Feasibility Study of Economics and Performance of Solar Photovoltaics at the Crazy Horse Landfill Site in Salinas, California

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

Blaise Stoltenberg, Craig Konz, and Gail Mosey

Produced under direction of the Environmental Protection Agency (EPA) by the National Renewable Energy Laboratory (NREL) under Interagency Agreement IAG-09-1751 and Task No. WFD4.1001.

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Technical Report
NREL/TP-7A30-57893
March 2013
Contract No. DE-AC36-08GO28308

NATIONAL RENEWABLE ENERGY LABORATORY

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List of Acronyms

AC	alternating current
a-Si	amorphous silicon
BOS	balance of system
CdTe	cadmium telluride
CHL	Crazy Horse Landfill
CSI	California Solar Initiative
DC	direct current
EPA	U.S. Environmental Protection Agency
FTE	full-time equivalent
IRR	internal rate of return
ITC	investment tax credit
JEDI	Jobs and Economic Development Impact model
kW	kilowatt
kWh	kilowatt-hour
LCOE	levelized cost of energy
LFG	landfill gas
MACRS	modified accelerated cost recovery system
MW	megawatt
NEG	net energy generated
NREL	National Renewable Energy Laboratory
O&M	operations and maintenance
PG&E	Pacific Gas & Electric
PPA	power purchase agreement
PV	photovoltaic
REC	renewable energy certificate
SAM	System Advisor Model
SPE	special purpose entity
SSA	solar services agreement
SVSWA	Salinas Valley Solid Waste Authority
TOU	time of use
VNM	virtual net metering

Executive Summary

The U.S. Environmental Protection Agency (EPA), in accordance with the RE-Powering America's Land initiative, selected the Crazy Horse Landfill site in Salinas, California, for a feasibility study of renewable energy production. The National Renewable Energy Laboratory (NREL) was contacted to provide 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, operation and maintenance requirements, 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.

Crazy Horse Landfill[1] is located just north of Salinas, California, and is owned by the Salinas Valley Solid Waste Authority (SVSWA). The 160-acre sanitary landfill site has operated since 1934; before that, it was used as an open burn dump. During the 1970s, waste also came from the Firestone Tire and Rubber Company. Since 1987, Pacific Energy has operated a 1.3-MW landfill gas plant for electricity generation on site, which was recently dismantled and will likely be replaced by a 3.2-MW plant. The landfill was closed to the public in 2009. Recently, the landfill has been capped with a geomembrane and covered by artificial turf.

The feasibility of a PV system installed on a landfill Superfund site is highly impacted by the available area for an array, solar resource, operating status, ground conditions and restrictions, distance to transmission lines, and distance to major roads. The Crazy Horse Landfill has suitable area for a large-scale PV system, and the solar resource in Salinas, California, is adequate.

The Crazy Horse Landfill site is approximately 160 acres with about 20 acres appropriate for installation of a PV system. While this entire area does not need to be developed at one time, calculations for this analysis reflect the solar potential if the total feasible area is used. It is possible to add to the installed capacity as funding becomes available.

The economic feasibility of a potential PV system on the Crazy Horse Landfill site depends greatly on the purchase price of the electricity produced. For a net-metered system, the economics of the potential system can also be analyzed using the current electric rate for Pacific Gas and Electric (PG&E) of $0.17/kWh and incentives available to the site. Current incentives considered include the California Solar Initiative performance-based incentive of $0.088/kWh produced for government/non-profits. This is the last remaining tier of the California Solar Initiative (CSI) rebates for PG&E territory and has 84.4 MW of capacity remaining. The incentive is paid monthly for 5 years, and the total paid based on estimated production is over $600,000. To be eligible, the system must produce electricity for the on-site load, using the prior 12-month usage history. The maximum system size for the incentive is 1 MW, so using the entire area available at the site would exceed this restriction and make a portion or possibly all of the system ineligible for the CSI incentive. If the system is developed and owned by a third party as recommended, the CSI incentives become irrelevant as the system size is over 1 MW and is non-government owned. Table ES-1 summarizes the system performance and economics of a potential system that would use all available areas that were surveyed at the Crazy Horse Landfill site. The table shows the annual energy output from the system along with the number

[1] The EPA website that describes the Crazy Horse Landfill Superfund site is located at: http://yosemite.epa.gov/r9/sfund/r9sfdocw.nsf/vwsoalphabetic/Crazy+Horse+Sanitary+Landfill?OpenDocument.

of average American households that could be powered off of such a system and estimated job creation.

As indicated in Table ES-1, the maximum system size of 3.5 MW for crystalline technology produces approximately 5,253 MWh/yr. The system is expected to have a payback of 13–14 years if SVSWA owns the system or a 15% internal rate of return to the investor if the power is sold to the utility through a power purchase agreement (PPA)—a contract to sell electricity at a negotiated rate over a fixed period of time. The PPA price is estimated to be $0.16–$0.18/kWh with a levelized cost of energy (LCOE) of $0.14–$0.16/kWh assuming third-party PPA financing. This includes the current cost of energy, expected installation cost of PV, site solar resource, operation and maintenance, and no incentives for the proposed PV system. This LCOE and PPA price range is deemed reasonable and, as such, a solar PV system represents a good solution for the site if solar production can offset retail electricity use or if lower installed costs can be achieved.

The system economics presented in this analysis are based on many assumptions that represent the best information that NREL can reference at the time of the analysis and, therefore, should be considered best estimates. Only a firm proposal developed by a solar installer or developer will give the true economics of a system. Based on this, there are two assumptions that should be addressed specifically. First, no incentives were modeled in this economic analysis. Even though there appears to be no incentives presently available in California, it is likely there will be more in the future that will improve system economics. Second, system cost is based on published data with adjustments for tracking and landfill applications based on industry research. Costs in the solar industry are changing more rapidly than the availability of published data; therefore, the proposed system cost from a solar developer might be considerably less than calculated in this report and could greatly improve system economics.

Table ES-1. Crazy Horse Landfill PV System Performance and Economics by System Type

Financing	PV System Size[a]	Net Annual Output	Annual O&M	LCOE Real Low [b]	LCOE Real High [c]	PPA Price Low [b]	PPA Price High [c]	Payback Period Low [b]	Payback Period High [c]	Jobs Created [d]	Jobs Sustained [e]
	(kW)	(kWh/year)	($/year)	($/kWh)	($/kWh)	($/kWh)	($/kWh)	(years)	(years)	(job-year)	(job-year)
PPA/ Investor	3,500	5,253,204	105,000 (year 1-15)	0.139	0.156	0.155	0.175	n/a	n/a	103	1.3
Municipal Ownership			70,000 (year 16-25)	0.147	0.166	n/a	n/a	12.7	14.2		

[a] Data assume a maximum usable area of 20 acres and 5.74 acres/MW

[b] "Low" is low end of installed cost range: $3.49/Watt

[c] "High" is the high end of the installed cost range: $4.00/Watt

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

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

n/a: not applicable

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1 Site Background

The Crazy Horse Landfill is located in Salinas, California. Salinas is located about 8 miles inland from the Pacific Coast of Central California. The city of 150,000 is well known as the home of the author John Steinbeck and is the hub of the valley's agricultural industry. Utility services are provided by Pacific Gas & Electric (PG&E), which is an investor-owned utility and is regulated by the California Public Utilities Commission.

Under the RE-Powering America's Land initiative, the U.S. Environmental Protection Agency (EPA) provided funding to the National Renewable Energy Laboratory (NREL) to support a feasibility study of solar renewable energy generation at the Crazy Horse Landfill in Salinas, California. The site is approximately 160 acres and is located in northern Monterey County 5 miles northeast of the city. The site operated as a landfill and was in operation from 1934–2009. Ownership of the landfill started with a private owner, then the City of Salinas, and currently the Salinas Valley Solid Waste Authority (SVSWA).

The Crazy Horse Landfill stopped accepting waste and was closed to the public in May 2009. Approximately 6 acres of the landfill were closed in 1988 and covered with a high-density, polyethylene membrane and 2 feet of soil. The site is complemented with a water treatment system in an attempt to stabilize the groundwater contamination. Six extraction wells were initially installed as an interim measure, followed by the installation of 17 additional wells to completely capture the migrating plume. Adjacent residential wells were either permanently sealed or converted into extraction or monitoring wells. Contaminated water was pumped from the extraction wells and treated by air stripping. Treated water is stored in collection tanks and then either re-injected into the ground through 27 recharge wells or used for dust control.[2]

The remaining portion of the landfill is now capped with a geomembrane/artificial turf cover system or paved with asphalt/concrete. The full capacity of the current electrical distribution lines to the property are likely to be used by the proposed landfill gas generator and/or exceeded by a 3.5-MW solar generation project. PG&E has already completed a study for the proposed 5-MW landfill gas generation plant, which listed the Prunedale substation (approximately 3.36 miles distant) as the interconnection point and the estimated cost for interconnection at $4.8 million. The study indicated that no other interconnection point was listed for consideration by applicant but it is assumed that the Prunedale substation was the most viable location at the time of the study. There are possible plans by PG&E to build a switching station close to Crazy Horse Landfill (CHL), but it is unknown if an interconnection could be made there with the hope of a lower interconnection cost.

The site is currently undergoing closure construction and is owned and operated by the SVSWA. The landfill is currently listed as an EPA Superfund site. Pumps are operated on-site to contain and remediate plumes emanating from the landfill. Due to the nature of

[2]http://yosemite.epa.gov/r9/sfund/r9sfdocw.nsf/vwsoalphabetic/Crazy+Horse+Sanitary+Landfill?OpenDocument.

the site and closure system (i.e., closure turf), any system installation at the site should not penetrate the surface of the landfill. Any system design must be submitted by a civil engineer and approved by the State of California. Some modifications to the liner system could be made, if necessary.

Feasibility assessment team members from NREL, the SVSWA, and EPA conducted a site assessment visit on February 2, 2012, to gather information integral to this economic feasibility study. Information, including solar resource, transmission availability, community acceptance, and ground conditions, were considered.

2 Development of a Photovoltaic System on Landfills

One very promising and innovative use of contaminated sites is to install solar photovoltaic (PV) systems. PV systems can be ground-mounted, and these types of systems work well on landfill sites where there are commonly large un-shaded areas. Because of development restrictions placed on the site due to the remediation efforts, PV can often represent the highest and best use feasible, generating significant revenue on a site that would otherwise go unused.

The Crazy Horse Landfill is owned by SVSWA, which is interested in potential revenue flows from the site. Understanding opportunities studied and realized by other similar sites demonstrates the potential for PV system development. PV systems on landfill sites have been successful at other EPA cleanup sites, such as the 2-MW plant at Fort Carson, Colorado, which uses thin-film PV modules on 15 acres of a decommissioned landfill. Also, the Hickory Ridge Landfill near Atlanta, Georgia, uses an integrated thin-film PV landfill cap to generate 1 MW of power.

The SVSWA is also exploring options to create electricity from its landfill gas (LFG). The generation from a 3.2-MW LFG system could commence within a short timeframe as LFG collection lines are already in place and a similar system was operated on the site for a number of years. Although LFG appears to be a good possibility for the site during its remaining years of LFG production, this report focuses on PV as a longer-term energy generator and revenue producer for the site.

Most states rely heavily on fossil fuels to operate their power plants. There are many compelling reasons to consider moving toward renewable energy sources for power generation instead of fossil fuels, including:

- Using fossil fuels to produce power might not be sustainable
- Burning fossil fuels can have negative effects on human health and the environment
- Extracting and transporting fossil fuels can lead to accidental spills, which can be devastating to the environment and communities
- Depending on foreign sources of fossil fuels can be a threat to national security
- Fluctuating electric costs are associated with fossil-fuel-based power plants
- Burning fossil fuels may contribute to climate change
- Generating energy without harmful emissions or waste products can be accomplished through renewable energy sources
- Obtaining a long-term, stable, and predictable energy cost for remediation operations if SVSWA chooses to buy the solar power or own the system.

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).

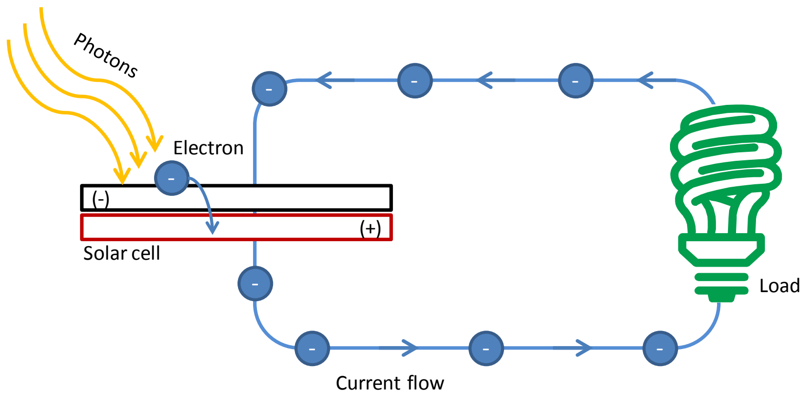

Figure 1. Generation of electricity from a PV cell

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

3.2 Major System Components

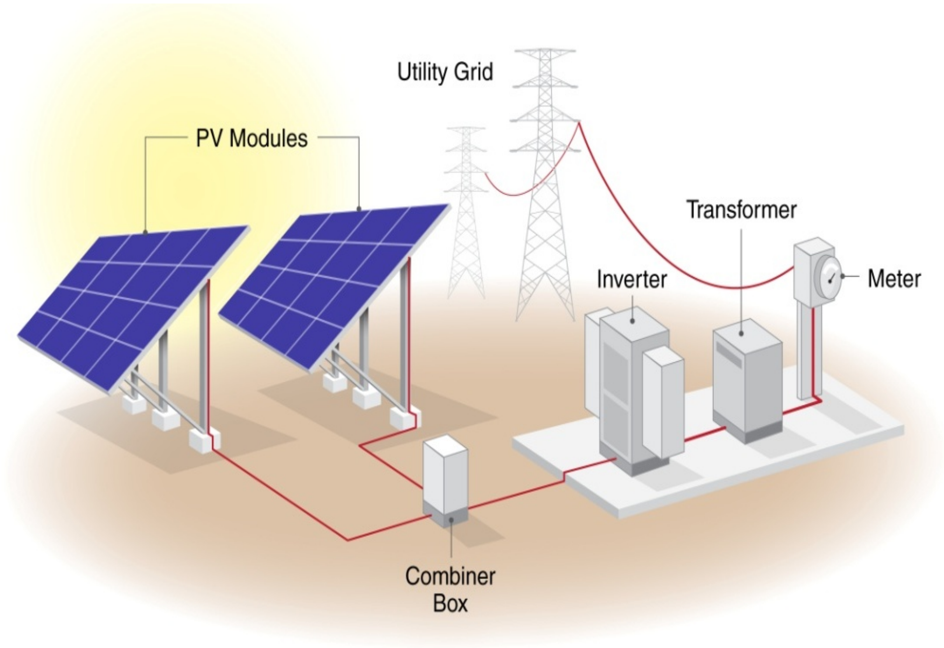

Figure 2. Ground-mounted array diagram

Source: NREL

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

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

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

3.2.1 PV Module

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

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

3.2.1.1 Crystalline Silicon

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

Typical overall efficiency of silicon solar panels is between 12% and 18%. However, some manufacturers of mono-crystalline panels claim an overall efficiency nearing 20%. This range of efficiencies represents significant variation among the crystalline silicon technologies available. The technology is generally divided into mono- and poly-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-crystalline and poly-crystalline silicon installed on tracking mounting systems.

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

3.2.1.2 Thin Film

Thin-film PV cells are made from amorphous silicon (a-Si) or non-silicon materials, such as cadmium telluride (CdTe). Thin-film cells use layers of semiconductor materials only a few micrometers thick. Due to the unique nature of thin films, some thin-film cells are constructed into flexible modules, enabling such applications as solar energy covers for landfills, such as a geomembrane system. Other thin-film modules are assembled into rigid constructions that can be used in fixed-tilt or, in some cases, tracking system configurations.

The efficiency of thin-film solar cells is generally lower than for crystalline cells. Current overall efficiency of a thin-film panel is between 6% and 8% for a-Si and 11% and 12% for CdTe. Figure 4 shows thin-film solar panels.

Figure 4. Thin-film solar panels installed on (left) solar energy cover and (middle/right) fixed-tilt mounting system. ***Photos by Republic Services, Inc., NREL 23817, (middle) Beck Energy, NREL 14726, and (right) U.S. Coast Guard Petaluma Site, NREL 17395***

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

3.2.2 Inverter

Inverters convert DC electricity from the PV array into AC and can connect seamlessly to the electricity grid. Inverter efficiencies can be as high as 98.5%.

Inverters also sense the utility power frequency and synchronize the PV-produced power to that frequency. When utility power is not present, the inverter will stop producing AC power to prevent "islanding" or putting power into the grid while utility workers are trying to fix what they assume is a de-energized distribution system. This safety feature is built into all grid-connected inverters in the market. Electricity produced from the system may be fed to a step-up transformer to increase the voltage to match the grid.

There are two primary types of inverters for grid-connected systems: string and micro-inverters. Each type has strengths and weaknesses and might be recommended for different types of installations.

String inverters are most common and typically range in size from 1.5–1,000 kW. These inverters tend to be cheaper on a capacity basis, as well as have high efficiency and lower operation and maintenance (O&M) costs. String inverters offer various sizes and capacities to handle a large range of voltage output. For larger systems, string inverters are combined in parallel to produce a single point of interconnection with the grid. Warranties typically run between 5 and 10 years with 10 years being the current industry standard. On larger units, extended warranties up to 20 years are possible. Given that the expected life of the PV panels is 25–30 years, an operator can expect to replace a string inverter at least one time during the life of the PV system.

Micro-inverters are dedicated to the conversion of a single PV module's power output. The AC output from each module is connected in parallel to create the array. This technology is relatively new to the market and in limited use in larger systems due to potential increase in O&M associated with significantly increasing the number of inverters in a given array. Current micro-inverters range in size between 175 W and 380 W. These inverters can be the most expensive option per watt of capacity. Warranties range from 10–20 years. Small projects with irregular modules and shading issues typically benefit from micro-inverters.

With string inverters, small amounts of shading on a solar panel will significantly affect the entire array production. Instead, it impacts only that shaded panel if micro-inverters are used. Figure 5 shows a string inverter.

Figure 5. String inverter. ***Photo by Warren Gretz, NREL 07985***

3.2.3 *Balance-of-System Components*

In addition to the solar modules and inverter, a solar PV system consists of other parts called BOS components, which include:

- Mounting racks and hardware for the panels
- Wiring for electrical connections.

3.2.3.1 Mounting Systems

The array has to be secured and oriented optimally to maximize system output. The structure holding the modules is referred to as the mounting system.

3.2.3.1.1 Ground-Mounted Systems

For ground-mounted systems, the mounting system can be either directly anchored into the ground (via driven piers or concrete footers) or ballasted on the surface without ground penetration. Mounting systems must withstand local wind loads, which range from 90–120 mph for most areas or 130 mph or more for areas with hurricane potential. Depending on the region, snow and ice loads must also be a design consideration for the mounting system. For brownfield applications, mounting system designs will be primarily driven by these considerations coupled with settlement concerns.

Typical ground-mounted systems can be categorized as fixed tilt or tracking. Fixed-tilt mounting structures consist of panels installed at a set angle, typically based on site latitude and wind conditions, to increase exposure to solar radiation throughout the year. Fixed-tilt systems are used at many brownfield sites. Fixed-tilt systems have lower maintenance costs but generate less energy (kWh) per unit power (kW) of capacity than tracking systems.

Tracking systems rotate the PV modules so they are following the sun as it moves across the sky. This increases energy output but also increases maintenance and equipment costs slightly. Single-axis tracking, in which PV is rotated on a single axis, can increase energy output up to 25% or more. With dual-axis tracking, PV is able to directly face the sun all day, potentially increasing output up to 35% or more. Depending on underlying soiling conditions, single- and dual-axis trackers may not be suitable due to potential settlement effects, which can interfere with the alignment requirements of such systems.

Table 1. Energy Density by Panel and System

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

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

3.2.3.2 Wiring for Electrical Connections

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

In most traditional applications, wiring from (1) the arrays to inverters and (2) inverters to point of interconnection is generally run as direct burial through trenches. In brownfield applications, this wiring may be required to run through above-ground conduit due to restrictions with cap penetration or other concerns. Therefore, developers should consider noting any such restrictions, if applicable, in requests for proposals in order to improve overall bid accuracy. Similarly, it is recommended that PV system vendors reflect these costs in the quote when costing out the overall system.

3.2.3.3 PV System Monitoring

Monitoring PV systems can be essential for reliable functioning and maximum yield of a system. It can be as simple as reading values such as produced AC power, daily kilowatt-hours, and cumulative kilowatt-hours locally on an LCD display on the inverter. For more sophisticated monitoring and control purposes, environmental data, such as module temperature, ambient temperature, solar radiation, and wind speed, can be collected. Remote control and monitoring can be performed by various remote connections. Systems can send alerts and status messages to the control center or user. Data can be stored in the inverter's memory or in external data loggers for further system analysis. Collection of this basic information is standard for solar systems and not unique to landfill applications.

Weather stations are typically installed in large-scale systems. Weather data, such as solar radiation and temperature, can be used to predict energy production, enabling comparison of the target and actual system output and performance and identification of under-performing arrays. Operators may also use this data to identify required maintenance, shade on panels, and accumulating dirt on panels, for example. Monitoring system data can also be used for outreach and education. This can be achieved with publicly available, online displays; wall-mounted systems; or even smart phone applications.

3.2.4 Operation and Maintenance

PV panels typically have a 25-year performance warranty. Inverters, which come standard with a 5-year or 10-year warranty (extended warranties available), would be expected to last 10–15 years. System performance should be verified on a vendor-provided website. Wire and rack connections should be checked annually. This economic analysis uses an annual O&M cost computed as $20/kW/yr, which is based on the historical O&M costs of installed fixed-axis, grid-tied PV systems. In addition, the system should expect a replacement of system inverters in year 15 at a cost of $0.25/W.

3.3 Siting Considerations

PV modules are very sensitive to shading. When shaded (either partially or fully), the panel is unable to optimally collect the high-energy beam radiation from the sun. As explained above, PV modules are made up of many individual cells that all produce a small amount of current and voltage. These individual cells are connected in series to produce a larger current. If an individual cell is shaded, it acts as resistance to the whole series circuit, impeding current flow and dissipating power rather than producing it.

The NREL solar assessment team uses a Solmetric SunEye solar path calculator to assess shading at particular locations by analyzing the sky view where solar panels will be located. By finding the solar access, the NREL team can determine if the area is appropriate for solar panels.

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

4 Proposed Installation Location Information

This section summarizes the findings of the NREL solar assessment site visit on February 2, 2012.

4.1 Crazy Horse Landfill Site PV System

As discussed in Section 1, the Crazy Horse Landfill site is managed by SVSWA. The site is 160 acres, with about 25 acres suitable for PV on the crown of the landfill. It is assumed that 80% of this (i.e., 20 acres) will be usable for PV after factoring, roads, LFG collection lines, and perimeter clearance. Figure 6 shows various views of the Crazy Horse Landfill site. As shown, there are large expanses of relatively flat (5% slope and under), un-shaded land, which makes it a suitable candidate for a PV system.

Figure 6. Views of the feasible area for PV at the Crazy Horse Landfill. ***Photos by Blaise Stoltenberg, NREL***

4.2 Utility-Resource Considerations

There are two possible options for the electrical tie-in point for the PV system at the Crazy Horse Landfill site. The most likely option for interconnection is PG&E's Prunedale 1107 distribution circuit approximately 3.5 miles to the southwest of the landfill. It appears the existing circuits are at capacity and new transmission will need to be built to accommodate the solar generation. The other option is a proposed switching station that could be approximately 2 miles away reducing the costs associated with building transmission from the PV site to the interconnection point. In 2011, a PG&E system impact study[3] was completed for a 5-MW LFG generator that estimated a $4.8 million total cost for transmission network upgrades, which is assumed to be a good proxy for the cost of a PV system interconnection unless the cost can be shared with another project. A more recent inquiry regarding a 3.2-MW LFG generator indicated that the interconnection costs would be higher than the $4.8 million calculated in the PG&E study.

The inverters and other power electronics (e.g., transformers) are likely to be placed near the solar panels under a canopy to shade from direct sunlight to reduce their temperature and increase efficiency and lifetime.

4.3 Feasible PV System Installation Area

PV arrays must be installed in un-shaded locations on the ground or on building roofs that have an expected life of at least 25 years.

Figure 7 shows an aerial view of the Crazy Horse Landfill site, and the feasible area for PV is shaded in orange. As shown, there is one relatively large area at the Crazy Horse Landfill site that is feasible for PV, which has an area of approximately 20 acres.

[3] "System Impact Study Generator Interconnection: Small Generator Interconnection Procedures." Salinas, CA: AMERESCO Crazy Horse LLC, May 2011.

Figure 7. Aerial view of the feasible area (orange) for PV at the Crazy Horse Landfill site

Credit: Google Earth

4.4 PV Site Solar Resource

The Crazy Horse Landfill site has been evaluated to determine the adequacy of the solar resource available using both on-site data and industry tools.

The assessment team for this feasibility study did not identify any shading obstructions on the recommended site and, therefore, found a solar access of 100%.

The predicted array performance was found using PVWatts Version 2 for Salinas, California.[4] Table 2 shows the station identification information, PV system specifications, and energy specifications for the site. For this summary array performance information, a hypothetical system size of 1 kW was used, allowing for clear inclusion in detailed economic analysis later in this report.

[4] PVWatts is a performance calculator for grid-connected PV systems. It was created by NREL's Renewable Resources Data Center. For more information, see http://www.nrel.gov/rredc/pvwatts/grid.html.

Table 2. Site Identification Information and Specifications

Station Identification	
Cell ID	173350
State	California
Latitude	36.7°N
Longitude	121.8°W
PV System Specifications	
DC Rating	1.00 kW
Derate Factor	0.8
AC Rating	0.80 kW
Array Type	Fixed Tilt
Array Tilt	20.0°
Array Azimuth	180.0°

Table 3 shows the performance results for a 1-kW, 20-degree fixed-tilt PV system in Salinas, California, as calculated by PVWatts Version 2.

Table 3. Performance Results for 1-kW, 20-Degree Fixed-Tilt PV

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)
1	3.54	82
2	4.55	97
3	5.18	122
4	6.40	145
5	6.72	160
6	6.97	158
7	6.75	157
8	6.38	149
9	6.05	135
10	4.87	112
11	3.96	88
12	3.34	77
Year	5.40	1,481

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4.5 Crazy Horse Landfill Energy Usage

The Crazy Horse Landfill site has a remediation system to capture contaminated ground water. The pumps used for remediation, recharging, and dust control likely use the majority of power presently consumed on-site.

4.5.1 Current Energy Use

The site has three different PG&E meters. Two of the meters are on the A1 Small General Service rate and record no or very low energy consumption. The other meter records considerably higher usage (22,880 kWh in May 2012) and is on the A10S Medium General Demand-Metered Service rate. It is recommended that the electricity from the system be sold directly to the utility, making the on-site consumption irrelevant. The current market price referrals in California are around $120/MWh, so it is expected that the PPA rate would be in a similar range. The majority of the energy use—364,188 kWh annually—is for the operation of the remediation pumps as well as the buildings on-site, specifically the gas recycling facility. The average utility rate given in the application is $0.17/kWh. Table 4 lists the meters, rate schedule, and consumption.

Table 4 . Meters and Rate Schedules

Meter ID	Rate Schedule	Total Annual Energy Consumption (kWh)	May 2012 Energy Consumption (kWh)
1009552593	A1-SG	Not available	0
1009552591	A1-SG	Not available	72
23675	A10S-MGDM	Not available	22,880

Table 5. PG&E A-1 Rate Schedule

Rate Schedule	Customer Charge	Season	Time-of-Use Period	Demand Charge (per kW)	Time-of-Use Period	Total Energy Charge (per kWh)
A-1	Single Phase Service per meter/day = $0.32854 Polyphase Service per meter/day = $0.65708	**Summer**		-		$0.20522
		Winter		-		$0.14493

Table 6. PG&E A-10 Rate Schedules

Rate Schedule	Customer Charge	Optional Meter Data Access Charge	Season	Demand Charge (per kW)	Time-of-Use Period	Energy Charges (per kWh)	PDP[1/] Charges	PDP[2/] Credits DEMAND (per kW)	PDP[2/] Credits ENERGY (per kWh)	"Average" Total Rate[3/] (per kWh)
A-10 **<u>TOU Secondary</u>** (Table B) Customers with high electric use and medium to high load factors generally benefit under Schedule A-10 TOU. Part of customer's bill varies according to the customer's maximum monthly electric demand.	$4.59959 per meter per day	$0.98563 per meter per day	**Summer**	$12.15	Peak	$0.15130	$0.90	($2.11)	($0.00875)	$0.15974
					Part-Peak	$0.14543			($0.00875)	
					Off-Peak	$0.12759			($0.00875)	
			Winter	$5.63	Part-Peak	$0.11116		-	-	
					Off-Peak	$0.09586				
A-10 **<u>TOU Primary</u>** (Table B) Customers with high electric use and medium to high load factors generally benefit under Schedule A-10 TOU. Part of customer's bill varies according to the customer's maximum monthly electric demand.			**Summer**	$11.38	Peak	$0.14026	$0.90	($1.99)	($0.00899)	$0.14847
					Part-Peak	$0.13607			($0.00899)	
					Off-Peak	$0.12008			($0.00899)	
			Winter	$5.84	Part-Peak	$0.10545		-	-	
					Off-Peak	$0.09293				
A-10 **<u>TOU Transmission</u>** (Table B) Customers with high electric use and medium to high load factors generally benefit under Schedule A-10 TOU. Part of customer's bill varies according to the customer's maximum monthly electric demand.			**Summer**	$7.47	Peak	$0.11521	$0.90	($2.23)	($0.00648)	$0.12227
					Part-Peak	$0.11139			($0.00648)	
					Off-Peak	$0.09686			($0.00648)	
			Winter	$4.13	Part-Peak	$0.09260		-	-	
					Off-Peak	$0.08108				

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,[5] 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.[6]

California's net-metering law,[7] which took effect in 1996, requires utilities to offer net metering to all customers with solar and wind-energy systems up to 1 MW. The portion of the Crazy Horse Landfill system in excess of 1 MW will therefore be ineligible for net metering. Also, the estimated annual production from a 3.5-MW system located at the site would be much larger than site consumption (5.2 million kWh produced compared to 364,000 kWh consumed).

Renewable energy certificates (RECs),[8] also known as green certificates, green tags, or tradable renewable certificates, are tradable commodities in the United States that represent proof of electric energy generation from eligible renewable energy resources (renewable electricity). The RECs that are associated with the electricity produced and are used on-site remain with the customer-generator. If, however, the customer chooses to receive financial compensation for the net-energy generated (NEG) remaining after a 12-month period, the utility will be granted the RECs associated with only that surplus they purchase.

California does not allow any new or additional demand charges, standby charges, customer charges, minimum monthly charges, interconnection charges, or other charges that would increase an eligible customer-generator's costs beyond those of other customers in the rate class to which the eligible customer-generator would otherwise be assigned. The California Public Utility Commission has explicitly ruled that technologies eligible for net metering (up to 1 MW) are exempt from interconnection application fees, as well as from initial and supplemental interconnection review fees.

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[5] For the full text of this bill see, http://www.gpo.gov/fdsys/pkg/PLAW-109publ58/pdf/PLAW-109publ58.pdf.
[6] Adopted by the Energy Policy Act of 2005 on page370, Subtitle E – Amendments to PURPA.
[7] For more information about California's net-metering law, see http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=CA02R&re=1&ee=1.
[8] For a description of RECs, see http://apps3.eere.energy.gov/greenpower/markets/certificates.shtml.

Publicly owned utilities may elect to provide co-energy metering, which is the same as net metering except that it incorporates a time-of-use (TOU) rate schedule. Customer-generators with systems sized between 10 kW and 1 MW, who are subject to TOU rates, are entitled to return electricity to the system for the same TOU (including real-time) price that they pay for power purchases. However, TOU customers who choose to co-energy meter must pay for the metering equipment capable of making such measurements. Customer-generators retain ownership of all RECs associated with the generation of electricity they use on-site.

4.5.3 Virtual Net Metering

Some states and utilities allow for virtual net metering (VNM). This arrangement can allow certain entities, such as a local government, to install renewable generation of up to 1 MW at one location within its geographic boundary and to generate credits that can be used to offset charges at one or more other locations within the same geographic boundary. California Assembly Bill 2466 (AB 2466),[9] codified as Section 2830 of the Public Utilities Code, was signed into law by Governor Schwarzenegger in September 2008 and became effective on January 1, 2009.[10]

The California State Legislature defined local government to include cities, counties, school districts, special districts, political subdivisions, or other local public agencies that are authorized to generate electricity. The legislature decided that the tariff would not be available for the state, any agency or department of the state, or any joint powers authority. This law could be used to offset power use at other SVSWA sites if needed but is also subject to the 1-MW maximum and, therefore, may not be feasible for the site. If a deal could be structured into two systems at the same site, up to 1 MW of the PV could be used for net metering and/or VNM while the rest would probably be a PPA with PG&E or another offtaker.

[9] California Legislature. Assembly Bill No. 2466. (Apr. 28, 2010). Accessed May 1, 2012: http://www.leginfo.ca.gov/pub/09-10/bill/asm/ab_2451-2500/ab_2466_bill_20100428_amended_asm_v98.pdf.

[10] For more information about VNM, see http://www.pge.com/b2b/newgenerator/ab2466/.

5 Economics and Performance

5.1 Assumptions and Input Data for Analysis

For this analysis, the following input data were used. The installed cost (i.e., all costs of a system except land cost and extraordinary interconnection cost) of a fixed-tilt ground-mounted system was assumed to be a range from $2.79/W–$3.20/W,[11] and the installed cost of a single-axis tracking system was assumed to be $3.35/W–$3.84/W. Single-axis tracking is not recommended for a landfill site with potential settling of the ground. The estimated increase in cost from this baseline for a ballasted system is 25%, bringing the assumed installed cost of a ground-mounted fixed-tilt ballasted system to $3.49/W–$4.00/W. A ballasted system is recommended due to the unique nature of the landfill site and the necessity for being able to easily adjust the ground-mounted racking system. 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. 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 $0.17/kWh, as reported by the State of California, based on electric bills for the site.[12]

A system derating of 80% was assumed. This included inverter losses, wire losses, PV module losses, and losses due to temperature effects. The System Advisor Model (SAM) and PVWatts Version 2 were both used to calculate energy performance.

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

Table 7 shows the technical and financial assumptions made for the included analysis. There were two primary financial structures considered: third-party ownership (PPA) and non-taxable entity owned (i.e., SVSWA). Summary assumptions are in Appendix A.

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[11] *Residential, Commercial, and Utility-Scale Photovoltaic (PV) System Prices in the United States: Current Drivers and Cost-Reduction Opportunities.* NREL/TP-6A20-53347, February 2012, p.33. Accessed February 6, 2013: http://www.nrel.gov/docs/fy12osti/53347.pdf.

[12] Solar Energy Industries Association "SEIA/GTM Research U.S. Solar Market Insight" 2011 year-end report. http://www.seia.org/cs/research/SolarInsight.

Table 7. Financial and Technical Assumptions Used in Analysis

	Assumptions		
Inputs	**PPA/Investor**	**Municipal Ownership**	**Notes**
TMY3	Salinas Municipal Airport	Salinas Municipal Airport	
Utility rate	N/A	0.17	Flat buy and sell rate with 2% utility rate escalation, net metering enabled
Analysis period (years)	25	25	
Inflation	2.50%	2.50%	
Real discount rate	5.85%	3.00%	
Federal tax rate	35%	0%	
State tax rate	8%	0%	
Insurance (% of installed cost)	0.50%	0.50%	
Property tax	0	0	0% per DSIRE for California
Construction loan	0	0	
Loan term	20	25	
Loan rate	6%	4%	
Debt fraction	46%	100%	45%–60% PPA, 100% municipal ownership, debt service coverage ratio of ~1.3 (>1.2)
Minimum internal rate of return	15%	N/A	
PPA escalation rate	1.50%	N/A	
Federal depreciation	5-year Modified accelerated cost recovery system MACRS with 50% 1st year bonus depreciation (50%,16%, 19.6%, 5.7%, 6%, 5.76%, 2.88%)	None	N/A for municipal ownership
State depreciation	5-year MACRS	None	N/A for municipal ownership

Fed investment tax credit (ITC)	30%	None	N/A for municipal ownership
Payment incentives	None	None	
Degradation	0.50%	0.50%	
Availability	100%	100%	
Cost range low - landfill ballasted per kW	$3,490.00	$3,490.00	
Cost range high- landfill ballasted per kW	$4,000.00	$4,000.00	
Grid interconnnection cost	$ -	$ -	
Land cost	$ -	$ -	
O&M	$30/kW/yr first 15 yrs & $20/kW/yr for yrs 16-25	$30/kW/yr first 15 yrs & $20/kW/yr for yrs 16-25	
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	

5.2 SAM Forecasted Economic Performance

Using the inputs and assumptions summarized in Section 5.1, the SAM tool predicts the levelized cost of energy (LCOE), PPA price, and payback period.

The LCOE in cents per kilowatt-hour accounts for a project's installation, financing, tax, and operating costs and the quantity of electricity it produces over its life. The LCOE makes it possible to compare alternatives with different project lifetimes and performance characteristics. Analysts can use the LCOE to compare the option of installing a residential or commercial project to purchasing electricity from an electric service provider or to compare utility and commercial PPA projects with investments in energy efficiency, other renewable energy projects, or conventional fossil fuel projects. The LCOE captures the trade-off between typically higher-capital-cost, lower-operating-cost renewable energy projects and lower-capital-cost, higher-operating-cost fossil-fuel-based projects.

The PPA price is the first-year price that electricity could be sold to the property owner allowing the developer to own a certain internal rate of return (IRR). For this analysis, the required IRR used was 15%, and the first-year PPA price escalates at 1.5% per year.

The payback period is the time in years that it takes for the capital investment to be recovered based on the dollar amount of savings. For this analysis, the price of electricity is $0.17/kWh with an escalation rate of 2% per year.

The system economics presented in this analysis are based on many assumptions that represent the best information that NREL can reference at the time of the analysis and, therefore, should be considered best estimates. Only a firm proposal developed by a solar installer or developer will give the true economics of a system. Based on this, there are two assumptions that should be addressed specifically. First, no incentives were modeled in this economic analysis. Even though there appears to be no incentives presently available in California, it is highly likely there will be more in the future that will improve system economics. Second, system cost is based on published data with adjustments for tracking and landfill applications based on industry research. Costs in the solar industry are changing more rapidly than the availability of published data; therefore, the proposed system cost from a solar developer might be considerably less than calculated in this report and could greatly improve system economics.

SAM results are available in Appendix B. A summary of the results of the economic analysis and the system considered is shown in Table 8.

Table 8. Crazy Horse Landfill Site Summary

<table>
<tr><th>Financing</th><th>PV System Size[a]</th><th>Net Annual Output</th><th>Annual O&M</th><th>LCOE Real Low [b]</th><th>LCOE Real High [c]</th><th>PPA Price Low [b]</th><th>PPA Price High [c]</th><th>Payback Period Low [b]</th><th>Payback Period High [c]</th><th>Jobs Created [d]</th><th>Jobs Sustained [e]</th></tr>
<tr><th></th><th>(kW)</th><th>(kWh/year)</th><th>($/year)</th><th>($/kWh)</th><th>($/kWh)</th><th>($/kWh)</th><th>($/kWh)</th><th>(years)</th><th>(years)</th><th>(job-year)</th><th>(job-year)</th></tr>
<tr><td>PPA/ Investor</td><td rowspan="2">3,500</td><td rowspan="2">5,253,204</td><td rowspan="2">105,000 (year 1-15) 70,000 (year 16-25)</td><td>0.139</td><td>0.156</td><td>0.155</td><td>0.175</td><td>n/a</td><td>n/a</td><td rowspan="2">103</td><td rowspan="2">1.3</td></tr>
<tr><td>Municipal Ownership</td><td>0.147</td><td>0.166</td><td>n/a</td><td>n/a</td><td>12.7</td><td>14.2</td></tr>
</table>

[a] Data assume a maximum usable area of 20 acres and 5.74 acres/MW
[b] "Low" is low end of installed cost range: $3.49/Watt
[c] "High" is the high end of the installed cost range: $4.00/Watt
[d] Job-years created as a result of project capital investment including direct, indirect, and induced jobs.
[e] Jobs (direct, indirect, and induced) sustained as a result of operations and maintenance (O&M) of the system.
n/a: not applicable

5.3 Job Analysis and Impact

To evaluate the impact on employment and economic impacts of the PV project associated with this analysis, the NREL Jobs and Economic Development Impact (JEDI) models are used.[13] JEDI estimates the economic impacts associated with the construction

[13] 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 information on JEDI, see http://www.nrel.gov/analysis/jedi/about_jedi.html.

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 support by the proposed facility.

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

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

For the Crazy Horse Landfill site, the following values were assumed:

- Capacity: 3.5 MW
- Placed in service year: 2013
- Installed system cost: $13,707,678
- Location: California.

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

The estimates of jobs associated with this project are presented as either construction period jobs or sustained operations jobs. Each job is expressed as a whole, or fraction, full-time equivalent (FTE) position. An FTE is defined as full-time employment 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 (i.e., typically 12–18 months).

As indicated in the results of the JEDI analysis provided in Appendix C, the total proposed system is estimated to support 103 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 $5.4 million, and total economic output is estimated to be $13.7 million. The annual O&M of the new PV system is estimated to support 1.3 FTEs per year for the life of the system. The jobs and associated spending are projected to account for approximately $76,000 in earnings and $140,000 in economic activity each year for the next 25 years.

5.4 Financing Opportunities

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

5.4.1 Owner and Operator Financing

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

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

5.4.2 Third-Party Developers with Power Purchase Agreements

Because many project site hosts do not have the financial or technical capabilities to develop a capital intensive project, many times they turn to third-party developers (and/or their investors). In exchange for access to a site through a lease or easement arrangement, third-party developers will finance, develop, own, and operate solar projects utilizing their own expertise and sources of tax equity financing and debt capital. Once the system is installed, the third-party developer will sell the electricity to the site host or local utility via a PPA. The PPA typically will be between the third-party developer and the site host if it is a retail (behind the meter) transaction or directly with an electric utility if it is a wholesale transaction.

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

5.4.3 Third-Party "Flip" Agreements

The most common use of this model is a site host working with a third-party developer who then partners with a tax-motivated investor in a 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 and Salt Lake City.

5.4.5 Solar Services Agreement and Operating Lease

The solar services agreement (SSA) and operating lease business models have been predominately used in the municipal and cooperative utility markets due to its treatment of tax benefits and the rules limiting federal tax benefit transfers from non-profit to for-profit companies. Under IRS guidelines, municipalities cannot enter capital leases with for-profit entities when the for-profit entities capture tax incentives. As a result, a number of business models have emerged as a workaround to this issue. One model is the SSA, wherein a private party sells solar services (i.e., energy and RECs) to a municipality over a specified contract period (typically long enough for the private party to accrue the tax credits). The non-profit utility typically purchases the solar services with either a one-time up-front payment equal to the turn-key system cost minus the 30% federal tax credit or may purchase the services in annual installments. The municipality may buy out the system once the third party has accrued the tax credits, but due to IRS regulations, the buyout of the plant cannot be included as part of the SSA (i.e., the SSA cannot be used as a vehicle for a sale and must be a separate transaction).

Similar to the SSA there are a variety of lease options that are available to municipalities that allow the capture of tax benefits by third-party owners, which result in a lower cost to the municipality. These include an operating lease for solar services (as opposed to an equipment capital lease).

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, they would be responsible for operating and maintaining the solar system as well as have the right to sell or use the power. In exchange for 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 entity is allowed to buy back the project at 100% fair market value after the tax benefits are exhausted.

5.4.7 Community Solar/Solar Gardens

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

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

There are some states that offer solar incentives for community solar projects, including Washington State (production incentive) and Utah (state income tax credit). Community solar is known as solar gardens depending on the location (e.g., Colorado).

6 Conclusions and Recommendations

The site location considered for a solar PV system in this report is a suitable area in which to implement solar PV systems. Using land that cannot be used for other purposes would minimize the environmental impact of a solar generation plant. Installing a PV system on the compromised land at the site could generate approximately 5.2 million kWh annually and represent a significant distributed generation facility for the area.

To establish the financial performance of the system, an analysis was performed using SAM.[14] Using the inputs and assumptions summarized in Section 5.1, the SAM tool predicts the IRR and the LCOE. The PPA option gives the investor an after tax IRR of 15% with an LCOE of $0.14–$0.16/kWh. The municipal ownership option has a payback period of 13–14 years with an LCOE of $0.15–$0.17/kWh. The entire results and summary of inputs to the SAM is available in Appendix B.

It is recommended that the site owner, SVSWA, further pursue opportunities for a solar system installation on the Crazy Horse Landfill site. The next steps for solar development are:

1. Determine financing structure
2. Issue request for proposal
3. Review proposals
4. Award contracts.

For multiple reasons—the high cost of energy, the dropping cost of PV, and the existence of a good solar resource and possible incentives—this report finds that a PV system is a reasonable use for the site. A government-owned PV system that provides a reasonable payback and is easy to implement is one recommended option if off-takers for the power can be found. Alternatively, a third-party ownership PPA may be the most feasible way for a system to be financed and installed on this site. Depending on the available capital and business model, an RFP could be written for any one of the finance options presented in Section 5.4.

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

Appendix A. Assessment and Calculations Assumptions

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

Cost Assumptions			
Variable	**Quantity of Variable**	**Unit of Variable**	
Cost of Site Electricity	0.17	$/kWh	
Annual O&M (fixed)	30 (first 15 years), 20 (years 16-25)	$/kW/year	
System Assumptions			
System Type	**Annual energy kWh/kW**	**Installed Cost ($/W)**	**Energy Density (MW/acre)**
Ground Fixed	1,501	$3.49–$4.00	5.74
Other Assumptions			
	1 acre	43,560 ft^2	
	1 MW	1,000,000 W	
	Ground utilization	80% of available area	

Appendix B. Results of the System Advisor Model

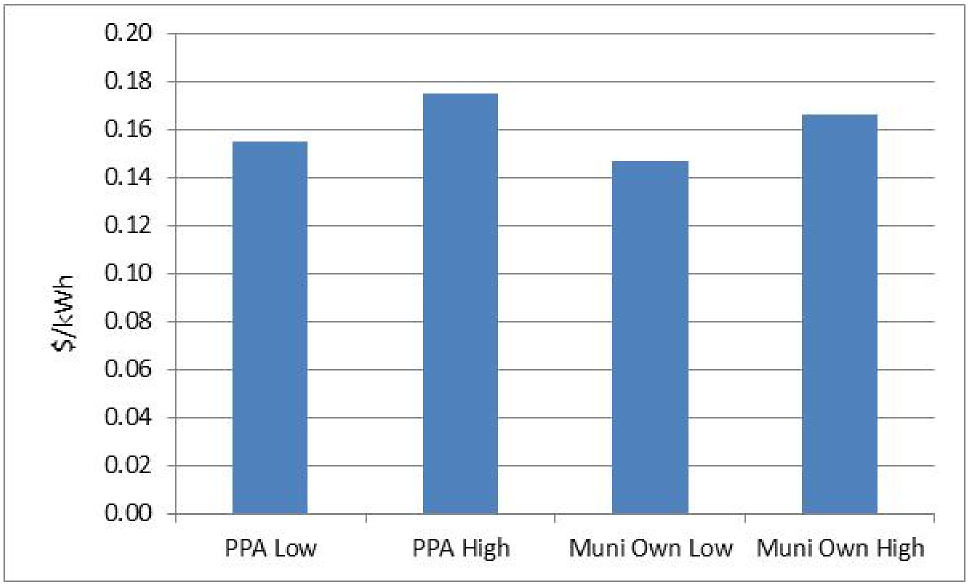

Figure B-1. Cost of electricity for different costs and ownership options

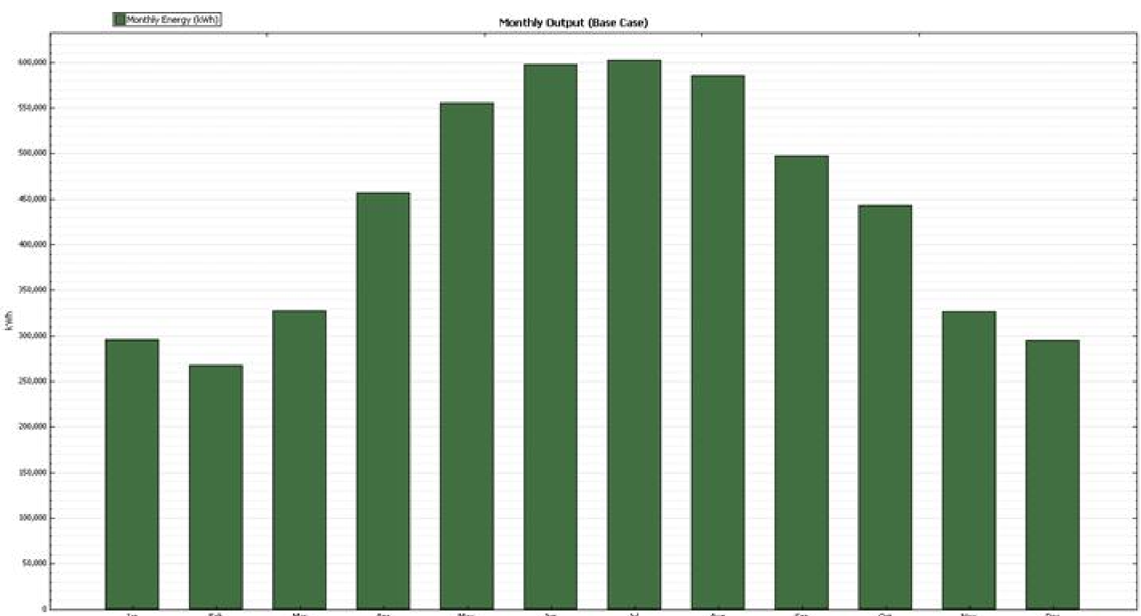

Figure B-2. System electricity production

Appendix C. Results of the JEDI Model

Photovoltaic - Project Data Summary based on model default values	
Project Location	California
Year of Construction or Installation	2013
Average System Size - DC Nameplate Capacity (kW)	3,500
Number of Systems Installed	1
Total Project Size - DC Nameplate Capacity (kW)	3,500
System Application	Utility
Solar Cell/Module Material	Crystalline Silicon
System Tracking	Fixed Mount
Base Installed System Cost ($/kWDC)	$3,916
Annual Direct Operations and Maintenance Cost ($/kW)	$25.00
Money Value - Current or Constant (Dollar Year)	2012
Project Construction or Installation Cost	$13,707,678
Local Spending	$6,644,914
Total Annual Operational Expenses	$1,612,888
Direct Operating and Maintenance Costs	$87,500
Local Spending	$80,500
Other Annual Costs	$1,525,388
Local Spending	$2,888
Debt Payments	$0
Property Taxes	$0

Local Economic Impacts - Summary Results

	Jobs	Earnings	Output
During construction and installation period		**$ (2012)**	**$ (2012)**
Project Development and On-Site Labor Impacts			
Construction and Installation Labor	18.5	$1,195.90	
Construction and Installation Related Services	21.1	$992.10	
Subtotal	39.6	$2,188.00	$3,645.70
Module and Supply Chain Impacts			
Manufacturing	0.0	$0.00	$0.00
Trade (Wholesale and Retail)	4.5	$263.90	$794.00
Finance, Insurance, and Real Estate	0.0	$0.00	$0.00
Professional Services	6.2	$313.70	$1,063.60
Other Services	10.5	$771.60	$2,672.90
Other Sectors	15.6	$603.40	$1,156.50
Subtotal	36.9	$1,952.50	$5,687.10
Induced Impacts	27.0	$1,231.90	$4,377.20
Total Impacts	**103.5**	**$5,372.40**	**$13,710.00**

During Operating Years	Annual Jobs	Annual Earnings $ (2012)	Annual Output $ (2012)
On-Site Labor Impacts			
PV Project Labor Only	0.8	$48.80	$48.80
Local Revenue and Supply Chain Impacts	0.3	$16.10	$53.20
Induced Impacts	0.2	$10.60	$37.60
Total Impacts	**1.3**	**$75.50**	**$139.60**

Notes: Earnings and Output values are thousands of dollars in year 2012 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 up due to independent rounding.