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Feasibility Study of Economics and Performance of Solar Photovoltaics at the Kolthoff Landfill in Cleveland, Ohio

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

James Salasovich, Jesse Geiger, Gail Mosey, and Victoria Healey

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.

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Technical Report
NREL/TP-7A40-58760
June 2013

Contract No. DE-AC36-08GO28308

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List of Acronyms

AC	alternating current
a-Si	amorphous silicon
BOS	balance of system
CdTe	cadmium telluride
DC	direct current
EPA	U.S. Environmental Protection Agency
FTE	full-time equivalent
HVAC	heating, ventilation, and air conditioning
JEDI	Jobs and Economic Development Impact
LCOE	levelized cost of energy
NREL	National Renewable Energy Laboratory
O&M	operations and maintenance
NPV	net present value
PPA	power purchase agreement
PV	photovoltaic
REC	renewable energy certificate
SAM	System Advisor Model
SPE	special purpose entity
SREC	solar renewable energy certificate
SSA	solar services agreement
VNM	virtual net metering

Executive Summary

The U.S. Environmental Protection Agency (EPA), Region 5, in accordance with the RE-Powering America's Land initiative, selected the Kolthoff Landfill site in Cleveland, Ohio, 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 Kolthoff Landfill is owned by the City of Cleveland and is classified as a brownfield site. The Kolthoff Landfill is approximately 48 acres, which includes the former Brook Park Landfill to the west (30 acres) and the former wastewater treatment plant to the east (18 acres). The landfill is inactive, and there are no major contamination issues that need to be addressed. In 2011, the Clean Ohio Assistance Fund grants awarded a $299,377 grant to the City of Cleveland to conduct a Phase II assessment of the Kolthoff Landfill property. The Phase II assessment includes installing 51 test pits, 14 monitoring wells, and 10 soil vapor probes and collecting 123 soil samples. The Phase II assessment will help to determine the environmental stability of the landfill.[1]

The feasibility of a PV system installed 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 the landfill site impact the feasibility of a PV system. Based on an assessment of these factors, the Kolthoff Landfill meets the first level of requirements for deployment of a large-scale PV system.

Out of the 30-acre Kolthoff Landfill, 12.8 acres are feasible for installing ground-mounted PV; 5.0 acres out of the 18-acre former wastewater treatment plant are feasible for installing ground-mounted PV. The construction of a hotel on the former wastewater treatment area has been proposed as a possible future reuse of the land. If a hotel were to be built, it was assumed that the footprint of the hotel would be approximately 11,000 ft^2. Both the 12.8-acre and the 5.0-acre areas are generally flat, and a majority of the area is cleared of trees and other possible shading obstructions. While this entire area does not need to be developed at one time due to the feasibility of staging installation as land or funding becomes available, calculations for this analysis reflect the solar potential if the total feasible area is used. The remaining area is not feasible for PV because it is either shaded, sloped, or both.

The potential PV system on Kolthoff Landfill depends on the purchase price of renewable energy certificates (RECs) as well as the utility sale price for electricity generated. The economics of the potential system were analyzed using the current average REC purchase price of $0.035/kWh for 10 years and an expected electricity generated purchase rate from FirstEnergy at $0.12/kWh. The incentives considered include the federal 30% of installed cost tax credit; Ohio Qualified Energy Property Tax Exemption of approximately 100% of the increased value attributed to a solar

[1] The Ohio Senate. "Senator Skindell Announces Clean Ohio Funds for Cleveland," 2011September 12. Accessed December 2012: http://www.ohiosenate.gov/skindell/press/senator-skindell-announces-clean-ohio-funds-for-cleveland.

system; and the Ohio Sales Tax Exemption of 100% of sales tax for all related solar equipment. Table ES-1 summarizes the system performance and economics of a potential system that would use all available areas that were surveyed at the landfill plus the potential roof area that could contain PV panels. The table shows the annual energy output from the system along with the number of average American households that could be powered off of such a system and estimated job creation.

As indicated in Table ES-1, the single-axis ground system is expected to have a payback of 13.3 years and a net present value of $162,619 for a 2,557-kW PV system producing approximately 3,617,495 kWh estimated annual energy generation. These indicators are in the range of what is typically considered economically attractive. This includes the current cost of energy, expected installation cost, site solar resource, and existing incentives for the proposed PV system.

Table ES-1. Price Landfill PV System Summary

System Type	PV System Size[a] (kW)	Array Tilt (deg)	Annual Output (kWh/year)	Number of Houses Powered[b]	Jobs Created[c] (job-year)	Jobs Sustained[d] (job-year)
Crystalline Silicon - 1-Axis Ground System	2,557	20	3,617,495	635	94.0	1.0
Crystalline Silicon - Fixed-Axis Ground System	3,101	21	3,533,062	620	76.7	1.2
Crystalline Silicon - Fixed Roof Mounted System	22	22	25,065	4	0.6	0

System Type	System Cost	Maximum Incentive Amount	PPA Price ¢/kWh	Net Present Value 2012$	Annual O&M ($/year)	Payback Period with Incentives (years)
Crystalline Silicon - 1-Axis Ground System	$ 10,529,140	$ 3,158,742	16.14	$ 162,619	$ 51,140	13.30
Crystalline Silicon - Fixed-Axis Ground System	$ 11,072,490	$ 3,321,747	17.95	$ (221,179)	$ 62,020	15.04
Crystalline Silicon - Fixed Roof Mounted System	$ 61,380	$ 18,414	13.49	$ 5,003	$ 440	10.94

a Data assume a maximum usable area of 17.8 acres

b Number of average American households that could hypothetically be powered by the PV system assuming 5,700 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.

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1 Study and Site Background

The U.S. Environmental Protection Agency (EPA), Region 5, in accordance with the RE-Powering America's Land initiative, selected the Kolthoff Landfill site in Cleveland, Ohio, 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 Kolthoff Landfill is located in Cleveland, Ohio, and is in close proximity to the Cleveland Hopkins International Airport. The Kolthoff Landfill is approximately 10.5 miles to the southwest of the city center. Cleveland has a population of 396,815 as of the 2010 census. Cleveland has on average approximately 163 sunny days per year, and the climate is hot and humid in the summer and cold in the winter. FirstEnergy is the energy provider to Cleveland; it is an unregulated utility that is investor owned.

FirstEnergy owns the transmission lines that run through the site. The IX Center Drive Substation is located right across the street from the site and is less than 200 feet to the north of the Kolthoff Landfill. Interconnection is governed by FirstEnergy. Performing an interconnection study can be a relatively slow process that would have to be performed through FirstEnergy and could involve considerable cost. Performing a detailed interconnection study is beyond the scope of this project, but FirstEnergy should be contacted to determine the extent of effort involved. There is currently no major electrical load at the site. There are surrounding buildings that could be potential off-takers of electricity produced by a utility-scale PV system.

The Kolthoff Landfill is owned by the City of Cleveland and is approximately 48 acres, which includes the former Brook Park Landfill to the west (30 acres) and the former wastewater treatment plant to the east (18 acres). The City of Cleveland is interested in utilizing the currently underutilized site for solar PV in order to minimize its impact on the environment.

The Kolthoff Landfill is capped with a clay cap that is 3 feet deep, which should not be disturbed. There are some trees on the site, and most of the settling at the landfill has occurred. The landfill is a pre-regulatory landfill, and there are no major environmental issues at the site. There is no pump and treat system on site.

Feasibility assessment team members from NREL and EPA conducted a site visit on August 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 Brownfield Sites

Through the RE-Powering America's Lands initiative, EPA has identified several benefits for siting solar PV facilities on brownfield sites, 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 might be adequately zoned for renewable energy
- Generally are located near existing roads and energy transmission or distribution infrastructure
- Could provide an economically viable reuse for sites that 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 Kolthoff Landfill is owned by the City of Cleveland, which is interested in potential revenue flows on the site. For many brownfield sites, the local community has 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. The City Solar project in Chicago, Illinois, is the largest urban PV system in the United States, and it is built on a brownfield site. The brownfield site is a former industrial site that has been vacant for 30 years. The 41-acre site is comparable to the areas available at the Kolthoff Landfill, and the site is owned by the City of Chicago, who leases the land to a solar developer. The City Solar project was completed in 2010 and is a 10-MW single-axis tracking system.[2]

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. The construction of a hotel on the east side of the site is being considered.

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

[2] Exelon. "Exelon City Solar." Accessed July 2012: http://www.exeloncorp.com/PowerPlants/exeloncitysolar/Pages/Profile.aspx.

- 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., a light bulb).

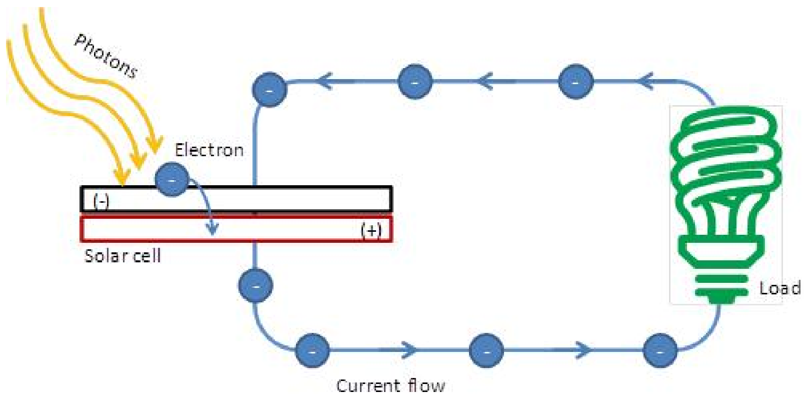

Figure 1. Generation of electricity from a PV cell

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

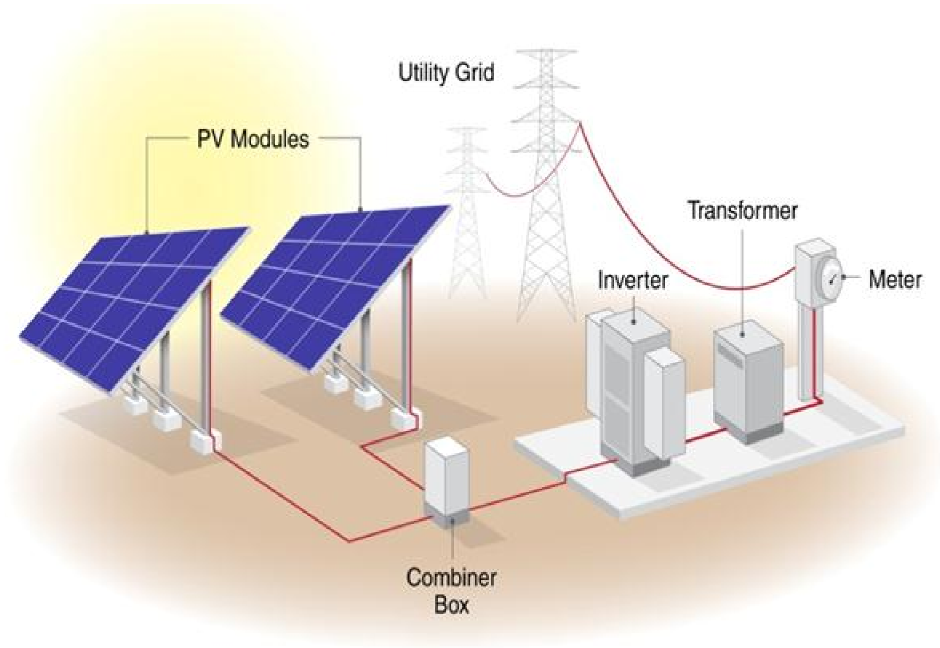

Figure 2. Ground-mounted array diagram

Source: NREL

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

- PV modules
- Inverter
- Balance-of-system (BOS) 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 been demonstrated to be functional 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 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.

Figure 3. 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 the unique nature of thin films, some thin-film cells are constructed into flexible modules, enabling 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 for 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.

Figure 4. Thin-film solar panels installed on (left) solar energy cover and (middle/right) fixed-tilt mounting system. ***Pictures from (left) Republic Services, Inc., NREL 23817; (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 could 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 might be recommended for different types of installations.

String inverters are most common and typically range in size from 1.5–1,000 kW. These inverters tend to be cheaper on a capacity basis, as well as 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 5 and 10 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 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 in limited use in larger systems due to a 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. Instead, only the shaded panels are affected if micro-inverters are used. Figure 5 shows a string inverter.

Figure 5. 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

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 range 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 Superfund site 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 Superfund sites. Fixed-tilt systems 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, the physical packing density of tracking arrays is not as high as fixed-tilt systems, and therefore the energy density for a fixed-tilt system is higher. Depending on underlying soiling conditions, single- and dual-axis trackers might not be suitable due to potential settlement effects, which can interfere with the alignment requirements of such systems.

Table 1. Energy Density by Panel and System

System Type	Fixed-Tilt Energy Density (DC-Watts/ft²)	Single-Axis Tracking Energy Density (DC-Watts/ft²)
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 could 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.

3.2.3.1.2 Roof-Mounted Systems

At the Kolthoff Landfill site, there is the potential to use the roof area of a future hotel building for PV. Installing PV on rooftops has many of the same considerations as installing ground-mounted PV systems. Factors, such as available area for an array, solar resource, shading, distance to transmission lines, and distance to major roads at the site, are just as important in roof-mounted systems as in ground-mounted systems. Rooftop systems can be ballasted or fixed to the roof, and it is recommended that the roof be relatively new (less than 5 years old) to avoid having to move the PV system in order to repair or replace the roof.

The Kolthoff Landfill has the potential to have new construction buildings on site. There are many relatively easy low-cost/no-cost measures that can be taken during the design phase so that the buildings are optimally built for rooftop PV systems. Design strategies, such as orienting the buildings so that the southern exposure is maximized and reducing the amount of mechanical equipment on the roof, are examples of measures that can be taken to optimize rooftop PV systems. A solar-ready design guide was published in order to help design teams optimize rooftop PV systems when designing buildings.[3] Table 2 shows the rooftop PV energy density. As shown, the energy density for rooftop PV systems is higher than ground mounted. This is because the spacing between rows of PV arrays in a ground-mounted system is typically larger than a rooftop system because maintenance trucks have to be able to drive in between the rows of PV panels.

[3] This guide can be found at www.nrel.gov/docs/fy10osti/46078.pdf.

Table 2. Rooftop Energy Density by Panel

System Type	Fixed-Tilt Energy Density (DC-Watts/ft^2)
Crystalline Silicon	10.0
Thin Film	4.3

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 Superfund site applications, this wiring could 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 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 and identification of under-performing arrays. Operators can also use this data to identify required maintenance, shade on panels, and accumulating 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. Inverters, which come standard with a 5-year or 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. In addition, the system should expect a replacement of system inverters in year 15 at a cost of $0.25/W.

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 all 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 determination that the site is adequate for a solar installation, an analysis to determine the ideal system size must be conducted. System size depends highly 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 August 30, 2012.

4.1 Kolthoff Landfill Site PV System

As discussed in Section 1, the Kolthoff Landfill site is owned by the City of Cleveland, and the landfill has no major environmental issues. Figure 6 shows an aerial view of the Kolthoff Landfill and the former wastewater treatment plant to the east. Both the Kolthoff Landfill and former wastewater treatment plant areas are potentially available for the installation of a PV system.

Figure 6. Aerial view of the Kolthoff Landfill and former wastewater plant (shaded in gray)

Illustration done in 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 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 Kolthoff Landfill and the former wastewater treatment plant site taken from Google Earth; the feasible area for ground-mounted PV is shaded in yellow, and the feasible area for roof-mounted PV is shaded in orange. As shown, 12.8 acres out of the 30-acre Kolthoff Landfill are feasible for installing ground-mounted PV, and 5.0 acres out of the 18-acre former wastewater treatment plant are feasible for installing ground-mounted PV. The construction of a hotel on the former wastewater treatment area has been proposed as a possible future reuse of the land. If a hotel were to be built, it was assumed that the footprint of the hotel would be approximately 11,000 ft^2. Both the 12.8-acre and the 5.0-acre areas are generally flat, and a majority of the area is cleared of trees. Figure 8 shows a stand of trees towards the north of the 12.8-acre site that would have to be removed before installing PV. There is no major infrastructure on either area.

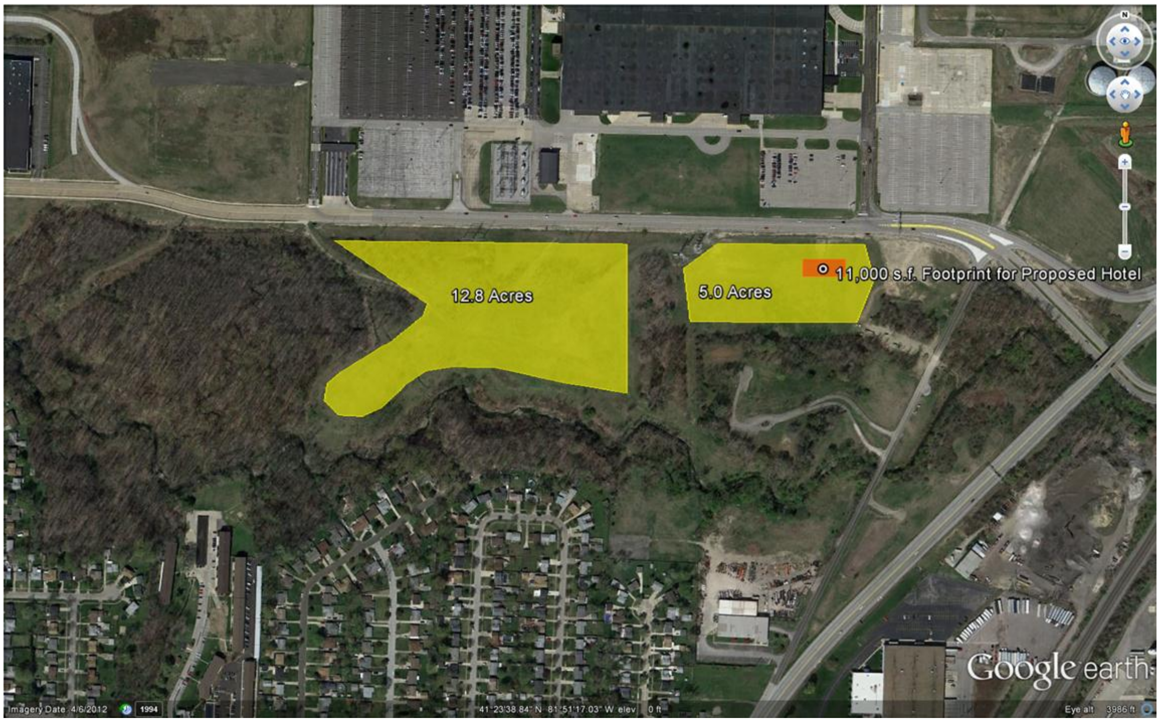

Figure 7. Aerial view of the current feasible area for PV at the Kolthoff Landfill and former wastewater plant (ground-mounted PV shaded in yellow and roof-mounted PV shaded in orange)

Illustration done in Google Earth

Figure 8. Trees that would have to be removed on the Kolthoff Landfill prior to PV installation. ***Photo by James Salasovich, NREL***

PV systems are relatively well suited to the Cleveland, Ohio, 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 4.15 kWh/m2/day.

Figure 9 shows various views of the Kolthoff Landfill site and the former wastewater treatment plant site. As shown, there are minimal shading obstructions, such as trees, that will have to be removed and both sites are relatively flat.

Figure 9. Views of the feasible area for PV at the approximate center of the Kolthoff Landfill. ***Photos by James Salasovich, NREL***

4.2 Utility-Resource Considerations

The closest electrical tie-in point for a PV system at the Kolthoff Landfill site is located less than 200 feet to the north of the site at the IX Center Drive Substation. There are also transmission lines that bisect the site running north-south and also transmission lines along the northern boundary of the site that run east-west. FirstEnergy owns both the IX Center Drive Substation and both sets of transmission lines that run through the site. The location of the IX Center Drive Substation relative to the Kolthoff Landfill and the transmission lines that run through the site are shown in Figure 10. Photos of the IX Center Drive Substation and the transmission lines are given in Figure 11. Interconnection is governed by FirstEnergy. A detailed interconnection study would have to be performed in order to determine if this would be a suitable location for interconnection. Performing an interconnection study can be a relatively slow process that would have to be performed through FirstEnergy and could involve considerable cost. The tie-in location is limited by the available capacity at the substation. When considering a ground-mounted system, an electrical tie-in location should be identified to determine how the energy would be fed back into the grid. Performing a detailed interconnection study is beyond the scope of this project, but FirstEnergy should be contacted to determine the extent of effort involved.

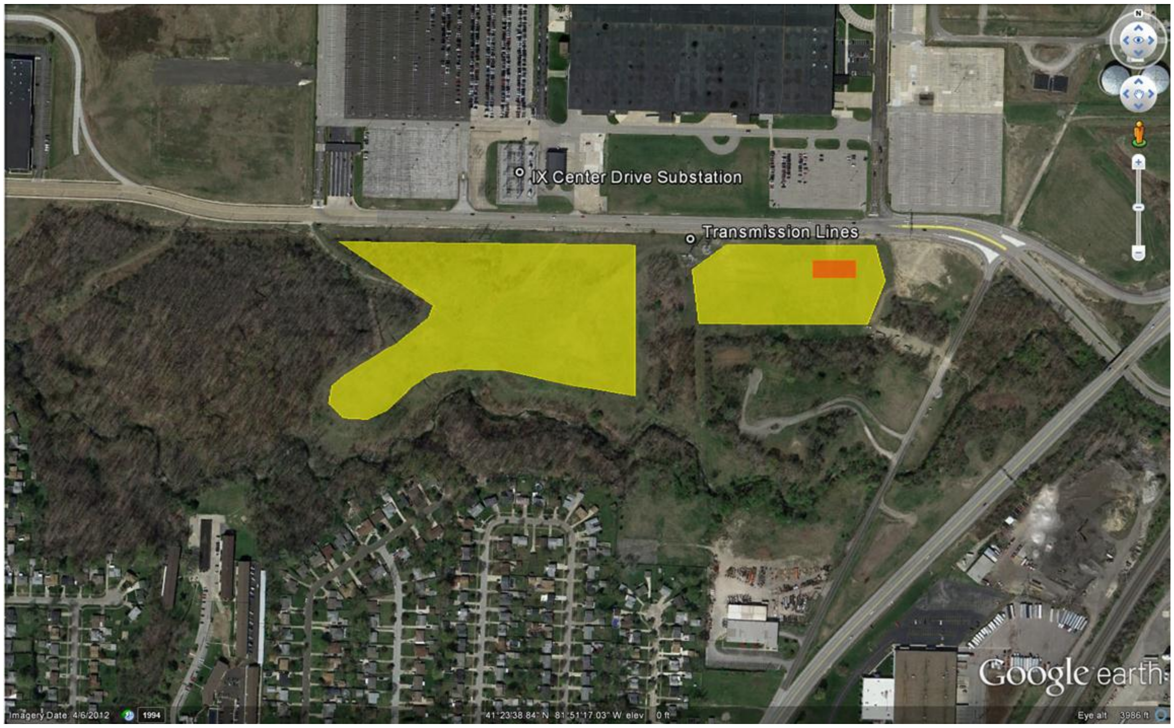

Figure 10. Kolthoff Landfill showing IX Center Drive Substation and the transmission lines

Illustration done in Google Earth

Figure 11. IX Center Drive Substation and electrical transmission lines at the Kolthoff Landfill. ***Photos by James Salasovich, NREL***

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 under-utilized 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 Kolthoff Landfill site has been evaluated to determine the adequacy of the solar resource available using both on-site data and industry tools. A site with a solar access of 90% or higher is considered to be a good site for PV.

The assessment team for this feasibility study collected multiple Solmetric SunEye data points and found a solar access of 90% and above on the 12.8-acre Kolthoff Landfill area and on the 5.0-acre former wastewater treatment plant. All data gathered using this tool is available in Appendix C.

The predicted array performance was found using PVWatts Version 2 for Cleveland, Ohio, weather hourly weather data. [4] 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.

Table 3. Site Identification Information and Specifications

Station Identification	
Cell ID	14820
City	Cleveland
State	Ohio
Latitude	41.40° N
Longitude	81.85° 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	20°
Array Azimuth	South
Energy Specifications	
Cost of Electricity	$0.12/kWh

Table 3 shows the performance results for a 20-degree fixed-tilt PV system in Cleveland, Ohio, as calculated by PVWatts.

[4] PVWatts. Accessed May 17, 2013: http://www.nrel.gov/rredc/pvwatts/.

Table 4. Performance Results for 20-Degree Fixed-Tilt PV

Month	Solar Radiation (kWh/m^2/day)	AC Energy (kWh)	Energy Value ($)
1	2.14	54	6.48
2	2.98	68	8.16
3	3.91	97	11.64
4	5.05	118	14.16
5	5.92	137	16.44
6	6.19	134	16.08
7	6.08	135	16.20
8	5.68	127	15.24
9	4.77	106	12.72
10	3.57	84	10.08
11	1.96	44	5.28
12	1.50	35	4.20
Year	4.15	1,139	136.68

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

Table 5. Performance Results for Zero-Degree Single-Axis PV

Month	Solar Radiation (kWh/m^2/day)	AC Energy (kWh)	Energy Value ($)
1	2.06	52	6.24
2	3.07	71	8.52
3	4.23	108	12.96
4	5.97	142	17.04
5	7.25	171	20.52
6	7.81	173	20.76
7	7.55	172	20.64
8	6.82	156	18.72
9	5.42	122	14.64
10	3.72	89	10.68
11	1.89	42	5.04
12	1.40	32	3.84
Year	4.78	1,329	159.48

4.5 Kolthoff Landfill Energy Usage

The electrical load at the Kolthoff Landfill is currently relatively small. Monthly electric bills showing the electricity usage and cost are not available. It is important to understand the energy use of the site to enable for a full analysis of whether or not energy produced would need to be sold or if it could offset on-site energy use. There are currently no buildings on the site that use electricity. There are also surrounding buildings that could be potential off-takers of electricity produced by a utility-scale PV system. There is the possibility of a hotel being built on the former wastewater treatment plant to the east.

4.5.1 Estimated Future Energy Use and Net-Zero Energy Potential

4.5.1.1 Hotel Building Assuming an 11,000-ft^2 Footprint

The buildout of the former wastewater treatment site that could have a hotel on-site has not yet been designed, and therefore no drawings for the potential future buildout of the site are available. The footprint of the hotel was assumed to be 11,000 ft^2, and the hotel was assumed to be four stories, which totals 44,000 ft^2. Details of the energy model are given in Appendix F.

The future energy use of a hotel sited on the former wastewater treatment plant area was estimated by creating an eQUEST building energy model of a typical hotel building. It is important to note that the hotel was assumed to be an all-electric building with an air-source heat pump and to be an energy efficient building with tight construction, low lighting, and plug load energy use. Using the energy model, the total annual energy use of the hotel is estimated to be approximately 366,457 kWh/yr. In order for the hotel to be net-zero, a 322-kW PV system would have to be installed to offset the energy use of the buildings, which assumes the solar PV system offsets all of the building energy use.

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 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.

Ohio's net-metering law, which took effect in 1999, requires utilities to offer net metering to all customers with PV, solar thermal electric, wind, hydroelectric, biomass, landfill gas, micro-turbines, and fuel cells. There is no system capacity limit in Ohio, but the system size cannot exceed the customer’s annual on-site energy use.

Renewable energy certificates (RECs),[5] 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 remaining after a 12-month period, the utility will be granted the RECs associated with only that surplus they purchase.

In 2008, Ohio enacted legislation that addresses the renewable energy procurement requirements for the state's utilities. The DSIRE[6] website provides a good summary of the renewable portfolio standard in Ohio.

> Under the standard, utilities must provide 25% of their retail electricity supply from alternative energy resources by 2025, with specific annual benchmarks for renewable and solar energy resources. Half of the standard can be met with "any new, retrofitted, refueled, or repowered generating facility located in Ohio," including fossil fuels, making the renewables portion of the standard 12.5% renewables by 2025.

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 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. Ohio is not one of seven states (California, Colorado, Connecticut, Delaware, Massachusetts, New Jersey, and Pennsylvania) that currently allow VNM.

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

[6] For a full description of the renewable portfolio standard in Ohio, see http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=OH14R&re=0&ee=0.

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 NREL's System Advisor Model (SAM).[7]

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. 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.

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.

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

The 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 $2.79/W in the first quarter of 2012. With an increasing demand and supply, potential of further cost reduction is expected as market conditions evolve.

The installed system cost assumptions are summarized in Table 6. For this analysis the market installed cost of fixed-tilt ground-mounted systems was assumed to be $2.79/W, and the market installed cost of single-axis tracking was assumed to be $3.35/W. This represents the best-case scenario for purchasing and labor costs before the extra cost of ballasting the system for a landfill because ground disturbance must be kept to a minimum. Because the site will likely require ballasting the system in order to minimize site disturbance, a 20% extra cost was added. These costs represent remediation consideration cost case scenarios for PV installation price on EPA landfills. The roof system will not include the ballasted cost and is expected to have the same cost as the fixed-axis system.

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

Table 6. Installed System Cost Assumptions

System Type	Fixed Tilt ($/W)	Single-Axis Tracking ($/W)
Baseline System	2.79	3.35
+ 20% Ballast	+0.56	+0.67
Ballasted Ground-Mounted System	3.49	4.02

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 cost for electrical tie-in was also modeled at $250,000.

The economics of grid-tied PV also depend on incentives, the cost of electricity, the solar resource, and panel tilt and orientation.

It was assumed for this analysis that relevant federal and state incentives are received for taxable entities. 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 could qualify for federal tax credits and accelerated depreciation on the PV system, which can be worth about 30% of the initial capital investment. The total potential tax benefits to the tax-paying entity can be as high as 43% 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 the systems can be reasonably expected to continue operation past this point. A full list of standard assumptions can be found in Appendix B-1. The electrical utility Ohio Edison is expected to supply energy to the site under the general demand rate schedule. This schedule is estimated to be, on average over the year, $0.12/kWh. For the sale of electricity, the site is expected to be able to take advantage of the net-metering incentive that allows the site to sell their electricity at the rate it was purchased. However, the size of the system will be limited to the expected energy of the proposed building. Because there is no current demand on site, it was modeled that all PV-generated electricity would be sold to Ohio Edison at the sale rate. Once there is a demand on site, the PV system should be sized to that load size. For the purposes of modeling how much PV could cover rooftops, it was assumed that 50% of roof space could contain PV. This roof coverage assumption is based on industry experience of what is feasible to cover in new development. The ground-mounted system is expected to cover 80% of the defined area, much of the uncovered area being for parking lots and utility structures. PVWatts Version 2 was used to calculate expected energy performance for the system.

The full list of incentives used in this study can be found in Table 7 with a summary and source list found in Appendix B-2. There are five policies listed below that can be applied to the Cleveland site.

Table 7. Summary of Incentives Evaluated

Incentive Title	Modeled Benefit	Expected End
Federal Investment Tax Credit	30% of total investment	1/1/2016
Solar Renewable Energy Certificates (SRECs)	$0.035/kWh	N/A
Property Tax Incentive	~100% of added property value	N/A
Sales Tax Exemption	100% of sales tax	N/A
Net Metering	Available to annual energy usage size	N/A

5.2 SAM-Forecasted Economic Performance

SAM predicts net present value (NPV), PPA price, and levelized cost of energy (LCOE), among other economic indicators. Three separate scenarios were investigated using SAM: single-axis ground system, fixed-axis ground system, and fixed-axis roof system. According to the modeling software under the given assumptions, the single-axis ground system and fixed-axis roof system were economically viable and had paybacks within the 25-year timeframe. These scenarios were sized to completely fill the available land space, but in the future, any system should be sized to the energy load size. All of the different options have pros and cons, which will play in deciding the correct path forward. These advantages and disadvantages are discussed below. Table 8 shows an important results breakdown for the three scenarios.

Table 8. Results Summary of Simulations

Cases	LCOE ($/kWh)	NPV	PPA ($/kWh)
Crystalline Silicon – Single-Axis Ground-Mounted System	0.0963	$ 162,619	0.1614
Crystalline Silicon – Fixed-Axis Ground-Mounted System	0.1072	$ (221,179)	0.1795
Crystalline Silicon – Fixed-Tilt Roof-Mounted System	0.0806	$ 5,003	0.1349

Three scenarios total were run for the Kolthoff Landfill to encompass the many options available to this site. The independent variables include: fixed- and single-axis tracking for the ground portion and third-party developer versus site developer ownership. There are multiple factors that go into choosing which scenario to pursue beyond NPV, PPA, and LCOE.

5.2.1 Fixed-Axis vs. Single-Axis Tracking

The primary differences between fixed- and single-axis tracking are the tradeoff between energy production and capital costs. The single-axis tracking system is able to gather a significantly greater portion of the sun's energy but costs more per watt and covers a greater amount of land than a fixed-axis system of the same size. The fixed-axis system gathers less solar energy but costs less, can be put on roofs, and can pack more panels together than single-axis tracking. The single-axis tracking system is the only economically feasible ground system. If the fixed-axis price were to be $0.92/W lower than the single-axis price, the fixed-axis tracking system would become more favorable from an NPV basis. For this site, it is recommended to pursue single-axis tracking for the ground-mounted systems.

5.2.2 Solar Investor vs. Developer Owned

The choice between going with a solar investor or developer ownership will depend on the desire for involvement and the risk appetite of the developer. While ownership of the system will bring a payback for the developer, it will also require hiring contractors to permit, build, and maintain the system. A solar investor inherits the risks and profit, and the site owner in turn will purchase the power produced from the solar investor. It is recommended by the feasibility study group for the developer to own the system, considering the projected PPA price is above the estimated cost of electricity and ownership of the system has a positive NPV. The site would need to acquire a PPA price of less than the Ohio Edison cost for electricity to consider pursuing a PPA.

The entire graphical results and summary of inputs to SAM is available in Appendix B and Appendix C.

A complete summary of the results of the economic analysis and the system considered is available in Table 9.

Table 9. PV System Summary

Tie-In Location	System Type	PV System Size[a] (kW)	Array Tilt (deg)	Annual Output (kWh/year)	Number of Houses Powered[b]	Jobs Created[c] (job-year)	Jobs Sustained[d] (job-year)
	Crystalline Silicon - 1-Axis Ground System	2,557	20	3,617,495	635	94.0	1.0
	Crystalline Silicon - Fixed-Axis Ground System	3,101	21	3,533,062	620	76.7	1.2
	Crystalline Silicon - Fixed Roof Mounted System	22	22	25,065	4	0.6	0

Tie-In Location	System Type	System Cost	Maximum Incentive Amount	PPA Price ¢/kWh	Net Present Value 2012$	Annual O&M ($/year)	Payback Period with Incentives (years)
	Crystalline Silicon - 1-Axis Ground System	$ 10,529,140	$ 3,158,742	16.14	$ 162,619	$ 51,140	13.30
	Crystalline Silicon - Fixed-Axis Ground System	$ 11,072,490	$ 3,321,747	17.95	$ (221,179)	$ 62,020	15.04
	Crystalline Silicon - Fixed Roof Mounted System	$ 61,380	$ 18,414	13.49	$ 5,003	$ 440	10.94

a Data assume a maximum usable area of 17.8 acres

b Number of average American households that could hypothetically be powered by the PV system assuming 5,700 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.

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 are used.[8] JEDI estimates the economic impacts associated with the construction and operation of distributed generation power plants. It 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.

JEDI represents 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 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 JEDI to predict the jobs and economic impact. It is important to note that JEDI 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 results are considered gross estimates as opposed to net estimates.

For the Kolthoff Landfill the values in Table 10 were used for the JEDI model. These values are from the single axis tracking case which has the highest NPV.

Table 10. JEDI Analysis Assumptions

Input	Assumed Value
Capacity	2,557 kW
Placed In Service Year	2013
Installed System Cost	$10,529,140
Location	Cleveland, Ohio

Using these inputs, JEDI 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 40 hours per week for one person 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 analysis provided in Appendix F, the total proposed system is estimated to support 94 direct and indirect jobs per year for the duration of the procurement and construction period. Total wages paid to workers during

[8] JEDI has 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 JEDI, see http://www.nrel.gov/analysis/jedi/about_jedi.html.

the construction period are estimated to be $3,962,800, and total economic output is estimated to be $10,329,300. The annual O&M of the new PV system is estimated to support 1.0 FTE per year for the life of the system. The jobs and associated spending are projected to account for approximately $53,100 in earnings and $91,300 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 each owner's/operator's assets and equity in the project. In addition, private entities can utilize any of 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 program, 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.

5.4.2 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 term of a PPA typically varies from 20–25 years.

5.4.3 Third-Party "Flip" Agreements

The most common use of the third-party "flip" agreement 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 each investor's 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. 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 hosts. New markets tax credits have been combined with PPAs and public debt in other locations, such as Denver and Salt Lake City.

5.4.5 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 to its 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 as a work-around to 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 turn-key system cost minus the 30% federal tax credit or in annual installments. The municipality can 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).

5.4.6 Sales/Leaseback

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 sales/leaseback. Under the sales/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 can purchase the solar project at fair market value.

5.4.7 Community Solar/Solar Gardens

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 can 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 by customers who rent/lease their homes or businesses, do not have good solar access at their site, or do not want to install a solar system on their facilities. Customer pro-rated 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 pro-rated share of the solar project produces each month; it is also known as VNM. Under the customer subscription option, 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 a specific number of panels.

Community solar garden and customer subscription-based projects can be owned solely by the utility, owned solely by third-party developers with facilitation of billing provided by the utility, or 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 known as solar gardens depending on the location (e.g., Colorado).

6 Conclusions and Recommendations

The inclusion of PV in the development of the Kolthoff Landfill to offset any local load through the net-metering program is an economically feasible project. Installing a PV system on the Kolthoff Landfill could potentially generate nearly 3,617 MWh annually and represents a very large potential load on the site. A 22-kW roof-mounted system is the first priority in building a PV system because it has the best payback and LCOE

As summarized in Section 5, the SAM economic analysis predicts a positive NPV for both the single-axis tracking ground system and a roof-mounted system. The roof-mounted system could achieve an NPV of $5,000 and a payback of 10.9 years. The single-axis tracking ground system, if built to full land availability, could have an NPV as high as $162,619 and a payback of 13.3 years. In a solar investor/PPA case, the starting year PPA price is modeled to be less than $0.1349/kWh in the first year for a roof system and $0.1614/kWh for the single-axis ground system.

The report used an estimated utility rate of $0.12/kWh. If the utility rate were to be lower than $0.115/kWh, the single-axis tracking ground system would no longer be attractive. If the utility price was below $0.096/kWh, the roof-mounted system would no longer be economically attractive. Losing any of the currently available incentives will negatively affect the economics of this project.

This project is economically beneficial, and the City of Cleveland should weigh the value of this project against other projects to determine if a solar PV system at the Kolthoff Landfill would bring the highest value. Pursuing available grants and new incentives will make the value of a solar PV system even more economically attractive if those become available in the future.

Appendix A. Provided Site Information

Figure A-1 shows various areas at the site.

Figure A-1. Areas at the Kolthoff Landfill site

Source: Melissa Haney, Burgess and Niple

Appendix B. Solar Access Measurements

Figure B-1 shows solar access measurements for the Kolthoff Landfill site.

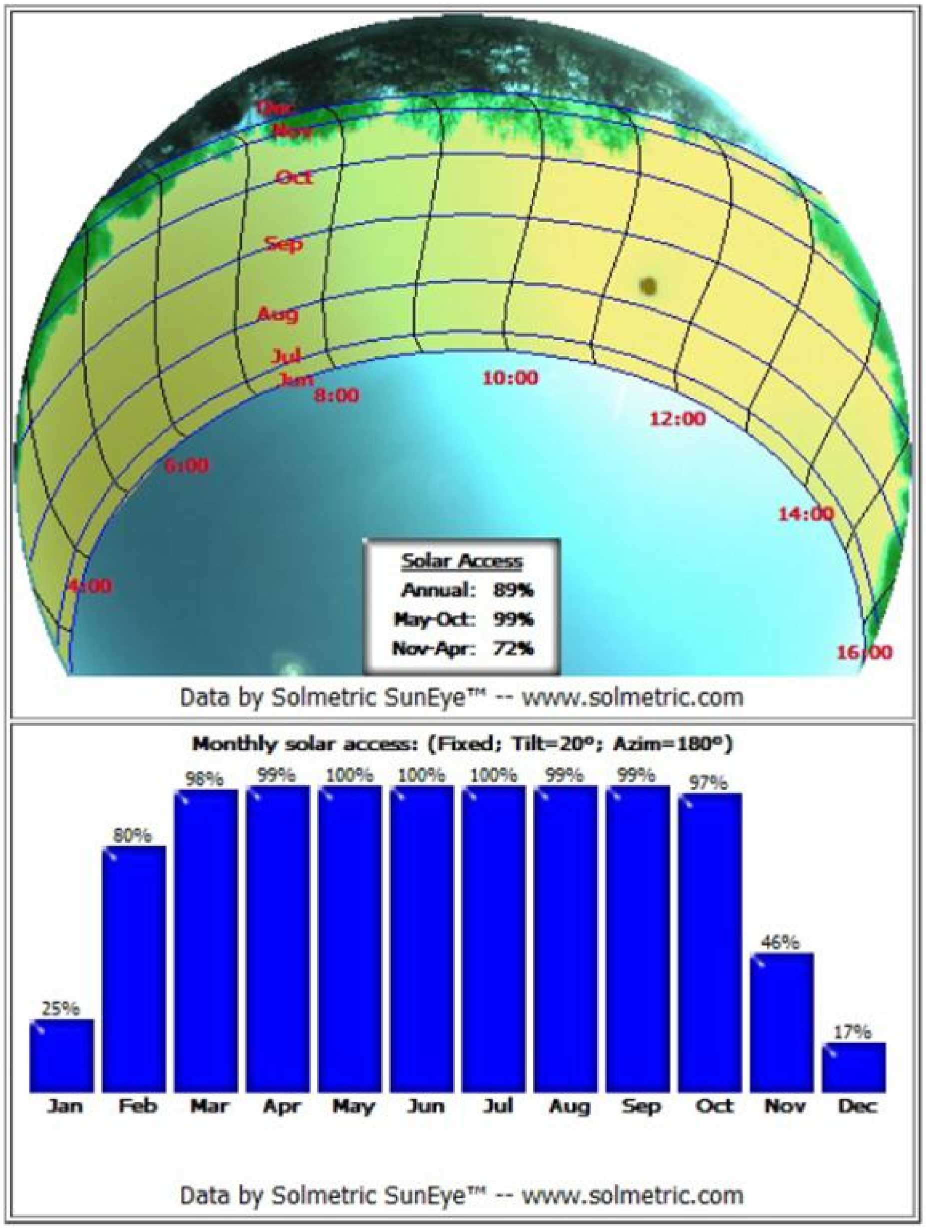

Figure B-1. Solar access measurements at the former wastewater treatment plant at the Kolthoff Landfill taken 50 feet north of the southern trees

Appendix C. Assumptions for the Assessment and Calculations

Table C-1 provides analysis-wide assumptions and important numbers.

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

Cost Assumptions			
Variable	**Quantity of Variable**	**Unit of Variable**	
Cost of Site Electricity	0.12	$/kWh	
Annual O&M (fixed)	30	$/kW/yr for first 15 years	
System Assumptions			
System Type	**Annual Energy (kWh/kW)**	**Installed Cost ($/W)**	**Energy Density (W/sq. ft.)**
Ground fixed	1,139	$2.79	4.0
Ground single-axis	1,329	$3.35	3.3
Other Assumption			
	Ground utilization	90% of available area	

Appendix D. Building Energy Modeling

Building energy modeling was used to estimate the energy use of the proposed hotel, which was assumed to be four stories and 44,000 ft^2. Because the proposed hotel at the Kolthoff Landfill site has not been designed, the building geometry, construction, lighting, equipment, and HVAC systems were all assumed. eQUEST was selected as the building simulation software tool to perform the energy modeling of this site. eQUEST is a commercially available interface for the DOE-2 hourly building energy simulation program originally developed by the Department of Energy. The program is capable of evaluating energy and energy cost savings that can be achieved by applying energy conservation measures such as improved envelope components, passive heating and cooling strategies, lighting system improvements, and HVAC system improvements. The software is commonly used to analyze new construction buildings and building retrofits. eQUEST requires a detailed description of the building envelope (for thermal and optical properties), internal loads, operating schedules, lighting and HVAC system requirements, and utility rate schedules. The major benefits of eQUEST include the ease of defining building geometry, space characteristics, schedules, and HVAC systems and running parametric analyses to study design and retrofit options. Another major benefit of eQUEST is the relatively short simulation run times.

An eQUEST building energy model of the proposed hotel at the Kolthoff Landfill site was created. The building construction, lighting, equipment, and operating condition of HVAC systems were modeled assuming that the hotel would have advanced energy efficiency features and that the hotel would be all-electric buildings that use air-source heat pump systems. The hotel energy model is described in detail in the section below.

Four-Story Hotel Building Energy Model

A sample four-story 44,000 ft^2 hotel building was modeled in eQUEST to determine the potential electricity loads generated. A graphical representation of the building energy model developed in eQUEST is shown in Figure D-1. The geometry of the building was assumed because a hotel building on the former wastewater treatment plant has been designed.

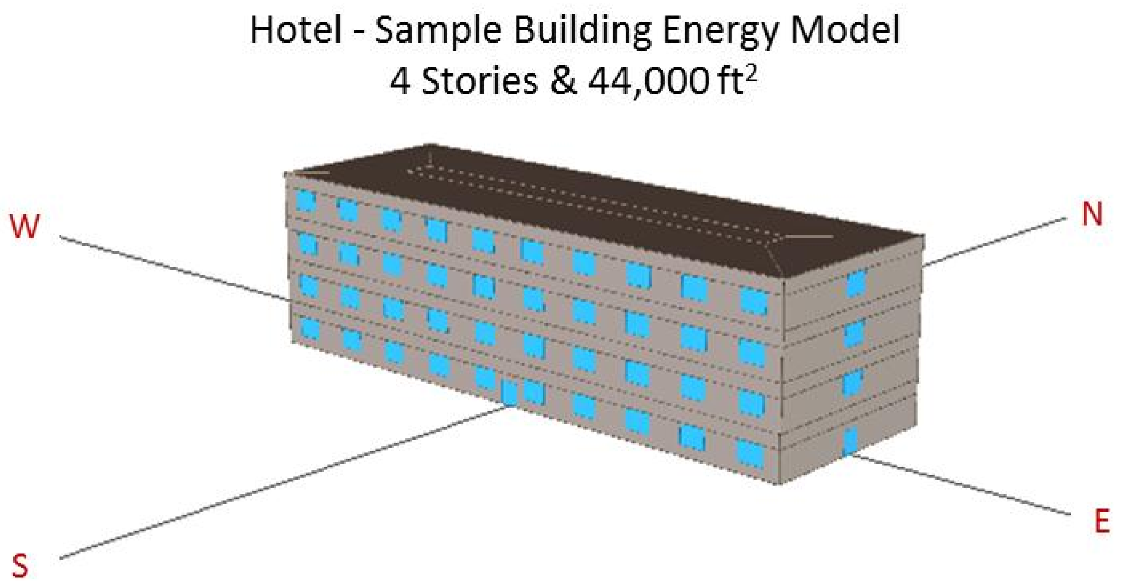

Figure D-1. Hotel building eQUEST model representation

The NREL team assumed advanced energy efficient building design to develop the eQUEST model of the sample hotel building. The general facility characteristics that were modeled are provided in Table D-1, and the results from the energy model are given in Figure D-2.

Table D-1. Hotel Building eQUEST Summary Information

Hotel Building – Cleveland, Ohio		
Project		
	Weather Data	TMY2 – Cleveland, Ohio
	Building Type	Hotel building
	Total Number of Buildings Modeled	1
	Building Areas	44,000 ft^2
	Above-Grade Floors	4
	Below-Grade Floors	0
Building Footprint		
	Building Orientation	Plan north
	Zoning Pattern	Perimeter/core
	Floor-to-Floor Height	13 ft
	Floor-to-Ceiling Height	9 ft
	Roof Pitch	0 deg
Roof		
	Construction	Steel framed
	Roof	Built-up roof
	Insulation	4” Polyisocyanurate (R-28)
Walls		
	Construction	Metal framed
	Finish	Stucco
	Insulation	2” Polystyrene (R-9) continuous R-21 batts
Ground Floor		
	Earth Contact	6” concrete
Infiltration		
	Perimeter	0.10 (CFM/ft^2)
Floors		
	Interior Finish	Carpet
	Construction	4” concrete
	Concrete Cap.	None
Exterior Doors		
	Door Type	Double pane glass
Exterior Windows		
	Window Type	Double pane glass U-0.28, SHGC 0.6, Tvis 0.6
Building Operation		
	Schedule	Open 24 hrs/day, 7 days/week
	Area Type	Hotel

Power Density		
	Lighting	0.75 Watts/ft^2 Lighting occupancy sensors
	Plug Loads	0.15 Watts/ft^2
HVAC Systems		
	System Type	Air-source heat pump
	System Cooling Source	Heat pump – 14 EER
	Economizer	Temperature/enthalpy based
	Heating System	Heat pump – COP 4.0
	Thermostat	Occupied/unoccupied Cooling - 73°F/82°F Heating - 70°F/64°F
Fan Schedules		
	Operation Schedule	Intermittent

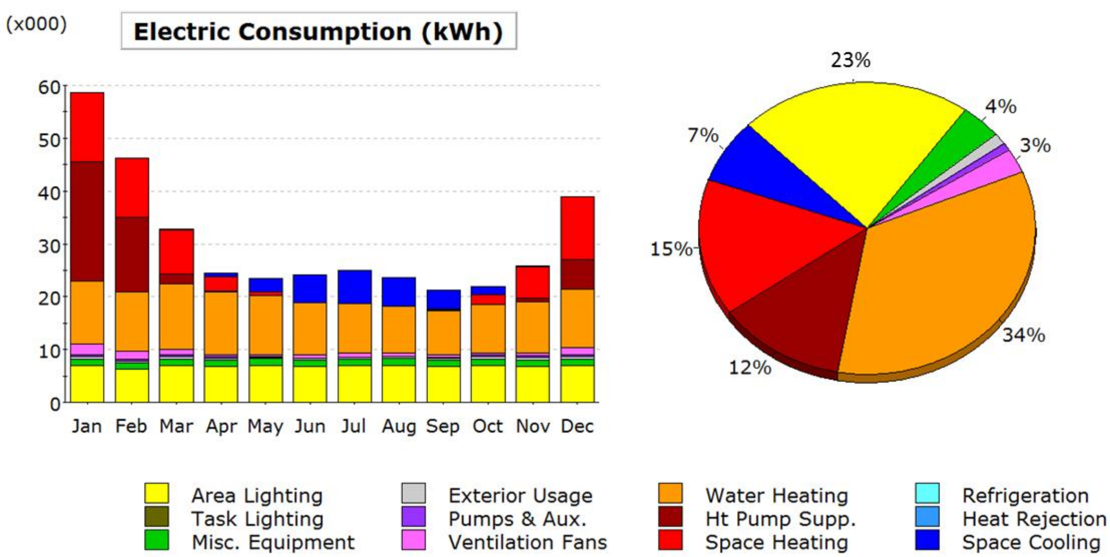

Figure D-2. Kolthoff Hotel eQUEST results for annual energy use

Appendix E. Results from the System Advisor Model

Figures E-1 through E-10 show the SAM graphs.

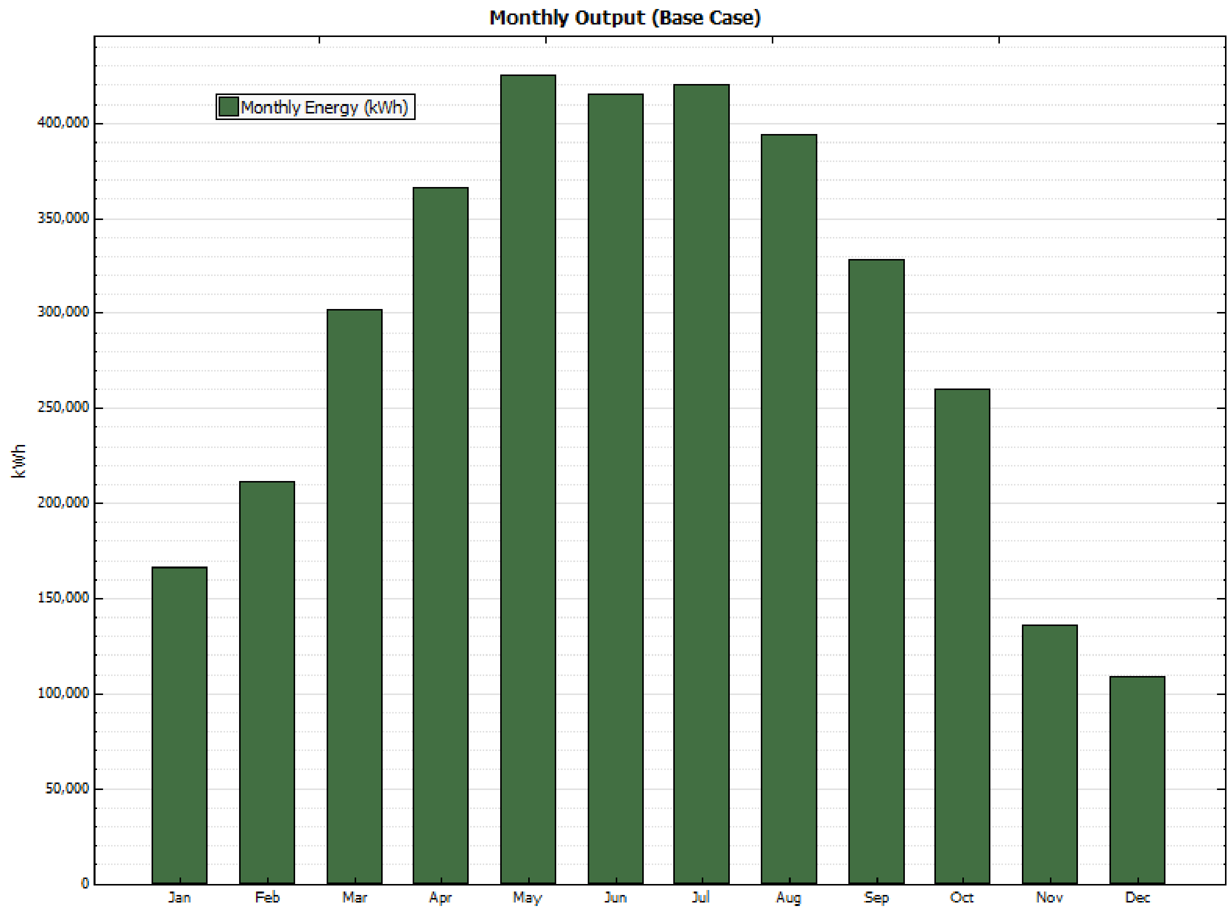

Figure E-1. Modeled output for a ground-mounted fixed-tilt system

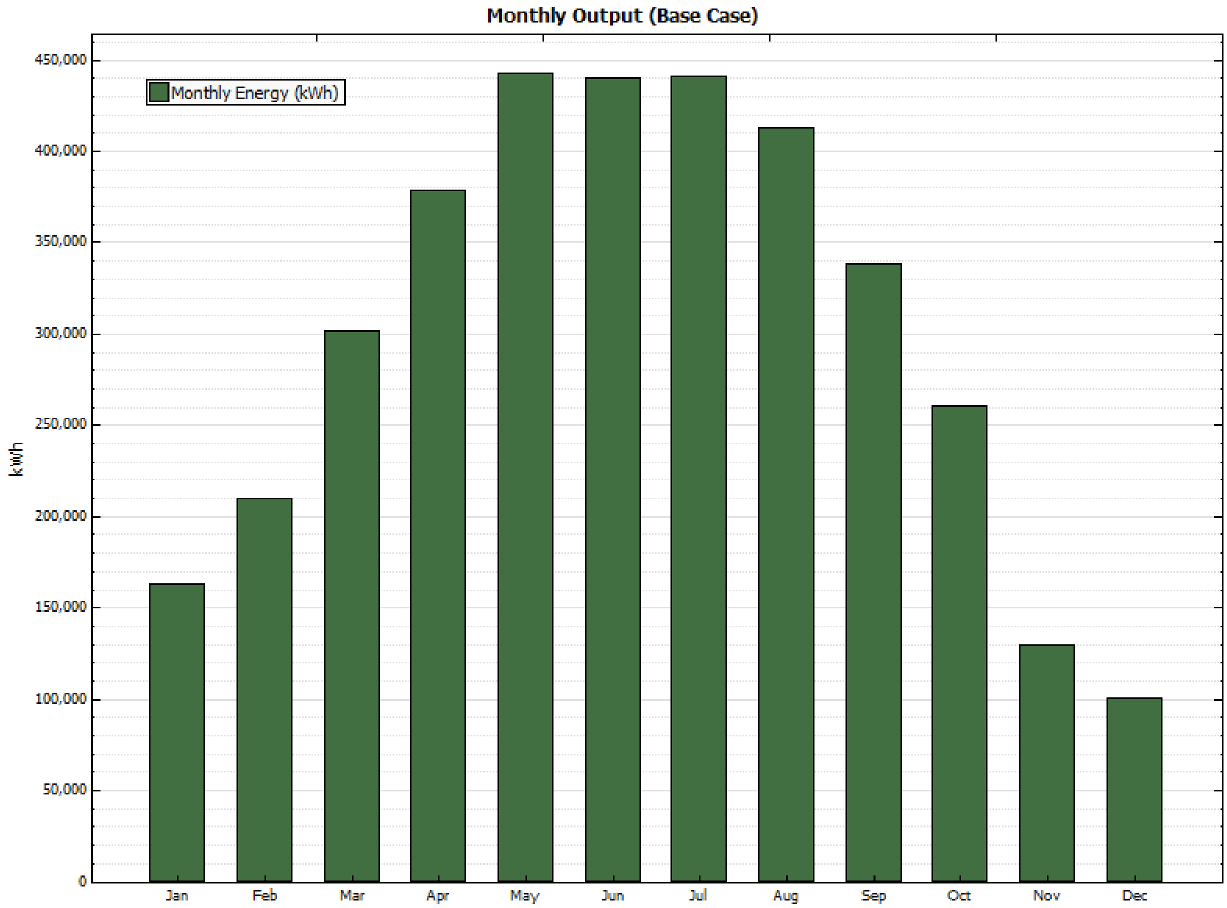

Figure E-2. Modeled output for a single-axis tracking ground PV system

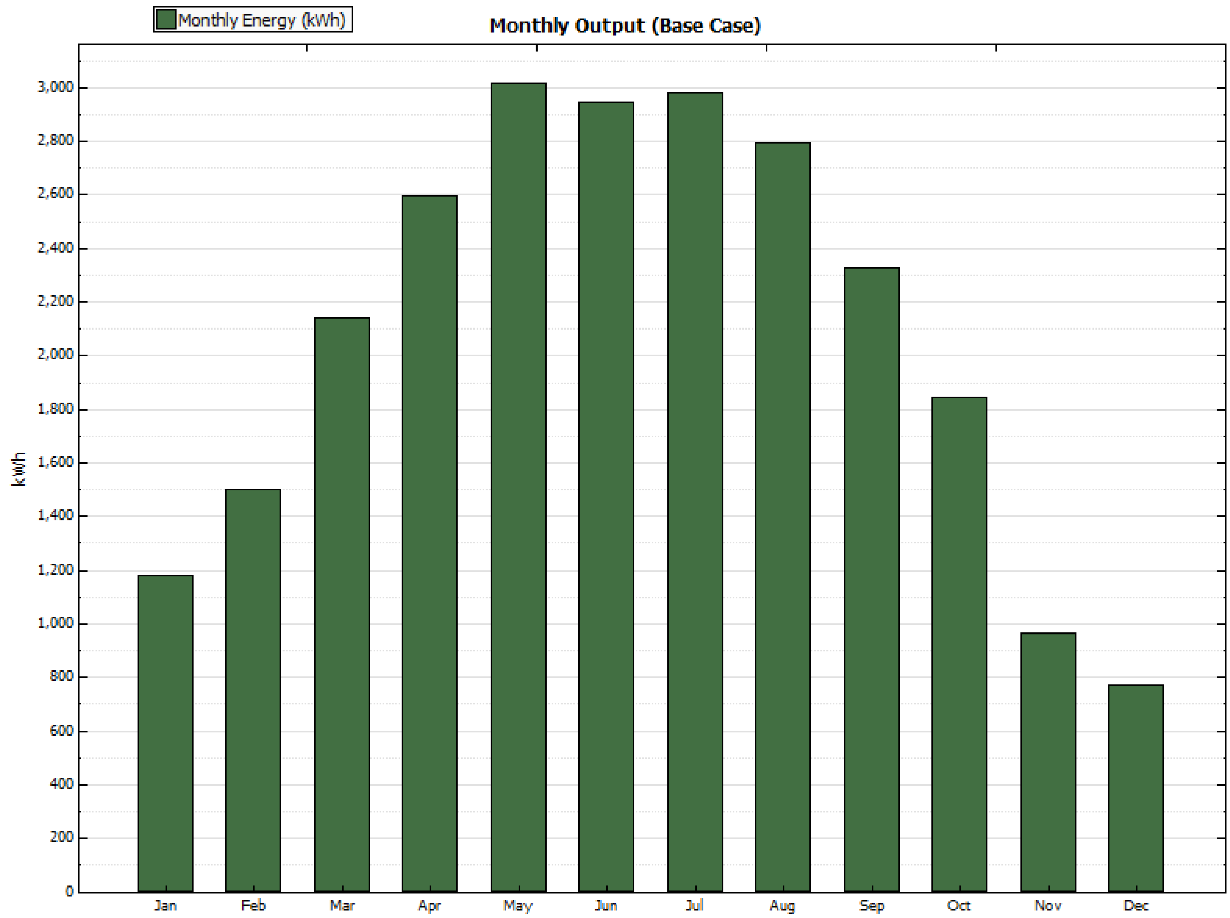

Figure E-3. Modeled output for a roof-mounted fixed-tilt system

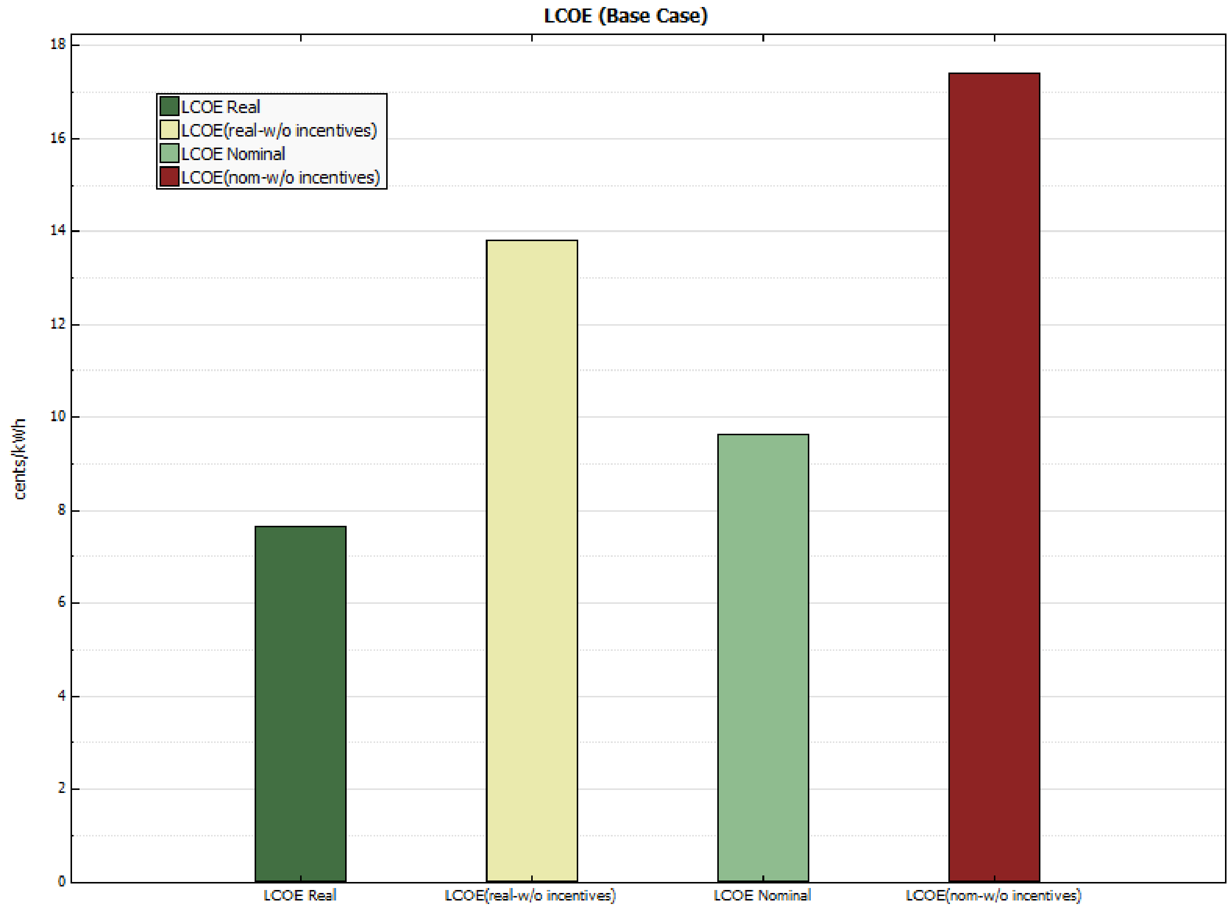

Figure E-4. LCOE for site owner purchase of a fixed-tilt ground system

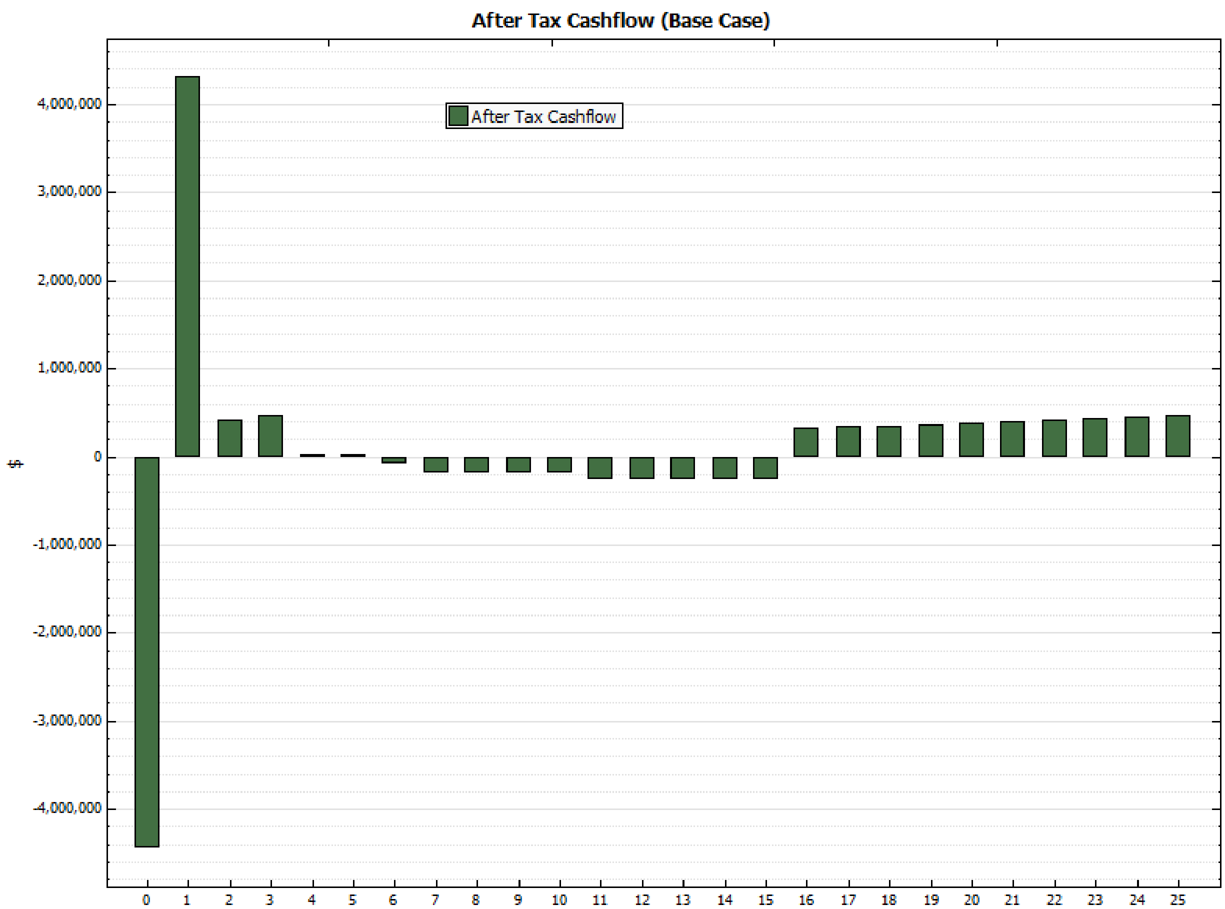

Figure E-5. After-tax cash flow for site owner purchase of a fixed-tilt ground system

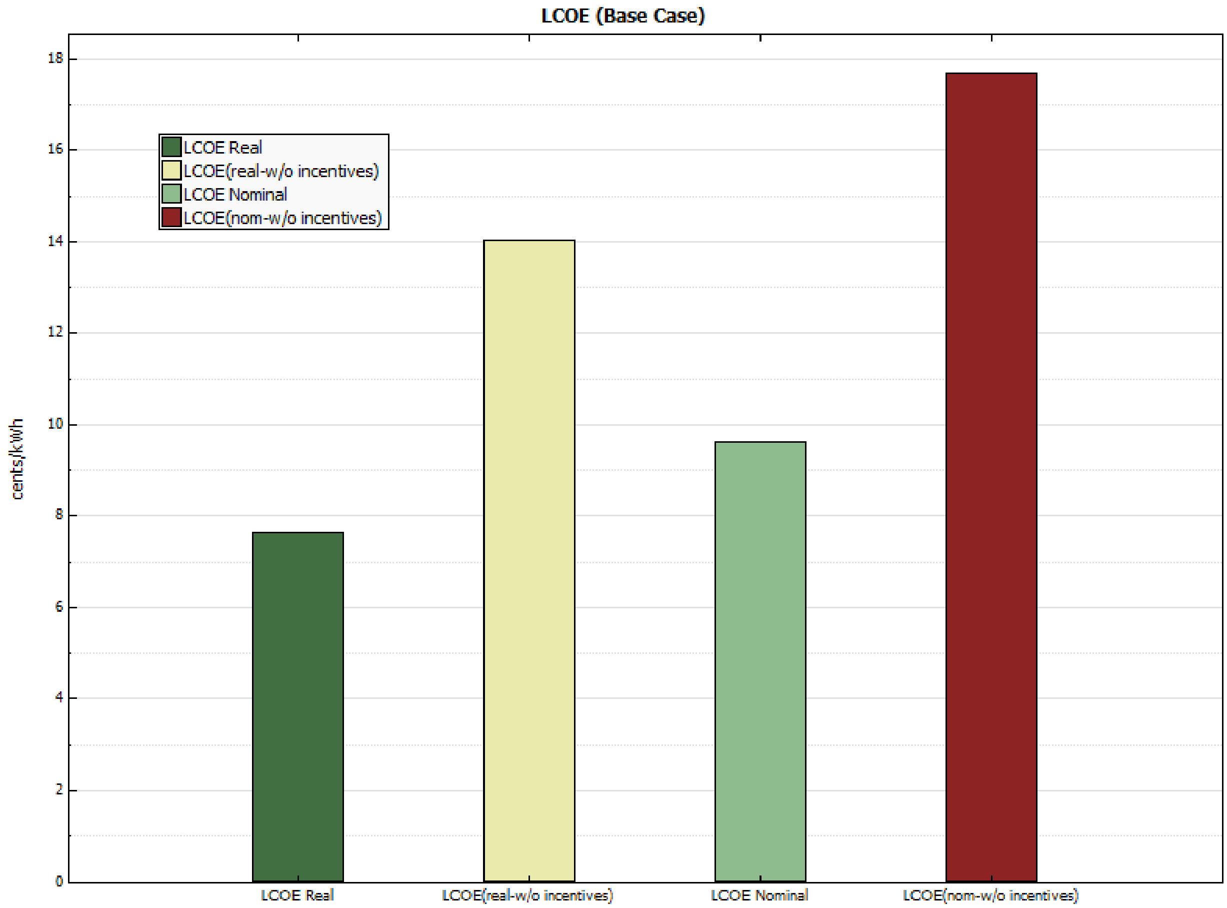

Figure E-7. LCOE for site owner purchase of a single-axis tracking PV system

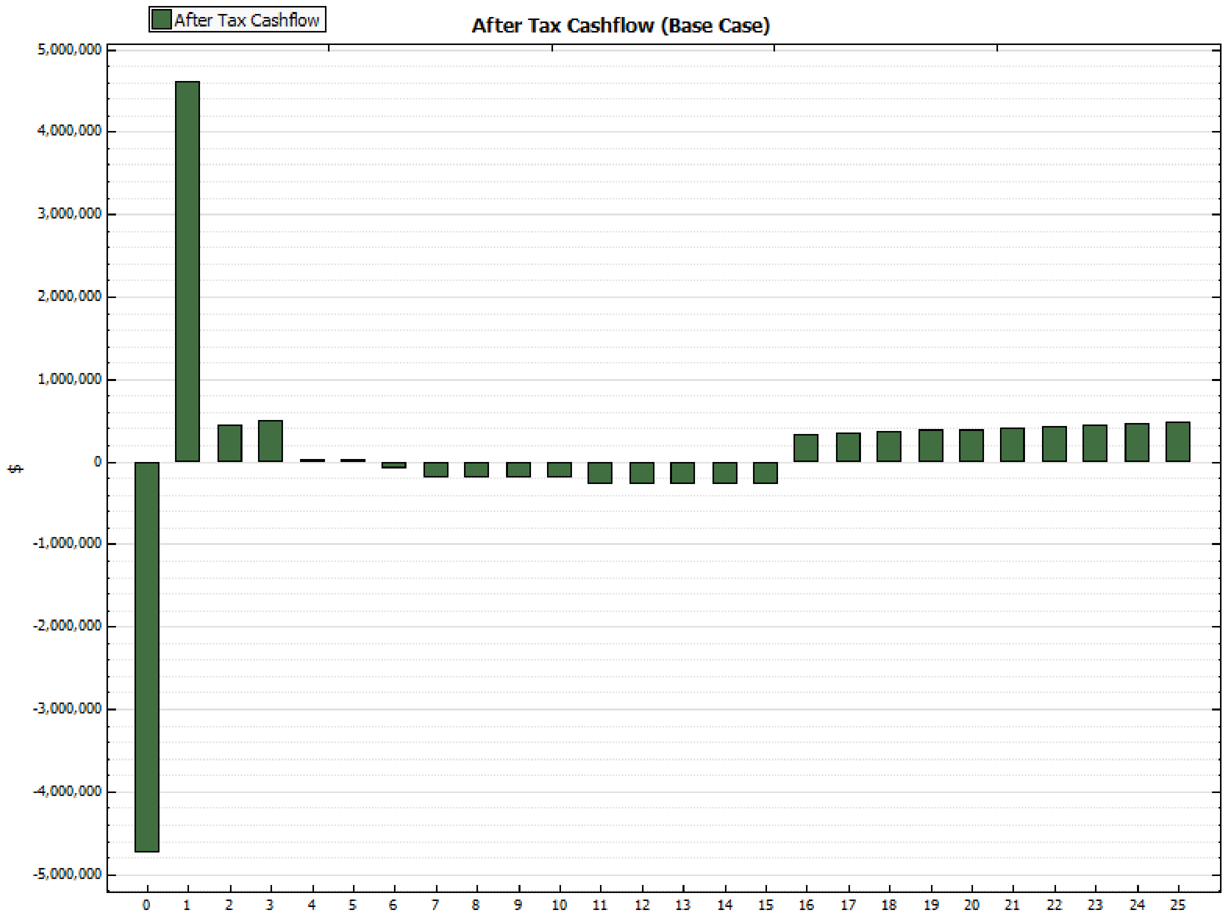

Figure E-8. After-tax cash flow for site owner purchase of a single-axis tracking PV system

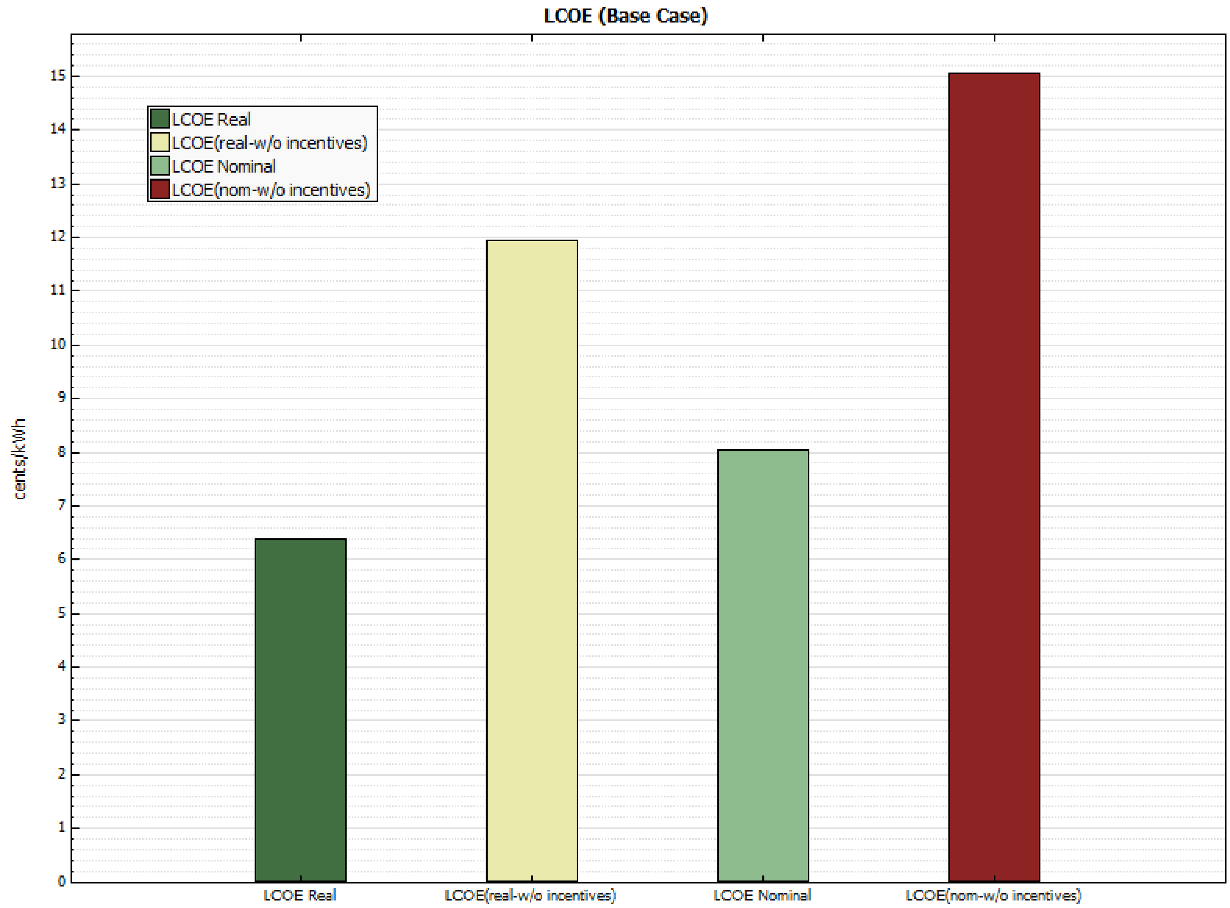

Figure E-9. LCOE for site owner purchase of a fixed-axis roof PV system

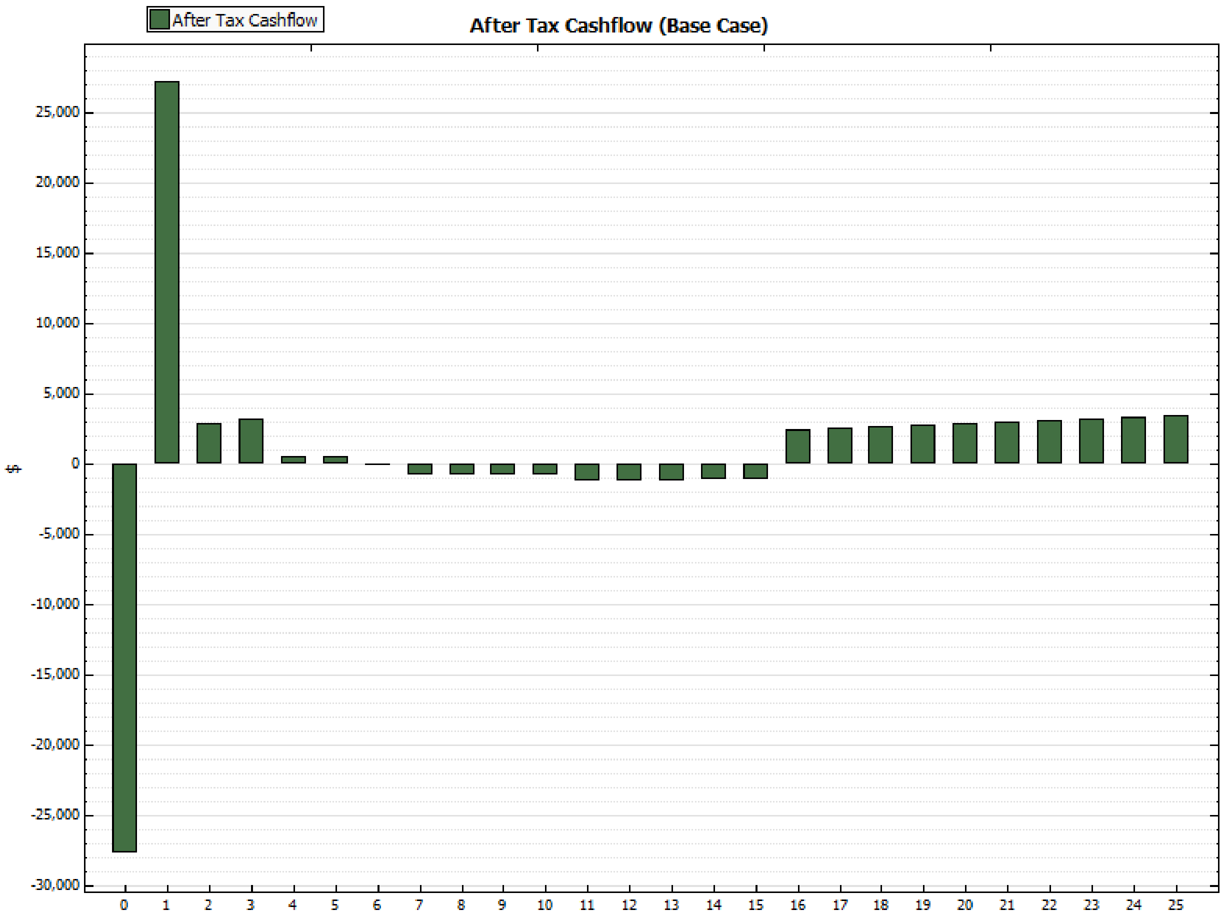

Figure E-10. After-tax cash flow for site owner purchase of a fixed-axis roof PV system

Appendix F. Results from the Job and Economic Development Impact Model

Tables F-1 through F-4 provide results from the JEDI model.

Table F-1. Data Summary for JEDI Model Analysis of Single-Axis Tracking PV System

Project Location	OHIO
Year of Construction or Installation	2013
Average System Size - DC Nameplate Capacity (KW)	2,557.0
Number of Systems Installed	1
Project Size - DC Nameplate Capacity (KW)	2,557.0
System Application	Utility
Solar Cell/Module Material	Crystalline Silicon
System Tracking	Single Axis
Total System Base Cost ($/$KW_{DC}$)	$4,020
Annual Direct Operations and Maintenance Cost ($/kW	$25.00
Money Value - Current or Constant (Dollar Year)	2012
Project Construction or Installation Cost	$10,279,140
Local Spending	$5,553,798
Total Annual Operational Expenses	$1,256,305
Direct Operating and Maintenance Costs	$63,925
Local Spending	$58,811
Other Annual Costs	$1,192,380
Local Spending	$0
Debt Payments	$0
Property Taxes	$0

Table F-2. Summary of Local Economic Impacts for JEDI Model Analysis of Single-Axis Tracking PV System

	Jobs	Earnings	Output
During construction and installation period		**$000 (2012)**	**$000 (2012)**
Project Development and Onsite Labor Impacts			
Construction and Installation Labor	12.3	$797.2	
Construction and Installation Related Services	22.6	$942.1	
Subtotal	34.9	$1,739.3	$3,192.3
Module and Supply Chain Impacts			
Manufacturing Impacts	0.0	$0.0	$0.0
Trade (Wholesale and Retail)	4.4	$240.4	$689.8
Finance, Insurance and Real Estate	0.0	$0.0	$0.0
Professional Services	6.6	$272.5	$872.0
Other Services	11.3	$760.8	$2,458.2
Other Sectors	13.3	$106.9	$346.1
Subtotal	35.5	$1,380.6	$4,366.1
Induced Impacts	23.6	$842.9	$2,770.9
Total Impacts	**94.0**	**$3,962.8**	**$10,329.3**
		Annual	**Annual**
	Annual	**Earnings**	**Output**
During operating years	**Jobs**	**$000 (2012)**	**$000 (2012)**
Onsite Labor Impacts			
PV Project Labor Only	0.6	$35.6	$35.6
Local Revenue and Supply Chain Impacts	0.2	$11.2	$34.9
Induced Impacts	0.2	$6.3	$20.8
Total Impacts	**1.0**	**$53.1**	**$91.3**

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.

Table F-3. Detailed Summary of Costs for JEDI Model Analysis of Single-Axis Tracking PV System

	OHIO	**Purchased**	**Manufactured**
Installation Costs	**Cost**	**Locally (%)**	**Locally (Y or N)**
Materials & Equipment			
Mounting (rails, clamps, fittings, etc.)	$550,619	100%	N
Modules	$3,516,953	100%	N
Electrical (wire, connectors, breakers, etc.)	$134,736	100%	N
Inverter	$523,034	100%	N
Subtotal	$4,725,342		
Labor			
Installation	$797,201	100%	
Subtotal	$797,201		
Subtotal	$5,522,543		
Other Costs			
Permitting	$56,078	100%	
Other Costs	$1,239,317	100%	
Business Overhead	$3,461,202	100%	
Subtotal	$4,756,597		
Subtotal	$10,279,140		
Sales Tax (Materials & Equipment Purchases)	$0	100%	
Total	$10,279,140		

Table F-4. Annual O&M Costs for JEDI Model Analysis of Single-Axis Tracking PV System

	Cost	Local Share	Manufactured Locally (Y or N)
Labor			
Technicians	$38,355	100%	
Subtotal	$38,355		
Materials and Services			
Materials & Equipment	$25,570	100%	N
Services	$0	100%	
Subtotal	$25,570		
Sales Tax (Materials & Equipment Purchases)	$0	100%	
Average Annual Payment (Interest and Principal)	$1,192,380	0%	
Property Taxes	$0	100%	
Total	$1,256,305		
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	5.50%	100%	
Sales Tax Exemption (percent of local taxes)	100%		
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%	