Feasibility Study of Economics and Performance of Solar Photovoltaics at the Santo Domingo Pueblo in Sandoval County, New Mexico

Jesse Geiger, Lars Lisell, and Gail Mosey

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Technical Report
NREL/TP-6A10-58844
July 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 Pueblo of Santo Domingo in Sandoval County, New Mexico, for a renewable energy production feasibility study. The National Renewable Energy Laboratory (NREL) provided technical assistance for this project. The purpose of this report is to assess specific areas on the site for potential installation of photovoltaic (PV) systems and to estimate the cost, performance, and site impacts of different PV options. The report also recommends financing options that could assist in the implementation of these PV systems. This study did not assess environmental conditions at the site.

The Santo Domingo Pueblo is an American Indian reservation located in New Mexico 40 miles northeast of the City of Albuquerque. The site has an 8.7-acre industrial site, a 3.95-acre landfill, and a number of government buildings (administrative areas) that are being evaluated for PV systems. The industrial site, referred to as the CC Housing Site by the EPA, was originally used as a lumber yard, particle board manufacturing facility, and modular housing manufacturing plant from the 1950s until it was abandoned in 1986. The industrial site is owned by the Santo Domingo Pueblo Tribe. The current plan for the site is to renovate and offer building space to starting companies and artists to build up the Tribal economy.

The feasibility of installing a PV system on a Resource Conservation and Recovery Act (RCRA) site is highly impacted by the available area for an array, solar resource, distance to transmission lines, and distance to major roads. In addition, the remediation status, ground conditions, and restrictions associated with redevelopment of the RCRA site also impact the feasibility of a PV system. Based on an assessment of these factors, the Santo Domingo Pueblo is suitable for deployment of a large-scale PV system. Roofs are unaffected by the ground contamination, but they do require structurally sound buildings.

The Pueblo industrial site is approximately 8.7 acres, and there is a high potential to renovate the site with roof-mounted PV but limited potential to build out the site with a ground-mounted PV system due to the limited land space. There are currently 0.44 acres available for a ground-mounted PV system at the site, without additional demolition and debris removal. There are 7.25 acres potentially available for a ground-mounted PV system on the landfill nearby. Calculations performed for this analysis are based on the total feasible area being developed. However, installations can be staged as area(s) and/or funding become available. It should be noted that the purpose of this report is not to determine how to develop the site but to investigate options and present the results in an unbiased manner.

Of the nine scenarios considered, eight had a positive net present value (NPV), and all had a payback in the analysis period. The economic feasibility of potential PV systems on the Santo Domingo Pueblo depends greatly on the price of electricity from Public Service Company of New Mexico (PNM). The economics were analyzed using $0.123219/kWh, which is a weighted average of middle-tier rates provided by PNM. This value is also used for the PV production sale price through the net-metering policy, which the site is assumed able to use for all energy produced on site. Table ES-1 shows the current incentives considered.

Table ES-1. Summary of Incentives Evaluated

Applicable to Tribe-Owned System	Incentive Title	Modeled Value	Expected End
	Federal Investment Tax Credit	30% of total investment	12/31/2015
	Advanced Energy Tax Credit	6% of total investment, must be over 1 MW	$60 million
X	Net Metering	Net meter up to 80 MW	-
	Renewable Energy Production Tax Credit (Corporate)	Average $0.027/kWh, 10 years	-
	Sales Tax Incentive	100% of receipts	-
X	REC Payment from PNM	$0.04/kWh, system sizes under 10 kW, 8 years $0.05/kWh, system sizes 10 kW – 1 MW, 8 years	12/31/2013, Restructured each year

The net metering applies to 80-MW and smaller cases, so each case in this analysis has applied the net-metering policy. The study did not consider other incentives for which the Santo Domingo Pueblo was not clearly eligible. The Santo Domingo Pueblo does qualify for funding opportunities through grants and the Reduce Your Use program from PNM, but these grants are expected to pay for the modeled cost.

Table ES-2 summarizes the performance and economics of potential systems that would use all available areas that were surveyed at the Santo Domingo Pueblo. All values represent Tribe ownership except for forecasted power purchase agreement (PPA) price, which is through a solar investor. The table shows the annual energy output from the systems along with the number of average American households that could be powered off of such a system and estimated job creation. All spaces evaluated at the Santo Domingo Pueblo can be developed with PV systems. The roof systems for the Santo Domingo Pueblo municipal buildings have good paybacks that could be taken advantage of immediately. The largest government building roof system, at 16 kW, would generate 26,951 kWh of electricity and have an NPV of $5,537 with 10.5 years to pay back. This includes the current cost of energy, expected installation cost, site solar resource, and existing incentives for the proposed PV system. The industrial site, once renovated, would benefit from installing PV systems that would match the projected energy use of the renovated industrial site. The landfill was also investigated for both offsetting energy use at the renovated industrial site as well as leasable land to a solar developer. The savings and payback are deemed reasonable, and as such, a solar PV system represents a viable reuse for the landfill under analyzed conditions.

Table ES-2. Santo Domingo Pueblo PV Systems Summary

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)
Industrial Site						
Industrial Building - Fixed-Axis Roof System	48	20	81,758	14	1.5	0.0
Industrial Site - 1-Axis Ground System	63	20	142,670	25	2.5	0.0
Industrial Site - Fixed-Axis Ground System	77	20	130,847	23	2.4	0.0
Landfill - 1-Axis Ground System	454	20	1,024,551	180	69.9	0.6
Landfill - Fixed-Axis Ground System	550	20	938,769	165	62.0	0.8
Municipal Buildings						
Recreation Center - Fixed-Axis Roof System	12	20	20,312	4	0.4	0.0
Senior Center- Fixed-Axis Roof System	7	20	12,071	2	0.2	0.0
Mental Health Center- Fixed-Axis Roof System	11	20	18,315	3	0.3	0.0
Utilities Building - Fixed-Axis Roof System	16	20	26,951	5	0.5	0.0

System Type	Installed Cost	System Cost	Maximum Incentive Amount	PPA Price	Net Present Value	Annual O&M	Payback Period with Incentives
	$/W			¢/kWh	2012$	($/year)	(years)
Industrial Site							
Industrial Building - Fixed-Axis Roof System	$ 2.79	$ 133,641	$ 32,703	-	$ 16,797	$ 31,135	10.4
Industrial Site - 1-Axis Ground System	$ 3.35	$ 211,787	$ 57,068	-	$ 56,252	$ 41,093	9.1
Industrial Site - Fixed-Axis Ground System	$ 2.79	$ 213,881	$ 52,339	-	$ 26,882	$ 49,829	10.4
Landfill - 1-Axis Ground System	$ 4.19	$ 1,902,260	$ 409,820	$ 0.11	$ 28,843	$ 295,100	11.7
Landfill - Fixed-Axis Ground System	$ 3.49	$ 1,919,500	$ 375,508	$ 0.12	$ (185,832)	$ 357,500	13.3
Municipal Buildings							
Recreation Center - Fixed-Axis Roof System	$ 2.79	$ 33,201	$ 8,125	-	$ 4,172	$ 7,735	10.4
Senior Center- Fixed-Axis Roof System	$ 2.79	$ 19,731	$ 4,828	-	$ 2,480	$ 4,597	10.4
Mental Health Center- Fixed-Axis Roof System	$ 2.79	$ 29,937	$ 7,326	-	$ 3,762	$ 6,975	10.4
Utilities Building - Fixed-Axis Roof System	$ 2.79	$ 44,054	$ 10,780	-	$ 5,537	$ 10,264	10.4

a Data assume a maximum usable area of 684 acres

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

c Job-years created as a result of project capital investment including direct, indirect, and induced jobs.

d Jobs (direct, indirect, and induced) sustained as a result of operations and maintenance (O&M) of the system.

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1 Study and Site Background

The U.S. Environmental Protection Agency (EPA), in accordance with the RE-Powering America's Land initiative, selected the Santo Domingo Pueblo, Sandoval County, New Mexico, for a renewable energy production feasibility study. Under the Region 6 Contract, EPA provided funding to the National Renewable Energy Laboratory (NREL) to support a feasibility study of solar renewable energy generation at the Santo Domingo Pueblo. NREL provided technical assistance for this project. The purpose of this report is to assess various sites at the Pueblo 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 Santo Domingo Pueblo is approximately 1 hour northeast of Albuquerque, New Mexico, and 1 hour south of Santa Fe, New Mexico. The site is home to approximately 5,000 residents and is approximately 115 square miles in area. The site experiences summers that are warm and dry with high temperatures typically in the low 90ºF range. The winters are cold and mostly dry with low temperatures in the 19ºF to 25ºF range. The site has on average over 250 days of sunshine each year. PNM is the utility providing electricity to the site.

This study assesses: (1) installation of roof-mounted PV systems on existing government buildings within the Pueblo administrative area; (2) installation of roof-mounted PV systems on existing buildings at the 8.7-acre industrial site; and (3) installation of ground-mounted PV systems on the industrial site and adjacent 3.95-acre landfill. The industrial site, referred to as the CC Housing Site by EPA, was originally used as a lumber yard, particle board manufacturing facility, and modular housing manufacturing plant from the 1950s until it was abandoned in 1986. The industrial site currently has abandoned buildings on it, and renovations or completely new construction is required for future utilization of the site. The adjacent landfill was used for the disposal of construction debris from the industrial site operations and contains primarily particle board chips. The industrial site analysis focuses on the use of PV arrays to primarily offset energy costs for future businesses and/or an artisan market on the site.

The major contaminants at the industrial site are related to years of manufacturing of housing materials and related components by lessees of the Atchison Topeka & Santa Fe Railroad, including CC Housing Company. These contaminants include low levels of polycyclic aromatic hydrocarbons (PAHs), total petroleum hydrocarbons (gasoline and motor oil range), metals, and polychlorinated biphenyls (PCBs). The contamination is primarily found in surface and shallow subsurface soil.[1]

Rooftop PV systems evaluated for the four government buildings in the administrative area will be able to tie directly into the existing meter at the building. However, PV systems for the industrial site (if unable to tie in at the site itself), will have to tie in at the substation located across the street. Having a substation within 1,000 feet makes the industrial site an ideal location for a large PV system. A detailed interconnection study will need to be performed through the

[1] "Historical Summary/Recommendations Report," Santo Domingo Pueblo Former CC Housing Site, Targeted Brownfields Assessment, USACE, January 2011.

local electric utility, PNM, to determine the feasibility of utilizing the substation as a tie-in point for a large PV system.

Feasibility assessment team members from NREL and the Santo Domingo Pueblo Tribe conducted a site visit on Monday, December 10, 2012, to gather information integral to this feasibility study. The team considered information, including solar resource, transmission availability, community acceptance, roof conditions, and ground conditions.

2 Development of PV Systems on Brownfield Sites

EPA Region 6 has identified several benefits for siting solar PV facilities on Resource Conservation and Recovery Act (RCRA) sites, noting that they:

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

The Santo Domingo Pueblo Tribe owns all of the sites investigated and is interested in potential revenue flows and cost savings for the tribe. This site development is community driven and will be developed and managed by community leaders. The purpose of this study is to analyze all PV options so that an informed decision can be made on how to best utilize the Tribe's funds and property.

The industrial site at the Santo Domingo Pueblo has potential to be used for other functions beyond the solar PV systems proposed in this report. Any potential use should align with the community vision for the site and should work to enhance the overall utility of the property. The current vision is to renovate and repurpose the buildings on the industrial site for startup community business and incubators.

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 reliable and 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 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).

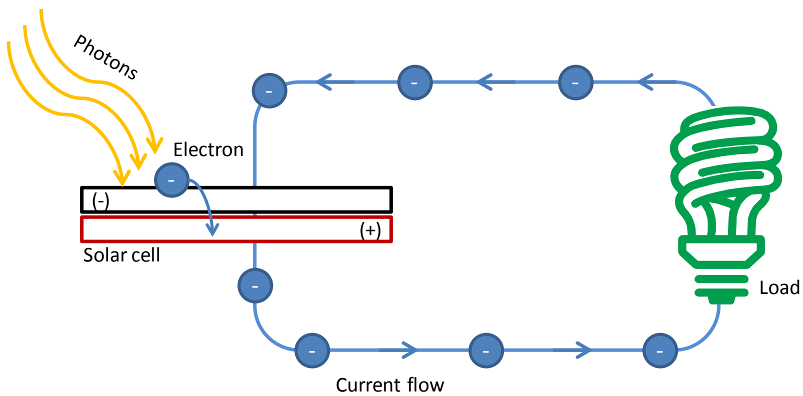

Figure 1. Generation of electricity from a PV cell

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 on the 100+ MW scale. Electricity from utility-scale systems is commonly sold back to the electricity grid.

3.2 Major System Components

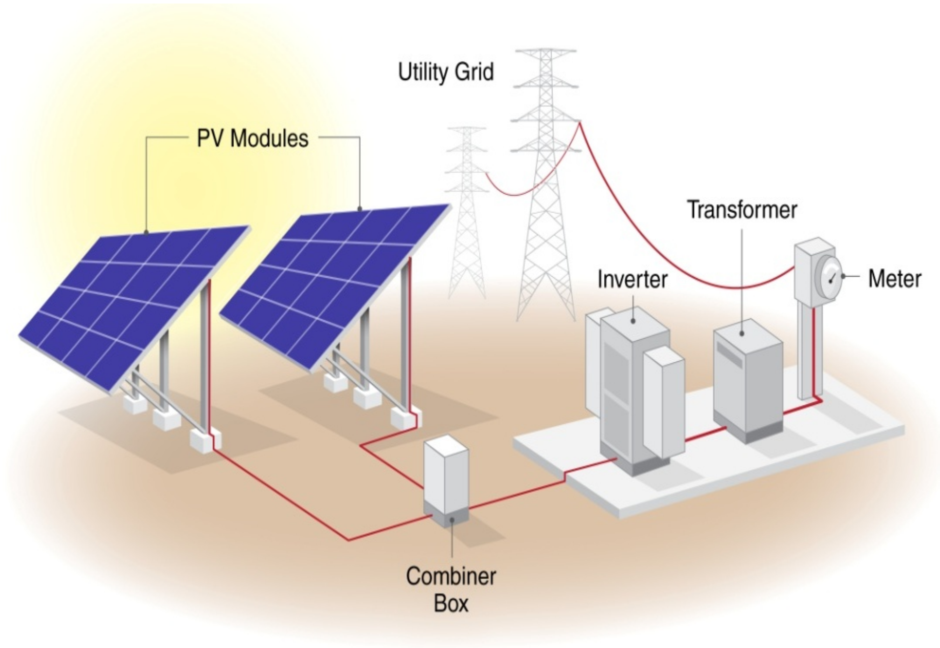

Figure 2. Ground-mounted array diagram

Source: NREL

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

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

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

3.2.1 PV Module

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

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

3.2.1.1 Crystalline Silicon

Traditional solar cells are made from silicon. Silicon is quite abundant and nontoxic. It builds on a strong industry on both the supply (silicon industry) and product sides. This technology has 30 years of demonstrated consistency and high efficiency in the field. The performance degradation, a reduction in power generation due to long-term exposure, is under 1% per year. Silicon modules have a lifespan in the range of 25–30 years but can keep producing energy beyond this range.

Typical overall efficiency of silicon solar panels is between 12% and 18%. However, some manufacturers of mono-crystalline panels claim an overall efficiency nearing 20%. This range of efficiencies represents significant variation among the crystalline silicon technologies available. The technology is generally divided into mono- and multi-crystalline technologies, which indicates the presence of grain-boundaries (i.e., multiple crystals) in the cell materials and is controlled by raw material selection and manufacturing technique. Crystalline silicon panels are widely used based on deployments worldwide.

Figure 3 shows two examples of crystalline solar panels: mono- and multi-crystalline installed on tracking mounting systems.

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

3.2.1.2 Thin Film

Thin-film PV cells are made from amorphous silicon (a-Si) or non-silicon materials, such as cadmium telluride (CdTe). Thin-film cells use layers of semiconductor materials only a few micrometers thick. Due to the unique nature of thin films, some thin-film cells are constructed into flexible modules, enabling 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) landfill geomembrane cover and (middle/right) fixed-tilt mounting system. ***Photos from (left) Republic Services, Inc., NREL 23817; (middle) Beck Energy, NREL 14726; and (right) U.S. Coast Guard Petaluma site, NREL 17395***

Industry-standard warranties of both crystalline and thin-film PV panels typically guarantee system performance of 80% of the rated power output for 25 years. After 25 years, they will continue producing electricity at a lower performance level.

3.2.2 Inverter

Inverters convert DC electricity from the PV array into AC power 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 could be recommended for different types of installations.

String inverters are most common and typically range in size from 1.5 kW to 1,000 kW. These inverters tend to be cheaper on a capacity basis, as well as have high efficiency and lower operations 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 potential increase in O&M cost 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 must be secured and oriented optimally to maximize system output. The structure holding the modules is referred to as the mounting system.

3.2.3.1.1 Ground-Mounted Systems

For ground-mounted systems, the mounting system can be either directly anchored into the ground (via driven piers or concrete footers) or ballasted on the surface without ground penetration. Mounting systems must withstand local wind loads, which range from 90–120 mph for most areas or 130 mph or more for areas with hurricane potential. Depending on the region, snow and ice loads must also be a design consideration for the mounting system. For brownfield applications, mounting system designs will be primarily driven by these considerations coupled with potential 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 slightly increases maintenance and equipment costs. 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 soil conditions, single- and dual-axis trackers might not be suitable due to potential settlement effects, which can interfere with the alignment requirements of such systems.

Table 1. Ground-Mounted Energy Density by Panel and System

System Type	Fixed-Tilt Energy Density (DC-Watts/ft^2)	Single-Axis Tracking Energy Density (DC-Watts/ft^2)
Crystalline Silicon	4.0	3.3
Thin Film	3.3	2.7

The mounting type selected depends 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.

The mounting system selected is also heavily dependent on anchoring or foundation options. The mounting system design will also need to meet applicable local building code requirements with respect to snow, wind, and seismic zones. Mounting type should also consider frost protection needs, especially in cold regions, such as New England. The Santo Domingo Pueblo administrative area has no areas suitable for large ground-mounted PV systems due to the high concentration of buildings at this location. However, there is potential for ground-mounted PV systems on the industrial site and adjacent landfill.

3.2.3.1.2 Roof-Mounted Systems

The Santo Domingo Pueblo administrative area and industrial site have great potential for roof-mounted PV systems on existing and future buildings. Installing PV on rooftops entails many of the same considerations as installing ground-mounted PV systems. Factors, such as available area for an array, solar resource, shading, distance to transmission lines, and distance to major roads, are just as important in roof-mounted systems as in ground-mounted systems. Rooftop systems can be ballasted or fixed to the roof. The roof should be relatively new (less than 5 years old) to avoid having to move the PV system in order to repair or replace the roof.

The Santo Domingo Pueblo Tribe is planning to renovate existing buildings at the industrial site. There are many relatively easy low-cost/no-cost measures that can be taken during the design phase so that the buildings are optimally built for rooftop PV systems. Design strategies, such as orienting new buildings so that the southern exposure is maximized and reducing the amount of mechanical equipment on the roof, are examples of measures that can be taken to optimize rooftop PV systems.[2]

Table 2. Rooftop Energy Density by Panel

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

[2] A solar-ready design guide has been published in order to help design teams optimize buildings for rooftop PV systems. This guide can be found at http://www.nrel.gov/docs/fy10osti/46078.pdf.

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 might be required to run through above-ground conduit due to restrictions with cap penetration or other concerns. Therefore, developers should note any such restrictions, if applicable, in requests for proposals in order to improve overall bid accuracy. Similarly, PV system vendors should reflect these costs in the quote when costing out the overall system.

3.2.3.3 PV System Monitoring

Monitoring is essential for reliable functioning and maximum yield of PV systems and can be as simple as reading values on the inverter LCD display, such as produced AC power, daily kilowatt-hours, and cumulative kilowatt-hours locally. For more sophisticated monitoring and control purposes, environmental data, such as module temperature, ambient temperature, solar radiation, and wind speed, can also be collected. Control and monitoring of these systems can be performed by various types of 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, thus enabling a comparison of the target versus actual system output and performance, as well as identification of under-performing arrays. Operators can use this data to identify required maintenance, shade on panels, and accumulating dirt on panels, for example. Monitoring system data can also be used for outreach and education via publicly available online displays, wall-mounted systems, or even smartphone applications.

3.2.4 Operation and Maintenance

PV panels typically have a 25-year performance warranty. Inverters, which come standard with a 5-year or 10-year warranty (extended warranties available), are expected to last 10–15 years. System performance should be verified on a vendor-provided website. Wire and rack connections should be checked annually. The economic analysis in this study assumes an annual O&M cost of $20/kW/year, which is based on the historical O&M costs of installed fixed-axis grid-tied PV systems. In addition, the analysis assumes replacement of the 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.

After collecting solar resource data using the Solmetric SunEye tool and determining that the site is adequate for a solar installation, an analysis of the ideal system size must be conducted. System size depends highly on the average energy use of the facilities on the site, power purchase agreements (PPAs), available incentives, and utility policy.

4 Proposed Installation Location Information

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

4.1 Santo Domingo Pueblo PV Systems

As discussed in Section 1, the Santo Domingo Pueblo Tribe owns all sites assessed in this study. Surface level remediation at the industrial site will need to be performed before any entities occupy the site.

The entire industrial site is approximately 8.7 acres and will potentially be reused by the Santo Domingo Pueblo Tribe for economic development purposes. The site renovations will consider ground- and roof-mounted PV systems for power-saving measures, with the landfill to the north considered for ground-mounted PV as well. In order to get the most out of the roof area available, it is important to consider whether the layout can be improved to better incorporate a solar system. If there are unused structures that can be removed, the un-shaded area can be increased to incorporate more PV panels. There are 0.44 acres for ground-mounted PV and 12,000 ft^2 potentially available for roof-mounted PV systems. Calculations for this analysis reflect the solar potential if the total feasible area is developed. However, installations can be staged as area(s) and/or funding become available. It should be noted that the purpose of this report is not to determine how to develop the site but to investigate the PV options in an unbiased manner. Because the buildings will require renovations for use, they could easily be redone to make the buildings "solar ready," even if the budget for a rooftop PV system is not available at the time of construction.

Figure 6 shows the industrial site and the landfill just to the north of the site. The shaded area indicates the space available for PV development. The land west and nearest to the buildings should be considered for ground PV development before exploring the option of developing the landfill to the north. The 3.95 acres of land to the north may also be ideal to lease to a solar developer if the market and policy conditions are favorable for large-scale development.

Figure 6. Aerial view of the feasible areas for PV at the Santo Domingo Pueblo industrial site (ground-mounted in dark blue and roof-mounted in light blue)

Illustration done in Google Earth

Figure 7 shows an aerial view taken from Google Earth of the roof areas with PV potential within the Santo Domingo Pueblo administrative area. The buildings with their available room for PV systems are:

- Utilities building: 3,948 ft^2
- Recreation center: 2,975 ft^2
- Mental health building: 2,682 ft^2
- Senior center: 1,768 ft^2.

No feasible areas for ground-mounted PV systems exist. The existing buildings suitable for roof-mounted PV are shaded in blue. Each building's PV system would be separate from the others and connected to that building's meter.

Figure 7. Aerial view of the feasible areas for PV within the Santo Domingo Pueblo (no ground-mounted PV potential exists; existing municipal buildings with potential roof-mounted PV in blue)

Illustration done in Google Earth

The Santo Domingo Pueblo is well suited for PV systems, as the average global horizontal annual solar resource—the total solar radiation for a given location, including direct and diffuse radiation—is 5.92 $kWh/m^2/day$. Figure 8 shows a view of one building in the administrative area where roof-mounted PV is feasible. Figure 9 shows a view of the industrial site, where ground-mounted PV is feasible.

Figure 8. View of utility building suitable for roof-mounted PV. ***Photo by Jesse Geiger, NREL***

Figure 9. View of industrial site area feasible for ground-mounted PV. Water tower is to the north.
Photo by Jesse Geiger, NREL

4.2 Utility Resource Considerations

All of the roof-mounted systems (administrative area and industrial site) are expected to be able to connect through the existing meters at each building. Further, each of these buildings is expected to be an off-taker of all generated solar energy and make use of the net-metering incentives offered by PNM. For the potential landfill ground-mounted PV system, interconnection through the local substation may be required and would need to be approved by PNM via a detailed interconnection study. Figure 10 shows the location of the substation relative to the landfill and industrial site.

Figure 10. Location of PNM Substation in relation to the landfill and industrial site

Illustration done in Google Earth

4.3 Useable Acreage for PV System Installation

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

4.4 PV Site Solar Resource

The Santo Domingo Pueblo area has been evaluated to determine the adequacy of the solar resource available using both on-site data and industry tools.

The assessment team for this feasibility study collected multiple Solmetric SunEye data points and found a solar access of 90% or higher. All data gathered using this tool is available in Appendix C.

The team used PVWatts Version 2 to predict array performance for the Santo Domingo Pueblo.[3] Table 3 shows the station identification information, PV system specifications, and energy specifications for the site. For array performance information, the team used a hypothetical system size of 1 kW 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.

[3] PVWatts. Accessed June 5, 2013: http://www.nrel.gov/rredc/pvwatts/.

Table 3. Site Identification Information and Specifications

Station Identification	
Cell ID	0199372
State	New Mexico
Latitude	35.3° N
Longitude	106.5° W
PV System Specifications	
DC Rating	1.00 kW
DC to AC Derate Factor	0.8
AC Rating	0.8 kW
Array Type	Fixed-Tilt
Array Tilt	20°
Array Azimuth	South
Energy Specifications	
Cost of Electricity	$0.1232/kWh

Table 4 shows the performance results for a 20-degree fixed-tilt PV system at the Santo Domingo Pueblo as calculated by PVWatts.

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

Month	Solar Radiation (kWh/m^2/day)	AC Energy (kWh)	Energy Value ($)
1	4.36	108	9.78
2	4.92	108	9.78
3	5.81	140	12.68
4	6.77	152	13.77
5	7.11	163	14.77
6	7.30	156	14.13
7	7.13	156	14.13
8	6.50	143	12.96
9	6.38	138	12.50
10	5.65	131	11.87
11	4.62	107	9.69
12	4.01	99	8.97
Year	5.88	1,601	197.24

Table 5 shows the performance results for a 20-degree-tilt single-axis tracking PV system at the Santo Domingo Pueblo as calculated by PVWatts.

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

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	5.59	141	12.77
2	6.23	139	12.59
3	7.58	185	16.76
4	8.92	203	18.39
5	9.49	220	19.93
6	9.80	212	19.21
7	9.18	204	18.48
8	8.48	189	17.12
9	8.22	180	16.31
10	7.44	175	15.86
11	5.87	138	12.50
12	5.11	130	11.78
Year	7.67	2,116	260.69

4.5 Santo Domingo Pueblo Energy Usage

It is important to understand the energy use of the buildings to fully determine whether or not energy produced would need to be sold or if it could offset on-site energy use.

4.5.1 Current Energy Use

No current monthly electricity usage or cost data was available for any of the sites evaluated for potential PV systems in the Pueblo. However, with the inclusion of net metering, any PV generation will offset current annual electricity usage.

4.5.2 Net Metering

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

> (11) NET METERING.—Each electric utility shall make available upon request net metering service to any electric consumer that the electric utility serves. For purposes of this paragraph, the term 'net metering service' means service to an electric consumer under which electric energy generated by that electric consumer from an eligible on-site generating facility and delivered to the local distribution facilities may be used to offset electric energy provided by the electric utility to the electric consumer during the applicable billing period.

New Mexico's net-metering law, which began in 1978 and was modified in 2008 to allow capacity up to 80 MW, requires that any qualifying system be allowed to be credited at the retail rate for any energy produced over the monthly use of the facility. The New Mexico law does not permit those who partake in the net-metering program to retain ownership of the renewable energy certificates (RECs) that they would own and forfeit them to their servicing utility, in this case PNM. Any net excess generation (NEG) in a month is carried forward into the next month's cycle if under $50, or paid to the system if over $50 in value.

5 Economics and Performance

The economic performance of a PV system installed on the site is evaluated using a combination of the assumptions and background information discussed previously as well as a number of industry-specific inputs determined by other studies. In particular, this study uses the NREL System Advisor Model (SAM).[4]

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

SAM makes performance predictions for grid-connected solar, solar water heating, wind, and geothermal power systems, and it makes economic calculations for both projects that buy and sell power at retail rates and power projects that sell power through a PPA.

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

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

5.1 Assumptions and Input Data for Analysis

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 has declined from $4.80/W in the first quarter of 2010 to $2.79/W in the first quarter of 2012. With an increasing demand and supply, the potential for further cost reduction is expected as market conditions evolve. This analysis assumes a baseline cost of $2.79/W for fixed-tilt roof-mounted systems. The cost for the fixed-axis ground-mounted systems was the same. Single-axis tracking systems were assumed in this analysis to have a 20% increase over the fixed-axis system cost at $3.35. Single-axis tracking is only available for use on the ground. Additional costs apply to systems built on landfills and land that requires minimal disturbance (e.g., brownfields). These systems use ballasting to minimize ground impact and increase the overall installation price by 25%.

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

Table 6. Installed System Cost Assumptions

System Type	Fixed-Tilt Roof/Fixed-Axis Ground ($/W)	Single-Axis Tracking ($/W)
Baseline System	2.79	3.35
+ 25% Ballast	+0.70	+0.84
Ballasted Ground-Mounted System	3.49	4.19

This price includes 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.

Santo Domingo Pueblo receives electricity through the servicer PNM. The utility retail rate used in the economic analysis is $0.123219/kWh. This rate is based upon correspondence with PNM and is the average rate received by the Tribe for commercial demand over 450 kWh per month. This rate is considered to be a conservative estimate of the electrical cost offset by a PV system. While there is a lower rate for electrical consumption up to 450 kWh per month, the actual usage for each building is expected to be much higher. Any energy that a PV system offsets in the highest rate tier will bring an even greater benefit.

This analysis assumes that relevant federal and state incentives are received for taxable entities. It is important to consider all applicable incentives or grants to make PV as cost effective as possible. The full list of incentives used in this study can be found in Table 7.

Table 7. Summary of Incentives Evaluated

Applicable to Tribe Owned System	Incentive Title	Modeled Value	Expected End
	Federal Investment Tax Credit	30% of total investment	12/31/2015
	Advanced Energy Tax Credit	6% of total investment, must be over 1 MW	$60 million
X	Net Metering	Net metering up to 80 MW	-
	Renewable Energy Production Tax Credit (Corporate)	Average $0.027/kWh, 10 years	-
	Sales Tax Incentive	100% of receipts	-
X	REC Payment from PNM	$0.04/kWh, system sizes under 10 kW, 8 years $0.05/kWh, system sizes 10 kW–1 MW, 8 years	12/31/2013, restructured each year

For the purposes of this analysis, the project is expected to have a 25-year lifetime, although the systems can be reasonably expected to continue operation past this point. A full list of standard assumptions can be found in Appendix B-1. The modeling assumed PV could cover 80% of the rooftop and ground space available. PVWatts Version 2 was used to calculate expected energy performance for the system.

5.2 SAM-Forecasted Economic Performance

Using varied inputs and the assumptions summarized in Section 5.1 of this report, SAM predicts net present value (NPV), PPA, and levelized cost of energy (LCOE). Nine scenarios total were run for the Santo Domingo Pueblo. Four cases were used to model filling the available roof spaces on municipal buildings with PV arrays. Three cases were done to investigate installing PV systems on the industrial site if the site were to be renovated, including a roof-mounted system. Two cases investigated the landfill for a large-scale system to possibly lease or use as a power source for the industrial site. All cases were run with applicable incentives to show the maximum benefit available to each system.

There are multiple factors that go into choosing the most appropriate scenario(s) beyond NPV, PPA, and LCOE; however, Table 8 shows the different options and their results. It is important to note that the economic models used the assumptions found in Appendix B-2, and further investigation is suggested before investing in a PV system. All roof systems have the same expected payback period of 10.45 years. The best municipal system from an NPV point of view is the utilities building, but all municipal buildings are expected to be favorable. The only unfavorable model for the industrial site is the fixed-axis ground system on the landfill. The benefits of the PV systems at the industrial site will not be realized until the site is repurposed and using significant amounts of electricity. All systems have a payback within the 25-year evaluation space and all are less than 15 years.

Table 8. Summary of SAM Results

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)
Industrial Site						
Industrial Building - Fixed-Axis Roof System	48	20	81,758	14	1.5	0.0
Industrial Site - 1-Axis Ground System	63	20	142,670	25	2.5	0.0
Industrial Site - Fixed-Axis Ground System	77	20	130,847	23	2.4	0.0
Landfill - 1-Axis Ground System	454	20	1,024,551	180	69.9	0.6
Landfill - Fixed-Axis Ground System	550	20	938,769	165	62.0	0.8
Municipal Buildings						
Recreation Center - Fixed-Axis Roof System	12	20	20,312	4	0.4	0.0
Senior Center- Fixed-Axis Roof System	7	20	12,071	2	0.2	0.0
Mental Health Center- Fixed-Axis Roof System	11	20	18,315	3	0.3	0.0
Utilities Building - Fixed-Axis Roof System	16	20	26,951	5	0.5	0.0

System Type	Installed Cost $/W	System Cost	Maximum Incentive Amount	PPA Price ¢/kWh	Net Present Value 2012$	Annual O&M ($/year)	Payback Period with Incentives (years)
Industrial Site							
Industrial Building - Fixed-Axis Roof System	$ 2.79	$ 133,641	$ 32,703	-	$ 16,797	$ 31,135	10.4
Industrial Site - 1-Axis Ground System	$ 3.35	$ 211,787	$ 57,068	-	$ 56,252	$ 41,093	9.1
Industrial Site - Fixed-Axis Ground System	$ 2.79	$ 213,881	$ 52,339	-	$ 26,882	$ 49,829	10.4
Landfill - 1-Axis Ground System	$ 4.19	$ 1,902,260	$ 409,820	$ 0.11	$ 28,843	$ 295,100	11.7
Landfill - Fixed-Axis Ground System	$ 3.49	$ 1,919,500	$ 375,508	$ 0.12	$ (185,832)	$ 357,500	13.3
Municipal Buildings							
Recreation Center - Fixed-Axis Roof System	$ 2.79	$ 33,201	$ 8,125	-	$ 4,172	$ 7,735	10.4
Senior Center- Fixed-Axis Roof System	$ 2.79	$ 19,731	$ 4,828	-	$ 2,480	$ 4,597	10.4
Mental Health Center- Fixed-Axis Roof System	$ 2.79	$ 29,937	$ 7,326	-	$ 3,762	$ 6,975	10.4
Utilities Building - Fixed-Axis Roof System	$ 2.79	$ 44,054	$ 10,780	-	$ 5,537	$ 10,264	10.4

a Data assume a maximum usable area of 684 acres

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

c Job-years created as a result of project capital investment including direct, indirect, and induced jobs.

d Jobs (direct, indirect, and induced) sustained as a result of operations and maintenance (O&M) of the system.

5.2.1 Solar Investor vs. Tribe Owned

While ownership of the system is profitable for the Santo Domingo Pueblo, it will require hiring the contractors to permit, install, and maintain the system. A solar investor assumes the risk and profit, and the Santo Domingo Pueblo in turn will receive power from the PV system at a rate determined by the investor. A solar investor will also be able to take advantage of federal and state tax benefits, which will lower the cost of the system. Solar investors also usually have a size threshold that they require before they will develop a site. Roof systems are typically not attractive sites for investors and were not considered in the study.

The recommendation of the feasibility team is for the Santo Domingo Pueblo Tribe to develop and own all roof systems (administrative area and industrial site) and the industrial site ground-mounted system and not pursue a PPA for those systems. For the landfill, however, the feasibility team recommends the Tribe pursue a PPA because an investor may be interested in building a PV system at that location. The model currently shows a PPA of $0.1145/kWh, with a 15% internal rate of return for the investor, for a single-axis PV system on the landfill area. The

PPA price is lower than what is expected to be paid to the utility and could potentially save the Tribe more than if they were to install and own the system.

5.2.2 Fixed-Axis vs. Single-Axis Tracking

The primary difference between fixed and single-axis tracking is the tradeoff between energy production and capital costs. The single-axis tracking system is able to gather a significantly greater portion of the sun's energy but costs more per watt and covers a greater amount of land than a fixed-axis system of the same size. The fixed-axis system gathers less solar energy but costs less, can be put on roofs, and more panels can be packed together than single-axis tracking. The single-axis tracking system is the more economically attractive ground system.

For this site, the feasibility team recommends pursuing single-axis tracking for the ground-mounted systems. If the fixed-axis installed price were to be $0.99 less than the single-axis installed price, the fixed-axis tracking system would become more favorable on an NPV basis. All roof systems must be fixed axis.

The entire results and summary of inputs to the SAM is available in Appendix E.

5.3 Job Analysis and Impact

To evaluate the employment and economic impacts of the PV projects associated with this analysis, the NREL Jobs and Economic Development Impact (JEDI) models are used.[5] JEDI estimates the economic impacts associated with the construction and operation of distributed generation power plants. It is a flexible input-output tool that estimates, but does not precisely predict, the number of jobs and economic impacts that can be reasonably supported by the proposed facility.

JEDI represents the entire economy, including cross-industry or cross-company impacts. For example, JEDI estimates the impact that the installation of a distributed generation facility would have on not only the manufacturers of PV modules and inverters but also on the associated construction materials, metal fabrication industry, project management support, transportation, and other industries that are required to enable the procurement and installation of the complete system.

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

For demonstrating the impact of constructing a single system in the Santo Domingo Pueblo, the system values in Table 9 were assumed.

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

Table 9. JEDI Analysis Assumptions

Input	Assumed Value
PV System Capacity	16 kW
Placed in Service Year	2013
Installed System Cost	$44,054
Location	Santo Domingo Pueblo, NM

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

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

As indicated in the results of the JEDI analysis provided in Appendix D, the total proposed system is estimated to support 0.5 direct and indirect jobs per year for the duration of the procurement and construction period. Total wages paid to workers during the construction period are estimated to be $19,800, and total economic output is estimated to be $480,700. The annual O&M of the new PV system is estimated to support zero FTEs per year for the life of the system. The jobs and associated spending are projected to account for approximately $300 in earnings and $500 in economic activity each year for the next 25 years.

5.4 Financing Opportunities

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

5.4.1 Owner and Operator Financing

The owner/operator financing structure is characterized by a single entity with the financial strength to fund all of the solar project costs and, if a private entity, sufficient tax appetite to utilize all of the project's tax benefits. Private owners/operators typically establish a special purpose entity (SPE) that solely owns the assets of the project. An initial equity investment into the SPE is funded by the private entity using existing funds, and all of the project's cash flows and tax benefits are utilized by the entity. This equity investment is typically matched with debt financing for the majority of the project costs. Project debt is typically issued as a loan based on each owner's/operator's assets and equity in the project. In addition, private entities can utilize any of federal tax credits offered.

For public entities that choose to finance, own, and operate a solar project, funding can be raised as part of a larger, general obligation bond; as a stand-alone tax credit bond; through a tax-exempt lease structure, bank financing, grant and incentive programs, or internal cash; or some combination of the above. Certain structures are more common than others, and grant programs for solar programs are on the decline. Regardless, as tax-exempt entities, public entities are unable to benefit directly from the various tax-credit-based incentives available to private companies. This has given way to the now common use of third-party financing structures, such as the PPA.

5.4.2 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, 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 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 is typically between the third-party developer and the site host if it is a retail "behind-the-meter" transaction or directly with an electric utility if it is a wholesale transaction.

Site hosts benefit by receiving either competitively priced electricity from the project via the PPA or land lease revenues for making the site available to the solar developer via a lease payment. This lease payment can take on the form of either a revenue-sharing agreement or an annual lease payment. In addition, third-party developers are able to utilize federal tax credits. For public entities, this arrangement allows them to utilize the benefits of the tax credits (low PPA price, higher lease payment) while not directly receiving them. The term of a PPA typically varies from 20–25 years.

5.4.3 Third-Party "Flip" Agreements

The most common use of 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 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 investors would begin with the majority ownership. Eventually, the ownership would flip to the developer once each investor's return is met.

5.4.4 Hybrid Financial Structures

As the solar market evolves, hybrid financial solutions have been developed in certain instances to finance solar projects. A particular structure, nicknamed "The Morris Model" after Morris County, New Jersey, combines highly rated public debt, a capital lease, and a PPA. Low-interest public debt replaces more costly financing available to the solar developer and contributes to a very attractive PPA price for the site hosts. New Markets Tax Credits have been combined with PPAs and public debt in other locations, such as Denver, Colorado, and Salt Lake City, Utah.

5.4.5 Solar Service Agreement and Operating Lease

The solar service agreement (SSA) and operating lease business models have been predominately used in the municipal and cooperative utility markets due to their treatment of tax benefits and the rules limiting federal tax benefit transfers from non-profit to for-profit companies. Under Internal Revenue Service (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 for this issue. One model is the SSA, wherein a private party sells "solar services" (i.e., energy and RECs) to a municipality over a specified contract period (typically long enough for the private party to accrue the tax credits). The 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 can buy out the system once the third party has accrued the tax credits, but due to IRS regulations, the buyout of the plant cannot be included as part of the SSA (i.e., the SSA cannot be used as a vehicle for a sale and must be a separate transaction).

Similar to the SSA, there are a variety of lease options that are available to municipalities that allow the capture of tax benefits by third-party owners, which 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."

5.4.6 Sale/Leaseback

In the widely accepted sale/leaseback model, the public or private entity would install the PV system, sell it to a tax investor, and then lease it back. As the lessee, the public or private entity would be responsible for operating and maintaining the solar system as well as have the right to sell or use the power. In exchange for use of the solar system, the public or private entity would make lease payments to the tax investor (the lessor). The tax investor would have rights to federal tax benefits generated by the project and the lease payments. Sometimes, the public or private entity is allowed to buy back the project at 100% fair market value after the tax benefits are exhausted.

5.4.7 Community Solar/Solar Gardens

The concept of "community solar" is one in which the costs and benefits of one large solar project are shared by a number of participants. A site owner may be able to make the land available for a large solar project, which can be the basis for a community solar project. Ownership structures for these projects vary, but the large projects are typically owned or sponsored by a local utility. Community solar projects are distributed solar projects wherein utility customers have a stake via a prorated share of the project's energy output. This business model is targeted to meet demand for solar projects by customers who rent/lease homes or businesses, do not have good solar access at their site, or do not want to install a solar system on their facilities. Customers acquire pro-rated shares of solar projects through a long-term transferrable lease of one or more panels, or they subscribe to a share of the project in terms of a specific level of energy output or the energy output of a set amount of capacity. Under the customer lease option, the customer receives a billing credit for the number of kilowatt-hours their pro-rated share of the solar project produces each month; it is also known as “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/month blocks) from the community solar project. Other models include monthly energy outputs from a specific investment dollar amount or from a specific number of panels.

Community solar gardens and customer subscription-based projects can be solely owned by the utility, solely owned by third-party developers with billing facilitated by the utility, or a joint venture between the utility and a third-party developer that leads 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, including Washington State (production incentive) and Utah (state income tax credit). Community solar is sometimes known as solar gardens depending on the location (e.g., Colorado).

6 Conclusions and Recommendations

The Santo Domingo Pueblo Tribe should consider installing small PV units on the roofs of government buildings at the Pueblo administrative area because they could be economically beneficial. Once the industrial site is renovated, both ground- and roof-mounted PV should be installed at the site to offset energy costs. Obtaining grants from PNM and other sources will help improve the economic benefits of these systems. Leasing the landfill space to a solar developer could be economically beneficial for the Tribe if the extra PV is needed for the renovated industrial site.

This analysis found that the installation of all roof- and ground-mounted PV systems for the administrative area, industrial site, and landfill is economically feasible, potentially generating 1,326,628 kWh annually.

The single-axis net-metering PV system on the industrial site has the best NPV and payback of $56,252 and 9.1 years, respectively, according to the SAM economic analysis summarized in Section 5. If the landfill PV system was developed under a solar investor/PPA arrangement, the best possible PPA price is $0.1145/kWh, which could potentially save the Tribe a larger sum of money than the Tribe owning the system on the landfill.

The administrative area has enough rooftop space available for four PV systems totaling 45 kW. These systems would potentially produce 77,649 kWh of energy annually, enough to power 14 homes.

Once the industrial site has been renovated, PV panels (roof- and ground-mounted) should be installed that could potentially offset 224,428 kWh/year from on-site production and up to 1,248,979 kWh/year if the landfill is developed. The economics for a larger PV system at the Santo Domingo Pueblo landfill should be more thoroughly studied to determine the practicality of leasing the land to a solar developer for either lease revenue or lower electrical rates.

The Santo Domingo Pueblo is a good site to pursue PV to offset energy use, and any grants available for PV development should be pursued. The modeled values in this feasibility study are also conservative in regards to financing the system and could potentially be better than modeled. If bonds were able to be obtained, the value of the system could potentially double. A more thorough study of available grants and potential funding sources should also be considered during an investigation of potential installers.

Appendix A. Provided Site Information

Table A-1. Utility Rates Provided by PNM Contact

In the Billing Months Of:	**June, July, and August**	**All Other Months**
Customer Charge:	$5.00/Bill x Per Metered Account)	$5.00/Bill x Per Metered Account)
Energy Charge: First 450 kWh per Month Next 450 kWh per Month All Additional kWh per Month	 $0.0906237/kWh $0.1373455/kWh $0.1576960/kWh	 $0.0906237/kWh $0.1185101/kWh $0.1283520/kWh

Table A-1 lists the utility rates, dependent on month of the year, for each service location.[6] Net utility rate is dependent upon total power purchased from each tier shown above.

All kilowatt-hour usage under this tariff will be subject to a Fuel and Purchase Power Cost Adjustment Clause ("FPPCAC") factor calculated according to the provisions in PNM's Rider 23. The rider allows for tariffs to change up or down according to changes in fuel and purchased power prices.[7]

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[6] Newby, C. Email, PNM Governmental Affairs, 1 January 2013.

[7] Public Service Company of New Mexico. "2nd Revised Rider No. 23," 30 December 2011. Accessed July 15, 2013: http://www.pnm.com/regulatory/pdf_electricity/rider_23.pdf.

Appendix B. Assessment and Calculations Assumptions

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

Cost Assumptions			
Variable	**Quantity of Variable**	**Unit of Variable**	
Cost of Site Electricity	0.123219	$/kWh	
Annual O&M (fixed)	20	$/kW/year	
System Assumptions			
System Type	**Annual Energy kWh/kW**	**Installed Cost ($/W)**	**Energy Density (W/sq. ft.)**
Roof Fixed	1,601	$2.79	4.00
Ground Fixed w/ Ballast	1,601	$3.49	4.00
Ground Single-Axis w/ Ballast	2,116	$4.19	3.30
Other Assumptions			
	1 acre	43,560 ft^2	
	1 MW	1,000,000 W	
	Ground utilization	90% of available area	

Table B-2. Modeling Assumptions

Item	PPA/Investor	Tribe Purchase	Notes
Analysis Period (years)	25	25	
Inflation	2.50%	2.50%	
Real Discount Rate	5.85%	5.85%	
Federal Tax Rate	35%	0%	
State Tax Rate	8%	0%	
Insurance (% of installed cost)	0.50%	0.50%	
Property Tax	0	0	
Construction Loan	0	0	
Loan Term	15	15	25-year bonds would greatly improve the economics
Loan Rate	6%	6%	May be lower for bonds
Debt Fraction	55%	55%	45%–60% PPA, 100% municipal ownership, DSCR of ~1.3 (>1.2)
Minimum IRR	15.00%	N/A	
PPA Escalation Rate	1.50%	N/A	
Fed Depreciation	5-year MACRS with 50% first-year bonus	N/A	N/A for municipal ownership
State Depreciation	5-year MACRS	N/A	N/A for municipal ownership
Fed ITC	30%	N/A	N/A for municipal ownership
Payment Incentives	0	0	
Degradation	0.50%	0.50%	
Availability	100%	100%	
Cost – Fixed-Axis per kW	$2.79–$3.20	$2.79–$3.20	
Cost – Single-Axis Tracking per kW	$3.35–$3.84	$3.35–$3.84	
Cost - Landfill Ballasted per kW	$3.49–$4.00	$3.49–$4.00	
Grid Interconnection Cost	$ -	$ -	

Land Cost	$ -	$ -	
O&M	$30/kW/yr first 15 yrs and $20/kW/yr yrs 16-25	$30/kW/yr first 15 yrs and $20/kW/yr yrs 16-26	
Derate Factor	0.8	0.8	
Fixed-Tilt	20°	20°	
Single-Axis Tilt	0°	0°	
Acres per MW Fixed	5.74	5.74	
Acres per MW Tracking	6.96	6.96	

Appendix C. Solar Access Measurements

All sites had greater than 90% solar access. Below is a representation of the sites.

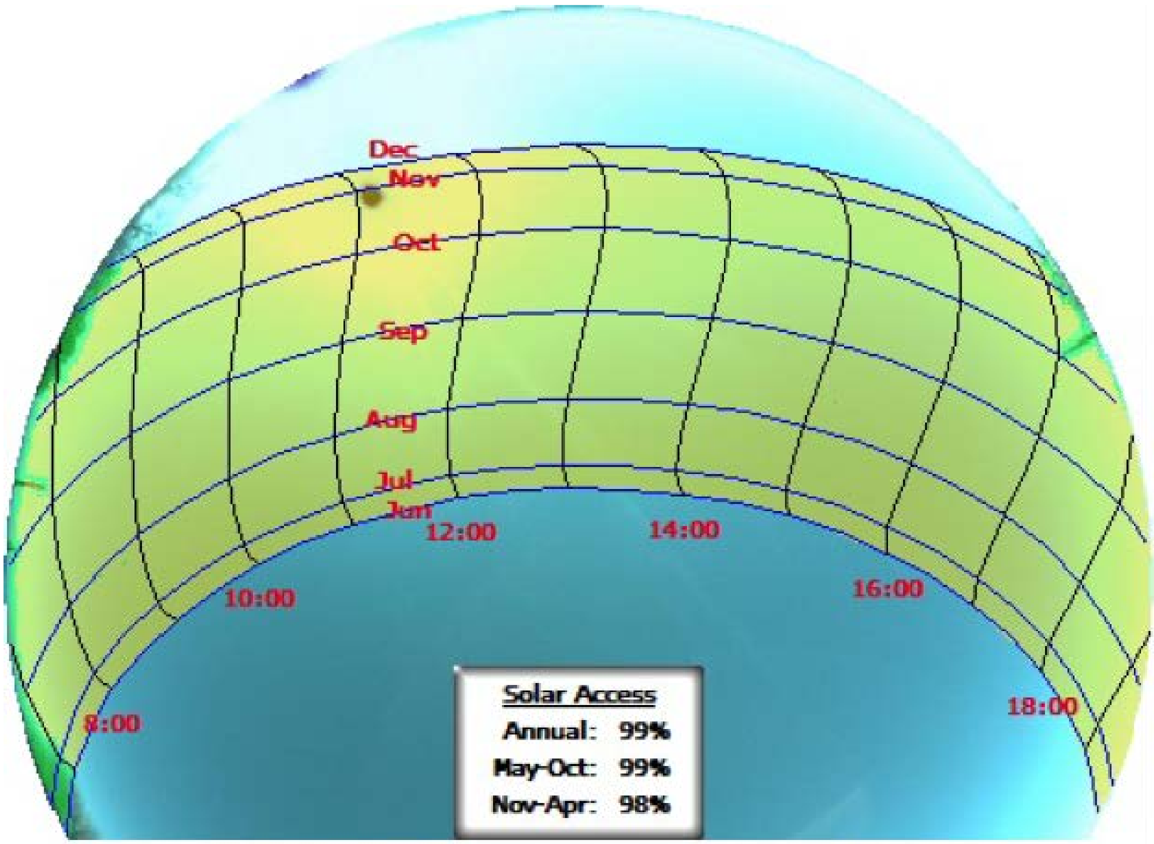

Figure C-1. Solar access measurement for Senior Center PV site

Appendix D. Results From the System Advisor Model

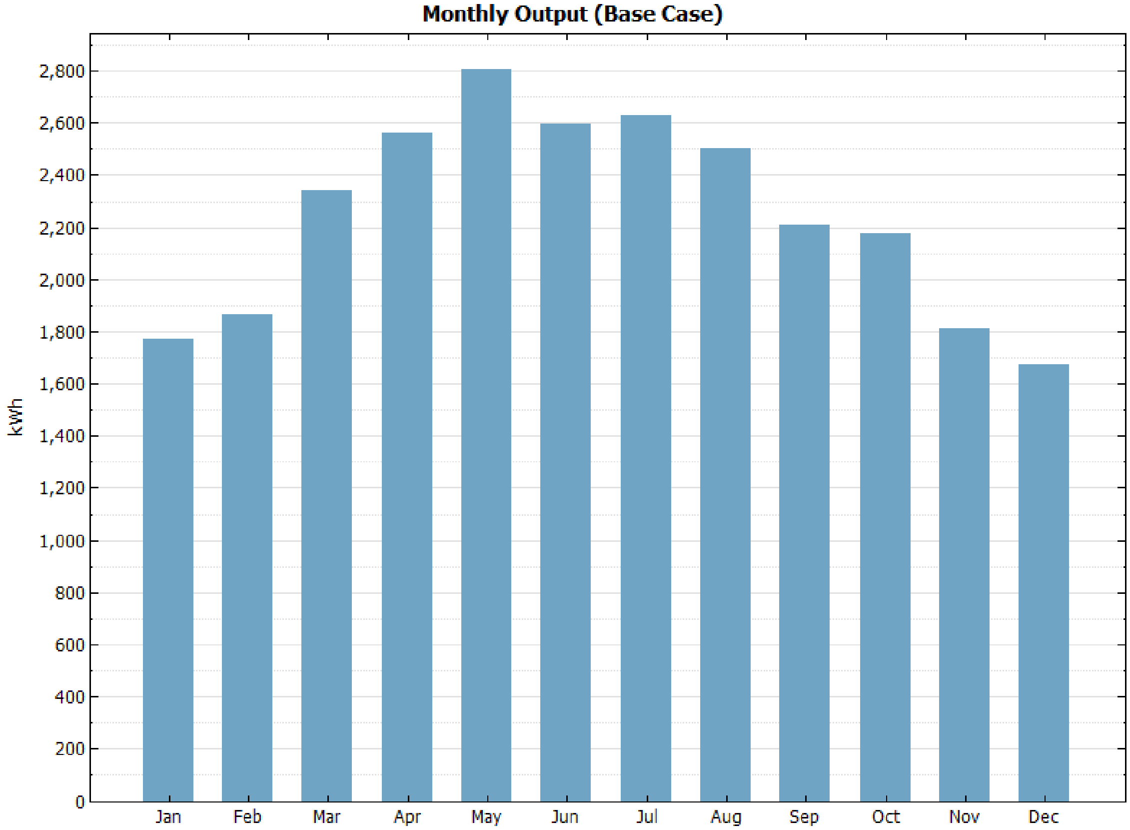

Figure D-1. 16-kW roof-mounted monthly production projection

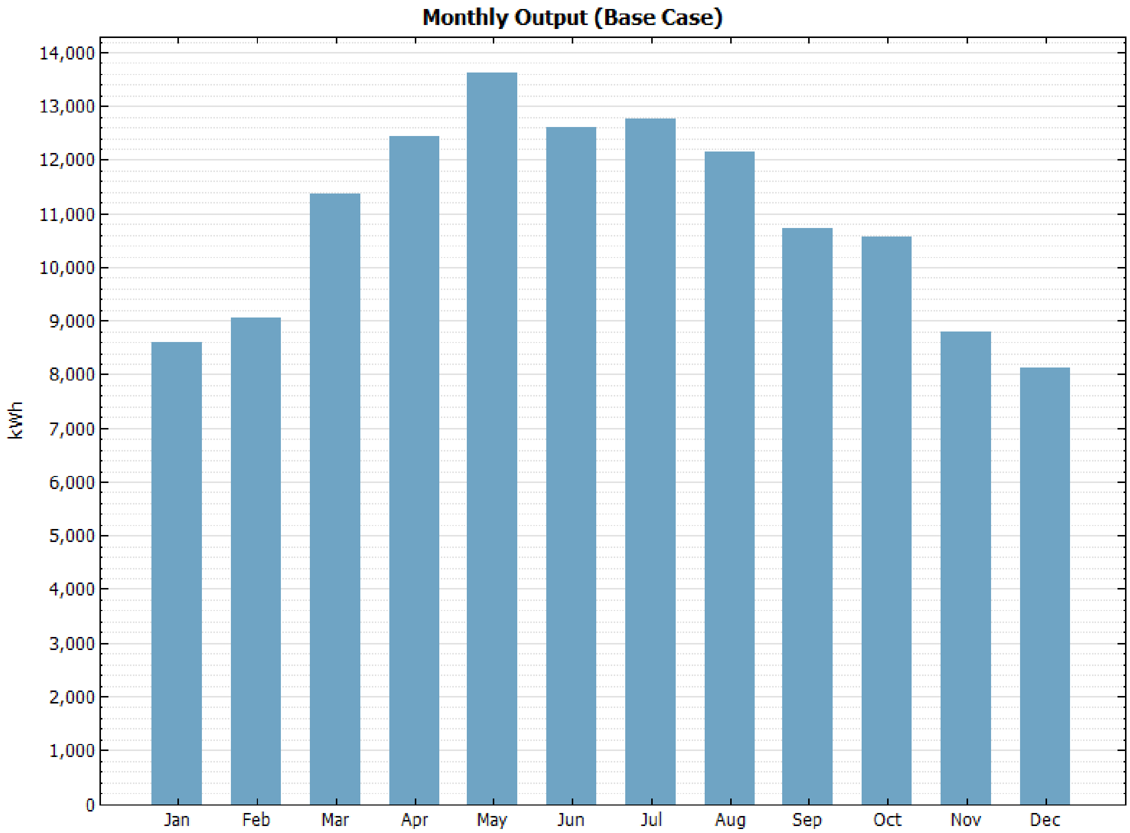

Figure D-2. 76-kW ground-mounted fixed-axis monthly production projection

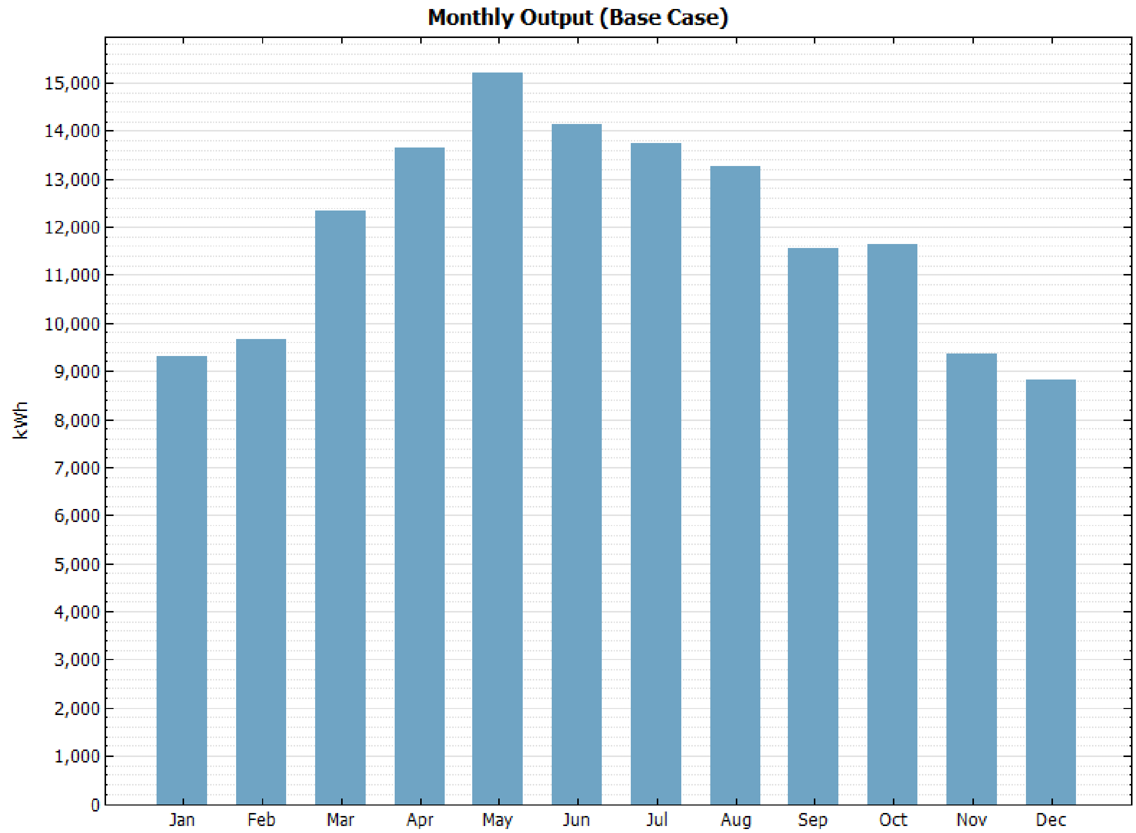

Figure D-3. 63-kW ground-mounted single-axis monthly production projection

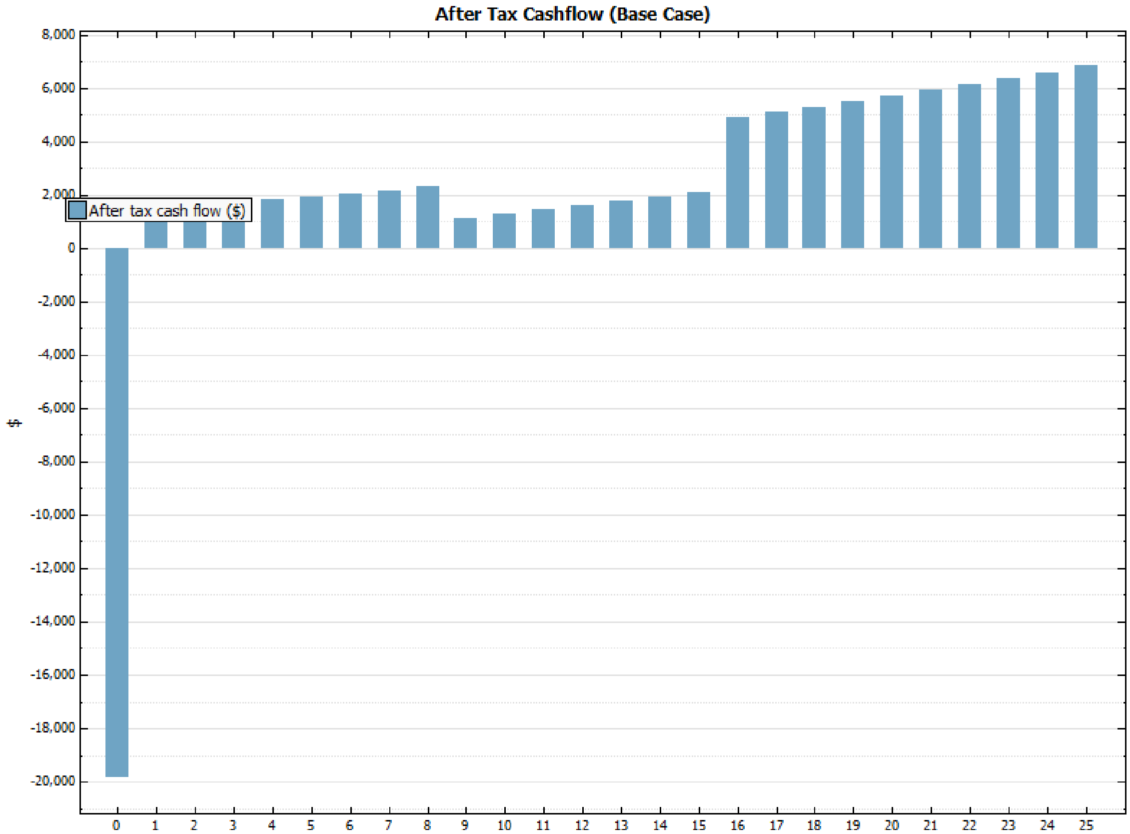

Figure D-4. 16-kW roof-mounted annual cash flow

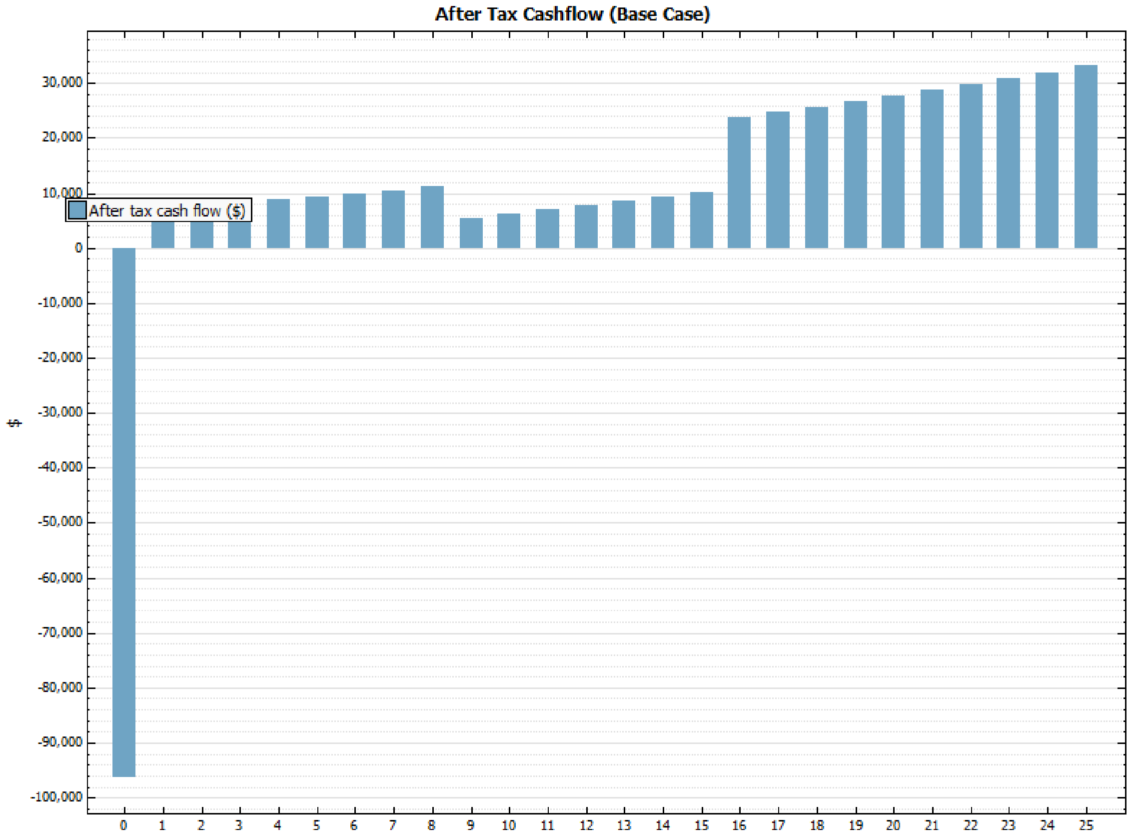

Figure D-5. 76-kW ground-mounted fixed-axis annual cash flow

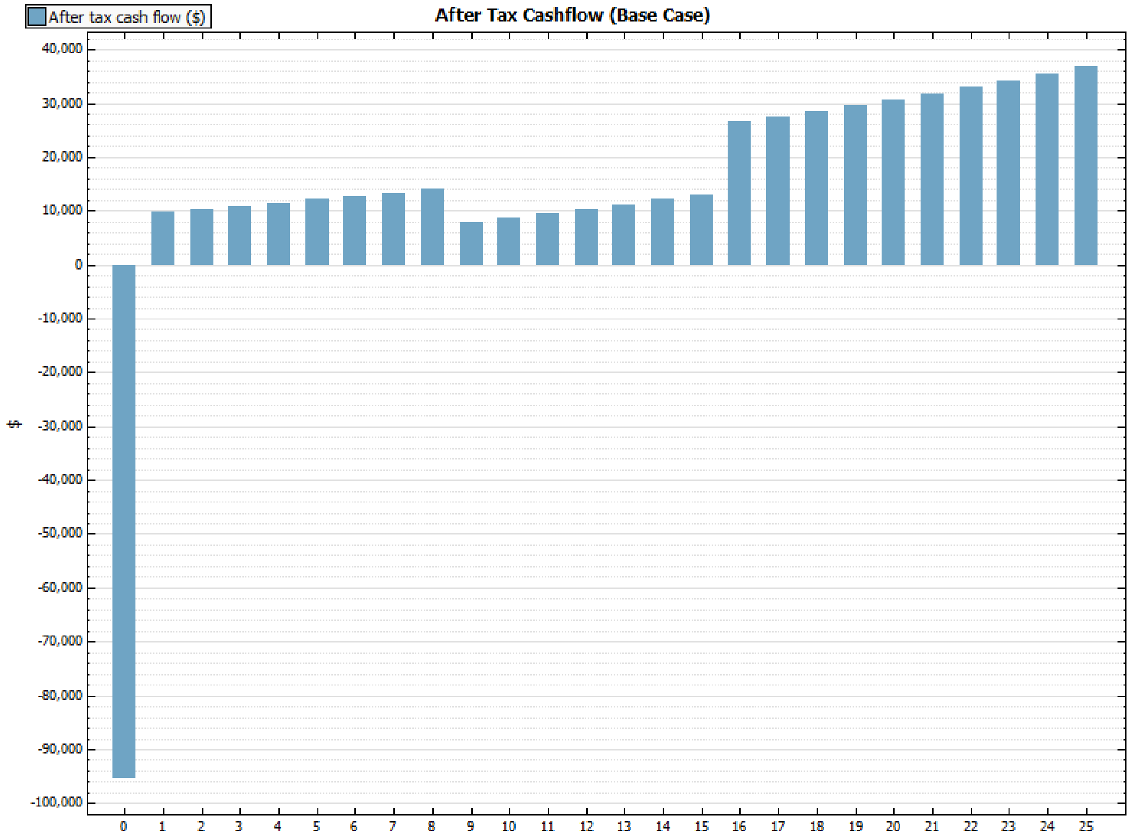

Figure D-6. 63-kW ground-mounted single-axis monthly annual cash flow

Appendix E. Results of the Job and Economic Development Impact Models

Appendix E shows the JEDI results from installing a 16-kW roof-mounted system. Other PV system sizes will be relative to this.

Table E-1. Photovoltaic Project Data Summary 16-kW Roof-Mounted System

Project Location	New Mexico
Year of Construction or Installation	2013
Average System Size - DC Nameplate Capacity (kW)	16.0
Number of Systems Installed	1
Project Size - DC Nameplate Capacity (kW)	16.0
System Application	Small Commercial
Solar Cell/Module Material	Crystalline Silicon
System Tracking	Fixed Mount
Total System Base Cost ($/kW$_{DC}$)	$2,853
Annual Direct Operations and Maintenance Cost ($/kW)	$25.00
Money Value – Current or Constant (Dollar Year)	2012
Project Construction or Installation Cost	$45,645
Local Spending	$29,953
Total Annual Operational Expenses	$5,588
Direct Operating and Maintenance Costs	$400
Local Spending	$364
Other Annual Costs	$5,188
Local Spending	$9
Debt Payments	$0
Property Taxes	$0

Table E-2. Local Economic Impacts – Summary Results

During Construction and Installation Period	Jobs	Earnings $000 (2012)	Output $000 (2012)
Project Development and On-Site Labor Impacts			
Construction and Installation Labor	0.1	$4.0	
Construction and Installation Related Services	0.1	$5.2	
Subtotal	0.2	$9.3	$16.2
Module and Supply Chain Impacts			
Manufacturing Impacts	0.0	$0.0	$0.0
Trade (Wholesale and Retail)	0.0	$1.9	$5.8
Finance, Insurance, and Real Estate	0.0	$0.0	$0.0
Professional Services	0.0	$1.2	$3.9
Other Services	0.0	$2.2	$7.5
Other Sectors	0.1	$2.3	$4.5
Subtotal	0.2	$7.6	$21.7
Induced Impacts	0.1	$3.0	$10.1
Total Impacts	**0.5**	**$19.8**	**$48.0**
During Operating Years	**Annual Jobs**	**Annual Earnings $000 (2012)**	**Annual Output $000 (2012)**
On-Site Labor Impacts			
PV Project Labor Only	0.0	$0.2	$0.2
Local Revenue and Supply Chain Impacts	0.0	$0.1	$0.2
Induced Impacts	0.0	$0.0	$0.1
Total Impacts	**0.0**	**$0.3**	**$0.5**

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 might not add up due to independent rounding.

Table E-3. Detailed PV Project Data Costs

Installation Costs	NEW MEXICO **Cost**	**Purchased Locally (%)**	**Manufactured Locally (Y or N)**
Materials and Equipment			
Mounting (rails, clamps, fittings, etc.)	$1,765	100%	N
Modules	$14,159	100%	N
Electrical (wire, connectors, breakers, etc.)	$1,136	100%	N
Inverter	$2,555	100%	N
Subtotal	$19,615		
Labor			
Installation	$4,024	100%	
Subtotal	$4,024		
Subtotal	$23,639		
Other Costs			
Permitting	$5,646	100%	
Other Costs	$2,305	100%	
Business Overhead	$13,050	100%	
Subtotal	$21,001		
Subtotal	$44,640		
Sales Tax (materials and equipment purchases)	$1,005	100%	
Total	$45,645		

Table E-4. PV System Annual Operating and Maintenance Costs

	Cost	Local Share	Manufactured Locally (Y or N)
Labor			
Technicians	$219	100%	
Subtotal	$219		
Materials and Services			
Materials and Equipment	$181	100%	N
Services	$0	100%	
Subtotal	$181		
Sales Tax (materials and equipment purchases)	$9	100%	
Average Annual Payment (interest and principal)	$5,178	0%	
Property Taxes	$0	100%	
Total	$5,588		
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	5.13%	100%	
Sales Tax Exemption (percent of local taxes)	0%		
Payroll Parameters	**Wage Per Hour**	**Employer Payroll Overhead**	
Construction and Installation Labor			
Construction Workers/Installers	$21.39	45.6%	
O&M Labor			
Technicians	$21.39	45.6%	