Feasibility Study of Economics and Performance of Solar Photovoltaics at the Refuse Hideaway Landfill in Middleton, Wisconsin

A Study Prepared in Partnership with the Environmental Protection Agency for the RE-Powering America's Land Initiative: Siting Renewable Energy on Potentially Contaminated Land and Mine Sites

James Salasovich and Gail Mosey

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

Technical Report
NREL/TP-6A20-49846
August 2011

Contract No. DE-AC36-08GO28308

NATIONAL RENEWABLE ENERGY LABORATORY

Feasibility Study of Economics and Performance of Solar Photovoltaics at the Refuse Hideaway Landfill in Middleton, Wisconsin

A Study Prepared in Partnership with the Environmental Protection Agency for the RE-Powering America's Land Initiative: Siting Renewable Energy on Potentially Contaminated Land and Mine Sites

James Salasovich and Gail Mosey

Prepared under Task No. WFD4.1000

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency & Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

National Renewable Energy Laboratory
1617 Cole Boulevard
Golden, Colorado 80401
303-275-3000 • www.nrel.gov

Technical Report
NREL/TP-6A20-49846
August 2011

Contract No. DE-AC36-08GO28308

Available electronically at http://www.osti.gov/bridge

Available for a processing fee to U.S. Department of Energy
and its contractors, in paper, from:

U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831-0062
phone: 865.576.8401
fax: 865.576.5728
email: mailto:reports@adonis.osti.gov

Available for sale to the public, in paper, from:

U.S. Department of Commerce
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
phone: 800.553.6847
fax: 703.605.6900
email: orders@ntis.fedworld.gov
online ordering: http://www.ntis.gov/help/ordermethods.aspx

Cover Photos: (left to right) PIX 16416, PIX 17423, PIX 16560, PIX 17613, PIX 17436, PIX 17721

Printed on paper containing at least 50% wastepaper, including 10% post consumer waste.

Acknowledgments

We would like to thank Hank Kuehling, Department of Natural Resources, and John Fagiolo, EPA, for assisting with the site visit of the Refuse Hideaway Landfill.

Executive Summary

The U.S. Environmental Protection Agency (EPA), in accordance with the RE-Powering America's Land initiative, selected the Refuse Hideaway Landfill in Middleton, Wisconsin, for a feasibility study of renewable energy production. Citizens of Middleton, city planners, and site managers are interested in redevelopment uses for landfills in Wisconsin that are particularly well suited for solar photovoltaic (PV) installation. The purpose of this report is to assess the Refuse Hideaway Landfill for possible PV installation and estimate the cost, performance, and site impacts of three different PV options: crystalline silicon (fixed tilt), crystalline silicon (single-axis tracking), and thin film (fixed tilt). Each option represents a standalone system that can be sized to use an entire available site area. In addition, the report outlines financing options that could assist in the implementation of a system. Landfill gas is another possible renewable energy option for the landfill in Middleton. Landfill gas is briefly addressed in this feasibility study, but PV is the main focus.

The feasibility of PV systems installed on landfills is highly impacted by the available area for an array, solar resource, operating status, landfill cap status, distance to transmission lines, and distance to major roads. The Refuse Hideaway Landfill is suitable in area to have a large-scale PV system, and the solar resource in Middleton, Wisconsin, is appropriate. The findings from this report can also be applied to other landfills in Wisconsin.

The economics of the potential systems were analyzed using the current Madison Gas and Electric (MG&E) electric rate of $0.1333/kWh and incentives offered by the State of Wisconsin and by the serving utility, MG&E. State incentives are currently not offered for commercial solar power systems in Wisconsin.

A 10 kW PV system was installed at the Refuse Hideaway Landfill in 2010, and this system occupies approximately 1% of the available land that is feasible for a PV system at the site. This PV system produces approximately 25% of the electricity required to run the pumps and fans related to the remediation system at the site. The entire site does not need to be developed; increasing the PV capacity as funds become available is a viable approach. Calculations for this analysis reflect the solar potential if the total feasible area is used. It is also assumed that the 30% federal tax credit incentive would be captured for the system.

The economics of a potential PV system on the Refuse Hideaway Landfill depend greatly on the cost of electricity. Currently, MG&E has an average electric rate of $0.1333/kWh. Based on past electric rate increases in Wisconsin, this rate could increase to $0.15/kWh or higher in a relatively short amount of time. Table ES-1 summarizes the system performance and economics of potential systems that would use all available areas that were surveyed at the Refuse Hideaway Landfill. The table shows the annual energy output from the system along with the number of average American households that could be powered off of such a system. The table lists results assuming the current electric rate of $0.1333/kWh and shows results assuming a hypothetical rate increase to $0.15/kWh. In the coming years, increasing electrical rates and increased necessity for clean power will continue to improve the feasibility of implementing solar PV systems at landfill sites.

Table ES-1. Refuse Hideaway PV System Performance and Economics by System Type, Including Job Creation Estimates[a]

			Annual Cost Savings ($/year)				Payback Period (years)			
PV System Size (kW)	Annual Output (kWh/year)	Number of Houses Powered [b]	With Current Rate ($0.13/kWh)	With Rate Increase ($0.15/kWh)	Annual O&M ($/year)	System Cost with Incentives ($)	With Incentives & Current Rate	With Incentives & Hypothetical Rate Increase	Jobs [c] Created (job-yr)	Jobs [d] Sustained (job-yr)
Crystalline Silicon (Fixed Tilt at 43.1°)										
1,350	1,661,850	150	$221,525	$249,278	$10,328	$4,252,500	20	18	66	0.11
Crystalline Silicon (Single-Axis Tracking)										
1,100	1,549,477	140	$206,545	$232,422	$23,100	$4,620,000	25	22	72	0.25
Thin Film (Fixed Tilt at 43.1°)										
550	677,050	61	$90,251	$101,558	$3,647	$1,501,500	17	15	23	0.04

[a] Data assume a maximum usable area of all feasible areas of the Refuse Hideaway Landfill of 378,384 ft^2.
[b] Number of average American households that could hypothetically be powered by the PV system assuming 11,040 kWh/year/household.[1]
[c] Job-years created as a result of project capital investment including direct, indirect, and induced jobs.
[d] Jobs (direct, indirect, and induced) sustained as a result of operations and maintenance (O&M) of the system.

[1] U.S. Energy Information Administration. http://www.eia.doe.gov/ask/electricity_faqs.asp#electricity_use_home. Accessed November 2, 2010.

Table of Contents

List of Figures

List of Tables

1 Study Location

The Refuse Hideaway Landfill is located in Middleton, Wisconsin. The town of Middleton is located west of the capital city of Madison. As of the 2000 census, Middleton has a population of approximately 16,000 people. It has a humid climate that is characterized by large seasonal temperature swings. The winters commonly experience temperatures well below freezing with moderate to heavy snowfall. The summers are humid and commonly experience temperatures between 80^{o} and 90^{o}F. The main utility company is Madison Gas and Electric (MG&E).

Under the RE-Powering America's Land Initiative, the Environmental Protection Agency (EPA) provided funding to the National Renewable Energy Laboratory (NREL) to support a feasibility study of solar renewable energy generation at the Refuse Hideaway Landfill in Middleton, Wisconsin. The landfill is 23 acres and sits on a 40-acre parcel of land. The landfill was in operation from 1974 through 1988 and is currently closed and capped. Due to the presence of contaminants, landfill sites have limited redevelopment potential. Therefore, renewable energy generation is a viable reuse.

One very promising and innovative use of closed landfills is to install solar photovoltaic (PV) systems. PV systems can be ground-mounted, and these types of systems work well on landfill sites where there are commonly large unshaded areas. In some cases, PV can be used to form the cap of the landfill. PV may generate revenue on a landfill site that may otherwise go unused. The Refuse Hideaway Landfill is owned by the State of Wisconsin, which is interested in potential revenue flows from PV systems on landfills. PV systems on landfills may give the state a reason to close other state-owned landfills in a timely manner and to maintain the landfill cap once it is in place. There is currently a 10 kW ground-mounted crystalline silicon PV system at the Refuse Hideaway Landfill, which will be discussed in Section 3.1.

The focus of this report is on PV systems, but another innovative use of closed landfills is to install a landfill gas plant. The landfill gas could be used in a heating application or used to operate a generator in order to make electricity. The key points that need to be investigated to determine whether landfill gas capture is feasible are the age of the landfill, the size, and the types of gases generated by the landfill. For landfill gas capture, it is best to have a newly capped landfill because the landfill gas production greatly declines after 20–30 years. It is also preferable to have a high organic waste content. The Refuse Hideaway Landfill was closed and capped in 1988, and it is therefore not an optimal candidate for a landfill gas plant. The types of gases that are generated by the landfill can be determined by doing a sample test. This involves drilling a hole into the landfill, putting a vacuum on the landfill, and sampling the rate and types of gases being generated. A detailed landfill gas study should be done in order to determine the feasibility of landfill gas capture and use at all relatively newly capped larger landfills in the state of Wisconsin.

Like most states, Wisconsin relies heavily on fossil fuels to operate its power plants. About two-thirds of Wisconsin's electricity is generated from coal, and the remaining one-third is generated from oil, natural gas, or nuclear.[2] There are many compelling reasons to consider moving toward renewable energy sources for power generation instead of fossil fuels, including:

- Using fossil fuels to produce power may not be sustainable.
- Burning fossil fuels can have negative effects on human health and the environment.
- Extracting and transporting fossil fuels can lead to accidental spills, which can be devastating to the environment and communities.
- Depending on foreign sources of fossil fuels can be a threat to national security.
- Fluctuating electric costs are associated with fossil-fuel-based power plants.
- Burning fossil fuels may contribute to climate change.
- Generating energy without harmful emissions or waste products can be accomplished through renewable energy sources.
- Abundant renewable resources are available in Wisconsin.

[2] U.S. Energy Information Administration. http://www.eia.doe.gov/state/state_energy_profiles.cfm?sid=WI. Accessed November 3, 2010.

2 PV Systems

Solar PV systems are semiconductor devices that convert sunlight directly into electricity. They do so without any moving parts and without generating any noise or pollution. They must be mounted in an unshaded location; rooftops, carports, and ground-mounted arrays are common mounting locations. PV systems work very well in Middleton, Wisconsin, where the average global horizontal annual solar resource is 4.6 kWh/m^2/day. This number, however, is not the amount of energy that can be produced by a PV panel. The amount of energy produced by a panel depends on several factors. These factors include the type of collector, the tilt and azimuth of the collector, the temperature, the level of sunlight, and weather conditions. An inverter is required to convert the direct current (DC) to alternating current (AC) of the desired voltage compatible with building and utility power systems. The balance of the system consists of conductors/conduit, switches, disconnects, and fuses. Grid-connected PV systems feed power into the facility's electrical system and do not include batteries.

Figure 1 shows the major components of a grid-connected PV system and illustrates how these components are interconnected.

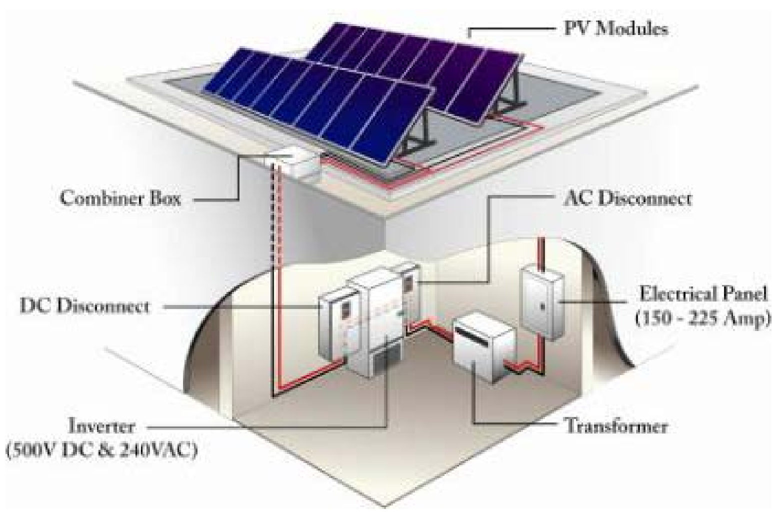

Figure 1. Major components of grid-connected PV system

Credit: Jim Leyshon, NREL

PV panels 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. PV panels are very sensitive to shading. When shade falls on a panel, the shaded portion of the panel cannot collect the high-energy beam radiation from the sun. If an individual cell is shaded, it will act as a resistance to the whole series circuit, impeding current flow and dissipating power rather than producing it. By determining solar access—the unimpeded ability of sunlight to reach a solar collector—one can determine whether an area is appropriate for solar panels.

For this assessment, the NREL team used a solar path calculator to assess shading at particular locations by analyzing the sky view where the solar panels will be located. The solar path calculator is equipped with a fisheye lens that takes a 360^o photo of the sky and plots out the shading obstructions throughout the year on a spherical axis, with the months listed longitudinally and the hour of day listed latitudinally. Shading analysis is typically done at locations where shading will most likely be an issue (e.g., close to a group of trees or a hill on the perimeter of a landfill).

If a site is found to have good solar access for a PV system, then the next step is to determine the size of that system, which highly depends on the average energy use of the on-site facilities. Providing more power than a site would use is dependent on the economics of most net-metering agreements. In the case of the Refuse Hideaway site, most of the electricity generated at the site would be sold to the serving utility, MG&E, because there is little electrical load except for the pumping and fan energy associated with the remediation system. The system size would thus be determined by the amount of electricity the electric company would be willing to purchase or by how much land area is available. For the purpose of this report, the NREL assessment team assumed MG&E would purchase any electricity that the site can generate. The systems will be broken down by site so the system size can be adjusted based on what the utility requests.

2.1 Types of PV Systems

2.1.1 Ground-Mounted Systems

A ground-mounted system is required at a landfill because there is little to no roof area. On a $/DC-Watt basis, ground-mounted PV systems are usually the lowest cost option to install. Several PV panel and mounting options are available, each having different benefits for different ground conditions. Table 1 outlines the energy density values that can be expected from each type of system.

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

System Type	Fixed-Tilt Energy Density (DC-Watts/ft^2)	Single-Axis Tracking Energy Density (DC-Watts/ft^2)
Crystalline Silicon	4.0	3.3
Thin Film	1.7	1.4
Hybrid HE*	4.8	3.9

* Because hybrid high efficiency (HE) panels do not represent a significant portion of the commercial market, they were not included in the analysis. Installing panel types that do not hold a significant portion of the commercial market would not be feasible for a large-scale solar generation plant.

Installing PV systems on landfills is a unique situation because the landfill cap cannot be penetrated. Therefore, a PV system that does not penetrate the landfill cap such as a ballasted system is required in landfill applications. With ballasted systems, the PV system is held down by weighting the racking system. For the purpose of this analysis, all fixed-tilt systems were assumed to be ballasted and mounted at latitude with a tilt of 43.1°. To get the most out of the available ground area, considering whether a site layout can be improved to better incorporate a solar energy system is important. If unused structures, fences, or electrical poles can be removed, the unshaded area can be increased to incorporate more PV panels. When considering a ground-mounted system, an electrical tie-in location should be identified to determine how the energy would be fed back into the grid. For this report, only fixed-tilt ground-mounted systems and single-axis tracking systems were considered.

Fixed-tilt systems are installed at a specified tilt and are fixed at that tilt for the life of the system. Single-axis tracking systems have a fixed tilt on one axis and a variable tilt on the other axis; the system is designed to follow the sun in its path through the sky. This allows the solar radiation to strike the panel at an optimum angle for a larger part of the day than can be achieved with a fixed-tilt system. A single-axis tracking system can collect nearly 30% more electricity per capacity than can a fixed-tilt system. The drawbacks include increased operation and maintenance (O&M) costs, less capacity per unit area (DC-Watt/ft^2), and greater installed costs ($/DC-Watt).

2.1.2 Roof-Mounted Systems

In many cases, a roof is the best location for a PV system. Roof-mounted PV systems are usually more expensive than ground-mounted systems, but a roof is a convenient location because it is out of the way and usually unshaded. Large areas with minimal rooftop equipment are preferred, but equipment can sometimes be worked around if necessary. If a building has a sloped roof, a typical flush-mounted crystalline silicon panel can achieve power densities on the order of 10 DC-Watt/ft^2. For buildings with flat roofs, rack-mounted systems can achieve power densities on the order of 8 DC-Watt/ft^2 with a crystalline silicon panel. Table 2 lists the energy density by panel type for roof-mounted PV.

Table 2. Energy Density by Panel Type for Roof-Mounted PV

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

Typically, PV systems are installed on roofs that either are less than 5 years old or have over 30 years left before replacement. There were no roof areas analyzed at the Refuse Hideaway Landfill.

2.2 PV System Components

The PV system considered here has these components:

- PV arrays, which convert light energy to DC electricity
- Inverters, which convert DC to AC and provide important safety, monitoring, and control functions
- Various wiring, mounting hardware, and combiner boxes
- Monitoring equipment.

2.2.1 PV Array

The primary component of a PV system, the PV array, converts sunlight to electrical energy; all other components simply condition or control energy use. Most PV arrays consist of interconnected PV modules that range in size from 50 peak DC-Watts to 300 peak DC-Watts. Peak watts are the rated output of PV modules at standard operating conditions of 25°C (77°F) and insolation of 1,000 W/m^2. Because these standard operating conditions are nearly ideal, the actual output will be less under typical environmental conditions. PV modules are the most reliable components in any PV system. They have been engineered to withstand extreme temperatures, severe winds, and impacts. ASTM E1038-05[3] subjects modules to impacts from one-inch hail balls at terminal velocity (55 mph) at various parts of the module. PV modules have a life expectancy of 20–30 years. The array is usually the most expensive component of a PV system; it accounts for approximately two-thirds the cost of a grid-connected system. Many PV manufacturers are available.[4]

2.2.2 Inverters

PV arrays provide DC power at a voltage that depends on the configuration of the array. This power is converted to AC at the required voltage and number of phases by the inverter. Inverters enable the operation of commonly used equipment such as appliances, computers, office equipment, and motors. Current inverter technology provides true sine wave power at a quality often better than that of the serving utility. The locations of both the inverter and the balance-of-system equipment are important. Inverters are available that include most or all of the control systems required for operation, including some metering and data-logging capability. Inverters must provide several operational and safety functions for interconnection with the utility system. The Institute of Electrical and Electronic Engineers, Inc. (IEEE) maintains standard *"P929 Recommended Practice for Utility Interface of Photovoltaic (PV) Systems,"*[5] which allows manufacturers to write "Utility-Interactive" on the listing label if an inverter meets the requirements of frequency and voltage limits, power quality, and non-islanding inverter testing. Underwriters Laboratory maintains "*UL Standard 1741, Standard for Static Inverters and Charge Controllers for Use in Photovoltaic Power Systems,"*[6] which incorporates the testing required by IEEE 929 and includes design (type) testing and production testing. A large choice of inverter manufacturers is available.[7]

2.3 Operation and Maintenance

The PV panels come with a 25-year performance warranty. The inverters, which come standard with a 5- or 10-year warranty (extended warranties available), would be expected to last 10–15 years. System performance should be verified on a vendor-provided website. Wire and rack connections should be checked. For this economic analysis, an annual O&M cost of 0.17% of total installed cost is used based on O&M costs of other fixed-tilt grid-tied PV systems. For the case of single-axis tracking, an annual O&M cost of 0.35% of total installed cost is used based on O&M costs of existing single-axis tracking systems.

---

[3] ASTM Standard E1038. "Standard Test Method for Determining Resistance of Photovoltaic Modules to Hail by Impact with Propelled Ice Balls." West Conshohocken, PA: ASTM International, 2005, DOI: 10.1520/E1038-05. http://www.astm.org/Standards/E1038.htm. Accessed November 2, 2010.

[4] Go Solar California, a joint effort of the California Energy Commission and the California Public Utilities Commission, provides consumer information for solar energy systems. See http://www.gosolarcalifornia.org/equipment/pvmodule.php. Accessed November 2, 2010.

[5] "ANSI/IEEE Std 929-1988 IEEE Recommended Practice for Utility Interface of Residential and Intermediate Photovoltaic (PV) Systems." http://standards.ieee.org/reading/ieee/std_public/description/powergen/929-1988_desc.html. Accessed November 2, 2010.

[6] "Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources: UL 1741." http://ulstandardsinfonet.ul.com/scopes/1741.html. Accessed November 2, 2010.

[7] Go Solar California approves inverters.

2.4 PV Size and Performance

PV arrays must be installed in unshaded locations on the ground or on building roofs that have an expected life of at least 25 years. The predicted array performance was found using a combination of PVWATTS, a performance calculator for grid-connected PV systems created by NREL's Renewable Resource Data Center,[8] and SolOpt, a solar performance tool currently being developed at NREL. The performance data was used to calculate the amount of revenue that could be expected each year.

[8] NREL. "PVWatts." http://www.nrel.gov/rredc/pvwatts/. Accessed November 2, 2010.

3 PV Site Location

This section summarizes the findings of the NREL solar assessment site visit on April 28, 2010.

3.1 Refuse Hideaway Landfill PV System

The State of Wisconsin is the responsible party at the Refuse Hideaway Landfill because the state sent waste there. The site is located to the north of highway 14 and is fairly visible from the highway. The Refuse Hideaway Landfill is 23 acres and sits on a 40-acre parcel of land. The landfill was in operation from 1974 through 1988 and is currently closed and capped. The landfill cap is made up of a minimum of 2 ft of clay, and the landfill is not lined. Some areas of the landfill have steep slopes, but there is a relatively large area with moderate to no slope that is suitable for a PV system. Figure 2 shows various views of the Refuse Hideaway Landfill. As shown, there are large expanses of relatively flat unshaded land, which makes it a suitable candidate for a PV system.

Figure 2. Views of the feasible area for PV at the Refuse Hideaway Landfill

Credits: Jimmy Salasovich, NREL

A 10 kW PV system was installed at the Refuse Hideaway Landfill in 2010, and this system occupies approximately 1% of the available land that is feasible for a PV system at the site. The

PV panels used at the site are 224 W crystalline-silicon modules manufactured by Sharp. The nameplate of the PV panels is shown in Figure 3. The PV system is a ballasted system so that there are no penetrations of the landfill cap. The ballasted system is shown in Figure 4. The area that the current 10 kW PV system occupies is approximately 3,400 ft^2. The site was relatively well kept and mowed at the time of the site visit. Figure 5 shows the 10 kW PV system currently in use at the Refuse Hideaway Landfill.

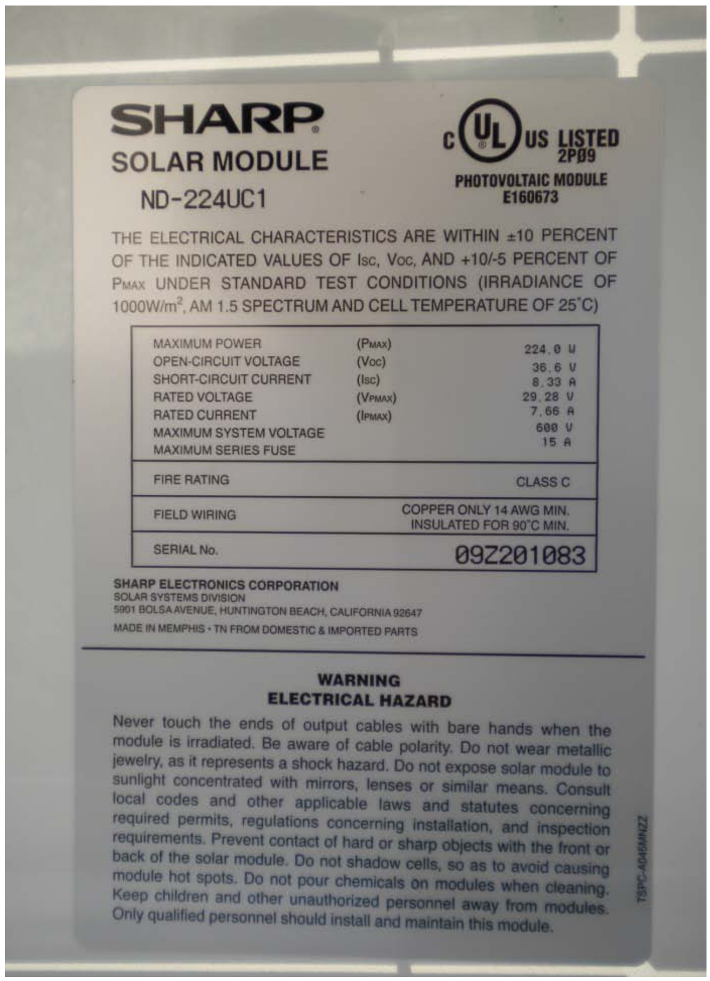

Figure 3. Sharp PV module nameplate

Credit: Jimmy Salasovich, NREL

Figure 4. Ballasted PV system at the Refuse Hideaway Landfill

Credit: Jimmy Salasovich, NREL

Figure 5. View of the 10 kW ballasted PV system currently at the Refuse Hideaway Landfill

Credit: Jimmy Salasovich, NREL

The electrical tie-in point and inverter for the PV system at the Refuse Hideaway Landfill is located approximately 950 ft to the east of the PV system and is close to the entrance of the landfill. A considerable portion of the initial PV system cost was trenching the electrical lines to the tie-in point. The electrical tie-in point is shown in Figure 6, and the inverter is shown in Figure 7. Expanding the PV system could potentially be started on this site immediately, and the costs for trenching the electrical lines to the tie-in point have already been incurred. This site would need to have a ballast-mounted system implemented, as ground disturbances are not permitted due to the clay cap.

Figure 6. Electrical tie-in point for the PV system at the Refuse Hideaway Landfill

Credit: Jimmy Salasovich, NREL

Figure 7. Inverter used in the PV system at the Refuse Hideaway Landfill

Credit: Jimmy Salasovich, NREL

The Refuse Hideaway Landfill has a remediation system that includes fans for methane gas extraction and pumps for leachate extraction. There are a total of 13 fans for the methane gas extraction and 9 diaphragm pumps for the leachate extraction. The Wisconsin Department of Natural Resources (WDNR) has control over the remediation system at the Refuse Hideaway Landfill, and it is believed that the remediation system will have to operate indefinitely in order to mitigate groundwater contamination. The remediation system consumes approximately 48,000 kWh/year, which is a relatively significant electrical load at the site. The current 10 kW PV system at the site produces approximately 12,310 kWh/year, which is approximately 25% of the annual electrical energy required for the remediation system. A 40 kW PV system would produce enough electricity to cover the 48,000 kWh annual load at the Refuse Hideaway Landfill.

Figure 8 shows the Refuse Hideaway Landfill taken from Google Earth; the feasible area for PV is shaded in orange, the current 10 kW PV system is shaded in green, and the electrical tie-in point for the PV system is given. As shown, there is one relatively large area at the Refuse Hideaway Landfill that is feasible for PV, which has an area of 378,384 ft^2.

Figure 8. Aerial view of the feasible area (orange) for PV at the Refuse Hideaway Landfill

Credit: Google Earth

Table 3 lists the ground-mounted PV system possibilities at the Refuse Hideaway Landfill. The three options outline the types of solar technology that could potentially be used.

Table 3. Refuse Hideaway Landfill PV System Performance and Economics by System Type[a]

PV System Size (kW)	Annual Output (kWh/year)	Number of Houses Powered[b]	Annual Cost Savings ($/year)	Annual O&M ($/year)	System Cost with Incentives ($)	Payback Period with Incentive (years)
Crystalline Silicon (Fixed Tilt 43.1°)						
1,350	1,661,850	150	$221,525	$10,328	$4,252,500	20
Crystalline Silicon (Single-Axis Tracking)						
1,100	1,549,477	140	$206,545	$23,100	$4,620,000	25
Thin Film (Fixed Tilt 43.1°)						
550	677,050	61	$90,251	$3,647	$1,501,500	17

[a] Data assume a maximum usable area of the Refuse Hideaway Landfill of 378,384ft^2.
[b] Number of average American households that could hypothetically be powered by the PV system assuming 11,040 kWh/year/household.[9]

[9] U.S. Energy Information Administration. http://www.eia.doe.gov/ask/electricity_faqs.asp#electricity_use_home. Accessed November 2, 2010.

4 Economics and Performance

4.1 Assumptions and Input Data for Analysis

It was assumed that the installed cost of fixed-tilt roof-mounted systems will be $6.00/W and fixed-tilt ground-mounted systems will be $4.50/W. These prices include the PV array and the balance-of-system components for each system, including the inverter, electrical equipment, and installation. The economics of grid-tied PV depend on incentives, the cost of electricity, and the solar resource including panel tilt and orientation. For this analysis, it was assumed that the cost of electricity was $0.1333/kWh.

A system DC to AC conversion of 77% was assumed. This includes losses in the inverter, wire losses, PV module losses, and losses due to temperature effects. PVWATTS was used to calculate energy performance.

It was assumed for this analysis that federal and state incentives are received. Identifying and leveraging state incentives and grants is an important part of making PV systems cost effective. A private, tax-paying entity that owns PV systems can qualify for a 30% federal business energy investment tax credit (ITC) and accelerated depreciation on the PV system, which are worth about 15%. The total potential tax benefits to the tax-paying entity are about 45% of the system cost. Alternatively, the tax-paying entity can opt to receive a cash payment of up to 30% of eligible project costs from the U.S. Department of Treasury Section 1603 program[10] once the eligible system is in service. The American Reinvestment and Recovery Act of 2009 (Recovery Act) allows for this cash payment in lieu of the ITC. Because the federal government does not pay taxes, private ownership of the PV system is required to capture tax incentives or Section 1603 grant payments.[11] Municipalities are not tax-paying entities and therefore would have to pursue a power purchase agreement (PPA) in order to get the 30% federal tax credit, which is described in the following section.

4.2 Incentives and Financing Opportunities

The Database of State Incentives for Renewables and Efficiency (DSIRE) provides a summary of net metering, interconnection rules, and other incentives available to Middleton, Wisconsin, utility customers.

Renewable energy systems, including commercial solar PV, are subject to interconnection rules promulgated at the state level. Interconnection rules for Wisconsin were found on the DSIRE website. The Wisconsin Public Service Commission developed interconnection standards in 2004 that set an interconnection system capacity limit at 15 MW. This requires all interconnected systems to comply with the safety and performance requirements put forth in the IEEE Standard 1547 as well as local construction and safety standards.

Wisconsin has a net-metering policy for residential, commercial, and industrial systems up to 20 kW in capacity. This is a very low capacity for net metering and is an issue for the Refuse Hideaway Landfill because not all of the electricity generated by a PV system will be used, so

[10] This program was codified in Section 1603 of the American Recovery and Reinvestment Act of 2009.
[11] DSIRE. "Wisconsin." http://www.dsireusa.org/incentives/index.cfm?re=1&ee=1&spv=0&st=0&srp=1&state=WI. Accessed November 2, 2010.

the remaining will have to be sent back to the electric utility grid. Discussions with MG&E should commence to determine if the net-metering capacity limit can be significantly raised if a PV system were to be installed at the Refuse Hideaway Landfill. Net excess generation will be carried over to a customer-generator's next bill.

State incentives are currently not offered for solar power systems in Wisconsin. The 30% tax credit federal incentive can be captured if the system is owned by a tax-paying entity.

The system facilitator could potentially pursue an agreement with MG&E that would negotiate both a higher price for the electricity produced by the PV system and the potential to sell renewable energy certificates (RECs). Any power that is produced by a solar PV system will help the state reach its renewable portfolio standard (RPS) and would be a major opportunity for MG&E to accelerate the diversification of their energy mix with clean energy. It has been demonstrated across the country that people are willing to pay a premium for certified clean energy,[12] and MG&E could start a voluntary green power purchase pilot program with energy from the Refuse Hideaway Landfill.[13]

Technical assistance to support project development is available through the U.S. Department of Energy (DOE) and the Office of Energy Efficiency and Renewable Energy (EERE). The program provides technical assistance to commercial power developers, technology projects involving liquid fuels developed from biomass, and information to the public on renewable energy applications. The DOE Office of EERE can assist commercial wind and solar developers by providing detailed renewable resource maps, interfacing with Wisconsin utilities, and contacting local economic developers.

There are several options for financing a solar PV system. However, obtaining investment from landowners with little on-site presence—such as is the case with the Refuse Hideaway Landfill—can be difficult. A potential alternative financing option is the third-party ownership PPA. The agreement works by having a solar contractor install, finance, and operate the system while the utility company purchases the electricity generated by the system. The system is financed by the solar contractor, and the payments are paid by the electricity and RECs that are sold to the utility. In this configuration, the land that the solar system is on would need to be leased to the owner of the system for the duration of the contract.

Another gap financing tool that may be available is tax increment financing (TIF). Connecticut, Iowa, Michigan, and Wisconsin have been leaders in structuring state-facilitated TIF financing as an effective and efficient means to enhance site reuse and redevelopment programs and to obtain successful cleanup and redevelopment results. A full list of incentives can be found in Appendix B.

[12] Transmission & Distribution World. "NREL Highlights Utility Green Power Leaders." http://tdworld.com/customer_service/doe-nrel-utility-green-power-0409/. Accessed November 2, 2010.

[13] An example of such a program is Xcel Energy's Windsource program. For more information, see http://www.xcelenergy.com/Colorado/Company/Environment/Renewable%20Energy/Pages/Wind_Power.aspx. Accessed November 2, 2010. For detailed information about federal, state, and local incentives in Wisconsin, see http://www.dsireusa.org/incentives/index.cfm?re=1&ee=1&spv=0&st=0&srp=1&state=WI. Accessed November 2, 2010.

4.3 Job Creation

The implementation of this project would represent a large amount of money entering the clean energy industry of Wisconsin. The Council of Economic Advisors (CEA) calculated the number of jobs (direct, indirect, and induced) created due to federal spending using economic models developed with real world data. CEA found that $92,000 in federal spending is equivalent to one job-year. This means that for every $92,000 of federal money that is spent, there is a job created that can be sustained for 1 year. See Table 4 for an estimate of job creation by system type if all the feasible area at the Refuse Hideaway Landfill were used for solar PV. This project represents a large amount of money that would create a significant number of jobs. A portion of these jobs, including the installation and system maintenance jobs, will be created within the community. The jobs created column refers to the number of job-years that would be created as a result of the one-time project capital investment. This means that the jobs will be created and sustained for one year. The jobs sustained column refers to the number of jobs that would be sustained as a result of the O&M of the system. These jobs will be sustained for the life of the system, due to the annual cost to keep the system operating.

Table 4. Estimated Job Creation by PV System Type

System Type	Jobs Created[a] (job-years)	Jobs Sustained[b] (number of jobs)
Crystalline Silicon (Fixed Tilt)	66	0.11
Crystalline Silicon (Single-Axis Tracking)	72	0.25
Thin Film (Fixed Tilt)	23	0.04

[a] Job-years created as a result of project capital investment including direct, indirect, and induced jobs.
[b] Jobs (direct, indirect, and induced) sustained as a result of O&M of the system.

5 Potential Rate Increases

The economics of a potential PV system on the Refuse Hideaway Landfill depend greatly on the cost of electricity. Currently, MG&E has an average electric rate of $0.1333/kWh. Based on past electric rate increases in Wisconsin, this rate could hypothetically increase to $0.15/kWh or higher in a relatively short amount of time. A rate increase of this magnitude would further improve the economics of a solar PV generation plant. See Table 5 for a summary of the system economics assuming a hypothetical rate increase to $0.15/kWh.

Table 5. PV System Performance and Economics with a Hypothetical Rate Increase to $0.15/kWh[a]

PV System Size (kW)	Annual Output (kWh/year)	Number of Houses Powered[b]	Annual Cost Savings ($/year)	Annual O&M ($/year)	System Cost with Incentives ($)	Payback Period with Incentive (years)
Crystalline Silicon (Fixed Tilt 43.1°)						
1,350	1,661,850	150	$249,278	$10,328	$4,252,500	18
Crystalline Silicon (Single-Axis Tracking)						
1,100	1,549,477	140	$232,422	$23,100	$4,620,000	22
Thin Film (Fixed Tilt 43.1°)						
550	677,050	61	$101,558	$3,647	$1,501,500	15

[a] Data assume a maximum usable area of the Refuse Hideaway Landfill of 378,384ft^2.
[b] Number of average American households that could hypothetically be powered by the PV system assuming 11,040 kWh/year/household.[14]

[14] U.S. Energy Information Administration. http://www.eia.doe.gov/ask/electricity_faqs.asp#electricity_use_home. Accessed November 2, 2010.

6 Conclusions and Recommendations

The Refuse Hideaway Landfill considered in this report is a feasible location to implement solar PV systems. Using obtainable and accessible land that is unavailable for other purposes allows for reuse of land that would not otherwise contribute to productivity for Middleton, Wisconsin. Installing a solar generation plant and the associated facilities on landfills relieves "greenfields" of land use impacts. The results from the Refuse Hideaway Landfill can be extrapolated to cover other landfills throughout Wisconsin. Developing solar facilities on landfills can provide an economically viable reuse option for landfills in Wisconsin. It is beneficial for the landfills to have existing transmission capacity, roads, industrial zoning, and all other critical infrastructure in place for PV systems. One obstacle to PV on landfills is that landfills require little to no electricity once they are capped and closed. Therefore, finding a use for the electricity generated by the PV system is a key element.

It is recommended that the party ultimately responsible for facilitating the implementation of the PV system contact MG&E and attempt to set up an agreement in which MG&E would purchase the electricity generated at the Refuse Hideaway Landfill. According to the site production calculations, the most cost-effective system in terms of return on investment is the thin-film fixed-tilt technology. The lower cost of the system combined with the ample land available makes a thin-film system a good fit for the Refuse Hideaway Landfill. Thin-film technology is a proven technology that can be successfully implemented with a ballasted-style mounting system. Crystalline silicon system styles—both fixed tilt and single-axis tracking systems—could also be implemented, but the increased cost of the crystalline silicon panels may extend the payback period.

For this feasibility study, system calculations and sizes were based on site area; however, actual system installation should be based on the availability of funds or on the amount of power that can be sold. There is currently a 10 kW PV system at the Refuse Hideaway Landfill, so adding capacity as funding becomes available might make sense. When the system goes out to bid, a design-build contract should be issued that requests the best performance (kWh/year) at the best price and that allows vendors to optimize system configuration, including slope. A third-party ownership PPA provides the most feasible way for a system to be financed on these sites. All payback calculations assumed that the 30% federal tax credit would be captured for the systems.

In the coming years, increasing electrical rates and increased necessity for clean power will continue to improve the feasibility of implementing solar PV systems at landfill sites in Wisconsin.

Appendix A. Assumptions for Calculations[15]

Table A-1. Calculation Assumptions for Ground-Mounted PV Systems at the Refuse Hideaway Landfill Using Current Electric Rate of $0.1333/kWh

Location	Array Tilt (Deg)	Max Usable Area (ft^2)	Rounded PV System Size (kW)	Annual Output (kWh/year)	Annual Cost Savings ($/year)	Annual O&M ($/year)	System Cost with Incentives ($)	Payback Period (years)
Crystalline Silicon (Fixed Tilt)								
Refuse Hideaway	43.1	378,384	1,350	1,661,850	$221,525	$10,328	$4,252,500	20
Crystalline Silicon (Single-Axis Tracking)								
Refuse Hideaway	0	378,384	1,100	1,549,477	$206,545	$23,100	$4,620,000	25
Thin Film (Fixed Tilt)								
Refuse Hideaway	43.1	378,384	550	677,050	$90,251	$3,647	$1,501,500	17

Table A-2. Calculation Assumptions for Ground-Mounted PV Systems at the Refuse Hideaway Landfill Using Hypothetical Electric Rate of $0.15/kWh

Location	Array Tilt (Deg)	Max Usable Area (ft^2)	Rounded PV System Size (kW)	Annual Output (kWh/year)	Annual Cost Savings ($/year)	Annual O&M ($/year)	System Cost with Incentives ($)	Payback Period (years)
Crystalline Silicon (Fixed Tilt)								
Refuse Hideaway	43.1	378,384	1,350	1,661,850	$249,278	$10,328	$4,252,500	18
Crystalline Silicon (Single-Axis Tracking)								
Refuse Hideaway	0	378,384	1,100	1,549,477	$232,422	$23,100	$4,620,000	22
Thin Film (Fixed Tilt)								
Refuse Hideaway	43.1	378,384	550	677,050	$101,558	$3,647	$1,501,500	15

[15] The calculations in Appendix A assume that the 30% federal tax credit is secured.

Table A-3. Other Assumptions, Including Assumptions for Costs and System Types

Cost Assumptions			
Variable	**Quantity of Variable**	**Unit of Variable**	
Cost of Site Electricity	$0.1333	$/kWh	
Annual O&M (Fixed)	0.17%	% of installed cost	
Annual O&M (Tracking)	0.35%	% of installed cost	
System Assumptions **System Type**	**Annual energy (kWh/kW)**	**Installed Cost ($/W)**	**Energy Density (W/ft^2)**
Ground Crystalline Fixed	1,231	$4.50	4.0
Ground Single-Axis Tracking	1,409	$6.00	3.3
Ground Thin-Film Fixed	1,231	$3.90	1.7
Roof Crystalline Fixed	1,231	$6.00	10.0
Roof Thin-Film Fixed	1,231	$5.40	4.3
Other Assumptions	Ground utilization	90% of available area	
	Incentives	Federal tax credit	

Appendix B. Renewable Energy Incentives[16]

Table B-1. Redevelopment and Renewable Energy Incentives and Financing Tools

Agency	Incentive Name	Incentive (I), Finance Tool (FT)	Public	Private	Funding Range
HUD	Brownfield Economic Development Initiative (BEDI) Competitive Grant Program	I	X	X[a]	$17.5 million appropriated in FY 2010. Award cap TBD as of 2/27/10.
HUD	Section 108 Loan Guarantee Program	FT	X	X[b]	Up to five times public entity's latest approved Community Development Block Grant (CDBG) amount.

[a] Must be used in conjunction with Section 108 loan guarantee commitment.
[b] Through re-loan from public entity.

[16] The calculations in Appendix B assume that the 30% federal tax credit is secured.

Table B-2. Renewable Energy Development Incentives and Financing Tools Applicable to PV[17,18]

Agency	Incentive Name	Incentive (I), Finance Tool (FT)	Public	Private	Funding Range
DOE	Loan Guarantee Program	FT	X	X	Not specified
DOE	Renewable Energy Production Incentive (REPI)	I	X		$0.021/kW
HUD	Community Development Block Grants (CDBG)	I	X		Based on community needs formula
Treasury	1603 Renewable Energy Grant Program *option to ITC	I		X	30% of the cost basis of the renewable energy project
Treasury	Business Energy ITC *option to 1603	I		X	30% of project expenditures
Treasury	Clean Renewable Energy Bonds (CREB)	FT	X		Varies
Treasury	Modified Accelerated Cost-Recovery System (MACRS)	FT		X	Various depreciation deductions
Treasury	Qualified Energy Conservation Bonds (QECB)	FT	X		Varies
USDA	Rural Energy for America Program (REAP) Grants	I	X	X	25% of project cost. Payment range $2.5K–$500K
USDA	REAP Loan Guarantees	FT	X	X	Up to 75% of project costs. Max. $25 million/Min. $5,000

[17] DSIRE. http://www.dsireusa.org/. Accessed September 2010.
[18] U.S. Department of Housing and Urban Development 2009. http://www.hud.gov/. Accessed September 2010.

Table B-3. State Rebates for Commercial-Sector PV Projects[19]

The programs included here are ongoing rebate and grant programs administered by state agencies or by third-party organizations on behalf of state governments. In addition to the programs highlighted, about 75 utilities in the United States offer PV rebates. In some states, such as Colorado and Arizona, solar rebates from utilities are available nearly statewide that must comply with state RPSs, but these are not shown in the table. Finally, programs that are purely performance-based, such as Washington's production incentive and California's feed-in tariff, are not included in this table.

State	Program Name	Incentive Amount	REC Ownership	Funding Source
California	California Solar Initiative	Varies by sector and system size.	Remains with project owner	Rate-payer funded
California	CEC - New Solar Homes Partnership	Varies. Incentives are adjusted based on expected performance and will decline over time based on the total installed capacity.	Remains with system owner	Rate-payer funded
Connecticut	Connecticut Clean Energy Fund (CCEF) - On-Site Renewable DG Program	For-profit owners: $3.00/W for first 100 kW, $2.00/W for next 100 kW. Not-for-profit owners: $4.50/W for first 100 kW, $4.00/W for next 100 kW. Additional $0.10/W premium for buildings that meet LEED Silver certification. CCEF also compensates system owners based on the estimated present value of the system's RECs.	RECs transfer to CCEF for systems 50 kW-PTC and larger. CCEF compensates system owners based on estimated present value of the system's RECs over 15 years.	CCEF (public benefits fund)
Delaware	Green Energy Program Incentives	Delmarva: 25% of installed cost (35% for non-profits and government); DEC: 33.3% of installed cost; Minis: 33.3% of installed cost, except 25% for Dover and Seaford; PV system cost may not exceed $12/W.	Remains with project owner	Green Energy Fund (Delmarva), DEC Renewable Resources Fund, Municipal Utility Green Energy Fund (public benefits fund)
District of Columbia	Renewable Energy Incentive Program	$3/DC-Watt for first 3 kW; $2/DC-Watt for next 7 kW; $1/DC-Watt for next 10 kW	Remains with system owner	Sustainable Energy Trust Fund (public benefits fund)

[19] DSIRE. http://www.dsireusa.org/. Accessed September 2010.

State	Program Name	Incentive Amount	REC Ownership	Funding Source
Florida	Solar Energy System Incentives Program	$4/DC-Watt	Remains with system owner	General Revenue Funds (appropriated annually)
Illinois	DCEO - Solar and Wind Energy Rebate Program	Residential and commercial: 30%; non-profit and public: 50%. Note (02/2010): Funding for FY 2010 has been fully allocated; no additional rebates are available.	Remains with customer/producer	Illinois Renewable Energy Resources Trust Fund (public benefits fund)
Maine	Solar and Wind Energy Rebate Program	$2/AC-Watt	Remains with customer/producer	Funded by assessment of up to 0.005 cents/kWh on transmission and distribution utilities plus $500,000 per fiscal year (FY 2009–2010 and FY 2010–2011) for 2 years using Recovery Act funding
Maryland	Mid-Size Solar Energy Grant Program	$500/kW for first 20 kW; $250/kW for next 30 kW; $150/kW for next 50 kW	Remains with project owner	Recovery Act
Maryland	Solar Energy Grant Program	$1.25/DC-Watt for first 2 kW; $0.75/W for next 6 kW; $0.25/W for next 12 kW	Remains with project owner	General Revenue Funds (appropriated annually); FY 2009 funds supplemented with RGGI proceeds
Massachusetts	CEC - Commonwealth Solar II Rebates	$1.00/DC-Watt base; $0.10/DC-Watt adder for MA components; $1.00/DC-Watt adder for moderate home value or for moderate income	Remains with project owner	Massachusetts Renewable Energy Trust
Massachusetts	CEC - Commonwealth Solar Stimulus	$1.50/DC-Watt for first 25 kW; $1.00/DC-Watt for 25–100 kW; $0.50/DC-Watt for 100–200 kW	Remains with project owner	Recovery Act
Nevada	NV Energy – Renewable Generations Rebate Program	(2010–2011 program year) Residential and small business: $2.30/AC-Watt; public facilities/schools: $5.00/AC-Watt	NV Energy	Rate-payer funded
New Jersey	New Jersey Customer-Sited Renewable Energy Rebates	Standard residential: $1.55/DC-Watt; residential with energy efficiency: $1.75/DC-Watt; residential new construction: varies by efficiency, $1.00–$1.75/DC-Watt; standard non-	Remains with project owner	New Jersey Societal Benefits Charge (public benefits fund)

State	Program Name	Incentive Amount	REC Ownership	Funding Source
		residential: $0.90/DC-Watt; non-residential with efficiency: $1.00/DC-Watt		
New Jersey	Renewable Energy Manufacturing Incentives (for end-use PV installations)	Varies by equipment type, sector, and system size; ranges from $0.05–$0.55/DC-Watt.	Not applicable	New Jersey Societal Benefits Charge (public benefits fund)
New York	NYSERDA - PV Incentive Program	Residential (first 5 kW): $1.75/DC-Watt; non-residential (first 50 kW): $1.75/DC-Watt; non-profit, government, schools (first 25 kW): $1.75/DC-Watt; bonus incentive: $0.50/W for Energy Star homes and BIPV systems	First 3 years: NYSERDA, thereafter customer/generator	RPS surcharge
Ohio	ODOD - Advanced Energy Program Grants - Non-Residential Renewable Energy Incentive	$3.50/DC-Watt, may be reduced by shading	Not specified	Ohio Advanced Energy Fund
Oregon	Energy Trust - Solar Electric Buy-Down Program	Residential: $1.50/DC-Watt for Pacific Power; $1.75/DC-Watt for PGE; residential, third-party: $1/DC-Watt for Pacific Power; $1.25/DC-Watt for PGE; commercial: $0.50–$1.00/W for Pacific Power; $0.75–$1.25/W for PGE; non-profit/government: $0.75–$1.25/W for Pacific Power; $1.00–$1.50/W for PGE	Residential: RECs for first 5 years owned by customer/producer; non-residential: RECs for first 5 years owned by consumer/producer, then Energy Trust owns RECs for years 6–20	Energy Trust of Oregon (public benefits fund)
Pennsylvania	Pennsylvania Sunshine Solar Rebate Program	Residential: $2.25/DC-Watt; commercial: $1.25/DC-Watt for first 10 kW, $1.00/DC-Watt for next 90 kW, $0.75/DC-Watt for next 100 kW; low-income: 35% of installed costs	Not specified; net-metering customers generally retain title to RECs	Pennsylvania Energy Independence Fund (state bonds)
Puerto Rico	Puerto Rico - State Energy Program - Sun Energy Rebate Program	Solar PV: residential and commercial $4/DC-Watt; governmental $8/DC-Watt	Not addressed	Recovery Act State Energy Program funds

State	Program Name	Incentive Amount	REC Ownership	Funding Source
Tennessee	Tennessee Clean Energy Technology Grant	40% of installed cost	Not specified	State of Tennessee Economic and Community Development Energy Division
Vermont	Vermont Small-Scale Renewable Energy Incentive Program	Individuals/businesses: $1.75/DC-Watt; multi-family, low-income: $3.50/DC-Watt	Not addressed	Utility settlement funds and the Vermont Clean Energy Development Fund
Wisconsin	Focus on Energy - Renewable Energy Cash-Back Rewards	Residential/businesses: $1.00/kWh for one year; non-profit/government: $1.50/kWh for one year (estimated one year production using PVWATTS). Efficiency First participants: add $0.25/kWh for one year.	Not addressed	Focus on Energy Program

Note: The information provided in this table presents an overview of state incentives, but it should not be used as the only source of information when making purchasing decisions, investment decisions, tax decisions, or other binding agreements. For more information about individual programs listed above, visit the DSIRE website at http://dsireusa.org/solar/comparisontables/.

Table B-4. State Tax Credits for Commercial-Sector PV Projects[20]

State	Program Name	Eligible Recipients	Incentive Amount	Third-Party Owner Eligible	Non-Profit/Government Eligible
Arizona	Non-Residential Solar & Wind Tax Credit (Corporate)	Any non-residential installation is eligible, including those for non-profits and governments. Individuals, corporations and S corporations, and partnerships may claim the credit. Third-party financiers/installers/mfrs. of eligible system may claim the credit.	10%	Yes	Yes
Florida	Renewable Energy Production Tax Credit	A non-residential taxpayer with facility placed in service or expanded after May 1, 2006. The credit is for electricity produced and sold by the taxpayer to an unrelated party during a given tax year. Florida corporate income taxpayers who own an interest in a general partnership, limited partnership, limited liability company, trust, or other artificial entity that owns a Florida renewable energy facility can apply for this credit.	$0.01/kWh	Not specified	Not specified
Georgia	Clean Energy Tax Credit (Corporate)	Taxpayer who has constructed, purchased, or leased renewable energy property and placed it in service.	35%	Yes	Not specified
Hawaii	Solar and Wind Energy Credit (Corporate)	Taxpayer that files a corporate net income tax return or franchise tax return; credit may be claimed for every eligible renewable energy technology system that is installed and placed in service. Third-party taxpaying entities may claim the credit if they install and own a	35%	Yes	Yes

[20] DSIRE. http://www.dsireusa.org/. Accessed September 2010.

State	Program Name	Eligible Recipients	Incentive Amount	Third-Party Owner Eligible	Non-Profit/Government Eligible
		system on a commercial taxpayer's building or on a non-profit or government building. Multiple owners of a single system may take a single tax credit. The credit is apportioned between the owners in proportion to their contribution to the system's cost.			
Iowa	Renewable Energy Production Tax Credits (Corporate)	Producers or purchasers of renewable energy from qualified facilities; installations must be at least 51% owned by a state resident or other qualifying owner and placed in service on or after July 1, 2005, and before January 1, 2012. Electricity must be sold to an unrelated person to qualify for the tax credit.	$0.015/kWh for 10 years after energy production begins	Yes, credits may be claimed by system owner or by electricity purchaser. System owners must meet certain eligibility criteria.	Schools and cooperative associations are eligible owners. Credits may be transferred or sold one time.
Kentucky	Renewable Energy Tax Credit (Corporate)	Any installation on a dwelling unit or on property that is owned and used by the taxpayer as commercial property.	$3/DC-Watt	Not specified	Not specified
Kentucky	Tax Credit for Renewable Energy Facilities	Companies that build or renovate facilities that utilize renewable energy.	100% Kentucky income tax or limited liability entity tax	Not specified	Not specified
Louisiana	Tax Credit for Solar and Wind Energy Systems on Residential Property (Corporate)	Taxpayer who purchases and installs an eligible system or who purchases a new home with such a system already in place.	50%	No	No

State	Program Name	Eligible Recipients	Incentive Amount	Third-Party Owner Eligible	Non-Profit/Government Eligible
Maryland	Clean Energy Production Tax Credit (Corporate)	All individuals and corporations that sell electricity produced by a qualified facility to an unrelated person; net-metering arrangements qualify.	$0.0085/kWh for 5 years after facility is placed in service	Not specified	No
Montana	Alternative Energy Investment Tax Credit (Corporate)	Corporation, partnership, or small business corporation that makes a minimum investment of $5,000.	35%	No	No
New Mexico	Advanced Energy Tax Credit (Corporate)	Any taxpayer.	6%	No	No
New Mexico	Renewable Energy Production Tax Credit (Corporate)	Taxpayer who holds title to a qualified energy generator that first produced electricity on or before January 1, 2018, or a taxpayer who leases property upon which a qualified energy generator operates from a county or municipality under authority of an industrial revenue bond and if the qualified energy generator first produced electricity on or before January 1, 2018.	Varies annually over 10 years; $0.027/kWh average	Not specified	Not specified
New Mexico	Solar Market Development Tax Credit	Residents and non-corporate businesses, including agricultural enterprises.	10% of purchase and installation costs	No	No

State	Program Name	Eligible Recipients	Incentive Amount	Third-Party Owner Eligible	Non-Profit/Government Eligible
North Carolina	Renewable Energy Tax Credit (Corporate)	Taxpayer who has constructed, purchased, or leased renewable energy property and placed it in service.	35% (distributed 7% per year for 5 years for non-residential installations)	Yes. For leasing, a taxpayer may take credit for property that the taxpayer leases if written verification is received from the owner that states that the owner will not take credit for renewable energy installation.	No
North Dakota	Renewable Energy Tax Credit	Corporate taxpayers filing a North Dakota income tax return. System must be installed on a building or on property owned or leased by the taxpayer in North Dakota.	15% (distributed 3% per year for 5 years)	A pass-through entity that installs the system at a property it owns or leases is considered the taxpayer. The credit amount allowed is determined at the pass-through entity level and must be passed through proportionally to corporate partners, shareholders, or members.	No
Oklahoma	Zero-Emission Facilities Production Tax Credit	Non-residential taxpayer who sells electricity to an unrelated person; non-taxable entities, including agencies of the State of Oklahoma, may transfer their credit to a taxpayer.	$0.005/kWh for first 10 years of operation	Yes	Yes, nontaxable entities, including agencies of the State of Oklahoma, or political subdivisions thereof, can take advantage of the tax credit by transferring it to a taxable entity.
Oregon	Business Energy Tax Credit	Trade, business, or rental property owners who pay taxes for a business site in Oregon are eligible for the tax credit. The business, its partners, or its shareholders may use the credit. A project owner also can be an Oregon non-profit organization, tribe, or public entity that partners with an Oregon	50% (distributed 10% per year for 5 years)	Yes	A project owner can be a non-profit, tribe, or public entity that partners with a business or resident to take advantage of the pass-through option. The pass-through option allows a project owner to transfer the 35% Business Energy

State	Program Name	Eligible Recipients	Incentive Amount	Third-Party Owner Eligible	Non-Profit/Government Eligible
		business or resident who has an Oregon tax liability. This can be done using the pass-through option.			Tax Credit project eligibility to a pass-through partner for a lump-sum cash payment. The pass-through option rate for 5-year Business Energy Tax Credits effective October 1, 2003, is 25.5%. The pass-through option rate for 1-year Business Energy Tax Credits (those with eligible costs of $20,000 or less) effective October 1, 2003, is 30.5%.
Puerto Rico	Puerto Rico - Solar Tax Credit (Corporate)	Any Puerto Rican taxpayer who has acquired, assembled, and installed eligible solar electric equipment.	75% during FY 2007–2008 and FY 2008–2009; 50% during FY 2009–2010 and FY 2010–2011; 25% starting FY 2011–2012	Not specified	Potentially; the tax credit may be transferred, sold, or otherwise given to "any other person."
Rhode Island	Residential Renewable Energy Tax Credit (Corporate)	Taxpayer who (1) owns, rents, or is the contract buyer of the dwelling(s) served by the system; the dwelling or dwellings must be in the main or secondary residence of the person who applies for the tax credit or of a tenant; (2) owns or is the contract buyer of the system and pays all or part of the cost of the system; or (3) is the contractor that owns the dwelling for speculative sale in which the system is installed.	25%	Yes. Credit is available to taxpayers who are the contract buyers of eligible systems and pay all or part of the cost of the system.	No

State	Program Name	Eligible Recipients	Incentive Amount	Third-Party Owner Eligible	Non-Profit/Government Eligible
South Carolina	Solar Energy and Small Hydropower Tax Credit (Corporate)	Taxpayers who purchase and install an eligible system in or on a facility owned by the taxpayer.	25% for 2010; was 30% in 2009	No	No
Utah	Renewable Energy Systems Tax Credit (Corporate)	Any company that owns a qualified system.	Residential: 25%; Commercial: 10%	No	No
Vermont	Business Tax Credit for Solar (Corporate)	Corporations that pay corporate income tax in Vermont that do not receive grants/funding from CEDF.	30% of expenditures for systems placed into service on or before December 31, 2010	Not specified	No
West Virginia	Residential Solar Energy Tax Credit	Any taxpayer who installs (or contracts for the installation of) an eligible solar system on residential property that he/she owns and uses as a residence in the state.	30%	Not specified	No

Note: The information provided in this table presents an overview of state incentives, but it should not be used as the only source of information when making purchasing decisions, investment decisions, tax decisions, or other binding agreements. For more information about individual programs listed above, visit the DSIRE website at http://dsireusa.org/solar/comparisontables/.

Table B-5. U.S. Department of Energy Brightfields Program Grants[21]

Award Year	Award Amount	Project	Project Description	Project Status
2000	$30,000	Brockton, MA: Brownfields to Brightfields Project	"This project involved attracting a PV system manufacturer to a Brockton Brownfield and building a solar array on a second site. Anticipation: This array will bring into productive use up to 27 acres of idle property and the array could also generate up to 6 MW of electricity. To create sufficient local demand to attract the manufacturer, other potential sites for photovoltaic applications will be surveyed."	425 kW facility commercially operational since September 27, 2006. Expanded by 35 kW to 460 kW in July 2007; grid-connected and selling 100% of output into New England Power Pool
	$50,000	Atlantic City, NJ: Cityscape Solar-Powered Bed and Breakfast on an Urban Brownfield.	"Involves the construction of a solar-powered bed and breakfast on an urban brownfield site in Atlantic City, New Jersey, as part of an overall neighborhood redevelopment plan with a sustainability theme. The project will showcase the use of PV in supplying renewable energy and also contain sustainable features such as recycled building materials and Energy Star appliances and will be located in the 'Cityscape Neighborhood,' an area designed to promote renewable energy, sustainable building materials, and concepts of New Urbanism."	Project canceled
	$50,000	Hanford, WA: Brightfield Project	"This project will ultimately be the largest PV installation of its kind and will bring the Brightfield concept to one of the worst Super Fund sites in the nation. The funding provided will cover a portion of the pilot phase of the project, involving 40 kW. Later phases will use a wind/solar green energy blending strategy to finance development up to 1 MW or larger. This solar array will act as a nucleation site around which Energy Northwest intends to grow a renewable energy industrial park."	38.7 kW system installed in May 2002

[21] U.S. DOE State Energy Program 2006. http://www.energy.gov/. Accessed September 2010.

2004	$65,400	Cedar Rapids, IA: Bohemian Commercial Historic District Solar Development Program	"The Iowa Department of Natural Resources (IDNR) will partner with the City of Cedar Rapids, the Iowa Renewable Energy Association, Alliant Energy, and Thorland Company to install a 7,200-watt solar array in Cedar Rapids on a multiuse converted former warehouse building in a designated brownfields redevelopment area. The IDNR has established partnerships with the City of Cedar Rapids, Alliant Energy, the Iowa Renewable Energy Association, and the building owner to increase the economic and environmental viability of a redeveloped brownfield area and expand the value and viability of solar projects."	7.2 kW installed
	$59,400	Brockton, MA: Solar Energy Park: Deploying a Solar Array on a Brownfield	"The City of Brockton will build New England's largest solar array at a remediated 27-acre brownfield site in fall 2004. The 500-kW solar PV array—or 'Brightfield'—will be installed in an urban park setting with interpretive displays. The Brightfield could include as many as 6,720 solar panels connected in strings that span the site. The Brightfield will grow incrementally to 1 MW with expansions financed through positive annual cash flow generated by the sale of RECs and electricity."	425 kW facility commercially operational since September 27, 2006. Expanded by 35 kW to 460 kW in July 2007; grid-connected and selling 100% of output into New England Power Pool
	$125,000	Raleigh, NC: Brightfield Technology Demonstration at NCSU	"Carolina Green Energy, LLC proposes to partner with the North Carolina Solar Center to design and install a 30-kW grid-tied PV system. As part of its continued efforts to bolster support for renewable energy, the Solar Center will incorporate the 'Brownfield to Brightfield' project at Lot 86 into its ongoing education and outreach programs."	75.6 kW PV generation project operational since October 2007

According to EPA, the term brightfields refers to "the conversion of contaminated sites into usable land by bringing pollution-free solar energy and high-tech solar manufacturing jobs to these sites, including the placement of PV arrays that can reduce cleanup costs, building integrated solar energy systems as part of redevelopment, and solar manufacturing plants on brownfields." For more information, see http://epa.gov/ and brownfields/partners/brightfd.htm.

Table B-6. State Policy and Incentive Comparisons: Massachusetts, North Carolina, and Colorado[22]

MASSACHUSETTS		
Incentive	**Specifics**	**Sector**
New Generation Energy - Community Solar Lending Program	$5,000–$100,000	Private
Massachusetts DOER - Solar Renewable Energy Credits (SRECs)	$300–$600 (per MWh)	Both
Mass Energy Consumers Alliance - Renewable Energy Certificate Incentive		Both
Renewable Energy Property Tax Exemption	100% exemption for 20 years	Private
CEC - Commonwealth Solar II Rebates	$5,500 (per host customer), up to $250,000 per parent company	Both
CEC - Commonwealth Solar Stimulus	$162,500 per project (up to $1 million for any host customer entity or parent company/organization)	Both
Policy	**Specifics**	**Sector**
Massachusetts - Net Metering		Both
Renewable Energy Trust Fund	Public benefit fund (PBF)	Private
RPS	In-state PV: mandated target of 400 MW	
NORTH CAROLINA		
Incentive	**Specifics**	**Sector**
Renewable Energy Tax Credit (Corporate)	35% or $2.5 million per installation	Private
Local Option - Revolving Loan Program for Renewable Energy and Energy Efficiency	Interest rate can be no more than 8%	Private
Local Option - Clean Energy Financing	Debt repaid via property assessment	Private
Renewable Energy Tax Credit (Personal)	35% or $2.5 million per installation	Private
NC GreenPower Production Incentive	Payments contingent on program success	Both
Progress Energy Carolinas - SunSense Commercial PV Incentive Program	$0.18/kWh for 20 years	Both
TVA - Generation Partners Program	$1,000 plus $0.12/kWh above the retail rate for solar and $0.03/kWh above the retail rate for all other eligible renewables	Private
Property Tax Abatement for Solar Electric Systems	80% of appraised value	Both
North Carolina Green Business Fund	Grant varies	Both
Energy Improvement Loan Program (EILP)	State Loan Program $500,000 maximum	Both

[22] DSIRE. http://www.dsireusa.org/. Accessed September 2010.

Policy	Specifics	Sector
North Carolina - Net Metering		
Renewable Energy and Energy Efficiency Portfolio Standard	Solar: 0.2% by 2018	

COLORADO

Incentive	Specifics	Sector
Boulder County - ClimateSmart Loan Program	Commercial: $3,000–$210,000	Private
Local Option - Improvement Districts for Energy Efficiency and Renewable Energy Improvements	Debt repaid via property assessment	Both
Renewable Energy Property Tax Assessment	Varies	Private
Boulder - Solar Sales and Use Tax Rebate	15% refund on sales and use tax for the solar installation	Private
Local Option - Sales and Use Tax Exemption for Renewable Energy Systems	Varies	Private
Sales and Use Tax Exemption for Renewable Energy Equipment	100%	Both
New Energy Economic Development Grant Program	Competitive grant, Recovery Act funded	Private
Xcel Energy - Solar*Rewards Program	$2/DC-Watt with a maximum rebate of $200,000; REC payments will step down over time as certain megawatt levels are reached for each system classification.	Private

Policy	Specifics	Sector
Colorado - Net Metering		Private
Mandatory Green Power Option for Large Municipal Utilities	Allows retail customers the choice of supporting emerging renewable technologies	Both
Boulder - Climate Action Plan Fund	PBF	Private
Renewable Energy Standard	Solar-electric (IOUs only): 4% of annual requirement (0.8% of sales in 2020); half of solar-electric requirement must be located on-site at customers' facilities	
Solar, Wind, and Energy-Efficiency Access Laws		

Table B-7. Key Policy Comparison for Subject States[23]

RPS	Massachusetts	North Carolina	Colorado
Policy In Place	Yes	Yes	Yes
Effective Date	4/1/02	2/29/08	12/1/04
Targets	15% by 2020 and an additional 1% each year thereafter; in-state PV mandated target of 400 MW	12.5% of 2020 retail electricity sales by 2021 with 0.2% from solar	20% by 2020; solar-electric: 4% of annual requirement
PBF	**Massachusetts**	**North Carolina**	**Colorado**
Policy In Place	Yes	No	City of Boulder only
Effective Date	3/1/98	N/A	4/1/07
Charge	$0.0005 per kWh in 2003 and in each following year	N/A	Maximum tax rates for electricity customers: Residential: $0.0049/kWh Commercial: $0.0009/kWh Industrial: $0.0003/kWh
NET METERING	**Massachusetts**	**North Carolina**	**Colorado**
Policy In Place	Yes	Yes	Yes
Effective Date	1982	10/20/05	7/2/06
System Capacity	2 MW for "Class III" systems; 1 MW for "Class II" systems; 60 kW for "Class I" systems	1 MW	120% of the customer's average annual consumption
REC Ownership	Customer owns RECs	Utility owns RECs (unless customer chooses to net meter under an unfavorable demand tariff)	Customer owns RECs (must be relinquished to utility for 20 years in exchange for incentives)
TAX INCENTIVES APPLICABLE TO PV	**Massachusetts**	**North Carolina**	**Colorado**
Incentives	*Property* – 100% exemption for 20 years	*Corporate* – 35% *Property* – 85% of appraised value	*Property* – Amount varies depending on rate set annually by the Division of Property Taxation
Effective Date	1984	Corporate 1/1/09 Property 7/1/08	2001

[23] DSIRE. http://www.dsireusa.org/. Accessed September 2010.