Feasibility Study of Economics and Performance of Solar Photovoltaics at the Tower Road Site in Aurora, Colorado

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

Otto VanGeet and Gail Mosey

Produced under direction of the U.S. Environmental Protection Agency (EPA) by the National Renewable Energy Laboratory (NREL) under Interagency Agreement IAG-08-0719 and Task No. WFD4.1000.

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-7A40-57467
March 2013
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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 Tower Road site in Aurora, Colorado, 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 Tower Road site is a 146-acre property owned by the City of Aurora. Portions of the property are contaminated with petroleum, solvents, and other contaminants from historic activities at Buckley Air Force Base. The proposed site is bordered by North Tower Road to the west, 6th Avenue to the south, and Sand Creek to the north and east. The property is zoned for industrial use, and adjacent land is owned by the city and maintained as parks, recreation, and open space. Buckley Air Force Base is located across 6th Avenue to the south. Because of its proximity to the base, development of the property is significantly restricted.

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

Of the 146 acres at the Tower Road site, 20 acres is planned for water tanks for Aurora Water, leaving approximately 126 acres appropriate for installation of a PV system. This area is large enough for up to 18 MW of single-axis tracking PV. This entire area does not need to be developed at one time. In fact, the need for staging areas during construction and the availability of incentives may dictate that the project be constructed in phases.

The economic feasibility of a potential PV system on the Tower Road site depends greatly on the purchase price of the electricity produced. The City of Aurora does not have any facilities that use a significant amount of electricity near the site, so the only solar development options at this time are to offer the site to a developer through a lease or purchase agreement. The developer would likely try to install solar under the solar gardens legislation through the Xcel Energy Solar*Rewards program.[1]

The economics of the potential system were analyzed using the current Xcel Energy Solar*Rewards Community program incentives available to the site. The City of Aurora could receive a portion of the solar energy generate as a bill credit from Xcel Energy in exchange for a land lease to a solar developer. The 500-kW PV system would require about 4 acres of land [a 2-MW (the upper limit of community solar) system would require 14 acres]. The lease value of the land for a 500-kW, 4-acre solar developer for the community solar system is unknown but

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[1] For more information about Xcel Energy's Solar*Rewards program, see www.xcelenergy.com/Save_Money_&_Energy/For_Your_Home/Solar*Rewards/Solar*Rewards_Community_System_Owners_-_CO.

assumed to be about $2,000/yr, which is a total of $40,000 over 20 years. The net present value of $2,000/yr for 20 years at a 3% discount rate is about $30,000.

Per discussion with developers, the expected cost for the subscribers for a community solar system is about $4/W for a fixed-tilt system. The subscriber would receive the renewable energy certificate (REC) payments of about $0.10/ kWh. It is assumed that the city would receive about 7 kW of PV installed gradually in proportion to the 500 kW as “payment” for the land lease and the annual energy generation of the PV credited to the city’s Xcel Energy bill at $0.068/kWh, or about $14,700 worth of electricity per year, and REC payments of about $1,020/yr for a total of about $1,720/yr. The city would select the solar vendor that provides the highest value to the city for the land lease. The city could also purchase PV at the site under the community solar program.

Current incentives considered include the community solar program, the federal investment tax credit, and depreciation. The solar developer would gather all incentives as part of the community solar system. Table ES-1 summarizes the system performance and economics of a potential system that would use all available areas surveyed at the Tower Road site. The table shows the annual energy output from the system, the number of average American households that could be powered off of such a system, and estimated job creation.

For multiple reasons—the high cost of energy, the dropping cost of PV, and the existence of an adequate solar resource, a community asset, and appropriate incentives—this report finds that a PV system is a reasonable use for the site currently as a community solar project (2 MW maximum), and in the future, as a larger system (up to 18 MW) when the economics allow.

Table ES-1. Tower Road PV System Summary

Tie-In Location	System Type	PV System Size[a] (kW)	Array Tilt (deg)	Annual Output (kWh/year)	Number of Houses Powered[b]	Jobs Created[c] (job-year)	Jobs Sustained[d] (job-year)
Tower Road	Crystalline Silicon (Fixed Tilt)	500	20.0	729,000	66	16	0.2
Tower Road	Crystalline Silicon (Single-Axis Tracking)	500	0.0	866,000	78	21	0.2

Tie-In Location	System Type	System Cost
Tower Road	Crystalline Silicon (Fixed Tilt)	$ 1,600,000
Tower Road	Crystalline Silicon (Single-Axis Tracking)	$ 1,920,000

[a] Data assumes a 500 kW system for Community Solar; the site is large enough for a 18 MW single-axis tracking system, which would produce approximately 31,900 MWh annually

[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 Tower Road site in Aurora, Colorado, 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 the implementation of a PV system at the site. This study did not assess environmental conditions at the site.

The City of Aurora has a documented goal in its comprehensive plan to increase the use of renewable energy on city property in order to offset the use of fossil fuels, reduce peak energy demand, and reduce Aurora's greenhouse gas emissions. The city's commitment to sustainability is demonstrated by the following:

- The city has installed PV electrical power-generation systems on three city buildings. Each system will generate up to 100 kW of power and will reduce Aurora's greenhouse gas emissions by more than 4,000 tons per year.
- The city purchased 1,762 acres of land on the eastern plains to establish the Aurora Campus for Renewable Energy (ACRE). ACRE is zoned to allow the development of new renewable energy technologies and fine tune existing ones.
- The Solar Technology Acceleration Center, a public-private partnership, is housed on ACRE to advance and accelerate the commercialization of solar technology.
- The city has used its Energy Efficiency and Conservation Block Grant (EECBG) allocation to improve energy efficiency and conservation in city, residential, and commercial buildings and the city's vehicle fleet.
- The city has a firm commitment to incentivize renewable energy applications for solar, wind, and geothermal by offsetting permit fees and creating a revolving loan fund.
- One of the Aurora city council's 2011 goals included developing the Aurora Sustainability Plan as part of the city's comprehensive plan to include strategies for implementing energy efficiency, energy conservation, and renewable energy at ACRE.

The Tower Road site is a 146-acre property in Arapahoe County, Colorado, owned by the City of Aurora. Portions of the property are contaminated with petroleum, solvents, and other contaminants from historic activities at Buckley Air Force Base (AFB). The proposed site is bordered by North Tower Road to the west, 6th Avenue to the south, and Sand Creek to the north and east. The property is zoned for industrial use, and adjacent land is owned by the city and maintained as parks, recreation, and open space. Buckley AFB is located across 6th Avenue to the south. Because of its proximity to the base, development of the property is significantly restricted.

1.1 Site Contamination

The subject property has no history of development and has remained vacant; however, contaminated ground water originating from Buckley AFB, which began operations in 1942, has migrated on to the site. The Buckley AFB site, directly to the south across 6th Avenue, served as a warehouse area, motor pool, coal pile, fire training center, utility yard, and barracks. Activities at the former warehouse area included the use of waste-cleaning solvents, primarily perchloroethene (PCE) and tetrachloroethene (TCE). Additionally, the former motor pool stored and dispensed gasoline. The 1993 phase I/II environmental assessment of the site found:

- Elevated chlorinated herbicide levels in the soils and groundwater, reflecting heavy farm usage in the past
- High concentrations of TCE and benzene/toluene/ethylbenzene and xylene (BTEX) in the groundwater.

In the fall of 2005, the U.S. Air Force conducted an Interim Remedial Action to address the on-base source area. The Interim Remedial Action included:

- Reducing and maintaining PCE concentrations in groundwater within the source area to 100 micrograms per liter (µg/l) or less by the end of 2007 and precluding additional PCE from moving past the base boundary in concentrations above the Colorado Basic Standard for Groundwater of 5 µg/l
- Excavating into the Denver formation bedrock, which included approximately 53,000 cubic yards of soil, disposing 2,300 cubic yards of hotspot-contaminated soil at Denver Arapahoe Disposal Site and then backfilling the excavated area along with materials (mulch, sugar) to augment bioremediation
- Pumping and treating groundwater from the excavation and discharging it to the storm sewer
- Installing a 1,500-ft air sparging wall at the base's north boundary.

The Air Force Environmental Restoration Program Community Involvement Plan[2] also reports a variety of volatile organic compounds (VOC), semivolatile organic compounds (SVOC), and metals have been detected in the soil and groundwater on the base. Groundwater samples from wells both on and off Buckley AFB indicate that a plume of PCE was shown to flow from the base and under the subject site property.

In 2008, the Colorado Department of Health and Environment released an Environmental Results Program (ERP) site study.[3] The study determined the best methods of cleanup, as well as acceptable uses and construction that would safely be permitted at or near the contamination site. No direct impact to area residents has been identified.

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[2] "Buckley Air Force Base Environmental Restoration Program Annual Report to Stakeholders." Accessed March 14, 2013: http://www.buckley.af.mil/shared/media/document/AFD-100113-051.pdf.

[3] The State of Colorado. Accessed March 14, 2013: http://www.colorado.gov/cs/Satellite/CDPHE-HM/CBON/1251616139361.

The 2005 interim remedial actions substantially reduced groundwater contaminant concentrations in the on-base source area and also the limited continued flow of contaminated groundwater off-base to the site. Maintenance of the treatment system is ongoing. In the fall of 2009, the Final Supplemental Remedial Investigation Report[4] was completed. Additional sampling events were conducted in 2009 and 2010, and remedial alternatives for the site are currently being evaluated.

1.2 Solar Energy

The investor-owned utility for the area is Xcel Energy. Xcel Energy has extensive PV experience under the Solar*Rewards program.[5] The utility also runs the Solar*Rewards Community program,[6] which could be used for PV on the Tower Road site.

The Tower Road site is suitable for PV because it is nearly flat, has adequate road and solar access, is zoned industrial uses, and has extensive electrical distribution nearby, serving Buckley AFB and the City of Aurora.

Feasibility assessment team members from NREL, Karen Hancock and Porter Ingrum from the City of Aurora, and the EPA conducted a site visit on December 19, 2011, to gather information integral to this feasibility study. The team considered information, such as solar resource, transmission availability, community acceptance, and ground conditions.

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[4] "Buckley Air Force Base Environmental Restoration Program Annual Report to Stakeholders." Accessed March 14, 2013: http://www.buckley.af.mil/shared/media/document/AFD-100113-051.pdf.

[5] For more information about Xcel Energy's Solar*Rewards program, see www.xcelenergy.com/Save_Money_&_Energy/For_Your_Home/Renewable_Energy_Programs/Solar*Rewards_-_CO.

[6] For more information about Xcel Energy's Solar*Rewards Community program, see www.xcelenergy.com/Save_Money_&_Energy/For_Your_Home/Solar*Rewards/Solar*Rewards_Community_System_Owners_-_CO.

2 Development of a Photovoltaic System on Brownfields

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

- Can reduce the need to place renewable energy on undeveloped land, thereby preserving habitat and carbon sinks
- Might 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
- Might 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, and in many cases, generate significant revenue on a site that would otherwise go unused.

The City of Aurora is interested in potential revenue flows on the site. For many brownfield sites, the local community has significant interest in the redevelopment of the site, and community engagement is critical to match future reuse options to the community's vision for the site.

Understanding opportunities studied and realized by other similar sites demonstrates the potential for PV system development. Due to the groundwater contamination, the site has limited building development opportunities. The site could be used for recreation activities; however, similar opportunities already exist in the area around the Beck Recreation Center to the west of the site. PV development that provides community energy and jobs may be the highest and best use of the site.[7]

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

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[7] For more information on similar projects, see the RE-Powering America's Lands website www.epa.gov/oswercpa/.

- 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.

3 Photovoltaic Systems

3.1 Photovoltaic 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).

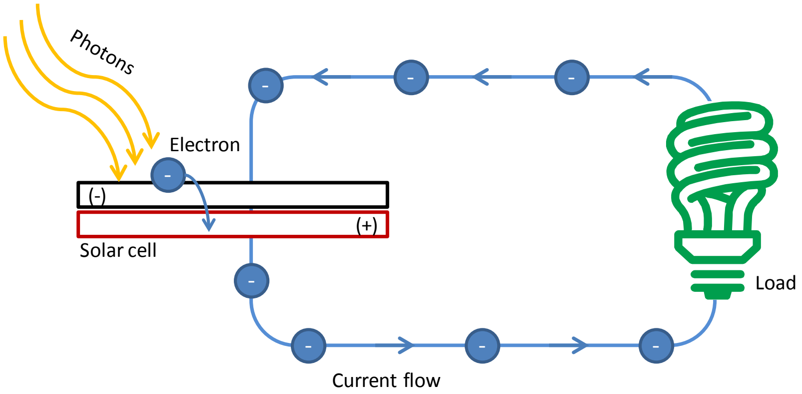

Figure 1. Generation of electricity from a PV cell

Source: EPA

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

3.2 Major System Components

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

- PV modules
- Inverter
- Balance-of-system (BOS) components.

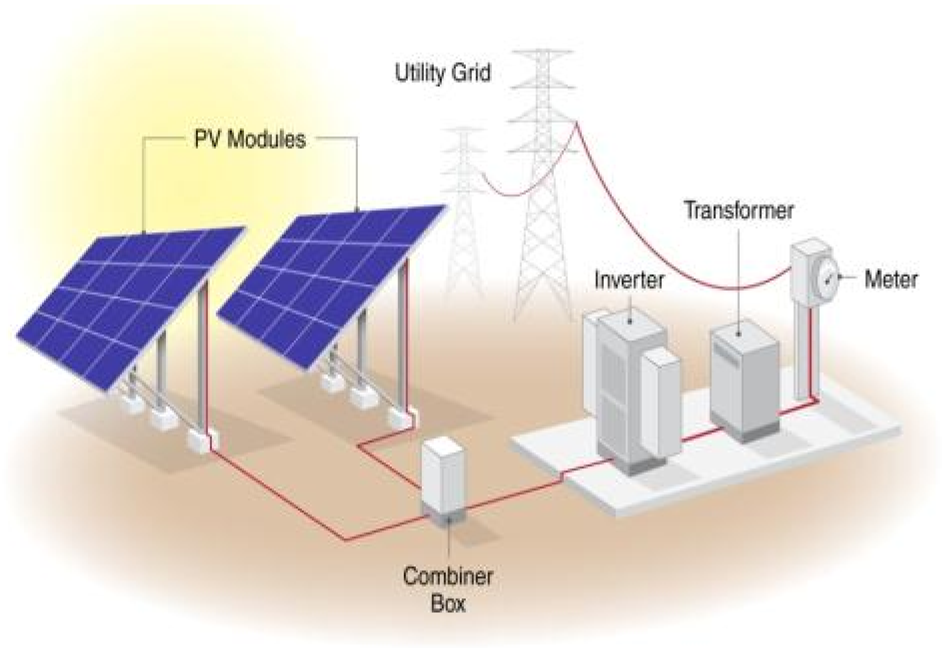

Figure 2. Ground-mounted array diagram

Source: NREL

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

3.2.1 Photovoltaic Module

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

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

3.2.1.1 Crystalline Silicon

Traditional solar cells are made from silicon, which is 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 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, both installed on tracking mounting systems.

Figure 3. Mono-crystalline (left) and multi-crystalline (right) solar panels. ***Photos from (left) SunPower Corporation, NREL 23816 and (right) SunPower, NREL 13823***

3.2.1.2 Thin Film

Thin-film PV cells are made from amorphous silicon (a-Si) or non-silicon materials, such as cadmium telluride (CdTe). Thin-film cells use layers of semiconductor materials only a few micrometers thick. Due to the unique nature of thin films, some thin-film cells are constructed into flexible modules, enabling 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 solar energy cover (left) and fixed-tilt mounting system (middle and right). ***Photos from (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 but 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 inverters and micro-inverters. Each type has strengths and weaknesses and may be recommended for different types of installations.

String inverters are most common and typically range in size from 1.5–1,000 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. If micro-inverters are used, only the shaded panel is impacted. 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 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. Because the site is largely undisturbed and has no cap, the mounting system will likely be directly anchored into the ground.

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 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

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 might raise additional design considerations due to site conditions, including differential settlement.

A zero-tilt (horizontal) single-axis tracking system will collect about 21% more electricity per capacity (kW) than a 40-degree sloped fixed-tilt (non-tracking) system at the site. The drawbacks include increased O&M costs, less capacity per unit area to avoid self-shading (DC-Watt/ft^2), and greater installed cost ($/DC-Watt). The annual energy production per unit area (kWh/ft^2) is slightly less with single-axis tracking but adequate land is available so this is not an issue. Most large PV systems currently being installed in Colorado are zero-tilt single-axis tracking so that is the type of system assumed for this analysis.

From Table 1, the energy density for a single-axis tracking crystalline silicon PV system is 3.3 DC-Watts/ft^2, which is 7 acres/MW. The site has 126 acres of land available, so a PV system of up to 18 MW could be installed.

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.

3.2.3.3 Photovoltaic 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 as well as performance and identification of under-performing arrays. Operators may also use this data to identify, for example, required maintenance, shade on panels, and accumulating dirt on panels. Monitoring system data can also be used for outreach and education. This can be achieved with publicly available online displays, wall-mounted systems, or even smartphone applications.

3.2.4 Operation and Maintenance

PV panels typically have a 25-year performance warranty. The inverters, which come standard with a 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 previously explained, 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 used a Solmetric SunEye solar path calculator to assess shading at the Tower Road property by analyzing the sky view where solar panels will be located and determining if shading will be a problem any time of the year. 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, available incentives, and utility policy.

4 Proposed Installation Location Information

This section summarizes the findings of the NREL solar assessment site visit performed on December 19, 2011, at the Tower Road site.

4.1 Tower Road Site PV System

As discussed previously, the Tower Road site is managed by the City of Aurora. It is a suitable location for PV because it is nearly flat, has adequate road and solar access, is zoned for industrial use, and has extensive electrical distribution nearby serving Buckley AFB and the City of Aurora.

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 unshaded area can be increased to incorporate more PV panels.

Figure 6 shows a map of the Tower Road site; the feasible area for PV is outlined in red, and the likely electrical tie-in point for the PV system is along the western edge or the southwest corner of the site. As shown, there are large expanses of relatively flat, unshaded land, which makes it a suitable candidate for a PV system. The area of the site that appears feasible for PV is 126 acres.

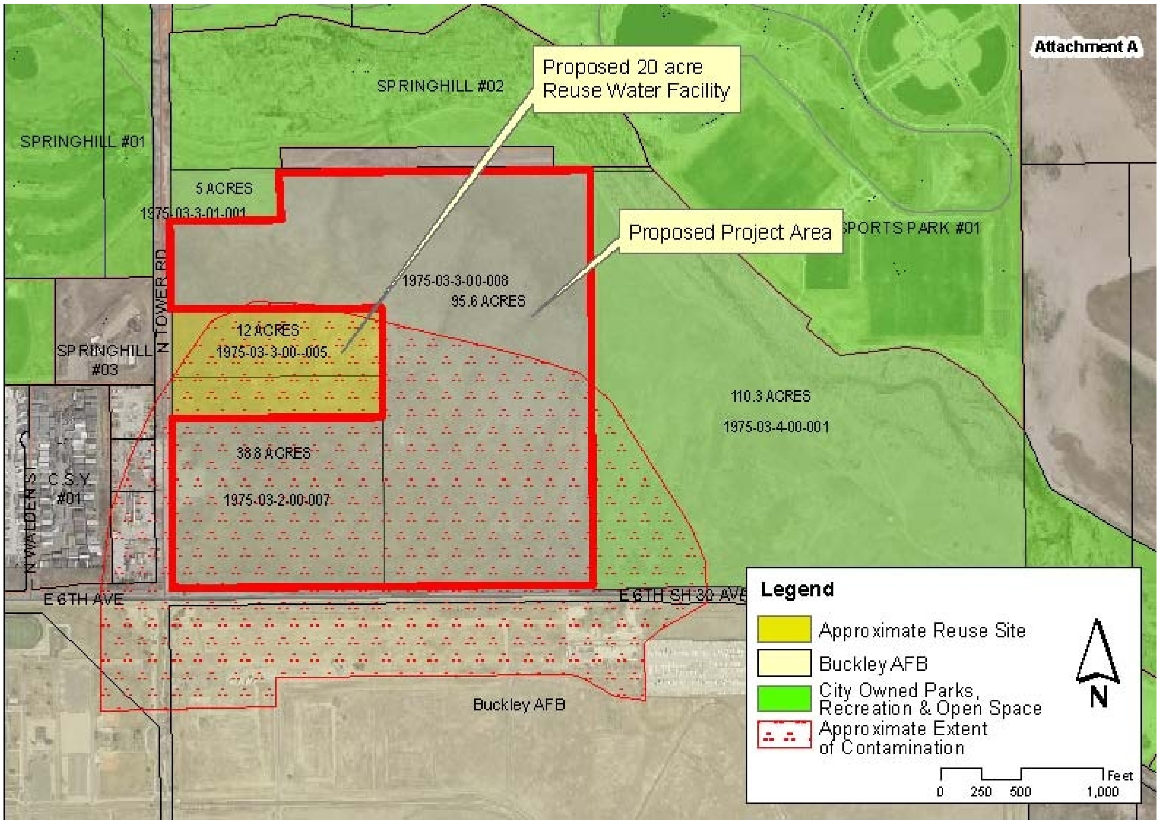

Figure 6. A map of the feasible area (red) for PV at the Tower Road site.[8] ***Illustration from the City of Aurora***

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[8] Groundwater underlies the southern part of the property; the highest concentrations of contamination (TCE and PCE) are near 6th Avenue. Cleanup activities, which the U.S. Air Force may start in 2013, will consist of fracking the bedrock (discontinuous sandstones) and injecting solutions that speed breakdown of contamination (probably permanganate). Injection wells for these actions will be located near 6th Avenue. To be on the safe side, a solar garden planned for the near term should be placed on the northern half of the site (comment from EPA Region 8).

Figure 7. A topographical map of the feasible area for PV at the Tower Road site.
Illustration from the City of Aurora

Figure 8 shows various views of the Tower Road site.

Figure 8. Views of the feasible area for PV at the Tower Road site. ***Photos by Porter Ingrum, City of Aurora***

4.2 Utility-Resource Considerations

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. The expected electrical tie-in point and inverter for the PV system at the Tower Road site is located along the western edge or the southwest corner of the site and is shown in Figures 9 and 10. The lines are 13 kV. It is assumed for this study that these lines are adequate to accommodate up to an 18-MW PV system. They are almost certainly large enough for a 2-MW PV system; however, more detailed evaluation will be required with Xcel Energy during the project's design phase.

Figure 9. Electrical distribution on the southwest corner of the site at the intersection of North Tower Road and East 6th Avenue. ***Photo by Randolph Hunsberger, NREL***

Figure 10. Electrical distribution along the southwest side of the site along North Tower Road and the possible electrical tie-in point for the PV system at the Tower Road site. ***Photo by Randolph Hunsberger, NREL***

4.3 Photovoltaic Site Solar Resource

The Tower Road site has been evaluated using both on-site 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 99% (a completely unobstructed site would have a score of 100%). All data gathered using this tool is available in Appendix C.

The predicted array performance was found using the PVWatts Grid Data (Version 2) calculator[9] for Aurora. Table 2 shows the station identification information, PV system specifications, and energy specifications for the site. For this summary of array performance information, a hypothetical system size of 1 kW was used to show the estimated production for each kilowatt so that additional analysis can be performed using the data indicated below. It is scaled linearly to match the proposed system size.

Table 2. Site Identification Information and Specifications

Station Identification	
Cell ID	Aurora/Boulder
State	Colorado
Latitude	40.0° N
Longitude	105.25° 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	$0.08/kWh

Table 3 shows the performance results for a 1-kW 20-degree fixed-tilt PV system in Aurora, as calculated by PVWatts.

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[9] For more information about the PVWatts Grid Data (Version 2) calculator, see www.nrel.gov/rredc/pvwatts/.

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

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	3.58	89	7.12
2	4.22	93	7.44
3	5.62	137	10.96
4	6.17	140	11.20
5	6.46	149	11.92
6	6.74	147	11.76
7	6.60	144	11.52
8	6.44	140	11.20
9	5.99	129	10.32
10	5.00	115	9.20
11	3.80	89	7.12
12	3.40	85	6.80
Year	5.34	1,458	116.64

Table 4 shows the performance results for a zero-tilt single-axis tracking 1-kW PV system in Aurora, Colorado, as calculated by PVWatts. As can be seen, zero-tilt single-axis tracking PV produces approximately 21% more energy per installed kilowatt in Aurora.

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

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	3.55	90	7.20
2	4.49	102	8.16
3	6.52	162	12.96
4	7.77	181	14.48
5	8.46	199	15.92
6	8.98	198	15.84
7	8.51	189	15.12
8	8.10	181	14.48
9	7.12	159	12.72
10	5.52	132	10.56
11	3.92	95	7.60
12	3.28	83	6.64
Year	6.36	1,772	141.76

Because there is enough land to install 18 MW of single-axis tracking PV that would generate 1,772 MWh/MW annually, the 18-MW system could generate 31,900 MWh annually.

4.4 Tower Road Energy Usage

The Tower Road site currently has no on-site energy use, and there is currently no significant planned site energy use. It is assumed that the energy produced will need to be sold.

5 Economics and Performance

Having a site with high solar resource potential, while important, is only half the battle, as the PV system also has to make economic sense. The economic performance of a proposed 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).[10]

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

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

The model calculates the cost of generating electricity based on information 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 $3.20/W in the fourth quarter of 2011. With an increasing demand and supply, potential of further cost reduction is expected as market conditions evolve.[11]

For this analysis, the following input data were used: the installed cost of fixed-tilt ground-mounted systems was assumed to be $3.20/W, and the installed cost of single-axis tracking was assumed to be $3.84/W. The installed cost of PV systems continues to drop and is significantly lower in 2012.

The installed system cost assumptions are summarized in Table 5.

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[10] For more information about NREL's System Advisor Model, see https://sam.nrel.gov/cost.

[11] "*SEIA/GTM Research U.S. Solar Market Insight*" report. (2011 year-end). Washington, D.C.: Solar Energy Industries Association. http://www.seia.org/cs/research/SolarInsight.

Table 5. Installed System Cost Assumptions

System Type	Fixed-Tilt ($\$/W_p$)	Single-Axis Tracking ($\$/W_p$)
Baseline system	3.20	3.84

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 cost of electricity was assumed to be $0.08/kW as reported by the City of Aurora based on electric bills for their facilities.

It was assumed for this analysis that relevant federal incentives are received. It is important to consider all applicable incentives or grants to make PV as cost-effective as possible. If the PV system is owned by a private tax-paying entity, this entity may qualify for federal tax credits (up to 30% reduction in cost of system) and accelerated depreciation on the PV system, which can be worth about 15% of the initial capital investment. 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. Inflation is assumed to be 1.5%, the real discount rate to be 6%, and financing secured via a 25-year loan at a 7% interest rate and 80% debt fraction. The panels are assumed to have a 1% per year degradation in performance. The O&M expenses are estimated to be $20/kW/yr for the life of the system. In addition, it is expected that there will be a $250/kW charge to O&M in year 15 to replace the inverters associated with the system. A system DC-to-AC conversion of 80% was assumed. This includes losses in the inverter, wire losses, PV module losses, and losses due to temperature effects. PVWatts (Version 2) was used to calculate expected energy performance for the system.

5.2 System Advisor Model Forecasted Economic Performance

Using the inputs and assumptions summarized in Section 5.1 of this report, the SAM tool predicts the internal rate of return and the levelized cost of energy. The entire results and summary of inputs to the SAM are available in Appendix E.

A summary of the results of the economic analysis and the system considered are available in Table 6.

Table 6. PV System Summary

Tie-In Location	System Type	PV System Size[a] (kW)	Array Tilt (deg)	Annual Output (kWh/year)	Number of Houses Powered[b]	Jobs Created[c] (job-year)	Jobs Sustained[d] (job-year)
Tower Road	Crystalline Silicon (Fixed Tilt)	500	20.0	729,000	66	16	0.2
Tower Road	Crystalline Silicon (Single-Axis Tracking)	500	0.0	866,000	78	21	0.2

Tie-In Location	System Type	System Cost
Tower Road	Crystalline Silicon (Fixed Tilt)	$ 1,600,000
Tower Road	Crystalline Silicon (Single-Axis Tracking)	$ 1,920,000

[a] Data assumes a 500 kW system for Community Solar; the site is large enough for a 18 MW single-axis tracking system, which would produce approximately 31,900 MWh annually

[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 were used.[12] The JEDI models are tools that estimate the economic impacts associated with the construction and operation of distributed-generation power plants. JEDI is a flexible input-output tool that estimates, but does not precisely predict, the number of jobs and economic impacts that can be reasonably supported by the proposed facility.

The JEDI models represent the hypothetical impacts to 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 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. As such, the JEDI model results are considered gross estimates as opposed to net estimates.

Table 7 lists the values that were assumed for this analysis.

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

Table 7. JEDI Analysis Assumptions

Input	Assumed Value
Capacity	500 kW
Placed In Service Year	2013
Installed System Cost	$1,920,000
Location	Aurora, CO

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

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

As indicated in the results of the JEDI model analysis provided in Appendix D, the total proposed system is estimated to support 21 direct, indirect, and induced jobs per year for the duration of the procurement and construction period. Total wages paid to workers during the construction period are estimated to be $987,000, and total economic output is estimated to be $2,665,000. The annual O&M of the new PV system is estimated to support 0.2 FTEs per year for the life of the system. The jobs and associated spending are projected to account for approximately $9,400 in earnings and $17,400 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. Figure 11 depicts an SPE. 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.

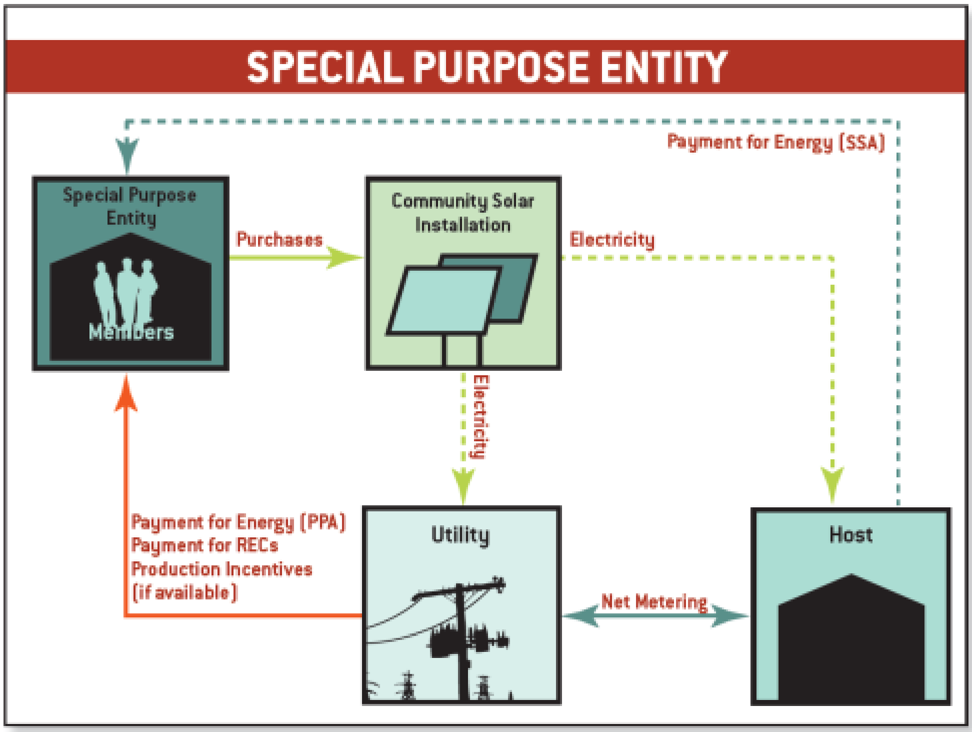

Figure 11. Special purpose entity. *Illustration by NREL*[13]

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; or 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 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" (customer side of the meter) transaction or directly with an electric utility if it is a wholesale transaction.

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[13] Coughlin, J.; Grove, J.; Irvine, L.; Jacobs, J.F.; Johnson Phillips, S.; Moynihan, L.; Wiedman, J. *A Guide to Community Solar: Utility, Private, and Non-profit Project Development.* Golden, CO: NREL, 2010. http://www.nrel.gov/docs/fy11osti/49930.pdf.

Site hosts benefit by either receiving competitively priced electricity from the project via the PPA or land-lease revenues or by 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 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, including 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 their treatment of tax benefits and the rules limiting federal tax benefit transfers from nonprofit to for-profit companies. Under IRS guidelines, municipalities cannot enter capital leases with for-profit entities when the for-profit entities capture tax incentives. As a result, a number of business models have emerged as a workaround to this issue. One model is the SSA, wherein a private party sells "solar services" [i.e., energy and renewable energy certificates (REC)] to a municipality over a specified contract period (typically long enough for the private party to accrue the tax credits). The nonprofit utility typically purchases the solar services with either a one-time up-front payment equal to the turn-key system cost minus the 30% federal tax credit or may purchase the services in annual installments. The municipality may buyout 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 are a variety of lease options that are available to municipalities that allow the capture of tax benefits by third-party owners, which result in a lower cost to the municipality. These include an operating lease for solar services (as opposed to an equipment capital lease) and a complex business model called a “sale/leaseback.” Under the sale/leaseback model, the municipality develops the project and sells it to a third-party tax equity investor who then leases the project back to the municipality under an operating lease. At the end of the lease period, and after the tax benefits have been absorbed by the tax equity investor, the municipality may purchase the solar project at fair market value.

5.4.6 Community Solar/Solar Gardens

There are some states that offer solar incentives for community solar projects, including Washington State (production incentive) and Utah (state income tax credit). Community solar is also known as solar gardens, depending on the location (e.g., Colorado). 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 that can be the basis for a community solar project. Ownership structures for these projects vary, but the large projects are typically owned or sponsored by a local utility. Community solar gardens are distributed solar projects wherein utility customers have a stake via a prorated share of the project’s energy output. This business model is targeted to meet demand for solar projects by customers who rent or lease their homes or businesses, do not have good solar access at their site, or do not want to install a solar system on their facilities. Customer prorated shares of solar projects are acquired through a long-term transferrable lease of one or more panels, or they subscribe to a share of the project in terms of a specific level of energy output or the energy output of a set amount of capacity. Under the customer lease option, the customer receives a billing credit for the number of kilowatt-hours their prorated share of the solar project produces each month; it is also known as “virtual net metering.” Under the customer subscription option, the customers typically pay a set price for a block of solar energy (i.e., 100-kWh per-month blocks) from the community solar project. The current Xcel Energy Solar*Rewards Community program discussed below is a customer subscription program. Other models include monthly energy outputs from a specific investment dollar amount or a specific number of panels.

Community solar garden and customer subscription-based projects can be owned solely by the utility, owned solely by third-party developers with facilitation of billing provided by the utility, or 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.

The City of Aurora does not have any facilities that use a significant amount of electricity near the site so the only solar development options at this time are to offer the site to a developer under a lease or for purchase. The developer would likely try to install solar through the Xcel Energy Solar*Rewards Community program.[14]

The Xcel Energy Solar*Rewards Community program is part of the solar garden legislation that was enacted by the Colorado government. Many similar programs across the United States exist; for a good overview of community solar programs, see NREL's guide on community solar.[15]

From the guide:

> Community Solar is defined as a solar-electric system that, through a voluntary program, provides power and/or financial benefit to, or is owned by, multiple community members. Community Solar advocates are driven by the recognition that the on-site solar market comprises only one part of the total market for solar energy. A 2008 study by the National Renewable Energy Laboratory found that only 22 to 27% of residential rooftop area is suitable for hosting an on-site photovoltaic (PV) system after adjusting for structural, shading, or ownership issue. Clearly, community options are needed to expand access to solar power for renters, those with shaded roofs, and those who choose not to install a residential system on their home for financial or other reasons. Fairness also supports expanding programs in ways that increase options for participation. As a group, ratepayers and/ or taxpayers fund solar incentive programs. Accordingly, as a matter of equity, solar energy programs should be designed in a manner that allows all contributors to participate.

The secondary goals met by many community solar projects include:

- Improved economies of scale
- Optimal project siting
- Increased public understanding of solar energy
- Generation of local jobs.

The City of Aurora has the potential to benefit itself and Arapahoe County residents by hosting a community solar project at the Tower Road site. Support for community solar projects already exists in Colorado—for example, the Solar Gardens Institute,[16] which is based in Denver, supports community solar efforts by assisting with the organization and development of solar projects.

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[14] For more information about Xcel Energy's Solar*Rewards Community program, see www.xcelenergy.com/Save_Money_&_Energy/For_Your_Home/Solar*Rewards/Solar*Rewards_Community_System_Owners_-_CO.

[15] Coughlin, J.; Grove, J.; Irvine, L.; Jacobs, J.F.; Johnson Phillips, S.; Moynihan, L.; Wiedman, J.. *A Guide to Community Solar: Utility, Private, and Non-profit Project Development.* Golden, CO: NREL, 2010; p. 2. http://www.nrel.gov/docs/fy11osti/49930.pdf.

[16] For more information about the Solar Gardens Institute, see www.solargardens.org/about/ and www.solargardens.org/frequently-asked-questions/.

Each solar garden in the Solar*Rewards Community program must meet the following requirements throughout the length of the contract:[17]

- Nameplate capacity of 2 MW or less
- Ten or more subscribers that are Xcel Energy electric customers in the same county as the garden
- Minimum of 5% allocation to income-qualified (low-income) subscribers
- No single subscriber can have more than 40% allocation
- Subscribers cannot exceed 120% allocation of the subscriber's annual electric energy usage in the county where the garden is located.

Xcel Energy will be offering incentives for 9 MW of solar gardens in 2012 and another 9 MW in 2013, divided among small systems (10–50 kW), medium-size systems (50–500 kW), and large systems (500 kW to 2 MW). The first 4.5 MW was awarded the week of August 20, 2012 (for a partial list of awarded sites, see Appendix A). Although nothing was awarded for Arapahoe County, a site for the City of Aurora and Adams County was included in the first round of awards.[18]

The standard offer, a performance-based incentive paid over 20 years ($/kWh) encompasses two programs—small program (systems 10–50 kW) and medium program (systems 50.1–500 kW).[19]

Table 8 shows the capacity and REC incentive levels for the 2012 standard offer program. The REC prices for subscriber organizations are paid monthly based on the solar garden.

Table 8. 2012 Solar*Rewards Acquisitions—Standard Offer[a]

Step	Capacity (MW)	Small Program 10–50 kW REC ($/kWh)	Medium Program 50.1–500 kW REC ($/kWh)
1	3	$0.14	$0.11
2	1.5	$0.13	$0.10

[a] Xcel Energy. "Solar*Rewards Community," 2012. Accessed December 31, 2012: http://www.xcelenergy.com/Save_Money_&_Energy/For_Your_Home/Solar*Rewards/Solar*Rewards_Community_System_Owners_-_CO.

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[17] Xcel Energy. "Solar*Rewards Community Requirement." Accessed March 6, 2013: http://www.xcelenergy.com/Save_Money_&_Energy/For_Your_Home/Solar*Rewards/Solar*Rewards_Community_Requirements.

[18] CEC. "Clean Energy Collective Awarded 6 Xcel Solar Gardens." Accessed March 6, 2013: http://www.easycleanenergy.com/Shownews.aspx?ID=39d38a81-5e91-415a-881e-504343f0735d.

[19] Xcel Energy. "Solar*Rewards Community," 2012. Accessed December 31, 2012: http://www.xcelenergy.com/Save_Money_&_Energy/For_Your_Home/Solar*Rewards/Solar*Rewards_Community_System_Owners_-_CO.

Xcel Energy will solicit competitive bids (systems between 500.1 kW and 2 MW) for up to 4.5 MW of installations through a request for proposal. Once the bid requirements are satisfied, Xcel Energy will make the project selections.[20]

The economics of the potential system were analyzed using the current Xcel Energy Solar*Rewards Community program incentives available to the site of $0.11/kWh for a 500-kW system. The incentives would be captured by the developer and passed on to the subscribers in the form of discounted PV system cost. Subscribers of the PV will get a credit on their bill of about $0.068/kWh.

The City of Aurora could purchase solar energy from the site to offset a portion of the energy use by city facilities in Arapahoe County at an average cost of $0.08/kWh. A 500-kW single-axis tracking PV system would have an expected annual energy generation of about 921,000 kWh. The 500-kW PV system would require about 4 acres of land [a 2-MW (upper limit of community solar) system would require 14 acres]. The lease value of the land to the solar developer for the community solar system is unknown but assumed to be about $1,000 annually based on the value of land leased from BLM for solar development,[21] which is $5,256/MW/yr + $63/acre/yr. Assuming a 0.5-MW system is installed that requires 4 acres, a value of $5,256/MW/yr x 0.5 MW + $63/acre/yr = $2,628/yr is given. It is assumed that brownfield land is worth less, so $2,000/yr is used for a 500-kW system for a total of $40,000 over 20 years. The net present value (NPV) of $2,000/yr for 20 years at a 3% discount rate is about $30,000. Per discussion with developers, the expected cost for the subscribers for a community solar system is about $4/W for a fixed-tilt system. The subscriber would receive the REC payments of about $0.10/ kWh (see Table 8). It is assumed that the city would receive about 7 kW of PV installed gradually in proportion to the 500 kW as "payment" for the land lease; annual energy generation of the PV credited to the city's Xcel Energy bill at $0.068/kWh, or about $700 worth of electricity per year; and REC payments of about $1,020/yr for a total of about $1,720/yr. The city would select the solar vendor that provides the highest value to the city for the land lease. The city could also purchase PV at the site under the community solar program.

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[20] Xcel Energy. "Solar*Rewards Community," 2012. Accessed December 31, 2012: http://www.xcelenergy.com/Save_Money_&_Energy/For_Your_Home/Solar*Rewards/Solar*Rewards_Community_System_Owners_-_CO.

[21] "Solar Energy Interim Rental Policy." U.S. Department of the Interior Bureau of Land Management, 2010. Accessed December 31, 2012: http://www.blm.gov/wo/st/en/info/regulations/Instruction_Memos_and_Bulletins/national_instruction/2010/IM_2010-141.html.

6 Conclusions and Recommendations

The Tower Road site considered for a solar PV system in this report is a suitable area in which to implement solar PV systems. Installing an 18-MW single-axis tracking PV system on the brownfield land that has groundwater contamination could generate up to approximately 31,900 MWh annually and represent a significant distributed generation facility for the area. Additionally, reusing land that cannot be used for other purposes would minimize the environmental impact of PV on a greenfield site.

It is recommended that the site facilitator, the City of Aurora, further pursue opportunities for a community solar system installation on the Tower Road site. When reviewing proposals for a PV system to be installed at this site, evaluation criteria should include the maximum annual output (kWh/yr) that would be credited to the city in exchange for the land lease, as well as price per kilowatt-hour if a PPA is used as part of the community solar project. The community solar system design should be left to the vendors to optimize system configuration, including slope and tracking.

For multiple reasons—the high cost of energy, the dropping cost of PV, and the existence of an adequate solar resource and incentives—this report finds that a PV system is a reasonable use for the site as a community solar project (2-MW maximum), and in the future, as a larger site when the economics allow.

Appendix A. Colorado Solar Gardens Awarded August 20, 2012

Clean Energy Collective

The Clean Energy Collective (CEC) was awarded eight Xcel Energy solar gardens, which included 2.5 MW of community solar for systems in Denver, Boulder, Jefferson, and Summit Counties. [22]

Arvada
Arvada, Colorado
County: Jefferson
Name Plate Capacity: 108 kW
Description: Located off Highway 72 in Arvada.

Breckenridge #1
Breckenridge, Colorado
County: Summit
Name Plate Capacity: 500 kW
Description: Located at the Stillson property, which is southeast of Breckenridge. The 500-kW system will provide the residents of Breckenridge and Summit County the ability to partake in community solar, something residents in Summit County have been eagerly awaiting.

Breckenridge #2
Breckenridge, Colorado
County: Summit
Name Plate Capacity: 500 kW
Description: Located at the McCain property, which is north of Breckenridge on Highway 9. This 500-kW system, along with the Stillson property system, will bring a total 1 MW of community solar to Summit County residents and local businesses.

Denver Public Schools: Evie Garret Dennis Campus
Denver, Colorado
County: Denver
Name Plate Capacity: 500 kW
Description: This solar garden will serve as an educational tool on a school campus that already has a strong commitment to sustainable development. Some of this school's buildings already have rooftop solar, and the campus has been recognized as Denver Public School's first effort toward achieving a net-zero energy campus.

Hangar 2 (Lowry)
Denver, Colorado
County: Denver
Name Plate Capacity: 400 kW

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[22] CEC. "Clean Energy Collective Awarded 6 Xcel Solar Gardens." Accessed March 5, 2013: http://www.easycleanenergy.com/Shownews.aspx?ID=39d38a81-5e91-415a-881e-504343f0735d.

Description: The proposed community solar array supplements the existing solar "skylights" on the curved roof of this award-winning historic building and will allow Denver and the Lowry community to continue their international leadership with appropriate and sustainable adaptive use of historic buildings.

Golden Hoof Farm (Boulder)
Boulder, Colorado
County: Boulder
Name Plate Capacity: 500 kW
Description: The solar garden will be built in conjunction with the Golden Hoof Sustainable Demonstration Farm in east Boulder. The conceptual layout for the solar garden is an artistic grouping of solar trees on the north side of the property. The garden will be used as a teaching tool as part of the demonstration farm

Aurora Solar Garden One
Aurora, Colorado
County: Adams
Name Plate Capacity: 497 kW
Description: Aurora Solar Garden One will be located southeast of Denver International Airport on retired farmland. Xcel Energy customers throughout the City of Aurora and throughout Adams County may participate.[23]

Saguache Solar Garden One
Saguache, Colorado
Counties: Saguache, Chaffee, Alamosa, Rio Grande, Mineral, and Hinsdale
Name Plate Capacity: 497 kW
Description: Saguache Solar Garden One will be hosted at Mountain Valley Lumber just south of town. Any Xcel Energy customers in Saguache, Chaffee, Alamosa, Rio Grande, Mineral, and Hinsdale counties may subscribe to Saguache Solar Garden One. Solar Power One is the developer.[24]

For more information on the Xcel Energy solar gardens:
Web: www.XcelSolarGardens.com
Phone: (800) 646-0323
Email: info@xcelsolargardens.com.

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[23] Xcel Energy. Accessed March 18, 2013: https://www.xcelenergy.com/Save_Money_&_Energy/For_Your_Home/Renewable_Energy_Programs/Solar*Rewards_Community_-_CO.

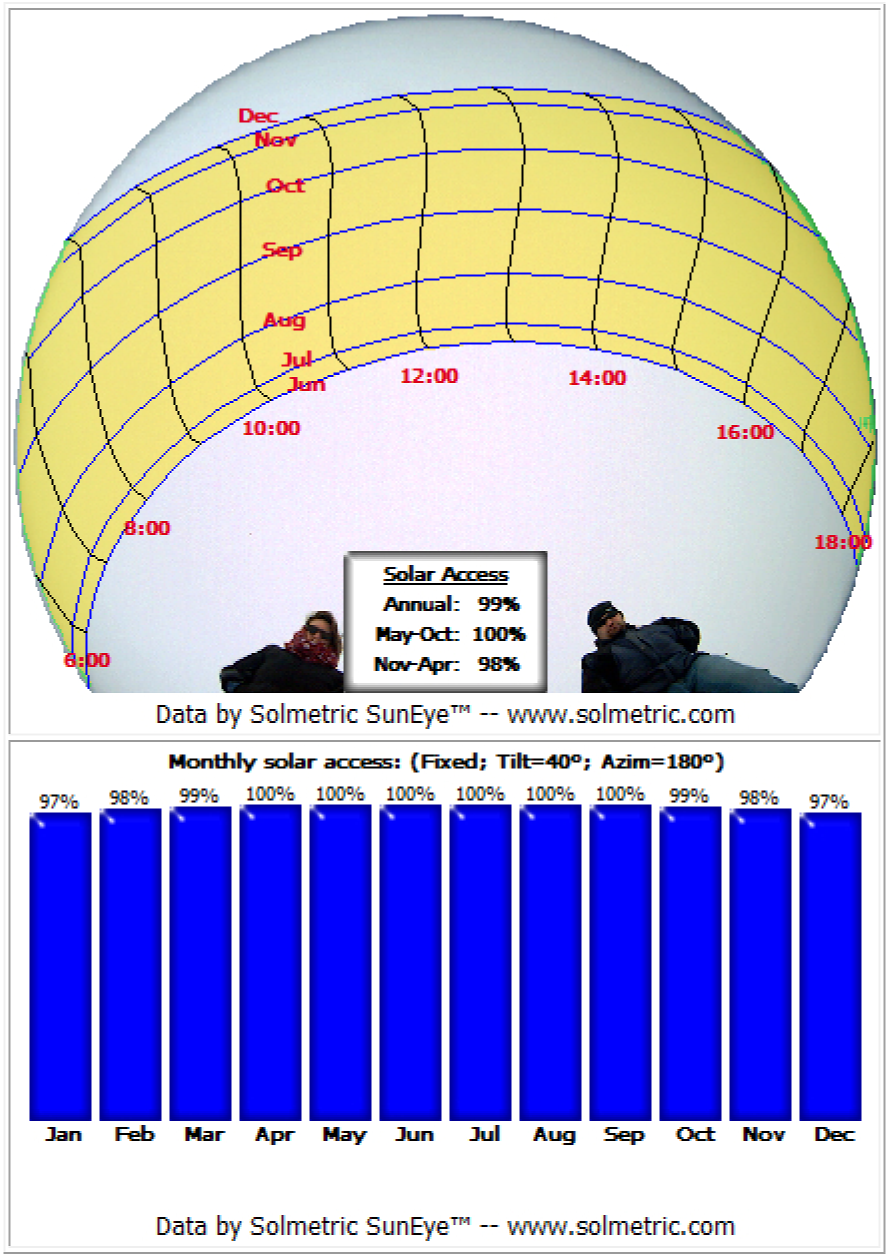
[24] Xcel Energy. Accessed March 18, 2013: https://www.xcelenergy.com/Save_Money_&_Energy/For_Your_Home/Renewable_Energy_Programs/Solar*Rewards_Community_-_CO.

Appendix B. Assessment and Calculations Assumptions

Table B-2. Cost, System, and Other Assessment Assumptions

Cost Assumptions			
Variable	**Quantity of Variable**	**Unit of Variable**	
Cost of site electricity	0.08	$/kWh	
Annual O&M (fixed)	20	$/kW/year	
System Assumptions			
System Type	**Annual energy kWh/kW**	**Installed Cost ($/W)**	**Energy Density (W/ ft^2)**
Ground fixed	1,458	$3.20	4.0
Ground single-axis	1,772	$3.84	3.3
Other Assumptions			
	1 acre	43,560 ft^2	
	1 MW	1,000,000 W	
	Ground utilization	90% of available area	

Appendix C. Solar Access Measurements



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

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

Figure C-1. Solar access measurements for PV site

Appendix D. Results of the JEDI Model

Table D-1. Results of the JEDI Model

Photovoltaic—Project Data Summary Based on Model Default Values	
Project Location	Colorado
Year of Construction or Installation	2013
Average System Size - DC Nameplate Capacity (KW)	500
Number of Systems Installed	1
Total Project Size - DC Nameplate Capacity (KW)	500
System Application	Small Commercial
Solar Cell/Module Material	Crystalline Silicon
System Tracking	Single Axis
Base Installed System Cost ($/kWDC)	$3,840
Annual Direct Operations and Maintenance Cost ($/kW)	$23.50
Money Value - Current or Constant (Dollar Year)	2010
Project Construction or Installation Cost	$1,920,000
Local Spending	$1,343,423
Total Annual Operational Expenses	$234,470
Direct Operating and Maintenance Costs	$11,750
Local Spending	$10,685
Other Annual Costs	$222,720
Local Spending	$0
Debt Payments	$0
Property Taxes	$0

Local Economic Impacts—Summary Results

During construction and installation period	**Jobs**	**Earnings $ (2010)**	**Output $ (2010)**
Project Development and On-Site Labor Impacts			
Construction and Installation Labor	2.3	$147.40	
Construction and Installation Related Services	5.4	$263.80	
Subtotal	7.6	$411.20	$758.20
Module and Supply Chain Impacts			
Manufacturing	0.0	$0.00	$0.0
Trade (Wholesale and Retail)	1.5	$90.70	$262.7
Finance, Insurance, and Real Estate	0.0	$0.00	$0.00
Professional Services	1.7	$78.30	$266.30
Other Services	1.8	$113.10	$416.50
Other Sectors	2.4	$72.50	$170.70
Subtotal	7.3	$354.60	$1,116.2
Induced Impacts	5.7	$221.00	$790.20
Total Impacts	**20.6**	**$986.90**	**$2,664.60**

During operating years	**Annual Jobs**	**Annual Earnings $ (2010)**	**Annual Output $ (2010)**
On-Site Labor Impacts			
PV Project Labor Only	0.1	$6.00	$6.00
Local Revenue and Supply Chain Impacts	0.0	$2.20	$7.10
Induced Impacts	0.0	$1.20	$4.30
Total Impacts	**0.2**	**$9.40**	**$17.40**

Notes: Earnings and output values are thousands of dollars in year 2010 dollars. Construction and operating period jobs are FTE 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 due to independent rounding.

Detailed PV Project Data Costs

Installation Costs	**Cost**	**Purchased Locally (%)**	**Manufactured Locally (Y or N)**
Materials and Equipment			
Mounting (rails, clamps, fittings, etc.)	$93,077	100%	N
Modules	$520,239	100%	N
Electrical (wire, connectors, breakers, etc.)	$13,508	100%	N
Inverter	$93,897	100%	N
Subtotal	$720,721		
Labor			
Installation	$147,438	100%	
Subtotal	$147,438		
Subtotal	$868,159		
Other Costs			
Permitting	$282,798	100%	
Other Costs	$115,428	100%	
Business Overhead	$653,615	100%	
Subtotal	$1,051,841		
Subtotal	$1,920,000		
Sales Tax (Materials and Equipment Purchases)	$0	100%	
Total	$1,920,000		

PV System Annual O&M Costs	**Cost**	**Local Share**
Labor		
Technicians	$6,423	100%
Subtotal	$6,423	
Materials and Services		
Materials and Equipment	$5,327	100%
Services	$0	100%
Subtotal	$5,327	
Sales Tax (Materials and Equipment Purchases)	$0	100%
Average Annual Payment (Interest and Principal)	$222,720	0%
Property Taxes	$0	100%
Total	$234,470	

Other Parameters		
Financial Parameters		
Debt Financing		
Percentage Financed	80%	0%
Years Financed (Term)	10	
Interest Rate	10%	
Tax Parameters		
Local Property Tax (Percent of Taxable Value)	0%	
Assessed Value (Percent of Construction Cost)	0%	
Taxable Value (Percent of Assessed Value)	0%	
Taxable Value	$0	
Property Tax Exemption (Percent of Local Taxes)	0%	
Local Property Taxes	$0	100%
Local Sales Tax Rate	2.90%	100%
Sales Tax Exemption (Percent of Local Taxes)	100.00%	
Payroll Parameters	**Wage Per Hour**	**Employer Payroll Overhead**
Construction and Installation Labor		
Construction Workers/Installers	$21.39	45.6%
O&M Labor		
Technicians	$21.39	45.6%

Appendix E. Results of the System Advisor Model

Table E-1. System Advisor Model Results

System Type	Net Annual Energy (kWh)	LCOE Nominal ($/kWh)	LCOE Real ($/kWh)	Capacity Factor	Installed Cost ($/kW)
Single-Axis Tracking	1,771.9	0.087	0.067	20.2	3,200.00
20-Degree Fixed Tilt	1,458.2	0.089	0.069	16.6	3,840.00

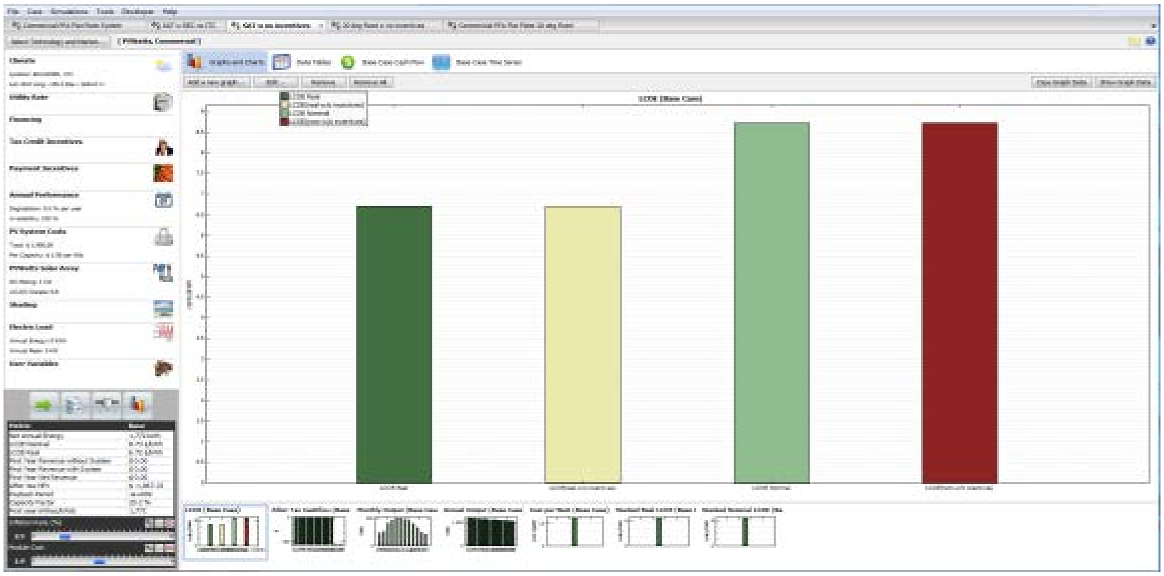


Figure E-1. Typical output screen from SAM—single-axis tracking