



## United States Environmental Protection Agency

### Solar Photovoltaic Screening Study of Properly Closed Municipal Solid Waste Landfills - Siting Solar Photovoltaics at the Town of Saugerties Landfill

Prepared by the Environmental Protection Agency, Region 2

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#### **Acknowledgments:**

We would like to thank Greg Helsmoortel, Town Supervisor, and Vernon Benjamin, Special Operations Coordinator, for their assistance with facilitating the Town of Saugerties 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 Town of Saugerties 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 Saugerties 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:

|  | <b>PAGES</b> |
|--|--------------|
| I. Purpose of the Solar Screening Report             | 3            |
| II. Background                                       | 3            |
| III. Solar PV System Overview                        | 3            |
| IV. Solar PV System Siting Considerations/Assessment | 4            |
| V. PVWatts System Sizing and Performance Results     | 9            |
| VI. Forecasted Economics                             | 11           |
| VII. Benefits  | 12           |
| VIII. Re-Powering America's Land                     | 14           |
| IX. Conclusions                                      | 15           |
| X. Next Steps  | 15           |

### List of Tables:

|  |    |
|--|----|
| Table 1. PVWatts Site Identification Information for the Town of Saugerties Landfill   | 10 |
| Table 2. PV System Yearly Performance Results for the Town of Saugerties Landfill and Surrounding Area for a Fixed-Tilt System | 10 |
| Table 3. PVWatts Initial Economic Considerations   | 11 |
| Table 4. Summary of Applicable Incentives  | 13 |

### Attachments:

|   |    |
|---|----|
| Attachment #1 The Town of Saugerties Landfill Information | 17 |
| Attachment #2 SunEye Solar Measurements                   | 18 |
| Attachment #3 Monthly Performance Results                 | 19 |
| Attachment #4 PV Systems Overview                         | 20 |
| Attachment #5 Glossary or Definition of Terms             | 23 |

## 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 Saugerties 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 Town of Saugerties 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

The Town of Saugerties landfill serviced the Town until its closure in 1996. According to the US Census, as of 2010, the population of the Saugerties was approximately 18,800 people. The Town of Saugerties landfill is operated by Town officials. The landfill is situated on Route 212 and approximately five miles west of Interstate 87 in Saugerties, Ulster County, New York.

A composite cap was used to cover the landfill in 1993, upon which some vegetation exists. The grass is mowed approximately annually. A passive venting system exists on the site. Gas monitoring occurs annually. There is a leachate collection system in place. 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.

## 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 #4.*



Figure 1. - Fixed Axis Solar PV Array on a ballasted concrete foundation

## IV. Solar PV Siting Consideration/Assessment

### Siting Considerations

On May 27, 2016, the U.S. Environmental Protection Agency, Region 2 (EPA) team, in cooperation with Town of Saugerties officials visited and screened the closed landfill and surrounding non-landfill areas 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:

| 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

SunEye<sup>1</sup> 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 Town of Saugerties landfill is available in Attachment #2*

## **Usable Landfill Acreage**

Figure 2 shows an aerial image of the proposed solar PV areas on the Town of Saugerties landfill. The total estimated potential usable area for solar PV consideration at the Town of Saugerties landfill is approximately 5 acres on the landfill based on GIS and on-site assessment. An additional 1 acre was determined to be potentially viable outside of the perimeter of the landfill, bringing the total area to 6 acres. These proposed usable PV areas are where the slope of the landfill is relatively flat and avoids the area where there is a steeper gradient. Although the EPA team recommends an estimated 6 acres for the proposed solar PV usable area, this acreage can be reassessed and adjusted by the municipality or potential third-party solar developers.

Figure 2 shows the proposed area on the landfill is shaded brown while the non-landfill areas that was considered viable for solar is shaded green. Figure 2 also includes sun icons that represent the locations where SunEye data points were taken to measure solar potential. **Overall, solar access yields averaged 97% annual solar exposure, which is within the favorable annual solar access range for PV systems.** More SunEye data can be found in Attachment #2.

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

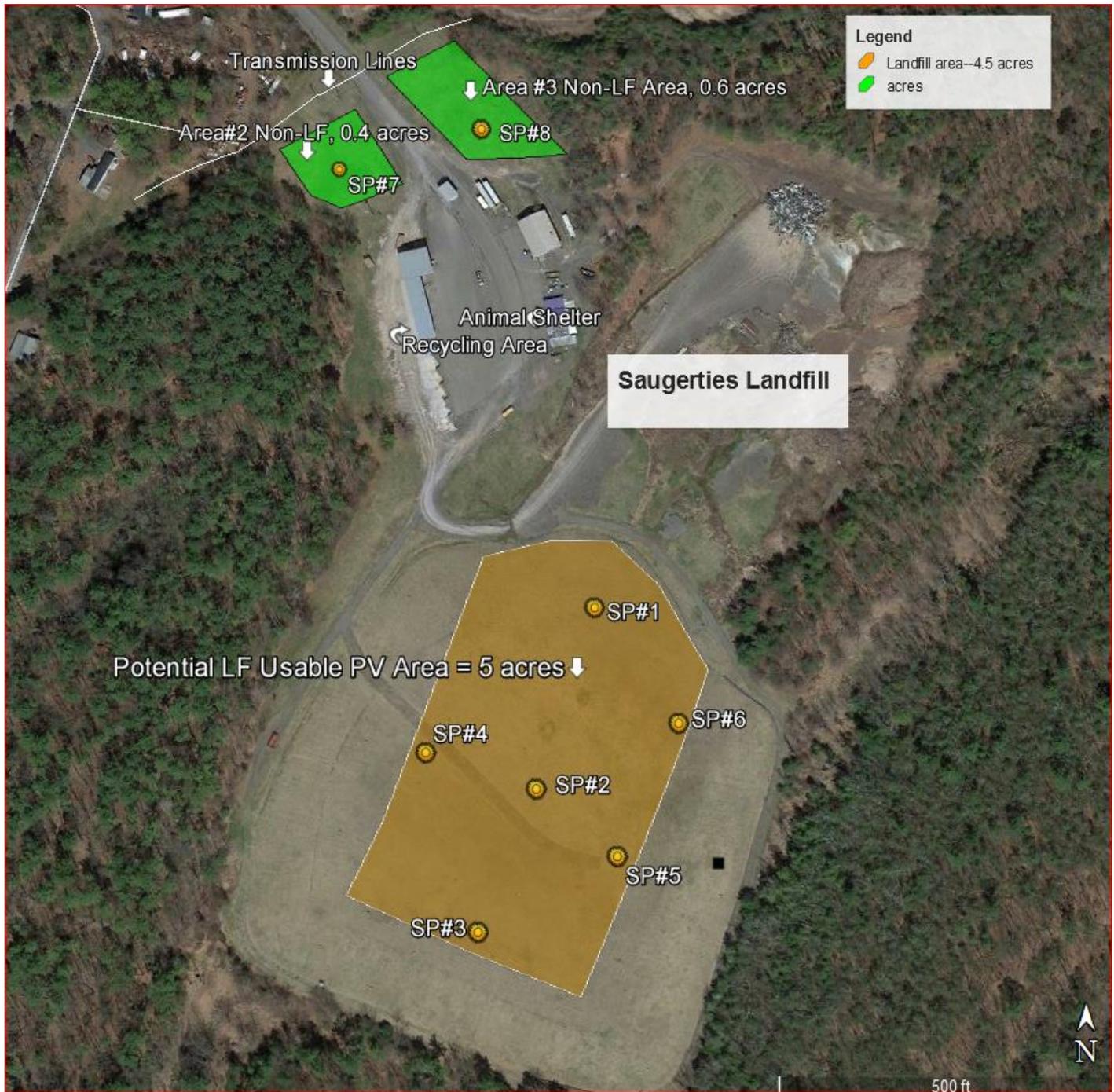


Figure 3. Aerial view of the feasible area for PV on the Town of Saugerties landfill (taken with Google Earth Pro)

The additional 1 acre of potential usable solar PV area (non-landfill areas #2 and #3) is located at the entrance of the landfill off Saugerties Woodstock Road. There's an active animal shelter, garage, and recycling staging area between the entrance of the landfill and the landfill. The animal shelter and garage both use electricity at these facilities.

The following photos of the Town of Saugerties landfill were collected during the site visit and illustrates the general potential usable PV solar areas.



*Figure 4a - Landfill Area looking north towards the animal shelter.*



*Figure 4b - Landfill Area looking east.*



*Figure 4d – Northeast portion of the landfill looking south.*



*Figure 4e - Non-landfill Area #3 looking east.*



*Figure 4f – Non-Landfill Area # 2 looking west.*



*Figure 4g – looking at the garage, animal shelter, and recycling area.*



*Figure 4h – Looking north from the southern portion of the landfill*



*Figure 4i – Electrical transmission lines running along the entrance of the landfill next to the proposed non landfill areas A and B (east and west of the road).*

**Figure 4 (a-i). Images taken by EPA of the Town of Saugerties Landfill and Non-Landfill Areas**

## **Transmission/Utility Resources**

Electrical transmission lines run east/west along Route 212 (Saugerties-Woodstock Road) less than .25 miles from the proposed solar PV area on the landfill. 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 Saugerties 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 is highly recommended early in the process if the Town officials decide to pursue PV solar generation on the landfill. The EDC serving the Town of Saugerties is Central Hudson Gas & Electric.<sup>2</sup>

The interconnection study will help Central Hudson Gas & Electric to determine the feasibility of interconnecting to the electrical grid, assess if potential electrical upgrades are needed, and estimate the interconnection costs. All technical pertinent information about the proposed solar PV system should be provided to Central Hudson Gas & Electric in accordance with the application requirements. While the interconnection of the landfill to the local transmission line seems favorable, the available capacity of the transmission line to accommodate the solar power generated from the landfill will need to be assessed by Central Hudson Gas & Electric. Coordination with Central Hudson Gas & Electric is required to ensure that installation 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 about net metering, go to section VII of the study or <http://www.centralhudson.com/dg/netmetering.aspx>.

### **Potential Off-Takers of the Generated Solar PV from the Town of Saugerties Landfill:**

Besides the existing animal shelter and garage located on site, there are no facilities in the immediate vicinity that would be potential off-takers of the electricity generated by solar PV on the landfill. However, the Town of Saugerties is currently exploring a potential remote net metering opportunities among municipal/town facilities. Another option for Town of Saugerties to considered is a Community Solar Distributed Generation

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<sup>2</sup> Central Hudson Gas and Electric, <http://www.cenhud.com/dg/>

Email - [distributedgeneration@cenhud.com](mailto:distributedgeneration@cenhud.com) or call (845) 486-5215.

(DG) Project under the NYPSC-NYSERDA program. A Community Solar DG project would allow electric customers to participate in a renewable energy project through net metering. It would make solar power available to residents who might not be able to install residential solar PV, limited solar access on their property, and other factors. The net metering would theoretically be available to any customer serviced by Central Hudson Gas and Electric. The Town of Saugerties targeted power generation for a Solar Community DG project is approximately 1.2 MW for 40 town accounts. The proposed usable solar PV landfill and non-landfill areas combined will offer an estimated 1.05 MW DC.

## V. PVWatts System Sizing and Performance Results

### PVWatts Analysis

PVWatts<sup>3</sup> 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 if it will be a fixed tilt or a single-axis tracking PV system. 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 Saugerties, this study recommends usable solar PV area on the landfill and non-landfill areas for a combined estimated area of 6 acres for a total system size of 1.045 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  $3.5 \text{ kWh}/m^2/\text{day}$ , is considered favorable when considering PV siting locations.

For the Town of Saugerties landfill, the TMY data is taken from Poughkeepsie, New York (21 miles from the landfill location) and the solar radiation level was measured at  **$3.92 \text{ kWh}/m^2/\text{day}$** . The weather station identification information, PV system specifications, energy specifications, and performance results for the Town of Saugerties landfill are provided in Table 1 and Table 2.

*The monthly performance results for the proposed solar PV systems at the Town of Saugerties Landfill as calculated by PVWatts can be found in Attachment #3.*

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

**Table 1 – PV Watts Site Identification Information for the Town of Saugerties Landfill**

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

\*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.

**Table 2. PV System Yearly Performance Results for the Town Saugerties Landfill and surrounding area for a Fixed-Tilt System**

| Locations             | Usable PV Area (Acres) | DC System Size (kWdc) | AC Energy Based on PVWATTS (kWh/year) | GHG Reduction* (metric tons CO <sub>2</sub> e) | GHG Emissions Equivalent to # of Vehicles Driven Yearly |
|-----------------------|------------------------|-----------------------|---------------------------------------|--|---|
| Landfill Area         | 5                      | 871.1                 | 989,890                               | 696  | 147 cars  |
| Non-Landfill Area #1  | .6                     | 104.5                 | 118,868                               | 84   | 18 cars   |
| Non-Landfill Area #2  | .4                     | 69.69                 | 79,914                                | 12   | 12 cars   |
| <b>Combined Total</b> | <b>6 acres</b>         | <b>1045.3 kWdc</b>    | <b>1,188,672 kWh/year</b>             | <b>792 MTCO<sub>2</sub>e</b>                   | <b>177 cars</b>   |

\*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 2 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 study<sup>4</sup>, significant cost reductions in 2015 shows the average cost for utility-scale ground-mounted systems (includes the engineering, procurement, and construction (EPC) system hardware, other EPC direct/indirect costs, and developer costs) declined from \$3.76/W in the fourth quarter of 2010 to \$1.77/W in the first quarter of 2015. However, this price is for systems 100 MW in size, much larger than the system that is being proposed for the Town of Saugerties landfill and the surrounding areas. Therefore, a median price of \$1.96/W was used for a preliminary economic analysis. This was obtained as the median between \$1.77/W and \$2.15/W, a typical cost for a system 0.2 MW in size. 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 the price used in this analysis to \$2.45/W. In the non-landfill areas, it is not necessary to use a ballasted system, therefore the \$1.96 price was used to estimate the cost of those areas.

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 3 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-year lifespan, although the system can be reasonably expected to continue operation past this point.

**Table 3. PVWatts Initial Economic Considerations**

| Fixed-Tilt PV System                             |                    |
|--|--------------------|
| Initial installation system cost (ballasted)     | \$2.45 /Wdc        |
| Landfill PV System Size (5 acres)*               | 871.08 kW DC       |
| Landfill Projected Estimated Cost                | \$2,134,146        |
| Initial installation system cost (non-ballasted) | \$1.96 /Wdc        |
| Non-Landfill PV System Size (1 acre)*            | 174.22 kW DC       |
| Non-Landfill Projected Estimated Cost            | \$341,471          |
| <b>Total Proposed System Size</b>                | <b>1.05 MW DC</b>  |
| <b>Total Projected Estimated Cost</b>            | <b>\$2,475,617</b> |

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

<sup>4</sup> <http://www.nrel.gov/docs/fy15osti/64746.pdf> U.S. Photovoltaic Prices and Cost Breakdowns: Q1 2015 Benchmarks for Residential, Commercial, and Utility Scale Systems

## 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 job opportunities in urban and rural communities;
- 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;
- 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.<sup>5</sup> 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](mailto:maureen.leddy@nyserda.ny.gov) or go to <http://www.ny-sun.ny.gov/>.

### **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>.

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<sup>5</sup> <http://www.nyserda.ny.gov/>

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<sup>6</sup>. It is highly recommended that the Town of Saugerties consult with Central Hudson Gas & Electric 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 project, 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 4 provides several possible financial incentives that can be considered by the Town of Saugerties officials to assist with financing the proposed solar PV systems.

**Table 4. Summary of Applicable Incentives**

|   |  |
|---|--|
| <b>Federal and State Investment Tax Credit*</b>             | 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.   |
| <b>Modified Accelerated Cost Recovery System (MACRS)</b>    | 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 MARCS is available at: <a href="http://www.seia.org/policy/finance-tax/depreciation-solar-energy-property-macrs">http://www.seia.org/policy/finance-tax/depreciation-solar-energy-property-macrs</a> .  |
| <b>NY-Sun Initiative for PV Systems Greater than 200 kW</b> | Incentives for solar PV installations are available on a rolling application first-come, first-served basis for eligible projects. More information is available at: <a href="http://www.nyserda.ny.gov/Funding-Opportunities/Current-Funding-Opportunities/PON-3082-NY-Sun-Commercial-Industrial-Incentive-Program">http://www.nyserda.ny.gov/Funding-Opportunities/Current-Funding-Opportunities/PON-3082-NY-Sun-Commercial-Industrial-Incentive-Program</a> .   |
| <b>Community Solar NY Round 2</b>                           | NYSERDA provides marketing materials and technical assistance as well as funding for campaign expenses for local governments, school districts, and other community partners who qualify to participate in Community Solar NY, a new effort to make solar easier and more affordable through community-driven initiatives. More information about the short term support from NYSERDA go to: <a href="http://www.nyserda.ny.gov/Funding-Opportunities/Current-Funding-Opportunities/PON-3011-Community-Solar-NY-Round-2">http://www.nyserda.ny.gov/Funding-Opportunities/Current-Funding-Opportunities/PON-3011-Community-Solar-NY-Round-2</a> |

<sup>6</sup> More information about net metering can be found at <https://energy.gov/savings/net-metering-23>

|  |  |
|--|--|
| <b>Clean Energy Financing Arrangements</b> | 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: <a href="http://www.nyscrda.ny.gov/Funding-Opportunities/Current-Funding-Opportunities/RFP-1-Clean-Energy-Financing-Arrangements">http://www.nyscrda.ny.gov/Funding-Opportunities/Current-Funding-Opportunities/RFP-1-Clean-Energy-Financing-Arrangements</a> |
| <b>Other Incentives</b>                    | For other applicable incentives, go to the following website:<br><a href="http://www.dsireusa.org/incentives/index.cfm?state=NY">http://www.dsireusa.org/incentives/index.cfm?state=NY</a>   |

## 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/oswercpa>.

- 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 <https://www.epa.gov/re-powering/re-powering-mapping-and-screening-tools>. 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 <https://www.epa.gov/re-powering/re-powering-feasibility-studies>.
- 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**” - <https://www.epa.gov/re-powering/best-practices-siting-solar-photovoltaics-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**” - <https://www.epa.gov/re-powering/financing-renewable-energy-projects-contaminated-lands-landfills-and-mine-sites> and “**Revised Bona Fide Prospective Purchaser (BFPP) Provisions Enforcement Guidance for Tenants**” - <https://www.epa.gov/enforcement/guidance-treatment-tenants-under-cerclas-bona-fide-prospective-purchaser-bfpp-provision>.
- 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. For information, go to <https://www.epa.gov/re-powering/re-powering-tracking-matrix>.

## IX. Conclusions

Overall, the Town of Saugerties landfill appears to have favorable site conditions to support solar PV generation and viable reuse. Additionally, there are available non-landfill areas nearby the landfill with favorable conditions to support solar PV. An active animal shelter is located north of the landfill next to a town garage facility. The proposed usable solar PV areas were relatively flat vegetative areas with high solar access, making it an ideal site to install solar panels. Shading obstructions on the landfill were minimal and only apparent near the perimeter of the landfill near the tree lines. Transmission lines are conveniently located within the landfill, offering potential interconnection with the local utility. In general, the proposed location appears to offer adequate usable areas for the potential installation of solar photovoltaic panels, both on the landfill and non-landfill areas. 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 Saugerties landfill.

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 operation and maintenance responsibilities and costs, job creation and stimulation of the local economy during solar construction, and reduction in greenhouse gas emissions from current power sources. Thus, using obtainable and accessible land that is unavailable for redevelopment allows for repurpose of land that would not otherwise be productive.

While this solar screening study provides the PV system sizes based on proposed usable areas, the Town of Saugerties would need to further assess the actual system PV size, installation costs, availability of funds, and the amount of power that can be utilized and sold. As indicated earlier, a third-party developer power purchase agreement (PPA) is another feasible way for a system to be financed for these sites. 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 solar PV systems were considered physically and financially viable to install at this site by a third-party solar developer, the third-party solar developer could sell the electricity to the site host (local town facilities) or local utility via a PPA at negotiated rate for a period of time typically varying from 20-25 years.

## 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):**



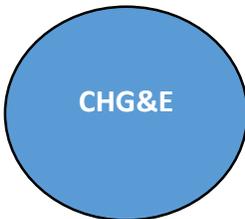
The Town of Saugerties must coordinate early with the **NYSDEC**. To initiate this process, contact James Lansing, Region 3 Materials Management Engineer at (845) 256-3123 or via email at [james.lansing@dec.ny.gov](mailto:james.lansing@dec.ny.gov). NYSDEC's review and approval of the proposed solar PV 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](mailto:gus.carayiannis@dec.ny.gov).

**Coordination with the Local Utility Provider:**



Central Hudson Gas & Electric should be consulted early in the planning stages so that the municipality can be alerted to any potential transmission interconnection issues that might exist or equipment upgrades needed to facilitate the solar project. The Town of Saugerties officials may request a transmission interconnection study from Central Hudson Gas & Electric. As indicated earlier, all technical pertinent information about the proposed solar PV system should be provided to Central Hudson Gas & Electric in accordance with their application requirements.

**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 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@nyserda.ny.gov](mailto:vicki.colello@nyserda.ny.gov) or call (518) 862-1090.

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 Saugerties 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.**

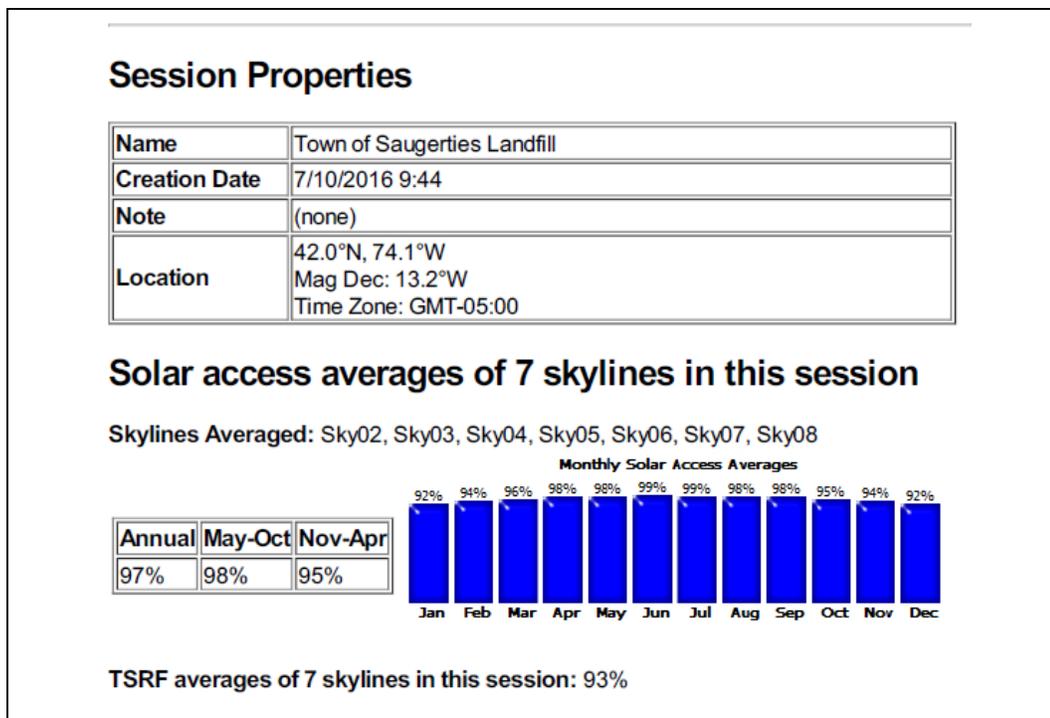
## Attachment #1 - The Town of Saugerties Landfill Information

| <b>Landfill General and Closure Information provided by the Town of Saugerties officials</b>  |  |
|---|--|
| <b>Landfill/site name</b>   | Town of Saugerties Transfer Station  |
| <b>Landfill physical address</b>  | 1765 Route 212, Saugerties, NY 12477   |
| <b>Landfill site operator/owner</b>   | Town of Saugerties   |
| <b>County official contact</b>  | Supervisor Greg Helsmoortel, 845-246-2800, <a href="mailto:ghelsmoortel@saugerties.ny.us">ghelsmoortel@saugerties.ny.us</a> ;<br>Highway Superintendent Doug Myer, 845-246-2400, <a href="mailto:dmyer@saugerties.ny.us">dmyer@saugerties.ny.us</a> ;<br>Special Operations Coordinator Vernon Benjamin, 845-901-2903, <a href="mailto:vernjamin@saugerties.ny.us">vernjamin@saugerties.ny.us</a> ; Solar Consultant Robert Hlavaty, 845-901-9736 <a href="mailto:roberthlavaty@gmail.com">roberthlavaty@gmail.com</a> ; |
| <b>Landfill closure date</b>  | 1996   |
| <b>Annual post-closure monitoring/<br/>maintenance report</b>                                 | Available upon request   |
| <b>Final landfill closure plan</b>  | Available upon request   |
| <b>Landfill Physical Characteristics</b>  |  |
| <b>Landfill size</b>  | 12 acres (inactive)  |
| <b>Landfill cap type</b>  | Grass, mowed regularly ( <i>note: what is the CAP? Not grass</i> )   |
| <b>Potential usable landfill area for solar PV</b>  | 5 acres  |
| <b>Landfill orientation</b>   | 4%- slopes roughly to the south  |
| <b>Physical conditions</b>  | Well maintained vegetative cover   |
| <b>Landfill shading concerns</b>  | Perimeter is surrounded by trees, but substantial area is unshaded/elevated  |
| <b>Landfill settlement/floodplains/wetlands concerns</b>                                      | None anticipated   |
| <b>Existing landfill treatment systems</b>  | Leachate   |
| <b>Landfill contour maps or other site maps</b>   | Available upon request.  |
| <b>Utility Information</b>  |  |
| <b>Utility company serving the area</b>   | Central Hudson Gas and Electric Corp.  |
| <b>Nearby major highways</b>  | Approx. 1,300 feet from closest point of landfill to Route 212   |
| <b>Distance to electrical transmission lines</b>  | Transmission lines on site or on Route 212   |
| <b>Location of substations</b>  | NW   |
| <b>Landfill electrical load/classification</b>  | SC No.18 Commercial/Small Industrial Rate E205 General Service Secondary<br>Single or Three Phase with Secondary Measured Demand<br>Most recent 12 months: Average demand 11.1 kW<br>Consumption 23,828 kWh, average monthly 1,986 kWh, peak monthly 3,628 kWh   |
| <b>Other</b>  |  |
| <b>Ongoing remediation at the site</b>  | Leachate collection  |
| <b>Private parties associated with the landfill</b>   | Not applicable.  |
| <b>Existing site liens/bankruptcy status</b>  | No   |
| <b>Previous solar or interconnection studies</b>  | No   |
| <b>Nearest critical infrastructure from landfill</b>  | 5 miles  |
| <b>Potential off-takers of solar power generated</b>  | Approx. 40 town electric accounts (~1.2 MW)  |
| <b>Community/municipality support</b>   | Yes, town is considering a 1.2 MW solar farm to provide energy for town bldgs.   |
| <b>Can the load bearing capacity of the landfill accommodate loading from a solar system?</b> | TBD  |
| <b>Potentially responsible parties (PRPs)</b>   | Not applicable.  |
| <b>Estimated PV solar energy generation based on potential usable landfill area</b>           | 5.74 acres/MW dc   |

## Attachment #2 – SunEye Solar Measurements

The EPA solar assessment team used a Solmetric SunEye<sup>7</sup> 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 seven Solmetric SunEye data points (skyline views) across the entire perimeter of the landfill in sections with adequate flat area as shown in Figure #3. Overall, solar access yields averaged **97% annual solar exposure**, which is well within the favorable annual solar access range for PV systems.



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. TRSF 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.

<sup>7</sup> More information on this tool can be found at: <http://www.solmetric.com/>

**Attachment #3 – Monthly Performance Results for the Town of Saugerties Landfill**

| Performance Results<br>Fixed-Tilt PV System: |  | 871.2 kW DC<br>on landfill<br>area | 174.19 kW DC<br>on non-landfill<br>areas |
|--|--|------------------------------------|--|
| Month  | Solar<br>Radiation*<br>(kWh/m <sup>2</sup> /day) | AC<br>Energy<br>(kWh)              | AC<br>Energy<br>(kWh)                    |
| January                                      | 3.02   | 69,924                             | 13,983                                   |
| February                                     | 2.71   | 57,413                             | 11,481                                   |
| March  | 4.73   | 105,011                            | 20,999                                   |
| April  | 4.14   | 86,877                             | 17,373                                   |
| May  | 5.45   | 115,030                            | 23,003                                   |
| June   | 5.28   | 105,404                            | 21,078                                   |
| July   | 5.20   | 107,626                            | 21,522                                   |
| August                                       | 4.53   | 92,920                             | 18,781                                   |
| September                                    | 3.74   | 76,581                             | 15,314                                   |
| October                                      | 3.15   | 68,391                             | 13,676                                   |
| November                                     | 2.85   | 61,225                             | 12,243                                   |
| December                                     | 2.28   | 52,488                             | 10,496                                   |
| <b>Total</b>                                 | <b>3.92*</b><br>Monthly Average                  | <b>998,890**</b><br>Annual         | <b>199,748**</b><br>Annual               |

\*Solar radiation values above 3.5 kWh/m<sup>2</sup>/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 #4 - PV Systems Overview

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

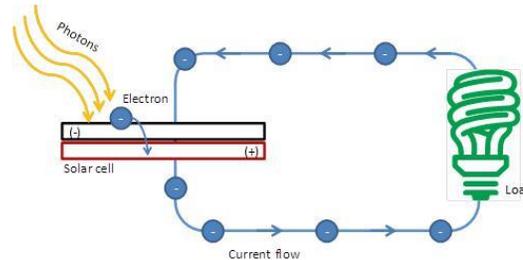
- PV modules,
- inverters and
- balance-of-system components (including mounting racks, hardware for the panels, and wiring for electrical connections). Electrical connections (including wiring, disconnect switches, fuses, and breakers) are required to meet electrical code (e.g., NEC Article 690) for 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 mounted 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 10 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 #5 – 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 packing 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  |
| 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. |