibility of dual-axis tracking systems for landfill applications.

Source: NREL PIX 17394

Source: NREL PIX 15280

Figure 6. 2-MWp PV system with fixed tilt on former landfill in Fort Carson, Colorado

Table 1. Energy Density by Panel and System

System Type	Fixed-Tilt Energy Density (DC-Watts/ft^2)	Single-Axis Tracking Energy Density (DC-Watts/ft^2)	Dual-Axis Tracking Energy Density (DC-Watts/ft^2)
Crystalline Silicon	4.0	3.5	3.0
Thin Film	3.3	2.7	2.5
Hybrid HE	4.8	3.9	3.5

The selection of mounting type is dependent on many factors, including installation size, electricity rates, government incentives, land constraints, latitude, and local weather. Contaminated land applications may raise additional design considerations due to site conditions, including differential settlement.

Selection of the mounting system is also heavily dependent on anchoring or foundation selection. Further, the mounting system design will need to meet applicable local building code requirements with respect to snow, wind, and seismic zones. Selection of mounting types should also consider frost protection needs, especially in cold regions such as Wisconsin.

3.2.3.1.2 Wiring for Electrical Connections

Electrical connections, including wiring, disconnect switches, fuses, and breakers are required to meet electrical code (e.g., NEC Article 690) for both safety and equipment protection.

In most traditional applications, wiring from (1) arrays to inverters and (2) inverters to point of interconnection is generally run as direct burial through trenches. In landfill applications, this wiring may be required to run through above-ground conduit due to restrictions with cap penetration or other concerns. Therefore, developers should consider noting any such restrictions, if applicable, in requests for proposals in order to improve overall bid accuracy. Similarly, it is recommended that PV system vendors reflect these costs in the quote when costing out the overall system.

3.2.3.2 PV System Monitoring

Monitoring PV systems can be essential for reliable functioning and maximum yield of a system. It can be as simple as reading values such as produced AC power, daily kilowatt-hours, and cumulative kilowatt-hours locally on an LCD display on the inverter. For more sophisticated monitoring and control purposes, environmental data such as module temperature, ambient temperature, solar radiation, and wind speed can be collected. Remote control and monitoring can be performed through various remote connections. Systems can send alerts and status messages to the control center or user. Data can be stored in the inverter's memory or in external data loggers for further system analysis. Collection of this basic information is standard for solar systems and is not unique to landfill applications.

Weather stations are typically installed in large-scale systems. Weather data such as solar radiation and temperature can be used to predict energy production, enabling comparison of the target and actual system output and performance. It can also identify under-performing arrays. Operators may use this data to identify required maintenance, shade on panels, and accumulated dirt on panels, for example. Monitoring system data can also be used for outreach and education. This can be achieved with publicly available, online displays, wall-mounted systems, or even smartphone applications.

3.2.4 Operation and Maintenance

PV panels typically have a 25-year performance warranty. The inverters, which come standard with a 10-year warranty (extended warranties available), would be expected to last 10–15 years. System performance should be verified on a vendor-provided website. Wire and rack connections should be checked annually. This economic analysis uses an annual O&M cost computed as $20/kW/yr, which is based on the historical O&M costs of installed fixed-axis grid-tied PV systems. Single-axis tracking system analysis uses an estimated annual O&M cost of $22/kW/yr, and dual-axis tracking system analysis uses an estimated annual O&M cost of $25/kW/yr.

3.3 Siting Considerations

PV modules are very sensitive to shading. When partially or fully shaded, the panel is unable to optimally collect the high-energy beam radiation from the sun. As explained above, PV modules are made up of many individual cells that collectively produce a small amount of current and voltage. These individual cells are connected in series to produce a larger current. If an individual cell is shaded, it acts as resistance to the whole series circuit, impeding current flow and dissipating power rather than producing it.

The NREL solar assessment team uses a Solmetric SunEye solar path calculator to assess shading at particular locations by analyzing the sky view where solar panels will be located. By finding the solar access, the NREL team can determine if the area is appropriate for solar panels.

After the NREL team collects data and determines a site is adequate for a solar installation, they need to decide on ideal system size, which depends on the average energy use of the facilities on the site, PPAs, incentives available, and utility policy.

4 Proposed Installation Location Information

This section summarizes the findings of the NREL solar assessment site visit on May 30, 2012.

4.1 Sky Park Landfill Site PV System

As discussed in Section 1, the Sky Park Landfill site is owned and managed by the City of Eau Claire.

The Sky Park Landfill site is sufficiently flat, with a maximum slope estimated to be under 2%. Closed in 1965, the site does not currently experience differential settlement at high enough levels for concern. Approximately 3 acres of the site is free of vegetation and associated shading. The remainder of the site has dense vegetation that would need to be removed to facilitate the installation of a solar PV system. The site owner has indicated a willingness to remove necessary vegetation and provide basic grading of the site in preparation for a solar installation.

Approximately one-half acre of land still experiences settlement likely beyond acceptable levels, due to the landfilling of downed trees and branches following a storm in the 1980s. This settlement would need to be mitigated before being appropriate for the installation of a solar PV system. For the purposes of this report, it is not considered a feasible area.

In order to get the most out of the ground area available, it is important to consider whether the site layout can be improved to better incorporate a solar system. If there are unused structures, fences, or electrical poles that can be removed, the un-shaded area can be increased to incorporate more PV panels.

Figure 7 shows an aerial view of the Sky Park Landfill site taken from Google Earth; the total area of the site is approximated in brown. The green area, inclusive of the blue area, demonstrates the potentially feasible area with removal of vegetation. The blue area approximates the area available without significant vegetation removal. As shown, there are large expanses of relatively flat available land, which makes it suitable for a PV system.

The total site area is 26.41 acres, shown in brown, and the feasible area shown in green is approximately 23 acres. Reasonable setbacks from property lines and adjacent shading elements, as well as other functional exemptions, were considered in determining the total feasible area. The area currently free of trees is approximately 3 acres.

Figure 7. Aerial view of the feasible area (green) for PV at the Sky Park Landfill site

Illustration done in Google Earth

PV systems are well-suited to the Eau Claire, Wisconsin, area, where the average global horizontal annual solar resource—the total solar radiation for a given location, including direct, diffuse, and ground-reflected radiation—is 4.49 kWh/m^2/day.

Figure 8 shows various views of the Sky Park Landfill site.

Figure 8. Views of the feasible area for PV at the Sky Park Landfill

Photos by Google Maps (top and bottom) & Ned Noel, City of Eau Claire (middle)

4.2 Utility-Resource Considerations

The expected electrical tie-in point and inverter for the PV system at the Sky Park Landfill site is expected to be located along the southern portion of the site, near the adjacent industrial development. As the site is surrounded by significant development and the system is expected to occupy a majority of the available land, the final location of the tie-in point is not expected to have a significant effect on the overall estimated cost of the system. The exact location will be dependent on the utility infrastructure in place and final design of any proposed system.

As a landfill on the site closed in 1965, there is not an existing tie-in location already on the site, but the location adjacent to industrial properties indicates sufficient capacity for the proposed solar system. Coordination with the local utility, Xcel Energy of Wisconsin, will be necessary to determine the capacity of the transmission lines. This information will be determined during the interconnection application process and system design.

The allowable trenching of electrical service to and throughout the site will also need to be considered. Any limitations on typical trenching installations may adversely affect the expected cost of development. When developing a ground-mounted system, an electrical tie-in location will need to be identified to determine how the energy would be fed back into the grid.

4.3 Useable Acreage for PV System Installation

Typically, a minimum of 2 useable acres is recommended to site commercial-scale PV systems. Useable acreage is typically characterized as "flat to gently sloping," with southern exposures that are free from obstructions. This acreage would get full sun for at least a 6-hour period each day. For example, eligible space for PV includes under-utilized or unoccupied land, vacant lots, and/or unused paved area (e.g., a parking lot, industrial site space, or existing building rooftops).

4.4 PV Site Solar Resource

The Sky Park Landfill site has been evaluated to determine the adequacy of the available solar resources, using both on-site data and industry tools.

The assessment team for this feasibility study collected multiple Solmetric SunEye datapoints and found a solar access of 97% in the presently un-shaded area. Some peripheral shading is expected due to remaining trees and adjacent facilities to the site but is expected to be minimal. All data gathered using this tool is available in Appendix C. Even following complete removal of trees on the site in preparation for a solar installation, the maximum assumed solar access for the area is approximately 98% due to peripheral shading and shading from other panels and equipment. Assuming that necessary clearing would occur, the financial analysis uses a 98% solar access factor.

The predicted array performance was found using PVWatts Version 2[1] for Eau Claire, Wisconsin. Table 2 shows the station identification information, PV system specifications, and energy specifications for the site. For this summary array performance information, a hypothetical system size of 1 kW was used to show the estimated production for each kilowatt so that additional analysis can be performed using the data indicated below. It can be scaled linearly to match the proposed system size.

[1] http://www.nrel.gov/rredc/pvwatts/.

Table 2. Site Identification Information and Specifications

Station Identification	
City	Eau Claire
State	Wisconsin
Latitude	44.87° N
Longitude	91.48° W
PV System Specifications	
DC Rating	1.00 kW
DC to AC Derate Factor	0.8
AC Rating	0.8 kW
Array Type	Fixed-Tilt
Array Tilt	44.9°
Array Azimuth	180°
Energy Specifications	
Cost of Electricity	$0.08/kWh

Table 3 shows the performance results for a latitude-matched fixed-tilt PV system in Eau Claire, Wisconsin, as calculated by PVWatts.

Table 3. Performance Results for 45-Degree Fixed-Tilt PV

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	3.29	89	7.12
2	4.63	110	8.80
3	5.24	134	10.72
4	4.84	114	9.12
5	5.42	125	10.00
6	5.61	121	9.68
7	5.67	127	10.16
8	5.31	118	9.44
9	4.68	103	8.24
10	3.82	92	7.36
11	2.46	58	4.64
12	2.33	60	4.80
Year	4.44	1,253	100.24

Table 4 shows the performance results for a zero-tilt single-axis tracking PV system in Eau Claire, Wisconsin, as calculated by PVWatts.

Table 4. Performance Results for Zero-Degree Single-Axis PV

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	3.77	102	8.16
2	5.44	130	10.40
3	6.28	162	12.96
4	6.02	144	11.52
5	7.23	172	13.76
6	7.47	166	13.28
7	7.82	174	13.92
8	6.91	157	12.56
9	5.86	131	10.48
10	4.53	110	8.80
11	2.76	66	5.28
12	2.62	68	5.44
Year	5.53	1,584	126.72

Table 5 shows the performance results for a two-axis tracking PV system in Eau Claire, Wisconsin, as calculated by PVWatts.

Table 5. Performance Results for Two-Axis PV

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	4.03	109	8.72
2	5.64	135	10.80
3	6.40	165	13.20
4	6.30	151	12.08
5	7.94	189	15.12
6	8.40	187	14.96
7	8.33	192	15.36
8	7.36	168	13.44
9	6.00	135	10.80
10	4.59	111	8.88
11	2.83	68	5.44
12	2.80	73	5.84
Year	5.89	1,682	134.56

4.5 Sky Park Landfill Energy Usage

When considering a site for a PV installation, it is important to understand the energy use of the site to enable a full analysis that considers whether energy produced would need to be sold or if it could offset on-site energy use.

4.5.1 Current Energy Use

The Sky Park Landfill site does not have any energy-consuming facilities or electric service on-site at this time. Since closure, the site has not been utilized for any energy-consuming purpose. The site does contain, however, several ground-monitoring wells along the perimeter of the site. The site is not currently served by the local utility, Xcel Energy, but it would likely be considered a commercial property should a significant PV installation be proposed.

Current information on the Eau Claire electric rates was supplied by an Xcel Energy analysis of the average blended rate the city pays. Published rates are also available on the Xcel Energy website.[2] The serving utility, Xcel Energy of Wisconsin, is operated by the Northern States Power Company-Wisconsin and is regulated by the Public Service Commission of Wisconsin.

4.5.2 Net Metering

Net metering is an electricity policy for consumers who own renewable energy facilities. "Net," in this context, is used to mean "what remains after deductions"—in this case, the deduction of any energy outflows from metered energy inflows. Under net metering, a system owner receives retail credit for at least a portion of the electricity the system generates. As part of the Energy Policy Act of 2005, under Sec. 1251, all public electric utilities are required upon request to make net metering available to their customers:

> (11) NET METERING.—Each electric utility shall make available upon request net metering service to any electric consumer that the electric utility serves. For purposes of this paragraph, the term 'net metering service' means service to an electric consumer under which electric energy generated by that electric consumer from an eligible on-site generating facility and delivered to the local distribution facilities may be used to offset electric energy provided by the electric utility to the electric consumer during the applicable billing period.

In 2009, the Wisconsin Public Utility Commission considered whether and how to expand the availability and use of advanced renewable tariffs, also known as feed-in tariffs, in Wisconsin. The commission concluded that federal and state law limited authority to order any Wisconsin utility to offer an advanced renewable tariff and recommended that tariffs only be voluntarily offered by willing utilities.

Renewable energy certificates (RECs),[3] also known as green certificates, green tags, or tradable renewable certificates, are tradable commodities in the United States that represent proof of electric energy generation from eligible renewable energy resources (renewable electricity). The RECs that are associated with the electricity produced and are used on-site remain with the customer-generator. If, however, the customer chooses to receive financial compensation for the REC remaining after a 12-month period, the utility will be granted the RECs associated with only that surplus they purchase.

[2] Current electric rates: http://www.xcelenergy.com/My_Account/Understand_Bill/Bill_Details/WI_Rates.

[3] For a description of RECs, see http://apps3.eere.energy.gov/greenpower/markets/certificates

4.5.3 Virtual Net Metering

Some states and utilities allow for virtual net metering (VNM). This arrangement can allow certain entities, such as a local government, to install renewable generation at one location within its geographic boundary and to generate credits that can be used to offset charges at one or more other locations within the same geographic boundary.

Often, separate allowances for VNM can be made for government facilities. Local government can be defined to include cities, counties, school districts, special districts, political subdivisions, or other local public agencies that are authorized to generate electricity. Because the subject site is owned by the City of Eau Claire, it may qualify for VNM, should the utility choose to enable such an installation. The Xcel Energy customer representative for the site should be asked if VNM is an option. For the purposes of this analysis, it is assumed that some form of VNM was acceptable and that the cost of electricity offset by the installed PV system is the city's average blended commercial rate of $0.08/kWh.

If Xcel Energy were to allow VNM, energy use for the entire site could be offset by a larger system. This would also allow all generated energy to be fed into the closest Xcel connection point and would avoid the need to determine a PPA with Xcel. A new transformer would be required. A "feed-in" meter would be installed and would credit the other meters on-site.

4.5.4 Community Solar

The concept of "community solar" is one in which the costs and benefits of one large solar project are shared by a number of participants. A site owner may be able to make the land available for a large solar project, which can be the basis for a community solar project. Ownership structures for these projects vary, but the large projects are typically owned or sponsored by a local utility.

Community solar gardens are distributed solar projects wherein utility customers have a stake via a pro-rated share of the project's energy output. This business model is targeted to meet demand for solar projects through customers who rent/lease homes or businesses, do not have good solar access at their site, or do not want to install solar systems on their facilities. Customer pro-rated shares of solar projects are acquired through a long-term transferrable lease of one or more panels or through subscription to a share of the project in terms of a specific level of energy output or the energy output of a set amount of capacity.

Under the customer lease option, the customer receives a billing credit for the number of kilowatt-hours their pro-rated share of the solar project produces each month; it is also known as VNM. Under the customer subscription option, the customers typically pay a set price for a block of solar energy (i.e., 100 kWh per-month blocks) from the community solar project. Other models include monthly energy outputs from a specific investment dollar amount or from a specific number of panels.

Community solar gardens and customer subscription-based projects can be solely owned by the utility, solely owned by third-party developers with facilitation of billing provided by the utility, or be a joint venture between the utility and a third-party developer leading to eventual ownership by the utility after the tax benefits have been absorbed by the third-party developer.

There are some states that offer solar incentives for community solar projects, including Washington (production incentive) and Utah (state income tax credit). Community solar is known as solar gardens depending on the location (e.g., Colorado).

Xcel Energy recently offered a community solar program in Colorado called Solar*Rewards Community[4] that proved to be extremely popular. It became fully subscribed within 30 minutes of release. The system was set up so that subscribing customers could purchase an interest in a solar garden developed by the community and benefit from the production of that system. The subscriber organization was able to install a system and receive production incentives from Xcel energy. The popularity of this system may increase interest in supporting this type of development in states such as Wisconsin in the future. At this time, however, community solar is not offered by Xcel Energy in Wisconsin. If this is a solution of interest to the site, interested parties should develop potential purchasers and the overall structure of the system before presenting interest to the local utility.

Xcel Energy also recently offered the "Experimental Advanced Renewable Energy Purchase Service"[5] tariff program, wherein distributed generation facilities are offered an advanced renewable energy tariff for the purchase of electricity produced. The service did reference some "community-based projects" for biomass/biogas and wind developments; however, community systems were not offered for solar, and the maximum system size for solar was listed as 10 kW. Due to the scale of the site, this tariff program is not feasible for the Sky Park Landfill site.

If interested in this option, the site will need to work with the state public service commission and the local utility to develop an approach that meets local requirements and expectations.

[4] Xcel Energy Colorado Solar*Rewards Community: http://www.xcelenergy.com/Save_Money_&_Energy/For_Your_Home/Renewable_Energy_Programs/Solar*Rewards_Community_2_-_CO.

[5] Sheet No. E54.2: http://www.xcelenergy.com/staticfiles/xe/Regulatory/2We_Section_3.pdf.

5 Economics and Performance

The economic performance of a PV system installed on the site is evaluated using a combination of the assumptions and background information discussed previously, as well as a number of industry-specific inputs determined by other studies. In particular, this study uses the NREL System Advisor Model (SAM).[6]

SAM is a performance and economic model designed to facilitate decision making for people involved in the renewable energy industry, ranging from project managers and engineers to incentive program designers, technology developers, and researchers.

SAM makes performance predictions for grid-connected solar, solar water heating, wind, and geothermal power systems and makes economic calculations for projects that buy and sell power at retail rates and power projects that sell power through a PPA.

SAM calculates a system's energy output on an hourly basis (sub-hourly simulations are available for some technologies). The financial model calculates annual project cash flows over a period of years for a range of financing structures for residential, commercial, and utility projects.

SAM makes performance predictions for grid-connected solar, small wind, and geothermal power systems and provides economic estimates for distributed energy and central generation projects. The model calculates the cost of generating electricity based on information provided about a project's location, installation and operating costs, type of financing, applicable tax credits and incentives, and system specifications.

5.1 Assumptions and Input Data for Analysis

Cost of a PV system depends on the system size and other factors, such as geographic location, mounting structure, and type of PV module. Based on significant cost reductions seen in 2011, the average cost for utility-scale ground-mounted systems have declined from \$4.80/W in Q1 2010 to \$3.20/W in Q4 2011. With an increasing demand and supply, further cost reduction is expected as market conditions evolve. Figure 9 shows the cost per watt of a PV system from 2010 to 2011 for utility-scale projects.

[6] For additional information on the NREL Solar Advisor Model, see https://sam.nrel.gov/cost.

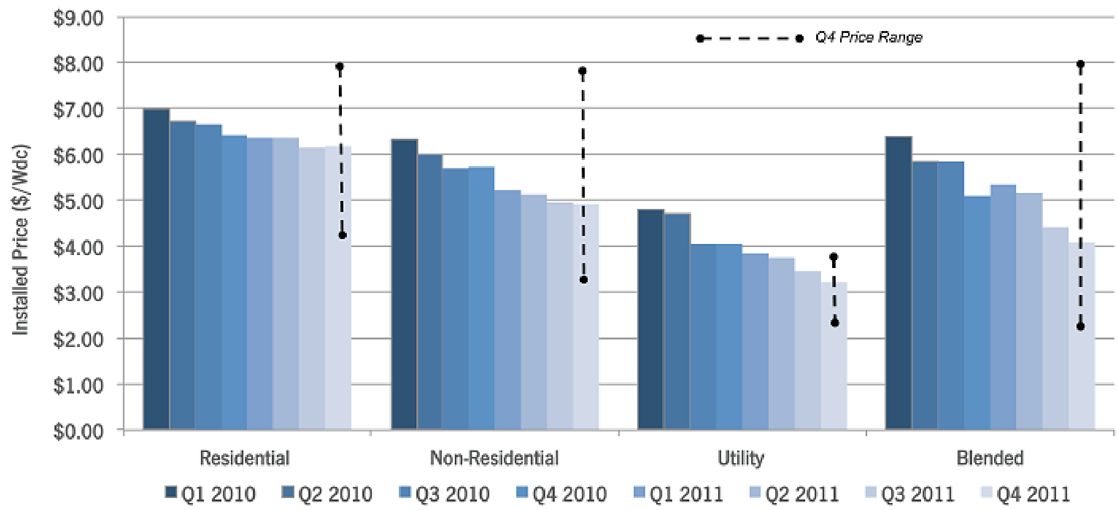

Figure 9. Solar market insight 2011 year-end summary of PV costs[7]

NREL recently released the *Residential, Commercial, and Utility-Scale Photovoltaic (PV) System Prices in the United States: Current Drivers and Cost-Reduction Opportunities* report, which cites the 2011 benchmark price at $2.79/W for utility ground-mounted fixed-axis systems. [8]

As the system for this site is not expected to be installed until Q4 2012 at the earliest, and the trends in price reduction have continued, the assumed installed cost for a fixed-tilt ground-mounted system is assumed to be $2.232/W. The installed cost of single-axis tracking was assumed to be $3.348/W.

The estimated increase in cost from this baseline for a ballasted system is 25%. This increased cost is due to limitations placed on design and construction methods due to the ground conditions at the site. Such limitations include restrictions on storm water runoff, weight loading of construction equipment, inability to trench for utility lines, additional engineering costs, permitting issues, and non-standard ballasted racking systems. The installed system cost assumptions are summarized in Table 6.

Table 6. Installed System Cost Assumptions

System Type	Fixed-Tilt ($/Wp)	Single-Axis Tracking ($/Wp)	Dual-Axis Tracking ($/Wp)
Baseline system	2.232	2.67	2.944
With ballast	0.558	0.678	0.736
Total installed cost	2.79	3.348	3.68

[7] Data and figure drawn from the Solar Energy Industries Association "SEIA/GTM Research U.S. Solar Market Insight" 2011 year-end report. See http://www.seia.org/cs/research/SolarInsight.
[8] Forecast of U.S. solar pricing: http://www.nrel.gov/docs/fy12osti/53347.pdf.

These prices include the PV array and the balance-of-system components for each system, including the inverter and electrical equipment as well as the installation cost. It covers estimated taxes and a national-average labor rate but does not include land cost. The economics of grid-tied PV depend on incentives, the cost of electricity, the solar resource, and panel tilt and orientation. For this analysis, the cost of electricity was assumed to be $0.08/kW, increasing at 2% annually, as indicated earlier with the assumption that a VNM agreement could be established with Xcel Energy to use the installed system to offset other city energy use.

An alternative scenario to VNM could be to develop a lease agreement with an adjacent industrial property to provide a behind-the-meter solar electric system. If the City of Eau Claire were able to develop a scenario where electricity produced by a solar system located on the Sky Park Landfill could be sold through a PPA to an adjacent facility to offset electricity already being used, a favorable economic situation could result. In this scenario, the value of the electricity produced by the system would correlate to the energy price being paid by the industrial facility. As indicated previously, the average blended rate for the City of Eau Claire is approximately $0.08/kWh. A small industrial property may have a higher blended rate and may pay based on the peak demand charge. If the facilities peak usage is correlated to a time of day when solar production is expected, the peak demand charge may be reduced significantly, often leading to a very significant savings compared to typical use, adding value to the renewable energy system.

While not established by the public service commission (PSC) or the utility at this time, VNM or community solar gardens are considered the most economically feasible solution for the site. A PPA with the utility would not be expected to result in an economically favorable installation. If the city is subject to time-of-use rates or peak demand charges, the economic feasibility of the system will likely become more favorable. If annual electric rate changes for the city increase faster than the 2%/annum assumed for this analysis, the system becomes significantly more favorable.

It was assumed for this analysis that relevant federal incentives are received. It is important to consider all applicable incentives or grants to make PV as cost-effective as possible. If the PV system is owned by a private tax-paying entity, this entity may qualify for a federal tax credit and accelerated depreciation on the PV system, which can be worth about 15% of the initial capital investment. The total potential tax benefits for the tax-paying entity can be as high as 45% of the initial system cost. Because state and federal governments do not pay taxes, private ownership of the PV system would be required to capture tax incentives.

For the purposes of this analysis, the project is expected to have a 25-year life, although systems can be reasonably expected to continue operation past this point. Inflation is assumed to be 1.5%, with the real discount rate at 5.85% and financing secured via a 15-year loan at a 6% interest rate and 55% debt fraction. Should the site choose to own and operate the system itself as a city-owned entity, there may be options for lower interest rate loans, such as the Board of Commissioners of Public Lands State Trust Fund Loan, fixed at a maximum level of 3.75%.[9]

The panels are assumed to have a 0.5%/yr degradation in performance. The O&M expenses are estimated to be $20/kW/yr for a fixed-tilt system, $22/kW/yr for a single-axis system, and $25/kW/yr for a dual-axis system. A system DC-to-AC conversion of 80% was assumed. This includes losses in the inverter, wire losses, PV module losses, and losses due to temperature effects. PVWatts Version 2 was used to calculate expected energy performance for the system.

5.2 SAM Forecasted Economic Performance

Using the inputs and assumptions summarized in the Section 5 of this report, the SAM tool predicts the internal rate of return (IRR) and the levelized cost of energy (LCOE). For a 4-MW fixed-tilt system—assuming that VNM was permitted, the system was owned and operated by a tax-paying third party, and all of the energy produced would offset energy that the city would otherwise have used while paying a rate of $0.08/kWh—the system could yield an after-tax NPV of -$1,007,989.90 on first-year annual revenue, beginning at $387,021/yr.

The system would be expected to produce approximately 4.8 MWh annually with an LCOE of approximately $0.0846/kWh. The complete results and summary of inputs for SAM are available in Appendix E. The system would require 20 acres of land.

Alternatively, for a 3.6-MW single-axis tracking system—assuming that VNM was permitted, the system was owned and operated by a tax-paying third party, and all of the energy produced would offset energy that the city would otherwise have used while paying a rate of $0.08/kWh—the system could yield an after-tax NPV of -$807,095.57 on annual revenue, beginning at $427,024/year. The system would be expected to produce approximately 5.3 MWh annually with an LCOE of approximately $0.0793/kWh.

A potential dual-axis system was also considered. A 4-MW dual-axis tracking system under VNM and owned by a third party would expect an after-tax NPV of -$900,799.34 on annual revenue beginning at $365,771, escalating thereafter. Estimated production is 4,572,138 kWh/yr.

A summary of the results of the economic analysis and the system considered is available in Table 7.

In addition, an alternate scenario wherein a PPA is established for the site was considered; results are summarized in Table 7. With an IRR of 8% and a PPA that escalates at 3.5%/annum, a 4-MW system would have an after-tax NPV of $96,991.21 and a 3.5-MW single-axis system would have an after-tax NPV of $101,219.

[9] Additional information on the BCPL State Trust Fund Loan: http://bcpl.state.wi.us/.

Table 7. PV System Summary

System Type	Financial Model	PV System Size[a] (kW)	Array Tilt (deg)	Annual Output (kWh/year)	Number of Houses Powered[b]	Construction Period Jobs[c]	Jobs Sustained[d]
Crystalline Silicon (Fixed Tilt)	VNM	4,007.52	LAT	4,837,763	438.2	n/a	n/a
Crystalline Silicon (Single-axis Tracking)	VNM	3,506.58	n/a	5,337,797	483.5	130.9	1.4
Crystalline Silicon (Dual-axis Tracking)	VNM	3,005.64	n/a	4,572,138	414.1	n/a	n/a
Crystalline Silicon (Fixed Tilt)	PPA	4,007.52	LAT	4,837,763	438.2	130.9	1.4
Crystalline Silicon (Single-axis Tracking)	PPA	3,506.58	n/a	5,337,797	483.5	n/a	n/a
Crystalline Silicon (Dual-axis Tracking)	PPA	3,005.64	n/a	4,572,138	414.1	n/a	n/a

System Type	Financial Model	Annual Output (kWh/year)	Cost of Electricty/PPA Price[e] (¢/kWh)	System Cost ($/watt)	Total System Cost	1ST Year Savings/Revenue ($/year)	After-tax NPV
Crystalline Silicon (Fixed Tilt)	VNM	4,837,763	8	$ 2.79	$ 11,179,632	$ 387,021	$ (1,007,989.90)
Crystalline Silicon (Single-axis Tracking)	VNM	5,337,797	8	$ 3.35	$ 11,688,105	$ 427,024	$ (807,095.57)
Crystalline Silicon (Dual-axis Tracking)	VNM	4,839,482	8	$ 3.68	$ 10,979,756	$ 387,159	$ (900,799.34)
Crystalline Silicon (Fixed Tilt)	PPA	4,837,763	10.61	$ 2.79	$ 11,179,632	$ 513,066	$ 96,991.21
Crystalline Silicon (Single-axis Tracking)	PPA	5,337,797	9.94	$ 3.35	$ 11,688,106	$ 530,635	$ 101,219.94
Crystalline Silicon (Dual-axis Tracking)	PPA	4,839,482	10.35	$ 3.68	$ 10,979,756	$ 500,767	$ 95,158.14

a Data assume a maximum usable area of 23 acres was used for all arrays. Array size determined by energy density indicated in Table 1.
b Number of average American households that could hypothetically be powered by the PV system assuming 11,040 kWh/year/household.
c Job-years created as a result of project capital investment including direct, indirect, and induced jobs.
d Jobs (direct, indirect, and induced) sustained as a result of operations and maintenance (O&M) of the system.
e Assumes a utility rate that increases at 2% per annum and a PPA that increases at 3.5% per annum. Inflation assumed to be 1.5%/year.

U.S. Energy Information Administration. http://www.eia.doe.gov/ask/electricity_faqs.asp#electricity_use_home. Accessed November 2, 2010.

5.3 Job Analysis and Impact

To evaluate the impact on employment and economic impacts of the PV project associated with this analysis, the NREL Jobs and Economic Development Impact (JEDI) models were used.[10] The JEDI models are tools that estimate the economic impacts associated with the construction and operation of distributed generation power plants. JEDI is a flexible input-output tool that estimates, but does not precisely predict, the number of jobs and economic impacts that can be reasonably supported by a proposed facility.

The JEDI models represent entire economies, including cross-industry or cross-company impacts. For example, JEDI estimates the impact that the installation of a distributed generation facility would have on not only the manufacturers of PV modules and inverters but also the associated construction materials, metal fabrication industry, project management support, transportation, and other industries that are required to enable the procurement and installation of the complete system.

For this analysis, inputs including the estimated installed project cost ($/kW), targeted year of construction, system capacity (kW), O&M costs ($/kW), and location were entered into the model to predict the jobs and economic impact. It is important to note that the JEDI model does not predict or incorporate any displacement of related economic activity or alternative jobs due to the implementation of the proposed project. As such, the JEDI model results are considered gross estimates as opposed to net estimates.

[10] The JEDI models have been used by the U.S. Department of Energy, the U.S. Department of Agriculture, NREL, and the Lawrence Berkeley National Laboratory, as well as a number of universities. For information on the NREL Jobs and Economic Development Impact tool, see http://www.nrel.gov/analysis/jedi/about_jedi.html.

For the Sky Park Landfill site, the values in Table 8 were assumed using the single-axis tracking system example.

Table 8. JEDI Analysis Assumptions

Input	Assumed Value
Capacity	4,007 kW
Placed In Service Year	2013
Installed System Cost	$11,688,105
Location	Eau Claire, WI

Using these inputs, the JEDI tool estimates the gross direct and indirect jobs, associated earnings, and total economic impact supported by the construction and continued operation of the proposed PV system.

The estimates of jobs associated with this project are presented as either construction period jobs or sustained operations jobs. Each job is expressed as a whole or fraction full-time equivalent (FTE) position. An FTE is defined as one person working 40 hours per week for the duration of a year. Construction period jobs are considered short-term positions that exist only during the procurement and construction periods.

As indicated in the results of the JEDI model analysis provided in Appendix D, the total proposed system is estimated to support 111.9 direct, indirect, and induced FTE jobs for the duration of the procurement and construction period. Total wages paid to workers during the construction period are estimated to be $4,784,400, and total economic output is estimated to be $14,465,700. The annual O&M of the new PV system is estimated to support 1.4 FTEs per year for the life of the system. The jobs and associated spending are projected to account for approximately $65,600 in earnings and $123,400 in economic activity each year for the next 25 years.

5.4 Financing Opportunities

The procurement, development, construction, and management of a successful utility-scale distributed generation facility can be owned and financed a number of different ways. The most common ownership and financing structures are described below.

5.4.1 Owner and Operator Financing

The owner/operator financing structure is characterized by a single entity with the financial strength to fund all of the solar project costs and, if a private entity, sufficient tax appetite to utilize all of the project's tax benefits. Private owners/operators typically establish a special purpose entity (SPE) that solely owns the assets of the project. An initial equity investment into the SPE is funded by the private entity using existing funds, and all of the project's cash flows and tax benefits are utilized by the entity. This equity investment is typically matched with debt financing for the majority of the project costs. Project debt is typically issued as a loan based on the owners'/operators' assets and equity in the project. In addition, private entities can utilize any federal tax credits offered.

For public entities that choose to finance, own, and operate a solar project, funding can be raised as part of a larger, general obligation bond; as a standalone tax credit bond; through a tax-exempt lease structure, bank financing, grant and incentive programs, or internal cash; or some combination of the above. Certain structures are more common than others and grant programs for solar programs are on the decline. Regardless, as tax-exempt entities, public entities are unable to benefit directly from the various tax credit-based incentives available to private companies. This has given way to the common use of third-party financing structures such as the PPA.

5.4.2 Third-Party Developers with Power Purchase Agreements

Because many project site hosts do not have the financial or technical capabilities to develop a capital-intensive project, many times they turn to third-party developers (and/or their investors). In exchange for access to a site through a lease or easement arrangement, third-party developers will finance, develop, own, and operate solar projects utilizing their own expertise and sources of tax equity financing and debt capital.

Once the system is installed, the third-party developer will sell the electricity to the site host or local utility via a PPA—a contract to sell electricity at a negotiated rate over a fixed period of time. The PPA typically will be between the third-party developer and the site host if it is a retail behind-the-meter transaction or directly with an electric utility if it is a wholesale transaction.

Site hosts benefit by either receiving competitively priced electricity from the project via the PPA or land lease revenues for making the site available to the solar developer via a lease payment. This lease payment can take on the form of either a revenue-sharing agreement or an annual lease payment. In addition, third-party developers are able to utilize federal tax credits. For public entities, this arrangement allows them to utilize the benefits of the tax credits (low PPA price, higher lease payment) while not directly receiving them. The terms of a PPA typically vary from 20–25 years.

5.4.3 Third-Party "Flip" Agreements

The most common use of this model is a site host working with a third-party developer who then partners with a tax-motivated investor in an SPE that would own and operate the project. Initially, most of the equity provided to the SPE would come from the tax investor and most of the benefit would flow to the tax investor (as much as 99%). When the tax investor has fully monetized the tax benefits and achieved an agreed-upon rate of return, the allocation of benefits and majority ownership (95%) would "flip" to the site host (but not within the first 5 years). After the flip, the site host would have the option to buy out all or most of the tax investor's interest in the project at the fair market value of the tax investor's remaining interest.

A flip agreement can also be signed between a developer and investors within an SPE, where the investor would begin with the majority ownership. Eventually, the ownership would flip to the developer once investors' return is met.

5.4.4 Hybrid Financial Structures

As the solar market evolves, hybrid financial solutions have been developed in certain instances to finance solar projects. One particular structure, nicknamed "The Morris Model"[11] after Morris County, New Jersey, combines highly rated public debt, a capital lease, and a PPA. Low-interest public debt replaces more costly financing available to the solar developer and contributes to a very attractive PPA price for the site hosts.

In addition, new markets tax credits, which were established by Congress in 2000 to encourage investments in low-income communities, can be leveraged in combination with PPAs and public debt to reduce the overall tax liability. The credit, claimed over 7 years, totals 39% of the original investment amount. New markets tax credits have been combined with PPAs and public debt in other locations, such as Denver and Salt Lake City. Additional information on new markets tax credits has been compiled by NREL[12] and the Department of the Treasury Community Development Financial Institutions Fund.[13]

5.4.5 Solar Services Agreement and Operating Lease

The solar services agreement (SSA) and operating lease business models have been predominantly used in the municipal and cooperative utility markets due to their treatment of tax benefits and the rules limiting federal tax benefit transfers from non-profit to for-profit companies. Under IRS guidelines, municipalities cannot enter capital leases with for-profit entities when the for-profit entities capture tax incentives. As a result, a number of business models have emerged to circumvent this issue.

One model is the SSA, wherein a private party sells "solar services" (i.e., energy and RECs) to a municipality over a specified contract period (typically long enough for the private party to accrue the tax credits). The non-profit utility typically purchases the solar services with either a one-time up-front payment equal to the turnkey system cost minus the 30% federal tax credit or may purchase the services in annual installments. The municipality may buy out the system once the third party has accrued the tax credits, but due to IRS regulations, the buyout of the plant cannot be included as part of the SSA (i.e., it cannot be used as a vehicle for a sale and must be a separate transaction).

Similar to the SSA, there are a variety of lease options that are available to municipalities that allow the capture of tax benefits by third-party owners, which result in a lower cost to the municipality. These include an operating lease for solar services (as opposed to an equipment capital lease) and a complex business model called a "sale/leaseback." Under the sale/leaseback model, the municipality develops the project and sells it to a third-party tax equity investor who then leases the project back to the municipality under an operating lease. At the end of the lease period, and after the tax benefits have been absorbed by the tax equity investor, the municipality may purchase the solar project at fair market value.

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[11] For more information on the Morris Model: http://www.co.morris.nj.us/improvement/renewable.asp.
[12] New markets tax credits NREL fact sheet: http://www.nrel.gov/docs/fy10osti/49056.pdf.
[13] Community Development Financial Institutions Fund: http://www.cdfifund.gov/what_we_do/programs_id.asp?programid=5.

5.4.6 Sale/Leaseback

In this widely accepted model, the public or private entity would install the PV system, sell it to a tax investor, and then lease it back. As the lessee, they would be responsible for operating and maintaining the solar system as well as have the right to sell or use the power. In exchange for use of the solar system, the public or private entity would make lease payments to the tax investor (the lessor). The tax investor would have rights to federal tax benefits generated by the project and the lease payments. Sometimes, the entity is allowed to buy back the project at 100% fair market value after the tax benefits are exhausted.

6 Conclusions and Recommendations

The site locations considered for a solar PV system in this report are reasonable areas for the implementation of solar PV systems. Installing a 3.6-MW single-axis tracking PV system on the Sky Park Landfill with VNM for the city could offset approximately $427,024 in energy costs during the first year of operation for the city. It would represent a significant distributed generation facility for the area.

Additionally, reusing land that cannot be used for other purposes would minimize the environmental impact of the site. While the net present value for a VNM installation would be negative, the value to the City of Eau Claire towards meeting its 25% by 2025 renewable energy goal, positive press, or other non-financial benefits may exceed this cost. If electricity rates were to increase faster than the 2%/annum used in this analysis, the feasibility of the system would increase.

As summarized in Section 5, the economic analysis completed using SAM predicts a negative net present value for fixed, single-axis, and dual-axis tracking systems installed at the site when using the average blended city cost of electricity of $0.08/kWh, should VNM with other city properties be allowed.

It should be noted that, as the site does not have significant energy use without VNM or community solar, the site would need to establish a PPA with the local utility to sell the electricity generated or establish a lease agreement with an adjacent facility to develop a behind-the-meter system wherein the site is leased to a developer who develops the system and sells the resultant energy to the adjacent consumer through a PPA. In order to earn an IRR of 8%, a PPA of about $0.10/kWh increasing at 3% annually would need to be established. This represents the expected minimum allowable IRR for a third-party developer and is therefore considered the breakeven price for this type of system. If the utility, or adjacent energy consumer, were willing to purchase electricity at this rate, the system would be considered feasible. This analysis also assumes that a third party owns and operates the system, enabling it to take advantage of tax credits. The fee for using the site would be negotiated through the city as the owner of the land and the site developer.

Due to the low blended cost of electricity paid by the city, low cost of electricity produced by Xcel Energy, limited interest in VNM on behalf of the utilty, and lack of on-site energy use, opportunities for solar system development at the Sky Park Landfill site are limited. Potential opportunities may exist if a behind-the-meter system could be developed in partnership with an adjacent industrial consumer, if the Wisconsin PSC establishes a market for RECs or requires utilities to purchase distributed generation solar electricity at a higher rate, or if the cost of electricity increases significantly.

When reviewing proposals for a PV system to be installed at this site, evaluation criteria should include the annual output (kWh/yr) as well as PPA price per kilowatt-hour for the electricity produced. Ideally, the price should be below the current cost of energy for the purchaser to ensure a positive return. A design-build contract can enable vendors to optimize system configuration, including slope and tracking requirements, or a specific system design can be required of the vendor.

As the cost of energy increases, the cost of PV continues to decline, and increased opportunities for distributed generation are developed with the local utility, the opportunity for successful development of a PV system on the Sky Park Landfill site will become more favorable. A PV system may be a reasonable use for the site if an appropriate opportunity to sell the electricity produced is developed—either through development of community solar, VNM, a PPA, or a behind-the-meter application for an adjacent consumer of electricity.

Appendix A. Provided Sky Park Landfill Site Information

Figure A-1. High resolution plan, available from City of Eau Claire, Wisconsin

Map provided by Ned Noel, City of Eau Claire

Appendix B. Assessment and Calculations Assumptions

Table B-1. Cost, System, and Other Assessment Assumptions

Cost Assumptions Variable	Quantity of Variable	Unit of Variable	
Cost of site electricity	0.08	\$/kWh	
Annual O&M (fixed)	20	\$/kW/year	
Annual O&M (single)	22	\$/kW/year	
Annual O&M (dual)	25	\$/kW/year	
System Assumptions			
System Type	**Annual energy kWh/kW**	**Installed Cost (\$/W)**	**Energy Density (W/sq. ft.)**
Ground fixed, ballasted	1,253	\$3.49	4.0
Ground single-axis, ballasted	1,584	\$4.19	3.5
Ground dual-axis, ballasted	1,682	\$4.62	3.0
Other Assumptions			
	1 acre	43,560 ft^2	
	1 MW	1,000,000 W	
	Ground utilization	23 acres	

Appendix C. Solar Access Measurements

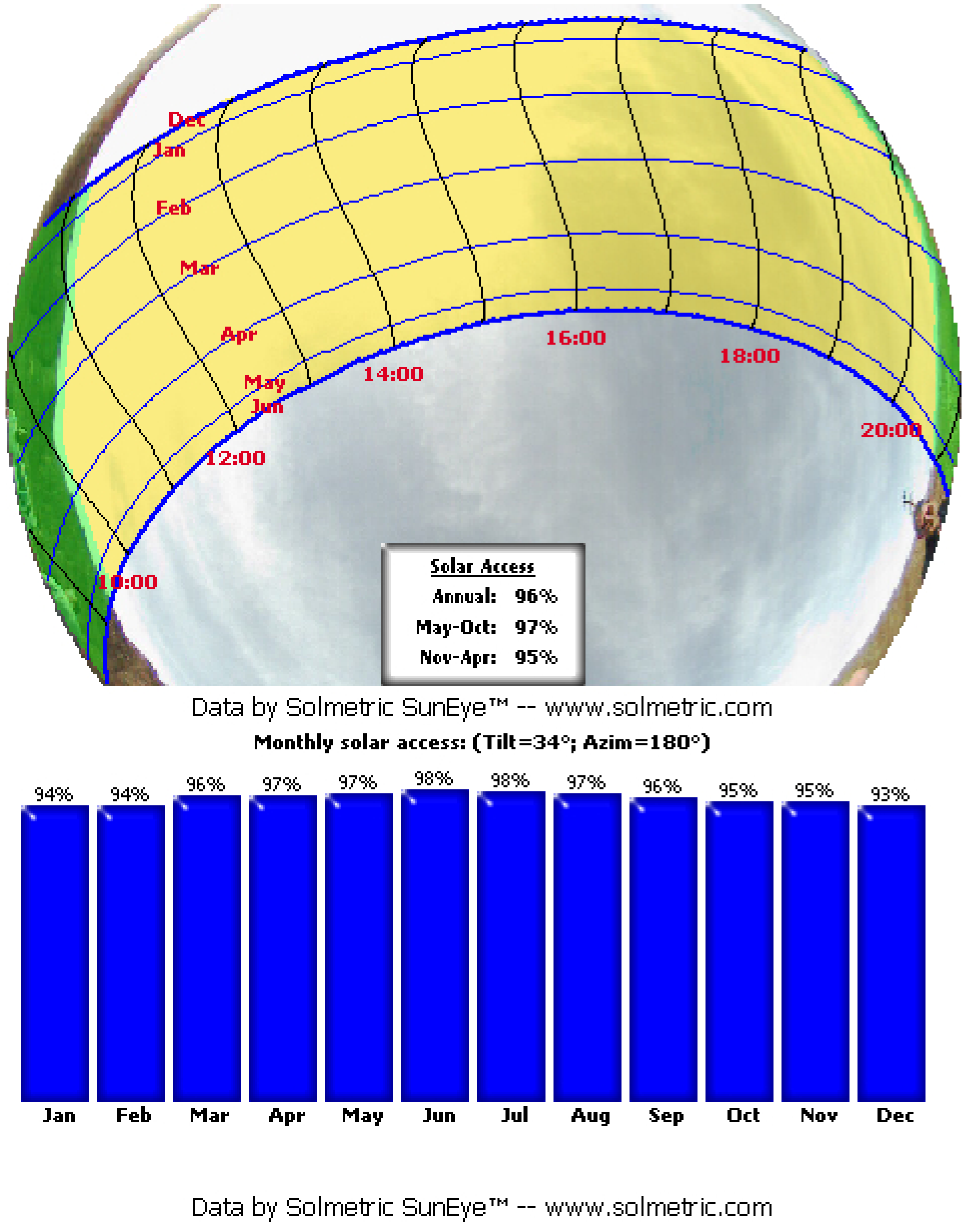

Figure C-1. Solar access measurements for Sky Park Landfill PV site

Appendix D. Results of the JEDI Model

Table D-1. Summary Results of the NREL JEDI Model

Photovoltaic (project data summary based on model default values)	
Project Location	WISCONSIN
Year of Construction or Installation	2013
Average System Size - DC Nameplate Capacity (KW)	4,008
Number of Systems Installed	1
Total Project Size - DC Nameplate Capacity (KW)	4,008
System Application	Utility
Solar Cell/Module Material	Crystalline Silicon
System Tracking	Single-axis
Base Installed System Cost ($/KWDC)	$3,348
Annual Direct Operations and Maintenance Cost ($/kW)	$22.00
Money Value - Current or Constant (Dollar Year)	2012
Project Construction or Installation Cost	$11,668,105
Local Spending	$8,024,549
Total Annual Operational Expenses	$1,664,558
Direct Operating and Maintenance Costs	$88,165
Local Spending	$81,112
Other Annual Costs	$1,556,393
Local Spending	$0
Debt Payments	$0
Property Taxes	$0

Local Economic Impacts - Summary Results

	Jobs	Earnings	Output
During construction and installation period		**$000 (2012)**	**$000 (2012)**
Project Development and On-Site Labor Impacts			
Construction and Installation Labor	19.7	$1,273.1	
Construction and Installation Related Services	29.7	$1,074.7	
Subtotal	49.3	$2,347.8	$4,410.6
Module and Supply Chain Impacts			
Manufacturing	0.0	$0.0	$0.0
Trade (Wholesale and Retail)	11.8	$599.0	$1,870.2

Finance, Insurance, and Real Estate	0.0	$0.0	$0.0
Professional Services	9.0	$240.6	$1,166.6
Other Services	9.1	$537.7	$2,044.7
Other Sectors	18.9	$411.4	$1,193.7
Subtotal	48.8	$1,788.7	$6,275.1
Induced Impacts	32.8	$647.9	$3,780.0
Total Impacts	**130.9**	**$4,784.4**	**$14,465.7**

During Operating Years	**Annual Jobs**	**Annual Earnings $000 (2012)**	**Annual Output $000 (2012)**
On-site Labor Impacts			
PV Project Labor Only	0.8	$49.1	$49.1
Local Revenue and Supply Chain Impacts	0.3	$12.2	$47.2
Induced Impacts	0.2	$4.3	$27.1
Total Impacts	**1.4**	**$65.6**	**$123.4**

Notes: Earnings and Output values are thousands of dollars in year 2012 dollars. Construction and operating period jobs are full-time equivalent for one year (1 FTE = 2,080 hours). Economic impacts "During operating years" represent impacts that occur from system/plant operations/expenditures. Totals may not add up due to independent rounding.

Detailed PV Project Data Costs

Installation Costs	**Cost**	**Purchased Locally (%)**	**Manufactured Locally (Y or N)**
Materials & Equipment			
Mounting (rails, clamps, fittings, etc.)	$585,970	100%	N
Modules	$4,865,708	100%	N
Electrical (wire, connectors, breakers, etc.)	$410,906	100%	N
Inverter	$878,201	100%	N
Subtotal	$6,740,785		
Labor			
Installation	$1,273,069	100%	
Subtotal	$1,273,069		
Subtotal	$8,013,854		
Other Costs			
Permitting	$1,452,736	100%	
Other Costs	$592,954	100%	
Business Overhead	$3,357,633	100%	
Subtotal	$5,403,323		
Subtotal	$13,417,177		
Sales Tax (Materials & Equipment Purchases)	$0	100%	
Total	$13,417,177		

PV System Annual Operating and Maintenance Costs	Cost	Local Share
Labor		
Technicians	$52,899	100%
Subtotal	$52,899	
Materials and Services		
Materials & Equipment	$35,266	100%
Services	$0	100%
Subtotal	$35,266	
Sales Tax (Materials & Equipment Purchases)	$0	100%
Average Annual Payment (Interest and Principal)	$1,556,393	0%
Property Taxes	$0	100%
Total	$1,644,558	

Other Parameters		
Financial Parameters		
Debt Financing		
Percentage financed	80%	0%
Years financed (term)	10	
Interest rate	10%	
Tax Parameters		
Local Property Tax (percent of taxable value)	0%	
Assessed Value (percent of construction cost)	0%	
Taxable Value (percent of assessed value)	0%	
Taxable Value	$0	
Property Tax Exemption (percent of local taxes)	100%	
Local Property Taxes	$0	100%
Local Sales Tax Rate	5.00%	100%
Sales Tax Exemption (percent of local taxes)	100.00%	
Payroll Parameters	**Wage Per Hour**	**Employer Payroll Overhead**
Construction and Installation Labor		
Construction Workers/ Installers	$21.39	45.6%
O&M Labor		
Technicians	$21.39	45.6%

Appendix E. Results of the Solar Advisor Model

Table E-1. Summary Inputs and Results for the SAM Model

SAM Results - Fixed 4-MW System - VNM		
Net Annual Energy		4,837,763 kWh
LCOE Nominal	$	0.0846/kWh
LCOE Real	$	0.0734/kWh
First Year Revenue without System	$	0.00
First Year Revenue with System	$	387,021.01
First Year Net Revenue	$	387,021.01
After-Tax NPV	$	-1,007,989.94
Payback Period		18.9125 years
Capacity Factor		13.8
First Year kWh/kW		1,208
System Performance Factor		0.79
Total Land Area		23 acres
SAM Results - Single-Axis 3.5-MW System – VNM		
Net Annual Energy		5,337,797
LCOE Nominal	$	0.0793
LCOE Real	$	0.0688
First Year Revenue without System	$	0.00
First Year Revenue with System	$	427,023.79
First Year Net Revenue	$	427,023.79
Capacity Factor		17.4%
Payback Period		17.6189 years
After-Tax NPV	$	-807,095.57
First Year kWh/kW		1,522
System Performance Factor		0.80
Total Land Area		23 acres
SAM Results – Dual-Axis 3-MW System - VNM		
Net Annual Energy		4,839,482 kWh
LCOE Nominal	$	0.0826/kWh
LCOE Real	$	0.0719/kWh
First Year Revenue without System	$	0.00
First Year Revenue with System	$	387,158.58
First Year Net Revenue	$	387,158.58
After-Tax NPV	$	-900,799.34
Payback Period		18.3924 years
Capacity Factor		18.4
First Year kWh/kW		1,611
System Performance Factor		0.8
Total Land Area		23 acres

SAM Results – Fixed-Axis 4-MW System - PPA

Net Annual Energy		4,837,763 kWh
PPA Price	$	0.1061/kWh
LCOE Nominal	$	0.1446/kWh
LCOE Real	$	0.1254/kWh
After-Tax IRR		8.00 %
Pre-Tax Min DSCR		0.60
After-Tax NPV	$	96,991.21
PPA Price Escalation		3.5%
Debt Fraction		55%
Capacity Factor		13.8%
First Year kWhac/kWdc		1,208
System Performance Factor		0.79
Total Land Area		23 acres

SAM Results – Single-Axis 3.5-MW System – PPA

Net Annual Energy		5,337,797 kWh
PPA Price	$	0.0994/kWh
LCOE Nominal	$	0.1356/kWh
LCOE Real	$	0.1176/kWh
After-Tax IRR		8.00 %
Pre-Tax Min DSCR		0.60
After-Tax NPV	$	101,219.94
PPA Price Escalation		3.5%
Debt Fraction		55%
Capacity Factor		17.4%
First Year kWhac/kWdc		1,522
System Performance Factor		0.80
Total Land Area		23 acres

SAM Results – Dual-Axis 3-MW System - PPA

Net Annual Energy		4,839,482 kWh
PPA Price	$	0.1035/kWh
LCOE Nominal	$	0.1411/kWh
LCOE Real	$	0.1224/kWh
After-Tax IRR		8.00 %
Pre-Tax min DSCR		0.60
After-Tax NPV	$	95,158.14
PPA Price Escalation		3.5%
Debt Fraction		55%
Capacity Factor		18.4%
First Year kWhac/kWdc		1,611
System Performance Factor		0.79
Total Land Area		23 acres