



Feasibility Study of Economics and Performance of Solar Photovoltaics at the Former Chicago, Milwaukee, and St. Paul Rail Yard Company Site in Perry, Iowa

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, Victoria Healey, and Gail Mosey

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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 Chicago, Milwaukee & St. Paul Rail Yard Company site in Perry, Iowa, 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 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 main contaminants on the site are polychlorinated biphenyls (PCBs), herbicides, heavy metals, and inorganic compounds. The site recently received \$400,000 in EPA brownfields funding for site assessment and remediation efforts.¹ The City of Perry is interested in employing the currently underutilized site for solar PV to minimize its impact on the environment.

The feasibility of installing a PV system depends highly on the land area available 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. According to our assessment of these factors, the Former Chicago, Milwaukee & St. Paul Rail Yard Company is suitable for deployment of a large-scale PV system.

The Former Chicago, Milwaukee & St. Paul Rail Yard Company site consists of approximately 138 acres, with two separate areas that are appropriate for installing PV systems. Approximately 36.6 acres on the east side of the site that are cleared of trees and other shading obstructions are currently the most suitable location for a large-scale PV. In addition, 46.2 acres to the west that are forested would have to be cleared before a PV system could be installed. Although the entire suitable area need not be developed at one time—for example, PV installation could be staged as land or funding becomes available—calculations for this analysis reflect the solar potential if the total feasible area—82.8 acres—were used.

The economic feasibility of a potential PV system on the Former Chicago, Milwaukee & St. Paul Rail Yard Company site depends greatly on the purchase price of the electricity produced. The economics of the potential system were analyzed using Alliant Energy's current electric rate of \$0.05/kWh and incentives available to the site owners. Current incentives considered include:

- Iowa Renewable Energy Production Tax Credit: \$0.015/kWh for 10 years for systems smaller than 53 MW
- Iowa Property Tax incentive: 100% exemption of the increased value attributed to a solar system for 5 years
- Iowa Sales Tax Incentive: 100% exemption of sales tax for all related solar equipment

¹ <http://yosemite.epa.gov/opa/admpress.nsf/0/688867BEE7589DEE85257A0F0071A28B>. Accessed June 2012.

- Iowa Alternative Energy Revolving Loan Program: 50% of the financed project cost at a 0% interested rate for 20 years for a maximum of \$1,000,000
- Alliant Energy Utility Rebate Program: \$0.50/kWh for a maximum of \$20,000.

Table ES-1 summarizes the system performance and economics of a system that would use all available areas that were surveyed at the Former Chicago, Milwaukee & St. Paul Rail Yard Company site. The table shows the annual energy output from the system, the number of average American households that such a system could power, and the estimated number of jobs created.

As indicated in Table ES-1, a 6,400-kW fixed-tilt PV system producing approximately 8,337,899 kWh annually is not expected to have a payback within the analysis period and a negative net present value. This includes the current cost of energy, expected installation cost, site solar resource, and existing incentives for the proposed PV system. This savings and payback are not deemed practical, and a solar PV system is not a viable use for the site.

Table ES-1. Former Chicago, Milwaukee & St. Paul Rail Yard Company PV System Summary

Tie-In Location	System Type	PV System Size ^a	Array Tilt	Annual Output	Number of Houses Powered ^b	Jobs Created ^c	Jobs Sustained ^d
		(kW)	(deg)	(kWh/year)		(job-year)	(job-year)
Treatment Plant	Crystalline Silicon (Fixed Tilt)	6,400	20	8,337,899	755	230	1
Treatment Plant	Crystalline Silicon (Single-Axis Tracking)	5,280	n/a	8,917,949	808	222	1.2

Tie-In Location	System Type	System Cost	Incentives	Annual Cost		Payback Period with Incentives
				Savings (\$/year)	Annual O&M (\$/year)	
Treatment Plant	Crystalline Silicon (Fixed Tilt) Direct Purchase	\$ 24,960,000	\$ 833,790	\$ -	\$ 566,400	N/A
Treatment Plant	Crystalline Silicon (Fixed Tilt) Investor Option	\$ 24,960,000	\$ 8,336,790	\$ -	\$ 566,400	N/A
Treatment Plant	Crystalline Silicon (Single-Axis Tracking) Direct Purchase	\$ 25,872,000	\$ 891,795	\$ -	\$ 566,400	N/A
Treatment Plant	Crystalline Silicon (Single-Axis Tracking) Direct Purchase	\$ 25,872,000	\$ 8,668,395	\$ -	\$ 566,400	N/A

^a Data assume a maximum usable area of 33 acres

Number of average American households that could hypothetically be powered by the PV system assuming 11,040

^b 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 Chicago, Milwaukee & St. Paul Rail Yard Company site in Perry, Iowa, 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 to estimate the cost, performance, and site impacts of different PV options. In addition, the report recommends financing options that could assist in implementing a PV system at the site. This study did not assess environmental conditions at the site.

The Former Chicago, Milwaukee & St. Paul Rail Yard Company ("the site") is located in Perry, Iowa. Perry is located approximately 30 miles northwest of the capital city of Des Moines, and it was formerly a major railroad hub. Perry has a population of 7,702 as of the 2010 census, and it has been named as one of Iowa's "Great Places." Perry has on average approximately 200 sunny days per year, and the climate is hot and humid in the summer and moderately cold and snowy in the winter. Alliant Energy Corporation, the local regulated utility, is the energy holding company that provides electricity to Perry.

The site consists of approximately 138 acres. From the early 1900s until its closure in 1986, the site operated as a rail yard and roundhouse (i.e., maintenance facility) for the railroads. The City of Perry acquired the site in 2004, but the original owner is the responsible party for cleanup of the site. The city has been working diligently to remediate the site. The main contaminants on the site are polychlorinated biphenyls (PCBs), herbicides, heavy metals, and inorganic compounds. The site recently received \$400,000 in EPA brownfields funding for site assessment and remediation efforts.² The highest levels of contamination are located where the roundhouse once stood. There are concerns with trenching and disturbing the soil at the site because of the contaminants present, but there are more clean areas than contaminated areas. Excavating at the site for a potential PV system is possible providing there is no potential to run into any contaminants. A map of the contaminated areas is given in Appendix A.

ITC Holdings Corporation owns the 34.5-kV and 161-kV transmission lines that run through the site. Alliant Energy Corporation has facilities on ITC-owned transmission lines. Interconnection at the 34.5-kV or 161-kV levels is governed by the Midwest Independent System Operator (MISO). Performing an interconnection study—a slow and costly process—would have to be performed through MISO. There is currently no major electricity use at the site.

Members of the assessment team from NREL, the City of Perry, and the EPA conducted a site visit on January 10, 2012, to gather information integral to this feasibility study. The team considered information, including solar resource, transmission availability, community acceptance, and ground conditions.

² <http://yosemite.epa.gov/opa/admpress.nsf/0/688867BEE7589DEE85257A0F0071A28B>. Accessed June 2012.

Section 2 outlines some benefits of PV systems on brownfields, and it presents a comparable brownfields site on which a PV system was developed. Section 3 presents an overview of PV technology, including major system components as well as siting considerations. Section 4 summarizes the findings of a site visit and assessment. Section 5 evaluates the economic performance of a PV system installed on the site. Section 6 contains the conclusions and recommendations of the assessment team.

2 Development of a PV System on the Site

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

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

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

The City of Perry, which owns the subject site, is interested in potential revenue flows from it. The City Solar project in Chicago, Illinois—which represents a site similar to the subject site—provides an example of the opportunities realized by other cities that have developed PV systems on brownfields. City Solar's single-axis tracking PV system was completed in 2010 on a former industrial site that had been vacant for 30 years. The project, which at 10 MW is the largest urban PV system in the United States, is comparable in size (41 acres) to the areas available at subject site. The City of Chicago owns the City Solar site and leases the land to a solar developer.³

For many brownfield sites, the local community has significant interest in redeveloping the sites, and community engagement is critical to matching future reuse options with the community's vision for these sites. The subject site could be used for functions other than the 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. Large-scale wind turbines could be installed at the site, if deemed feasible by a detailed wind feasibility study, or the site could be used to create a park that is linked to the nearby Raccoon River Valley Recreational Trail.

³ <http://www.exeloncorp.com/PowerPlants/exeloncitysolar/Pages/Profile.aspx>. Accessed July 2012.

There are many compelling reasons to consider moving toward renewable energy sources for power generation instead of fossil fuels, including:

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

3 PV Systems

3.1 PV Overview

Solar PV technology converts energy from solar radiation directly into electricity. Solar PV cells are the electricity-generating component of a solar energy system. When sunlight (photons) strikes a PV cell, an electric current is produced by stimulating electrons (negative charges) in a layer in the cell designed to give up electrons easily. The existing electric field in the solar cell pulls these electrons to another layer. By connecting the cell to an external load, this current (movement of charges) can then be used to power the load (e.g., light bulb). Figure 1 shows a generalized model of a solar PV electrical current loop.

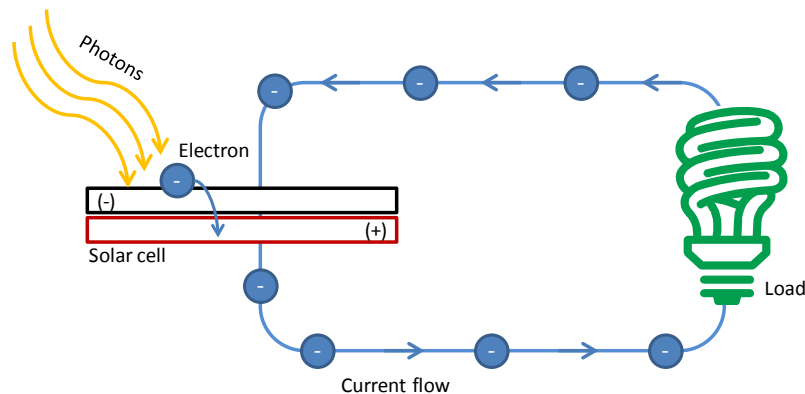


Figure 1. Generation of electricity from a PV cell

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

A typical PV system is made up of several key components, including PV modules, inverter, and balance-of-system (BOS) components (e.g., combiner box, transformer, and meter). These components (see Figure 2), and other PV system components, are discussed below.

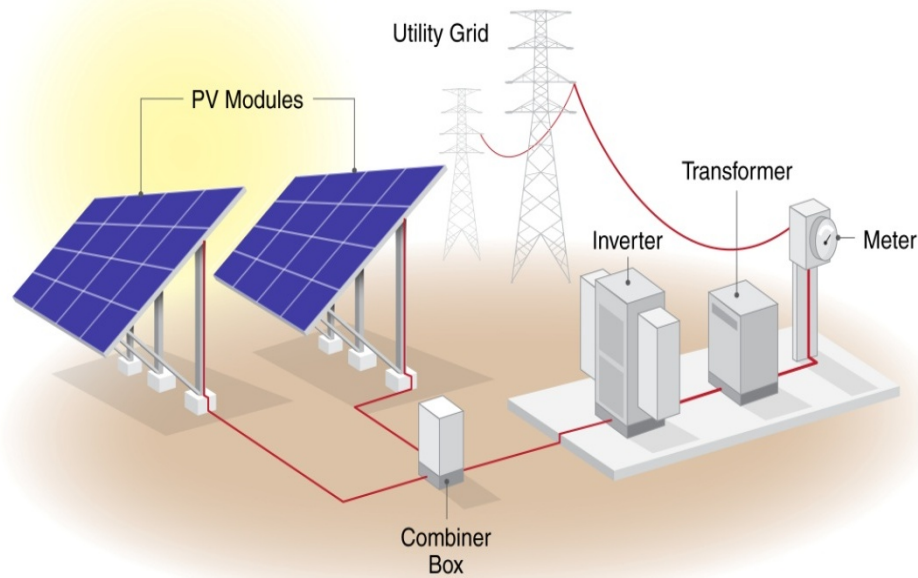


Figure 2. Array for a ground-mounted system

Source: NREL

3.2.1 PV Module

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

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

3.2.1.1 Crystalline Silicon

Traditional solar cells are made from silicon. 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 in the 25–30-year range 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-crystalline 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 (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 may be fed to a step-up transformer to increase the voltage to match the grid.

There are two primary types of inverters for grid-connected systems: string and micro-inverters. Each type has strengths and weaknesses and 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 the potential increase in O&M associated with significantly increasing the number of inverters in a given array. Current micro-inverters range in size between 175 W and 380 W. These inverters can be the most expensive option per watt of capacity. Warranties range from 10–20 years. Small projects with irregular modules and shading issues typically benefit from micro-inverters.

With string inverters, small amounts of shading on a solar panel will significantly affect the entire array production. 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. Energy Density by Panel and System (DC-Watts/ft²)

System Type	Fixed-Tilt PV System	Single-Axis Tracking PV System
Crystalline Silicon	4.0	3.3
Thin Film	3.3	2.7
Hybrid High Efficiency	4.8	3.9

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

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

3.2.3.2 Wiring for Electrical Connections

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

In most traditional applications, wiring from (1) the arrays to inverters and (2) inverters to point of interconnection is generally run as direct burial through trenches. In 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 may also use these 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. 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/year, 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,⁴ available incentives, and utility policy.

⁴ A PPA is a contract to sell electricity at a negotiated rate for a fixed period.

4 Proposed Installation Location Information

This section summarizes the findings of the NREL solar assessment site visit on January 10, 2012.

Figure 6, an aerial view of the Former Chicago, Milwaukee & St. Paul Rail Yard Company site, shows two portions of the site, one that is currently suitable for a large-scale PV system and one that could be made suitable for a PV system.

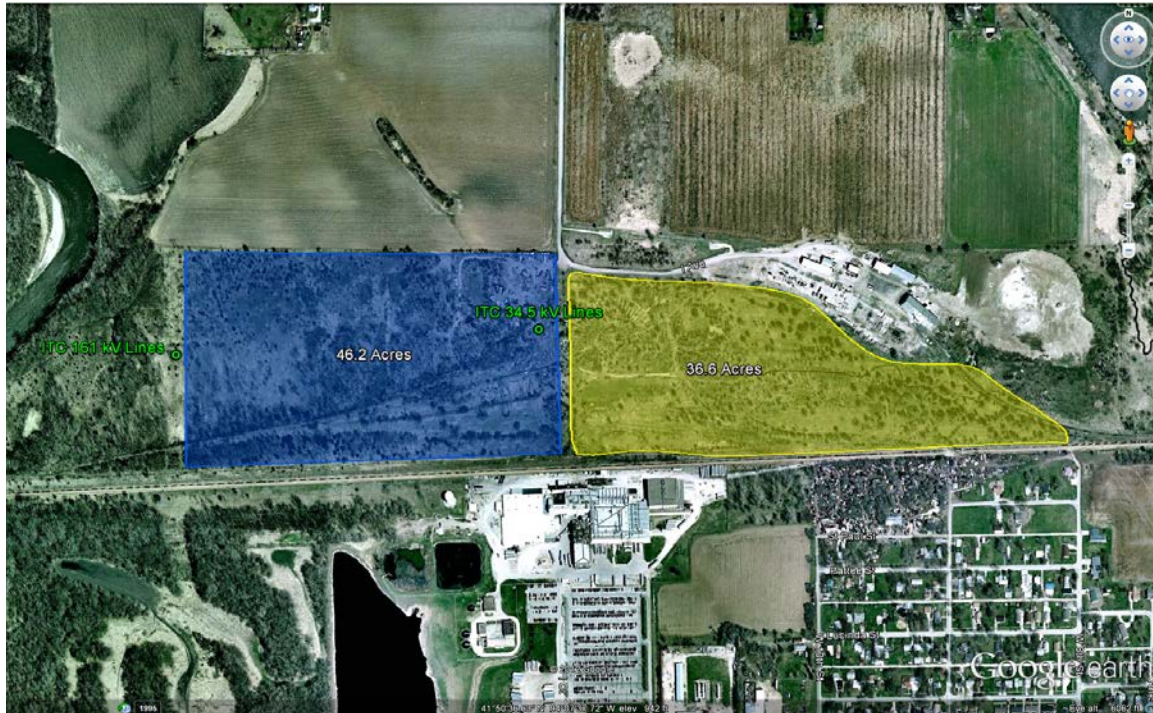


Figure 6. Aerial view of the currently feasible area (yellow) for PV and the potentially feasible area (blue) for PV at the Former Chicago, Milwaukee & St. Paul Rail Yard Company site

Illustration done in Google Earth; transmission lines are shown

The area of the site that is currently feasible for installing PV technology (highlighted in yellow in Figure 6) consists of 36.6 acres. This area is flat and cleared of trees and other shading obstructions. No major infrastructure on this portion of the site would have to be removed. The area highlighted in blue on Figure 6, which consists of 46.2 acres, is forested and would have to be cleared before a PV system could be installed. For this report, only the feasibility of the 36.6-acre area is considered because the 46.2-acre area would require significant clearing and leveling before PV could be installed.

Both the 36.6-acre and the 46.2-acre are close to existing roads. Two transmission lines—a 34.5-kV line and a 161-kV line—run through the site. To maximize the ground area available, it is important that the site developers consider whether the site layout can be improved to better incorporate a PV system. If unused structures, fences, and electrical poles could be removed from other areas (i.e., those not highlighted in blue or green in Figure 6), those areas could be also used for PV panels.

Figure 7 shows various views of the Former Chicago, Milwaukee & St. Paul Rail Yard Company site.



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

PV systems are well suited to the Perry 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 4.71 kWh/m²/day.

4.1 Utility-Resource Considerations

The expected electrical tie-in point for the PV system at the Former Chicago, Milwaukee & St. Paul Rail Yard Company site is located within a few miles of the site at a substation that is on either the 34.5-kV or the 161-kV line. A detailed interconnection study would have to be performed to determine which, if either, transmission line would be suitable. The 34.5-kV and 161-kV lines are shown in Figure 8. The tie-in location is limited by the available capacity on the transmission lines. Ground disturbances and trenching are not allowed at the site because of the contaminants present in the soil; this would increase the cost of installing a PV system on the site. When considering a ground-mounted system, an electrical tie-in location should be identified to determine how the energy would be fed back into the grid.



Figure 8. Electrical transmission lines for the PV system at the site. Photos by Jimmy Salasovich, NREL

4.2 Useable Acreage for PV System Installation

Typically, a minimum of 2 useable acres is recommended to site PV systems. Useable acreage is usually 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 unused paved areas (e.g., a parking lot or industrial site space), as well as existing building rooftops. The 36.6-acre area is flat and free of all major shading obstructions.

4.3 PV Site Solar Resource

The Former Chicago, Milwaukee & St. Paul Rail Yard Company site was evaluated using onsite data and industry tools to determine the adequacy of the solar resource available.

The assessment team for this feasibility study collected multiple Solmetric SunEye data points and found a solar access of 96% and above on the 36.6-acre area. All data gathered using this tool are available in Appendix B.

The predicted array performance was found using PVWatts Version 2⁵ for Perry. Table 2 shows the station identification information, PV system specifications, and energy specifications for the site. For this summary array performance information, a hypothetical system size of 1 kW was used to show the estimated production for each kilowatt so that additional analysis can be performed using the data indicated below. It is scaled linearly to match the proposed system size.

⁵ <http://www.nrel.gov/rredc/pvwatts/>.

Table 2. Site Identification Information and Specifications

Station Identification	
Cell ID	14933
City	Des Moines
State	Iowa
Latitude	41.53° N
Longitude	93.65° 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	\$0.05/kWh

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

Table 3. Performance Results for a 20-Degree Fixed-Tilt PV System

Month	Solar Radiation (kWh/m²/day)	AC Energy (kWh)	Energy Value (\$)
1	2.96	78	3.90
2	3.94	92	4.60
3	4.52	113	5.65
4	5.33	124	6.20
5	6.01	137	6.85
6	6.53	143	7.15
7	6.75	148	7.40
8	5.90	131	6.55
9	5.07	111	5.55
10	4.08	97	4.85
11	2.83	66	3.30
12	2.52	64	3.20
Year	4.71	1,303	65.15

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

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

Month	Solar Radiation (kWh/m ² /day)	AC Energy (kWh)	Energy Value (\$)
1	2.87	76	3.80
2	4.21	101	5.05
3	5.08	129	6.45
4	6.45	153	7.65
5	7.65	178	8.90
6	8.48	189	9.45
7	8.74	196	9.80
8	7.39	168	8.40
9	5.93	133	6.65
10	4.36	106	5.30
11	2.82	67	3.35
12	2.38	60	3.00
Year	5.54	1,556	77.80

4.4 Energy Use on the Site

The Former Chicago, Milwaukee & St. Paul Rail Yard Company site does not have any major electricity use at the site. It is important to understand the application of energy generated on the site to enable for a full analysis of whether energy produced would need to be sold or whether it could offset future onsite energy use.

4.4.1 Net Metering

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

(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.

Iowa's net-metering law,⁶ which took effect in 1984, requires utilities to offer net metering to all customers with PV, wind, biomass, hydroelectric, municipal solid waste, and small hydroelectric systems up to 500 kW.

Renewable energy certificates (RECs),⁷ also known as green certificates, green tags, or tradable renewable certificates, are tradable commodities in the United States that represent proof of electric energy generation from eligible renewable energy resources (renewable electricity). The RECs that are associated with the electricity produced and are used onsite remain with the customer-generator. If, however, the customer chooses to receive financial compensation for the net energy gain remaining after a 12-month period, the utility will be granted the RECs associated with only that surplus it purchases.

Currently, Alliant Energy has more than enough renewables from wind in its renewable energy portfolio to meet all state mandates. Therefore, they are not as interested in purchasing RECs as they were a few years ago.

4.4.2 Virtual Net Metering

Under virtual net metering, certain entities, such as a local government, can install renewable generation of up to 1 MW at one location within its geographic boundary and to generate credits that can be used to offset charges at one or more other locations within the same geographic boundary. Some states and utilities allow virtual net metering; Iowa does not.

⁶ For the full text of this bill, see http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=IA02R&re=0&ee=0.

⁷ For a description of RECs, see <http://apps3.eere.energy.gov/greenpower/markets/certificates.shtml>.

5 Economics and Performance

NREL evaluated the economic performance of a PV system installed on the site using the assumptions and background information discussed in Section 5.1 and several industry-specific inputs determined by other studies. In particular, this study used NREL's System Advisor Model (SAM),⁸ a performance and economic model designed to facilitate decision making for people involved in the renewable energy industry. It makes performance predictions for grid-connected solar, solar water heating, wind, and geothermal power systems, and it makes economic calculations both for projects that buy and sell power at retail rates and for power projects that sell power through PPAs.

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 it makes economic estimates for distributed energy and central generation projects. The model calculates the cost of generating electricity based on information the user provides 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

The cost of a PV system depends on the system size and other factors, such as geographic location, mounting structure, and type of PV module. Based on significant cost reductions seen in 2011, the average cost for utility-scale, ground-mounted systems have declined from \$4.80/W in the first quarter of 2010 to \$2.79/W in the first quarter of 2012. With increasing demand and supply, potential of further cost reduction is expected as market conditions evolve.

For this study, the following input data were used. The installed cost of fixed-tilt ground-mounted systems was assumed to be \$2.79/W, and the installed cost of single-axis tracking PV was assumed to be \$3.35/W. These costs represent best case scenarios for purchase price on EPA brownfields. The installed system cost assumptions are summarized in Table 5.

Table 5. Installed System Cost Assumptions (\$/Watt)

System Type	Fixed-Tilt PV System	Single-Axis Tracking PV System
Baseline system	2.79	3.35

⁸ For additional information on SAM, see <https://sam.nrel.gov/cost>.

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. For this analysis, the buyback rate of the electricity was assumed to be \$0.05/kWh as reported by Alliant Energy.

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

For the purposes of this analysis, the project was expected to have a 25-year life, although the PV system can be reasonably expected to continue operation past this point. Inflation was assumed to be 2.5%; the real discount rate was assumed to be 3% for municipalities and 5.85% for private investors; and financing was assumed to be secured via a 15-year loan at a 6% interest rate and 55% debt fraction. The panels were assumed to have a 0.5% per year degradation in performance. The O&M expenses were estimated to be \$30/kW/yr for the first 15 years to replace the inverter and \$20/kW/yr for the remaining 10 years of the study. A system DC-to-AC conversion of 80% was assumed. This includes losses in the inverter, wire losses, PV module losses, and losses due to temperature effects. PVWatts Version 2⁹ was used to calculate expected energy performance for the system. Other assumptions can be found in Appendix C.

5.2 Estimated Economic Performance

Using the inputs and assumptions summarized in Section 5.1, SAM predicts the internal rate of return and the levelized cost of energy (LCOE). Four SAM cases were modeled for the site: a direct purchase by the City of Perry and a PPA by an investor with Alliant Energy, the local utility company, for both fixed and single-axis tracking modules. No cases modeled were economically viable as modeled and would not have a payback by the end of the 25-year project lifetime. Table 6 summarizes the economic results for the modeled cases.

⁹ For more information about PVWatts, NREL's calculator that determines energy production and cost savings for grid-connected PV systems, see <http://www.nrel.gov/redc/pvwatts/grid.html>.

Table 6. Economic Results for Four Modeled Cases

Single-Axis Tracking PV System	8,917,949 kWh Annual Production	
	Municipal	Commercial
Breakeven Sale Rate (\$/kWh)	0.11	0.091
Payback <25 Years Sale Rate (\$/kWh)	0.076	0.056
LCOE (\$/kWh)	0.1539	0.0758
Investor-Required PPA Price (\$/kWh)		0.1142
Flat-Plate System	8,337,899 kWh Annual Production	
	Municipal	Commercial
Breakeven Purchase Rate (\$/kWh)	0.122	0.107
Payback <25 Years Sale Rate (\$/kWh)	0.085	0.065
LCOE (\$/kWh)	0.1712	0.0891
Investor-Required PPA Price (\$/kWh)		0.1277

5.2.1 Flat-Plate Systems

Flat-plate systems are the simplest to set up, and they cost less on a per-watt basis than single-axis tracking PV systems. The flat-plate systems allow for a greater portion of area to be covered with solar panels but do not have a perpendicular sun angle for much of the day, which lowers the amount of energy generating area. For the Perry site, both the city- and investor-purchased cases had a negative net present value and no projected payback period.

5.2.2 Single-Axis Tracking PV Systems

Using a single-axis tracking PV system lowers the required system size—in comparison with a flat-plate system on the same area—but increases the purchase price by approximately \$0.60/W. Despite being a smaller system, the single-axis tracking PV array would produce a 7% increase in electricity generation. The single-axis tracking PV system had slightly better economics than the flat-plate system, but they were still very unfavorable.

5.2.3 Variations Between the Investor and Direct Purchase Cases

The City of Perry is a non-taxable entity, which greatly reduces the benefits of immediate investment credits to boost the net present value. The investor case modeled has a much better net present value due to the offered tax breaks that the city cannot receive. The PPA price from the investor is higher than the LCOE of the direct purchase because of the expected >15% internal rate of return, which raises the cost to the purchaser.

All results and a summary of inputs to the SAM are available in Appendix D. A summary of the results of the economic analysis and the system considered is available in Table 7.

Table 7. PV System Summary

Tie-In Location	System Type	PV System Size ^a (kW)	Array Tilt (deg)	Annual Output (kWh/year)	Number of Houses Powered ^b	Jobs	Jobs
						Created ^c (job-year)	Sustained ^d (job-year)
Train Yard	Crystalline Silicon (Fixed Tilt)	6,400	20	8,337,899	755	136	2
Train Yard	Crystalline Silicon (1-Axis)	5280	n/a	8,917,949	808	133	2

Tie-In Location	System Type	System Cost	Incentives	Annual Cost		Payback Period with Incentives (years)
				Savings (\$/year)	Annual O&M (\$/year)	
Train Yard	Crystalline Silicon (Fixed Tilt) Municipal Purchase	\$ 17,856,000	\$ 25,000	\$ -	\$ 566,400	N/A
Train Yard	Crystalline Silicon (Fixed Tilt) Investor Purchase	\$ 17,856,000	\$ 8,336,790	\$ -	\$ 566,400	N/A
Train Yard	Crystalline Silicon (1-Axis) Municipal Purchase	\$ 17,688,000	\$ 25,000	\$ -	\$ 566,400	N/A
Train Yard	Crystalline Silicon (1-Axis) Direct Purchase	\$ 17,688,000	\$ 8,668,395	\$ -	\$ 566,400	N/A

a Data assume a maximum usable area of 33 acres

Number of average American households that could hypothetically be powered by the PV system assuming 11,040

b 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.

5.2.4 Incentives to the Market to Improve Feasibility

Current market conditions, primarily the maximum PPA rate offered by Alliant Energy, prohibit market penetration for solar energy at the site. Because the solar resource and incentives at the site are not optimal, the revenue from the low electricity sale price would not be able to pay for loan repayments and O&M costs. Improving the revenue stream for this and other projects will be crucial to market penetration. Ways to improve the revenue stream through policy adjustments already employed by other states include:

- Implementing virtual net metering, such as the policy in place in New Jersey, would take advantage of the large area at the site to eliminate utility costs for the municipality.
- Creating a REC market in Iowa, such as the markets along the East Coast, to sell credits from green projects to utilities attempting to meet renewable portfolio standards would improve revenue streams.

These improvements to the revenue stream could make this project, and others like it, feasible. Other more quantifiable incentives were analyzed to investigate which policies would have the greatest impacts. For this study, the single-axis modeling case was used to evaluate the impact on LCOE (for the municipality or investor-owned case) and the PPA price in the investor case. The policies evaluated were loan guarantees, capacity-based incentives (CBI), production-based incentives (PBI), and investment tax credits (ITC).

Table 8. LCOE for Single-Axis Tracking PV System After Applied Incentives

	Municipal LCOE (\$/kWh)	Commercial LCOE (\$/kWh)	Investor PPA (\$/kWh)
Loan Guarantees (all pieces)	-	\$0.0104	\$0.0644
Extend to 25 years (15 years)	-	\$0.0682	\$0.0817
Drop to 3% interest (6%)	-	\$0.0705	\$0.0991
100% debt fraction (55%)	-	\$0.0542	*
CBI			
State CBI payment (\$0.50/W)	\$0.1363	\$0.0658	\$0.0873
State CBI payment (\$1/W)	\$0.1186	\$0.0515	\$0.0604
PBI (for 10 years)			
State PBI payment (\$0.02/kWh)	\$0.1409	\$0.0722	\$0.0998
State PBI payment (\$0.05/kWh)	\$0.1212	\$0.0604	\$0.0782
ITC			
State ITC 15% No maximum	-	\$0.062	\$0.0734

The results show that the largest impact could come from loan guarantees, which lower the cost of capital for the project. All incentive types could be used together to maximize their individual benefits to generate market penetration. Total government costs were calculated for each different incentive; these can be found in Appendix D. Based on these totals, the most effective policy of lowering the LCOE and PPA is the unbounded ITC. The 15% ITC is currently in place in Iowa with a \$15,000 cap; removing that cap would create the most cost-effective policy shift. Results for the cost-effectiveness table can be found in Appendix D.

5.3 Job Analysis and Impact

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

The JEDI models represent the entire economy, including cross-industry or cross-company impacts. For example, the JEDI models estimate 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 procure and install a complete system.

¹⁰ The JEDI models have been used by the U.S. Department of Energy, the U.S. Department of Agriculture, NREL, and the Lawrence Berkeley National Laboratory, as well as several universities. For information on JEDI, see <http://www.nrel.gov/analysis/jedi/>.

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

For the Former Chicago, Milwaukee & St. Paul Rail Yard Company site, the values in Table 9 were assumed.

Table 9. JEDI Analysis Assumptions

Input	Assumed Value
Capacity	6,400 kW
Placed In Service Year	2013
Installed System Cost	\$24,960,000
Location	Perry, IA

Using these inputs, the JEDI models estimated 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 40 hours per week for one person for the duration of a year. Construction period jobs are considered short-term positions that exist only during the procurement and construction periods.

As indicated in the results of the JEDI model analysis provided in Appendix E, the total proposed system was estimated to support 189.6 direct and indirect jobs per year for the duration of the procurement and construction period. Total wages paid to workers during the construction period were estimated to be \$7,428,300, and total economic output was estimated to be \$18,727,800. The annual O&M of the new PV system was estimated to support 1.9 FTEs per year for the life of the system. The jobs and associated spending were projected to account for approximately \$98,300 in earnings and \$160,300 in economic activity each year for the next 25 years.

5.4 Financing Opportunities

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

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 that entity is a private entity, sufficient tax appetite to use 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 used 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 use 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 programs, internal cash; or some combination of the above. Certain structures are more common than others are, and grant programs for solar programs are on the decline. Regardless, as tax-exempt entities, public entities cannot 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 have the financial or technical capabilities to develop a capital-intensive project, they often 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 finance, develop, own, and operate solar projects using their own expertise and sources of tax equity financing and debt capital. Once the system is installed, the third-party developer sells the electricity to the site host or local utility via a PPA. The PPA is typically (1) between the third-party developer and the site host if the transaction is a retail "behind-the-meter" transaction or (2) 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 from land-lease revenues that they receive 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 use federal tax credits. For public entities, this arrangement allows them to use the benefits of the tax credits (low PPA price, higher lease payment) while not directly receiving them. The term of a PPA typically varies from 20 to 25 years.

5.4.3 Third-Party "Flip" Agreements

The most common use of this model is a site host working with a third-party developer who then partners with a tax-motivated investor in an SPE that would own and operate the project. Initially, most of the equity provided to the SPE would come from the tax investor and most of the benefit (as much as 99%) would flow to the tax investor. 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, in which case, the investor would begin with the majority ownership. Eventually, the ownership would flip to the developer once the investor's return was 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, including Denver and Salt Lake City.

5.4.5 Solar Services Agreement and Operating Lease

The solar services agreement and operating lease business models have been used predominately in the municipal and cooperative utility markets for their treatment of tax benefits and the rules limiting federal tax benefit transfers from non-profit to for-profit companies. Under Internal Revenue Service guidelines, municipalities cannot enter capital leases with for-profit entities when the for-profit entities capture tax incentives. As a result, several business models, including the solar services agreement, have emerged as a work-around to this issue. With a solar services agreement, a private party sells "solar services" (i.e., energy and RECs) to a municipality over a specified contract period (typically long enough for the private party to accrue the tax credits). The non-profit utility typically purchases the solar services with either a one-time up-front payment equal to the turnkey system cost minus the 30% federal tax credit, or it 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 Internal Revenue Service regulations, the buyout of the plant cannot be included as part of the solar services agreement (i.e., the agreement cannot be used as a vehicle for a sale and must be a separate transaction).

5.4.6 Sale/Leaseback

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

In this widely accepted model, the public or private entity would install the PV system, sell it to a tax investor and then lease it back. As the lessee, they would be responsible for operating and maintaining the solar system and they would have the right to sell or use the power. In exchange for use of the 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 several participants share the costs and benefits of one large solar project. A site owner may be able to make the land available for a large solar project, which could then be the basis for a community solar project. Ownership structures for these large projects vary, but local utilities typically own or sponsor them. Community solar gardens are distributed solar projects wherein utility customers have a stake via a prorated share of the project’s energy output.

This business model is intended to meet demand for solar projects by customers who rent or lease homes or businesses, do not have good solar access at their site, or do not want to install a solar system on their facilities. Customer prorated shares of solar projects are acquired through a long-term transferrable lease of one or more panels, or customers 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 virtual net metering. Under the customer subscription option, a customer typically pays a set price for a block of solar energy (i.e., 100-kWh per-month blocks) from the community solar project. Other models include monthly energy outputs from a specific investment dollar amount or a specific number of panels.

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

Some states offer solar incentives for community solar projects. For example, Washington State offers a production incentive, and Utah offers a state income tax credit. Community solar is known as Solar Gardens depending on the location (e.g., Colorado).

6 Conclusions and Recommendations

A PV system on the site could generate approximately 8,900 MWh annually and could represent a significant distributed generation facility for the area. While reusing land that cannot be used for other purposes would minimize the environmental impact of the brownfield, using the site for PV is not economically feasible under current conditions.

As summarized in Section 5, the economic analysis completed using SAM predicts an internal rate of return and LCOE of 0% and \$0.08–\$0.18/kWh, respectively.

Several policy changes could improve the economics of this and other projects in Iowa. The best improvements for commercial investors would be a robust loan guarantee program with lowered rates and longer payback periods. These loans could effectively lower the cost of production to the PPA price currently offered by Alliant Energy. An increase in revenue would also be very important to a solar project's success. REC markets would be very effective in raising the revenue stream for investors to gain greater market penetration for renewable energy across the state. The successful shift of any policy would require a broad array of policy additions and cooperation with local utilities.

The best available economic case for the City of Perry would involve setting up multiple smaller systems on existing municipal buildings to take advantage of net metering. The many different small systems take advantage of tax incentives written to promote small electricity generation. Systems ranging in size from 50 kW to 100 kW have payback periods from 17 to 18.3 years, respectively. If using a PPA through an investor, over the same system size range, the PPA price would range from \$0.13/kWh to \$0.16/kWh. The systems would need to be sized according to actual building load and available space. Smaller systems were modeled to have lower PPA prices because they take greater advantage of incentives; however, systems of smaller sizes will limit investor attraction and raise the cost per watt not modeled.

Investigating state, local, and utility-based policy changes that could make a large-scale PV system financially viable is recommended for the City of Perry at this time.

Appendix A. Provided Site Information

Figure A-1 shows contaminated areas at the site.

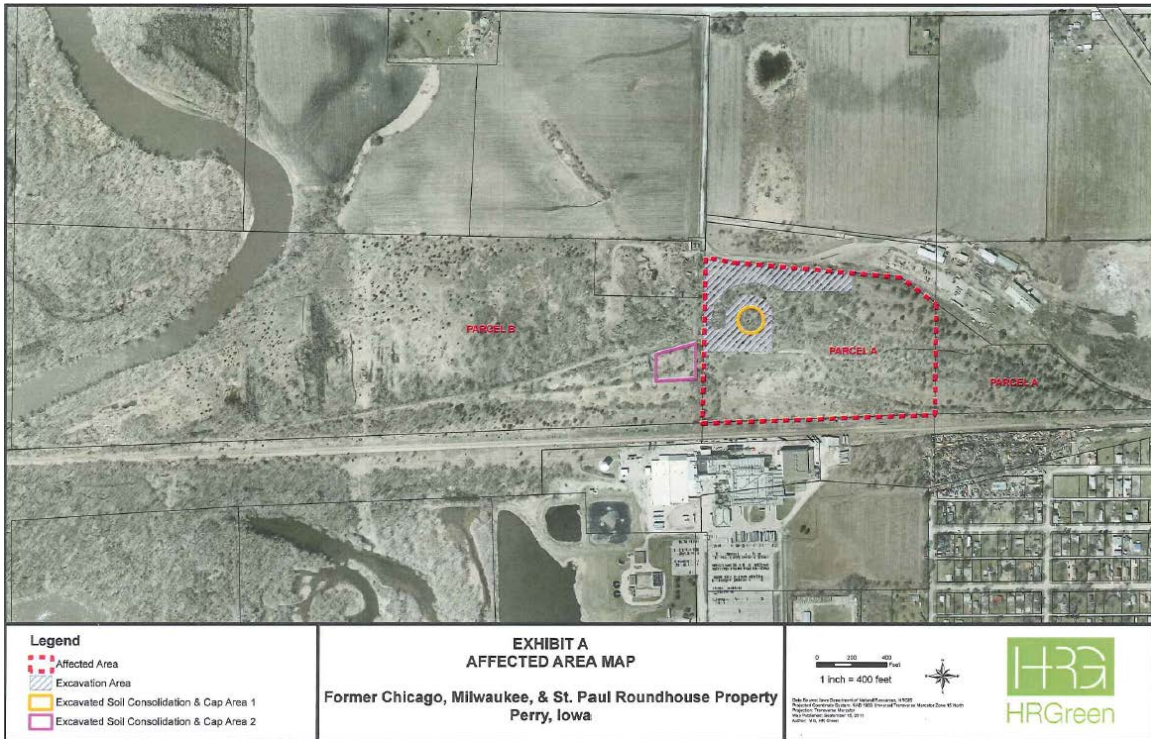


Figure A-1. Contaminated areas at the Former Chicago, Milwaukee & St. Paul Rail Yard Company site

Source: City of Perry

Appendix B. Solar Access Measurements

Figure B-1 shows solar access measurements for the Former Chicago, Milwaukee & St. Paul Rail Yard Company PV site

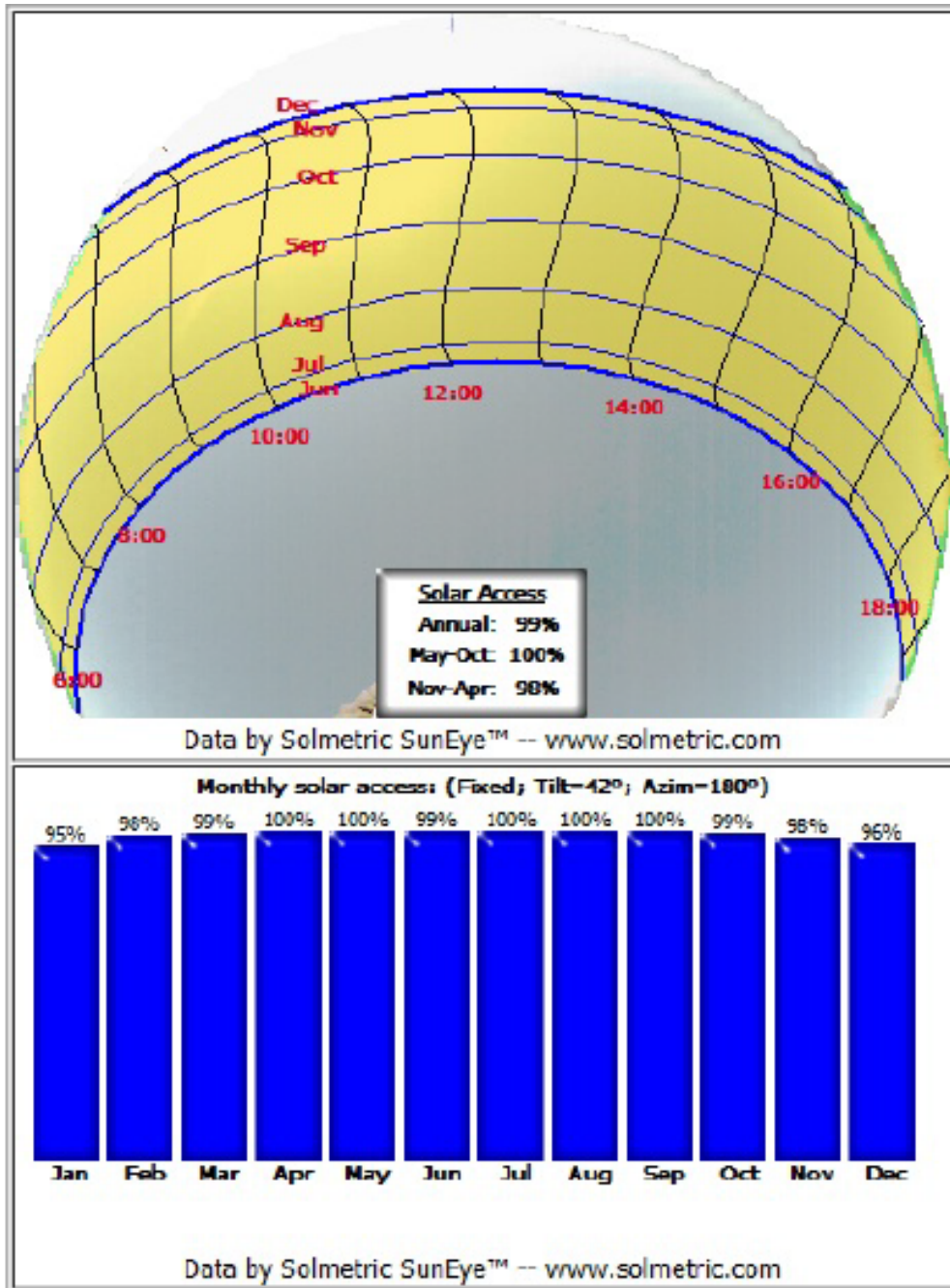


Figure B-1. Solar access measurements for Former Chicago, Milwaukee & St. Paul Rail Yard Company PV site

Appendix C. Assumptions for the Assessment and Calculations

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

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

Cost Assumptions			
Variable	Quantity of Variable	Unit of Variable	
Cost of Site Electricity	0.05	\$/kWh	
Annual O&M (fixed)	30	\$/kW/year for first 15 years	
System Assumptions			
System Type	Annual Energy (kWh/kW)	Installed Cost (\$/W)	Energy Density (W/sq. ft.)
Ground Fixed	1,303	\$2.79	4.0
Ground Single-Axis	1,556	\$3.35	3.3
Other Assumption			
	Ground utilization	90% of available area	

Appendix D. Results from the System Advisor Model

Figures D-1 through D-11 show the graphs from the SAM models. Table D-1 and D-2 show estimates on the impact of policy on both the economics of PV systems and budgets of policy implementers.

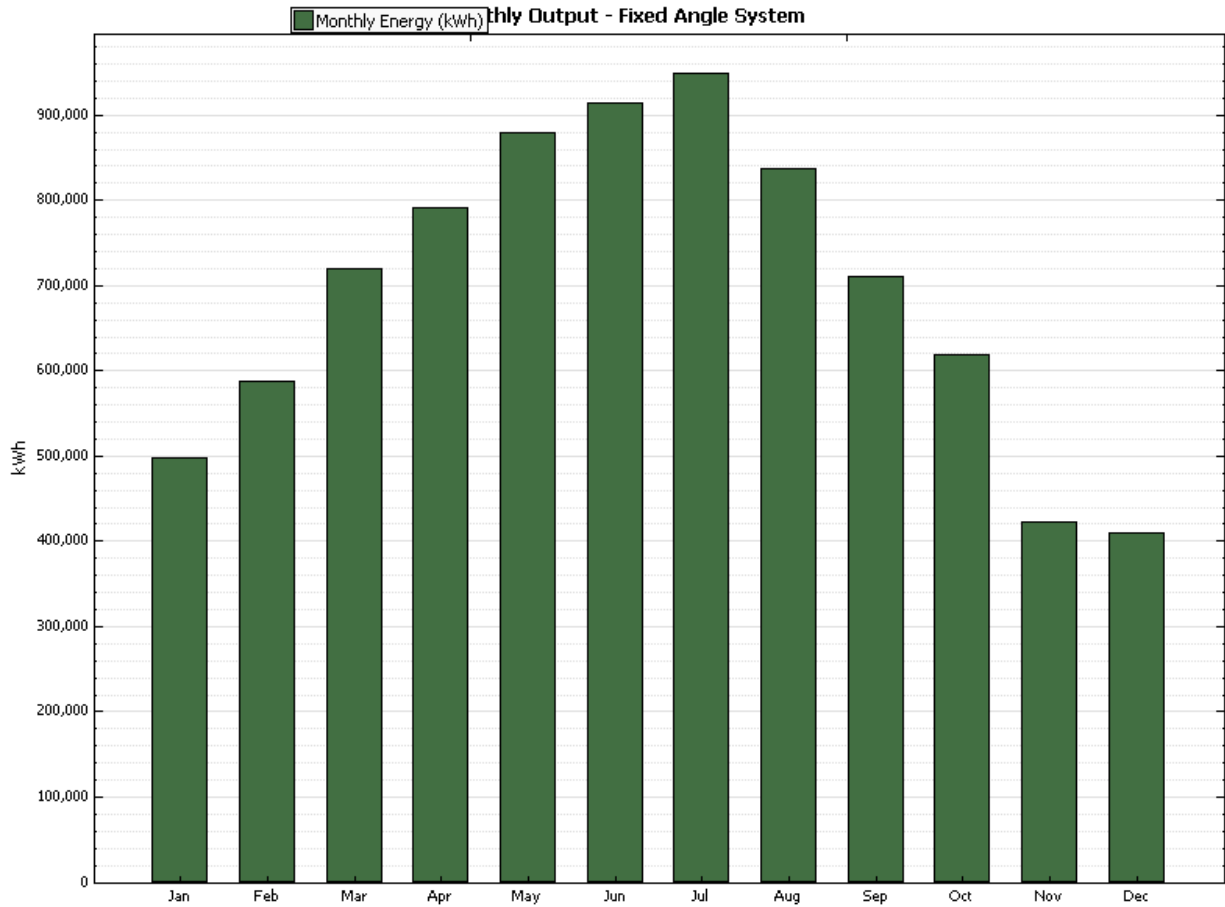


Figure D-1. Modeled output for a flat-plate system

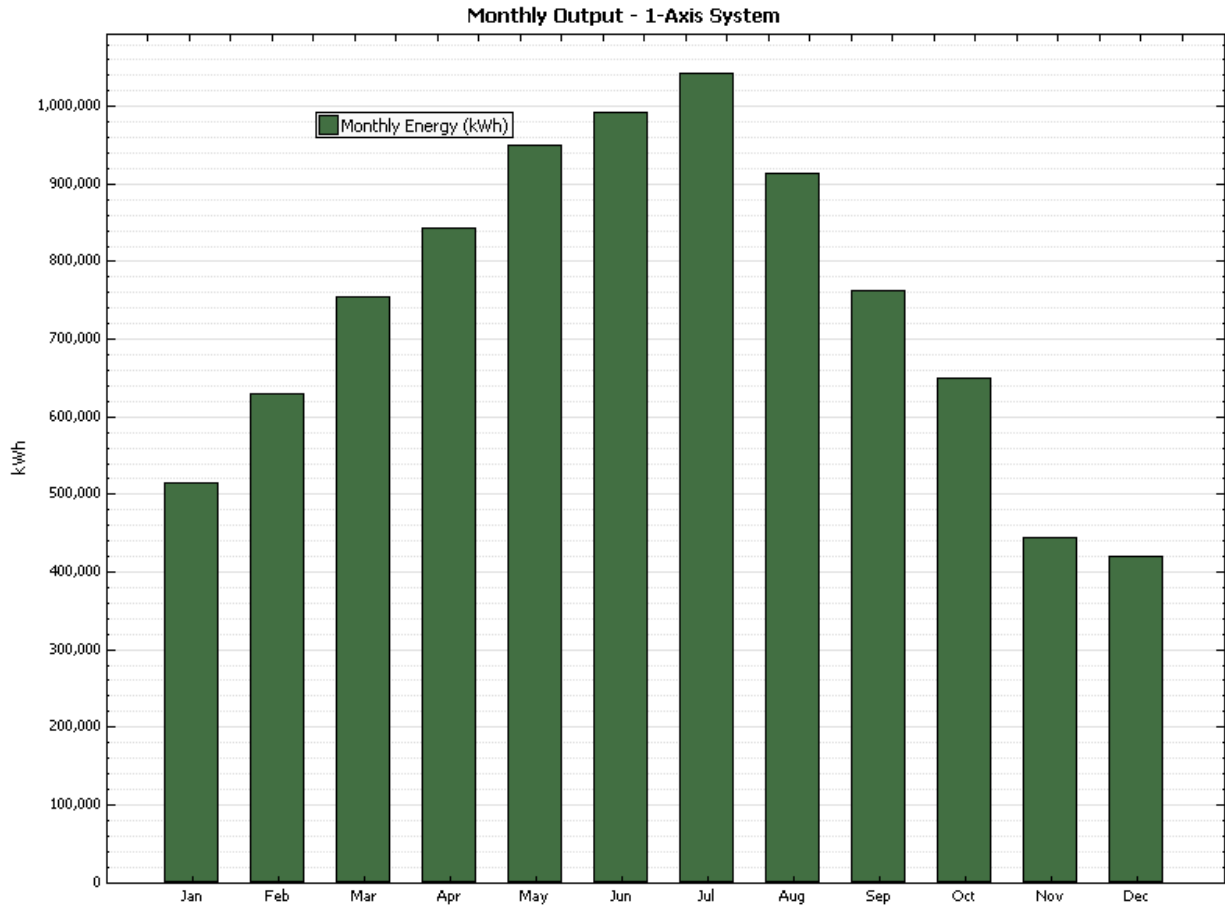


Figure D-2. Modeled output for a single-axis tracking PV system

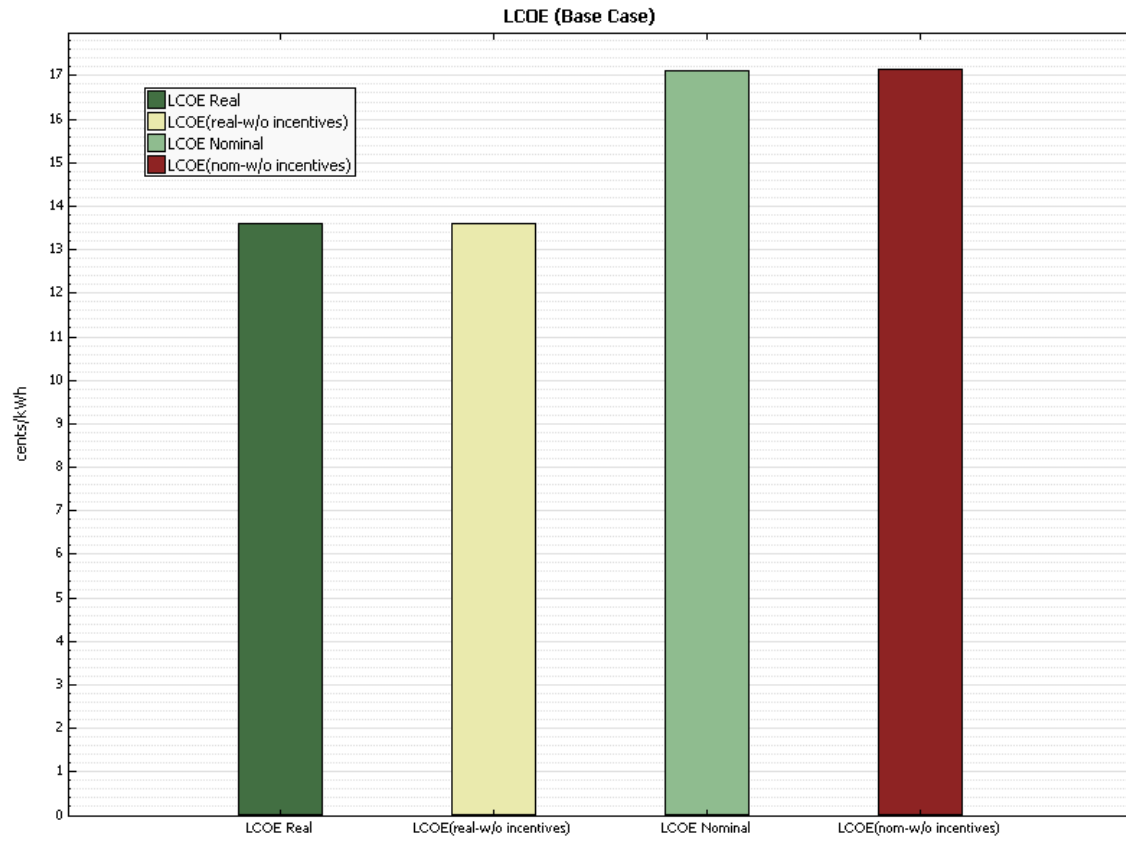


Figure D-3. LCOE for municipal purchase of a flat-plate system

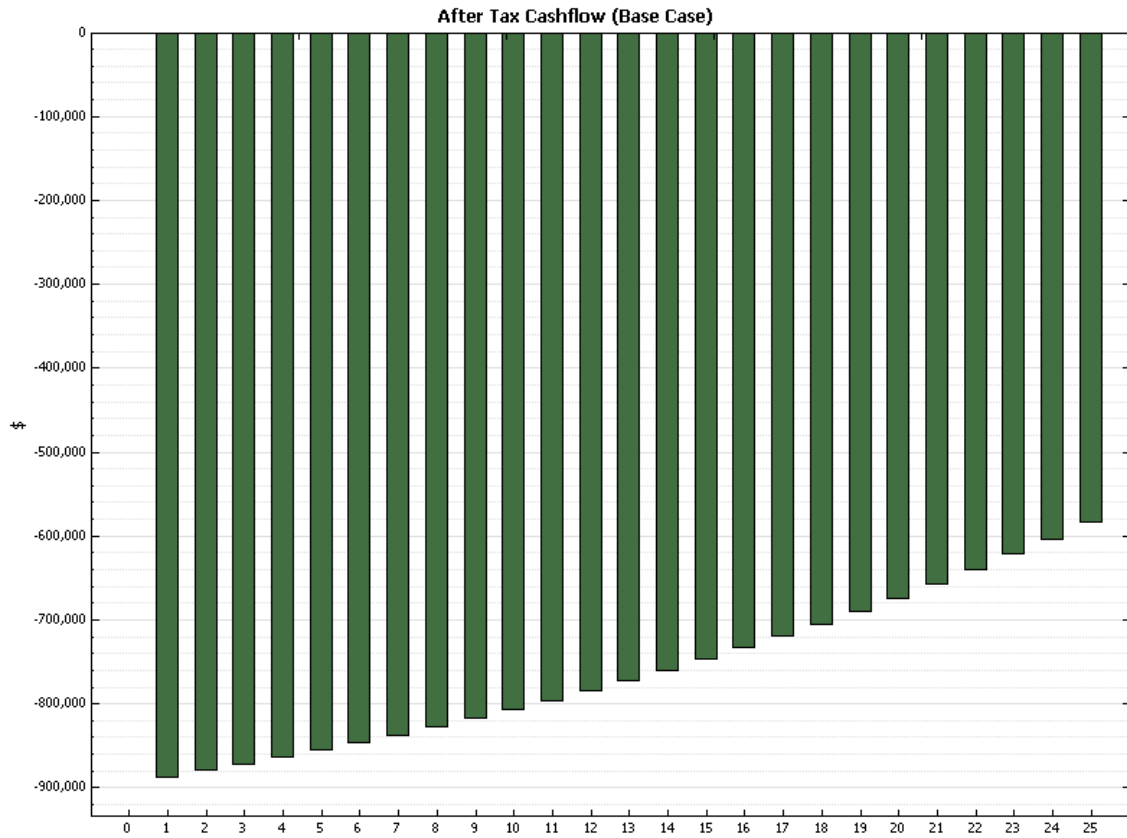


Figure D-4. After-tax cash flow for municipal purchase of a flat-plate system

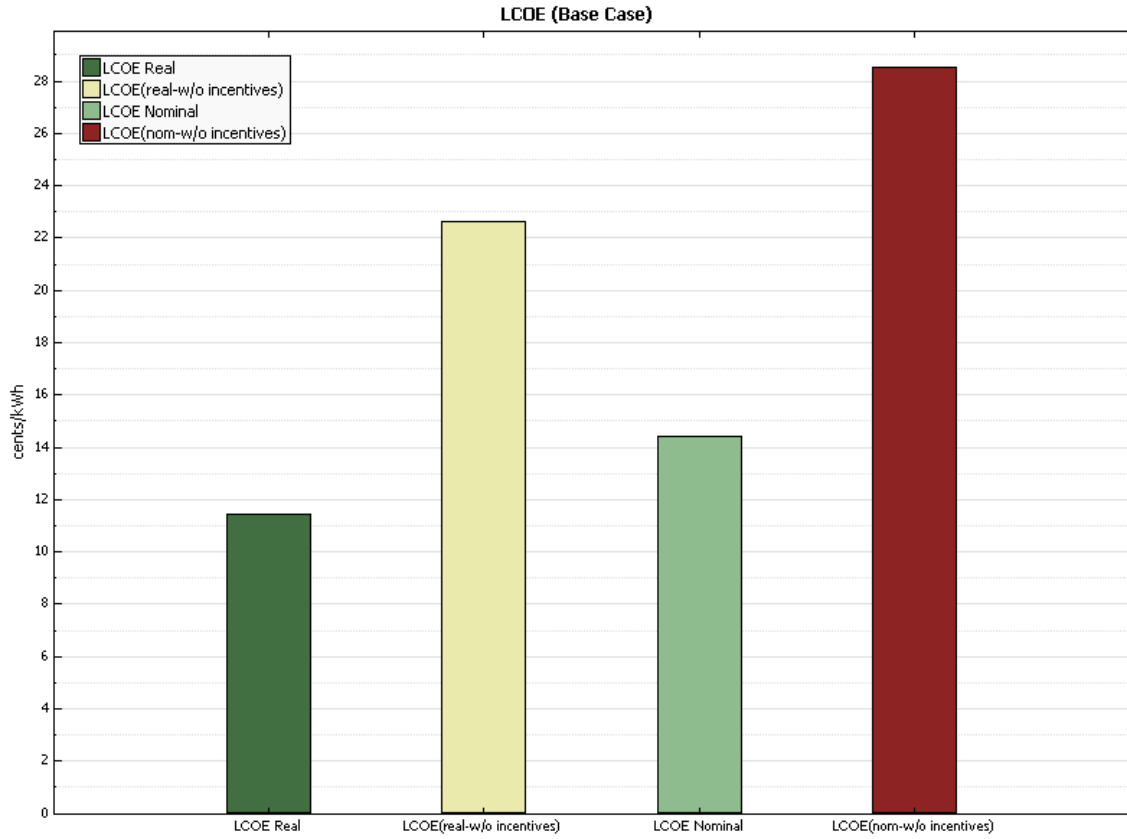


Figure D-5. LCOE for a developer-purchased flat-plate system

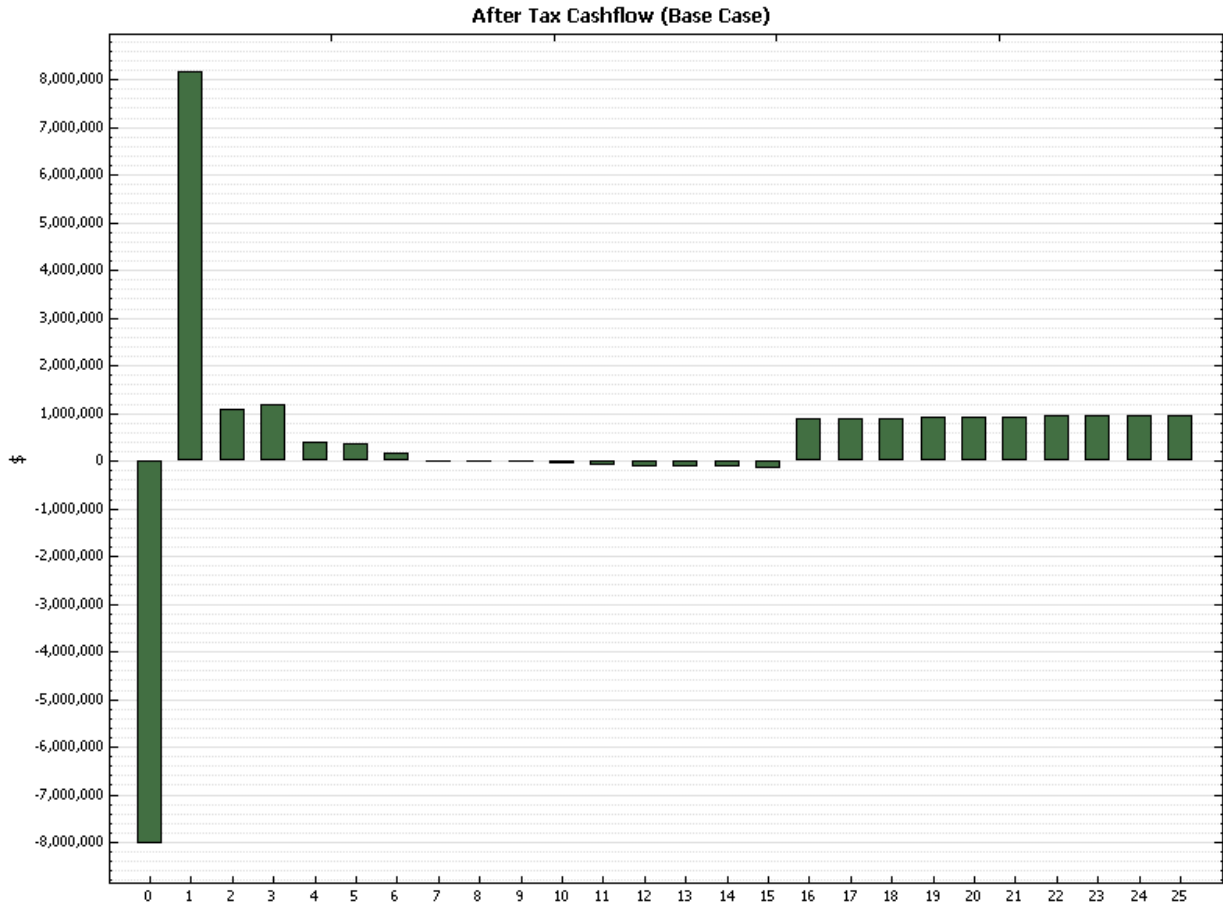


Figure D-6. After-tax cash flow for a developer-purchased flat-plate system

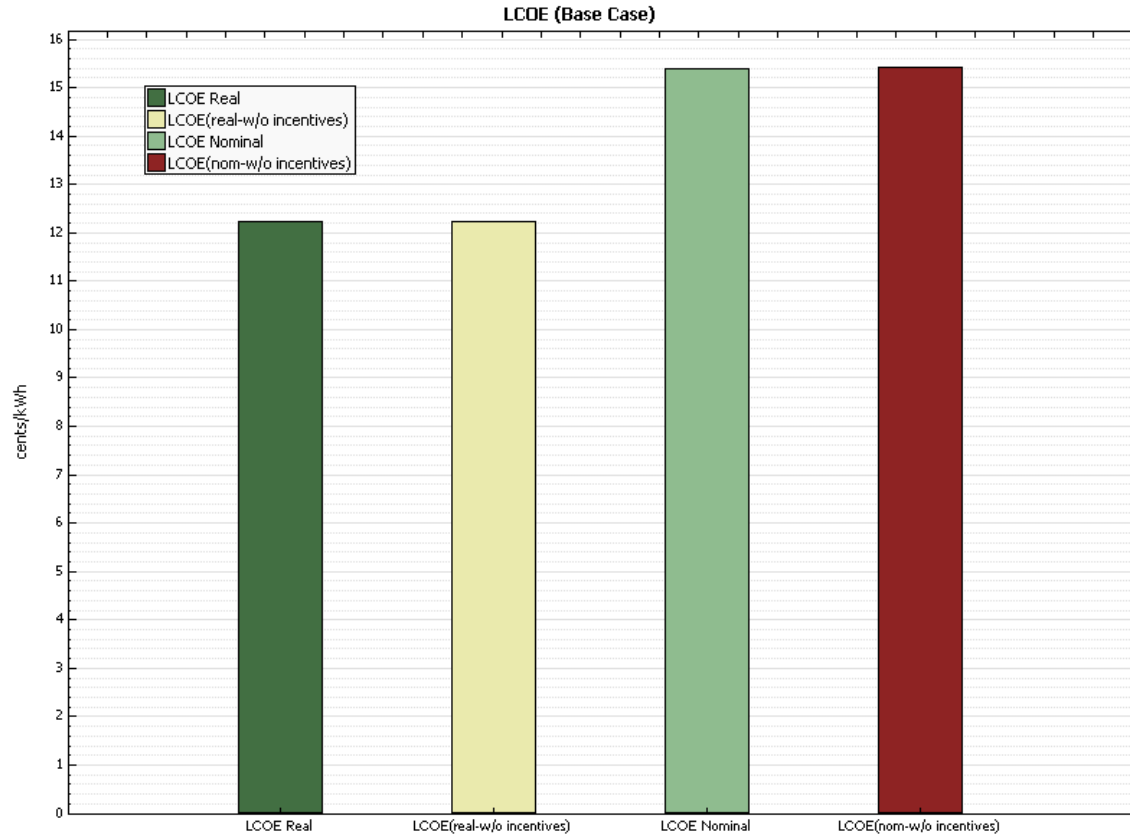


Figure D-7. LCOE for municipal purchase of a single-axis tracking PV system

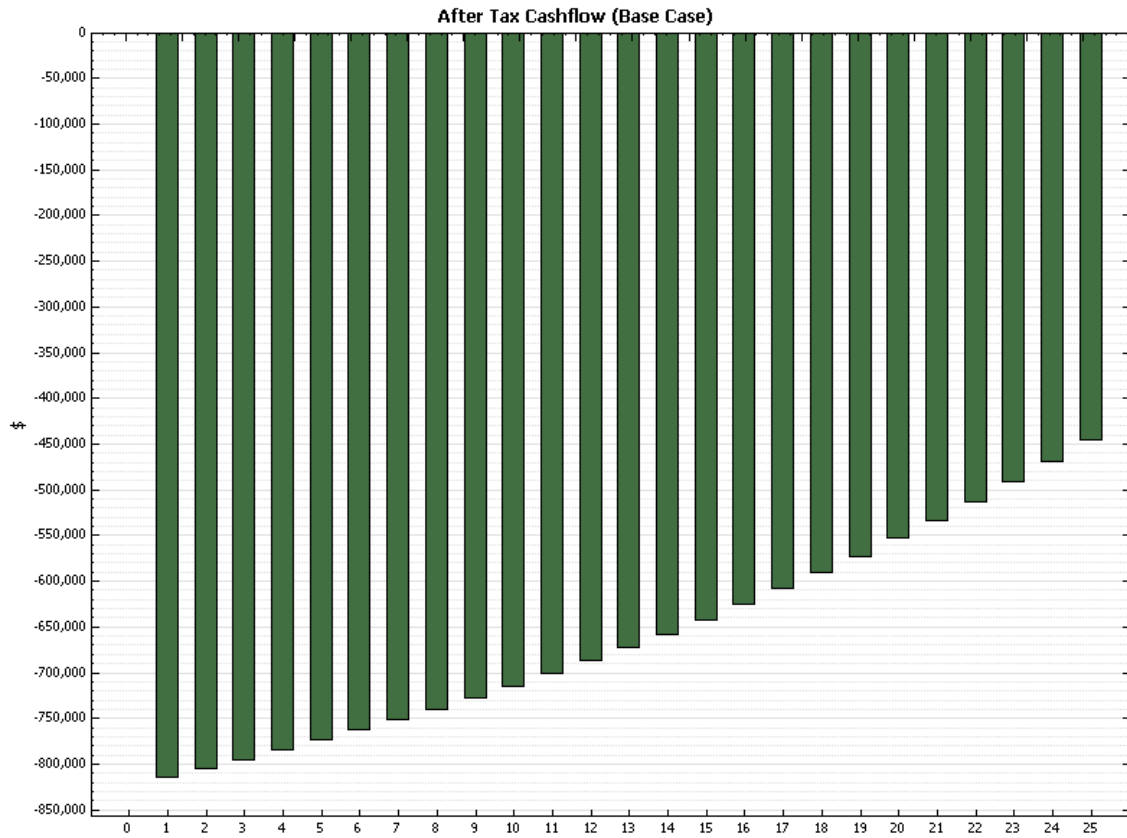


Figure D-8. After-tax cash flow for municipal purchase of a single-axis tracking PV system

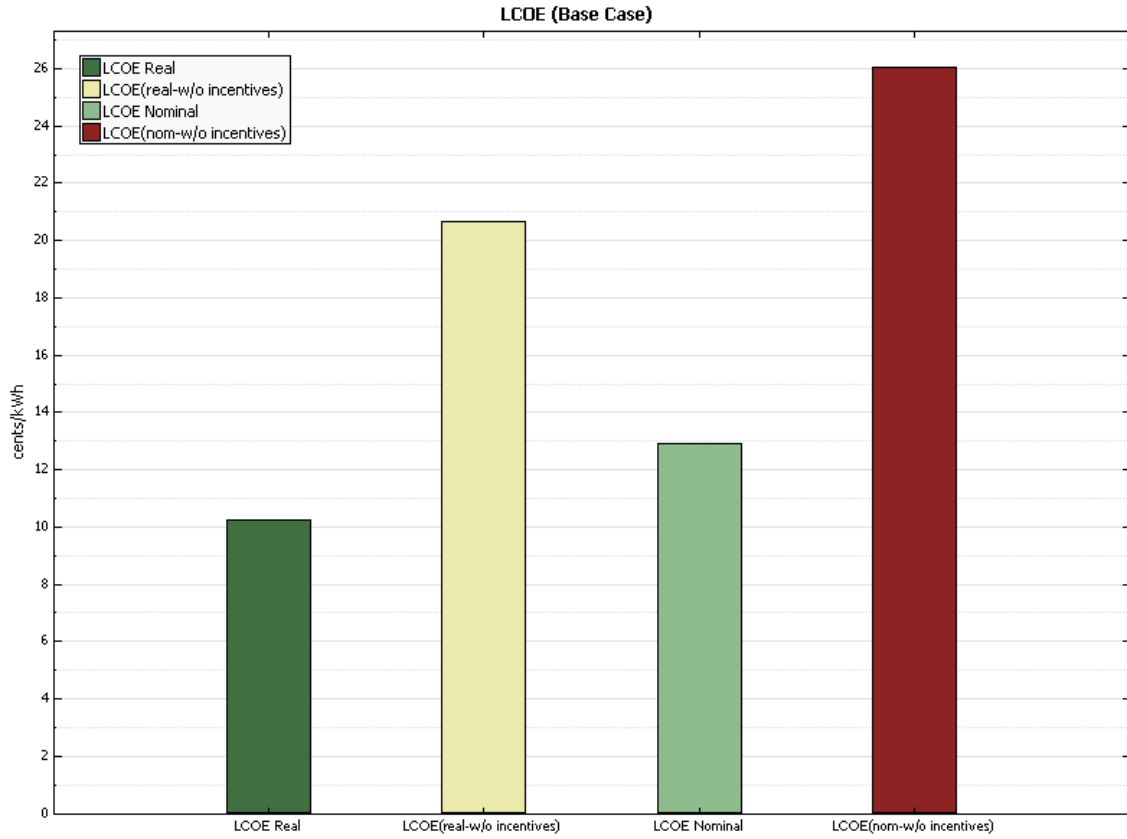


Figure D-9. LCOE for a developer-purchased single-axis tracking PV system

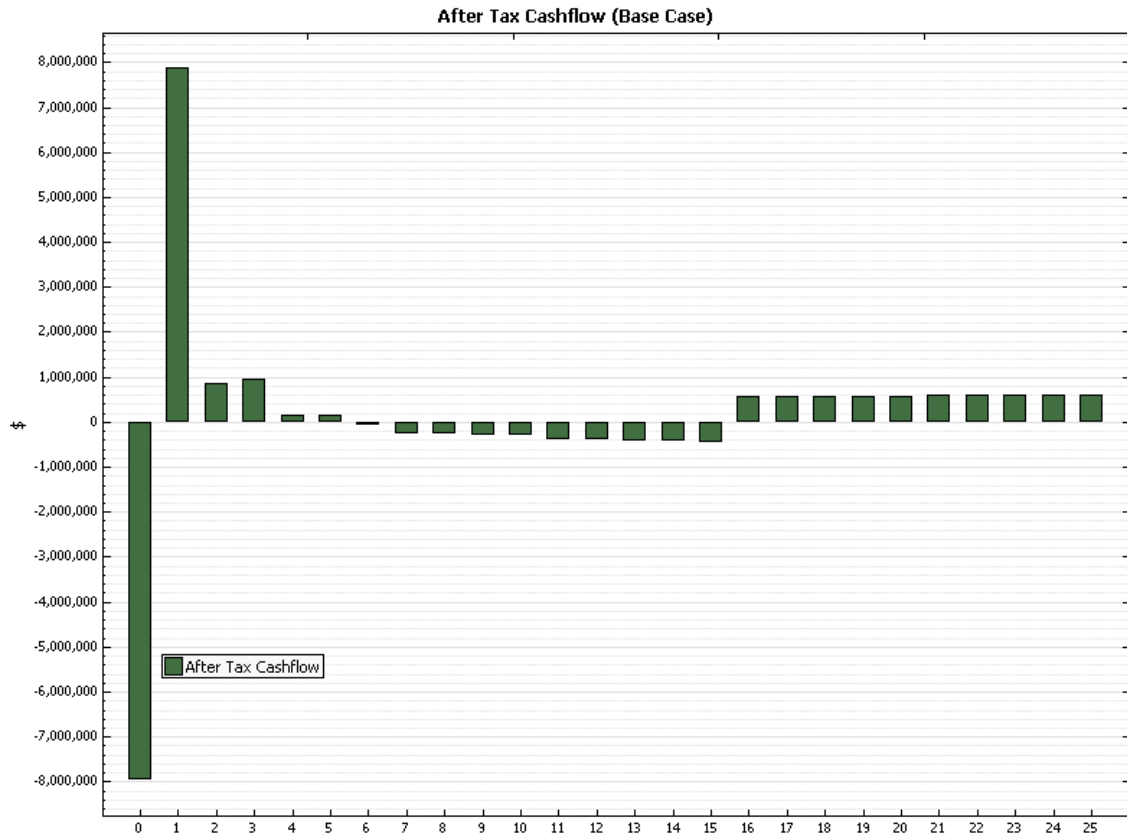


Figure D-10. After-tax cash flow for a developer-purchased single-axis tracking PV system

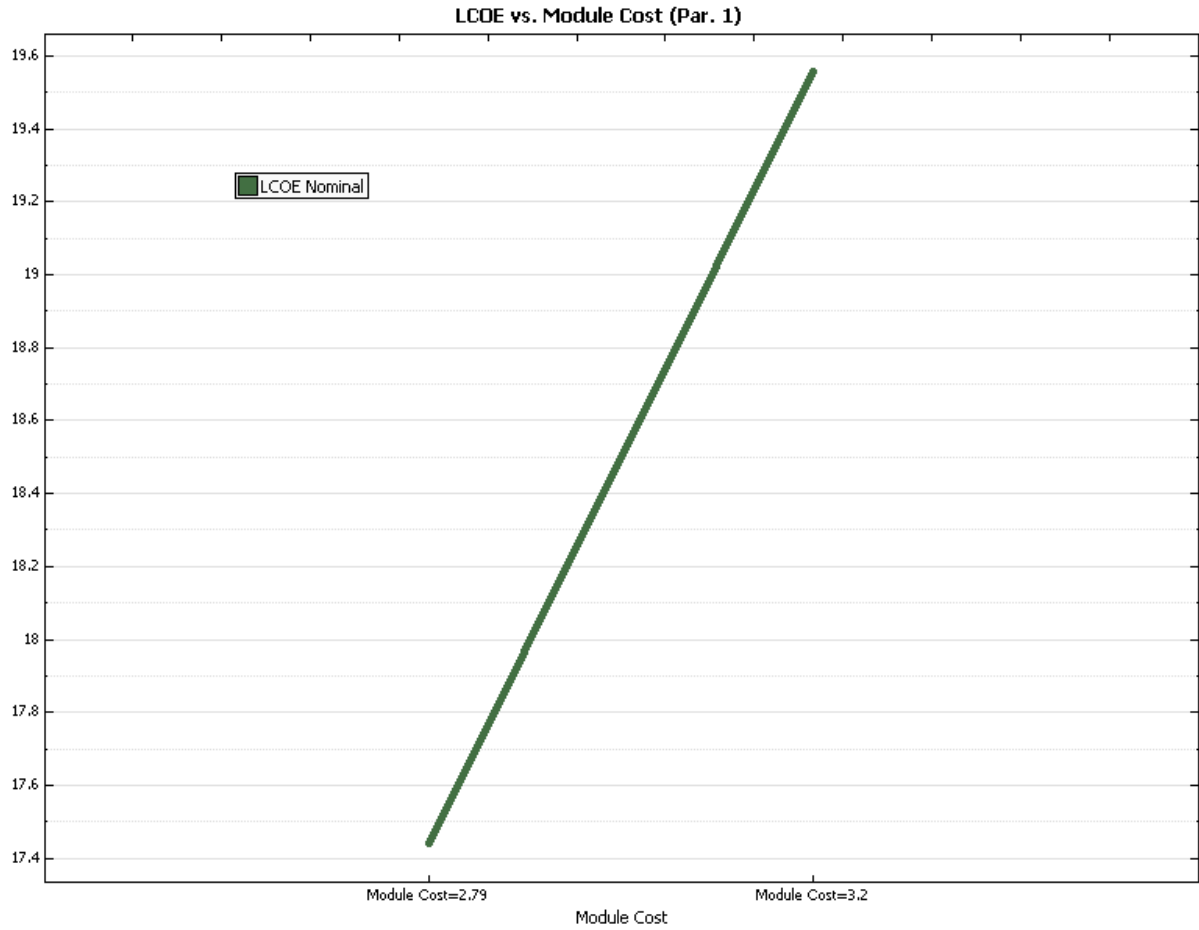


Figure D-11. Range of LCOE for municipal purchase of a flat-plate system

The range is similar for all four cases modeled (see Table 6).

Table D-1. Public Funds Allocated to the Project With Analyzed Incentives

	Municipal Public Funds Cost	Commercial Public Funds Cost	Investor PPA Public Funds Cost
CBI			
State CBI Payment (\$0.50/W)	\$2,640,000	\$2,640,000	\$2,640,000
State CBI Payment (\$1.00/W)	\$5,280,000	\$5,280,000	\$5,280,000
PBI (10 years)			
State PBI Payment (\$0.02/kWh)	\$1,743,988	\$1,743,988	\$1,743,988
State PBI Payment (\$0.05/kWh)	\$4,359,974	\$4,359,974	\$4,359,974
ITC			
State ITC (15%, No Max.)	\$2,653,200	\$2,653,200	\$2,653,200

Table D-2. Amount of Public Funds Used to Lower the LCOE or PPA by \$0.01/kWh

	Municipal Effectiveness (Incentive Dollars)	Commercial LCOE Effectiveness	PPA Effectiveness
CBI			
State CBI Payment (\$0.50/W)	\$1,500,000	\$1,859,154.93	\$981,412.64
State CBI Payment (\$1.00/W)	\$1,495,751	\$1,852,631.58	\$981,412.64
PBI (10 years)			
State PBI Payment (\$0.02/kWh)	\$1,341,529	\$2,235,882	\$1,211,103
State PBI Payment (\$0.05/kWh)	\$1,333,325	\$2,224,477	\$1,211,104
ITC			
State ITC (15%, No Max.)	-	\$1,474,000	\$650,294

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

Tables E-1 through E-8 provide results from the JEDI model

Table E-1. Data Summary for JEDI Model Analysis of a Fixed-Tilt PV System

Project Location	IOWA
Year of Construction or Installation	2013
Average System Size - DC Nameplate Capacity (KW)	6,400.0
Number of Systems Installed	1
Project Size - DC Nameplate Capacity (KW)	6,400.0
System Application	Utility
Solar Cell/Module Material	Crystalline Silicon
System Tracking	Fixed Mount
Total System Base Cost (\$/KW _{DC})	\$3,900
Annual Direct Operations and Maintenance Cost (\$/kW)	\$25.00
Money Value - Current or Constant (Dollar Year)	2012
Project Construction or Installation Cost	\$24,960,000
Local Spending	\$11,528,641
Total Annual Operational Expenses	\$3,055,360
Direct Operating and Maintenance Costs	\$160,000
Local Spending	\$147,200
Other Annual Costs	\$2,895,360
Local Spending	\$0
Debt Payments	\$0
Property Taxes	\$0

Table E-2. Summary of Local Economic Impacts for JEDI Model Analysis of a Fixed-Tilt PV System

	Jobs	Earnings	Output
During construction and installation period		\$000 (2012)	\$000 (2012)
Project Development and Onsite Labor Impacts			
Construction and Installation Labor	35.1	\$2,274.3	
Construction and Installation Related Services	46.3	\$1,638.4	
Subtotal	81.5	\$3,912.7	\$6,933.0
Module and Supply Chain Impacts			
Manufacturing Impacts	0.0	\$0.0	\$0.0
Trade (Wholesale and Retail)	8.8	\$420.8	\$1,255.1
Finance, Insurance and Real Estate	0.0	\$0.0	\$0.0
Professional Services	10.4	\$370.4	\$1,254.0
Other Services	17.0	\$1,298.2	\$4,497.7
Other Sectors	32.8	\$194.9	\$663.1
Subtotal	69.0	\$2,284.2	\$7,669.9
Induced Impacts	36.8	\$1,137.3	\$3,887.9
Total Impacts	187.2	\$7,334.2	\$18,490.7
		Annual	Annual
	Annual	Earnings	Output
During operating years	Jobs	\$000 (2012)	\$000 (2012)
Onsite Labor Impacts			
PV Project Labor Only	1.5	\$89.2	\$89.2
Local Revenue and Supply Chain Impacts	0.5	\$23.8	\$76.6
Induced Impacts	0.3	\$10.4	\$35.4
Total Impacts	2.3	\$123.3	\$201.1

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 E-3. Detailed Summary of Costs for JEDI Model Analysis of a Fixed-Tilt PV System

	IOWA	Purchased	Manufactured
Installation Costs	Cost	Locally (%)	Locally (Y or N)
Materials & Equipment			
Mounting (rails, clamps, fittings, etc.)	\$910,236	100%	N
Modules	\$9,996,622	100%	N
Electrical (wire, connectors, breakers, etc.)	\$1,037,824	100%	N
Inverter	\$1,486,677	100%	N
Subtotal	\$13,431,359		
Labor			
Installation	\$2,274,310	100%	
Subtotal	\$2,274,310		
Subtotal	\$15,705,669		
Other Costs			
Permitting	\$105,093	100%	
Other Costs	\$2,322,551	100%	
Business Overhead	\$6,826,688	100%	
Subtotal	\$9,254,331		
Subtotal	\$24,960,000		
Sales Tax (Materials & Equipment Purchases)	\$0	100%	
Total	\$24,960,000		

Table E-4. Annual O&M Costs for JEDI Model Analysis of a Fixed-Tilt PV System

	Cost	Local Share	Manufactured Locally (Y or N)
Labor			
Technicians	\$96,000	100%	
Subtotal	\$96,000		
Materials and Services			
Materials & Equipment	\$64,000	100%	N
Services	\$0	100%	
Subtotal	\$64,000		
Sales Tax (Materials & Equipment Purchases)	\$0	100%	
Average Annual Payment (Interest and Principal)	\$2,895,360	0%	
Property Taxes	\$0	100%	
Total	\$3,055,360		
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	6.00%	100%	
Sales Tax Exemption (percent of local taxes)	100%		
Payroll Parameters	Wage per hour	Employer Payroll Overhead	
Construction and Installation Labor			
Construction Workers / Installers	\$21.39	45.6%	
O&M Labor			
Technicians	\$21.39	45.6%	

Table E-5. Data Summary for JEDI Model Analysis of a Single-Axis Tracking PV System

Project Location	IOWA
Year of Construction or Installation	2013
Average System Size - DC Nameplate Capacity (KW)	5,280.0
Number of Systems Installed	1
Project Size - DC Nameplate Capacity (KW)	5,280.0
System Application	Utility
Solar Cell/Module Material	Crystalline Silicon
System Tracking	Single Axis
Total System Base Cost (\$/KW _{DC})	\$4,900
Annual Direct Operations and Maintenance Cost (\$/kW)	\$25.00
Money Value - Current or Constant (Dollar Year)	2012
Project Construction or Installation Cost	\$25,872,000
Local Spending	\$13,978,587
Total Annual Operational Expenses	\$3,133,152
Direct Operating and Maintenance Costs	\$132,000
Local Spending	\$121,440
Other Annual Costs	\$3,001,152
Local Spending	\$0
Debt Payments	\$0
Property Taxes	\$0

Table E-6. Summary of Local Economic Impacts for JEDI Model Analysis of a Single-Axis Tracking PV System

	Jobs	Earnings	Output
During construction and installation period		\$000 (2012)	\$000 (2012)
Project Development and Onsite Labor Impacts			
Construction and Installation Labor	31.0	\$2,006.5	
Construction and Installation Related Services	60.0	\$2,120.1	
Subtotal	90.9	\$4,126.6	\$8,034.9
Module and Supply Chain Impacts			
Manufacturing Impacts	0.0	\$0.0	\$0.0
Trade (Wholesale and Retail)	11.3	\$544.1	\$1,623.1
Finance, Insurance and Real Estate	0.0	\$0.0	\$0.0
Professional Services	13.5	\$479.4	\$1,622.8
Other Services	22.0	\$1,678.7	\$5,815.9
Other Sectors	40.7	\$193.3	\$651.9
Subtotal	87.5	\$2,895.5	\$9,713.7
Induced Impacts	44.4	\$1,372.0	\$4,690.1
Total Impacts	222.8	\$8,394.1	\$22,438.8
		Annual	Annual
	Annual	Earnings	Output
During operating years	Jobs	\$000 (2012)	\$000 (2012)
Onsite Labor Impacts			
PV Project Labor Only	1.2	\$73.6	\$73.6
Local Revenue and Supply Chain Impacts	0.4	\$19.6	\$63.2
Induced Impacts	0.3	\$8.5	\$29.2
Total Impacts	1.9	\$101.7	\$165.9

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 E-7. Detailed Summary of Costs for JEDI Model Analysis of a Single-Axis Tracking PV System

	IOWA	Purchased	Manufactured
Installation Costs	Cost	Locally (%)	Locally (Y or N)
Materials & Equipment			
Mounting (rails, clamps, fittings, etc.)	\$1,385,875	100%	N
Modules	\$8,851,968	100%	N
Electrical (wire, connectors, breakers, etc.)	\$339,124	100%	N
Inverter	\$1,316,446	100%	N
Subtotal	\$11,893,413		
Labor			
Installation	\$2,006,508	100%	
Subtotal	\$2,006,508		
Subtotal	\$13,899,921		
Other Costs			
Permitting	\$141,144	100%	
Other Costs	\$3,119,290	100%	
Business Overhead	\$8,711,644	100%	
Subtotal	\$11,972,079		
Subtotal	\$25,872,000		
Sales Tax (Materials & Equipment Purchases)	\$0	100%	
Total	\$25,872,000		

Table E-8. Annual O&M Costs for JEDI Model Analysis of a Single-Axis Tracking PV System

	Cost	Local Share	Manufactured Locally (Y or N)
Labor			
Technicians	\$79,200	100%	
Subtotal	\$79,200		
Materials and Services			
Materials & Equipment	\$52,800	100%	N
Services	\$0	100%	
Subtotal	\$52,800		
Sales Tax (Materials & Equipment Purchases)	\$0	100%	
Average Annual Payment (Interest and Principal)	\$3,001,152	0%	
Property Taxes	\$0	100%	
Total	\$3,133,152		
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	6.00%	100%	
Sales Tax Exemption (percent of local taxes)	100%		
Payroll Parameters	Wage per hour	Employer Payroll Overhead	
Construction and Installation Labor			
Construction Workers / Installers	\$21.39	45.6%	
O&M Labor			
Technicians	\$21.39	45.6%	