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Feasibility Study of Economics and Performance of Solar Photovoltaics at the VAG Mine Site in Eden and Lowell, Vermont

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-09-1751 and Task No. WFD4.1001.

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Technical Report
NREL/TP-7A30-57766
April 2013
Contract No. DE-AC36-08GO28308

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National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
303-275-3000 • www.nrel.gov

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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 Vermont Asbestos Group (VAG) Mine site in Eden, Vermont, and Lowell, Vermont, 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 1,550-acre VAG site is located in the townships of Eden and Lowell in northern Vermont. The site was mined for asbestos from 1936 until closure in 1993. The mine covers approximately 650 acres and consists of two large tailing piles, several rock piles, quarries, a mill, mining-related buildings, and a pit lake. Since closure, several interim measures have taken place to mitigate releases from the site, and while the site has been considered a candidate for the National Priorities List, the townships of Eden and Lowell have voted against pursuing Superfund status for the site. Additional information on the site is available through the EPA RE-Powering America's Land fact sheet for Lowell and Eden[1] and the Vermont Department of Environmental Conservation website.[2]

The scale of the mine is such that many large, non-vegetated flat open areas containing removed and graded cap rock within the 1,550-acre site could potentially be used for utility-scale solar development. Approximately 113 acres are potentially suitable for a PV installation, consisting of up to a 2.2-MW array on the waste-rock area (approximately 11 acres) on the northeast portion of the site, a 4.6-MW array in the current entry and building area (approximately 21 acres), and an 11.6-MW array on the south facing slopes (approximately 81 acres) of the Eden and Lowell piles.

The feasibility of a PV system installed is highly impacted by the available area for an array, the solar resource, distance to transmission lines, and distance to major roads. In addition, the operating status, ground conditions, and restrictions associated with redevelopment of contaminated mine sites impact the feasibility of a PV system.

The economic feasibility of a potential PV system on the VAG Mine site depends greatly on the purchase price of the electricity produced. The economics of the potential system were analyzed using the current Vermont Sustainably Priced Energy Development (SPEED) standard offer for systems up to 2.2 MW in size of $0.27/kWh, non-escalating. For the analysis of a larger system, the average negotiated rate for systems within the SPEED program of $0.13/kWh was used. Table ES-1 summarizes the system performance and economics of a potential system that would use all available areas that were surveyed at the VAG Mine site. The table shows the annual

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[1] RE-Powering America's Land: Evaluating the Feasibility of Siting Renewable Energy Production on Potentially Contaminated Land. EPA/Office of Solid Waste and Emergency Response, November 2011. http://www.epa.gov/oswercpa/docs/r01-11-009_edenandlowell.pdf.

[2] For more information about the Vermont Department of Environmental Conservation, see http://www.anr.state.vt.us/dec/dec.htm.

energy output from the system, along with the number of average American households that could be powered from such a system and estimated job creation.

As indicated in Table ES-1, a 2.2-MW ballasted fixed-tilt system installed on the flat cap-rock area of the site to take full advantage of the Vermont SPEED standard offer program prior to extensive site remediation could realize a net present value (NPV) of $2,199,995 and an internal rate of return (IRR) of approximately 24%. This analysis considers the current cost of energy, expected installation cost, 20% premium for working on a non-remediated site, site solar resource, and existing incentives for the proposed PV system. This savings and after-tax IRR is attractive, and as such, a solar PV system represents a viable reuse for the site and should be considered.

A comparative single-axis tracking system would yield an after-tax NPV of $3,012,237 on first-year annual revenue of $970,033/year. The after-tax IRR is estimated at 26%. While this is higher, it is important to note that complications associated with installing a tracking system on the existing land may incur atypical costs. Any differential settlement would also negatively impact the performance of the system and increase maintenance costs on the site.

Secondly, a scenario was considered wherein the entire currently flat area potentially feasible for PV was used following, or as part of, a potential remediation strategy. Finally, a scenario was considered wherein a cap-integrated thin-film PV system would be installed on all of the south-facing slopes of the Eden and Lowell pile as part of a remediation plan. As both of these systems would be larger than 2.2 MW, a negotiated rate of $0.13/kWh was used. Both of these scenarios resulted in a negative NPV and low IRR. Due to the currently low NPV forecast, the lack of an agreed-upon remediation strategy for the Eden and Lowell piles, and potential complications of installing thin-film solar on the steep slopes of the piles, this solution is not attractive at this time.

Table ES-1. VAG Mine PV System Summary

System Type	Financial Model	PV System Size[a] (kW)	Array Tilt (deg)	Array Size (acres)	Annual Output (kWh/year)	Number of Houses Powered[b]	Construction Period Jobs[c]	Jobs Sustained[d]
Crystalline Silicon (Fixed Tilt)	PPA	2,200	LAT	9.9	2,879,581	260.8	70.3	0.7
Crystalline Silicon (Single-axis Tracking)	PPA	2,200	n/a	11	3,592,714	325.4	*	*
Crystalline Silicon (Fixed Tilt)	PPA	4,600	n/a	20.7	8,386,334	759.6	*	*
Crystalline Silicon (Single-axis Tracking)	PPA	4,600	LAT	23	10,462,389	947.7	*	*
Thin-film (Integrated into cap)	PPA	11,600	n/a	81	16,456,059	1490.6	*	*

System Type	Financial Model	Annual Output (kWh/year)	PPA Price[e] (¢/kWh)	System Cost ($/watt)	Total System Cost	1ST Year Revenue ($/year)	After-tax NPV	After-tax IRR %
Crystalline Silicon (Fixed Tilt)	PPA	2,879,581	27	$ 3.34	$ 7,402,062	$ 777,486	$ 2,189,995.00	24.08
Crystalline Silicon (Single-axis Tracking)	PPA	3,592,714	27	$ 4.02	$ 8,843,860	$ 970,033	$ 3,012,237.96	26.11
Crystalline Silicon (Fixed Tilt)	PPA	8,386,344	13	$ 2.77	$ 17,728,946	$ 1,090,224	$ (913,636.00)	3.46
Crystalline Silicon (Single-axis Tracking)	PPA	10,462,389	13	$ 3.34	$ 21,338,936	$ 1,360,110	$ (490,451.00)	5.28
Thin-film (Integrated into cap)	PPA	16,456,059	13	$ 2.79	$ 32,363,629	$ 2,139,287	$ (510,574.00)	5.74

[a] Array size determined by available acerage for each scenario. 2.2 MW used for the first scenario to take adavantage of SPEED standard offer.

[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 fixed PPA rate. Inflation assumed to be 1.5%/year.

* JEDI analysis was not completed for these systems

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 Vermont Asbestos Group (VAG) Mine site in Eden, Vermont, and Lowell, Vermont, 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 1,550-acre VAG site is located in the townships of Eden and Lowell in northern Vermont. Major commercial asbestos mining at the site took place from 1936 until the site closed in 1993. The mine covers approximately 650 acres and consists of two large tailing piles, several rock piles, quarries, a mill, mining-related buildings, and a pit lake. Since closure, several interim measures have taken place to mitigate releases from the site, and while the site has been considered a candidate for the National Priorities List, the townships of Eden and Lowell have voted against pursuing Superfund status for the site. Additional information on the site is available through the EPA RE-Powering America's Land fact sheet for Eden and Lowell[3] and the State of Vermont's website for the VAG Mine site.[4]

Under the RE-Powering America's Land initiative, the EPA provided funding to NREL to support a feasibility study of solar renewable energy generation at the VAG Mine site.

The site contains several major features and areas important for consideration of eligible solar installation. Figure 1 provides an aerial view of the site. In addition, Figure 2 shows the current condition of the site. Currently, the mine site consists of 11 mine and mill buildings and several large tailing and waste rock piles containing asbestos. The two largest tailing piles are estimated at 30 million tons. As demonstrated, a wide range of conditions exist. Several areas have unstable, non-vegetated ground conditions with significant slopes. As the site has not been remediated as of the writing of this report, a full understanding of the current ground conditions and contamination is necessary. The purpose of this report is not to summarize current conditions but rather to indicate the potential feasibility of a solar system installation, assuming that environmental risks could be overcome or mitigated. Summary information on the site is available through the State of Vermont and the EPA.

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[3] *RE-Powering America's Land: Evaluating the Feasibility of Siting Renewable Energy Production on Potentially Contaminated Land (Eden and Lowell, Vermont)*. U.S. Environmental Protection Agency Office of Solid Waste and Emergency Response, November 2011. http://www.epa.gov/oswercpa/docs/r01-11-009_edenandlowell.pdf.

[4] For more information about the VAG Mine site, see http://www.anr.state.vt.us/dec/wastediv/sms/VAG.htm.

Figure 1. Aerial view of the VAG Mine

Source: Image generated using Google Earth

Figure 2. Images of the VAG Mine. ***Photos by Joe Simon, NREL***

Feasibility assessment team members from NREL, the State of Vermont, VAG, and the Township of Eden conducted a site visit on July 17, 2012, to gather information integral to this feasibility study. The team considered a variety of information, including solar resource, transmission availability, community acceptance, and ground conditions.

2 Development of a PV System on Mine Sites

Through the RE-Powering America's Lands initiative, the EPA has identified several benefits for siting solar PV facilities on contaminated mine lands, noting that they:

- Can be developed in place of limited greenfields, preserving the land carbon sink
- Could have environmental conditions that are not well-suited for commercial or residential redevelopment and may be adequately zoned for renewable energy
- Are generally located near existing roads and energy transmission or distribution infrastructure
- Might provide an economically viable reuse for sites that might 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, and in many cases, generate significant revenue on a site that would otherwise go unused.

The VAG Mine is owned by the Vermont Asbestos Group, which along with the community and the State of Vermont, is interested in potential revenue flows on the site. As a large, significant site in the area, the local communities of Eden and Lowell have significant interest in the redevelopment of the site, and community engagement is critical to match future reuse options to the community's vision for the site.

Understanding opportunities studied and realized by other similar sites demonstrates the potential for PV system development. EPA has published the "Handbook on Siting Renewable Energy Projects While Addressing Environmental Issues," which is relevant to the potential development at the VAG mine site.[5] Past studies and developments have occurred at other mine sites, including the Molycorp site[6] in Questa, New Mexico; the Freeport McMoRan Chino Mine[7] in Silver City, New Mexico; and the Leviathan Mine superfund site[8] in Alpine County, California.

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[5] *Handbook on Siting Renewable Energy Projects While Addressing Environmental Issues.* U.S. Environmental Protection Agency Office of Solid Waste and Emergency Response's Center for Program Analysis, 2012. http://www.epa.gov/oswercpa/docs/handbook_siting_repowering_projects.pdf.

[6] *RE-Powering America's Land Fact Sheet: Siting Renewable Energy Projects While Addressing Environmental Issues.* U.S. Environmental Protection Agency, December 2011. http://www.epa.gov/oswercpa/docs/decision_tree_factsheet.pdf

[7] *RE-Powering America's Land: Evaluating the Feasibility of Siting Renewable Energy Production on Potentially Contaminated Land (Silver City, New Mexico).* U.S. Environmental Protection Agency Office of Solid Waste and Emergency Response, November 2011. http://www.epa.gov/oswercpa/docs/r06-11-002_silver_city.pdf.

[8] *RE-Powering America's Land: Evaluating the Feasibility of Siting Renewable Energy Production on Potentially Contaminated Land (Alpine County, California).* U.S. Environmental Protection Agency, November 2011. http://www.epa.gov/oswercpa/docs/develop_potential/alpine.pdf.

Due to the scale and topographical conditions of the VAG mine site, it is unlikely that any PV system installed on the site would use all available land. Depending on remediation strategies pursued, the subject site has 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.

Beyond the financial benefits resulting from the development of renewable energy on the subject site, many additional nonfinancial benefits exist for the site, the community, and the state. 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 stimulating electrons (negative charges) in a layer in the cell 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 3 shows the generation of electricity from a PV cell.

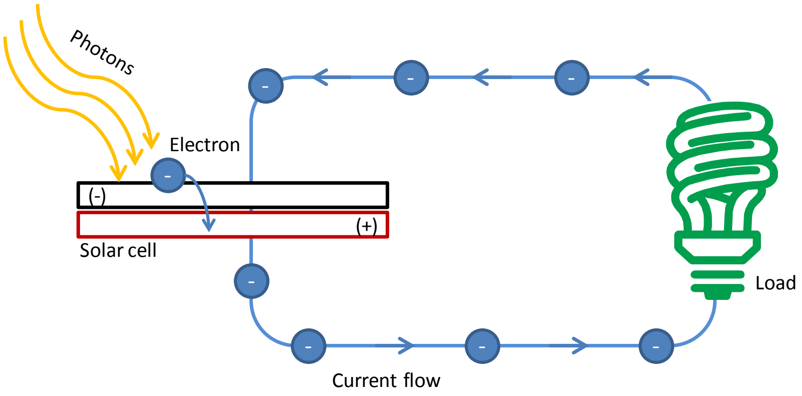

Figure 3. Generation of electricity from a PV cell

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

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

- PV modules
- Inverter
- Balance-of-system (BOS) components (e.g., combiner box, transformer, and meter).

These components (see Figure 4) and other PV system components are discussed below.

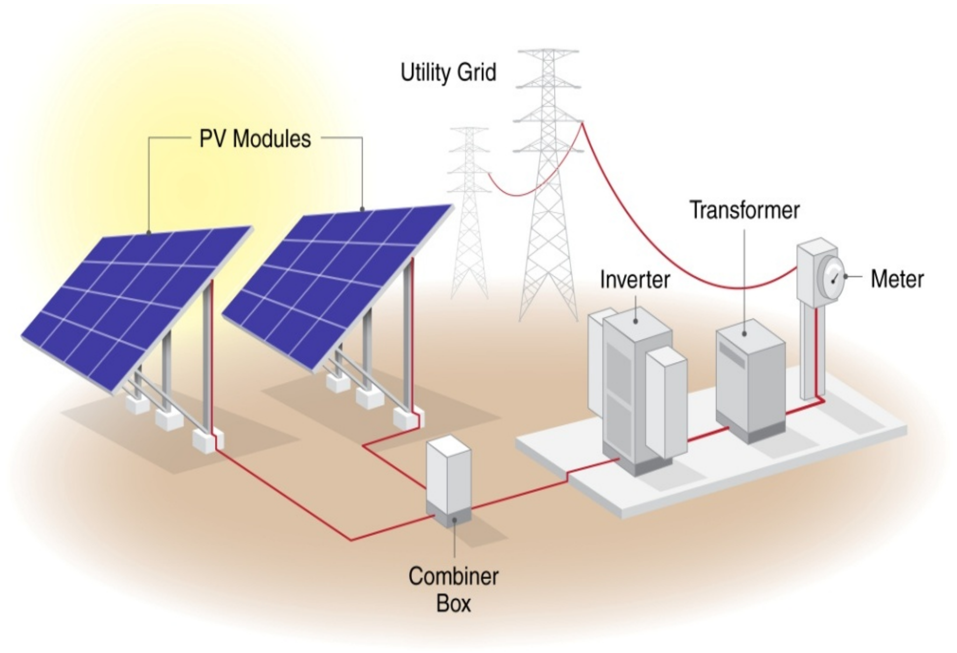

Figure 4. Ground-mounted array diagram

Source: NREL

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, which is abundant and nontoxic. It builds on a strong industry on both supply (silicon industry) and product side. This technology has been demonstrated for a consistent and high efficiency for over 30 years in the field. The performance degradation, a reduction in power generation due to long-term exposure, is under 1% per year. Silicon modules have a lifespan in the range 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 it is controlled by raw material selection and manufacturing technique. Crystalline silicon panels are widely used based on deployments worldwide.

Figure 5 shows two examples of crystalline solar panels: mono- and multi-silicon installed on tracking mounting systems.

Figure 5. Mono- and multi-crystalline solar panels. ***Photos from (left) SunPower Corporation, NREL 23816 and (right) SunPower, NREL 13823***

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 their unique nature, some thin-film cells are constructed into flexible modules, enabling such applications as solar energy covers for landfills, such as a geomembrane system. Other thin-film modules are assembled into rigid constructions that can be used in a fixed-tilt or, in some cases, tracking system configurations.

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

Figure 6. Thin-film solar panels installed on (left) solar energy cover and (middle and right) fixed-tilt mounting system. ***Pictures from (left) City of San Antonio, NREL 18068; (middle) Beck Energy, NREL 14726; and (right) U.S. Coast Guard Petaluma site, NREL 17395***

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 would 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. They also have high efficiency and lower operation 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 between 10 and 20 years with 10 years being the current industry standard. On larger units, extended warranties up to 20 years are possible. Given that the expected life of 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 in limited use in larger systems due to 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 can be the most expensive option per watt of capacity. Warranties range from 10–20 years. Small projects with irregular modules and shading issues typically benefit from micro-inverters.

With string inverters, small amounts of shading on a solar panel will significantly affect the entire array production. However, if micro-inverters are used, it impacts only that shaded panel and not the entire array production. Figure 7 shows a string inverter.

Figure 7. String inverter. ***Photo by Warren Gretz, NREL 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 BOS components, which include:

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

3.2.3.1 *Mounting Systems*

An 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 surface applications on potentially contaminated mine sites, such as the VAG mine, 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 brownfield 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, where 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. Depending on underlying soil 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.

Each type of system requires a different amount of land per DC-watt of rated energy output. Table 1 summarizes the areas required and demonstrates that tracking systems require more land due to a need to avoid having the modules shade each other. While the DC-watts per square foot are lower, some of this difference is recouped because tracking systems are able to have a higher output, as described above. Table 1 also demonstrates that, for example, thin-film panels are not as efficient per square foot of area as crystalline silicon, though their cost is lower.

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)
Crystalline Silicon	4.0	3.3
Thin Film	3.3	2.7
Hybrid High Efficiency	4.8	3.9

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. The mounting system design will also 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 New England.

3.2.3.2 *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) the arrays to inverters and (2) inverters to point of interconnection is generally run as direct burial through trenches. In contaminated mine 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.

3.2.3.3 *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 by 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 brownfield or contaminated site 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 and identification of under-performing arrays. Operators might also use these data to identify, for example, required maintenance, shade on panels, and accumulating dirt on panels. 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), are 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 systems assume an annual O&M cost of $22/kW/yr, and dual-axis tracking systems assume an annual O&M cost of $25/kW/yr. In addition, the system should expect a replacement of system inverters in year 15 at a cost of $0.25/W. This is already factored in to the average O&M costs cited above. The values used here are industry averages. For a system placed in an area of the site that has not been remediated, the O&M costs may be higher. For the purposes of this report, however, the average values were used.

3.3 Siting Considerations

PV modules are very sensitive to shading. When shaded (either partially or fully), 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.

Following the successful collection of solar resource data using the Solmetric SunEye tool and the determination that a site is adequate for a solar installation, an analysis must be conducted to determine the ideal system size. System size depends highly on the average energy use of the facilities on the site, PPAs, available incentives, and utility policy.

4 Proposed Installation Location Information

This section summarizes the findings of the NREL solar assessment site visit on July 17, 2012.

4.1 VAG Mine Site PV System

As discussed in Section 1, the VAG Mine site is currently owned by the Vermont Asbestos Group.

When considering the feasibility of any PV system on the VAG Mine site, consideration must be made to the current site condition as well as the various potential remediation strategies. While the entire site is approximately 1,550 acres in total, a majority of the site is heavily vegetated, with a slope that is too steep to accommodate PV installation economically or has inappropriately facing slopes. Under a full remediation strategy, it is estimated that up to 113 acres could be available for a PV system. Use of 113 acres would require significant removal of infrastructure, remediation, development of electrical transmission, site grading, and access road development.

Alternatively, approximately 11 acres are available and potentially suitable on portions of the site that are currently flat, stable, free of buildings, near electrical infrastructure, and unshaded with a suitable solar resource. Demonstrated in Figure 8, the waste-rock displacement area to the east of the Eden pile is potentially feasible for ballasted solar development in its current state. The largest flat area of waste-rock totals approximately 8.2 acres, and the total flat, effective surface available is approximately 11 acres. This area is also reasonably close to the point where the mine previously tied into the electric utility, as indicated below.

Figure 8. View of feasible PV area at the VAG Mine site

Source: Image generated using Google Earth

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 and when substantial remediation of the site occurs, consideration can be made as to the potential future feasibility of a PV system on a larger portion of the site.

Figure 9 shows an aerial view of the VAG Mine site taken from Google Earth; the total potential area feasible for ballasted PV systems is shaded. As shown, there are large expanses of relatively flat, un-shaded land that may be suitable for a PV system. In addition, the south-facing portions of the Eden and Lowell piles could potentially be used for thin-film PV panels integrated into any capping system that may be developed and implemented. The area highlighted in orange, as discussed above, is approximately 11 acres. The area currently consisting of the significant mine structures and facilities is approximately 21.5 acres of flat, unshaded land and is highlighted in green. The existing buildings would need to be removed prior to any potential development of this area. Finally, the area highlighted in purple represents the south-facing slopes of the Eden and Lowell piles. It is possible that a cap-integrated thin-film PV system could be integrated into any remediation strategy considered for the site. This area totals approximately 81 acres. In total, the shaded area represents approximately 113 acres.

Figure 9. Aerial view of the feasible area for PV at the VAG Mine site

Source: Image generated using Google Earth

PV systems are viable in the Eden and Lowell 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 1,374 kWh/m^2/day.

Figure 10 shows various views of the VAG Mine site.

Figure 10. Views of the VAG Mine site. ***Photos by Joe Simon, NREL***

4.2 Utility-Resource Considerations

The expected electrical tie-in point and inverter for the PV system at the VAG Mine site is located on the northeast side of the site along Mines Road. When the mine was operating, the utility located a dedicated substation at this site to accommodate the electricity use. The substation has since been removed, but the distribution infrastructure remains, as well as the overhead electrical lines throughout the mine site. The expected electrical tie-in point is shown in Figure 11. While the site transmission lines still exist, they have been unused for many years and may not be sufficient for a new PV installation. The route, however, remains free and could likely be used. The capacity of the transmission lines is not known at this time; however, the large energy consumption of the prior mine indicates that capacity is likely adequate. This would need to be confirmed with the local utility, should the project move forward. Due to the site conditions and potential contamination, it is likely that an overhead solution would need to be used as trenching would either disturb existing potentially contaminated conditions or any potential remediation solution. Depending on the site location, the distance from the substation to the solar installation may range from under a quarter mile to over 1 mile.

Figure 11. Electrical tie-in point for the PV system (left) and site distribution (right). ***Photos by Joe Simon, NREL***

Figure 12. Electrical tie-in point (A) for the PV system and site distribution

Source: Image generated using Google Earth

4.3 Useable Acreage for PV System Installation

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

4.4 PV Site Solar Resource

The VAG Mine site has been evaluated to determine the adequacy of the solar resource available using both on-site data and industry tools. The assessment team for this feasibility study collected multiple Solmetric SunEye data points and found a solar access of 99% in unshaded areas, such as along the waste-rock deposits highlighted in orange in Figure 9 and estimated solar resource of 1,374 kWh/m^2. All data gathered using this tool is available in Appendix C.

The predicted array performance was found using PVWatts Version 2[9] for Eden and Lowell, Vermont. 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 is scaled linearly to match the proposed system size. The cost of electricity used was provided by PVWatts and is the estimate of the average for the location.

Table 2. Site Identification Information and Specifications

Station Identification	
Cell ID	0270360
State	Vermont
Latitude	44.6° N
Longitude	72.56° E
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	20°
Array Azimuth	180°
Energy Specifications	
Cost of Electricity	$0.163/kWh

Table 3 shows the performance results for a fixed-tilt PV system in Eden and Lowell, Vermont, as calculated by PVWatts.

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[9] For more information on NREL's PVWatts Version 2 tool, see http://www.nrel.gov/rredc/pvwatts/.

Table 3. Performance Results for Fixed-Tilt PV

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	3.06	81	13.19
2	4.18	100	16.28
3	5.00	127	20.68
4	4.84	113	18.40
5	5.16	121	19.70
6	5.51	114	18.56
7	5.46	122	19.87
8	5.16	117	19.05
9	4.80	108	17.59
10	3.49	84	13.68
11	2.39	57	9.28
12	2.50	64	10.42
Year	4.27	1,210	197.05

Table 4 shows the performance results for a zero-tilt single-axis tracking PV system in Eden and Lowell, Vermont, 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	3.43	92	14.98
2	4.93	119	19.38
3	6.01	155	25.24
4	6.14	146	23.78
5	6.67	159	25.89
6	6.73	151	24.59
7	7.14	165	26.87
8	6.71	156	25.40
9	5.90	135	21.98
10	4.16	102	16.61
11	2.66	64	10.42
12	2.79	72	11.73
Year	5.27	1,516	246.88

4.5 VAG Mine Energy Usage

The VAG Mine site has limited present energy use. One caretaker currently lives just outside the main entrance to the site. The remainder of the facility is not used and does not have any significant energy use. As remediation has not been determined at this time, it is unknown what any potential future energy use will be. It is important to understand the energy use of the site to allow for a full analysis of whether or not energy produced would need to be sold or if it could offset on-site energy use.

4.5.1 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 it 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.[10]

In 1997, Vermont passed legislation allowing net metering with utilities in the state. This law was updated in January 2012 with the passing of bill "H.475 An Act Relating to Net Metering and Definitions of Capacity (Act 0125)."[11] These bills, however, relate primarily to residential-scale systems and are not particularly useful for the VAG Mine site. Separately, net metering in Vermont is generally limited to systems up to 250 kW in capacity per HB 56 passed in May 2011.

Renewable energy certificates (RECs),[12] 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 net energy gain (NEG) remaining after a 12-month period, the utility will be granted the RECs associated with only that surplus they purchase.

Vermont does not currently support a solar renewable energy credit market; however, if developed over time, the income associated with the sale of RECs can potentially improve the economics of any proposed system. For the purposes of this report, it is assumed that no REC market exists.

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[10] Energy Policy Act of 2005: http://www.gpo.gov/fdsys/pkg/PLAW-109publ58/pdf/PLAW-109publ58.pdf.

[11] H.475 An Act Relating to Net Metering and Definitions of Capacity: http://www.leg.state.vt.us/docs/2012/bills/Intro/H-475.pdf.

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

4.5.2 Virtual Net Metering

Some states and utilities allow for virtual net metering (VNM). Vermont does not currently allow VNM, but should this be introduced in the future, it is worthwhile to consider. This arrangement can allow certain entities, such as a local government, to install renewable generation of up to 1 MW 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.

Each state may determine whether or not local governments, often including cities, counties, school districts, special districts, political subdivisions, or other local public agencies, are authorized to generate electricity. As the site is not owned by the state or local government, this option is likely not feasible.

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).[13]

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 both projects that buy and sell power at retail rates and power projects that sell power through a PPA.

SAM consists of a performance model and financial model. The performance model 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.

The model calculates the cost of generating electricity based on information you provide 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 the first quarter of 2010 to $3.20/W in the fourth quarter of 2011. With an increasing demand and supply, potential of further cost reduction is expected as market conditions evolve.

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-scale ground-mounted fixed-axis systems.[14]

At this time, there is not a developer or a specific plan to install a PV system on site; thus, it is uncertain if and when a PV system would be installed. However, for cost estimation purposes, system installation was assumed to take place in the first quarter of 2013, and as the trends in price reduction have continued, the assumed installed cost for a fixed-tilt

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

[14] Goodrich, A.; James, T.; Woodhouse, M. *Residential, Commercial, and Utility-Scale Photovoltaic (PV) System Prices in the United States: Current Drivers and Cost-Reduction Opportunities.* Technical Report NREL/TP-6A20-53347. Golden, CO: National Renewable Energy Laboratory, 2012. http://www.nrel.gov/docs/fy12osti/53347.pdf.

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 nonstandard ballasted racking systems. In addition, due to the unique considerations with regard to the VAG Mine site and delayed remediation activities, a conservative increase of an additional 20% is assumed to accommodate additional training, precautions, and installation requirements for any system installed prior to any potential remediation. The installed system cost assumptions are summarized in Table 5. This increased value for work on a nonremediated site is not substantiated for this report and should be carefully considered by any party interested in developing a system on this site prior to remediation. The increased labor and management costs could be very significant.

Table 5. Installed System Cost Assumptions

System Type	Fixed-Tilt ($/Wp)	Single-Axis Tracking ($/Wp)
Baseline system	2.232	2.67
With ballast	0.558	0.678
Total installed cost (postremediation)	2.79	3.348
Total with increased cost for work preremediation	3.348	4.017

These prices include the PV array and the BOS components for each system, including the inverter and electrical equipment, as well as the installation cost. This includes 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.

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. Assuming the PV system is owned by a private tax-paying entity, this entity may qualify for federal tax credits and accelerated depreciation on the PV system, which can be worth about 15% of the initial capital investment. The total potential tax benefits to the tax-paying entity can be as high as 45% of the initial system cost.

For the purposes of this analysis, the project is expected to have a 25-year life, although the systems can be reasonably expected to continue operation past this point. Inflation is assumed to be 1.5%, the real discount rate to be 6%, and the financing secured via a 25-year loan at a 7% interest rate and 55% debt fraction.

The panels are assumed to have a 0.5% per year degradation in performance. The O&M expenses are estimated to be $20/kW/yr for the life of the system for a fixed-tilt system and $22/kW/yr for a single-axis tracking system. Similar to installation costs, the O&M would be likely be higher if the system was installed on the site prior to remediation. A dual-axis tracking system was not considered for this analysis due to potential concerns associated with grading, differential settlement, and increased labor costs due to higher expected maintenance and existing site contamination. 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 Proposed PV Systems Analyzed

For the purposes of this analysis, three separate scenarios were analyzed.

5.2.1 Scenario 1

The first scenario assumes that installation of a ballasted system could be completed on the current site, prior to remediation, atop the cap-rock areas indicated in orange in Figure 8 of this report. Due to the existing level of nature, clear solar access, potentially limited ground contamination, and close proximity to electrical distribution lines, this area is considered most likely to support an installation prior to any potential overall site remediation.

The economic feasibility of a potential PV system on the VAG Mine site depends greatly on the purchase price of the electricity produced. The state of Vermont currently supports the Vermont Sustainably Priced Energy Development (SPEED) standard offer for systems up to 2.2 MW in size of $0.27/kWh. Both a fixed-axis and a single-axis PV system of 2.2 MW would sufficiently fill the currently clear cap-rock area on the site and, consequently, are analyzed for viability. This standard offer is the levelized cost of energy (LCOE) and will not increase over the life of the system.

5.2.2 Scenario 2

The second scenario considered evaluates the potential of using both the cap-rock area as well as the flat entry and structure area, which is indicated in green in Figure 9. This area totals 33 acres, and this scenario assumes that work is completed postremediation, so the increased construction cost associated with the potential ground contamination is not used. For the analysis of a larger system, the average negotiated rate for systems within the SPEED program of $0.13/kWh was used.

5.2.3 Scenario 3

Finally, a scenario was considered for the installation of a cap-integrated thin-film PV on the south-facing slopes of the Eden and Lowell piles. This system could be developed in addition to either of the previously summarized scenarios. As this installation would be done following a potential remediation, the increased construction cost associated with working on a potentially contaminated site is not used. This system would also realize the average negotiated rate of $0.13/kWh.

5.3 SAM-Forecasted Economic Performance

Using the inputs and assumptions summarized in Section 5 of this report, the SAM tool predicts the internal rate of return (IRR) and the LCOE for the three scenarios. In each scenario, a break-even point was not considered because this depends on the required IRR, which is different for every investor and hard to estimate. A project that requires an IRR of 7% will have a much different break-even point than one with a different cost of capital or a different IRR. The examples in Sections 5.3.1, 5.3.2, and 5.3.3 are indicative of the overall performance of the system, as an investment. In general, an IRR around 12% is considered satisfactory for this type of project; however, due to the unremediated nature of the site, other concerns relating to construction, and SPEED funding, it is likely that an investor would require a significantly higher IRR for this particular project.

5.3.1 Scenario 1

For a 2.2-MW fixed-tilt system designed to take full advantage of the Vermont SPEED standard offer on the waste-rock area, the system could yield an after-tax NPV of $2,189,995 on first-year annual revenue, beginning at $777,486/yr.

The fixed-tilt system would be expected to produce approximately 2.9 MWh annually, which is enough to offset approximately 260 households’ annual energy use. The complete results and summary of inputs for SAM are available in Appendix E. At current packing factors of 4–5 acres/MW of peak DC power, a 2.2-MW system would fully utilize the area available on the waste-rock while simultaneously taking full advantage of the existing SPEED system. The after-tax IRR of this system would be about 24%. This assumes a 20% premium for construction on contaminated lands. If this premium were to increase, the IRR would decrease accordingly.

A comparative single-axis tracking system would yield an after-tax NPV of $3,012,237 on first-year annual revenue of $970,033/yr. The after-tax IRR is estimated at 26%. While this is higher, it is important to note that complications associated with installing a tracking system on the existing land may incur atypical costs. Any differential settlement would also negatively impact the performance of the system and increase maintenance costs on the site.

A summary of the results of the economic analysis and the system considered is available in Appendix E.

5.3.2 Scenario 2

The second scenario considers wherein the entire currently flat area potentially feasible for PV was used following, or as part of, a potential remediation strategy. This area totals 32 acres and considers a 4.6-MW system for both a fixed-axis and single-axis tracking array. Both would result in a negative NPV and low IRR. Given the current available negotiable rate through the Vermont SPEED standard offer program as well as the amount of work required to prepare this land for a solar installation, this option is not recommended at this time.

5.3.3 Scenario 3

The third scenario considers wherein a cap-integrated thin-film PV system would be installed on all of the south-facing slopes of the Eden and Lowell piles as part of a remediation plan. This would total approximately 81 acres and, at the energy density factor indicated in Table 1, would represent approximately an 11.64-MW system. This system would also utilize the $0.13/kWh negotiated purchase price for electricity generated and utilizes an estimated installed cost of $2.79/W. This system would also realize a negative NPV and low IRR. Due to the low current NPV forecast, lack of resources to develop and implement a long-term remedy for the Eden and Lowell piles, and potential complications of installing thin-film solar on the steep slopes of the piles, this solution is not recommended at this time.

Table 6. PV System Summary

System Type	Financial Model	PV System Size[a] (kW)	Array Tilt (deg)	Array Size (acres)	Annual Output (kWh/year)	Number of Houses Powered[b]	Construction Period Jobs[c]	Jobs Sustained[d]
Crystalline Silicon (Fixed Tilt)	PPA	2,200	LAT	9.9	2,879,581	260.8	70.3	0.7
Crystalline Silicon (Single-axis Tracking)	PPA	2,200	n/a	11	3,592,714	325.4	*	*
Crystalline Silicon (Fixed Tilt)	PPA	4,600	n/a	20.7	8,386,334	759.6	*	*
Crystalline Silicon (Single-axis Tracking)	PPA	4,600	LAT	23	10,462,389	947.7	*	*
Thin-film (Integrated into cap)	PPA	11,600	n/a	81	16,456,059	1490.6	*	*

System Type	Financial Model	Annual Output (kWh/year)	PPA Price[e] (¢/kWh)	System Cost ($/watt)	Total System Cost	1ST Year Revenue ($/year)	After-tax NPV	After-tax IRR %
Crystalline Silicon (Fixed Tilt)	PPA	2,879,581	27	$ 3.34	$ 7,402,062	$ 777,486	$ 2,189,995.00	24.08
Crystalline Silicon (Single-axis Tracking)	PPA	3,592,714	27	$ 4.02	$ 8,843,860	$ 970,033	$ 3,012,237.96	26.11
Crystalline Silicon (Fixed Tilt)	PPA	8,386,344	13	$ 2.77	$ 17,728,946	$ 1,090,224	$ (913,636.00)	3.46
Crystalline Silicon (Single-axis Tracking)	PPA	10,462,389	13	$ 3.34	$ 21,338,936	$ 1,360,110	$ (490,451.00)	5.28
Thin-film (Integrated into cap)	PPA	16,456,059	13	$ 2.79	$ 32,363,629	$ 2,139,287	$ (510,574.00)	5.74

a Array size determined by available acerage for each scenario. 2.2 MW used for the first scenario to take adavantage of SPEED standard offer.
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 fixed PPA rate. Inflation assumed to be 1.5%/year.
* JEDI analysis was not completed for these systems
U.S. Energy Information Administration. http://www.eia.doe.gov/ask/electricity_faqs.asp#electricity_use_home. Accessed November 2, 2010.

5.4 Job Analysis and Impact

To evaluate the employment and economic impacts of the PV project associated with this analysis, the NREL Jobs and Economic Development Impact (JEDI) models are used.[15] 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 the proposed facility.

The JEDI models represent the entire economy, 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 on the associated construction materials, metal fabrication industry,

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[15] 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.

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. This analysis uses the proposed 2.2-MW fixed-tilt system as this is seen as the most economically and practically realizable system at this time.

For the VAG Mine site, the values in Table 7 were assumed.

Table 7. JEDI Analysis Assumptions

Input	Assumed Value
Capacity	2,200 kW
Placed In Service Year	2013
Installed System Cost	$7,402,062
Location	Eden and Lowell, Vermont

Using these inputs, the JEDI tool estimates the gross direct, indirect, and induced 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 hrs/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 70 direct, indirect, and induced jobs per year for the duration of the procurement and construction period. Total wages paid to workers during the construction period are estimated to be $2,928,000, and total economic output is estimated to be $7,505,000. The annual O&M of the new PV system is estimated to support 0.7 FTEs per year for the life of the system. The jobs and associated spending are projected to account for approximately $34,600 in earnings and $57,400 in economic activity each year for the next 25 years.

5.5 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.

5.5.1 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 assets and equity of the owners/operators for the project. In addition, private entities can utilize any of federal tax credits offered.

Although not applicable to this site, given that it is privately owned, public entities that choose to finance, own, and operate a solar project can raise funding 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 now common use of third-party financing structures, such as the PPA.

5.5.2 Third-Party Developers with Power Purchase Agreements

Because many project site hosts do 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 term of a PPA typically varies from 20–25 years.

5.5.3 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 a 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 each investor’s return is met.

5.5.4 Hybrid Financial Structures

As the solar market evolves, hybrid financial solutions have been developed in certain instances to finance solar projects. A particular structure, nicknamed “The Morris Model” 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 host. New markets tax credits have been combined with PPAs and public debt in other locations, such as Denver and Salt Lake City.

5.5.5 Solar Services Agreement and Operating Lease

The solar services agreement (SSA) and operating lease business models have been predominately used in the municipal and cooperative utility markets due its treatment of tax benefits and the rules limiting federal tax benefit transfers from nonprofit 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 as a workaround to this issue. One model is the solar services agreement, 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 nonprofit utility typically purchases the solar services with either a one-time, up-front payment equal to the turn-key system cost minus the 30% federal tax credit or purchases 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., the SSA 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.

5.5.6 Sale/Leaseback

In the widely accepted sale/leaseback 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.

5.5.7 Community Solar Gardens/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 prorated share of the project's energy output. This business model is targeted to meet demand for solar projects by customers who rent/lease homes or business, do not have good solar access at their site, or do not want to install a solar system on their facilities. Customer prorated shares of solar projects are acquired through a long-term transferrable lease of one or more panels, or they subscribe 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 prorated 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/month blocks) from the community solar project. Other models include monthly energy outputs from a specific investment dollar amount or a specific number of panels.

Community solar garden 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 state (production incentive) and Utah (state income tax credit). Community solar is also known as solar gardens depending on the location (e.g., Colorado).

6 Conclusions and Recommendations

The site locations considered for a solar PV system in this report have various qualities that make them feasible areas in which to implement solar PV systems. Following analysis of three site scenarios, including installing a 2.2-MW system on the cap-rock areas of the site, installing a 4.6-MW system on all existing flat and unshaded areas of the site, and installing thin-film geomembrane cap system on the Eden and Lowell piles as part of a remediation strategy, it was determined that only the first is economically viable at this time. Installing a PV system on flat waste-rock land at the site could generate approximately 2,879,581 kWh annually and 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 currently abandoned mine site.

As summarized in Section 5, the economic analysis completed using SAM predicts an IRR and LCOE of 24.08% and $0.2332/kWh, respectively. A 2.2-MW fixed-tilt system installed at the site would have an after-tax NPV of $2,189,995 and represents a good value for the site. This option is seen as having the most likely feasible installation and maintenance strategy given the current conditions of the site and current expectations for potential future remediation.

It should be noted that this analysis assumes that the current potential level of contamination on the proposed cap-rock land area can be mitigated through various construction and safety solutions combined with a ballasted PV system for an approximate increased cost of 20% over national averages for ballasted systems. If the premium were to be greater than a 20%, the NPV and after-tax IRR would decrease accordingly.

It is recommended that the interested site parties move forward with additional investigation as to whether or not it is possible to install a system on the waste-rock area of the VAG Mine site given current ground contamination conditions. If feasible, a request for proposals should be developed to determine whether or not a developer may be interested in undertaking this project. This work should be done soon to take advantage of the current Vermont SPEED standard offer program. As appropriate, the site should work to submit an application to Vermont SPEED for consideration as part of the 2013 site selection process. 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 price per kilowatt-hour. Careful consideration will also need to be made as to the safety of the construction workers installing the PV system on the site prior to remediation strategies. 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.

For multiple reasons—the high cost of energy, the dropping cost of PV, and the existence of a reasonable solar resource—this report finds that a PV system is a reasonable use for the site when partnered with the Vermont SPEED standard offer.

Appendix A. Provided Site Information

Several studies and evaluations of the VAG mine site located on Belvidere Mountain in Eden, Vermont, and Lowell, Vermont, have been conducted and provide extensive and valuable information regarding the history, current condition, and potential remediation strategies being considered. The following is a brief summary of some of the resources used in the development of this report.

- EPA Waste Site Cleanup & Reuse in New England/VAG Mine Site

  http://www.epa.gov/region1/removal-sites/VAGMineSite.html

- University of Vermont, Department of Geology Summary of Mine Site Mineralogy

  http://www.uvm.edu/~gdrusche/Mineralogy%20of%20VAG%20mine%20waste_VGS%20talk.pdf

- State of Vermont Waste Management Division Vermont Asbestos Group Mine

  http://www.anr.state.vt.us/dec/wastediv/sms/VAG.htm

- Program Case for Pursuing Superfund Listing of the VAG Mine

  http://www.anr.state.vt.us/dec/wastediv/sms/VAG/0423.final.caseforsuperfund.figures.appendicies.pdf

- Rejecting Superfund Status Puts End To Asbestos Cleanup, Vermont Public Radio News

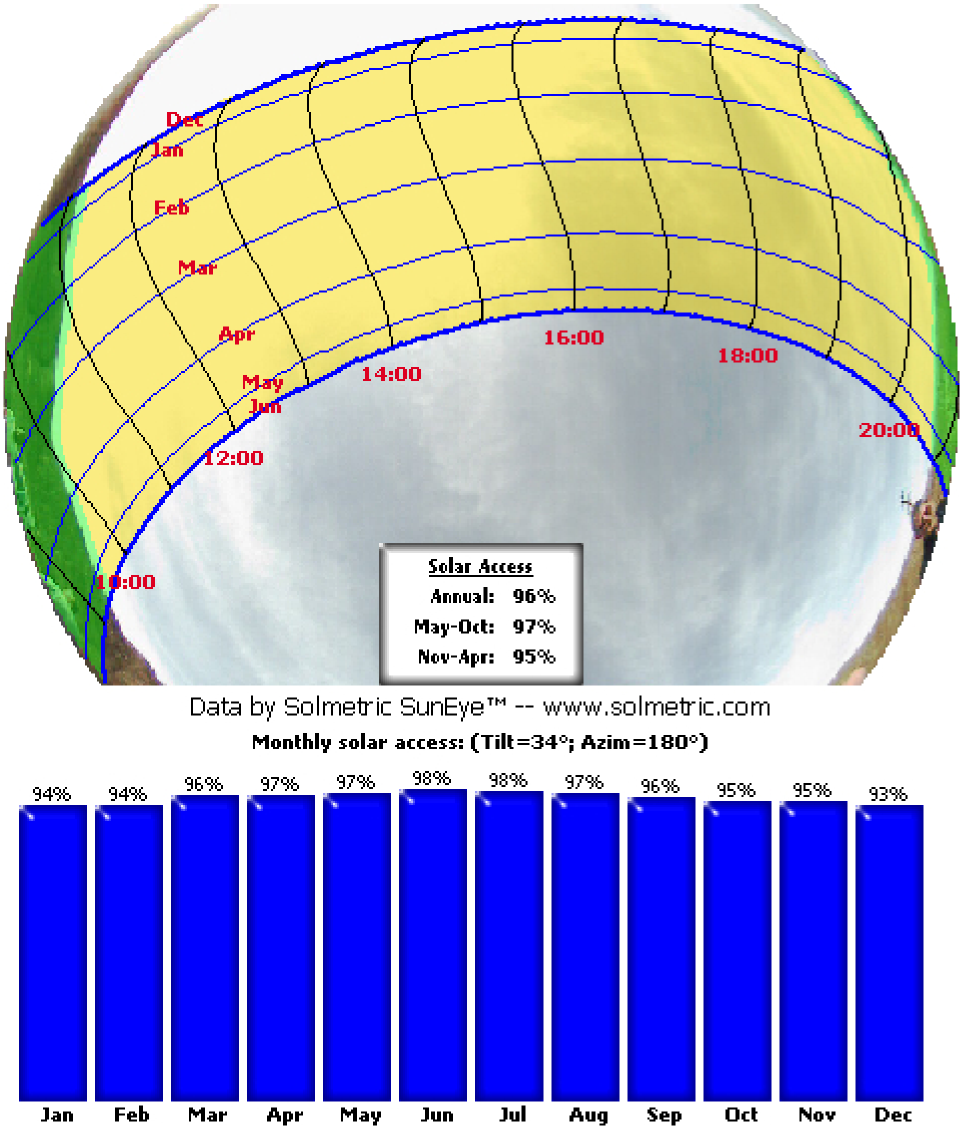
  http://www.vpr.net/news_detail/93698/rejecting-superfund-status-puts-end-to-asbestos-cl/

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	N/A	$/kWh
Annual O&M (fixed)	20	$/kW/year
Annual O&M (single)	22	$/kW/year
Other Assumptions		
	1 acre	43,560 ft^2
	1 MW	1,000,000 W
	Ground utilization	90% of available area

Appendix C. Solar Access Measurements



Data by Solmetric SunEye™ -- www.solmetric.com

Figure C-1. Solar access measurements for the VAG Mine PV site

Appendix D. Results of the JEDI Model

Table D-1. PV Data Summary

Photovoltaic—Project Data Summary Based on Model Default Values	
Project Location	Vermont
Year of Construction or Installation	2013
Average System Size—DC Nameplate Capacity (kW)	2,200
Number of Systems Installed	1
Total Project Size—DC Nameplate Capacity (kW)	2,200
System Application	Large Commercial
Solar Cell/Module Material	Crystalline Silicon
System Tracking	Fixed Mount
Base Installed System Cost ($/kWDC)	$3,340
Annual Direct Operations and Maintenance Cost ($/kW)	$20.00
Money Value—Current or Constant (Dollar Year)	2013
Project Construction or Installation Cost	$7,348,000
Local Spending	$4,394,694
Total Annual Operational Expenses	$896,368
Direct Operating and Maintenance Costs	$44,000
Local Spending	$40,480
Other Annual Costs	$852,368
Local Spending	$0
Debt Payments	$0
Property Taxes	$0

Local Economic Impacts—Summary Results

During construction and installation period	**Jobs**	**Earnings** $000 (2013)	**Output** $000 (2013)
Project Development and On-Site Labor Impacts			
Construction and Installation Labor	10.8	$697.20	
Construction and Installation-Related Services	16.8	$634.60	
Subtotal	27.6	$1,331.80	$2,415.50

Module and Supply Chain Impacts			
Manufacturing	0.0	$0.00	$0.0
Trade (Wholesale and Retail)	6.6	$336.50	$994.20
Finance, Insurance, and Real Estate	0.0	$0.00	$0.00
Professional Services	5.0	$176.10	$592.20
Other Services	4.8	$326.40	$1,092.60
Other Sectors	10.3	$232.50	$628.70
Subtotal	26.7	$1,071.50	$3,307.80
Induced Impacts	16.1	$525.50	$1,781.80
Total Impacts	**70.3**	**$2,928.80**	**$7,505.00**

During operating years	**Annual Jobs**	**Annual Earnings $000 (2013)**	**Annual Output $000 (2013)**
On-Site Labor Impacts			
PV Project Labor Only	0.4	$24.50	$24.50
Local Revenue and Supply Chain Impacts	0.1	$6.70	$21.30
Induced Impacts	0.1	$3.40	$11.60
Total Impacts	**0.7**	**$34.60**	**$57.40**

Notes: Earnings and output values are thousands of dollars in year 2013 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 and Equipment			
Mounting (rails, clamps, fittings, etc.)	$320,910	100%	N
Modules	$2,664,735	100%	N
Electrical (wire, connectors, breakers, etc.)	$225,035	100%	N
Inverter	$480,952	100%	N
Subtotal	$3,691,633		
Labor			
Installation	$697,204	100%	
Subtotal	$697,204		
Subtotal	$4,388,837		
Other Costs			
Permitting	$795,600	100%	

Other Costs	$324,735	100%
Business Overhead	$1,838,829	100%
Subtotal	$2,959,163	
Subtotal	$7,348,000	
Sales Tax (Materials and Equipment Purchases)	$0	100%
Total	$7,348,000	

PV System Annual Operating and Maintenance Costs	**Cost**	**Local Share**
Labor		
Technicians	$26,400	100%
Subtotal	$26,400	
Materials and Services		
Materials and Equipment	$17,600	100%
Services	$0	100%
Subtotal	$17,600	
Sales Tax (Materials and Equipment Purchases)	$0	100%
Average Annual Payment (Interest and Principal)	$852,368	0%
Property Taxes	$0	100%
Total	**$896,368**	

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)	0%	

Local Property Taxes	$0	100%
Local Sales Tax Rate	6.00%	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 System Advisor Model

Table E-1. SAM Results

	2.2 MW Fixed-Axis System	2.2 MW Single-Axis System	6.4 MW Fixed-Axis System	6.4 MW Single-Axis System	11.6 MW Thin-Film System
Metric	Base	Base	Base	Base	Base
Net Annual Energy	2,879,581 kWh	3,592,714 kWh	8,386,344 kWh	10,462,389 kWh	16,456,059 kWh
PPA price	27.00 ¢/kWh	27.00 ¢/kWh	13.00 ¢/kWh	13.00 ¢/kWh	13.00 ¢/kWh
LCOE Nominal	27.00 ¢/kWh	27.00 ¢/kWh	13.00 ¢/kWh	13.00 ¢/kWh	13.00 ¢/kWh
LCOE Real	23.32 ¢/kWh	23.32 ¢/kWh	11.23 ¢/kWh	11.23 ¢/kWh	11.23 ¢/kWh
After-tax IRR	24.08%	26.11%	3.46%	5.28%	5.74%
Pre-tax min DSCR	1.37	1.46	0.69	0.74	0.76
After-tax NPV	$2,189,995.03	$3,012,237.96	($913,636.00)	($490,451.10)	($510,574.14)
PPA price escalation	0.00%	0.00%	0.00%	0.00%	0.00%
Debt Fraction	55.00%	55.00%	55.00%	55.00%	55.00%
Capacity Factor	15.00%	18.70%	15.00%	18.70%	16.10%
First year kWhac/kWdc	1,310	1,635	1,310	1,635	1,414
System Performance Factor	0.88	0.89	0.88	0.89	0.95