



United States Environmental Protection Agency

Solar Photovoltaic Screening Study of Properly Closed Municipal Solid Waste Landfills - Siting Solar Photovoltaics at the Town of Gardiner Landfill, New York

Prepared by the Environmental Protection Agency, Region 2
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Acknowledgments:

We would like to thank Marybeth Majestic, Town Supervisor for her assistance with facilitating the Town of Gardiner landfill visit.

This report is to be used for screening purposes only.

Additional evaluations will need to be conducted to fully characterize the feasibility and economics of the Gardiner landfill for photovoltaic (PV) installation. Third party solar developers and local utility companies may have technical and financial interests in pursuing potential solar renewable energy projects and should perform additional solar assessments to determine if projects are economically viable.

While the Town of Gardiner landfill has been screened for solar PV, the findings of this solar screening study should not be the sole basis for determining if a PV system at the site is viable. The results of this study are presented in an unbiased manner.

This study does not assess the environmental conditions at the site.

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Table of Contents

I. Purpose of the Solar Screening Report	3
II. Background	3
III. Solar PV System Overview	4
IV. Solar PV Siting Consideration/Assessment	5
V. PVWatts System Sizing and Performance Results	9
VI. Forecasted Economics	10
VII. Benefits	11
VIII. RE-Powering America's Land	13
IX. Conclusions	14
X. Next Steps	15

List of Tables

Table 1. Siting considerations for solar photovoltaics	5
Table 2. Potential off-takers for the Gardiner Landfill	8
Table 3. PV Watts Site Identification Information for the Gardiner Landfill	9
Table 4. PV System Yearly Performance Results for the Gardiner Landfill	10
Table 5. PVWatts Initial Economic Considerations	11
Table 6. Summary of Applicable Incentives	13

Attachments

Attachment #1 – SunEye Solar Measurements	17
Attachment #2 – Monthly Performance Results for the Gardiner Landfill	18
Attachment #3 – PV Systems Overview	19
Attachment #4 – Glossary or Definition of Terms	22

I. Purpose of the Solar Screening Report

Through the U.S. EPA RE-Powering America's Land Initiative, EPA promotes the reuse of potentially contaminated properties, landfills, and mining sites for renewable energy generation. This initiative identifies the renewable energy potential of these sites and provides useful resources for communities, developers, industry, state and local governments or anyone interested in reusing these sites for renewable energy development. A list of RE-Powering America Initiative resources is provided at the end of this report (Section VIII) and can be found at <http://www.epa.gov/oswercpa>.

This solar screening report provides screening/preliminary information to assist the Town of Gardiner officials in determining the potential for solar photovoltaic (PV) electricity generation at the town landfill. In general, the solar PV system represented in this report is a standalone system sized on proposed available area located at the Gardiner Landfill. It should be noted that the viability of implementing a solar PV system on a landfill is highly impacted by the available area for an array, solar resource, shading, operating status, landfill cap status, distance to transmission lines, distance to major roads, favorable economic conditions, and community support.

II. Background

According the US Census as of 2010, the population of Gardiner is approximately 5,713 people. The Gardiner Landfill is operated by officials of the Town of Gardiner and located in 139 Steves Lane, Gardiner, Ulster County, New York. The landfill is situated approximately 0.67 miles west of the Dusenberre Road, north of US Route 44/New York State Route 55, and east of Wallkill River.

A passive venting system exists on the landfill to manage landfill gas emissions which must be considered before installing solar panels as they may obstruct construction. The New York State Department of Environmental Conservation (NYSDEC) requires quarterly and/or annual monitoring pursuant to approved closure plans and solid waste management facility regulations. For more information about the landfill covers, landfill designs, and NYSDEC annual monitoring, contact **James Lansing Region 3 - Materials Management Supervisor**, New Paltz Regional NYSDEC Sub-Office, via email james.lansing@dec.ny.gov or call (845) 256-3000.

III. Solar PV System Overview

Major System Components - A typical PV system is made up of several key components including:

- PV modules,
- Inverters and
- Balance-of-System components (including mounting racks, hardware for the panels, and 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 the arrays to inverters (typically positioned off the landfill cap) and inverters to point of interconnection is generally run as direct burial through trenches or above ground using water/gas proof electrical conduits. For landfills, a solar PV array is connected to a mounting system that is anchored to a uniformly loaded concrete foundation or a ballasted system (see figure 1). It is recommended that PV system vendors reflect these costs in the requests for proposals when costing out the overall system.

Additional information about solar PV systems can be reviewed in Attachment #3.



Figure 1. Kinsley Landfill NJ, 11.15 MW – PSEG Solar for All Program
https://www.pseg.com/info/media/newsreleases/2015/2015-02-05.jsp#_WHegL33J6BQ

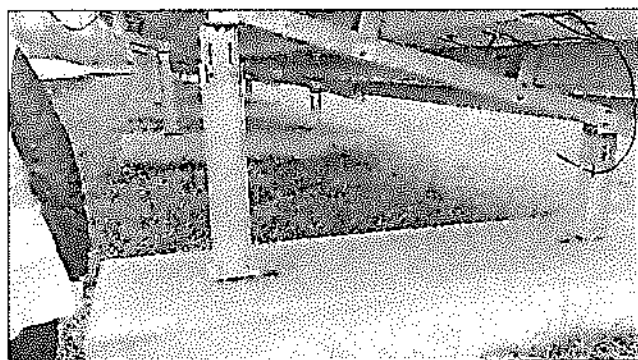
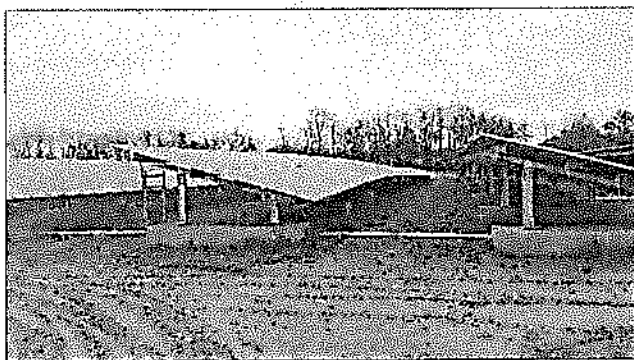


Figure 2. Fixed Axis Solar PV Array on a ballasted concrete foundation

IV. Solar PV Siting Consideration/Assessment

Siting Considerations

On January 25, 2017, the U.S. Environmental Protection Agency, Region 2 (EPA) team, in cooperation with Town of Gardiner officials visited and screened the closed landfill for potential solar photovoltaic (PV) renewable energy generation. In general, for closed landfills, a minimum of 2 usable acres is recommended to site PV systems. Usable 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. Other considerations for siting landfills for solar PV generation include:

Table 1. Siting considerations for solar photovoltaics

Siting Concerns	Looking for
Age of the properly closed/capped landfill	Minor settlement impacts based on the type of waste and age of the landfill. Landfill cap integrity must be maintained during construction and life of the solar PV array.
Site topography	Existing flat area and surface stability for the PV Array. Avoid slope/grade landfill areas > 10 degrees. Slope instability can give way and displace panels & impact solar performance.
Surface and vegetative conditions	Well maintained vegetative cover with minimum soil erosion concerns. Need to have existing storm water controls.
Shading/physical sunlight obstructions on the landfill	Open area with minimum shading from trees and existing on-site buildings in order to maximize sunlight on each solar panel.
Available access roads and close distance to highways/developed roads	Developed roads and easy access for material shipment and to support heavy construction vehicles entering the landfill.
Distance to available electrical transmission lines	Nearby utility lines to interconnect with the proposed solar PV system. Longer distance will have cost and efficiency impacts.
Landfill Gas	Inactive or passive gas wells with proper engineering controls. Integrating solar and landfill gas systems may require the use of gas-proof electrical conduits/fittings.
Nearby natural resources	Nearby wetlands or streams/water bodies. Be aware of any potential flooding concerns and existing endangered species inhabiting the landfill.
Town restrictions	Any specific local codes requirements/restrictions and future land reuse established by the municipality.

During the landfill visit, the EPA solar team screened for available flat and open landfill area, free from sunlight obstruction and suitable to support solar panels. The EPA solar team also used a Solmetric SunEye¹ solar path calculator to assess shading at particular locations by analyzing the sky view where solar panels can be potentially located. By finding the solar access, the instrument can determine if the area is appropriate for solar energy generation.

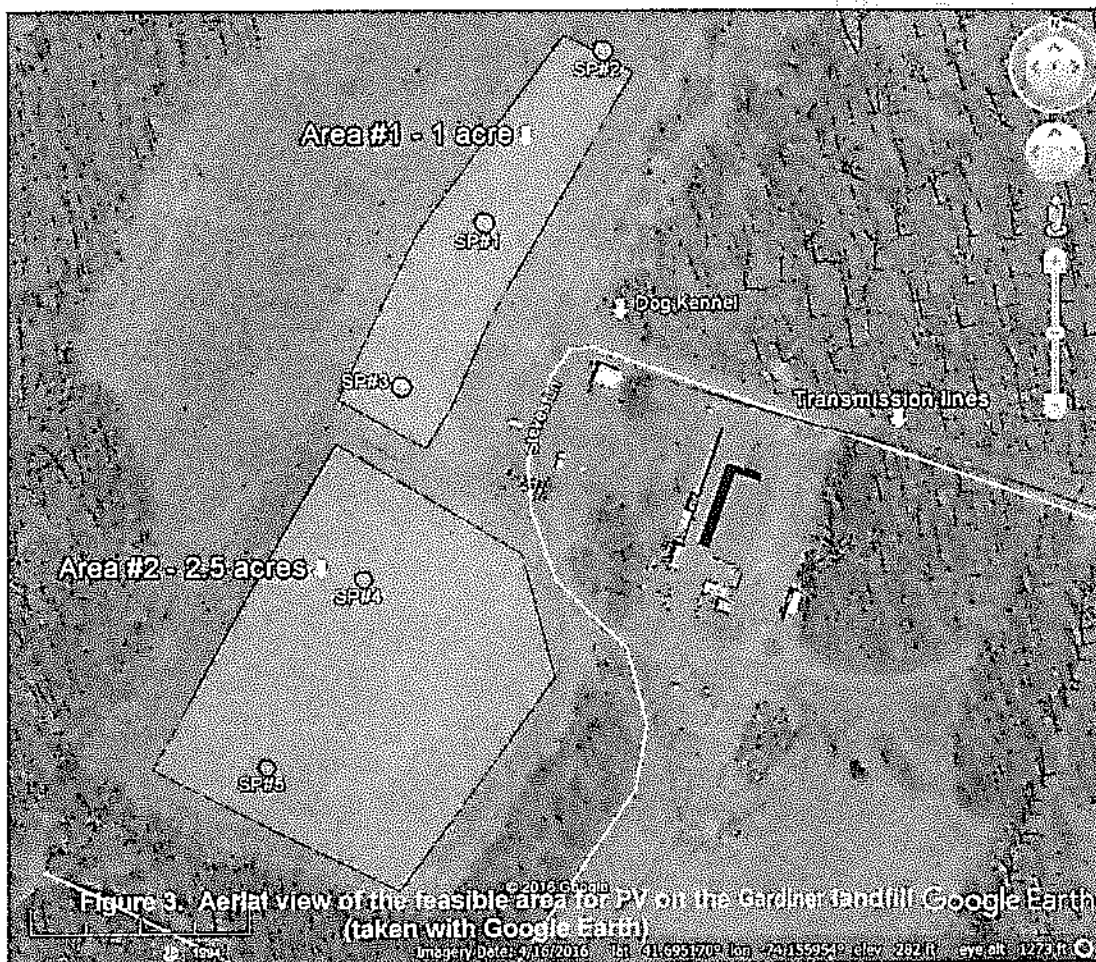
For information about the Solmetric SunEye and the SunEye annual solar access summary for the Gardiner landfill see Attachment #1.

¹ More information on this tool can be found at: <http://www.solmetric.com/>

Usable Landfill Acreage

Based on Geographic Information System (GIS) and on site assessment, the total recommended usable landfill area for solar PV generation is approximately 3.5 acres of vegetative cover. This proposed usable area corresponds to a relatively flat open portion of the landfill and avoids the area with a steeper gradient, (along the northwest and northeast sections of the landfill). Figure 3 shows an aerial image of the Town of Gardiner landfill with the recommended usable solar PV areas shaded in light blue polygons. Although the EPA team recommends an estimated 3.5 acres for the proposed solar PV usable area, this acreage can be reassessed and adjusted by the municipality or a potential third-party solar developer.

The sun icons in figure 3 represent the locations where SunEye data points were taken to measure solar potential. More information about SunEye data can be found in Attachment #1. Overall, solar access yields averaged above 98% annual solar exposure for all landfills, which are within the favorable annual solar access range for PV systems. More SunEye data can be found in Attachment #2.



Landfill observations:

- The access to the landfill is located near the dog kennel on Steve's Lane.
- An electrical transmission line is feeding into the dog kennel.
- The Wallkill River is located approximately 0.25 miles west of the landfill.
- The northwest portion of the landfill was considered too steep to safely place a solar array system.

The following photos of the Gardiner landfill were collected during the site visit and illustrate the general potential usable PV solar areas.



Figure 4A. Looking west from Steves Lane. Area #1 is located at the top of the landfill, as shown in Figure 3.

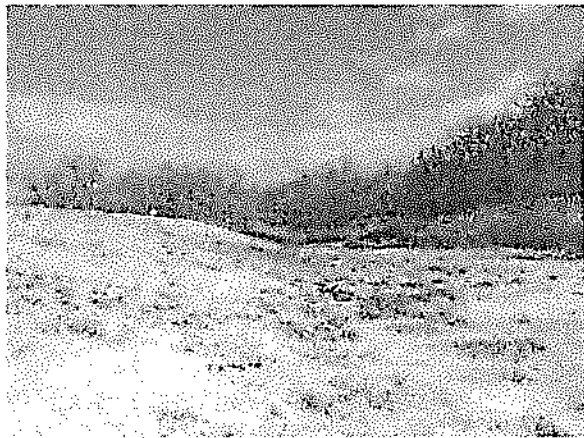


Figure 4B. Looking north by the entrance (showing northeast sloped landfill area).



Figure 4C. Looking south from north portion of landfill, view of landfill Area #1.

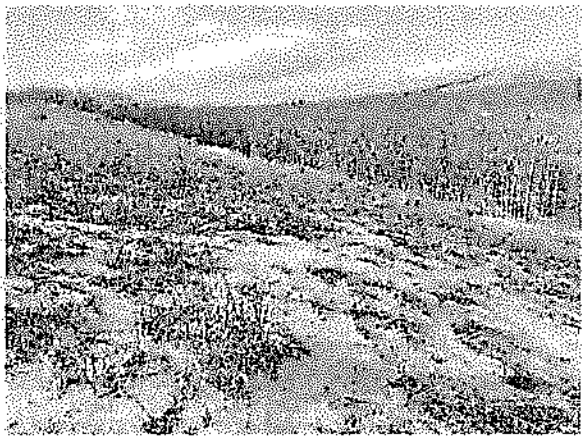


Figure 4D. Looking southwest from the northern portion of the landfill (western sloped area not recommended for usable solar PV area).

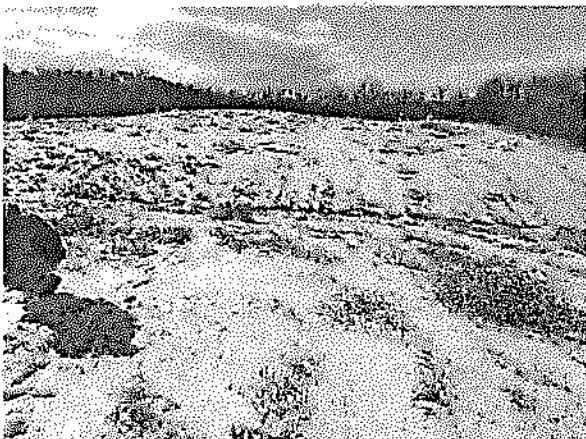


Figure 4E. Looking south at Area #2 from southern edge of Area #1.

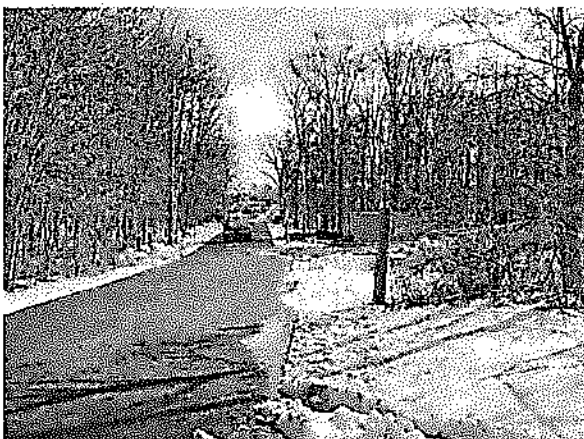


Figure 4F. Looking east along Steves Lane. Electrical transmission lines are located along the road.



Figure 4g – Panoramic view of the landfill showing the northern portion and southeast portion of the landfill. Area #1 is visible on the left side of the picture while Area #2 is visible at the right side.

Figure 4 (A-G). Images taken by EPA of the Gardiner landfill.

Transmission/Utility Resources

Transmission lines run in approximately 0.15 miles east of the landfill, along Steves Lane and at the intersection along Dusenberre Road. In general, the distance from the proposed solar PV system to the point of interconnection with electrical transmission should be within a half mile distance in order to yield more viable economic conditions.

It is highly recommended that the Town of Gardiner consult with the electric distribution company (EDC) serving the area to discuss the potential for a solar project. In general, a preliminary interconnection transmission study from the local EDC should be performed early in the process if the Gardiner Town officials decide to pursue PV solar generation on the landfill. The EDC serving the Town of Gardiner landfill is Central Hudson Gas and Electric². While the interconnection of the landfill to the local transmission line seems favorable, early coordination with the Central Hudson Gas and Electric is required to ensure that installations of distributed generation systems are properly designed to safely operate in parallel to the utility system, and to provide for net metering if applicable. In New York State, net metering is allowed for non-residential solar PV generation systems less than 2 MWs in size. For more information, go to section VII of the study or visit <http://www.cen hud.com/dg/netmetering.aspx>.

The interconnection study will also help the EDC to determine the feasibility of interconnecting to the electrical grid, assess whether potential electrical upgrades are needed, and estimate the interconnection costs. The EDC will also evaluate the available capacity of the transmission line to accommodate the solar power generated from the landfill. All technical pertinent information about the proposed solar PV system should be provided to the EDC in accordance with the application requirements.

Potential Off-Takers of the Generated Solar PV from the Gardiner Landfill

As part of the PV siting consideration, potential solar PV off-takers were also identified. there are several local facilities in the town that could be potential off-takers of the electricity generated by solar PV on the landfill. Some potential off-takers are:

Table 2. Potential off-takers for the Gardiner Landfill

Potential Off-takers	Address
Gardiner Animal Hospital	177 Main St, Gardiner, NY 12525
Gardiner Library	133 Farmer's Turnpike, Gardiner, NY 12525
Town of Gardiner Town Hall	2340 Rt. 44/55, Gardiner, NY 12525

² Central Hudson Gas and Electric, <http://www.cen hud.com/dg/>, Email - distributedgeneration@cen hud.com or call (845) 486-5215.

V. PVWatts System Sizing and Performance Results

PVWatts Analysis

PVWatts³ calculator is an online tool developed by the Department of Energy - National Renewable Energy Laboratory (DOE-NREL) to estimate the electricity production of a grid-connected ground- or roof-mounted photovoltaic system. It requires only a few inputs including the location of the system, system size, and basic design parameters such as whether the system will be a fixed tilt or a single-axis tracking. The design parameters have default values or users can adjust them according to their needs.

The DC system size required in PVWatts is determined with an acre-to-power conversion factor. Based on research done by NREL of ground mounted solar PV systems, a value of 5.74 acre/MW factor was used for a fixed-tilt system. For the Town of Gardiner landfill, this study recommends usable solar PV on an estimated 3.5 acres of the landfill area for a system size of 0.61 MW DC.

The landfill location is used to connect to NREL's Typical Meteorological Year (TMY) data which is the closest weather data source. NREL has compiled TMY data for thousands of locations throughout the United States. This data includes the solar irradiance, which is a measurement of solar radiation on the surface of the earth and is measured by the power (Watts) per unit area (m^2), W/m^2 . The solar radiation values represent the resource available to a flat plate collector, such as a photovoltaic panel, oriented due south at an angle from horizontal to equal to the latitude of the collector location. Solar radiation, or insolation (irradiance multiplied by time), is measured in units of Watt hours per unit area during a specific time interval. Solar radiation above 3.5 kWh/ m^2 /day is considered favorable when considering PV siting locations.

For the Gardiner landfill, the TMY data is taken from Poughkeepsie Dutchess CO AP, New York (15 miles from the landfill location) and the solar radiation level was measured at 3.92 kWh/ m^2 /day. The weather station identification information, PV system specifications, energy specifications, and performance results for the Gardiner landfill are provided in Table 3 and Table 4.

The monthly performance results for the proposed solar PV systems at the Town of Gardiner Landfill as calculated by PVWatts can be found in Attachment #2.

Table 3. PV Watts Site Identification Information for the Gardiner Landfill

Weather and PV System Technical Specifications	
Weather Data Source:	Poughkeepsie, Dutchess County, New York
State:	New York
Latitude:	41.63° N
Longitude:	73.88° W
Array Type:	Fixed-Tilt
Solar Radiation Levels:	3.92 kWh/ m^2 /day
System Losses*:	14%
Array Tilt:	20°
Array Azimuth:	180° South

*Systems Losses is another input parameter for the PV Watts calculator. It is also referred to as the DC to AC Derate Factor and is calculated from all of the losses that the system experiences when converting DC power to grid-ready AC power. These include accuracy for PV module nameplate DC rating, conversion efficiency of the inverter and transformer, mismatch, diodes and connections (voltage drops), DC and AC wiring (resistive losses), soiling, system availability, shading, sun-tracking and age.

³ <http://www.nrel.gov/rredc/pvwatts/> PVWatts®

Table 4. PV System Yearly Performance Results for the Gardiner Landfill

Usable LF Area for Solar PV	Fixed-Tilt PV System			
	DC System Size [*]	AC Energy Based on PVWATTS	GHG Reduction ^{**} (metric tons CO _{2e})	GHG Emissions Equivalent to # of Vehicles Driven Yearly ^{**}
Area #1: 1 acre	0.174 MW dc	199,759 kWh/yr	140 MTCO _{2e}	30 Cars
Area #2: 2.5 acres	0.435 MW dc	499,399 kWh/yr	351 MTCO _{2e}	74 Cars
3.5 acres Total Combined	0.61 MW dc	699,158 kWh/yr	491 MTCO_{2e}	104 Cars

^{*}Assumes an area-to-power conversion of 5.74 Acres/MW based on historical data provided by NREL.

^{**}EPA's Greenhouse Gas (GHG) Equivalencies Calculator (<http://www2.epa.gov/energy/greenhouse-gas-equivalencies-calculator>) was used to determine the GHG reductions based on the proposed AC energy.

Cautions for Interpreting Results – Weather Variability

Monthly and yearly energy production is modeled using photovoltaic system selected parameters and weather data that is typical or representative of long-term averages. Because weather patterns vary from year to year, the values in Table 4 are better indicators of long-term performance than of performance for a specific month or year. Photovoltaic system performance is largely proportional to the amount of solar radiation received, which may vary from the long-term average by ±30% for monthly values and ±10% for annual values.

VI. Forecasted Economics

In general, the forecasted economics for the solar PV system will factor in the needed PV arrays/tilt and orientation and balance of system (BOS) components including the inverter and electrical supply/equipment costs, as well as installation cost. Other cost factors for a PV system will depend on the system size, geographic location, mounting structure, type of PV module, and other soft costs (permit fees, installation/interconnection labor costs, sales tax, installer/developer profit, customer acquisitions costs, and transaction costs). For more information about understanding and managing solar soft costs go to <http://energy.gov/eere/sunshot/soft-costs>.

Based on NREL's Solar PV Price and Cost Breakdown Study⁴, significant cost reductions in 2016 shows the average cost for commercial and utility-scale ground-mounted systems (includes the engineering, procurement, and construction (EPC) system hardware, other EPC direct/indirect costs, and developer costs) for different installed capacities. The actual cost declined from \$3.76/W in the fourth quarter of 2010 to \$1.42/W in the first quarter of 2016. However, this price is for systems 100 MW in size, much larger than the system that is being proposed for the Gardiner landfill. An interpolation was made using data from the NREL Prices and Cost Breakdown to estimate cost for a system of 0.61 MW. As a result, an installed capacity of 0.61 MW gives a cost of \$2.05/W. However, for a landfill site it is necessary to use a ballasted system in order to ensure the integrity of the landfill cap. This increases the cost by approximately 25%, bringing it to \$2.57/W, which is the value used for this analysis.

⁴ <http://www.nrel.gov/docs/fy16osti/67142.pdf> U.S. Photovoltaic Prices and Cost Breakdowns: Q1 2016 Benchmarks for Residential, Commercial, and Utility Scale Systems

With an increasing demand and supply, potential cost reductions may be expected as market conditions continue to evolve. It should be emphasized that this is a very rudimentary estimation of the economics involved for this proposed area and a more detailed analysis will be necessary moving forward. The projected estimated cost only factors the estimated initial installation costs and does not reflect the true cost of the system since available NYS incentives that may lower the costs are not included and the associated soft costs to develop the solar PV can vary for this project. Additional steps may be necessary in order to install PV panels at these sites, such as site preparation and the interconnection requirements, which can drive the overall cost. Table 5 provides the initial system costs for a fixed tilt PV system based on the above stated pricing assumptions. The project is expected to have an optimal 25 years lifespan, although the system can be reasonably expected to continue operation past this point.

Table 5. PVWatts Initial Economic Considerations

Fixed-Tilt PV System	
Initial installation system cost	\$2.57 /Wdc
Town of Gardiner Landfill PV System Size (3.5 acres) *	0.61 MW
Projected Estimated System Cost (without financial incentives)	\$1,564,394
Average regional cost of electricity** (combined sectors as of February 2017)	13.81 ¢/kWh

*Assumes an area-to-power conversion of 5.74 Acres/MW based on historical data provided by NREL.

**Average regional combined cost of electricity for the State of NY found through the US Energy Information Administration (USEIA) as of May 15, 2017. http://www.eia.gov/electricity/monthly/epm_table_grapher.cfm?t=epmt_5_6_a

VII. Benefits

In general, due to the presence of suspected or known contaminants, landfills have limited redevelopment potential and solar PV installations can be a viable reuse. Many municipal solid waste (MSW) landfills are particularly well-suited for solar development because they are often:

- Located near critical infrastructure including electric transmission lines and roads;
- Located near areas with high energy demand (e.g., large population bases);
- Constructed in areas of low grade (0-10%) needed for siting of solar PV structures;
- Offered at lower land costs when compared to open space;
- May be adequately zoned for renewable energy;
- May have environmental conditions that are not well-suited for commercial or residential redevelopment;
- Are able to accommodate net metered or utility scale projects; and

Other benefits with solar on landfills:

- Can provide short and long term job opportunities;
- May reduce the environmental impacts of energy systems (e.g., reduce greenhouse gas emissions).

The New York State Energy Research and Development Authority (NYSERDA) promotes energy efficiency and the use of renewable energy sources in New York. According to NYSERDA, solar PV generation offers the following key benefits:

- PV systems are gentle on the environment, in contrast with electricity generated by fossil fuels;
- PV-generated electricity creates no noise, air, or water pollution;
- PV systems provide long-term stabilization of electrical costs;
- When combined with a battery backup system, a PV unit can provide power when utility power is not available.

In addition, this study outlines various financial incentives (Section VI – Incentives) that could assist in financing the implementation of a solar PV system including incentives offered by NYSERDA.⁵ To learn about programs and funding opportunities available through NYSERDA from the NY-Sun Initiative, contact Maureen Leddy, Associate Project Manager, NYSERDA via email at maureen.leddy@nyserda.ny.gov or go to <http://www.ny-sun.ny.gov/> or <https://www.nyserda.ny.gov/All-Programs/Programs/NY-Sun/Megawatt-Block-Dashboards>.

Net Metering/Remote Net Metering:

In New York State, another benefit to implementing a renewable energy system is **net metering/remote net metering**. Net metering/remote net metering is allowed for non-residential solar PV generation systems less than 2 MWs in size. In a conventional net metering situation, a **customer-sited renewable energy system** is connected to the utility grid through a customer's utility meter. This is known as "behind-the-meter generation." At any given moment, if the site is using more electricity than the system is producing, all the electricity produced by the system is used on-site and the site's electricity needs are supplemented from the grid. If the site is using less electricity than the system is producing, the excess electricity is exported to the grid and the customer receives a credit. This is typically recorded as negative use and is commonly referred to as the "meter spinning backwards." At the end of the billing cycle, the grid-supplied electricity and the credits for any exported electricity are reconciled, and any surplus credits can be carried forward to the next billing cycle. The specifics of net metering are dependent on the customer's service classification. Customers who are eligible for remote net metering may apply those credits to electric bills from facilities that are not located at the same physical location as the PV system. Additional information about net/remote net metering can be found at: <http://www.nyserda.ny.gov/Energy-Efficiency-and-Renewable-Programs/Renewables/Net-Metering-Interconnection.aspx> or go to <http://programs.dsireusa.org/system/program/detail/453>.

It should be noted that in March 2017, the New York State Public Service Commission (PSC) issued an order regarding the future of net metering in the state. The order is considered one of the major milestones in the Reforming the Energy Vision (REV) proceeding, and addresses the transitional steps from traditional net metering into a Value of Distributed Energy Resource (VDER) tariff that accurately values and compensates distributed energy resources. More information about this order can be found at <https://energy.gov/savings/net-metering-23>. It is highly recommended that the Town of Gardiner consult with NYSEG to discuss net metering opportunities.

Power Purchase Agreements:

A number of municipalities that own or operate landfills have expressed interest in potential revenue flow from solar PV systems. In some cases, revenue can be generated by the use of PV on a landfill site pending actual site conditions, financial incentives, economic conditions, and support from the utility companies. While the findings of this report do not recommend how a solar array at a landfill will be financed, if the municipality decides that they do not want to invest their own funds to build the solar site, they can consider entering into a Power Purchase Agreement (PPA) with a solar developer who would assume the cost of development. To learn more about PPA structures, please go to the following PPA checklist for state and local governments link: <http://www.nrel.gov/docs/fy10osti/46668.pdf> or the Interstate Renewable Energy Council PPA toolkit for local governments: <http://www.irecusa.org/solar-power-purchase-agreements-a-toolkit-for-local-governments/>

Incentives:

The economics of a PV system will also depend on NYS financial incentives, available federal tax credit, the regional cost of electricity, the solar resource, solar panel tilt and orientation, site conditions, distance to the electrical interconnection, and other critical requirements highlighted in this report. Table 6 provides several possible financial incentives that can be considered by the Town of Gardiner officials to assist with financing the proposed solar PV systems.

⁵ <http://www.nyserda.ny.gov/>

Table 6. Summary of Applicable Incentives

Federal and State Solar Investment Tax Credit	As of December 2015, system owners may continue to qualify up to 30% Federal Investment Tax Credit which is expected to step down to 26 percent in 2020 and 22 percent in 2021. After 2023, the residential credit will drop to zero while the commercial and utility credit will drop to a permanent 10 percent. Always consult with your qualified tax professional or accountant to determine your eligibility for tax credits.
Modified Accelerated Cost Recovery System (MACRS)	MACRS depreciation is also considered another important financial incentive. The MACRS is a method of depreciation in which a business' investments in certain tangible property are recovered, for tax purposes, over a specified time period through annual deductions. Qualifying solar energy equipment is eligible for a cost recovery period of five years. More information about MACRS is available at: http://www.seia.org/policy/finance-tax/depreciation-solar-energy-property-macrs .
NY-Sun Commercial/Industrial Incentive Program (PON 3082)	For installations of Solar PV Systems greater than 200 kW, incentives are available on a rolling application first-come, first-served basis for eligible projects. More information is available at: http://www.nyserda.ny.gov/Funding-Opportunities/Current-Funding-Opportunities/PON-3082-NY-Sun-Commercial-Industrial-Incentive-Program .
NY-Sun Solar Electric Incentive Program	NYSERDA provides cash incentives for the installation by Eligible Installers/Contractors of new grid-connected Electric Photovoltaic (PV) systems that are 200 kW or less for non-residential sites. (Revised 4/2016) More information is available at: http://www.nyserda.ny.gov/Funding-Opportunities/Current-Funding-Opportunities/PON-2112-Solar-PV-Program-Financial-Incentives
Clean Energy Financing Arrangements	The New York Green Bank invites private sector capital providers and other clean energy industry participants to propose partnership arrangements with the Green Bank that would facilitate the financing of clean energy projects (including energy generation and energy savings projects) in the State of New York. More information is available at: http://www.nyserda.ny.gov/Funding-Opportunities/Current-Funding-Opportunities/RFP-1-Clean-Energy-Financing-Arrangements
Other Incentives	For other applicable incentives, go to the following website: http://programs.dsireusa.org/system/program?fromSir=0&state=NY

VIII. RE-Powering America's Land

Through the RE-Powering America's Land Initiative, the U.S. EPA promotes the reuse of potentially contaminated properties, landfills, and mining sites for renewable energy generation. This initiative identifies the renewable energy potential of these sites and provides useful resources for communities, developers, industry, state and local governments or anyone interested in reusing these sites for renewable energy development. Various RE-Powering America Initiative resources are summarized below and can be found at <http://www.epa.gov/oswerpcpa>.

- **Mapping and Screening Tools** - Under Mapping and Screening tools, EPA's RE-Powering America's Land team screened more than 80,000 potentially contaminated sites and MSW landfills covering nearly 43 million acres across the United States for suitability to site renewable energy generation facilities, including utility-scale solar. Maps depicting the locations of these EPA tracked sites and their potential for supporting renewable energy generation can be found at www.epa.gov/oswerpcpa/mapping_tool.htm. These maps enable users to view screening results for various renewable energy technologies at each site.
- **Technical Assistance and Support** - As part of the RE-Powering America's Land Initiative, the EPA and the U.S. Department of Energy's National Renewable Energy Laboratory (NREL) are evaluating the feasibility of developing renewable energy production on Superfund, brownfields, and former landfills or mining sites. This project pairs EPA's expertise on contaminated sites with the renewable energy expertise of NREL. A list of feasibility studies for renewable energy production for various technologies including solar and can be found at www.epa.gov/oswerpcpa/rd_tech_assist.htm.

- **Redevelopment Tools and Resources** – Under Redevelopment Tools and Resources, EPA and NREL created the joint publication, “Best Practices for Siting Solar PV on Municipal Solid Waste Landfills” to provide assistance in addressing common technical challenges of siting PV on MSW landfills (such as impacts to landfill settlement differentials and the PV solar performance, impacts to other landfill systems, understanding landfill cap integrity/characteristics, and understanding landfill post-closure requirements for solar PV design considerations) and provide other useful information for solar developers, landfill owners, and federal, state, and local government entities. Other documents for stakeholders to consider are “RE-Powering Finance Fact Sheet, “Handbook on Siting Renewable Energy Projects while Addressing Environmental Issues”, and “Revised Bona Fide Prospective Purchaser (BFPP) Provisions Enforcement Guidance for Tenants.”

Fact Sheets and Success Stories - The RE-Powering team highlights numerous successful stories and fact sheets of renewable energy projects implemented throughout the United States. The RE-Powering America team also maintains a list of completed renewable energy installations on contaminated sites and landfills. To date, the RE-Powering Initiative has identified 213 renewable energy installations on 207 contaminated lands, landfills, and mine sites, with a cumulative installed capacity over 1,235 megawatts (MW) and consistent growth in total installations since the inception of the RE-Powering Initiative.

IX. Conclusions

Overall, the Town of Gardiner Landfill appears to have favorable site conditions to support solar PV generation and economic viable use. The landfill offered relatively flat open vegetative area with minimal shading concerns and high solar access making it an ideal site to install solar panels. The recommended usable solar PV areas and proposed locations are depicted in Figure 3. Shading obstruction were only apparent near the tree line at the south section of the landfill. The solar PV system size and performance for the landfill is based on the recommended usable areas (illustrated in Table 4). In general, the proposed usable area for solar PV amounted to 3.5 acres with an installed capacity of 0.61 MW dc. Electrical transmission lines are conveniently located near the landfill, however early coordination with the EDC for interconnection studies will be required if Town officials decide to move forward with a solar PV project.

While this solar screening study provides the PV system sizes based on proposed usable area, the actual system installation will need to factor the availability of funds and the amount of power that can be sold. As indicated earlier, a third-party developer power purchase agreement (PPA) is another feasible way for a system to be financed for this site. In exchange for access to a site through a lease arrangement, third-party solar developers can finance, develop, own, and operate the solar projects utilizing their own expertise and sources of financing. These private enterprises are also able to take advantage of the federal tax benefits that cannot be captured by municipalities (or other entities that do not pay corporate income taxes), which should lower the total system cost. If the town decides to proceed with a solar system installation and work with a third-party solar developer, the developer can sell the electricity to the site host (local town facilities) or local utility via a PPA - which will sell the electricity at negotiated rate for a fixed period of time for a term typically varying from 20-25 years. Thus, economic benefits from solar generation on the landfill could include competitively priced electricity from the project, revenues via land lease payments from a solar developer, potentially reduced landfill maintenance costs, job creation and stimulation of the local economy during solar construction.

By using obtainable and accessible land that is unavailable for redevelopment allows for repurpose of land that would not otherwise be productive and reduces greenhouse gas emission from current power sources. In case town officials are interested in pursuing solar PV generation, additional options could be explored to make the solar PV generation more viable while understanding the economic impacts and maintaining the integrity of the landfill cap design. In general, town officials or a potential third-party solar developer could reassess and expand the proposed usable PV area, and consider placing fencing along the perimeter of the landfill to safeguard the solar equipment. Based on EPA's screening and assessment of the existing physical landfill conditions, EPA supports the potential of solar PV generation at the Town of Gardiner landfill.

X. Next Steps

Early and proper planning with other key stakeholders is critical to the success of a solar PV system. The following stakeholders should be consulted in the early stages of a solar PV project:

New York State Department of Environmental Conservation (NYSDEC)



The Town of Gardiner must coordinate early with the **NYSDEC**. To initiate this process, contact James Lansing, Region 3 Materials Management Engineer at (845) 256-3123 or via email at james.lansing@dec.ny.gov. NYSDEC's review and approval of the proposed solar PV work is necessary in order to ensure that the integrity and protective measures put in place for the existing landfill cap are maintained throughout the life of the project. To that end, it will be necessary to provide all related information to NYSDEC for the proposed solar PV system including:

- Location of the landfill and the PV system size,
- Estimated usable area on the landfill for the solar PV installation,
- The mounting foundation type placed on the landfill,
- The landfill cap's ability to withstand both the construction and long-term operation loads of the PV system,
- Impacts to the landfill cap integrity,
- Proper set back from the gas vents and no impacts to the gas venting,
- Potential storm water management issues, and
- Any additional information requested by NYSDEC.

In general, NYSDEC regional representatives' names and contact information can be found at <http://www.dec.ny.gov/chemical/76718.html>. For general questions associated with solar development at New York landfills, contact Gus Carayiannis, Chief, Bureau of Permitting and Planning at (518) 402-8678 or via email at gus.carayiannis@dec.ny.gov.

Coordination with the Electric Distribution Company (EDC):



The local utility provider should be consulted early in the planning stages so that the Town/County officials can be alerted to any potential transmission interconnection issues that might exist or equipment upgrades needed to facilitate the solar project. The Town of Gardiner officials may request a transmission interconnection studies from Central Hudson Gas and Electric. As indicated earlier, all technical pertinent information about the proposed solar PV system should be provided to the utility provider in accordance with their application requirements. For more information about the interconnection requirements, go to <http://www.cenhud.com/dg/>.

Coordination with the NYSERDA, NY SUN - PV Training Network (PVTN):



In addition to the solar PV financial incentives from NYSERDA, the NY-Sun PV Trainer Network (PVTN) can offer education, training, and technical assistance for municipalities interested in identifying and developing solar electric markets while mitigating barriers. The NY-Sun PVTN can also provide help and training to municipalities with the solar procurement process, streamlining the solar permit process, and one on one technical assistance.

For more information and training offered by the NY-Sun PVTN, go to <https://training.ny-sun.ny.gov> or contact Vicki Colello at vicki.colello@nyserdera.ny.gov or call (518) 862-1090 ext 3273. The NY-Sun PVTN offers additional resources at <https://training.ny-sun.ny.gov/resources>. Of particular interest to municipalities, is the "Solar Procurement Guidelines for Local Governments in New York State".

As a reminder, this report is to be used for screening purposes only.

Additional evaluations will need to be conducted to fully characterize the feasibility and economics of the Town of Gardiner landfill for PV installation. Third party solar developers and local utility companies may have technical and financial interests in pursuing potential solar renewable energy projects and should perform additional solar assessments to determine if projects are economically viable.

This study does not assess the environmental conditions at the site.

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Attachment #1 – SunEye Solar Measurements

The EPA solar assessment team used a Solmetric SunEye⁶ 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 instrument can determine if the area is appropriate for solar panels. 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. 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. By finding the solar access, it can be determined if the area is appropriate for solar power generation.

The assessment team collected five Solmetric SunEye data points (skyline views) at across the entire perimeter of the landfill in sections with adequate flat area as shown in Figure 3. Overall, **solar access yields averaged 98%** annual solar exposure, which is within the favorable annual solar access range for PV systems.

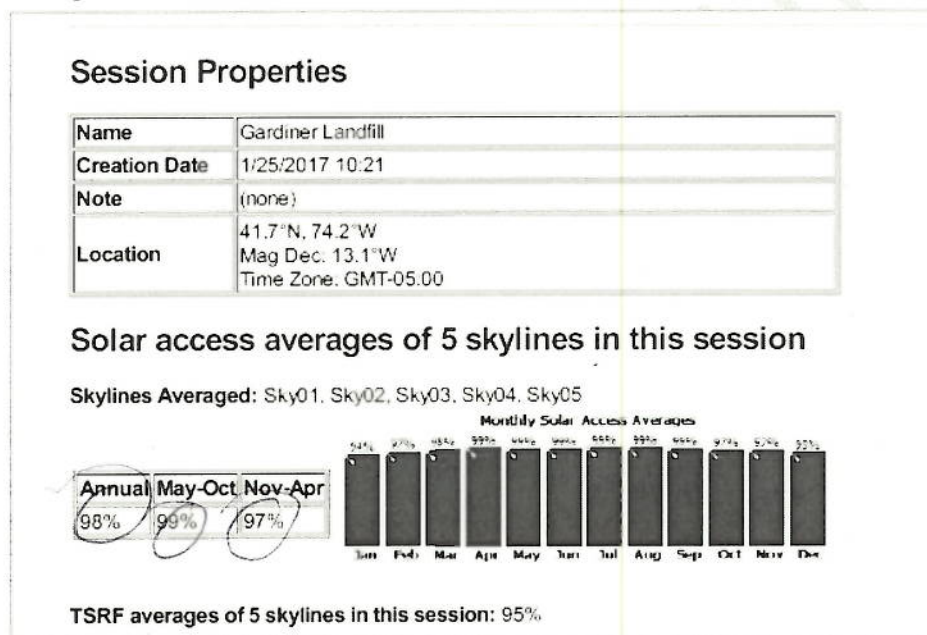


Figure 5. Session properties for Solmetric SunEye

The Total Solar Resource Fraction (TSRF) is the ratio of insolation available accounting for both shading and Tilt and Orientation Factor (TOF), compared to the total insolation available at a given location at the optimum tilt and orientation and with no shading. TSRF is also expressed in percent. The TOF is the solar insolation at the actual tilt and orientation divided by the insolation at the optimum tilt and orientation, expressed in percent.

⁶ More information on this tool can be found at: <http://www.solmetric.com/>

Attachment #2 – Monthly Performance Results for the Gardiner Landfill

Performance Results 610 kW Fixed-Tilt PV System		
Month	Solar Radiation* (kWh/m ² /day)	AC Energy (kWh)
January	3.02	48,942
February	2.71	40,185
March	4.73	73,501
April	4.14	60,808
May	5.45	80,513
June	5.28	73,776
July	5.20	75,331
August	4.53	65,038
September	3.74	53,602
October	3.15	47,869
November	2.85	42,854
December	2.28	36,738
Total	3.92* Monthly Average	699,158**

*Solar Radiation values above 3.5 kWh/m²/day are considered favorable when considering PV siting locations.

**The solar photovoltaic 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. For information about, a reduction in power generation due to long-term exposure, go to <http://www.nrel.gov/docs/fy12osti/51664.pdf>

Attachment #3 – PV Systems Overview

Major System Components

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

- PV modules,
- inverters and
- balance-of-system components (including mounting racks, hardware for the panels, and 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 the arrays to inverters and inverters to point of interconnection is generally run as direct burial through trenches. It is recommended that PV system vendors reflect these costs in the requests for proposals when costing out the overall system.

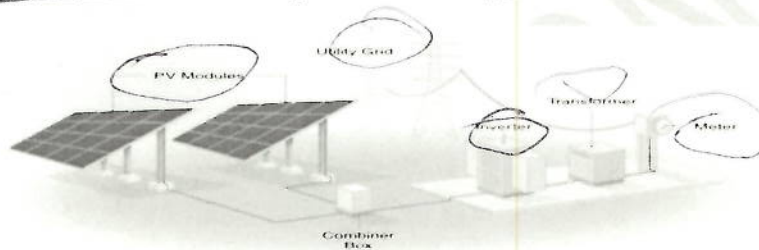


Figure 6. Ground mount array (source: NREL)

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.

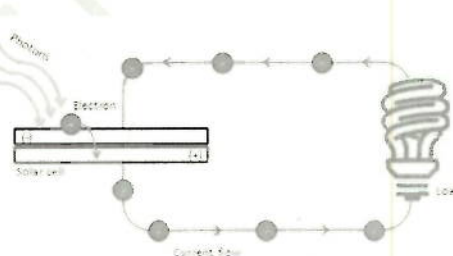


Figure 7. Generation of electricity from a PV cell (source: EPA)

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 usable 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 kilowatts (kW)), commercial (100-500 kW), to large utility scale (10+ megawatts (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.

The solar array has to be secured and oriented optimally to maximize system output. The structure holding the modules is referred to as the mounting system. The mounting systems can be ground mounted utilizing a ballast system on top of a landfill cap where there are commonly large unshaded areas. For ground mount systems, the mounting system can be either directly anchored into the ground (via driven piers or concrete footers) or ballasted on the surface without ground penetration. Mounting systems must withstand local wind loads, which range from 90–120 mph range for most areas or 130 mph or more for areas with hurricane potential. Depending on the region, snow and ice loads must also be a design consideration for the mounting system.

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.

Crystalline Silicon

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

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

Figure 8 shows two examples of crystalline solar panels: mono- and multi-silicon installed on tracking mounting systems.

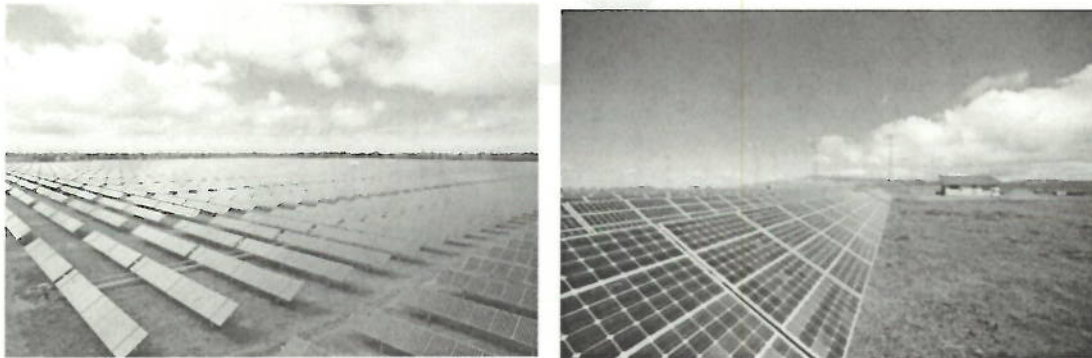


Figure 8. Mono- and multi-crystalline solar panels. Photos by (left) SunPower Corporation, NREL 23816 and (right) SunPower, NREL 13823

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 11-12% for CdTe. 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.

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. 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 landfill sites. Fixed-tilt systems have lower maintenance costs but generate less energy (kWh) per unit power (kW) of capacity than tracking systems. The selection of mounting type is dependent on many factors including installation size, electricity rates, government incentives, land constraints, soil conditions, alignment and latitude requirements, and local weather.

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. 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.

Inverters

Inverters convert DC electricity from the PV array into AC electricity, which 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," a condition which could be dangerous to utility workers trying to fix a de-energized distribution system. This safety feature is built into all grid-connected inverters in the market.

Electricity produced from the PV system may also 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 weakness and may be recommended for different types of installations.

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 (i) the arrays to inverters and (ii) inverters to point of interconnection is generally run as direct burial through trenches.

Attachment #4 – Glossary or Definition of Terms

Glossary or Definition of Terms	
PV	Photovoltaic energy
AC	Alternating current, which can be transmitted over+ power lines
DC	Direct current, which cannot be transmitted over power lines
Ballast	A footing on which a solar panel can be placed which will not penetrate the landfill cap
Inverter	A machine which takes in direct current and converts it to alternating current, which can then be transmitted to an electrical substation for transmission to a utility company
Energy Density	The amount of energy available per a given region of space (per unit volume); this is impacted by the <u>packing</u> factor, which is the number of solar arrays that can be placed in a specific area
kW or kWh	Kilowatt or kilowatt hours
MW or MWh	Megawatt or megawatt hours
ITC	Investment tax credits
O&M	Operations and maintenance
Payback Period	Number of years until the project is paid for
PPA	Power purchase agreement, which is a legal contract between an electricity provider and a purchaser that defines all commercial terms for the sale of electricity
Transformer	An electrical device used to increase or decrease the alternating voltage in electrical power applications. A transformer on a solar power facility is primarily used to step-up the voltage to deliver the renewable energy to the utility grid.
EDC	Electric Distribution Company
GIS	Geographic information Systems