




Feasibility Study of Economics and Performance of Solar Photovoltaics at the Former Bethlehem Steel Plant Brownfield Site in Lackawanna, New York

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 by the National Renewable Energy Laboratory (NREL) under Interagency Agreement IAG-08-0719 and Task No. WFD3.1001.

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

Technical Report
NREL/TP-7A40-58194
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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 Former Bethlehem Steel Plant site in Lackawanna, New York, 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 Former Bethlehem Steel Plant site is located on the eastern shore of Lake Erie in the City of Lackawanna, New York, which is south of the City of Buffalo. The Bethlehem Steel Plant was in operation for over 80 years from 1902–1983. At the height of operations during the first half of the 20th century, the plant employed approximately 20,000 people. There was a large decline in U.S. steel production in the second half of the 20th century, which led to the plant being closed in the mid-1980s. The site is currently home to the Steel Winds project, a huge success story in repurposing brownfields. The City of Lackawanna and the owner of the property, ArcelorMittal Tecumseh Redevelopment, Inc., are interested in developing this underused land for wind and solar power as well as constructing light industrial buildings.

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 brownfield site impact the feasibility of a PV system. Based on an assessment of these factors, the Former Bethlehem Steel Plant is suitable for deployment of a large-scale PV system.

The Former Bethlehem Steel Plant site is approximately 1,100 acres and there is the potential to build out a portion of the site with a ground-mounted PV system and to also build out a portion of the site with light industrial buildings that have roof-mounted PV. There are currently 325 acres available for a ground-mounted PV system in the center of the site and 93 acres available for a ground-mounted PV system using micro-inverters around the Steel Winds large-scale wind site (micro-inverters are selected for this area because there will be some shading from the wind turbines). There are 364 acres that will contain buildings that are potentially available for a roof-mounted PV system; however, 60% of the 364-acre site is estimated to be available for solar panels due to potential roof obstruction and roof orientations. While the entire area does not need to be developed at one time due to the feasibility of staging installation as land or as funding becomes available, calculations for this analysis reflect the solar potential if the total feasible area is used. It should be noted that the purpose of this report is not to determine how to develop the site but to investigate both options and present the results in an unbiased manner.

Of the 10 scenarios considered, none had a positive net present value, but 7 had a payback in the analysis period. The economic feasibility of a potential PV system on the Former Bethlehem Steel Plant site depends on the purchase price of the PV panels. The economics were analyzed using the average New York State Electric retail rate provided during the site visit of $0.12/kWh and generated electricity sale rate of $0.05/kWh. This report also considered all available

financial incentives that would be available to the site. Table ES-1 shows the current incentives considered that were found on the DSIRE website.[1]

Table ES-1. Summary of Incentives Evaluated

Incentive Title	Modeled Value	Expected End Date
PV Incentive Program	$1.50/W, $75,000 cap	12/31/2015
Federal Investment Tax Credit	30% of total investment	2016
Accelerated MACRS Schedule	Bonus 50% in the first year for federal depreciation	None currently
Net Metering	Net meter up to 2 MW	None currently
Sales Tax Exemption	0% sales tax	None currently

The net metering applied only to the 2-MW cases. Other incentives that the Lackawanna site was not eligible for were not considered at this time.

Table ES-2 summarizes the system performance and economics of a potential system that would use all available areas that were surveyed at the Former Bethlehem Steel Plant site. 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. The net metering single-axis system, which is the best economic case, is expected to have a payback of 14.8 years and a net present value of $(46,780), producing approximately 2,801,366 kWh annually. This includes the current cost of energy, expected installation cost, site solar resource, and existing incentives for the proposed PV system. The savings and payback are not deemed reasonable and as such, a solar PV system does not represent a viable reuse for the site under current policy conditions.

[1] Database of State Incentives for Renewables & Efficiency (DSIRE). Accessed April 30, 2013: http://www.dsireusa.org/.

Table ES-2. Former Bethlehem Steel Plant PV System Summary

System Type	PV System Size[a] (kW)	Array Tilt (deg)	Annual Output (kWh/year)	Houses Powered[b]	Jobs Created[c] (job-year)	Jobs Sustained[d] (job-year)
Crystalline Silicon (1-Axis Ground System) - Net Meter Max	2,000	20	2,801,366	254	49.1	0.7
Crystalline Silicon (Fixed Tilt Ground System) - Net Meter Max	2,000	20	2,240,741	203	36.7	0.7
Crystalline Silicon (1-Axis Ground System) - Micro Inverters Near Wind Turbines	10,022	20	14,036,243	1271	245.9	3.5
Crystalline Silicon (Fixed Tilt Ground System) - Micro Inverters Near Wind Turbines	12,152	20	13,614,744	1233	222.9	4.3
Crystalline Silicon (1-Axis Ground System) - Highly Contaminated Are	9,626	20	13,482,974	1221	324.3	4.6
Crystalline Silicon (Fixed Tilt Ground System) - Highly Contaminated Area	11,672	20	13,076,966	1185	294.0	5.6
Crystalline Silicon (1-Axis Ground System) - Industrial Complex	40,948	20	43,952,029	3981	770.0	11.0
Crystalline Silicon (Fixed Tilt Ground System) - Industrial Complex	49,652	20	42,628,981	3861	697.8	13.3
Crystalline Silicon (1-Axis Ground System) - Primary Area	36,207	20	52,323,911	4739	916.6	13.1
Crystalline Silicon (Fixed Tilt Ground System) - Primary Area	43,902	20	50,748,307	4597	830.7	15.9
Crystalline Silicon (1-Axis Ground System) - Best NPV	50	20	70,034	6	1.4	0.0
Crystalline Silicon (Fixed Tilt Ground System) - Best Payback	50	20	56,019	5	1.1	0.0
Crystalline Silicon (1-Axis Ground System) - Breakeven Size	862	20	1,207,389	109	24.7	0.3

System Type	System Cost	Maximum Base Incentives	PPA ¢/kWh	NPV ($)	Annual O&M ($/year)	Period with Incentives (years)
Crystalline Silicon (1-Axis Ground System) - Net Meter Max	$ 6,700,000	$ 2,085,000	-	$ (46,780)	$ 60,000	14.8
Crystalline Silicon (Fixed Tilt Ground System) - Net Meter Max	$ 5,580,000	$ 1,749,000	-	$ (174,696)	$ 60,000	18.5
Crystalline Silicon (1-Axis Ground System) - Micro Inverters Near Wind Turbines	$ 40,509,893	$ 12,227,968	19.13	$ (4,058,268)	$ 200,420	19.6
Crystalline Silicon (Fixed Tilt Ground System) - Micro Inverters Near Wind Turbines	$ 38,681,060	$ 11,679,318	20.17	$ (4,977,595)	$ 243,040	21.1
Crystalline Silicon (1-Axis Ground System) - Highly Contaminated Are	$ 40,332,940	$ 12,174,882	20.65	$ (5,017,727)	$ 192,520	22.7
Crystalline Silicon (Fixed Tilt Ground System) - Highly Contaminated Area	$ 40,735,280	$ 12,295,584	21.79	$ (5,905,123)	$ 233,440	22.5
Crystalline Silicon (1-Axis Ground System) - Industrial Complex	$ 105,119,650	$ 31,610,895	17.46	$ (18,389,547)	$ 941,370	24.5
Crystalline Silicon (Fixed Tilt Ground System) - Industrial Complex	$ 106,156,710	$ 31,922,013	18.54	$ (20,782,942)	$ 1,141,470	-
Crystalline Silicon (1-Axis Ground System) - Primary Area	$ 125,142,600	$ 37,617,780	17.42	$ (23,256,722)	$ 1,120,680	-
Crystalline Silicon (Fixed Tilt Ground System) - Primary Area	$ 126,375,840	$ 37,987,752	18.54	$ (26,072,800)	$ 1,358,880	-
Crystalline Silicon (1-Axis Ground System) - Best NPV	$ 167,500	$ 125,250	-	$ 33,412	$ 1,500	5.4
Crystalline Silicon (Fixed Tilt Ground System) - Best Payback	$ 139,500	$ 116,850	-	$ 30,036	$ 1,500	4.64
Crystalline Silicon (1-Axis Ground System) - Breakeven Size	$ 2,887,700	$ 941,310	-	$ 19	$ 25,860	14.6

a *Data assume a maximum usable area of 950 acres*

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.

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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 Former Bethlehem Steel Plant site in Lackawanna, New York, 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 Former Bethlehem Steel Plant is located on the west side of Lackawanna, New York, which is located on the east coast of Lake Erie and is south of the City of Buffalo. Lackawanna has a population of 18,141 as of the 2010 census. Lackawanna experiences summers that are warm and humid with high temperatures typically in the 80^{o}F range. The winters are cold and snowy with low temperatures in the 20^{o}F range. Lackawanna has on average 158 days of sunshine each year. National Grid is the utility that provides electricity to Lackawanna, and it is a deregulated utility.

The site is approximately 1,100 acres. The major components and buildings related to steel mill have been removed, but some remnants of the steel mill still remain. The site owner is open to removing any structures that could inhibit a large-scale solar PV plant. Currently, the west side of the site has fourteen 2.5-MW wind turbines, which require a 500-ft easement around each turbine. The middle portion of the site is mostly free of structures and other shading obstructions. The eastern portion of the site along the Hamburg Highway has some light industrial buildings, and there are future plans to further build out this area with more light industrial buildings. The southwest corner of the site is the most contaminated area and remediation efforts are underway in this area.

The major contaminants at the site are related to approximately 80 years of steel production at the site. Currently, the most contaminated area is located in the southwest portion of the site.

The closest electrical tie-in location is on site, and the Steel Winds project ties into this substation on site. The 30-acre eastern portion of the site currently has a large-scale wind turbine plant named the Steel Winds Project. The Steel Winds Project is a great success story of turning a brownfield site into a productive parcel of land. The Steel Winds Project was built in two phases with the first phase completed in 2007 and the second phase completed in 2012. The total project is composed of fourteen 2.5-MW turbines, for a total of 35 MW. Having a substation on site makes it an ideal location for a PV system to tie into. A detailed interconnection study will have to be performed through the local electric utility, National Grid, to determine the feasibility of utilizing the on-site substation as a tie-in point for a PV system. The site is planned to have buildings, but the extent of the build-out has not been determined. The buildings on the site are potential off-takers of the electricity produced by a PV system.

Feasibility assessment team members from NREL, the City of Lackawanna, and EPA conducted a site visit on Tuesday, April 3, 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
- Can have environmental conditions that are not well suited for commercial or residential redevelopment
- Might be adequately zoned for renewable energy
- Generally are located near existing roads and energy transmission or distribution infrastructure
- Can 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 Former Bethlehem Steel Plant is owned by ArcelorMittal Tecumseh Redevelopment, Inc., 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. For the Lackawanna site, the vision of the community aligns well with the vision of the developer. The purpose of this study is to analyze all options so that an informed decision can be made on how to best utilize 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 had been vacant for 30 years. The 41-acre 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. There is potential to build light industrial buildings on the site as the community sees fit. As has been mentioned, the Steel Winds Project is an example of a success story for installing large-

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

scale wind turbines on a brownfield site. Further development of wind at the site could be pursued.

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 (PPA) 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).

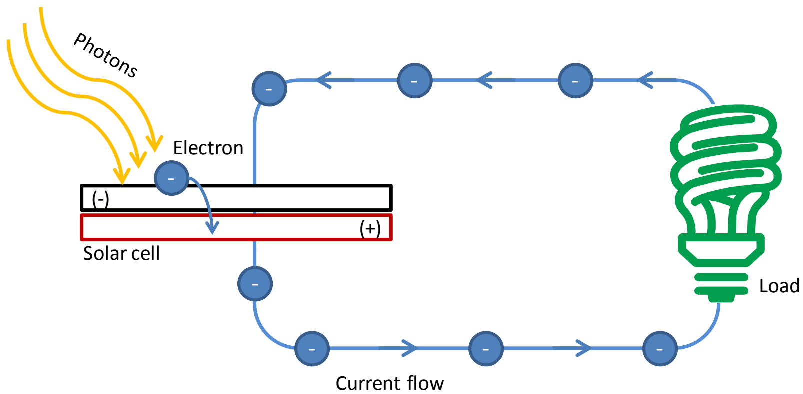

Figure 1. Generation of electricity from a PV cell

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

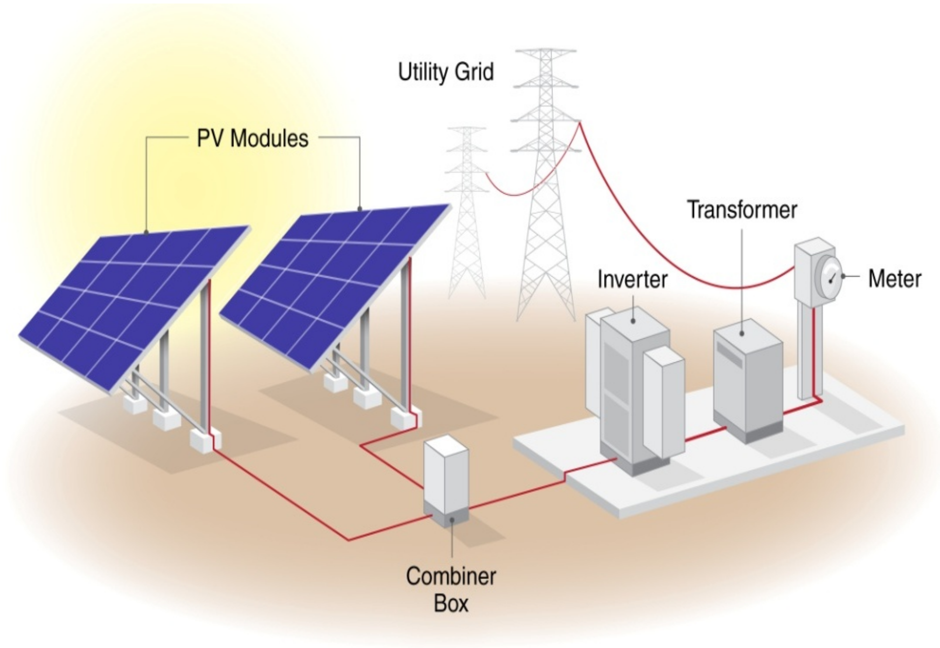

Figure 2. Ground-mounted array diagram

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 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 for a consistent and high efficiency 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 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 by (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 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 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 a (left) solar energy cover and (middle/right) fixed-tilt mounting system. ***Photos by (left) Republic Services, 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 might 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, it impacts only that shaded panel 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 brownfield 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 brownfield 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. Depending on underlying soiling conditions, single- and dual-axis trackers may not be suitable due to potential settlement effects, which can interfere with the alignment requirements of such systems.

Table 1. Ground-Mounted 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 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 Former Bethlehem Steel Plant site, there is the potential to use the roof area of future light industrial buildings 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 development plan at the Former Bethlehem Steel Plant site has new construction light industrial buildings. 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.[3]

[3] A solar-ready design guide was published in order to help design teams optimize rooftop PV systems when designing buildings; this guide can be found at http://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 brownfield 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 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 smart phone applications.

3.2.4 Operation and Maintenance

PV panels typically have a 25-year performance warranty. The 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 April 3, 2012.

4.1 Former Bethlehem Steel Plant Site PV System

As discussed in Section 1, the Former Bethlehem Steel Plant site is owned by ArcelorMittal Tecumseh Redevelopment, Inc.

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.

The Former Bethlehem Steel Plant site is approximately 1,100 acres, and there is potential to build out a portion of the site with a ground-mounted PV system and build out a portion of the site with light industrial buildings that have roof-mounted PV. The site is relatively flat, but some grading will be necessary in some areas to accommodate a ground-mounted PV system. The entire site could be feasible for PV after any remediation measures are completed. There is a plan to develop the eastern side of the site with light industrial buildings. These light industrial buildings would be new construction and the rooftops are potential areas for PV systems. Because the buildings are new construction, they could easily be designed to be "solar ready," even if the budget for a rooftop PV system is not available at the time of construction.

There are currently 325 acres available for a ground-mounted PV system in the left-center of the site, and 93 acres available for a ground-mounted PV system using micro-inverters around the Steel Winds large-scale wind site (micro-inverters are selected for this area because there will be some shading from the wind turbines). There are approximately 364 acres potentially available for roof-mounted PV systems on the northeast side on the site; however, 60% of the 364 acres is estimated to be available roof space. 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. It should be noted that the purpose of this report is not to determine how to develop the site but to investigate various options and present the results in an unbiased manner.

Figure 6 shows an aerial view of the potential areas for PV at the Former Bethlehem Steel Plant site taken from Google Earth; the feasible area for ground-mounted micro-inverter PV is shaded in green; the feasible area for ground-mounted PV is shaded in yellow; the light industrial building rooftop PV is shaded in red; and the highly contaminated area is shaded in purple. The yellow, red, and green sections were given various "packing factors," which define how much of the area would be able to house PV arrays. The yellow shaded area is assumed to be able to fill 80% of the defined area with PV panels. The green area has a 75% packing factor due to the existing wind turbines, and the red area has a packing factor of 60%. As shown, there are large expanses of relatively flat, un-shaded land, which makes it a suitable candidate for a ground-mounted PV system.

There are also large expanses of possible un-shaded rooftop area, which makes it a suitable candidate for rooftop PV systems.

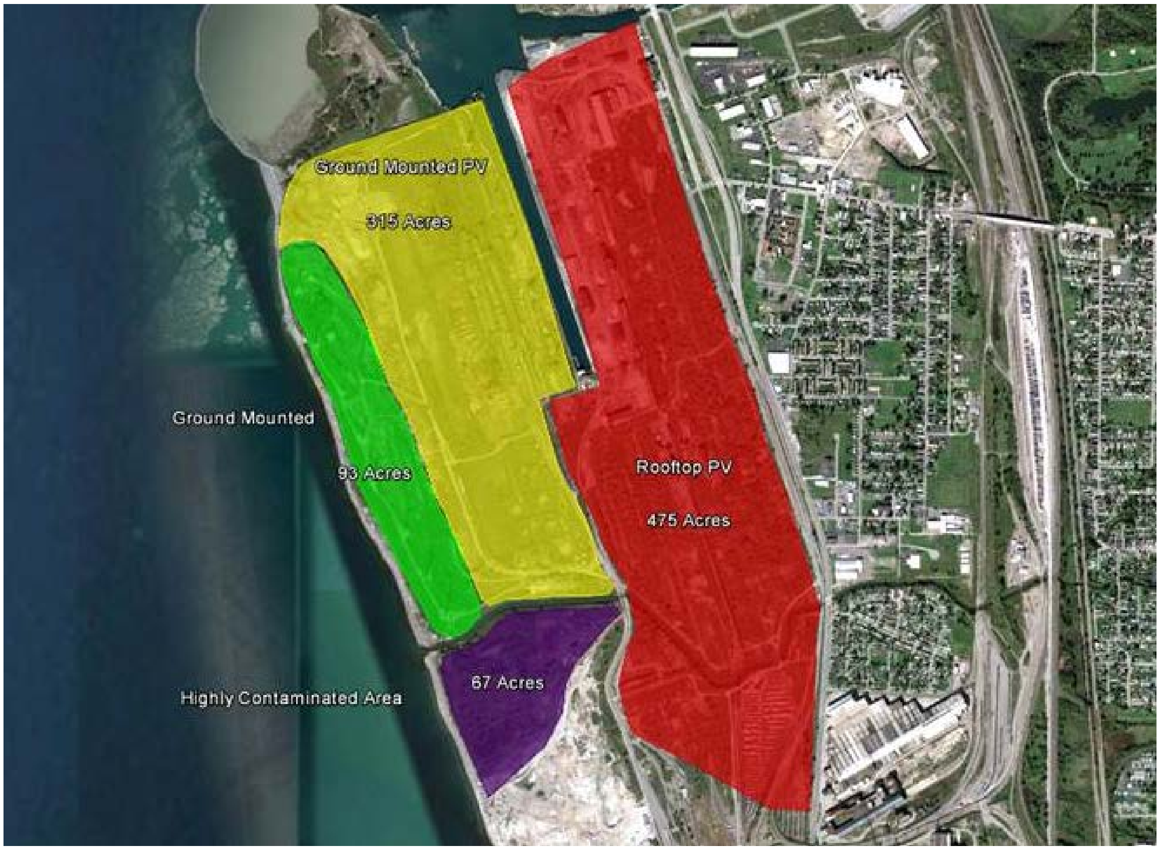

Figure 6. Aerial view of the feasible areas for PV at the Former Bethlehem Steel Plant (ground-mounted micro-inverter PV in green; ground-mounted PV in yellow; light industrial rooftop PV in red; highly contaminated area in purple)

Illustration done in Google Earth

PV systems are not well suited to the Lackawanna 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 4.02 kWh/m^2/day. Figure 7 and Figure 8 show various views of the Former Bethlehem Steel Plant site.

Figure 7. Views of the feasible area for ground-mounted PV at the Lackawanna site.
Photos by Jimmy Salasovich, NREL

Figure 8. Views of the feasible area for ground-mounted PV with micro-inverters at the Steel Winds portion of the Lackawanna site. ***Photos by Jimmy Salasovich, NREL***

4.2 Utility-Resource Considerations

The closest electrical tie-in location is on site at the National Grid substation where the Steel Winds project ties into the electric grid. The location of the National Grid substation in relation to the Lackawanna site is given in Figure 9. As shown, the substation is located in the southeast corner of the site, which could make it an ideal location for a PV system to tie into. A detailed interconnection study will have to be performed through National Grid to determine the feasibility of utilizing the on-site substation as a tie-in point for a PV system. The site is planned to have buildings, but the extent of the build-out has not been determined. The buildings on the site are potential off-takers of the electricity produced by a PV system.

Figure 9. Location of on-site substation in relation to the Lackawanna site

Illustration done in 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 under-utilized or unoccupied land, vacant lots, and/or unused paved area (e.g., a parking lot, industrial site space, or existing building rooftops).

4.4 PV Site Solar Resource

The Former Bethlehem Steel Plant 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 90% or higher.

The predicted array performance was found using PVWatts Version 2 for Lackawanna.[4] Table 3 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 analyses can be performed using the same data. It is scaled linearly to match the proposed system size.

[4] PVWatts. Accessed March 12, 2013: http://www.nrel.gov/rredc/pvwatts/.

Table 3. Site Identification Information and Specifications

Station Identification	
Cell ID	0259365
State	New York
Latitude	43.0° N
Longitude	78.7° 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	180°
Energy Specifications	
Cost of Electricity	$0.12/kWh

Table 4 shows the performance results for a 20-degree fixed-tilt PV system in Lackawanna, as calculated by PVWatts.

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

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	2.07	52	6.24
2	2.86	67	8.04
3	4.16	105	12.60
4	4.90	116	13.92
5	5.73	134	16.08
6	6.05	133	15.96
7	5.98	134	16.08
8	5.39	122	14.64
9	4.52	100	12.00
10	3.25	77	9.24
11	1.99	45	5.40
12	1.72	41	4.92
Year	4.06	1,126	135.12

Table 5 shows the performance results for a zero-tilt single-axis tracking PV system in Lackawanna, as calculated by PVWatts.

Table 5. Performance Results for 20-Degree Single-Axis PV

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	2.36	61	7.32
2	3.32	79	9.48
3	5.04	129	15.48
4	5.97	143	17.16
5	7.13	170	20.40
6	7.60	170	20.40
7	7.69	176	21.12
8	6.81	157	18.84
9	5.57	126	15.12
10	3.88	93	11.16
11	2.27	53	6.36
12	1.93	47	5.64
Year	4.97	1,403	168.36

4.5 Former Bethlehem Steel Plant Energy Usage

The Former Bethlehem Steel Plant site currently has buildings on the site that use electricity. There are future plans to build a significant number of buildings on the site. 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.

4.5.1 Current Energy Use

There are currently buildings on the site that use electricity. No current electricity usage or cost data was available for the site.

4.5.2 Estimated Future Energy Use and Net-Zero Energy Potential

4.5.2.1 Light Industrial Buildings Assuming a 10% Build-Out of the Area

The build-out of the site that could have various light industrial buildings has not yet been designed, and therefore no drawings for the potential future build-out of the site are available. The build-out of the site was assumed to be 10% of the available 364 acres, which is approximately 1.6 million square feet of light industrial building area. The future light industrial buildings were all assumed to be one-story buildings that are each 100,000 square feet.

The future energy use of the light industrial buildings on the site was estimated by creating a building energy model of a typical light industrial building and details of the energy model are given in Appendix D. It is important to note that buildings were assumed to be electric buildings and energy efficient buildings with tight construction, low lighting and equipment energy use, and ground- or lake-source heat pump with backup electric boiler systems. The estimated total building area of the site build-out is approximately 1.6 million square feet. Using the energy model, the total annual energy use of the site is estimated to be approximately 18 million kWh/yr. In order for the light industrial buildings on site to be net-zero, a 12.85-MW 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. The 35-MW large-scale wind plant was not included in the net-zero estimates, but it would contribute an estimated 50 million kWh/year to offset the electricity use.

4.5.3 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 the electricity it generates up to a designated system capacity. 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.

New York's net-metering law, which began in 1997, requires that an investor-owned utility offer net metering for all customers up to 1% of the utility's 2005 total aggregate demand.

New York does not allow any new or additional demand charges, standby charges, customer charges, minimum monthly charges, interconnection charges, or other charges that would increase an eligible customer-generator's costs beyond those of other customers in the rate class to which the eligible customer-generator would otherwise be assigned. The New York Department of Public Service has explicitly ruled that technologies eligible for net metering (up to 2 MW) are exempt from interconnection application fees, as well as from initial and supplemental interconnection review fees.

Any net excess generation (NEG) in a 12-month period is carried forward into the next 12-month cycle.

4.5.4 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 up to a 1-MW limit 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. New York currently does not offer VNM to PV generators.

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).[5]

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.

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

5.1 Assumptions and Input Data for Analysis

Cost of a PV system depends on the system size and other factors, such as geographic location, mounting structure, and type of PV module. Based on significant cost reductions seen in 2011, the average cost for utility-scale ground-mounted systems have declined from $4.80/W in 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 installed cost of the baseline fixed-tilt ground-mounted systems was assumed to be $2.79/W, and the installed cost of single-axis tracking was assumed to be $3.34/W. For the high contamination area of the site, a ballasted system will be required. This will add 25% to the baseline scenario. The area next to the existing wind turbines will require micro-inverters in order to operate effectively with the turbine shading. Micro-inverters increase the installed cost by 10% and decrease the O&M costs for this scenario. These costs represent remediation consideration cost case scenarios for PV installation price on EPA brownfields.

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

Table 6. Installed System Cost Assumptions

System Type	Fixed Tilt ($/Wp)	Single-Axis Tracking ($/Wp)
Baseline System	2.79	3.34
+ Ballasted System (25%)	0.70	0.84
+ Micro-Inverters (10%)	0.30	0.33

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 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 may qualify for federal tax credits and accelerated depreciation on the PV system. The total potential tax benefits to the tax-paying entity can be as high as 50% of the initial system cost in Lackawanna. 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 A. For the purposes of modeling how much PV could cover rooftops and spaces on site, it was assumed that 80% of the land space could contain PV. PVWatts Version 2 was used to calculate expected energy performance for the system.

The list of incentives used in this study can be found in Table 7 with the full descriptions and sources found in Appendix A. Incentives were found on the Database of State Incentives for Renewables and Efficiency (DSIRE) website, which catalogs most incentives to the state level.[6] Local incentives not included on the DSIRE website were not included in the modeling.

[6] Database of State Incentives for Renewables and Efficiency (DSIRE). http://www.dsireusa.org/.

Table 7. Summary of Incentives Evaluated

Incentive Title	Modeled Value	Expected End
PV Incentive Program	$1.5/W, $75,000 cap	12/31/2015
Federal Investment Tax Credit	30% of total investment	2016
Accelerated MACRS Schedule	Bonus 50% in the first year for Federal Depreciation	-
Net Metering	Net meter up to 2 MW	-
Sales Tax Exemption	0% Sales Tax	-

The net-metering program was only applied to the 2,000-kW system case.

5.2 SAM-Forecasted Economic Performance

Using varied inputs and the assumptions summarized in Section 5.1, SAM predicts net present value (NPV), PPA, and levelized cost of energy (LCOE). A total of 10 models were run for the Former Bethlehem Steel Plant to encompass the many options available to this site. These options included community and developer site recommendations; roof space and ground space utilization; 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(s) to use beyond NPV, PPA and LCOE; however, Table 8 shows the different options and their results.

Table 8. Summary of SAM Results

Cases	System Cost	LCOE ($/kWh)	NPV	PPA ($/kWh)	Payback (years)
Single-Axis Ground System - Net Meter Maximum	$ 6,700,000	0.1026	$ (46,780)	-	14.8
Fixed-Axis Ground System - Net Meter Maximum	$ 5,580,000	0.1091	$ (461,765)	-	18.5
Single-Axis Ground System – Micro-Inverters Near Wind Turbines	$ 40,509,893	0.1136	$ (4,058,268)	0.1913	19.6
Fixed-Axis Ground System – Micro-Inverters Near Wind Turbines	$ 38,681,060	0.1203	$ (4,977,595)	0.2017	21.1
Single-Axis Ground System - Highly Contaminated Area	$ 55,383,420	0.1138	$ (9,269,563)	0.2066	22.7

Fixed-Axis Ground System - Highly Contaminated Area	$ 55,934,230	0.1299	$ (8,170,200)	0.2180	24.2
Single-Axis Ground System - Industrial Complex	$ 105,119,650	0.1038	$ (18,389,547)	0.1746	24.5
Fixed Axis Ground System - Industrial Complex	$ 106,156,710	0.1107	$ (20,782,942)	0.1854	-
Single-Axis Ground System - Primary Area	$ 125,142,600	0.1038	$ (23,256,722)	0.1742	-
Fixed-Axis Ground System - Primary Area	$ 126,375,840	0.1107	$ (26,072,800)	0.1854	-
50-kW Fixed-Axis System	$ 139,500	0.0464	$ 30,036	-	4.6
50-kW Single-Axis System	$ 167,500	0.0524	$33,412	-	5.4
862-kW – Breakeven Sized System	$ 2,887,700	0.1009	$ 19	-	14.6

The analysis breaks down each system that would be installed in each highlighted area in Figure 6. It also includes various systems sized to different incentive limits. The best system size economically is 50 kW, which maxes out the New York PV Incentive Program. The largest system size that modeled a positive NPV is 862 kW. Any system larger than 862 kW has a NPV less than $0 under current incentive conditions. The site does not have adequate solar resource, and combined with few incentives, prices for solar energy on site become prohibitively expensive. New incentives and higher prices for both purchase and sale electricity would improve the economics and increase the size of economically viable systems. All of the different options have pros and cons that will play in deciding the correct path forward.

5.2.1 Fixed Plate Versus Single-Axis Tracking

According to the simulations, single-axis tracking for the ground-mounted system will provide the best payback for a slightly lower LCOE. While this may seem like an obvious choice, single-axis systems could be considered a higher risk option. Installation costs may be higher than modeled due to availability of installers and equipment. Despite having similar O&M costs to fixed-axis systems, more moving parts generally lead to higher malfunctions. While these higher risk considerations are important for evaluation, NREL recommends pursuing single-axis tracking systems for the ground-mounted portions of the Former Bethlehem Steel Plant.

5.2.2 Third-Party PPA Versus 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 high value payback for the developer, it will also require hiring the contractors to permit, build, and maintain the system. A solar investor inherits that risk and profit, and the Former Bethlehem Steel Plant in turn will receive power from the PV system at a rate determined by the investor. The recommendation of the feasibility team is to not pursue a PPA because the economic benefit below the net-metering ceiling of 2 MW is likely higher than the price for electricity from the utility. A PPA should be pursued, however, if the owner prefers the value of the PPA over ownership and upkeep.

5.2.3 Possible Ways to Improve the Economics Not Modeled

The economics for a PV system at the Former Bethlehem Steel Plant could be feasible under slightly lower installed prices, slightly higher electricity prices, or incentives from policies. If the installed cost for single-axis tracking modules were to fall to \$3.28/W, the 2-MW net-metering system would become economically viable. If the price for electricity were to increase by \$0.01, both of the net-meter cases would become economically feasible. One incentive available to the City of Lackawanna is to opt back into the property tax exemption currently available by the State of New York. This alone would make the 2-MW net-metering systems viable with both fixed- and single-axis tracking. Likewise, if there was an investment-based incentive worth 2% of the project, or \$134,000, the system would be feasible.

The entire results and summary of inputs to SAM are available in Appendix B.

A full summary of the results of the economic analysis and the systems modeled is available in Table 9. This table shows the sizes, number of homes powered, and jobs created through construction and maintenance for each system modeled. It also includes the full results for each system.

Table 9. PV System Summary

System Type	PV System Size[a] (kW)	Array Tilt (deg)	Annual Output (kWh/year)	Houses Powered[b]	Jobs Created[c] (job-year)	Jobs Sustained[d] (job-year)
Crystalline Silicon (1-Axis Ground System) - Net Meter Max	2,000	20	2,801,366	254	49.1	0.7
Crystalline Silicon (Fixed Tilt Ground System) - Net Meter Max	2,000	20	2,240,741	203	36.7	0.7
Crystalline Silicon (1-Axis Ground System) - Micro Inverters Near Wind Turbines	10,022	20	14,036,243	1271	245.9	3.5
Crystalline Silicon (Fixed Tilt Ground System) - Micro Inverters Near Wind Turbines	12,152	20	13,614,744	1233	222.9	4.3
Crystalline Silicon (1-Axis Ground System) - Highly Contaminated Are	9,626	20	13,482,974	1221	324.3	4.6
Crystalline Silicon (Fixed Tilt Ground System) - Highly Contaminated Area	11,672	20	13,076,966	1185	294.0	5.6
Crystalline Silicon (1-Axis Ground System) - Industrial Complex	40,948	20	43,952,029	3981	770.0	11.0
Crystalline Silicon (Fixed Tilt Ground System) - Industrial Complex	49,652	20	42,628,981	3861	697.8	13.3
Crystalline Silicon (1-Axis Ground System) - Primary Area	36,207	20	52,323,911	4739	916.6	13.1
Crystalline Silicon (Fixed Tilt Ground System) - Primary Area	43,902	20	50,748,307	4597	830.7	15.9
Crystalline Silicon (1-Axis Ground System) - Best NPV	50	20	70,034	6	1.4	0.0
Crystalline Silicon (Fixed Tilt Ground System) - Best Payback	50	20	56,019	5	1.1	0.0
Crystalline Silicon (1-Axis Ground System) - Breakeven Size	862	20	1,207,389	109	24.7	0.3

System Type	System Cost	Maximum Base Incentives	PPA ¢/kWh	NPV ($)	Annual O&M ($/year)	Period with Incentives (years)
Crystalline Silicon (1-Axis Ground System) - Net Meter Max	$ 6,700,000	$ 2,085,000	-	$ (46,780)	$ 60,000	14.8
Crystalline Silicon (Fixed Tilt Ground System) - Net Meter Max	$ 5,580,000	$ 1,749,000	-	$ (174,696)	$ 60,000	18.5
Crystalline Silicon (1-Axis Ground System) - Micro Inverters Near Wind Turbines	$ 40,509,893	$ 12,227,968	19.13	$ (4,058,268)	$ 200,420	19.6
Crystalline Silicon (Fixed Tilt Ground System) - Micro Inverters Near Wind Turbines	$ 38,681,060	$ 11,679,318	20.17	$ (4,977,595)	$ 243,040	21.1
Crystalline Silicon (1-Axis Ground System) - Highly Contaminated Are	$ 40,332,940	$ 12,174,882	20.65	$ (5,017,727)	$ 192,520	22.7
Crystalline Silicon (Fixed Tilt Ground System) - Highly Contaminated Area	$ 40,735,280	$ 12,295,584	21.79	$ (5,905,123)	$ 233,440	22.5
Crystalline Silicon (1-Axis Ground System) - Industrial Complex	$ 105,119,650	$ 31,610,895	17.46	$ (18,389,547)	$ 941,370	24.5
Crystalline Silicon (Fixed Tilt Ground System) - Industrial Complex	$ 106,156,710	$ 31,922,013	18.54	$ (20,782,942)	$ 1,141,470	-
Crystalline Silicon (1-Axis Ground System) - Primary Area	$ 125,142,600	$ 37,617,780	17.42	$ (23,256,722)	$ 1,120,680	-
Crystalline Silicon (Fixed Tilt Ground System) - Primary Area	$ 126,375,840	$ 37,987,752	18.54	$ (26,072,800)	$ 1,358,880	-
Crystalline Silicon (1-Axis Ground System) - Best NPV	$ 167,500	$ 125,250	-	$ 33,412	$ 1,500	5.4
Crystalline Silicon (Fixed Tilt Ground System) - Best Payback	$ 139,500	$ 116,850	-	$ 30,036	$ 1,500	4.64
Crystalline Silicon (1-Axis Ground System) - Breakeven Size	$ 2,887,700	$ 941,310	-	$ 19	$ 25,860	14.6

a *Data assume a maximum usable area of 950 acres*

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.

5.3 Job Analysis and Impact

To evaluate the employment and economic impacts of the PV project associated with this analysis, NREL's Jobs and Economic Development Impact (JEDI) models are used.[7] 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 the model 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 Former Bethlehem Steel Plant site, the values in Table 10 were assumed.

Table 10. JEDI Analysis Assumptions

Input	Assumed Value
Capacity	2,000 kW
Year Placed In Service	2013
Installed System Cost	$6,700,000
Location	Lackawanna, NY

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 one person working 40 hours per week for the duration of a year. Construction period jobs are considered short-term positions that exist only during the procurement and construction periods.

[7] 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 the NREL Jobs and Economic Development Impact tool, see http://www.nrel.gov/analysis/jedi/about_jedi.html.

As indicated in the results of the JEDI analysis provided in Appendix C, the total proposed system is estimated to support 49.1 direct and indirect 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 $2,839,600, and total economic output is estimated to be $7,230,100. 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 $43,100 in earnings and $74,400 in economic activity each year for the next 25 years.

5.4 Financing Opportunities

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

5.4.1 Owner and Operator Financing

The owner/operator financing structure is characterized by a single entity with the financial strength to fund all of the solar project costs and, if a private entity, sufficient tax appetite to utilize all of the project's tax benefits. Private owners/operators typically establish a special purpose entity (SPE) that solely owns the assets of the project. An initial equity investment into the SPE is funded by the private entity using existing funds, and all of the project's cash flows and tax benefits are utilized by the entity. This equity investment is typically matched with debt financing for the majority of the project costs. Project debt is typically issued as a loan based on 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 (lower 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 model is a site host working with a third-party developer who then partners with a tax-motivated investor in an SPE that would own and operate the project. Initially, most of the equity provided to the SPE would come from the tax investor and most of the benefit would flow to the tax investor (as much as 99%). When the tax investor has fully monetized the tax benefits and achieved an agreed-upon rate of return, the allocation of benefits and majority ownership (95%) would flip to the site host (but not within the first 5 years). After the flip, the site host would have the option to buy out all or most of the tax investor's interest in the project at the fair market value of the tax investor's remaining interest.

A flip agreement can also be signed between a developer and investors within an SPE, where the investor would begin with the majority ownership. Eventually, the ownership would flip to the developer once 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 their treatment of tax benefits and the rules limiting federal tax benefit transfers from non-profit to for-profit companies. Under IRS guidelines, municipalities cannot enter capital leases with for-profit entities when the for-profit entities capture tax incentives. As a result, a number of business models have emerged as a workaround to this issue. One model is the SSA wherein a private party sells solar services [i.e., energy and renewable energy certificates (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 may purchase the services in annual installments. The municipality may buy out the system once the third party has accrued the tax credits, but due to IRS regulations, the buyout of the plant cannot be included as part of the SSA (i.e., 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 "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.

5.4.6 Sales/Leaseback

In the widely accepted sales/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 using 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.

5.4.7 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 may be able to make the land available for a large solar project, which can be the basis for a community solar project. Ownership structures for these projects vary, but the large projects are typically owned or sponsored by a local utility. Community solar gardens are distributed solar projects wherein utility customers have a stake via a pro-rated share of the project's energy output. This business model is targeted to meet demand for solar projects by customers who rent/lease homes or businesses, do not have good solar access at their site, or do not want to install 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 solely owned by the utility, solely owned 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

PV arrays at the Lackawanna site are economically feasible at smaller sizes that maximize the incentives available in New York. The best size economically is the 50-kW single-axis system with an NPV of $33,412, and the largest system that remains economically attractive is an 862-kW single-axis system. These systems should be pursued through site ownership rather than with solar developers because currently the modeled PPA prices are higher than the cost for electricity.

Installing PV systems on the Former Bethlehem Steel Plant, which would cover the entire usable space for PV arrays, could potentially generate 131,637,776 MWh annually, producing nearly 7.5 times the electricity modeled for the site.

The inclusion of large-scale PV is not currently an economically viable option, but small changes in policy, PV cost, or electricity could make 2-MW systems, which take full advantage of the net-metering policy, viable. One incentive that is available to the City of Lackawanna is to opt back into the property tax exemption currently available by the State of New York. This would make 2-MW systems viable with both fixed and single-axis tracking. The breakeven price for a 2-MW single-axis system is $3.28/W. Likewise, if there was an investment-based incentive worth 2% of the project, or $134,000, the system would be feasible. Finally, if the price for electricity were to increase by $0.01, both of the net-meter cases would become economically feasible.

Appendix A. Assessment and Calculations Assumptions

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

Cost Assumptions			
Variable	**Quantity of Variable**	**Unit of Variable**	
Cost of Site Electricity	0.05	$/kWh	
Annual O&M (fixed)	20	$/kW/year	
System Assumptions			
System Type	**Annual energy kWh/kW**	**Installed Cost ($/W)**	**Energy Density (W/sq. ft.)**
Ground Fixed	1,126	$3.49	4.0
Ground Single-Axis	1,403	$4.18	3.3
Other Assumptions			
	1 acre	43,560 ft^2	
	1 MW	1,000,000 W	
	Ground utilization	90% of available area	

Table A-2. SAM Modeling Assumptions

Item	PPA/Investor	Municipal Purchase	Notes
Analysis period (years)	25	25	
Inflation	2.50%	2.50%	
Real discount rate	5.85%	3%	
Federal tax rate	35%	0%	
State tax rate	8%	0%	
Insurance (% of installed cost)	0.50%	0.50%	
Property tax	0	0	
Construction loan	0	0	
Loan term	15	25	25-year bonds
Loan rate	6%	6%	May be lower for bonds
Debt fraction	55%	100%	45%–60% PPA, 100% municipal ownership, Debt-Service Coverage Ratio of ~1.3 (>1.2)
Minimum internal rate of return	15%	15%	
PPA escalation rate	1.5%	1.5%	

Federal depreciation	5-year MACRS with 50% first-year bonus	N/A	N/A for municipal ownership
State depreciation	5-year MACRS	N/A	N/A for municipal ownership
Federal investment tax credit	30%	N/A	N/A for municipal ownership
Payment incentives	0	0	
Degradation	0.50%	0.50%	
Availability	100%	100%	
Cost - fixed axis per kW	$2.79–$3.20	$2.79–$3.20	
Cost – single-axis tracking per kW	$3.35–$3.84	$3.35–$3.84	
Cost - landfill ballasted per kW	$3.49–$4.00	$3.49–$4.00	
Grid interconnection cost	$ -	$ -	
Land cost	$ -	$ -	
O&M	$30/kW/yr first 15 yrs and $20/kW/yr for yrs 16-25	$30/kW/yr first 15 yrs and $20/kW/yr for yrs 16-25	
Derate factor	0.8	0.8	
Fixed tilt	20°	20°	
Single-axis tilt	20°	20°	
Acres per MW fixed	5.74	5.74	
Acres per MW tracking	6.96	6.96	

Table A-3. Full Incentive Information

Incentives Summary

Category	Incentive Name	Summary	Amount	Cap	Incentive Ending Criteria
Capacity Based Incentive	NYSERDA -PV Incentive Program	The New York State Energy Research and Development Authority (NYSERDA) provides an incentive of $1.50 per watt (DC) to eligible installers for the installation of approved, grid-connected photovoltaic (PV) systems.	$1.5/W, $75000 cap	$75,000	12/31/2015
Investment Based Incentive	Federal Investment Tax Credit	The federal business energy investment tax credit available under 26 USC § 48 was expanded significantly by the Energy Improvement and Extension Act of 2008 (H.R. 1424), enacted in October 2008. This law extended the duration -- by eight years -- of the existing credits for solar energy, fuel cells and microturbines; increased the credit amount for fuel cells; established new credits for small wind-energy systems, geothermal heat pumps, and combined heat and power (CHP) systems; allowed utilities to use the credits; and allowed taxpayers to take the credit against the alternative minimum tax (AMT), subject to certain limitations. The credit was further expanded by The American Recovery and Reinvestment Act of 2009, enacted in February 2009.	30% of total investment	N/A	2016
Regulation	Net Metering	Net metering is available on a first-come, first-served basis to customers of the state's major investor-owned utilities, subject to technology, system size and aggregate capacity limitations.	Net Meter	2 MW	-
Investment Based Incentive	Sales Tax Exemption	New York enacted legislation in July 2005 exempting the sale and installation of residential solar-energy systems from the state's sales and compensating use taxes. The exemption was extended to non-residential solar systems in August 2012 (S.B. 3203), effective beginning January 1, 2013.	0% Sales Tax	N/A	-
Investment Based Incentive	Property Tax Incentive *	Section 487 of the New York State Real Property Tax Law provides a 15-year real property tax exemption for solar, wind energy, and farm-waste energy systems constructed in New York State. As currently effective, the law is a *local option* exemption, meaning that local governments are permitted decide whether or not to allow it.	100% of Assessed Value	15 yrs	-
	* Not applied in the report				

Appendix B. Results of the System Advisor Model

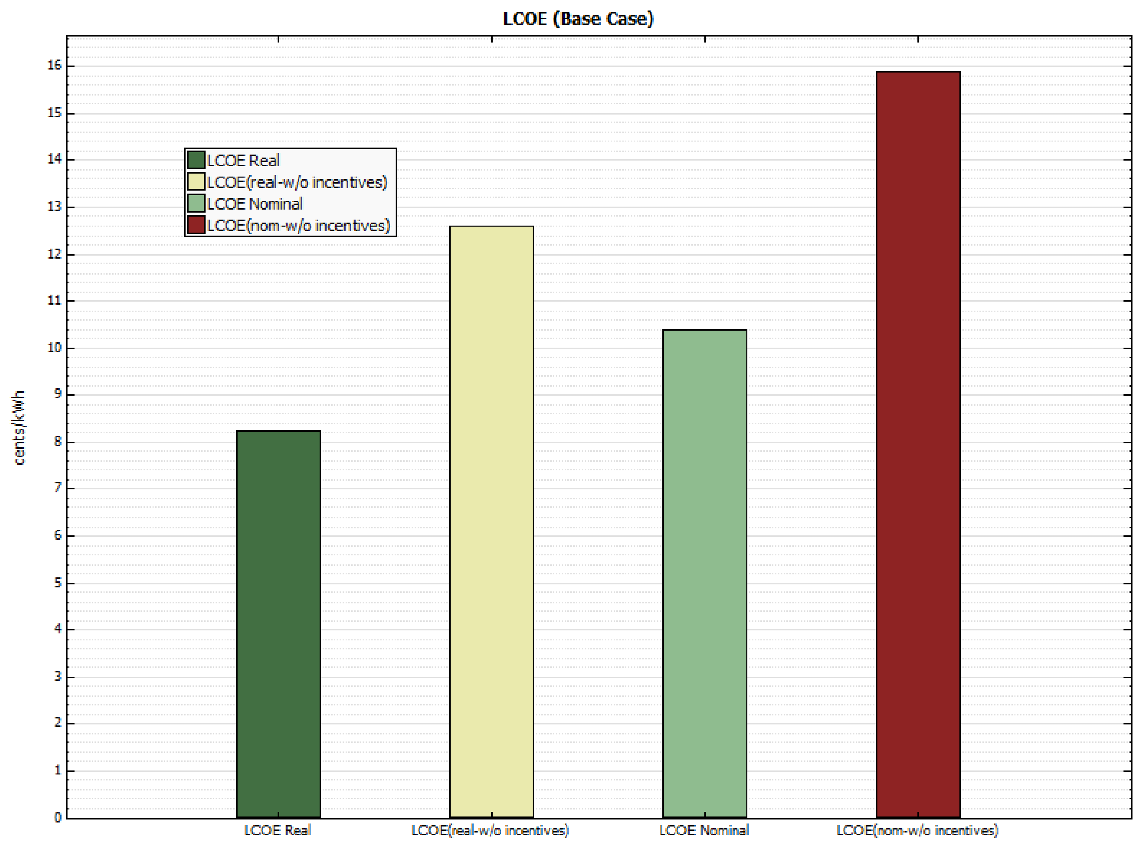

Figure B-1. Levelized cost of energy—Primary (yellow shaded) area—Single axis—36,206 kW

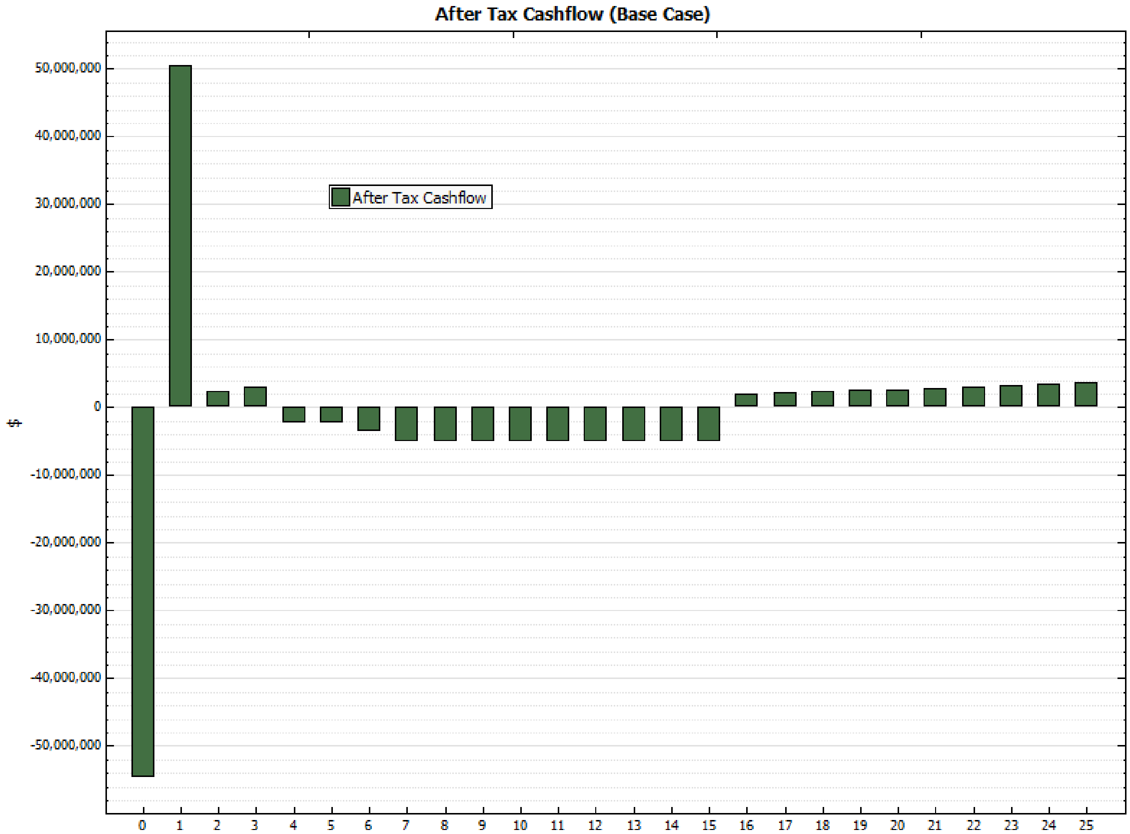

Figure B-2. Annual cash flow—Primary (yellow shaded) area—Single axis—36,206 kW

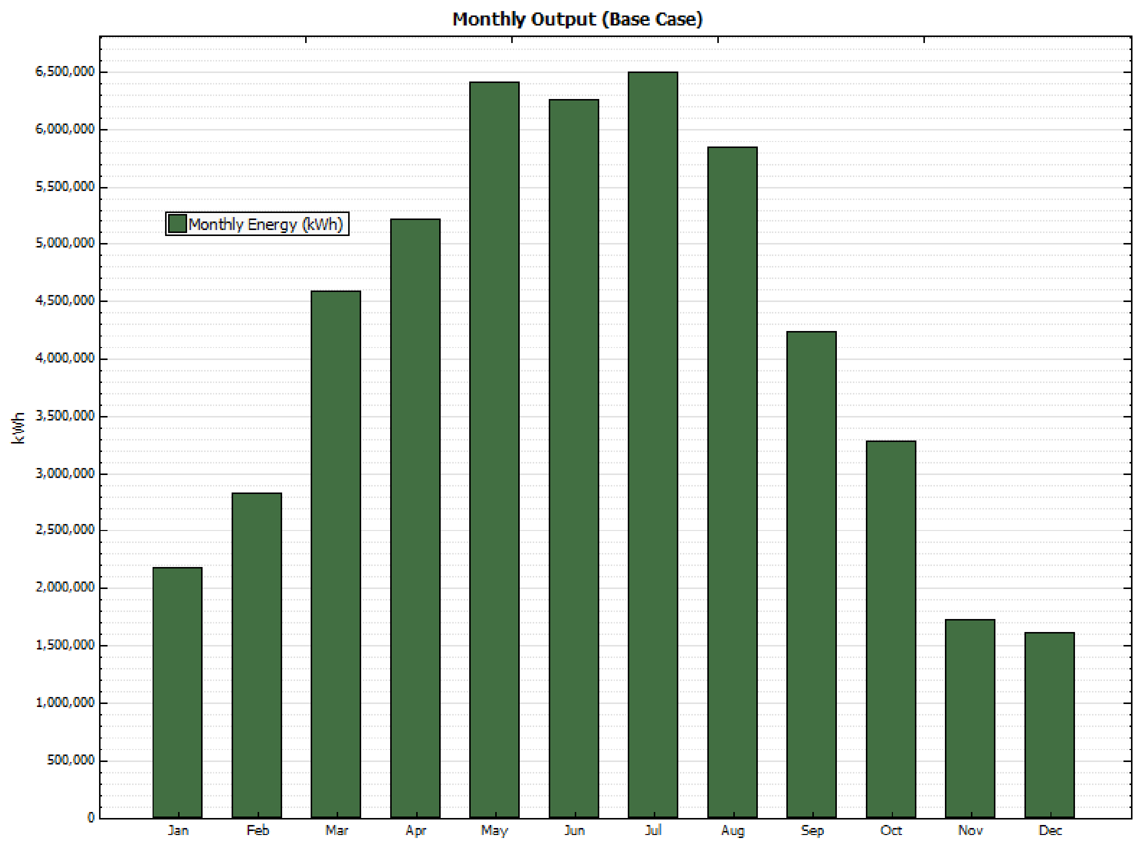

Figure B-3. Monthly energy output—Primary (yellow shaded) area—Single axis—36,206 kW

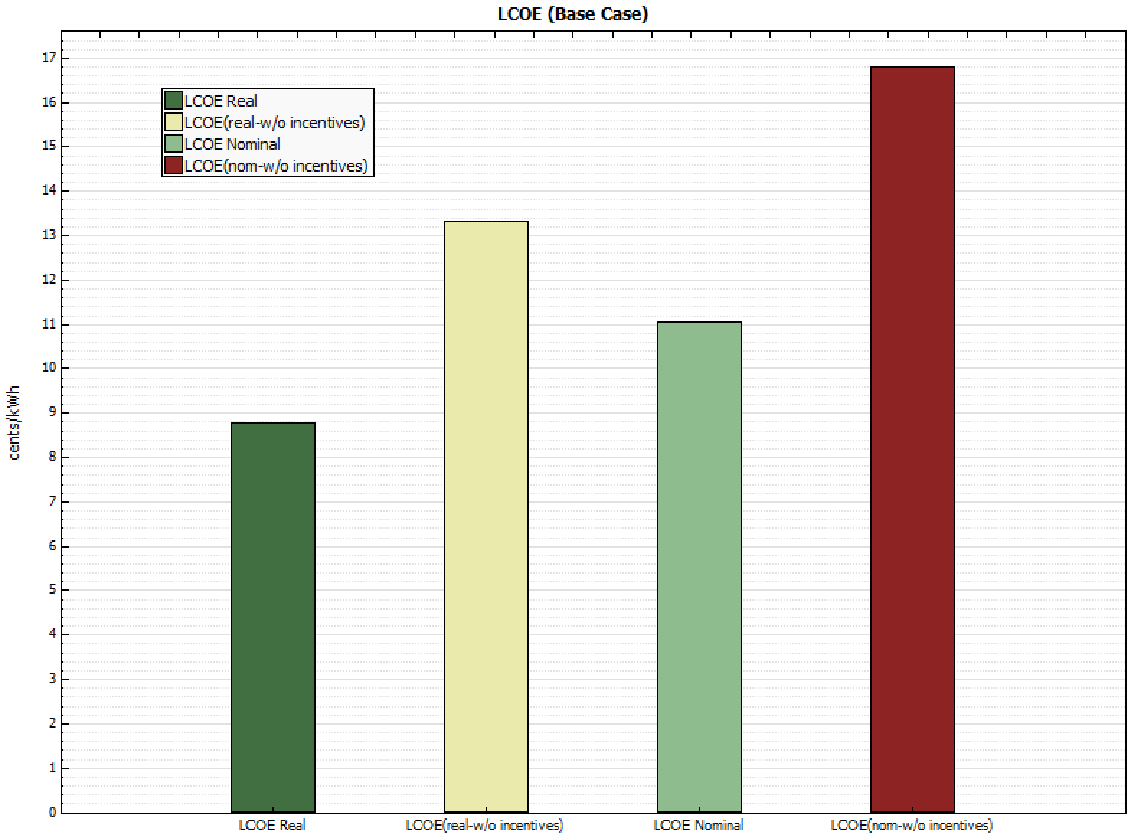

Figure B-4. Levelized cost of energy—Primary (yellow shaded) area—Fixed axis—43,902 kW

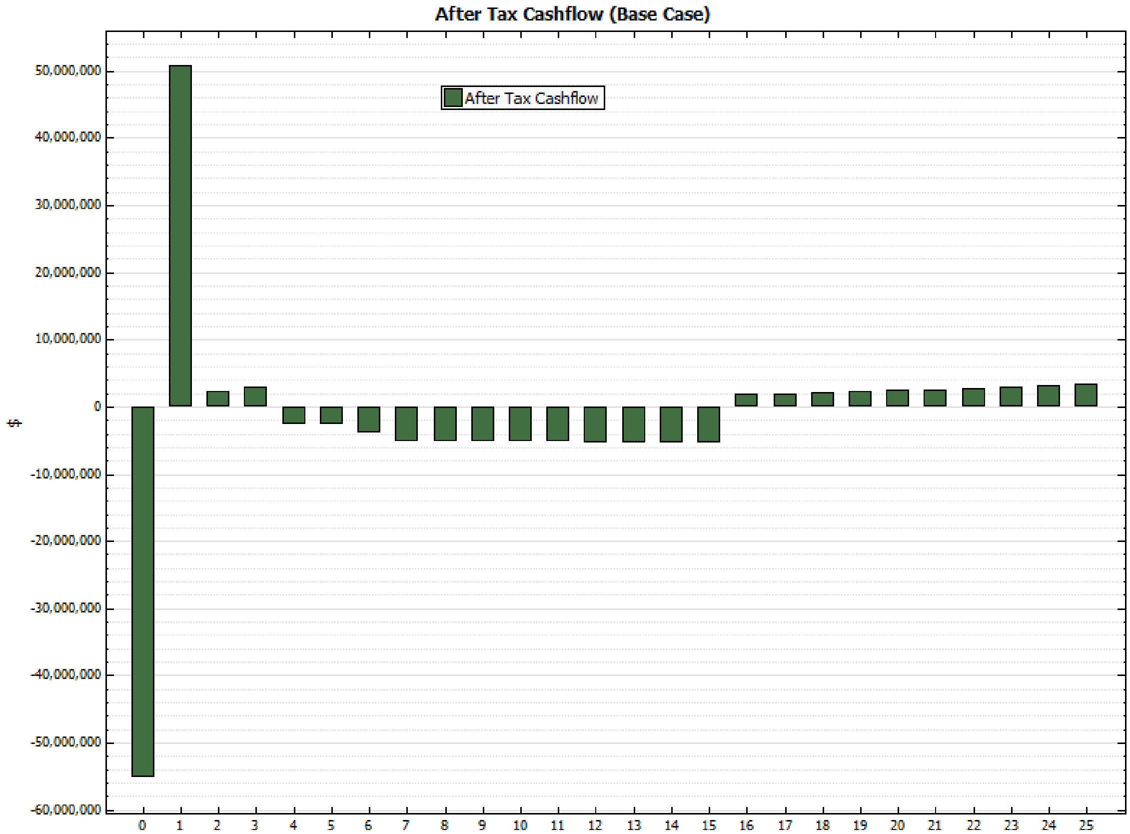

Figure B-5. Annual cash flow—Primary (yellow shaded) area—Fixed axis—43,902 kW

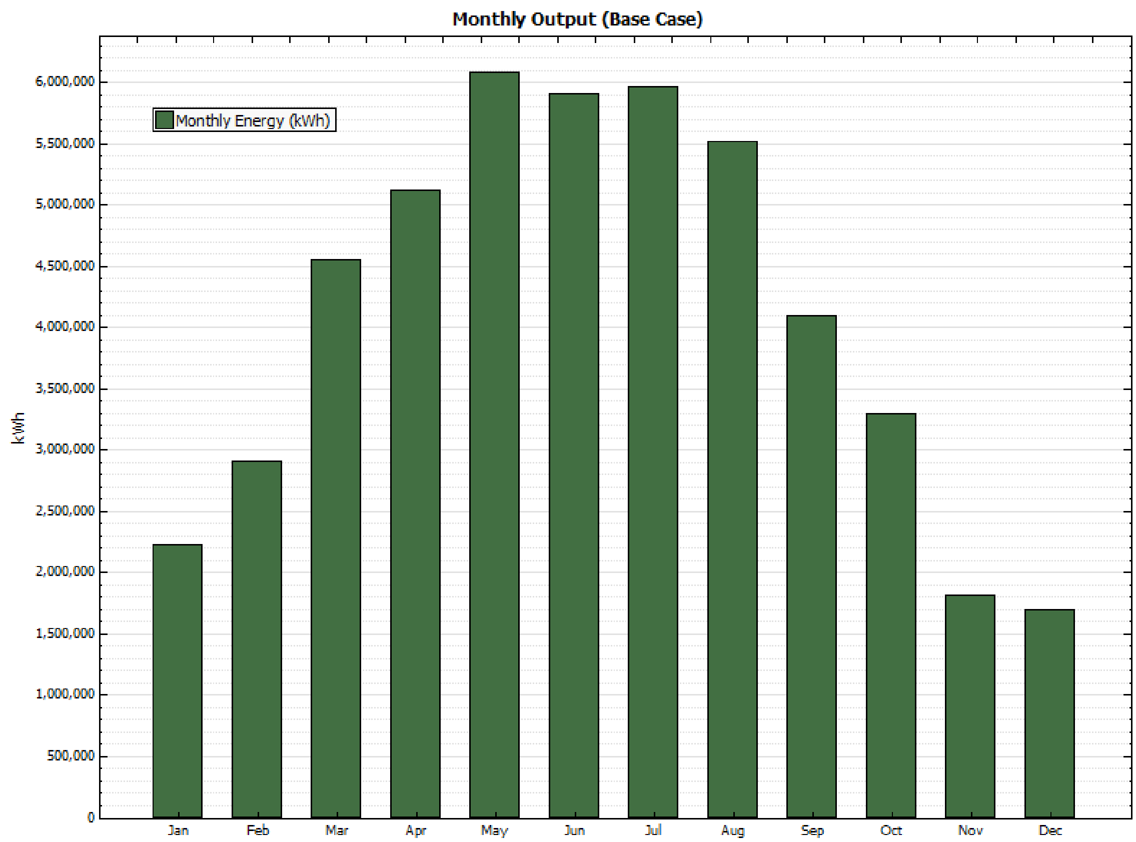

Figure B-6. Monthly energy output—Primary (yellow shaded) area—Fixed axis—43,902 kW

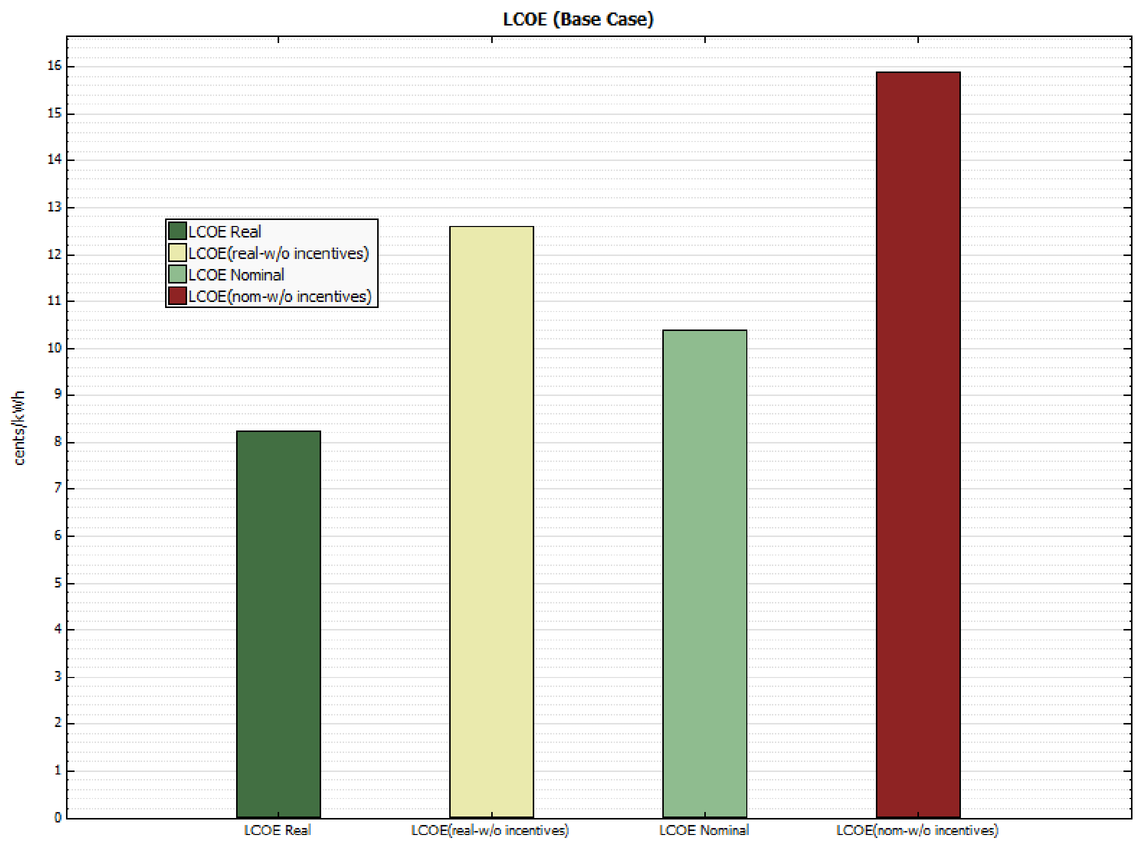

Figure B-7. Levelized cost of energy—Industrial (red shaded) area—Single axis—40,948 kW

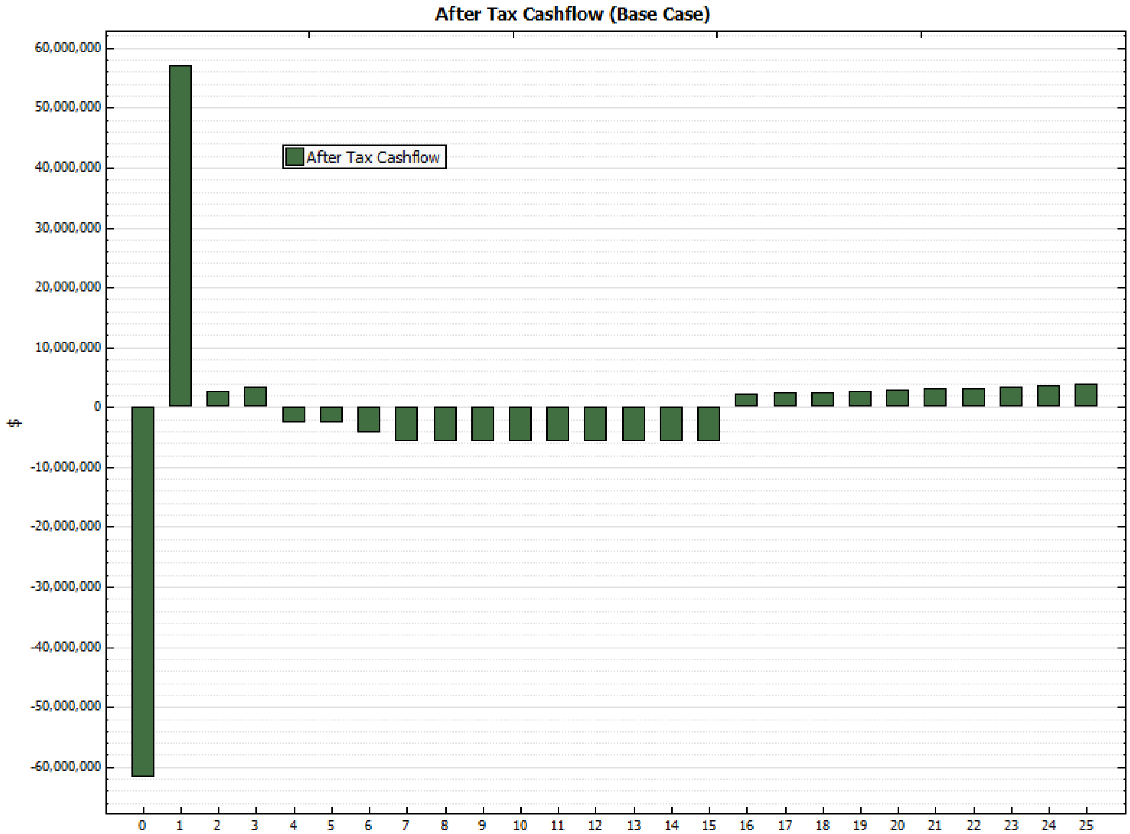

Figure B-8. Annual cash flow—Industrial (red shaded) area—Single axis—40,948 kW

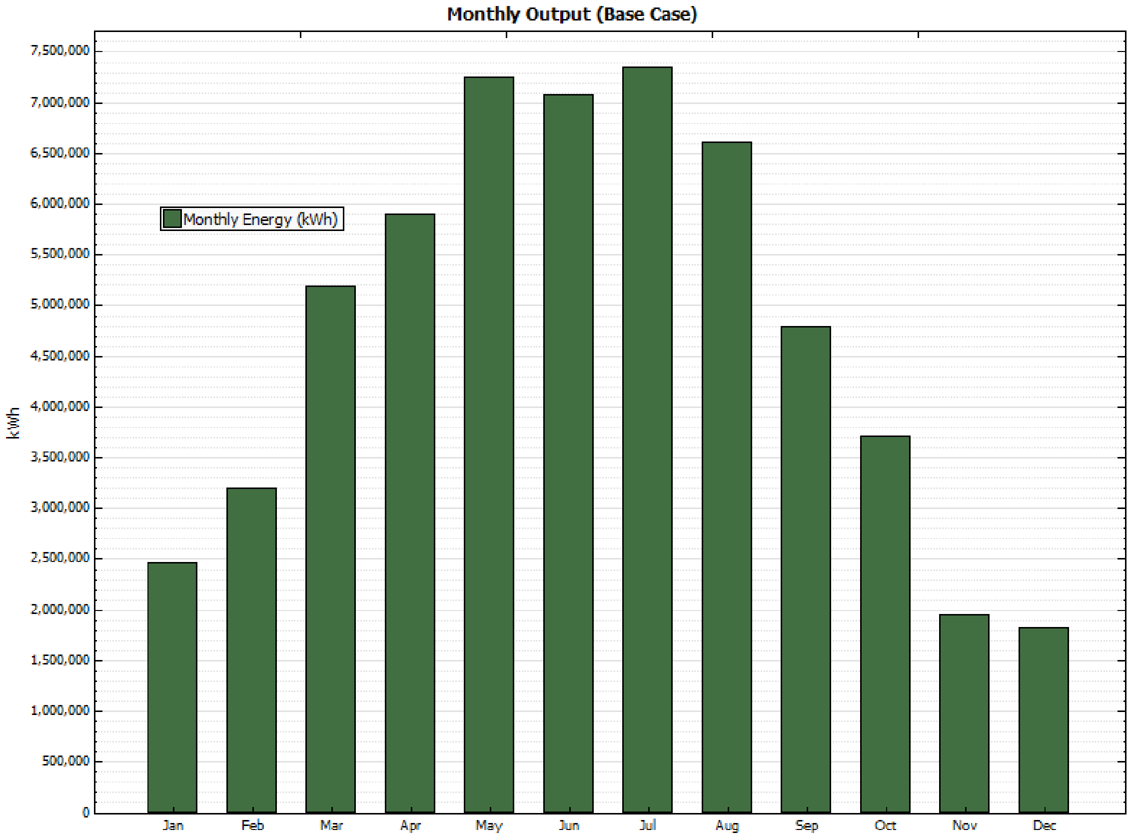

Figure B-9. Monthly energy output—Industrial (red shaded) area—Single axis—40,948 kW

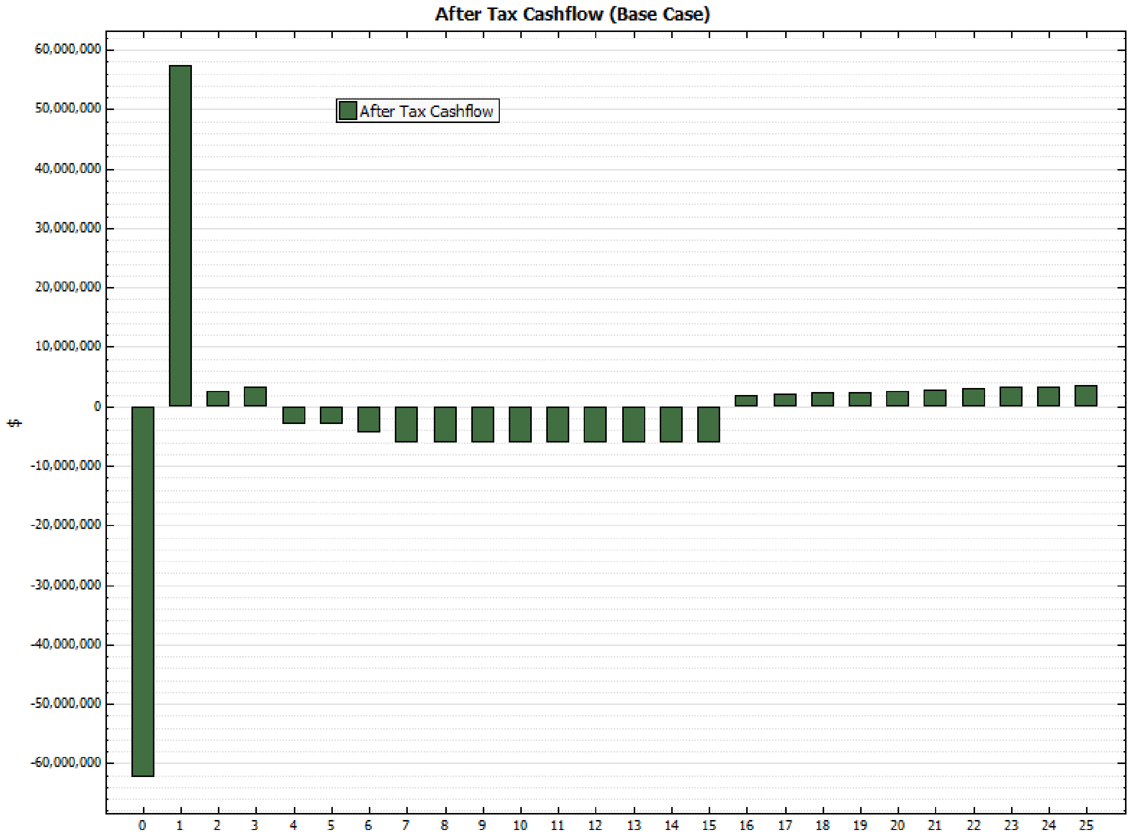

Figure B-10. Annual cash flow—Industrial (red shaded) area—Fixed axis—49,651 kW

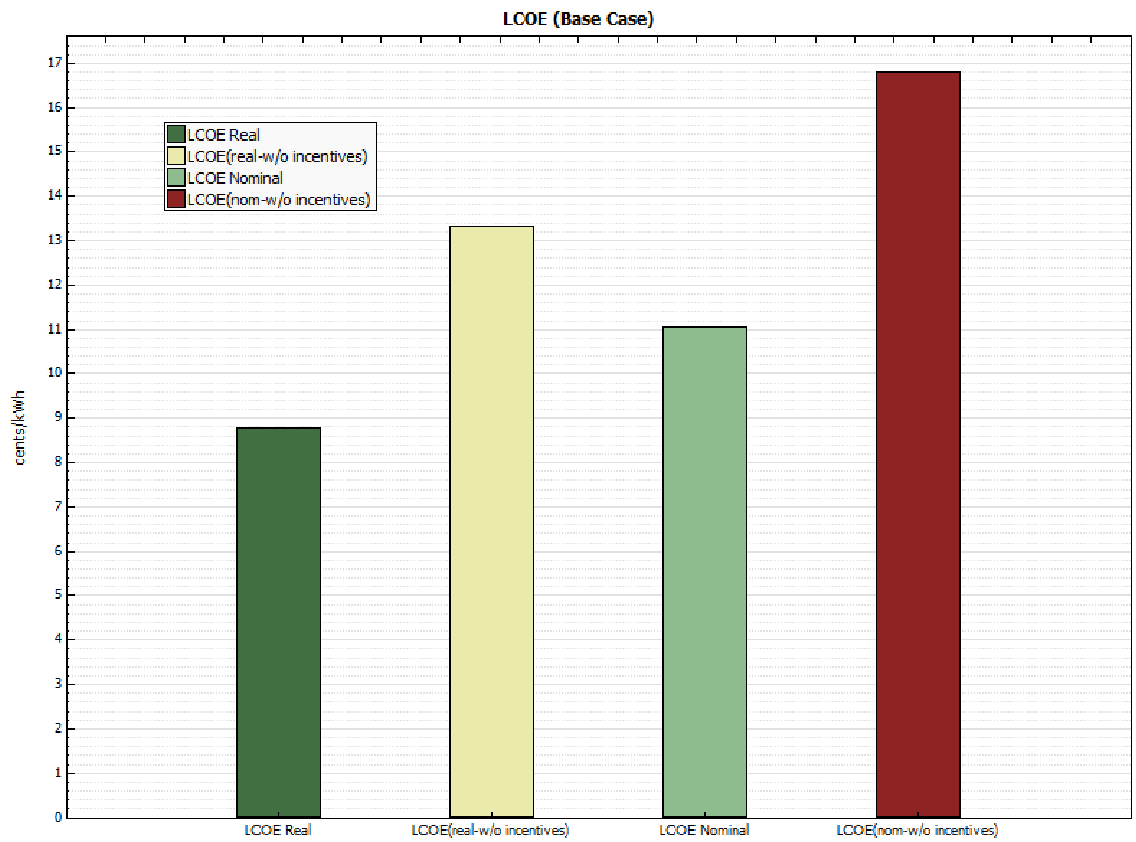

Figure B-11. Levelized cost of energy—Industrial (red shaded) area—Fixed axis—49,651 kW

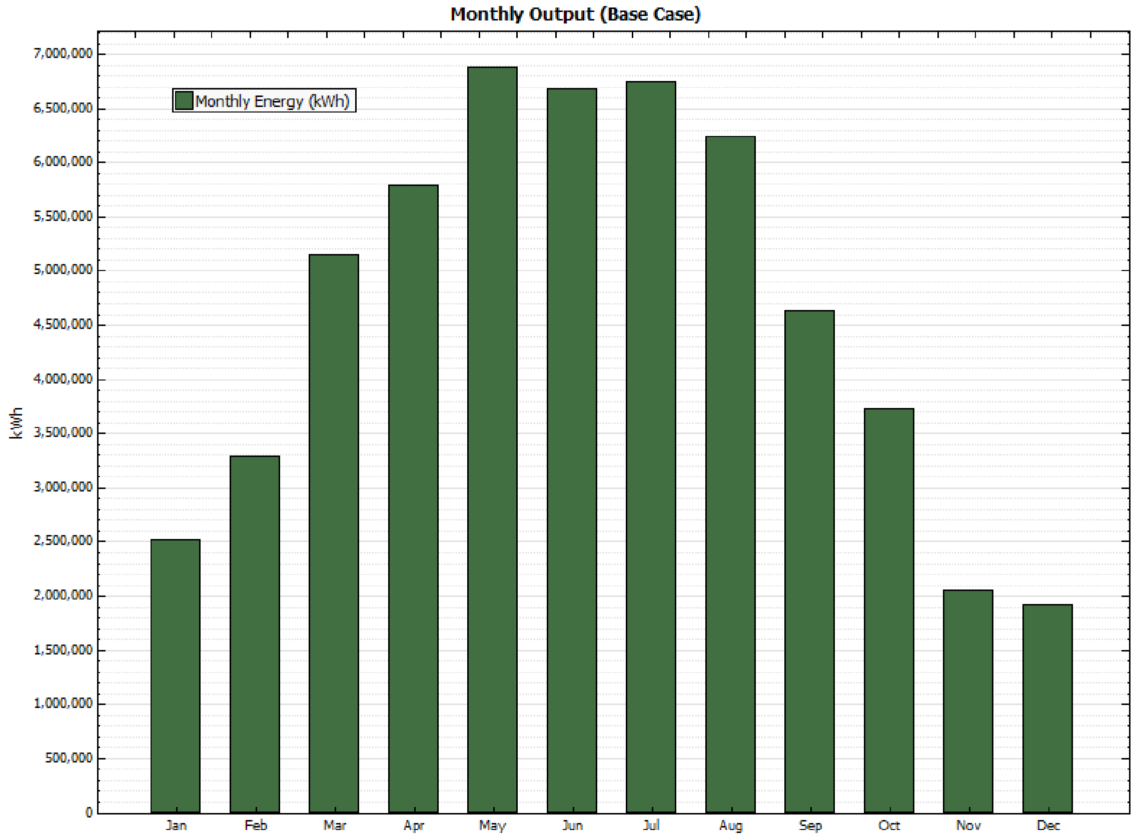

Figure B-12. Monthly energy output—Industrial (red shaded) area—Fixed axis—49,651 kW

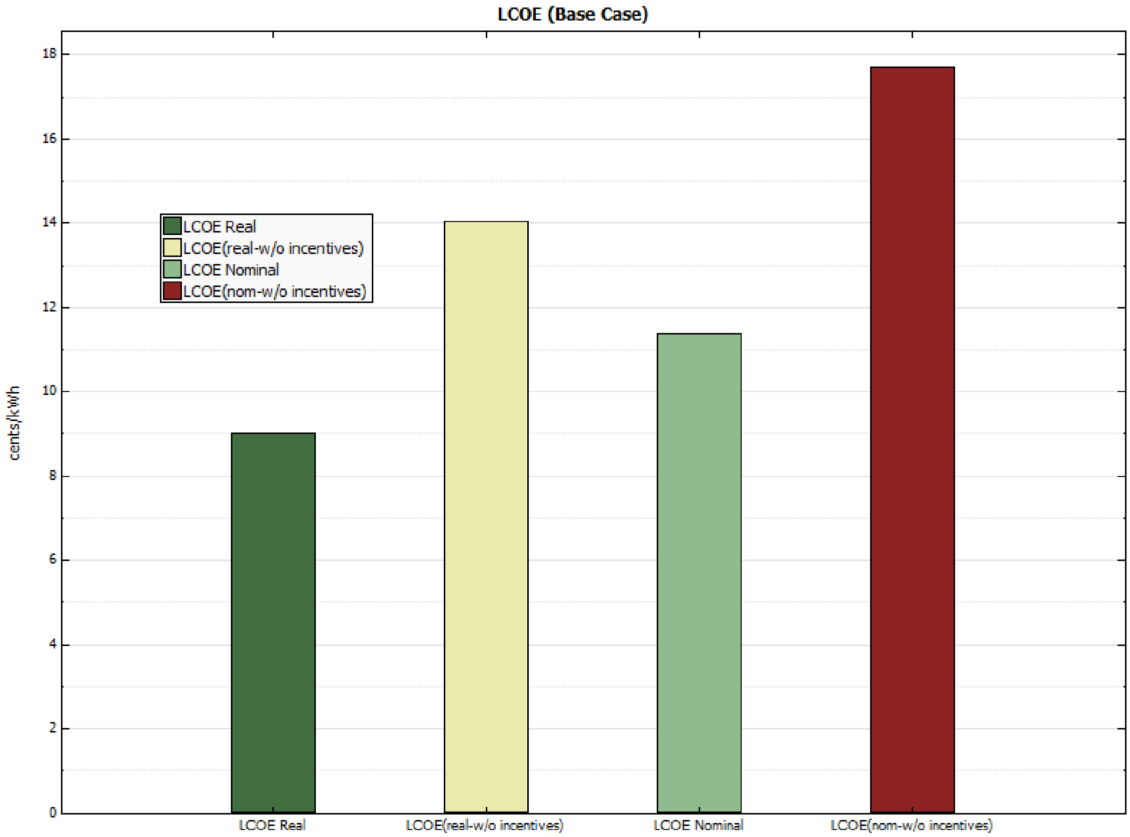

Figure B-14. Levelized cost of energy—Wind turbine (green shaded) area—Single axis—10,021 kW

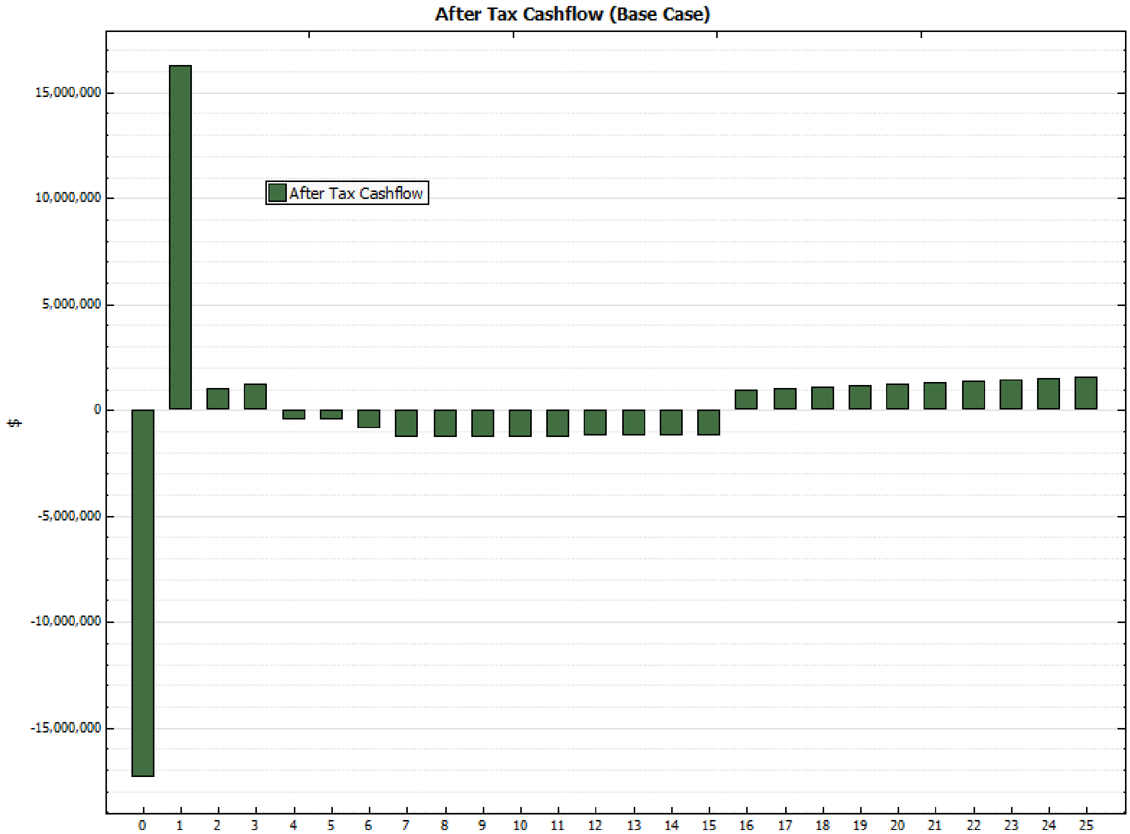

Figure B-15. Annual cash flow—Wind turbine (green shaded) area—Single axis—10,021 kW

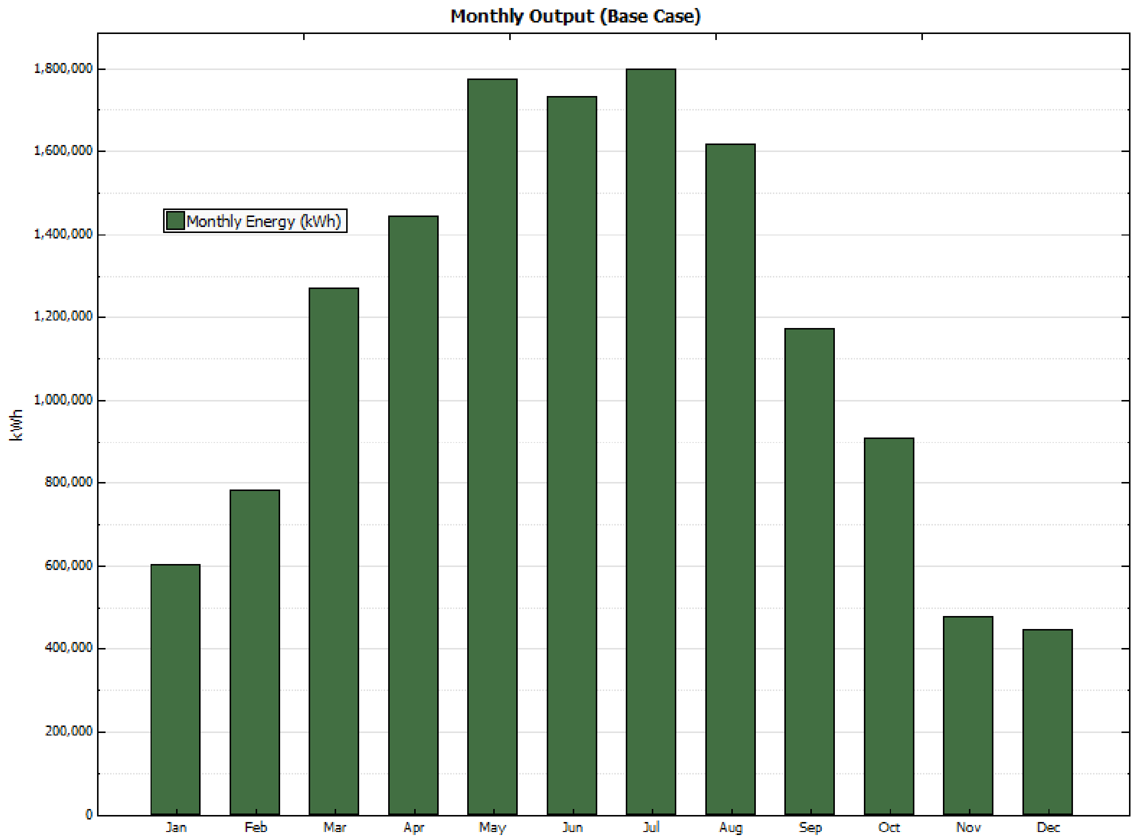

Figure B-16. Monthly energy output—Wind turbine (green shaded) area—Single axis—10,021 kW

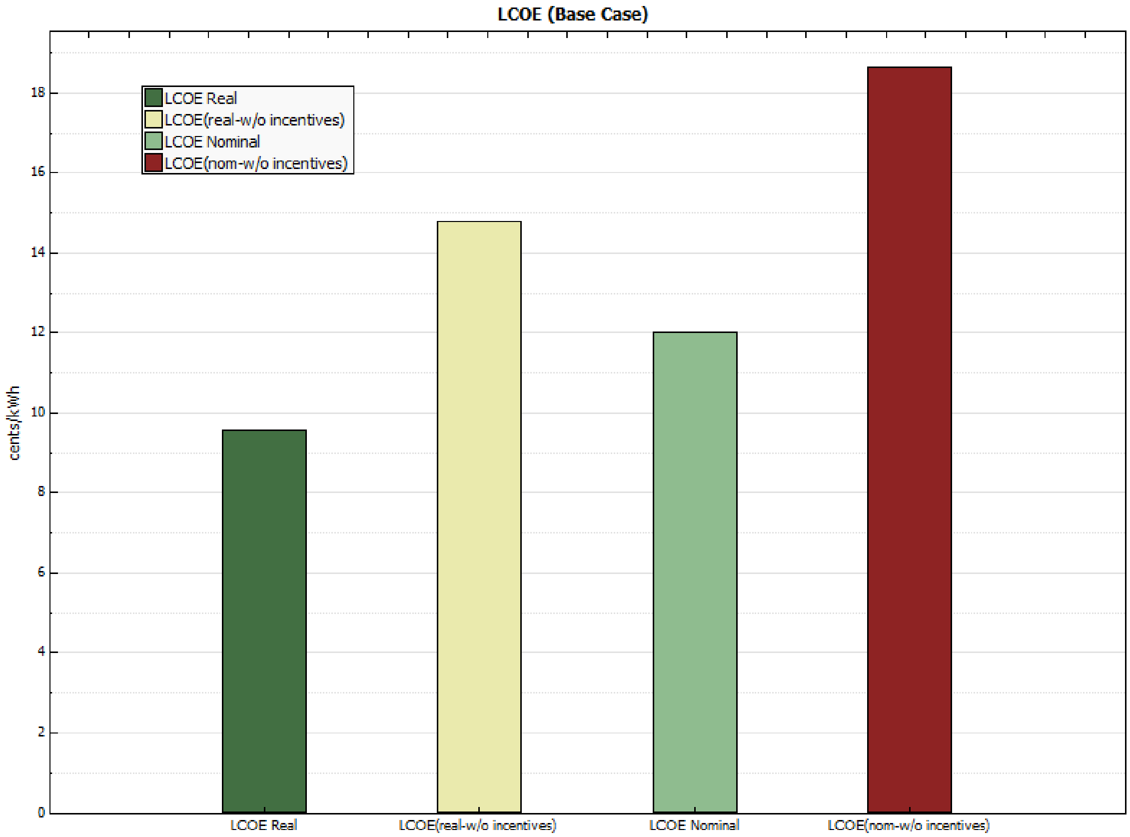

Figure B-17. Levelized cost of energy—Wind turbine (green shaded) area—Fixed axis—12,152 kW

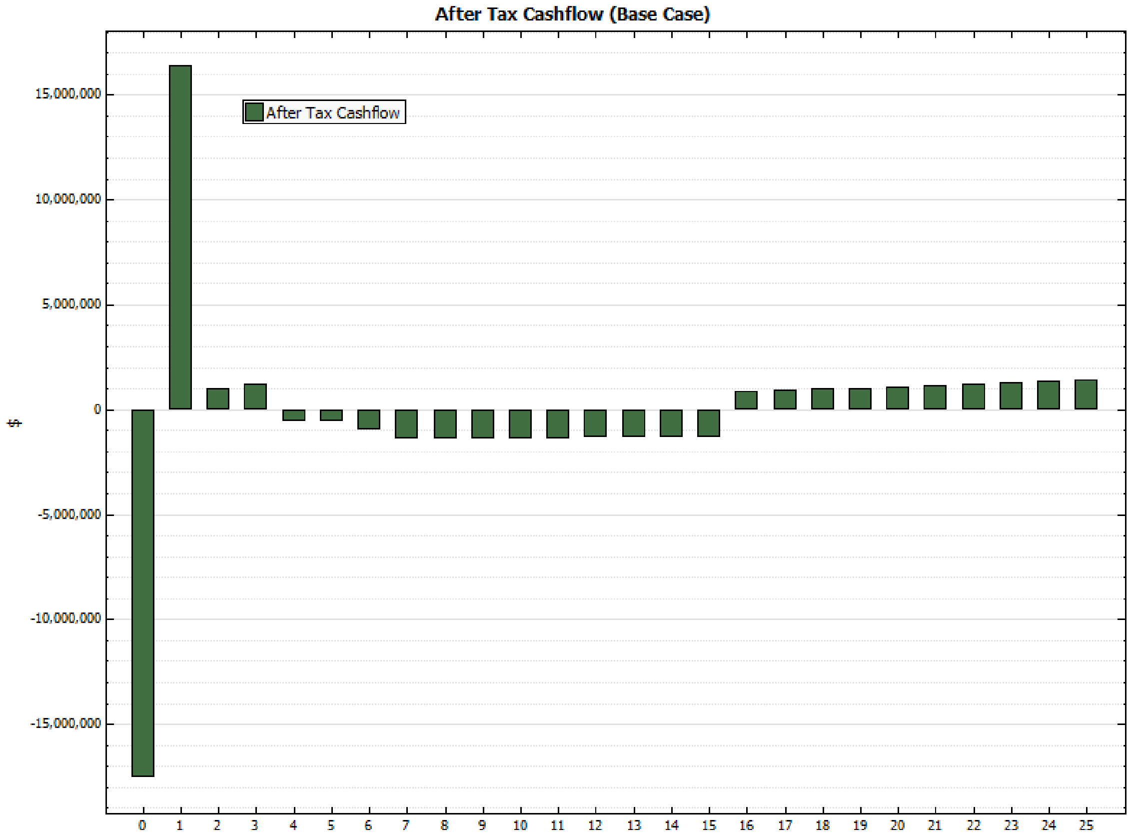

Figure B-18. Annual cash flow—Wind turbine (green shaded) area—Fixed axis—12,152 kW

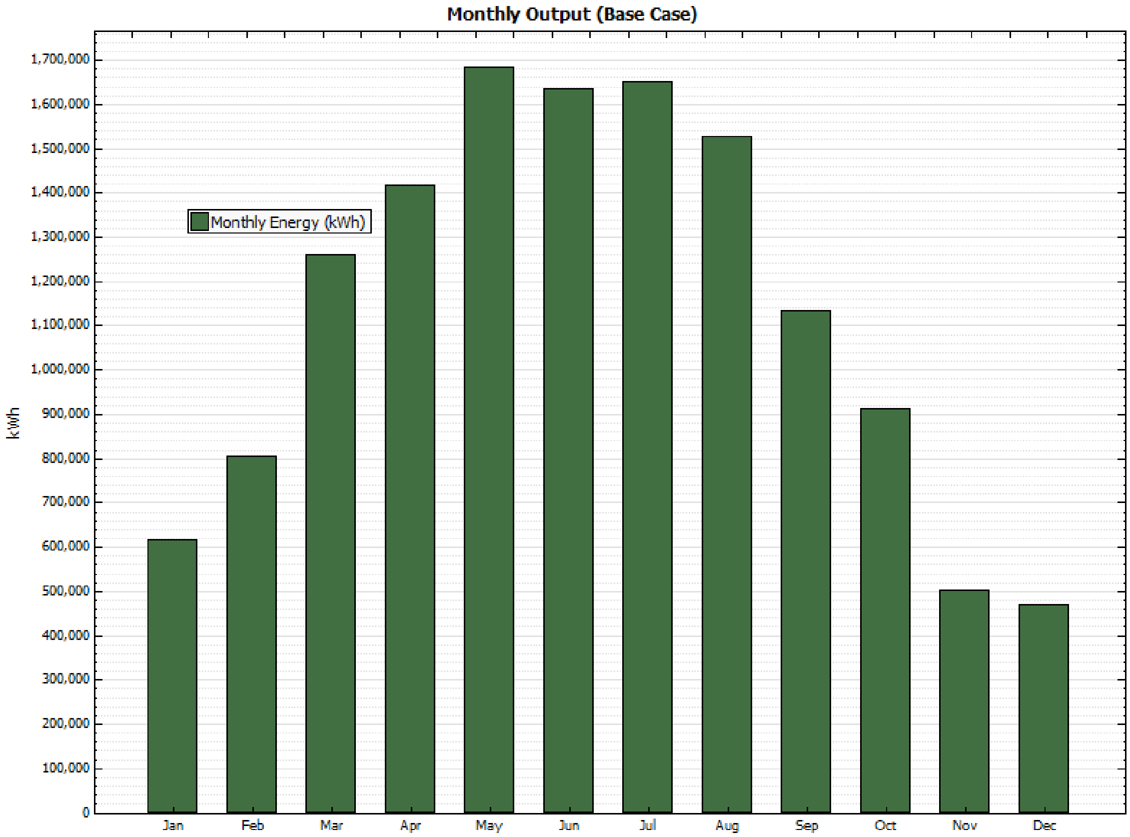

Figure B-19. Monthly energy output—Wind turbine (green shaded) area—Fixed axis—12,152 kW

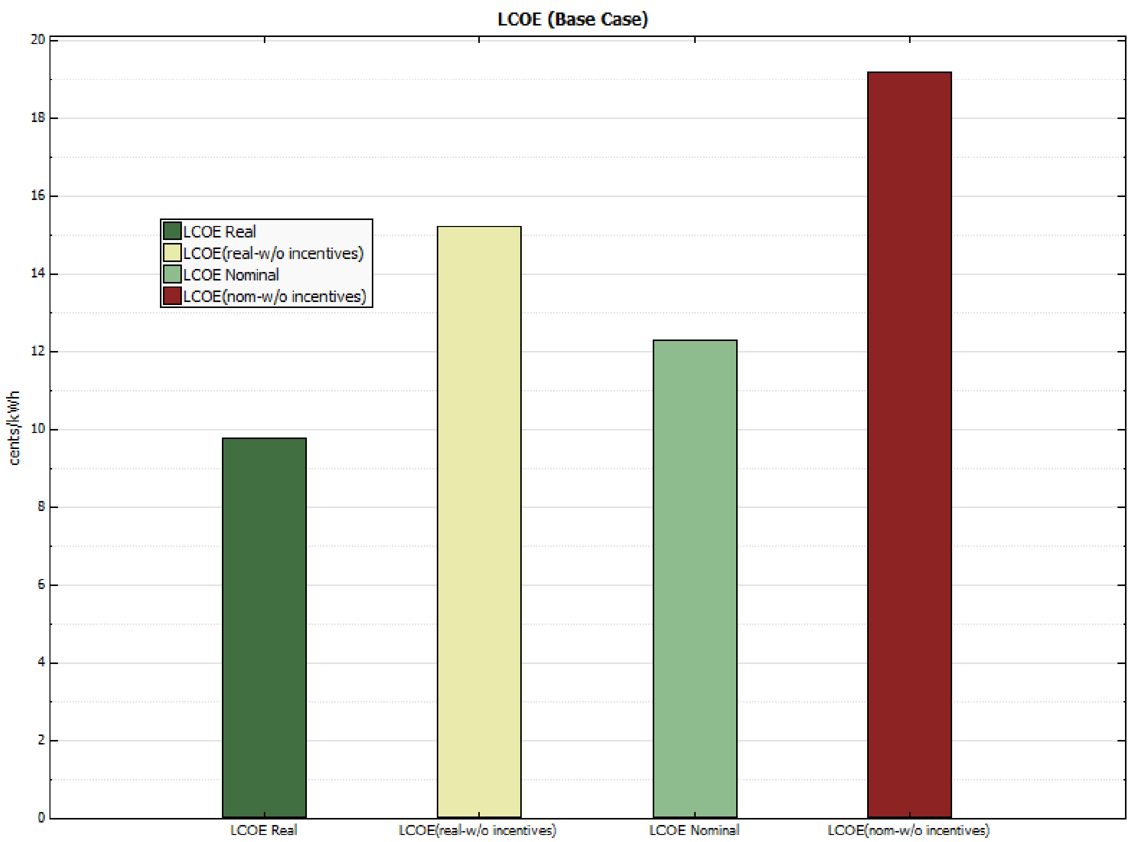

Figure B-20. Levelized cost of energy—Highly contaminated (purple shaded) area—Single axis—9,626 kW

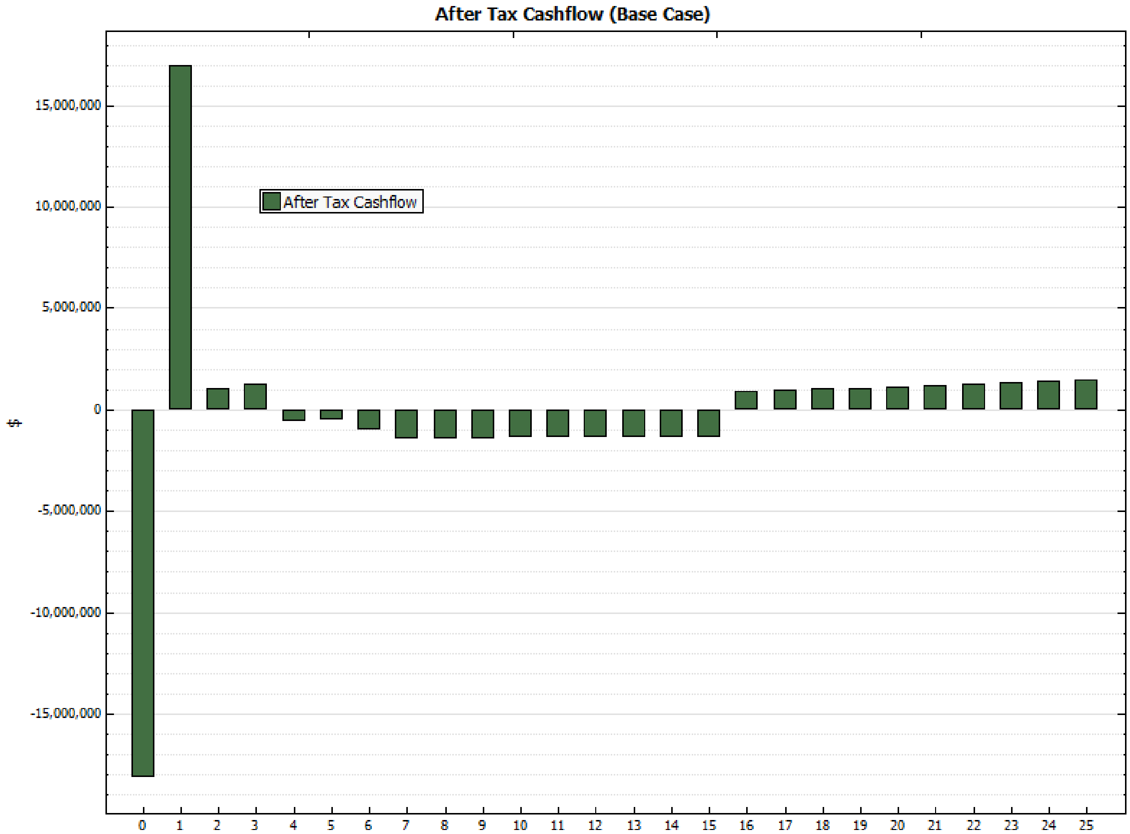

Figure B-21. Annual cash flow—Highly contaminated (purple shaded) area—Single axis—9,626 kW

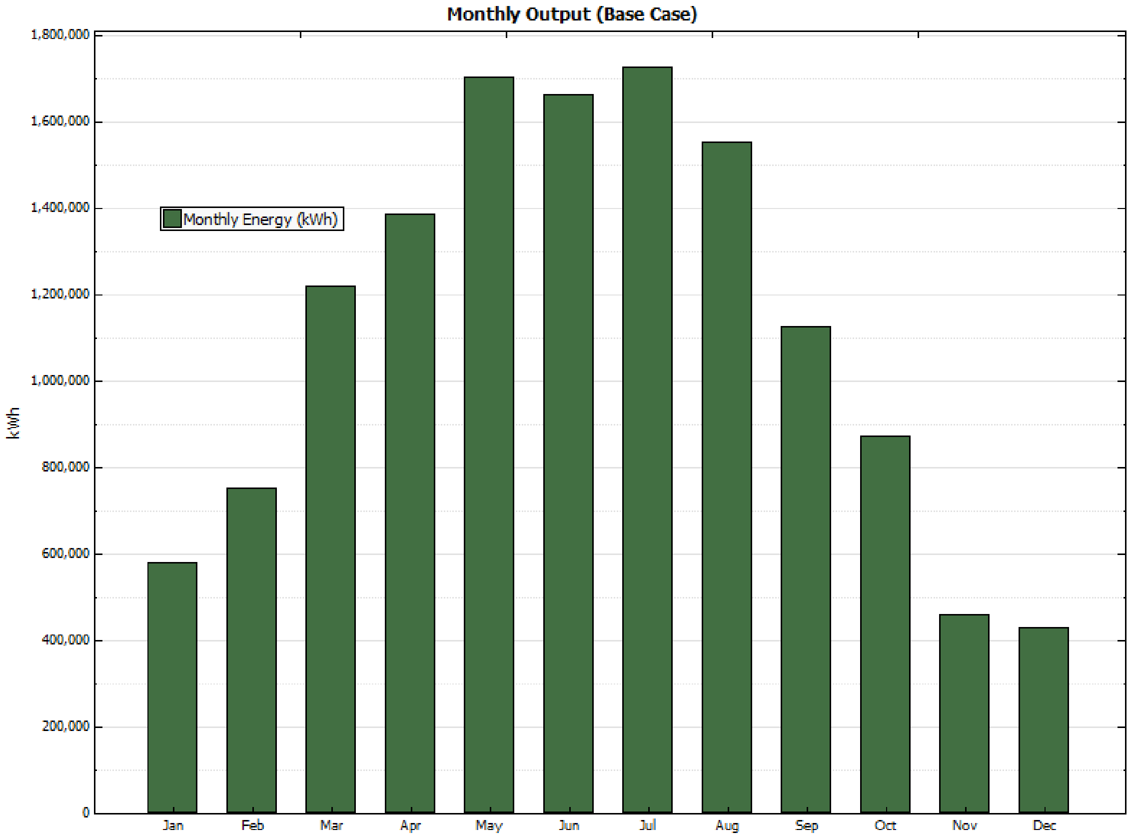

Figure B-22. Monthly energy output—Highly contaminated (purple shaded) area—Single axis—9,626 kW

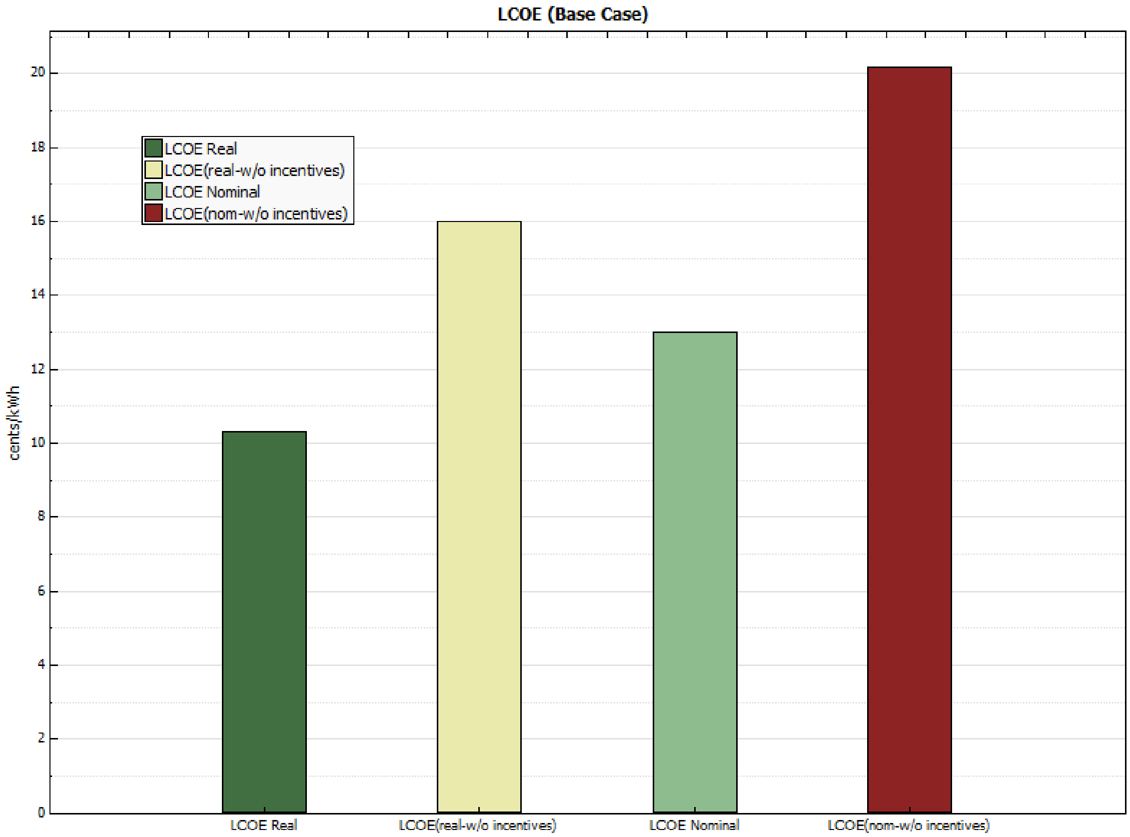

Figure B-23. Levelized cost of energy—Highly contaminated (purple shaded) area—Fixed axis—11,672 kW

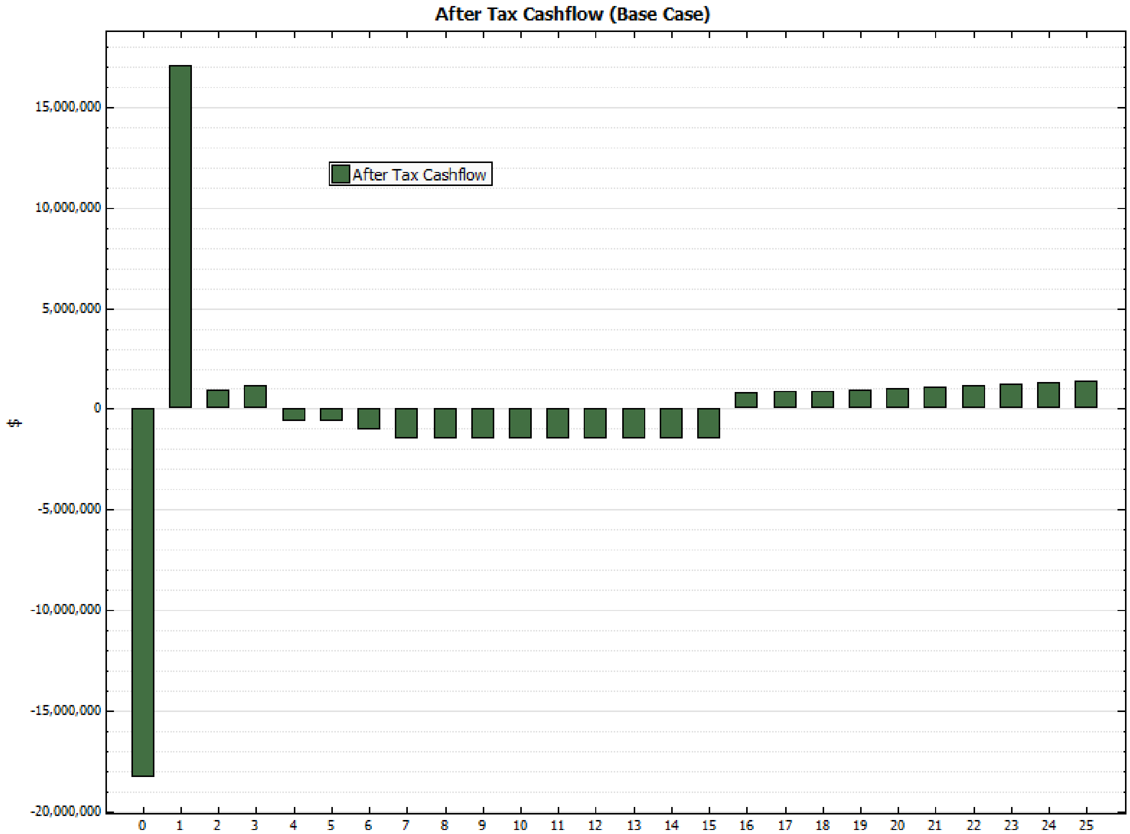

Figure B-24. Annual cash flow—Highly contaminated (purple shaded) area—Fixed axis—11,672 kW

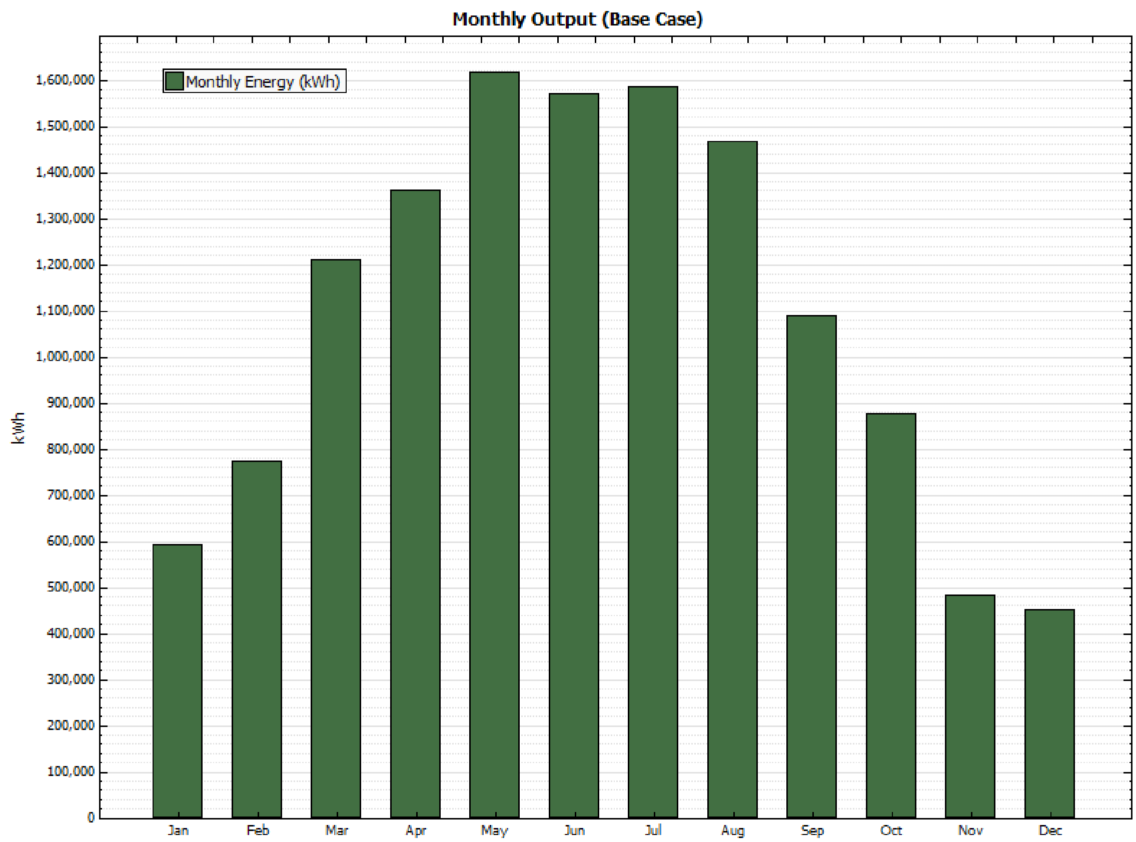

Figure B-25. Monthly energy output—Highly contaminated (purple shaded) area—Fixed axis—11,672 kW

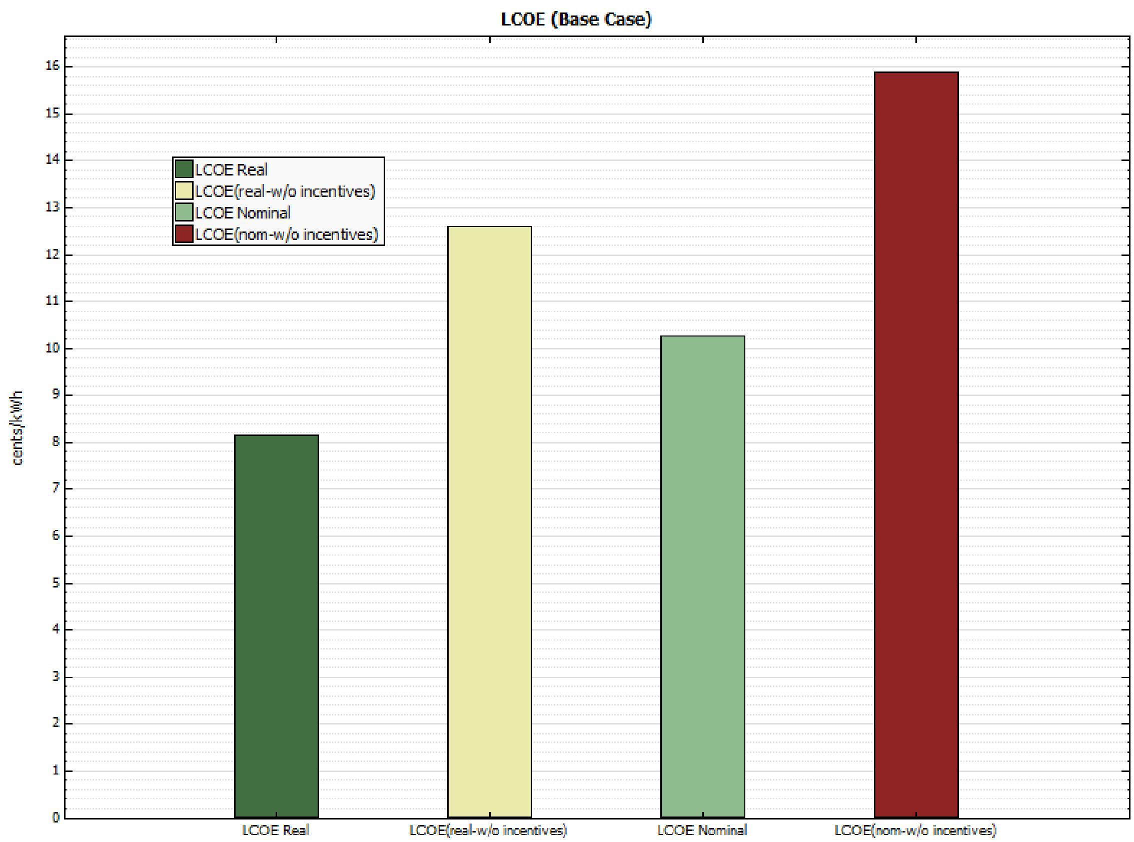

Figure B-26. Levelized cost of energy—Net-metering limit—Single axis—2,000 kW

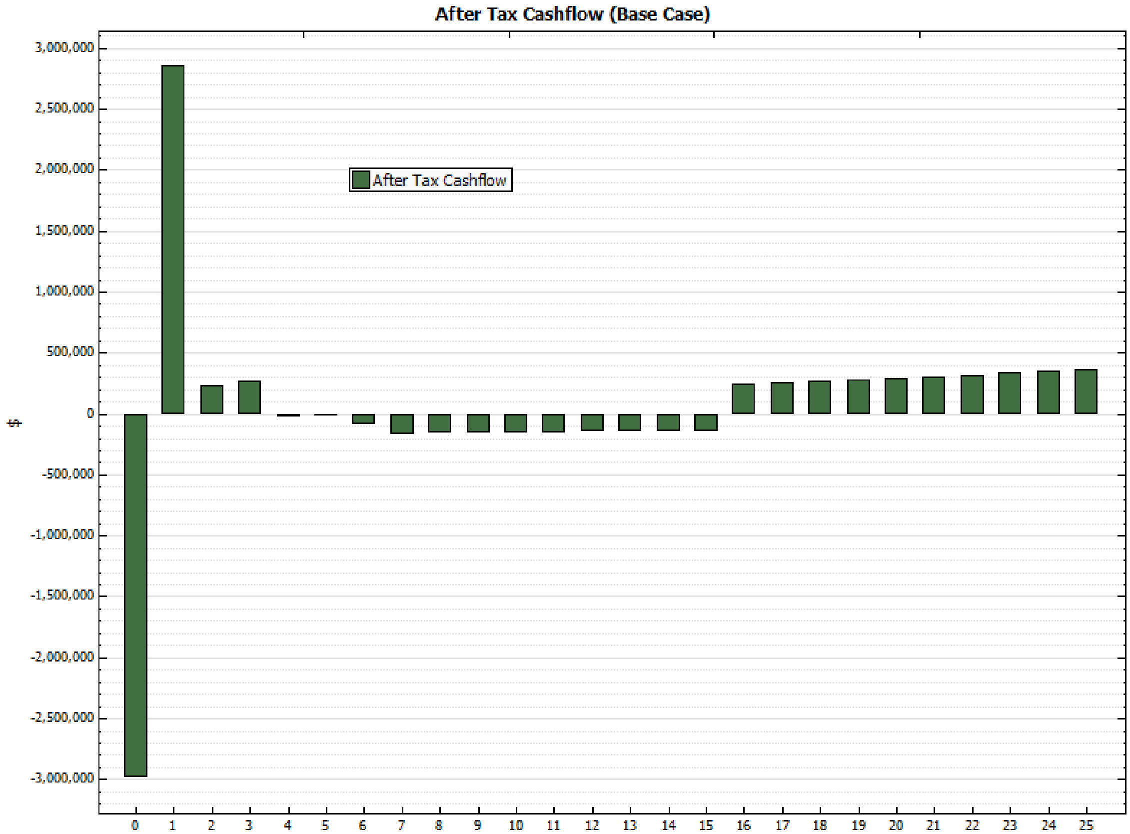

Figure B-27. Annual cash flow—Net-metering limit—Single axis—2,000 kW

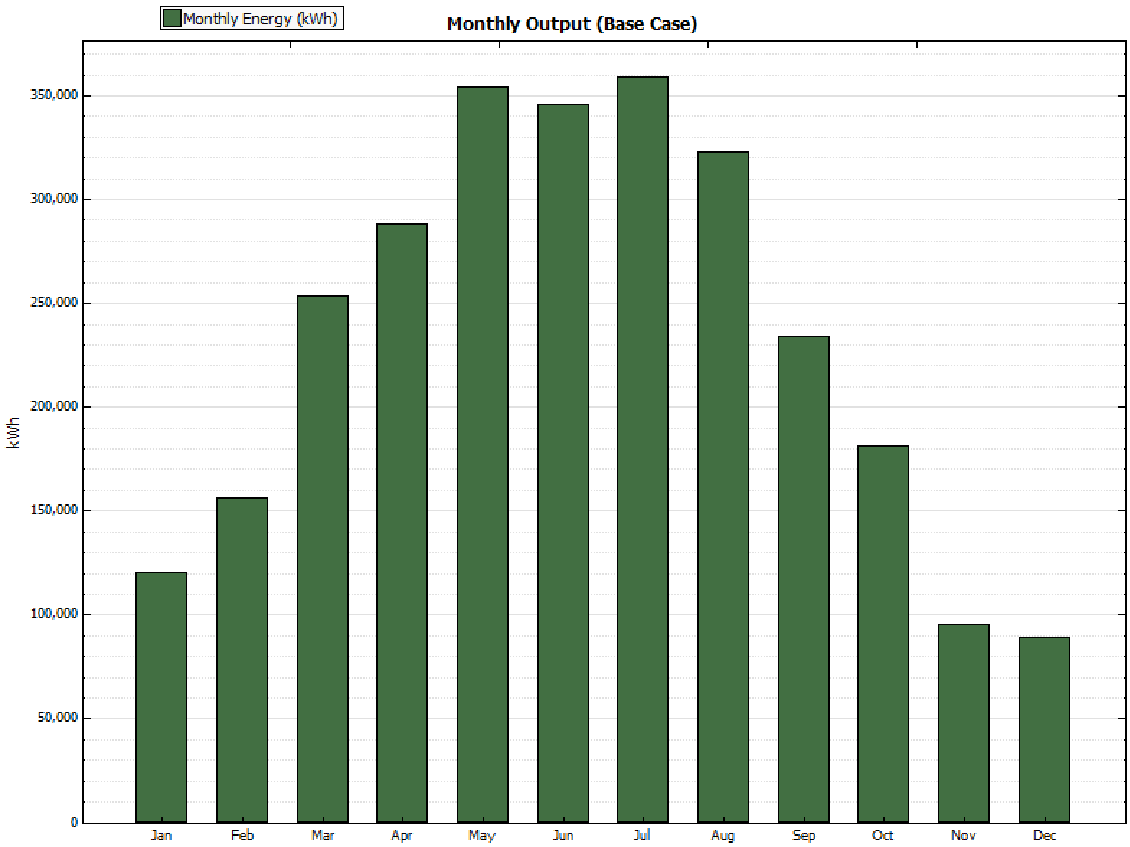

Figure B-28. Monthly energy output—Net-metering limit—Single axis—2,000 kW

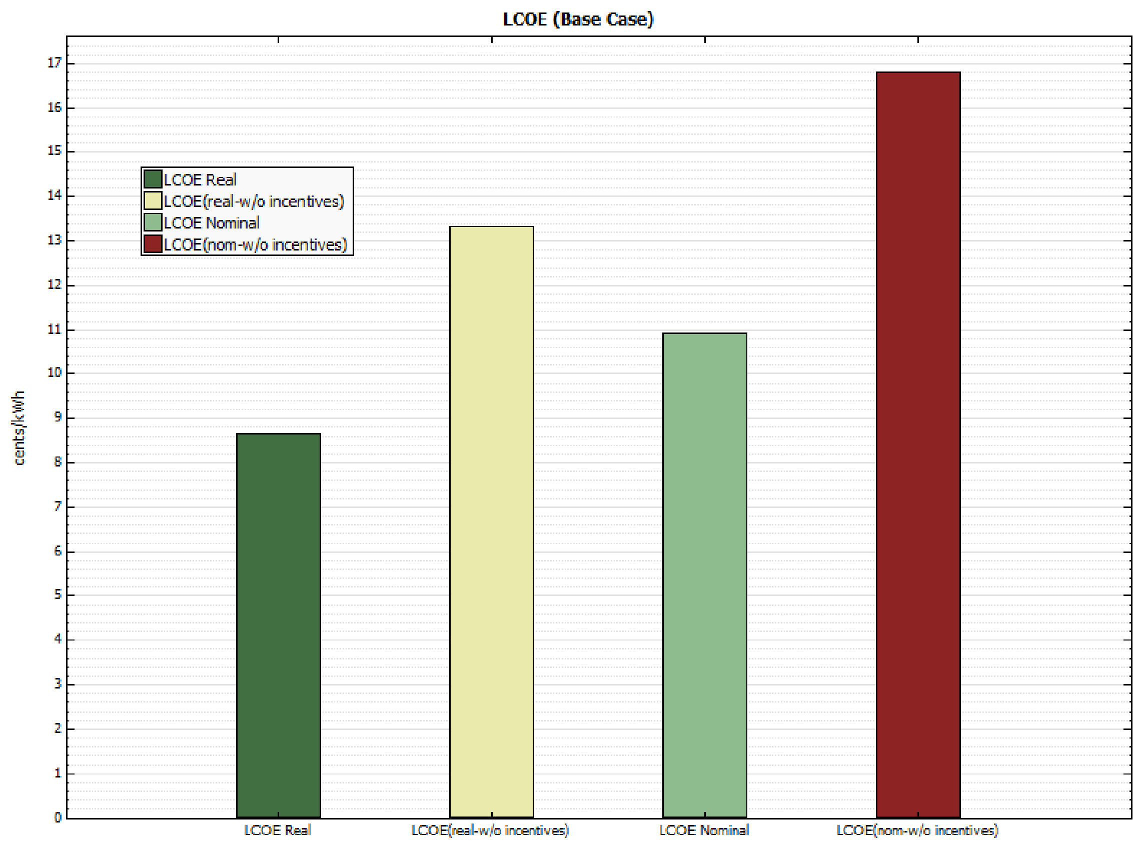

Figure B-29. Levelized cost of energy—Net-metering limit—Fixed axis—2,000 kW

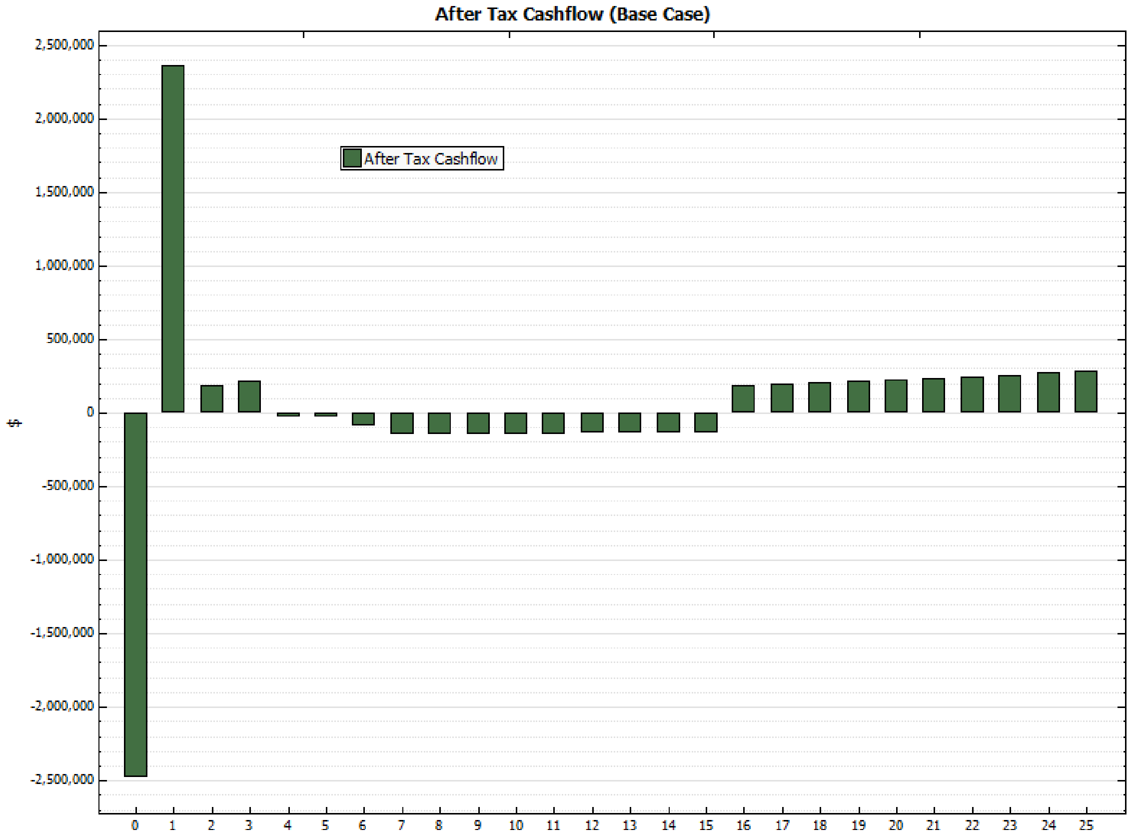

Figure B-30. Annual cash flow—Net-metering limit—Fixed axis—2,000 kW

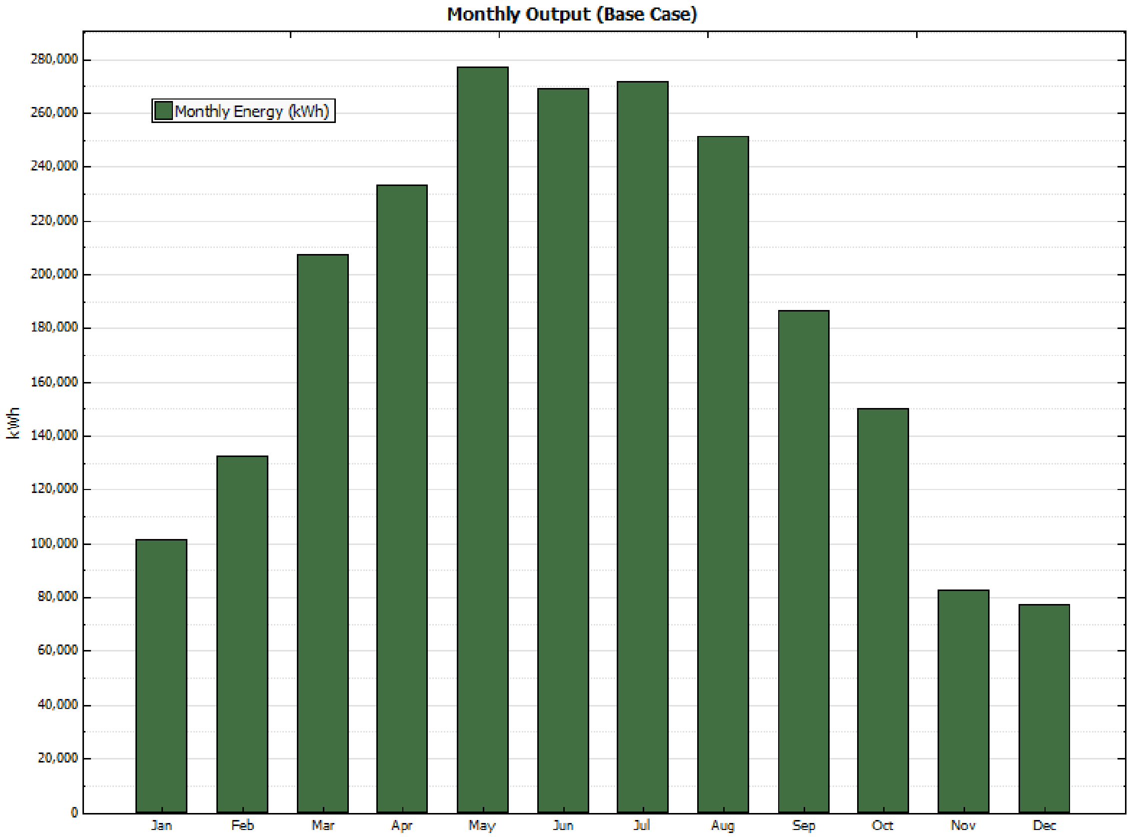

Figure B-31. Monthly energy output—Net-metering limit—Fixed axis—2,000 kW

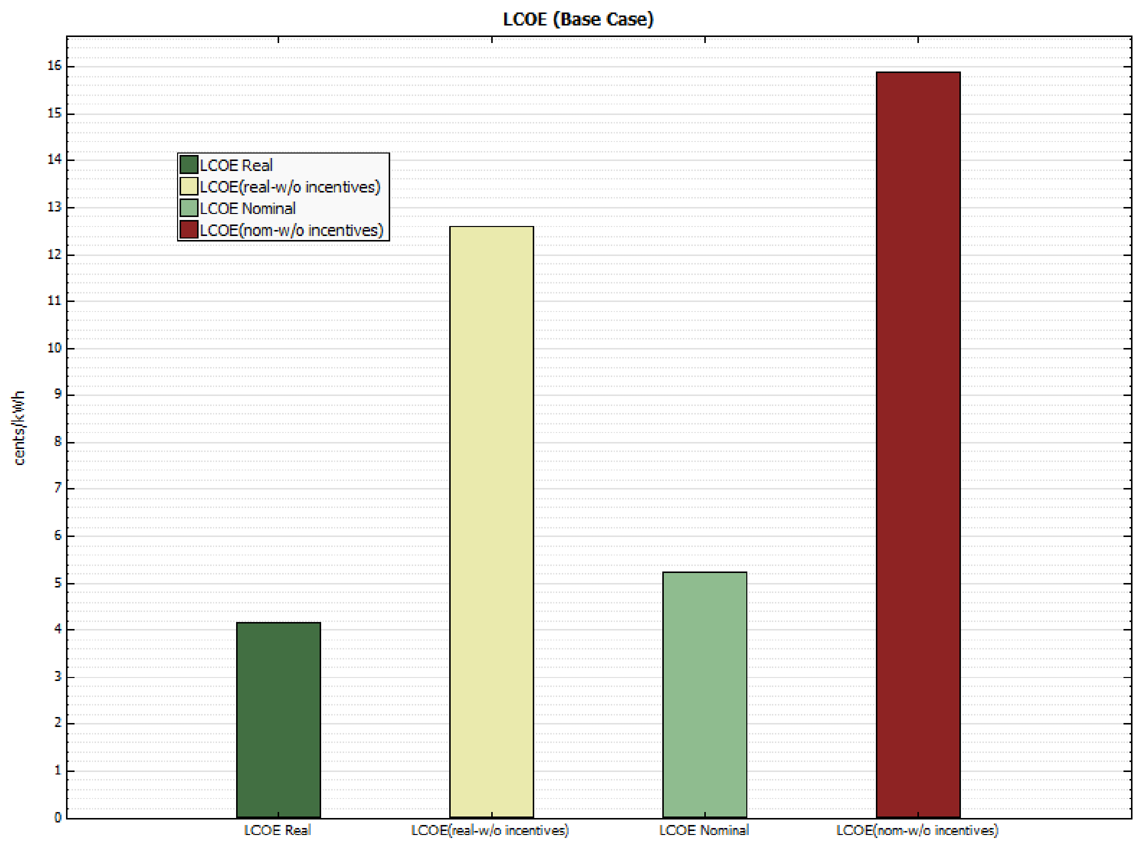

Figure B-32. Levelized cost of energy—Capacity-based incentive limit—Single axis—50 kW

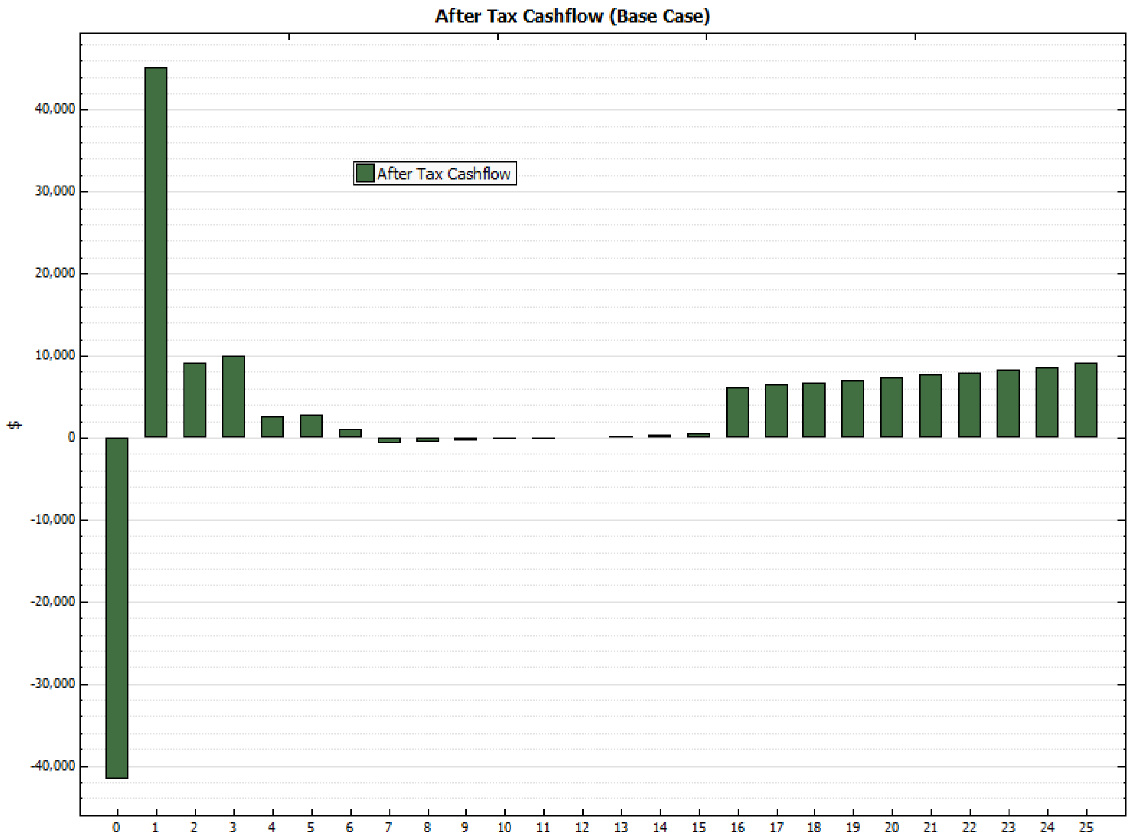

Figure B-33. Annual cash flow—Capacity-based incentive limit—Single axis—50 kW

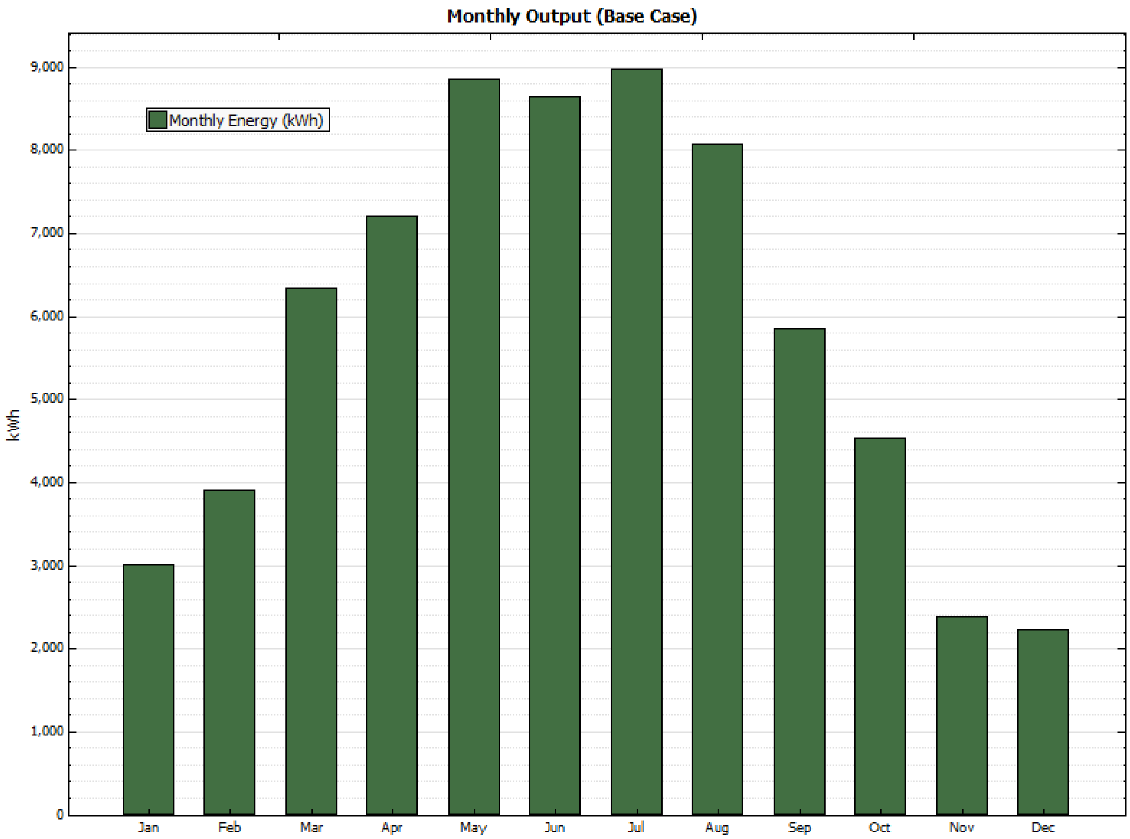

Figure B-34. Monthly energy output—Capacity-based incentive limit—Single axis—50 kW

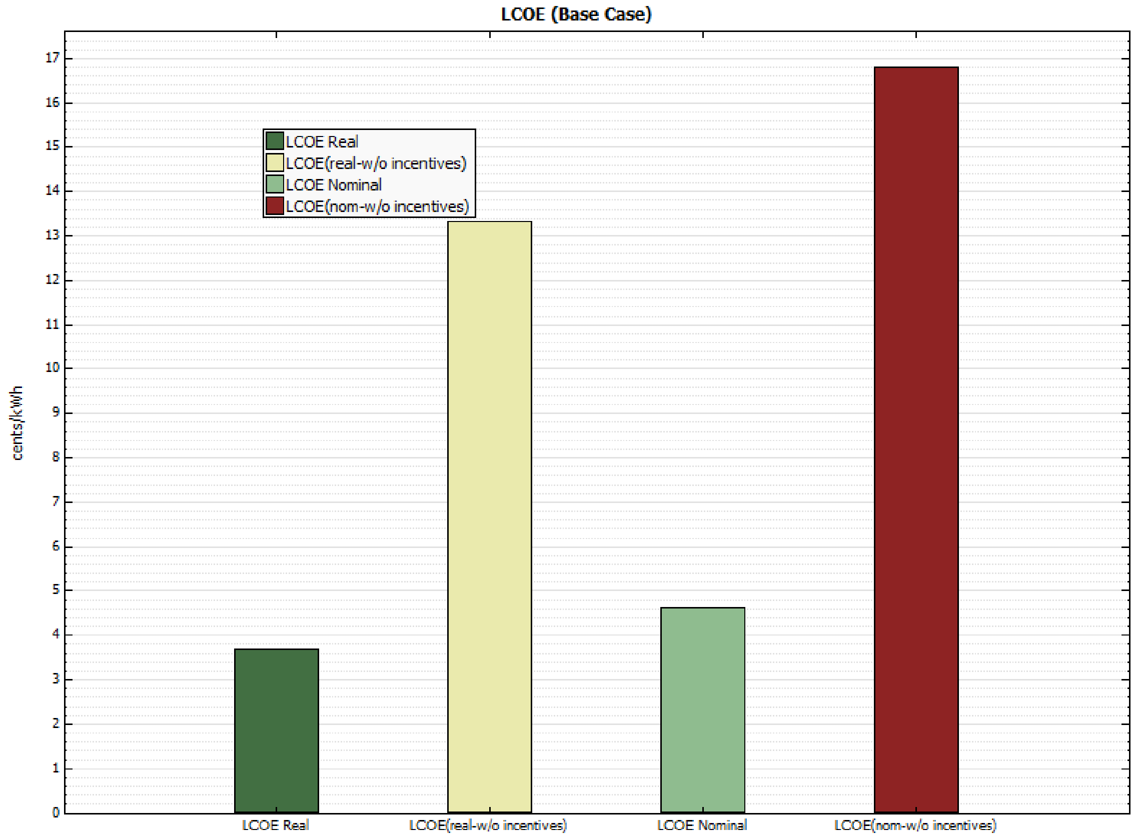

Figure B-35. Levelized cost of energy—Capacity-based incentive limit—Fixed axis—50 kW

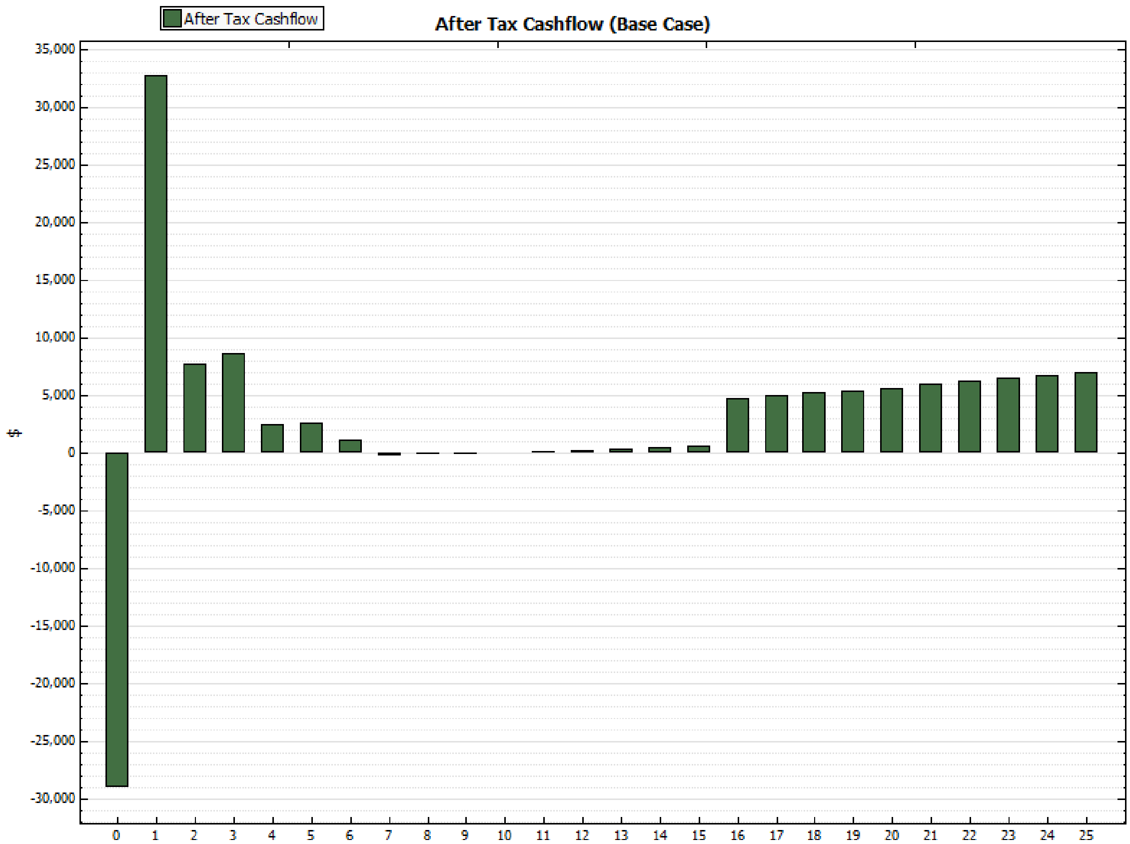

Figure B-36. Annual cash flow—Capacity-based incentive limit—Fixed axis—50 kW

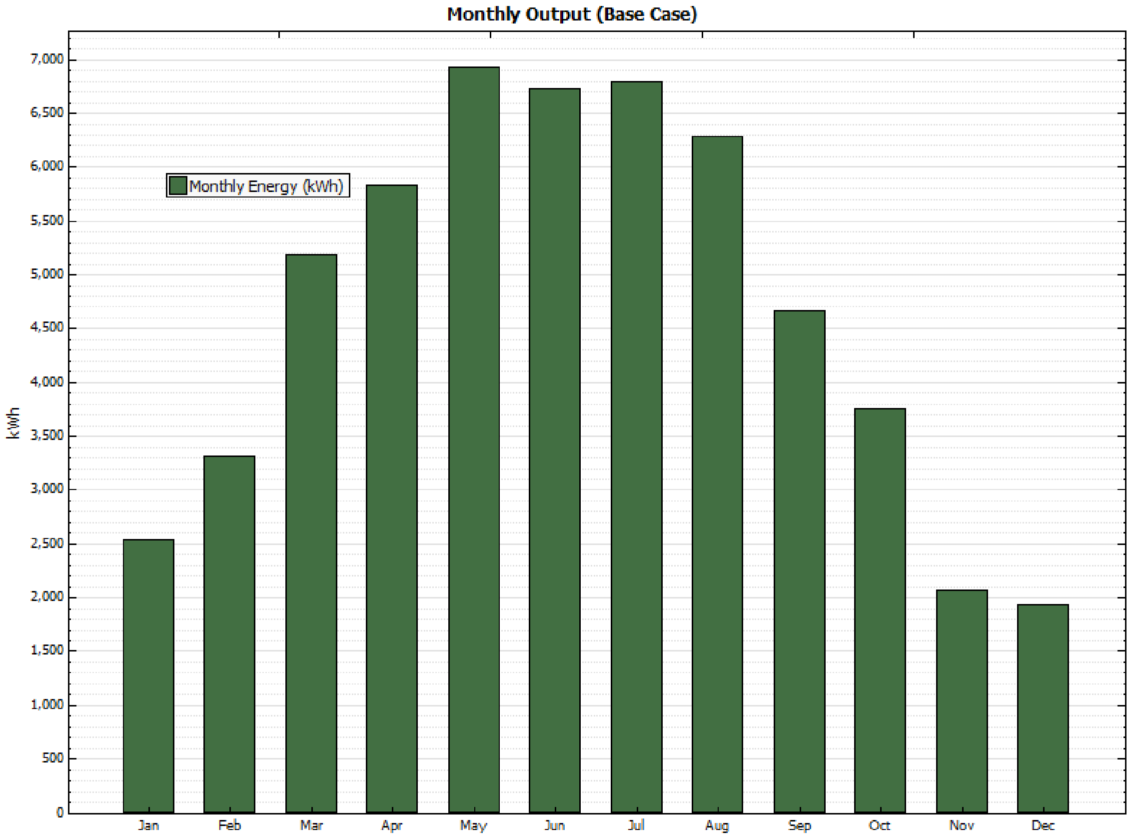

Figure B-37. Monthly energy output—Capacity-based incentive limit—Fixed axis—50 kW

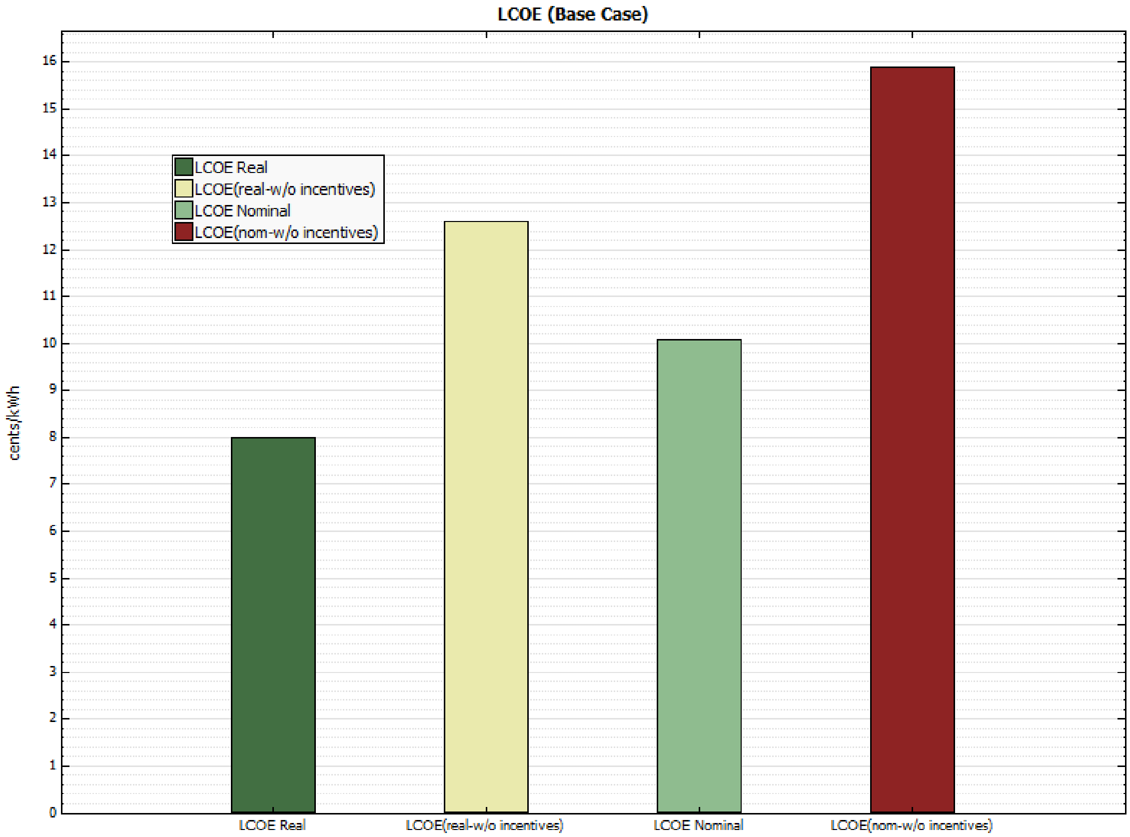

Figure B-38. Levelized cost of energy—Largest system with positive NPV—Fixed axis—862 kW

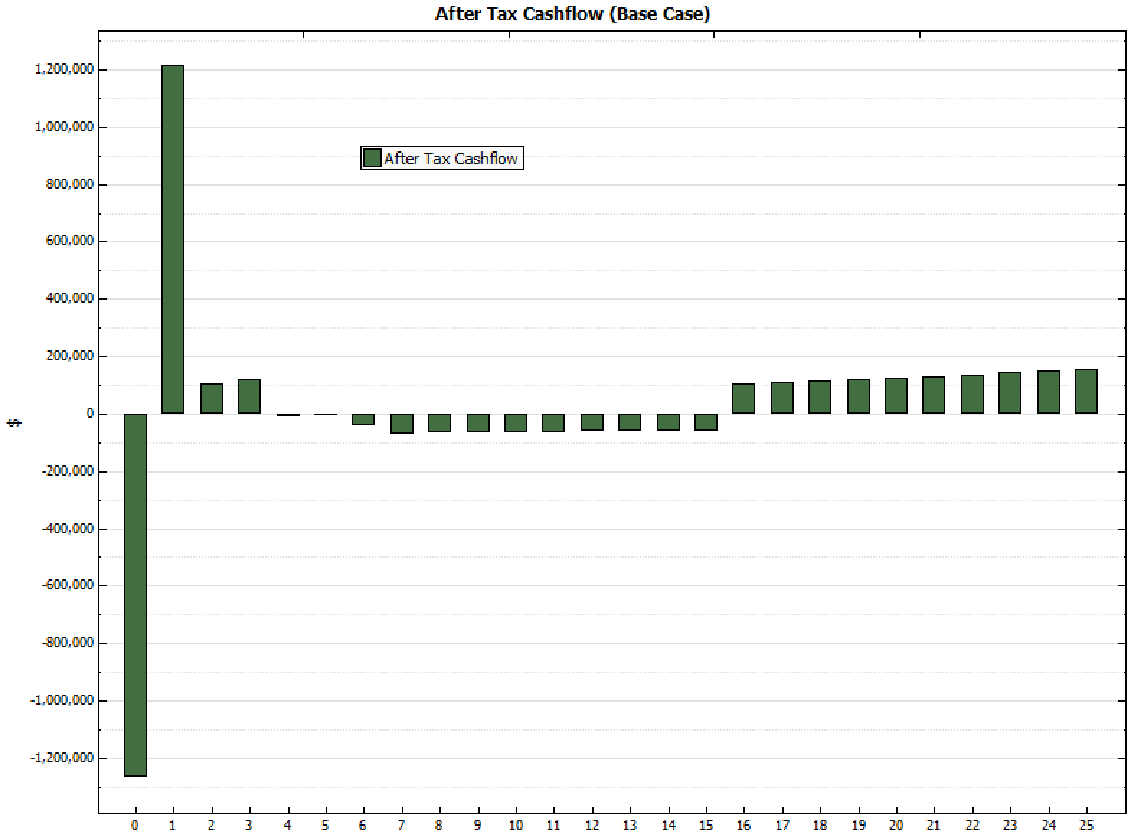

Figure B-39. Annual cash flow—Largest system with positive NPV—Fixed axis—862 kW

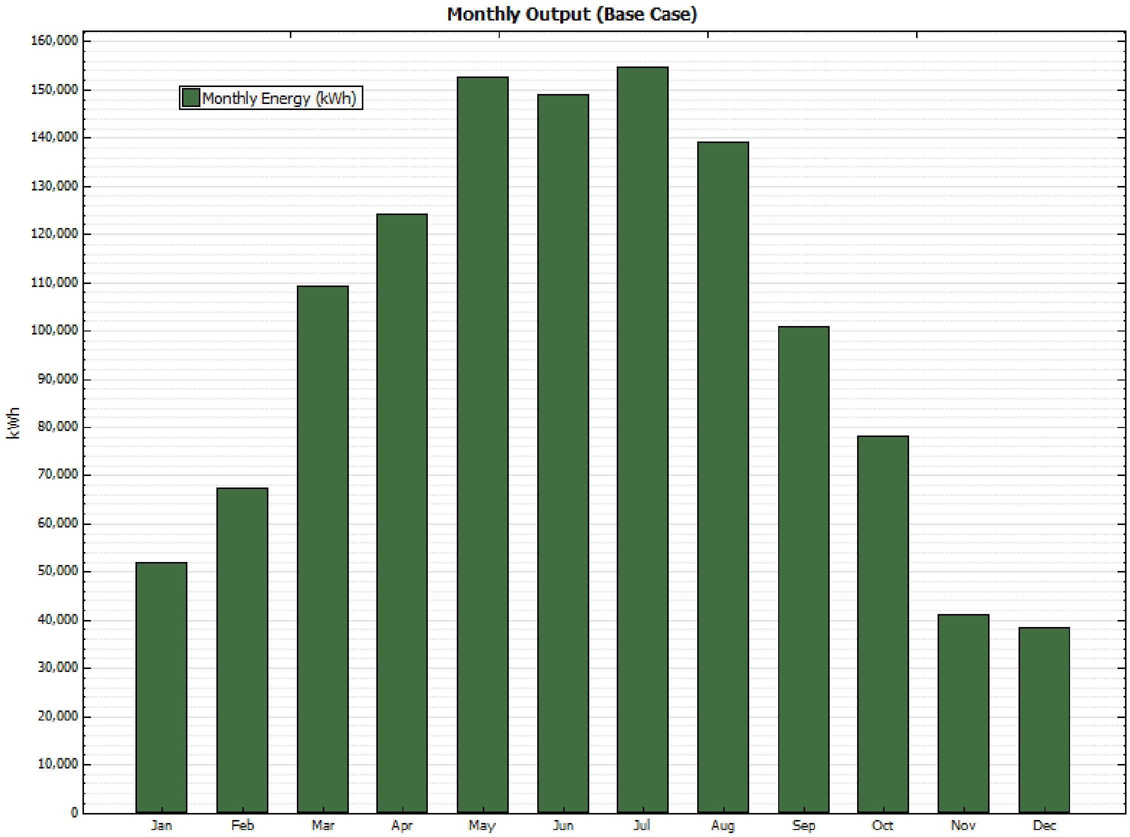

Figure B-40. Monthly energy output—Largest system with positive NPV—Fixed axis—862 kW

Appendix C. Results of the Jobs and Economic Development Impact Model

Table C-1. JEDI Model Single-Axis Tracking Project Data Summary

Project Location	NEW YORK
Year of Construction or Installation	2013
Average System Size - DC Nameplate Capacity (KW)	2,000.0
Number of Systems Installed	1
Project Size - DC Nameplate Capacity (KW)	2,000.0
System Application	Utility
Solar Cell/Module Material	Crystalline Silicon
System Tracking	Single Axis
Total System Base Cost ($/KW$_{DC}$)	$3,412
Annual Direct Operations and Maintenance Cost ($/kW	$25.00
Money Value - Current or Constant (Dollar Year)	2012
Project Construction or Installation Cost	$6,823,200
Local Spending	$3,743,196
Total Annual Operational Expenses	$828,000
Direct Operating and Maintenance Costs	$50,000
Local Spending	$46,000
Other Annual Costs	$778,000
Local Spending	$800
Debt Payments	$0
Property Taxes	$0

Table C-2. JEDI Model Single-Axis Tracking Local Economic Impacts Summary

	Jobs	Earnings	Output
During construction and installation period		**$000 (2012)**	**$000 (2012)**
Project Development and Onsite Labor Impacts			
Construction and Installation Labor	8.0	$519.6	
Construction and Installation Related Services	10.5	$632.3	
Subtotal	18.6	$1,151.9	$2,080.8
Module and Supply Chain Impacts			
Manufacturing Impacts	0.0	$0.0	$0.0
Trade (Wholesale and Retail)	2.4	$163.7	$469.6
Finance, Insurance and Real Estate	0.0	$0.0	$0.0
Professional Services	3.0	$195.7	$589.6
Other Services	5.6	$499.7	$1,635.2
Other Sectors	6.9	$160.1	$327.8
Subtotal	17.9	$1,019.2	$3,022.2
Induced Impacts	12.6	$668.4	$2,127.1
Total Impacts	**49.1**	**$2,839.6**	**$7,230.0**
		Annual	**Annual**
	Annual	**Earnings**	**Output**
During operating years	**Jobs**	**$000 (2012)**	**$000 (2012)**
Onsite Labor Impacts			
PV Project Labor Only	0.5	$27.9	$27.9
Local Revenue and Supply Chain Impacts	0.1	$9.4	$27.9
Induced Impacts	0.1	$5.9	$18.7
Total Impacts	**0.7**	**$43.1**	**$74.4**

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

Table C-3. JEDI Model Single-Axis Tracking Detailed PV Project Data Costs Summary

	NEW YORK	Purchased	Manufactured
Installation Costs	**Cost**	**Locally (%)**	**Locally (Y or N)**
Materials & Equipment			
Mounting (rails, clamps, fittings, etc.)	$358,896	100%	N
Modules	$2,292,369	100%	N
Electrical (wire, connectors, breakers, etc.)	$87,822	100%	N
Inverter	$340,916	100%	N
Subtotal	$3,080,004		
Labor			
Installation	$519,620	100%	
Subtotal	$519,620		
Subtotal	$3,599,624		
Other Costs			
Permitting	$36,552	100%	
Other Costs	$807,794	100%	
Business Overhead	$2,256,030	100%	
Subtotal	$3,100,376		
Subtotal	$6,700,000		
Sales Tax (Materials & Equipment Purchases)	$123,200	100%	
Total	$6,823,200		

Table C-4. JEDI Model Single-Axis Tracking PV System Annual Operating and Maintenance Costs

	Cost	Local Share	Manufactured Locally (Y or N)
Labor			
Technicians	$30,000	100%	
Subtotal	$30,000		
Materials and Services			
Materials & Equipment	$20,000	100%	N
Services	$0	100%	
Subtotal	$20,000		
Sales Tax (Materials & Equipment Purchases)	$800	100%	
Average Annual Payment (Interest and Principal)	$777,200	0%	
Property Taxes	$0	100%	
Total	$828,000		
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	4.00%	100%	
Sales Tax Exemption (percent of local taxes)	0%		
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 D. Building Energy Modeling

Building energy modeling was used to estimate the energy use of the proposed building types, which include light industrial buildings. Because none of the proposed buildings at the Lackawanna site have 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, 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 a light industrial building at the Lackawanna site was created. The building construction, lighting, equipment, and operating condition of HVAC systems were modeled assuming that the building would have advanced energy efficiency features and the building would be an all-electric building that uses a lake-source heat pump system with backup electric boilers. The light industrial building that was modeled is described in detail in the next section.

Lackawanna Light Industrial Building Energy Model

A sample light industrial building was modeled in eQUEST. 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 none of the new construction light industrial buildings on the Lackawanna site have been designed.

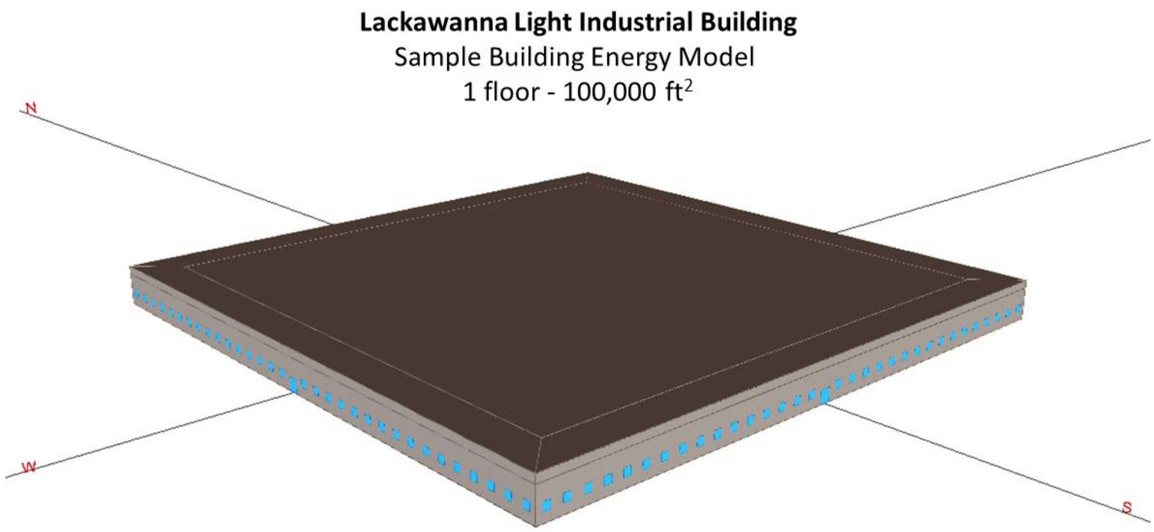

Figure D-1. Lackawanna site light industrial building eQUEST model representation

The NREL team assumed advanced energy efficient building design to develop the eQUEST model of the sample light industrial building. The general facility characteristics that were modeled are provided in Table D-1.

Table D-1. Lackawanna Site Light Industrial Building eQUEST Summary Information

Lackawanna site light industrial building – Lackawanna, New York		
Project		
	Weather Data	TMY2 – Buffalo, New York
	Building Type	Light industrial building
	Total Number of Buildings Modeled	1
	Building Areas	100,000 ft^2
	Above Grade Floors	1
	Below Grade Floors	0
Building Footprint		
	Building Orientation	Plan north
	Zoning Pattern	Perimeter/core
	Floor to Floor Height	20 ft
	Floor to Ceiling Height	16 ft
	Roof Pitch	0 deg
Roof		
	Construction	Steel framed
	Roof	Built-up roof
	Insulation	4” Polyisocyanurate (R-28)
Walls		
	Construction	Metal frame
	Finish	Metal
	Insulation	2” Polystyrene (R-9) continuous R-21 batts
Ground Floor		
	Earth Contact	8” Concrete
Infiltration		
	Perimeter	0.10 (CFM/ft^2)
Floors		
	Interior Finish	No finish
	Construction	8” 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	8 hours/day, 5 days/week
	Area Type	Light manufacturing, office, corridors, restrooms

Power Density		
	Lighting	0.8 to 1.5 W/ft^2 Daylighting Controls
	Plug Loads	0.35 to 2.0 W/ft^2
HVAC Systems		
	System Type	Lake-source heat pump with back-up electric boiler
	System Cooling Source	Heat pump – 14 EER
	Economizer	Temperature/enthalpy based
	Heating System	Heat pump – COP 4.0
	Thermostat	Occupied / Unoccupied Cooling - 73^{o}F / 82^{o}F Heating - 70^{o}F / 64^{o}F
Fan Schedules		
	Operation Schedule	10 hours/day, 5 days/week

Figure D-2 presents the eQUEST output for the Brisbane Baylands light industrial building energy model. As shown, lighting energy uses the most energy followed by equipment energy and ventilation fans.

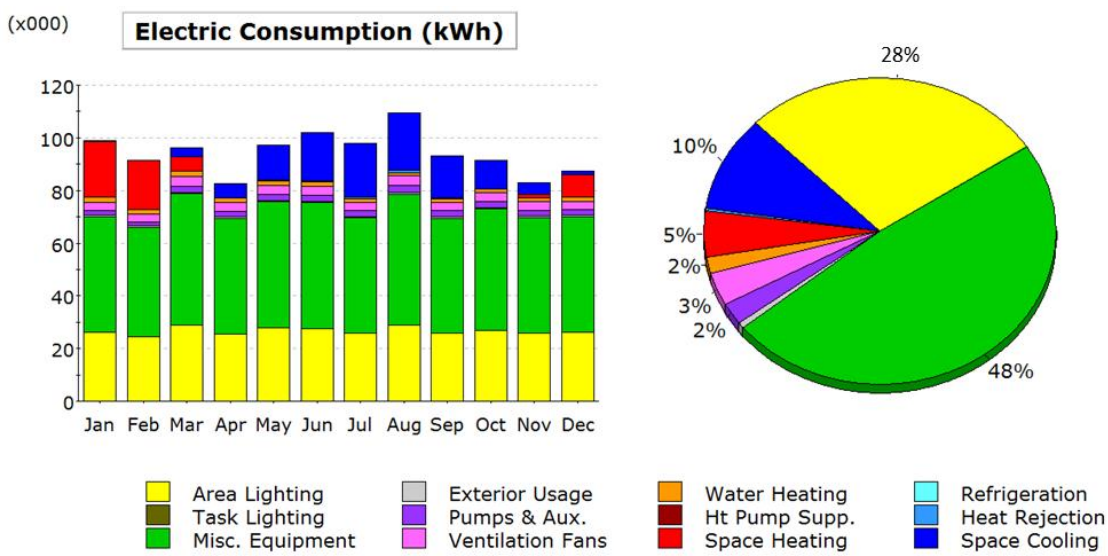

Figure D-2. Lackawanna site light industrial eQUEST results for annual energy use