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Feasibility Study of Economics and Performance of Solar Photovoltaics at the Kerr McGee Site in Columbus, Mississippi

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

Joe Simon and Gail Mosey

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

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.

Work for Others Report
NREL/TP-7A30-57251
January 2013
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Special thanks go to Charles King and Shea Jones from EPA and Christina Berry from the City of Columbus for hosting the site visit. The authors would also like to thank the Memphis Town Community Action Group and Reverend Jamison for their interest in the site, support, and information.

Executive Summary

The U.S. Environmental Protection Agency (EPA), in accordance with the RE-Powering America's Land initiative, selected the Kerr McGee site in Columbus, Mississippi, for a feasibility study of renewable energy production. The National Renewable Energy Laboratory (NREL) provided technical assistance for this project. The purpose of this report is to assess the site for a possible photovoltaic (PV) system installation and estimate the cost, performance, and site impacts of different PV options. In addition, the report recommends financing options that could assist in the implementation of a PV system at the site. This study did not assess environmental conditions at the site.

The subject of this feasibility study is the former Kerr McGee Chemical Facility located in Columbus, Mississippi. Located within the city, the site is adjacent to several residential and commercial properties. As early as 1928, the site functioned as a wood-preserving facility using creosote, tar solutions, and pentachlorophenol, resulting in groundwater and soil contamination. Operations ceased in July 2003, and since that time, all tanks, equipment, and process buildings have been removed with the exception of a small office building and a maintenance structure housing groundwater treatment equipment. The site received Superfund NPL designation in September 2010.

The local community actively supports the cleanup and redevelopment of the site toward productive use. The redevelopment of the site is envisioned as a multi-use complex that addresses residential, community, and business needs including a large-scale solar-generating facility. Contamination of the site primarily affects groundwater, and current cleanup efforts have left the land suitable for PV installations.[1]

The feasibility of installing a PV system is highly impacted by the available area for an array, solar resource, distance to transmission lines, and distance to major roads. In addition, the operating status, ground conditions, and restrictions associated with redevelopment of previously contaminated manufacturing sites may impact the feasibility of a PV system. Based on an assessment of these factors, the Kerr McGee site is suitable for deployment of a large-scale PV system.

The Kerr McGee site is approximately 90 acres with a majority of the site feasible for the installation of a PV system. This entire area does not need to be developed at one time. Timing considerations, including staging, land remediation, funding, and community goals for mixed use of the site, will all influence the size of a system to install.

The economic feasibility of a potential PV system on the Kerr McGee site depends greatly on the purchase price of the electricity produced. The site is serviced by the Columbus Light and Water Department, which distributes power produced by the Tennessee Valley Authority (TVA). Initial discussions with the TVA and the Columbus Light and Water Department indicate an ability to accept a large-scale system on the existing electric grid. Purchase prices in line with TVA's Renewable Standard Offer were used throughout the analysis, with time-of-use pricing averaging approximately \$0.06/kWh annually and escalating at 3% per year. Because the purchase rates are

[1] For more information on the EPA RE-Powering America's Land initiative and the Kerr McGee site, see http://www.epa.gov/oswercpa/index.htm.

time-dependent, however, the analysis uses an average rate of $0.072/kWh due to the times of day in which energy would be sold to the utility. Alternatively, a scenario is considered wherein the property could sell the electricity produced to an adjacent manufacturer for $0.12/kWh as a behind-the-meter PPA. Table ES-1 summarizes the system performance and economics of a potential system of 5 MW using between 28 and 35 acres of the Kerr McGee site. 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 and estimated job creation.

As indicated in Table ES-1, a 5-MW system is not expected to be economically viable given the purchase price of electricity associated with the TVA's Renewable Standard Offer. Given the low eligible purchase cost of electricity, lack of applicable incentives, and climate considerations, this does not represent an attractive investment opportunity.

The TVA does, however, offer a program called the Solar Solutions Initiative, which is a pilot that began in February 2012, and offers a higher PPA rate for systems up to 1 MW that use local installers in the valley region. This program provides a 10-year incentive of $0.04/kWh above the typical Renewable Standard Offer discussed above. As indicated in Table ES-1, a 1-MW system installed at the site is economically viable and should be considered.

Alternatively, if a PPA or virtual net-metering arrangement were established wherein electricity produced could be sold for $0.12/kWh or higher, a 5-MW solar PV system would have an internal rate of return between 11.48% and 12.95% with a net present value between $1,014,751 and $1,324,823, depending on system type. The sale of electricity at $0.12/kWh could represent a significant cost savings to a manufacturer or commercial facility while simultaneously creating a reasonable investment opportunity and solution for the site. This includes the current cost of energy, expected installation cost, site solar resource, and existing incentives for the proposed PV system. Under a scenario wherein electricity produced could be sold for $0.12/kWh for a single-axis tracking system, gross revenue for the system would equal approximately $1,000,000/year, increasing annually. For multiple reasons—the escalating cost of energy, the dropping cost of PV, and the existence of a quality solar resource—this report finds that a PV system is a reasonable use for the site if an adequate PPA was able to be established.

Table ES-1. Kerr McGee PV System Summary

System Type	PV System Size[a]	Array Tilt	Annual Output	Number of Houses Powered[b]	Construction Period Jobs[c]	Jobs Sustained[d]
	(kW)	(deg)	(kWh/year)		(job-year)	(job-year)
Crystalline Silicon (Fixed Tilt)	5,000	33.4	6,611,294	599	141	1.5
Crystalline Silicon (Single-Axis Tracking)	5,000	n/a	8,285,480	750	199	1.6
Crystalline Silicon (Dual-Axis Tracking)	5,000	n/a	8,863,384	803	218	1.8
Crystalline Silicon (Fixed Tilt)	1,000	33.4	1,321,896	120		
Crystalline Silicon (Single-Axis Tracking)	1,000	n/a	1,656,311	150		
Crystalline Silicon (Dual-Axis Tracking)	1,000	n/a	1,735,761	157		

System Type	Annual Output	System Area	System Cost	Scenario	PPA Price[e]	System Cost	After-tax IRR	After-tax NPV
	kWh/year	(Acres req'd)	($/watt)					
Fixed Tilt - Utility	6,611,294	28.70	$ 2.79	Utility PPA	$0.072	$ 13,878,118.66	-0.21	$ (1,843,512.99)
Single-Axis Tracking - Utility	8,285,480	34.78	$ 3.34	Utility PPA	$0.072	$ 16,710,322.35	0.8	$ (1,923,388.22)
Dual-Axis Tracking - Utility	8,683,384	38.26	$ 3.68	Utility PPA	$0.072	$ 18,384,949.33	-0.18	$ (2,429,268.00)
Fixed Tilt - PPA	6,611,294	28.70	$ 2.79	VNM or PPA	$0.012	$ 13,878,118.66	11.53	$ 1,014,751.20
Single-Axis Tracking - PPA	8,285,480	34.78	$ 3.34	VNM or PPA	$0.012	$ 16,710,322.35	12.94	$ 1,658,682.95
Dual-Axis Tracking - PPA	8,683,384	38.26	$ 3.68	VNM or PPA	$0.012	$ 18,384,949.33	11.48	$ 1,324,823.98
Fixed Tilt - SSI	1,321,595	3.50	$ 2.79	Utility SSI	$0.072+$0.04	$ 2,771,742.25	7.08	$ (10,624.54)
Single-Axis Tracking - SSI	1,656,061	4.00	$ 3.34	Utility SSI	$0.072+$0.04	$ 3,337,606.39	9.23	$ 63,710.65
Dual-Axis Tracking - SSI	1,735,535	5.00	$ 3.68	Utility SSI	$0.072+$0.04	$ 3,677,089.10	6.98	$ (17,794.40)

a *Data assume a system size of 5MW.*
b *Number of average American households that could hypothetically be powered by the PV system assuming 11,040 kWh/year/household.*
c *Job-years created as a result of project capital investment including direct, indirect, and induced jobs.*
d *Jobs (direct, indirect, and induced) sustained as a result of operations and maintenance (O&M) of the system.*
e *The Solar Solutions Initiative offers $0.04/kWh production credit for the first 10 years of system operation.*

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1 Study and Site Background

The U.S. Environmental Protection Agency (EPA), in accordance with the RE-Powering America's Land initiative, selected the Kerr McGee site in Columbus, Mississippi, for a feasibility study of renewable energy production. The National Renewable Energy Laboratory (NREL) provided technical assistance for this project. The purpose of this report is to assess the site for a possible photovoltaic (PV) system installation and estimate the cost, performance, and site impacts of different PV options. In addition, the report recommends financing options that could assist in the implementation of a PV system at the site. This study did not assess environmental conditions at the site.

The Kerr McGee site is located in Columbus, Mississippi. Columbus is a city of approximately 25,000 residents in eastern Mississippi. The site is served by Columbus Light & Water, a distributor for the Tennessee Valley Authority (TVA). The utility serves over 12,000 customers including 9,500 residential electricity customers. Initial discussions with Columbus Light & Water and TVA have indicated that the existing infrastructure could accommodate 2–5 MW of solar generation.

The Kerr McGee site is approximately 90 acres and is adjacent to both residential and industrial sites. Significant energy consumers adjacent to the site include a plastics manufacturing facility, a brick manufacturer, and a steel fabricator. The City of Columbus is interested in the potential redevelopment of this site and is expected to work to secure the necessary zoning adjustments, if any, to allow the installation of a PV system.

The subject of this feasibility study is the former Kerr McGee Chemical Facility located at 2300 14th Avenue North, Columbus, Lowndes County, Mississippi. Located within the city, the site is adjacent to several residential and commercial properties. As early as 1928, the site functioned as a wood-preserving facility using creosote, tar solutions, and pentachlorophenol, resulting in groundwater and soil contamination. Operations ceased in July 2003, and since that time, all tanks, equipment, and process buildings have been removed with the exception of a small office and a maintenance building housing groundwater treatment equipment. The site received Superfund NPL designation in September 2010.

The local community actively supports the cleanup and redevelopment of the site towards productive use. The redevelopment of the site is envisioned as a multi-use complex that addresses resident, community, and business needs, including a large-scale solar-generating facility. Contamination of the site primarily affects groundwater, and current cleanup efforts have left the land suitable for PV installations.[2]

The Greenfield Environmental Multistate Trust LLC, Trustee of the Multistate Environmental Response Trust (the MST), is the current owner of the site and was created in partnership between the federal government and several states, including the State of Mississippi, as part of the resolution of the Tronox (successor to Kerr McGee)

[2] For more information on the EPA RE-Powering America's Land initiative and the Kerr McGee site, see http://www.epa.gov/oswercpa/index.htm.

bankruptcy. The beneficiaries of the MST for the Kerr McGee site are the EPA and the State of Mississippi, through the Mississippi Department of Environmental Quality (MDEQ). All interested parties, including the surrounding community and the City of Columbus, are committed to maximizing the future potential of this site.

After initial investigations were completed for the Kerr McGee site in partnership with MDEQ in 1981, two plumes composed of both free creosote product and dissolved constituents were identified in groundwater. Initial corrective action was implemented in 1996 to recover free creosote product and dissolved constituents and to construct containment trenches with collection sumps. Groundwater recovery wells were installed to collect free product. Groundwater monitoring continues at this time. In addition, soil excavations were performed on-site in 1998 to remove contaminated soil and backfill with clean soil. Additional drainage ditches were constructed off-site to contain contamination. At the present time, the surface of the site is useable for PV development. All site information relating to contamination and remediation has been provided through proposals and site-provided information and is not the subject of this report. Information stated above is provided for general information purposes only. Additional information can be obtained from the site's Superfund application as well as the property owners.

All significant buildings have been removed from the Kerr McGee site except for a small office building and a maintenance shed containing ground-monitoring equipment.

Feasibility assessment team members from NREL, the State of Mississippi, the City of Columbus, the Memphis Community Action Group, and the EPA conducted a site visit on January 25, 2012, to gather information integral to this feasibility study. The team considered information including solar resource, transmission availability, community acceptance, and ground conditions.

2 Development of a PV System on Contaminated Sites

Through the RE-Powering America's Lands initiative, EPA has identified several benefits for siting solar PV facilities on previously contaminated lands, noting that they:

- Can be developed in place of limited greenfields, preserving the land carbon sink
- May have environmental conditions that are not well suited for commercial or residential redevelopment and may be adequately zoned for renewable energy
- Generally are located near existing roads and energy transmission or distribution infrastructure
- May provide an economically viable reuse for sites that may have significant cleanup costs or low real estate development demand
- Can provide job opportunities in urban and rural communities
- Can advance cleaner and more cost-effective energy technologies and reduce the environmental impacts of energy systems (e.g., reduce greenhouse gas emissions).

By taking advantage of these potential benefits, PV can provide a viable, beneficial reuse, in many cases, generating significant revenue on a site that would otherwise go unused.

Understanding studied performed at similar sites demonstrates the potential for PV system development. The site is cleared and flat within a developed city in need of locally produced power. The contamination on the site relates primarily to groundwater, and remediation is at a stage to allow for installation of a PV system.

The subject site has the potential to be used for other functions beyond the solar PV systems proposed in this report. Any potential use should align with the community vision for the site and should work to enhance the overall utility of the property. Given the local utility's scale and transmission restrictions, utilizing the entire site for PV may not represent the highest and best use. Other potential solutions following the completion of remediation for an industrial site with groundwater contamination can include retail, commercial, and community redevelopment within the limitations of ground-penetration restrictions.

Beyond the financial benefits of installing a large-scale PV system, additional non-financial benefits of renewable energy deployment exist. Property owners can consider many additional compelling reasons to consider moving toward renewable energy sources for power generation instead of fossil fuels, including:

- Renewable energy sources offer a sustainable energy option in the broader energy portfolio.
- Renewable energy can have a net positive effect on human health and the environment.

- Deployment of renewable energy bolsters national energy independence and increases domestic energy security.
- Fluctuating electric costs can be mitigated by locking in electricity rates through long-term power purchase agreements (PPA) linked to renewable energy systems.
- Generating energy without harmful emissions or waste products can be accomplished through renewable energy sources.

3 PV Systems

3.1 PV Overview

Solar PV technology converts energy from solar radiation directly into electricity. Solar PV cells are the electricity-generating component of a solar energy system. When sunlight (photons) strikes a PV cell, an electric current is produced by stimulating electrons (negative charges) in a layer in the cell designed to give up electrons easily. The existing electric field in the solar cell pulls these electrons to another layer. By connecting the cell to an external load, this current (movement of charges) can then be used to power the load (e.g., light bulb).

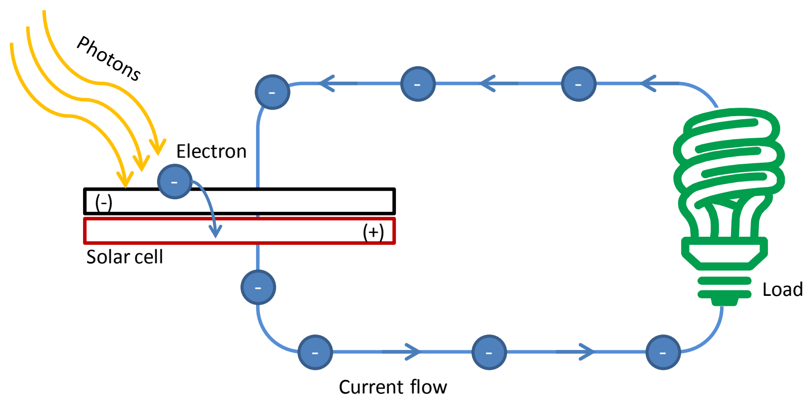

Figure 1. Generation of electricity from a PV cell

Source: EPA

PV cells are assembled into a PV panel or module. PV modules are then connected to create an array. The modules are connected in series and then in parallel as needed to reach the specific voltage and current requirements for the array. The direct current (DC) electricity generated by the array is then converted by an inverter to useable alternating current (AC) that can be consumed by adjoining buildings and facilities or exported to the electricity grid. PV system size varies from small residential (2–10 kW), to commercial (100–500 kW), to large utility scale (10+ MW). Central distribution plants are also currently being built in the 100+ MW scale. Electricity from utility-scale systems is commonly sold back to the electricity grid.

3.2 Major System Components

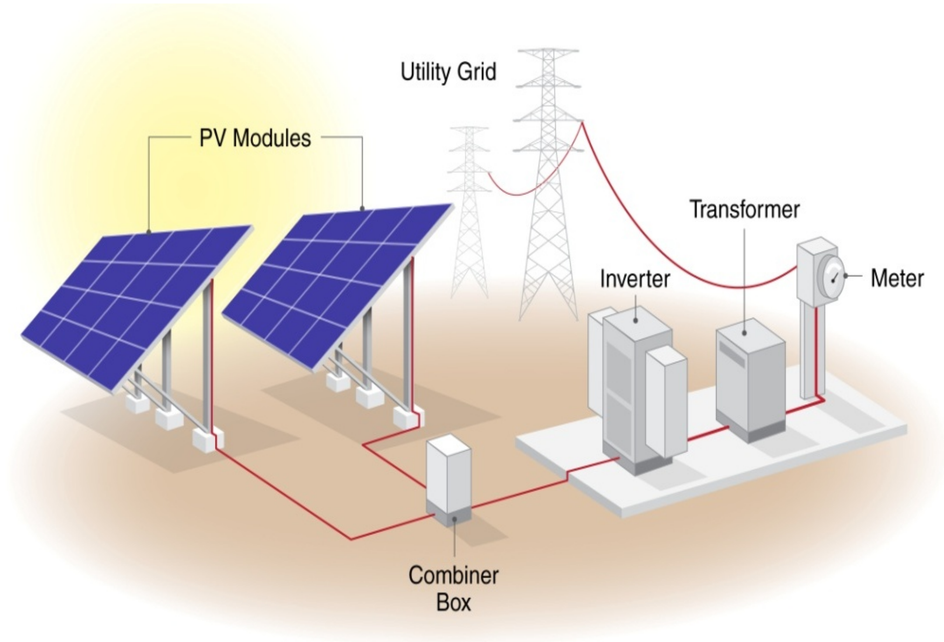

Figure 2. Ground-mounted array diagram

Source: NREL

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

- PV modules
- Inverter
- Balance-of-system components.

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

3.2.1 PV Module

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

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

3.2.1.1 Crystalline Silicon

Traditional solar cells are made from silicon. Silicon is quite abundant and nontoxic. It builds on a strong industry on both supply (silicon industry) and product side. This technology has been demonstrated for a consistent and high efficiency over 30 years in the field. The performance degradation, a reduction in power generation due to long-term exposure, is under 1% per year. Silicon modules have a lifespan 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 3 shows two examples of crystalline solar panels: mono- and multi-silicon installed on tracking mounting systems.

Source: Sunpower, NREL PIX-23816 *Source: NREL PIX-13823*

Figure 3. Mono- and multi-crystalline solar panels

3.2.1.2 Thin Film

Thin-film PV cells are made from amorphous silicon (a-Si) or non-silicon materials such as cadmium telluride (CdTe). Thin-film cells use layers of semiconductor materials only a few micrometers thick. Due to the unique nature of thin films, some 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 6%–8% for a-Si and 11%–12% for CdTe. Figure 4 shows thin-film solar panels.

Source: NREL PIX-18068 *Source: NREL PIX 14726* *Source: NREL PIX 17395*

Figure 4. Thin-film solar panels installed on (left) solar energy cover and (middle and right) fixed-tilt mounting system

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

3.2.2 Inverter

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

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

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

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

Micro-inverters are dedicated to the conversion of a single PV module’s power output. The AC output from each module is connected in parallel to create the array. This technology is relatively new to the market and in limited use in larger systems due to the potential increase in O&M associated with significantly increasing the number of inverters in a given array. Current micro-inverters range in size between 175 W and 380 W. These inverters can be the most expensive option per watt of capacity. Warranties range from 10 to 25 years. Small projects with irregular modules and shading issues typically benefit from micro-inverters.

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

Figure 5. String inverter

Source: NREL PIX 07985

3.2.3 *Balance-of-System Components*

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

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

3.2.3.1 Mounting Systems

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

3.2.3.1.1 Ground-Mounted Systems

For ground-mounted systems, the mounting system can be either directly anchored into the ground (via driven piers or concrete footers) or ballasted on the surface without ground penetration. Mounting systems must withstand local wind loads, which range from 90–120 mph 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. For sites such as Kerr McGee with contaminated groundwater plumes and associated below-ground hazards, mounting system designs will be primarily driven by these considerations coupled with settlement concerns and ground penetration restrictions.

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 have lower maintenance costs but generate less energy (kWh) per unit power (kW) of capacity than tracking systems.

Tracking systems rotate the PV modules so they are following the sun as it moves across the sky. This increases energy output but also increases maintenance and equipment costs slightly. Single-axis tracking, in which PV is rotated on a single axis, can increase energy output up to 25% or more. With dual-axis tracking, PV is able to directly face the sun all day, potentially increasing output up to 35% or more. Depending on underlying soiling conditions, single- and dual-axis trackers may not be suitable on some remediated sites due to potential settlement effects, which can interfere with the alignment requirements of such systems. The energy density, or amount of land required for each DC-watt of capacity, changes depending on system type to limit the effects of panels shading each other. Fixed-tilt systems have the highest energy density followed by single-axis tracking and then dual-axis tracking systems. Land-use constraints coupled with installation and maintenance cost must be considered jointly with energy production estimates to determine the ideal system for each situation.

Table 1. Energy Density by Panel and System

System Type	Fixed-Tilt Energy Density (DC-watt/ft^2)	Single-Axis Tracking Energy Density (DC-watt/ft^2)	Dual-Axis Tracking Energy Density (DC-watt/ft^2)
Crystalline Silicon	4.0	3.3	3.0
Thin Film	3.3	2.7	2.5
Hybrid High Efficiency	4.8	3.9	3.5

The selection of mounting type is dependent on many factors, including installation size, electricity rates, government incentives, land constraints, latitude, and local weather. Contaminated land applications may raise additional design considerations due to site conditions, including differential settlement.

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

3.2.3.2 Wiring for Electrical Connections

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

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

3.2.3.3 PV System Monitoring

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

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

3.2.4 Operation and Maintenance

The PV panels typically have a 25-year performance warranty. The inverters, which come standard with a 10-year warranty (extended warranties available), would be expected to last 10–15 years. System performance should be verified on a vendor-provided website. Wire and rack connections should be checked annually. This economic analysis uses an annual O&M cost computed as $20/kW/year for a fixed-tilt system, which is based on the historical O&M costs of installed fixed-axis grid-tied PV systems. Single-axis tracking system analysis uses an estimated annual O&M cost of $22/kW/year, and dual-axis tracking system analysis uses an estimated annual O&M cost of $25/kW/year.

3.3 Siting Considerations

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

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

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

4 Proposed Installation Location Information

This section summarizes the findings of the NREL solar assessment site visit on January 25, 2012.

4.1 Kerr McGee Site PV System

The Kerr McGee site is owned by Greenfield Environmental Multistate Trust LLC, which is interested in potential revenue flows on the site. For many contaminated land sites, the local community has significant interest in the redevelopment of the site, and community engagement is critical to match future reuse options to the community's vision for the site. For Kerr McGee, the community has been actively involved in the cleanup and treatment of the site and is keenly interested in the future opportunities for this land. The Memphis Town Community Action Group is supportive of potential solar installations on the site.

The total Kerr McGee site is approximately 90 acres, divided into two major sections by 14^{th} Street West. The northern portion of the site is approximately 50 acres and the southern portion of the site is approximately 40 acres.

Following the closure of the Kerr McGee Chemical Facility, all major buildings and structures were removed, leaving a site that is nearly void of any elements that would cause shading on a potential PV installation. The site is substantially flat with minimal grading work expected to be required to allow for the installation of a PV system. A majority of the site is surrounded by old growth trees, so some setback from property lines is likely required, but due to the scale of the overall property, the effect on total system design and performance was measured to be negligible using the Solmetric SunEye. The site has utility service remaining; however, capacity is likely undersized for a large-scale PV system. The electric utility has a substation located approximately one-quarter mile from the northwest corner of the site at 14^{th} Avenue North and Railroad Street, which appears adequate for a large-scale commercial PV system.

The site is located within city limits and is adjacent to adequate roads for transporting construction materials and personnel. In addition, rail service was provided to the Kerr McGee site during operation and rail access remains.

In order to get the most out of the ground area available, it is important to consider whether the site layout can be improved to better incorporate a solar system. If there are unused structures, fences, or electrical poles that can be removed, the un-shaded area can be increased to incorporate more PV panels.

The northernmost portion of the Kerr McGee site remains heavily forested, and it is not recommended that this vegetation be removed for the installation of a solar system. The remainder of the land, approximately 60 acres, is relatively clear and available for PV system development. Besides the vegetated section on the north end, the Kerr McGee site contains only minimal elements that would potentially shade the PV panels and all elements that do exist, with the exception of the utility building housing the ground-monitoring equipment and the office building, could be easily removed or relocated.

Figure 6 shows an aerial view of the Kerr McGee site taken from Google Earth; the overall area of the site is shaded in brown. The areas being considered for PV are shaded in green, represented by approximately 15 acres on the north and 40 acres on the south. As previously discussed, it is possible to develop less than the land indicated here, if deemed desirable given utility, site, financing, or community considerations. The local utility substation is also labeled, located to the west of the site. The electrical tie-in point for the PV system is noted as “SUBSTATION.” The areas highlighted in green are large expanses of relatively flat, un-shaded land, which is a suitable candidate for a PV system. The area of the site that appears feasible for PV is approximately 55–60 acres.

Figure 6. Aerial view of the feasible area (green) for PV at the Kerr McGee site (brown)

Illustration done in Google Earth

PV systems are well suited to the Columbus, Mississippi, area, where the average global horizontal annual solar resource—the total solar radiation for a given location, including direct, diffuse, and ground-reflected radiation—is 4.5 kWh/m^2/day.

Figure 7 shows various views of the Kerr McGee site, including the northern property, remaining infrastructure, and southern portion of the site.

Figure 7. Views of the feasible area for PV at the Kerr McGee site

Photos by Joe Simon, NREL

4.2 Utility-Resource Considerations

The expected electrical tie-in point and inverter for the PV system at the Kerr McGee site is located on the northwest side of the site. Other connections remain throughout the site but the quality and sizing is not known. A significant transmission line and substation exist approximately one-quarter mile to the west of the site along 14th Avenue North. An image showing the typical type and condition of electrical tie-in points at the site is shown in in Figure 8 along with the previously mentioned substation. Costs associated with upgrading and repairing the existing electrical service and connecting to the local utility at the Brickyard substation are expected but should not be abnormal or prohibitive. Prior to development of a request for proposals, additional information from the utility should be obtained and an electrical tie-in location should be identified to determine how the energy would be fed back into the grid.

Initial discussions with the local utility indicate that a system size of 2–5 MW would be best suited for this site. A larger system would be possible given the 55–60 acres available; however, due to ground remediation, shading, future development opportunities, and utility limitations, 5 MW is considered the ideal system size for this report.

Figure 8. Electrical tie-in point for the PV system at the Kerr McGee site

Photos by Joe Simon, NREL

4.3 Useable Acreage for PV System Installation

Typically, a minimum of 2 useable acres is recommended to site commercial PV systems. Useable acreage is typically characterized as "flat to gently sloping" southern exposures that are free from obstructions and get full sun for at least a 6-hour period each day. For example, eligible space for PV includes under-utilized or unoccupied land, vacant lots, and unused paved areas (e.g., a parking lot or industrial site space), as well as existing building rooftops.

4.4 PV Site Solar Resource

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

The assessment team for this feasibility study collected multiple Solmetric SunEye data points and found a solar access of 99%. All data gathered using this tool is available in Appendix C.

The predicted array performance was found using PVWatts Version 2[3] for Columbus, Mississippi. Table 2 shows the station identification information, PV system specifications, and energy specifications for the site. For this summary array performance information, a hypothetical system size of 1 kW was used to show the estimated production for each kilowatt so that additional analysis can be performed using the data indicated in Table 2. It can be scaled linearly to match the proposed system size.

[3] http://www.nrel.gov/rredc/pvwatts/.

Table 2. Site Identification Information and Specifications

Station Identification	
Cell ID	0237389
State	Mississippi
Latitude	33.6° N
Longitude	88.4° W
PV System Specifications	
DC Rating	1.00 kW
DC to AC Derate Factor	0.8
AC Rating	0.8 kW
Array Type	Fixed Tilt
Array Tilt	33.6°
Array Azimuth	180°
Energy Specifications	
Cost of Electricity	$0.10/kWh

Table 3 shows the performance results for a 33.4-degree fixed-tilt PV system in Columbus, Mississippi, as calculated by PVWatts.

Table 3. Performance Results for Fixed-Tilt PV

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	3.78	92	9.20
2	4.12	90	9.00
3	5.19	122	12.20
4	5.78	127	12.70
5	5.47	121	12.10
6	5.59	117	11.70
7	5.54	119	11.90
8	5.67	122	12.20
9	5.52	118	11.80
10	5.05	114	11.40
11	4.02	91	9.10
12	3.48	84	8.40
Year	4.94	1,316	131.60

Table 4 shows the performance results for a zero-tilt single-axis tracking PV system in Columbus, Mississippi, as calculated by PVWatts.

Table 4. Performance Results for Zero-Degree Single-Axis PV

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	4.41	108	10.80
2	4.92	108	10.80
3	6.37	151	15.10
4	7.29	162	16.20
5	6.83	154	15.40
6	7.13	152	15.20
7	6.93	152	15.20
8	7.06	155	15.50
9	6.75	146	14.60
10	6.18	141	14.10
11	4.76	109	10.90
12	4.03	98	9.80
Year	6.06	1,636	163.60

Table 5 shows the performance results for a dual-axis tracking PV system in Columbus, Mississippi, as calculated by PVWatts.

Table 5. Performance Results for Dual-Axis PV

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	4.62	113	11.30
2	5.01	110	11.00
3	6.47	154	15.40
4	7.57	168	16.80
5	7.34	165	16.50
6	7.86	168	16.80
7	7.52	165	16.50
8	7.38	161	16.10
9	6.86	148	14.80
10	6.32	144	14.40
11	4.96	113	11.30
12	4.26	102	10.20
Year	6.35	1,711	171.10

4.5 Kerr McGee Energy Usage

The Kerr McGee site has limited groundwater monitoring wells situated throughout the site. Most equipment is located within the maintenance shed located towards the center of the property. Overall energy use, expected duration and growth potential, and utility information are outlined in Section 4.5.1. It is important to understand the energy use of the site to enable for a full analysis of whether or not energy produced would need to be sold or if it could offset onsite energy use.

4.5.1 Current Energy Use

In 2010, Columbus City Light and Water charged approximately $5,400 annually for electric services at the site, representing approximately 4,500 kWh of use per month. The site, however, was originally a significant energy consumer and is located adjacent to industrial facilities, including Sanderson Plumbing Products, Inc. and Columbus Brick Company. Both properties, combined with the prior Kerr McGee Chemical Facility, supported the development of substantial transmission lines and utility services. Approximately one-quarter mile west of the site is a primary electric substation. Ground monitoring is expected to continue; however, as a relatively small energy consumer, large-scale PV facilities would not be appropriate to be "behind-the-meter" at this site.

The estimated cost of electricity is, therefore, $0.10/kWh; however, most commercial customers pay a higher rate due to time-of-use charges and peak demand metering. The electricity rates for Columbus Light and Water, the relevant utility, as demonstrated by the electric rate schedule, depends on the type of facility and the amount of energy consumed.[4] The monthly charge for this type of facility relates to the peak demand. Integrating a solar system behind-the-meter can reduce the monthly peak, significantly reducing the cost of energy for a facility.

4.5.2 Net Metering

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

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

[4] The Columbus Light and Water electric rate schedule can be viewed at http://columbuslw.com/images/pdf/ElectricRates.pdf.

offset electric energy provided by the electric utility to the electric consumer during the applicable billing period.[5]

As of 2011, Mississippi was one of only four U.S. states that did not have a net-metering option; however, on January 6, 2011, the Mississippi Public Service Commission issued an order to develop net metering and interconnection standards. This has not yet been completed, and net metering is currently under the purview of each individual utility.

In addition, the TVA is piloting a Solar Solutions Initiative in 2012 and 2013 that provides incentive payments for mid-size solar projects using local certified installers. To qualify for this incentive payment, however, the system must be between 50 kW and 1,000 kW. This program will provide a 10-year incentive of $0.06/kWh above and beyond the TVA's Renewable Standard Offer rates for projects between 50 kW and 200 kW and an incentive of $0.04/kWh for projects between 200 kW and 1,000 kW.[6]

Renewable energy certificates (RECs),[7] also known as green certificates, green tags, or tradable renewable certificates, are tradable commodities in the United States that represent proof of electric energy generation from eligible renewable energy resources (renewable electricity). The RECs that are associated with the electricity produced and are used on-site remain with the customer-generator. If, however, the customer chooses to receive financial compensation for the net energy generation remaining after a 12-month period, the utility will be granted the RECs associated with only that surplus they purchase.

Utilities may elect to provide co-energy metering, which is the same as net metering except that it incorporates a time-of-use rate schedule. As part of the Renewable Standard Offer with TVA, customer-generators with systems sized between 200 kW and 20 MW, are able to sell electricity to the system based on the time of day and time of year. Table 6 summarizes the current rates for the TVA Renewable Standard Offer as of August 1, 2012.[8] These rates are guaranteed to increase by at least 3% per year for the term of the contract, which can be 10, 15, or 20 years. Customer-generators retain ownership of all RECs associated with the generation of electricity they use on-site.

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[5] Energy Policy Act of 2005, page 370: http://www.gpo.gov/fdsys/pkg/PLAW-109publ58/pdf/PLAW-109publ58.pdf.

[6] Additional information on the Tennessee Valley Authority Solar Solutions Initiative is available at http://www.tva.com/renewablestandardoffer/ssi.htm.

[7] For a description of RECs, see http://apps3.eere.energy.gov/greenpower/markets/certificates.

[8] The rate schedule for the Tennessee Valley Authority Renewable Standard Offer is available at http://www.tva.com/renewablestandardoffer/.

Table 6. TVA Renewable Standard Offer PPA Prices

	January	February	March	April	May	June	July	August	September	October	November	December
12:00 AM	4.272	4.272	4.151	3.793	3.793	3.963	4.078	4.078	3.963	3.793	3.793	4.151
1:00 AM	4.272	4.272	4.151	3.793	3.793	3.963	4.078	4.078	3.963	3.793	3.793	4.151
2:00 AM	4.272	4.272	4.151	3.793	3.793	3.963	4.078	4.078	3.963	3.793	3.793	4.151
3:00 AM	4.272	4.272	4.151	3.793	3.793	3.963	4.078	4.078	3.963	3.793	3.793	4.151
4:00 AM	4.272	4.272	4.151	3.793	3.793	3.963	4.078	4.078	3.963	3.793	3.793	4.151
5:00 AM	4.272	4.272	4.151	3.793	3.793	3.963	4.078	4.078	3.963	3.793	3.793	4.151
6:00 AM	5.937	5.937	5.596	5.616	5.616	5.263	6.42	6.42	5.263	5.616	5.616	5.596
7:00 AM	5.937	5.937	5.596	5.616	5.616	5.263	6.42	6.42	5.263	5.616	5.616	5.596
8:00 AM	5.937	5.937	5.596	5.616	5.616	5.263	6.42	6.42	5.263	5.616	5.616	5.596
9:00 AM	5.937	5.937	5.596	5.616	5.616	5.263	6.42	6.42	5.263	5.616	5.616	5.596
10:00 AM	5.937	5.937	5.596	5.616	5.616	5.263	6.42	6.42	5.263	5.616	5.616	5.596
11:00 AM	5.937	5.937	5.596	5.616	5.616	5.263	6.42	6.42	5.263	5.616	5.616	5.596
12:00 PM	5.937	5.937	5.596	5.616	5.616	8.139	15.966	15.966	8.139	5.616	5.616	5.596
1:00 PM	5.937	5.937	5.596	5.616	5.616	8.139	15.966	15.966	8.139	5.616	5.616	5.596
2:00 PM	5.937	5.937	5.596	5.616	5.616	8.139	15.966	15.966	8.139	5.616	5.616	5.596
3:00 PM	5.937	5.937	5.596	5.616	5.616	8.139	15.966	15.966	8.139	5.616	5.616	5.596
4:00 PM	5.937	5.937	5.596	5.616	5.616	8.139	15.966	15.966	8.139	5.616	5.616	5.596
5:00 PM	5.937	5.937	5.596	5.616	5.616	8.139	15.966	15.966	8.139	5.616	5.616	5.596
6:00 PM	5.937	5.937	5.596	5.616	5.616	8.139	15.966	15.966	8.139	5.616	5.616	5.596
7:00 PM	5.937	5.937	5.596	5.616	5.616	8.139	15.966	15.966	8.139	5.616	5.616	5.596
8:00 PM	5.937	5.937	5.596	5.616	5.616	5.263	6.42	6.42	5.263	5.616	5.616	5.596
9:00 PM	5.937	5.937	5.596	5.616	5.616	5.263	6.42	6.42	5.263	5.616	5.616	5.596
10:00 PM	4.868	4.868	4.717	4.431	4.431	5.263	6.42	6.42	5.263	4.431	4.431	4.717
11:00 PM	4.868	4.868	4.717	4.431	4.431	5.263	6.42	6.42	5.263	4.431	4.431	4.717

4.5.3 Virtual Net Metering

Some states and utilities allow for virtual net metering (VNM). This arrangement can allow certain entities, such as a local government, to install renewable generation at one location within its geographic boundary to generate credits that can be used to offset charges at one or more other locations within the same geographic boundary.

The local utility has not previously indicated support for VNM; however, as a smaller utility with limited experience regarding distributed generation, the possibility may exist to develop a VNM program. Additional conversations with Columbus Light and Water would be required to determine the feasibility of VNM at this site. As the site is currently owned by a multi-state trust, and not the city, lease agreements would be required to clearly define the ownership of the system and resultant power generated.

5 Economics and Performance

The economic performance of a PV system installed on the site is evaluated using a combination of the assumptions and background information discussed previously as well as a number of industry-specific inputs determined by other studies. In particular, this study uses the NREL System Advisor Model (SAM).[9]

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

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

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

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

5.1 Assumptions and Input Data for Analysis

Cost of a PV system depends on the system size and other factors such as geographic location, mounting structure, and type of PV module. Based on significant cost reductions seen in 2011, the average cost for utility-scale ground-mounted systems have declined from $4.80/W in the first quarter (Q1) of 2010 to $3.20/W in Q4 2011.[10] With an increasing demand and supply, potential of further cost reduction is expected as market conditions evolve. Considering this trend, an expected cost of $2.79/W is used for analysis as any project associated with the Kerr McGee site is not expected to begin before Q1 2013 at the earliest. Figure 9 shows the cost per watt of PV systems from 2010 to 2011 for utility-scale projects. As previously noted, due to constraints regarding the utility transmission, alternative reuse of the site, and ground remediation strategies, a solar system of 5 MW using between 28 and 35 acres of land will be required, depending on system type. By limiting the system size to 5 MW and 35 acres, it is expected that installation could occur on remediated areas where ground penetration is permitted and a ballasted system would not be required. A 1-MW system designed to participate in the Solar Solutions Initiative pilot would require between 4 and 7 acres of land.

[9] For additional information on the NREL Solar Advisor Model, see https://sam.nrel.gov/cost.
[10] Data drawn from the Solar Energy Industries Association "SEIA/GTM Research U.S. Solar Market Insight" 2011 year-end report. See http://www.seia.org/cs/research/SolarInsight.

For this analysis, the following input data were used. The installed cost of fixed-tilt ground-mounted systems was assumed to be $2.79/W, and the installed cost of single-axis tracking was assumed to be $3.348/W. Dual-axis tracking was assumed to be $3.68/W.

The estimated increase in cost from this baseline for a ballasted system is 25%. This increased cost is due to limitations placed on design and construction methods due to the ground conditions at the site. Such limitations include restrictions on storm water runoff, weight loading of construction equipment, inability to trench for utility lines, additional engineering costs, permitting issues, and non-standard ballasted racking systems. The installed system cost assumptions are summarized in Table 7. As previously indicated, system analysis was conducted assuming a ballasted system would not be required.

Table 7. Installed System Cost Assumptions

System Type	Fixed Tilt ($/Wp)	Single-Axis Tracking ($/Wp)	Dual-Axis Tracking ($/Wp)
Baseline system	2.79	3.348	3.68
With ballast	0.69	0.837	0.92
Total cost, ballasted	3.48	4.185	4.60

These prices include the PV array and the balance-of-system components for each system, including the inverter and electrical equipment, as well as the installation cost. This includes estimated taxes and a national-average labor rate but does not include land cost. The economics of grid-tied PV depend on incentives, the cost of electricity, the solar resource, and panel tilt and orientation.

It was assumed for this analysis that relevant federal incentives are received. It is important to consider all applicable incentives or grants to make PV as cost effective as possible. If the PV system is owned by a private tax-paying entity, this entity may qualify for federal tax credits and accelerated depreciation on the PV system, which can be worth about 15% of the initial capital investment. The total potential tax benefits to the tax-paying entity can be as high as 45% of the initial system cost, depending on federal, state, and local incentives. Because state and federal governments do not pay taxes, private ownership of the PV system would be required to capture tax incentives.

For the purposes of this analysis, the project is expected to have a 30-year life, although the systems can be reasonably expected to continue operation past this point. Inflation is assumed to be 2.5%, the real discount rate to be 5.85%, financing secured via a 15-year loan at a 6% interest rate, and 55% debt fraction. The panels are assumed to have a 0.5% per year degradation in performance. The O&M expenses are estimated to be $20/kW/yr for the life of a fixed-tilt system. O&M charges for a single-axis tracking system are estimated at $22/kW/yr and $25/kW/yr for a dual-axis tracking system. A system DC-to-AC conversion of 80% was assumed. This includes losses in the inverter, wire losses, PV module losses, and losses due to temperature effects. PVWatts Version 2 was used to calculate expected energy performance for the system.

5.2 SAM Forecasted Economic Performance

Using the inputs and assumptions summarized in the Economics and Performance section of this report, several scenarios were created and the SAM tool predicted an associated internal rate of return (IRR) and levelized cost of energy. Table 8 summarizes the results of this analysis. A summary of the results of the economic analysis and the system considered is available in Appendix E.

As demonstrated in Table 8, a utility-scale PV system at the Kerr McGee site would likely not be feasible if electricity were to be sold directly to the utility via the TVA's Renewable Standard Offer PPA. If, however, a VNM agreement or behind-the-meter PPA with an adjacent manufacturing facility were to be developed with a purchase rate of $0.12/kWh escalating at 3% annually, an after-tax IRR of 11%–13% could be realized, depending on system type. A 1-MW system participating in the Solar Solutions Initiative pilot would also be feasible, earning an estimated after-tax IRR up to 9.23%.

Table 8. PV System Summary

System Type	PV System Size[a]	Array Tilt	Annual Output	Number of Houses Powered[b]	Construction Period Jobs[c]	Jobs Sustained[d]
	(kW)	(deg)	(kWh/year)		(job-year)	(job-year)
Crystalline Silicon (Fixed Tilt)	5,000	33.4	6,611,294	599	141	1.5
Crystalline Silicon (Single-Axis Tracking)	5,000	n/a	8,285,480	750	199	1.6
Crystalline Silicon (Dual-Axis Tracking)	5,000	n/a	8,863,384	803	218	1.8
Crystalline Silicon (Fixed Tilt)	1,000	33.4	1,321,896	120		
Crystalline Silicon (Single-Axis Tracking)	1,000	n/a	1,656,311	150		
Crystalline Silicon (Dual-Axis Tracking)	1,000	n/a	1,735,761	157		

System Type	Annual Output	System Area	System Cost	Scenario	PPA Price[e]	System Cost	After-tax IRR	After-tax NPV
	kWh/year	(Acres req'd)	($/watt)					
Fixed Tilt - Utility	6,611,294	28.70	$ 2.79	Utility PPA	$0.072	$ 13,878,118.66	-0.21	$ (1,843,512.99)
Single-Axis Tracking - Utility	8,285,480	34.78	$ 3.34	Utility PPA	$0.072	$ 16,710,322.35	0.8	$ (1,923,388.22)
Dual-Axis Tracking - Utility	8,683,384	38.26	$ 3.68	Utility PPA	$0.072	$ 18,384,949.33	-0.18	$ (2,429,268.00)
Fixed Tilt - PPA	6,611,294	28.70	$ 2.79	VNM or PPA	$0.012	$ 13,878,118.66	11.53	$ 1,014,751.20
Single-Axis Tracking - PPA	8,285,480	34.78	$ 3.34	VNM or PPA	$0.012	$ 16,710,322.35	12.94	$ 1,658,682.95
Dual-Axis Tracking - PPA	8,683,384	38.26	$ 3.68	VNM or PPA	$0.012	$ 18,384,949.33	11.48	$ 1,324,823.98
Fixed Tilt - SSI	1,321,595	3.50	$ 2.79	Utility SSI	$0.072+$0.04	$ 2,771,742.25	7.08	$ (10,624.54)
Single-Axis Tracking - SSI	1,656,061	4.00	$ 3.34	Utility SSI	$0.072+$0.04	$ 3,337,606.39	9.23	$ 63,710.65
Dual-Axis Tracking - SSI	1,735,535	5.00	$ 3.68	Utility SSI	$0.072+$0.04	$ 3,677,089.10	6.98	$ (17,794.40)

a Data assume a system size of 5MW.
b Number of average American households that could hypothetically be powered by the PV system assuming 11,040 kWh/year/household.
c Job-years created as a result of project capital investment including direct, indirect, and induced jobs.
d Jobs (direct, indirect, and induced) sustained as a result of operations and maintenance (O&M) of the system.
e The Solar Solutions Initiative offers $0.04/kWh production credit for the first 10 years of system operation.

5.3 Job Analysis and Impact

To evaluate the impact on employment and economic impacts of the PV project associated with this analysis, the NREL Jobs and Economic Development Impact (JEDI) models were used.[11] The JEDI models are tools that estimate the economic impacts associated with the construction and operation of distributed generation power plants. It is a flexible input-output tool that estimates, but does not precisely predict, the number of jobs and economic impacts that can be reasonably supported by the proposed facility.

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

For this analysis, inputs including the estimated installed project cost ($/kW), targeted year of construction, system capacity (kW), O&M costs ($/kW), and location were entered into the model to predict the jobs and economic impact. These costs associated with a 5-MW fixed-tilt non-ballasted system were used. It is important to note that the JEDI model does not predict or incorporate any displacement of related economic activity or alternative jobs due to the implementation of the proposed project. As such, the JEDI model results are considered gross estimates as opposed to net estimates.

For the Kerr McGee site, the values in Table 9 were assumed.

Table 9. JEDI Analysis Assumptions

Input	Assumed Value
Capacity	5,000 kW
Placed In Service Year	2013
Installed System Cost	$13,900,000
Location	Columbus, Mississippi

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

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

[11] The JEDI models have been used by the U.S. Department of Energy, the U.S. Department of Agriculture, NREL, and the Lawrence Berkeley National Laboratory, as well as a number of universities. For information on the NREL Jobs and Economic Development Impact tool, see http://www.nrel.gov/analysis/jedi/about_jedi.html.

As indicated in the results of the JEDI model analysis provided in Appendix D, the total proposed system is estimated to support the equivalent of 141 FTE direct and induced jobs for the duration of the procurement and construction period. Total wages paid to workers during the construction period are estimated to be $5,292,600, and total economic output is estimated to be $13,282,800. The annual O&M of the new PV system is estimated to support 1.5 FTEs per year for the life of the system. The jobs and associated spending are projected to account for approximately $75,100 in earnings and $121,500 in economic activity each year for the next 25 years.

5.4 Financing Opportunities

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

5.4.1 Owner and Operator Financing

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

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

5.4.2 Third-Party Developers with Power Purchase Agreements

Since many project site hosts have the financial or technical capabilities to develop a capital intensive project, many times they turn to third-party developers (and/or their investors). In exchange for access to a site through a lease or easement arrangement, third-party developers will finance, develop, own, and operate solar projects utilizing their own expertise and sources of tax equity financing and debt capital. Once the system is installed, the third-party developer will sell the electricity to the site host or local utility via a PPA—a contract to sell electricity at a negotiated rate over a fixed period of time. The PPA typically will be between the third-party developer and the site host if it is a retail "behind-the-meter" transaction or directly with an electric utility if it is a wholesale transaction.

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

5.4.3 Third-Party "Flip" Agreements

The most common use of this model is a site host working with a third-party developer who then partners with a tax-motivated investor in a SPE that would own and operate the project. Initially, most of the equity provided to the SPE would come from the tax investor and most of the benefit would flow to the tax investor (as much as 99%). When the tax investor has fully monetized the tax benefits and achieved an agreed-upon rate of return, the allocation of benefits and majority ownership (95%) would "flip" to the site host (but not within the first 5 years). After the flip, the site host would have the option to buy out all or most of the tax investor's interest in the project at the fair market value of the tax investor's remaining interest.

A flip agreement can also be signed between a developer and investors within an SPE, where the investor would begin with the majority ownership. Eventually, the ownership would flip to the developer once the investors' return is met.

5.4.4 Hybrid Financial Structures

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

5.4.5 Solar Services Agreement and Operating Lease

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

Similar to the SSA, there are a variety of lease options that are available to municipalities that allow the capture of tax benefits by third-party owners, which result in a lower cost to the municipality. These include an operating lease for solar services (as opposed to an equipment capital lease) and a complex business model called a sale/leaseback. Under the sale/leaseback model, the municipality develops the project and sells it to a third-party tax equity investor who then leases the project back to the municipality under an operating lease. At the end of the lease period, and after the tax benefits have been absorbed by the tax equity investor, the municipality may purchase the solar project at fair market value.

5.4.6 Sale/Leaseback

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

5.4.7 Community Solar/Solar Gardens

The concept of "community solar" is one in which the costs and benefits of one large solar project are shared by a number of participants. A site owner may be able to make the land available for a large solar project, which can be the basis for a community solar project. Ownership structures for these projects vary, but the large projects are typically owned or sponsored by a local utility. Community solar gardens are distributed solar projects wherein utility customers have a stake via a pro-rated share of the project's energy output. This business model is targeted to meet demand for solar projects by customers who rent/lease homes or businesses, do not have good solar access at their site, or do not want to install solar system on their facilities. Customer pro-rated shares of solar projects are acquired through a long-term transferrable lease of one or more panels, or they subscribe to a share of the project in terms of a specific level of energy output or the energy output of a set amount of capacity. Under the customer lease option, the customer receives a billing credit for the number of kilowatt-hours their pro-rated share of the solar project produces each month; it is also known as VNM. Under the customer subscription option, the customers typically pay a set price for a block of solar energy (i.e., 100 kWh per month blocks) from the community solar project. Other models include monthly energy outputs from a specific investment dollar amount or a specific number of panels.

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

Columbus Light and Water has demonstrated an interest in the development of a large-scale PV system on the Kerr McGee site, and as a small local distributor of electricity, may have interest separate from the producer, TVA, in a community solar arrangement.

There are some states that offer solar incentives for community solar projects, including Washington State (production incentive) and Utah (state income tax credit). Community solar may also be known as solar gardens depending on the location (e.g., Colorado). Currently, Mississippi does not have any history or past precedent regarding community solar.

5.4.8 Site Land Lease and PPA Agreement

Given the site's proximity to major manufacturing facilities, the potential may exist for a hybrid development and ownership approach that allows for the site owner to receive lease payments and the local manufacturers to receive a lower cost of electricity through the successful development of a PV system. Directly adjacent to the site include multiple manufacturers that are large consumers of electricity, including Columbus Brick and Sandersen Plumbing Products. It may be possible to develop an arrangement wherein a solar system installed on a portion of the adjacent Kerr McGee site could be tied in to the manufacturing facility behind-the-meter. A third-party developer could install, own, and manage the system with little or no upfront cost to the manufacturer and establish a PPA or solar lease agreement with the manufacturer to purchase the electricity produced by the system at a reasonable cost that is below the cost of electricity purchased from Columbus Light and Water but high enough to provide a reasonable rate of return for the developer as well as income for the site owner itself through a land lease or revenue share with the developer. Given that the manufacturer would not own the land on which the PV system was installed, additional research into this potential solution would be required to determine legality, feasibility, and permissibility from the utility to transfer energy from one parcel of land to another without the involvement of the utility.

6 Conclusions and Recommendations

The site locations considered for a solar PV system in this report are highly suitable areas in which to implement solar PV systems. Installing a PV system on the prior Kerr McGee Chemical Facility land at the site could generate significant clean, renewable power, depending on the total area developed. Using only a portion of the land to install a 5-MW system would require between 28 and 34 acres and would represent between 6,611,294 kWh and 8,683,384 kWh of production annually.

As summarized in Section 5, the economic analysis completed using SAM predicts an IRR between 11.48% and 12.94% with a net present value up to $1,658,682 if a PPA were able to be established with an adjacent manufacturer with a purchase price of $0.12/kWh, which is reasonable. Annual gross revenue for the system would be approximately $1,000,000/yr, as demonstrated in Appendix E.

The site should also consider placing a smaller system, up to 1 MW, which qualifies for the TVA Solar Solutions Initiative, which would establish a more reasonable PPA price and would result in acceptable project returns. This would also build the expertise of local installers.

When reviewing proposals for a PV system to be installed at this site, evaluation criteria should include the annual output (kWh/yr) as well as price per kilowatt-hour. A design-build contract can enable vendors to optimize system configuration, including slope and tracking requirements or a specific system design can be required of the vendor.

For multiple reasons—the escalating cost of energy, the dropping cost of PV, and the existence of a quality solar resource—this report finds that a PV system is a reasonable use for the site if an adequate PPA is established or if the site pursues participation on TVA's Solar Solutions Initiative for a 1-MW system.

Appendix A. Provided Site Information: Utility Infrastructure

Figure A-1 demonstrates the electric utility infrastructure surrounding the site.

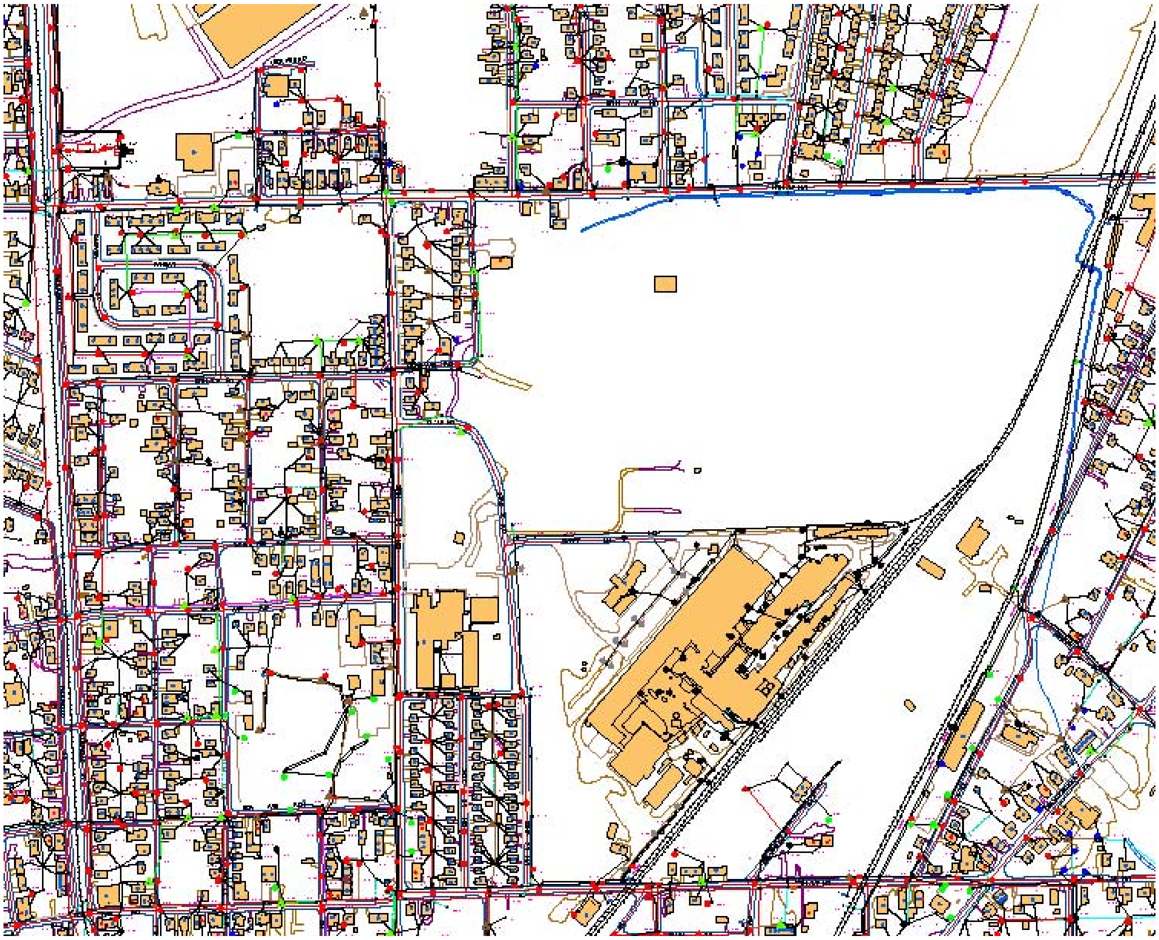

Figure A-1. Columbus, Mississippi, utility infrastructure

Figure provided by the site owner and the City of Columbus Utility.

Appendix B. Summary of Assessment Assumptions

The data in Table B-1 summarizes important assumptions used throughout the feasibility study. The reasoning behind each assumption is explained in the body of the report.

Table B-1. Summary of Assessment Assumptions

Cost Assumptions			
Variable	**Quantity of Variable**	**Unit of Variable**	
Cost of Site Electricity	0.10-0.15	$/kWh	
Annual O&M (fixed)	20	$/kW/year	
Annual O&M (one-axis tracking)	22	$/kW/year	
Annual O&M (two-axis tracking)	25	$/kW/year	
System Assumptions			
System Type	**Annual energy kWh/kW**	**Installed Cost ($/W)**	**Energy Density (W/sq. ft.)**
Ground fixed	1,316	$2.79	4.0
Ground 1-axis	1,636	$3.34	3.3
Ground 2-axis	1,711	$3.68	3.0
Other Assumptions			
	1 acre	43,560 ft^2	
	1 MW	1,000,000 W	
	Ground utilization	90% of available area	

Appendix C. Solar Access Measurements

The review team used a Solmetric SunEye tool to capture the solar access conditions of the site. The image and data in Figure C-1 were taken from the center of the southern portion of the site.

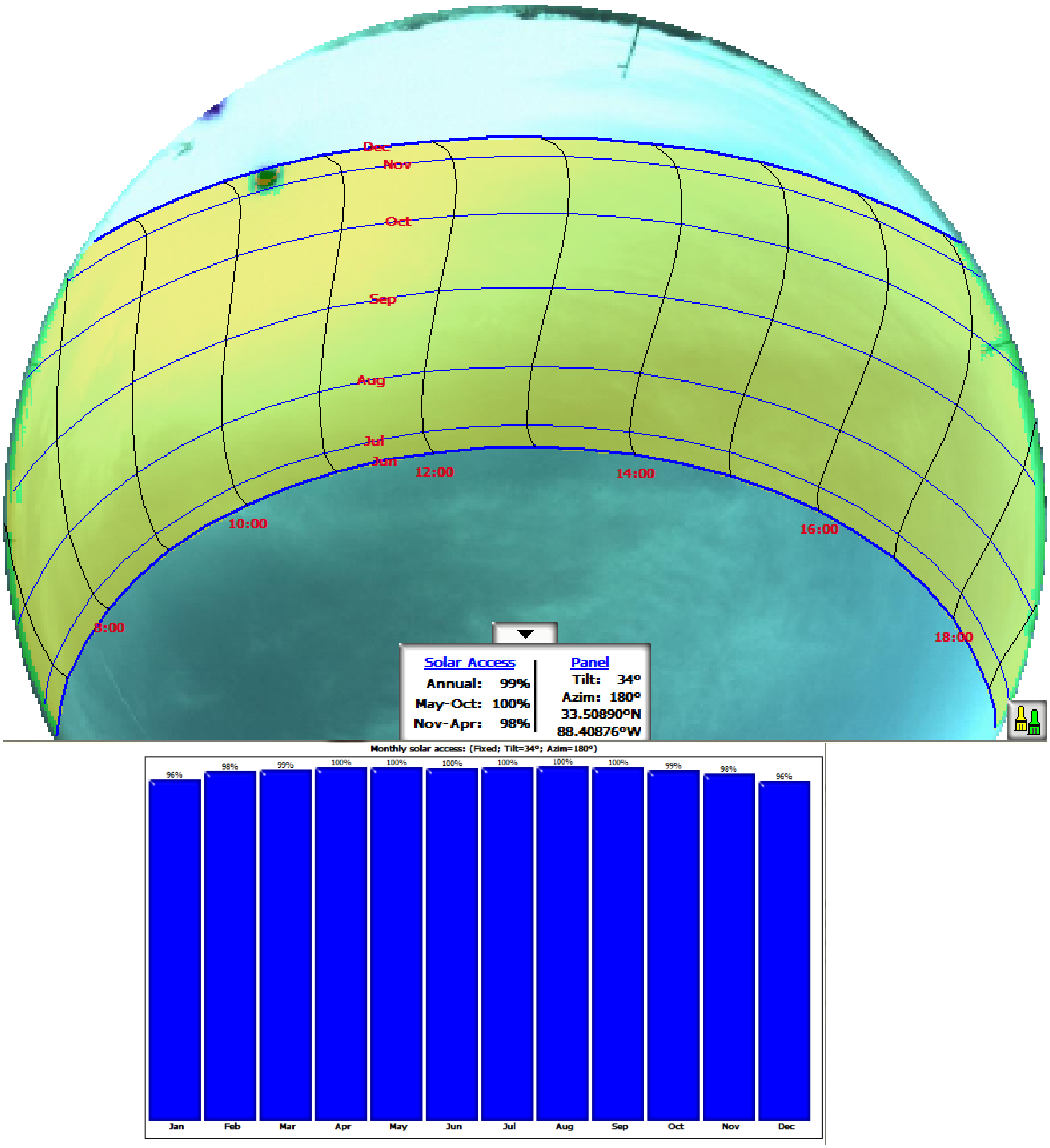

Figure C-1. SunEye solar access measurements

Appendix D. Results of the JEDI Model

The NREL JEDI tool was used to forecast employment and impacts of the evaluated solar system. Additional information on the inputs is provided in the body of the report.

Table D-1. Summary Results of JEDI Model

Photovoltaic - Project Data Summary Based on Model Default Values	
Project Location	Mississippi
Year of Construction or Installation	2013
Average System Size - DC Nameplate Capacity (kW)	5,000
Number of Systems Installed	1
Total Project Size - DC Nameplate Capacity (kW)	5,000
System Application	Large Commercial
Solar Cell/Module Material	Crystalline Silicon
System Tracking	Fixed Mount
Base Installed System Cost ($/kWDC)	$2,795
Annual Direct Operations and Maintenance Cost ($/kW)	$20.00
Money Value - Current or Constant (Dollar Year)	2010
Project Construction or Installation Cost	$13,950,000
Local Spending	$8,548,851
Total Annual Operational Expenses	$1,668,800
Direct Operating and Maintenance Costs	$100,000
Local Spending	$92,000
Other Annual Costs	$1,568,800
Local Spending	$2,800
Debt Payments	$0
Property Taxes	$0

Local Economic Impacts - Summary Results			
	Jobs	**Earnings**	**Output**
During construction and installation period		**(thousands of 2010 dollars)**	
Project Development and On-site Labor Impacts			
Construction and Installation Labor	19.8	$1,280.9	
Construction and Installation Related Services	35.8	$1,109.4	
Subtotal	55.6	$2,390.3	$4,437.8

Module and Supply Chain Impacts			
Manufacturing	0.0	$0.0	$0.0
Trade (Wholesale and Retail)	13.0	$575.7	$1,782.9
Finance, Insurance, and Real Estate	0.0	$0.0	$0.0
Professional Services	8.2	$253.1	$880.2
Other Services	7.3	$529.4	$1,895.9
Other Sectors	29.3	$779.4	$1,582.1
Subtotal	57.9	$2,137.6	$6,141.1
Induced Impacts	27.7	$764.7	$2,703.9
Total Impacts	**141.2**	**$5,292.6**	**$13,282.8**

During operating years	Annual Jobs	Annual Earnings (thousands of 2010 dollars)	Annual Output (thousands of 2010 dollars)
On-Site Labor Impacts			
PV Project Labor Only	0.9	$55.7	$55.7
Local Revenue and Supply Chain Impacts	0.3	$13.5	$45.0
Induced Impacts	0.2	$5.9	$20.8
Total Impacts	**1.5**	**$75.1**	**$121.5**

Notes: Construction and operating period jobs are FTE for one year (1 FTE = 2,080 hours). Economic impacts "during operating years" represent impacts that occur from system/plant operations/expenditures. Totals may not add due to independent rounding.

Detailed PV Project Data Costs

Installation Costs	Cost	Purchased Locally (%)	Manufactured Locally (Y or N)
Materials and Equipment			
Mounting (rails, clamps, fittings, etc.)	$589,587	100%	N
Modules	$4,895,743	100%	N
Electrical (wire, connectors, breakers, etc.)	$413,443	100%	N
Inverter	$883,622	100%	N
Subtotal	$6,782,395		
Labor			
Installation	$1,280,927	100%	
Subtotal	$1,280,927		
Subtotal	$8,063,323		
Other Costs			
Permitting	$1,461,704	100%	
Other Costs	$596,614	100%	

Business Overhead	$3,378,359	100%
Subtotal	$5,436,677	
Subtotal	$13,500,000	
Sales Tax (materials and equipment purchases)	$474,768	100%
Total	**$13,974,768**	

PV System Annual Operating and Maintenance Costs	**Cost**	**Local Share**
Labor		
Technicians	$60,000	100%
Subtotal	$60,000	
Materials and Services		
Materials & Equipment	$40,000	100%
Services	$0	100%
Subtotal	$40,000	
Sales Tax (materials and equipment purchases)	$2,800	100%
Average Annual Payment (interest and principal)	$1,566,000	0%
Property Taxes	$0	100%
Total	**$1,668,800**	

Other Parameters		
Financial Parameters		
Debt Financing		
Percentage Financed	80%	0%
Years Financed (term)	10	
Interest Rate	10%	
Tax Parameters		
Local Property Tax (percent of taxable value)	0%	
Assessed Value (percent of construction cost)	0%	
Taxable Value (percent of assessed value)	0%	
Taxable Value	$0	
Property Tax Exemption (percent of local taxes)	0%	
Local Property Taxes	$0	100%
Local Sales Tax Rate	7.00%	100%
Sales Tax Exemption (percent of local taxes)	0.00%	
Payroll Parameters	**Wage per hour**	**Employer Payroll Overhead**

Construction and Installation Labor		
Construction Workers/Installers	$21.39	45.6%
O&M Labor		
Technicians	$21.39	45.6%

Appendix E. Results of the Solar Advisor Model

This feasibility study used the NREL Solar Advisor Model to evaluate the potential performance of the various proposed systems. Tables E-1 and E-2 summarize the results.

Table E-1. Results of Solar Advisor Model

Scenario	Net Annual Energy (kWh)	PPA Price (¢/kWh)	LCOE Nominal (¢/kWh)	LCOE Real (¢/kWh)	After-tax IRR (%)	After-tax NPV ($)	PPA Price Escalation (%)	Debt Fraction (%)	Capacity Factor (%)	First year kWhac/kWDC	System Performance Factor
VNM/PPA - Fixed	6,611,294.00	12	15.61	13.54	11.53	$ 1,014,751	3	55	15.1	1323	0.76
VNM/PPA - Single Axis	8,285,480.00	12	15.61	13.54	12.94	1658682.92	3	55	18.9	1658	0.77
VNM/PPA - Dual axis	8,683,384.00	12	15.61	13.54	11.48	$ 1,324,824	3	55	19.8	1737	0.77
Utility PPA - Fixed	6,611,294.00	7.2	9.37	8.12	-0.21	$ (1,843,513)	3	55	15.1	1323	0.76
Utilty PPA - Single Axis	8,285,480.00	7.2	9.37	8.12	0.8	$ (1,923,383)	3	55	18.9	1658	0.77
Utility PPA - Dual Axis	8,683,384.00	7.2	9.37	8.12	-0.18	$ (2,429,268)	3	55	19.8	1737	0.77
Utility SSI - Fixed	1,321,595.00	7.2	9.37	8.12	7.08	$ (10,625)	3	55	15.1	1323	0.76
Utility SSI - Single Axis	1,656,061.00	7.2	9.37	8.12	9.23	$ 63,711	3	55	18.9	1658	0.77
Utility SSI - Dual Axis	1,735,535.00	7.2	9.37	8.12	6.98	$ (17,794)	3	55	19.8	1738	0.77

Table E-2. Cash Flow Summary for VNM/PPA—Single-Axis Scenario

	0	1	2	3	4	5	6	7	8	9
Energy (kWh)	0	8,285,480	8,244,053	8,202,833	8,161,818	8,121,009	8,080,404	8,040,002	7,999,802	7,959,803
Energy Price ($/kWh)	0	0.12	0.124	0.127	0.131	0.135	0.139	0.143	0.148	0.152
Energy Value ($)	0	994,257.62	1,018,964.93	1,044,286.20	1,070,236.72	1,096,832.10	1,124,088.38	1,152,021.97	1,180,649.72	1,209,988.86
Operating Expenses										
Fixed O&M Annual	0	0	0	0	0	0	0	0	0	0
Fixed O&M	0	109,964.38	111,613.85	113,288.05	114,987.38	116,712.19	118,462.87	120,239.81	122,043.41	123,874.06
Variable O&M	0	0	0	0	0	0	0	0	0	0
Insurance	0	83,551.61	84,804.89	86,076.96	87,368.11	88,678.64	90,008.81	91,358.95	92,729.33	94,120.27
Property Assessed Value	0	0	0	0	0	0	0	0	0	0
Property Taxes	0	0	0	0	0	0	0	0	0	0
Net Salvage Value	0	0	0	0	0	0	0	0	0	0
Total Operating Expenses	0	193,515.99	196,418.73	199,365.01	202,355.49	205,390.82	208,471.68	211,598.76	214,772.74	217,994.33
Operating Income	0	800,741.63	822,546.19	844,921.19	867,881.23	891,441.28	915,616.69	940,423.21	965,876.98	991,994.53
Financing										
Debt Balance	0	-9,190,677.29	-8,795,820.39	-8,377,272.08	-7,933,610.87	-7,463,329.98	-6,964,832.25	-6,436,424.64	-5,876,312.59	-5,282,593.81
Debt Interest Payment	0	551,440.64	527,749.22	502,636.32	476,016.65	447,799.80	417,889.93	386,185.48	352,578.76	316,955.63
Debt Repayment	0	394,856.90	418,548.31	443,661.21	470,280.88	498,497.74	528,407.60	560,112.06	593,718.78	629,341.91
Debt Total Payment	0	946,297.54	946,297.54	946,297.54	946,297.54	946,297.54	946,297.54	946,297.54	946,297.54	946,297.54
Federal ITC		5,013,096.71								
Tax Effect on Equity (State)										
State Depreciation Schedule (%)	0	20	32	19.2	11.52	11.52	5.76	0	0	0
State Depreciation	0	2,840,754.80	4,545,207.68	2,727,124.61	1,636,274.76	1,636,274.76	818,137.38	0	0	0
State Income Taxes	0	-207,316.30	-340,032.86	-190,787.18	-99,552.82	-95,410.66	-25,632.85	44,339.02	49,063.86	54,003.11
State Tax Savings	0	207,316.30	340,032.86	190,787.18	99,552.82	95,410.66	25,632.85	-44,339.02	-49,063.86	-54,003.11
Tax Effect on Equity (Federal)										
Federal Depreciation Schedule (%)	0	20	32	19.2	11.52	11.52	5.76	0	0	0
Federal Depreciation	0	2,840,754.80	4,545,207.68	2,727,124.61	1,636,274.76	1,636,274.76	818,137.38	0	0	0
Federal Income Taxes	0	-715,241.25	-1,173,113.36	-658,215.77	-343,457.21	-329,166.79	-88,433.33	152,969.61	169,270.31	186,310.74
Federal Tax Savings	0	5,728,337.96	1,173,113.36	658,215.77	343,457.21	329,166.79	88,433.33	-152,969.61	-169,270.31	-186,310.74
After Tax Cashflow	-7,519,645.06	5,790,098.35	1,389,394.87	747,626.60	364,593.72	369,721.19	83,385.34	-203,182.96	-198,754.73	-194,616.85
PreTax Debt Service Coverage Ratio	0	0.85	0.87	0.89	0.92	0.94	0.97	0.99	1.02	1.05

	10	11	12	13	14	15	16	17	18	19
Energy (kWh)	7,920,004	7,880,404	7,841,002	7,801,797	7,762,788	7,723,974	7,685,354	7,646,928	7,608,693	7,570,649
Energy Price ($/kWh)	0.157	0.161	0.166	0.171	0.176	0.182	0.187	0.193	0.198	0.204
Energy Value ($)	1,240,057.09	1,270,872.51	1,302,453.69	1,334,819.66	1,367,989.93	1,401,984.48	1,436,823.79	1,472,528.86	1,509,121.21	1,546,622.87
Operating Expenses										
Fixed O&M Annual	0	0	0	0	0	0	0	0	0	0
Fixed O&M	125,732.17	127,618.15	129,532.43	131,475.41	133,447.54	135,449.26	137,481	139,543.21	141,636.36	143,760.90
Variable O&M	0	0	0	0	0	0	0	0	0	0
Insurance	95,532.08	96,965.06	98,419.53	99,895.83	101,394.26	102,915.18	104,458.90	106,025.79	107,616.17	109,230.42
Property Assessed Value	0	0	0	0	0	0	0	0	0	0
Property Taxes	0	0	0	0	0	0	0	0	0	0
Net Salvage Value	0	0	0	0	0	0	0	0	0	0
Total Operating Expenses	221,264.25	224,583.21	227,951.96	231,371.24	234,841.81	238,364.43	241,939.90	245,569	249,252.53	252,991.32
Operating Income	1,018,792.84	1,046,289.29	1,074,501.73	1,103,448.42	1,133,148.12	1,163,620.05	1,194,883.89	1,226,959.87	1,259,868.67	1,293,631.55
Financing										
Debt Balance	-4,653,251.90	-3,986,149.47	-3,279,020.91	-2,529,464.62	-1,734,934.96	-892,733.53	0	0	0	0
Debt Interest Payment	279,195.11	239,168.97	196,741.25	151,767.88	104,096.10	53,564.01	0	0	0	0
Debt Repayment	667,102.42	707,128.57	749,556.28	794,529.66	842,201.44	892,733.53	0	0	0	0
Debt Total Payment	946,297.54	946,297.54	946,297.54	946,297.54	946,297.54	946,297.54	0	0	0	0
Federal ITC										
Tax Effect on Equity (State)										
State Depreciation Schedule (%)	0	0	0	0	0	0	0	0	0	0
State Depreciation	0	0	0	0	0	0	0	0	0	0
State Income Taxes	59,167.82	64,569.63	70,220.84	76,134.44	82,324.16	88,804.48	95,590.71	98,156.79	100,789.49	103,490.52
State Tax Savings	-59,167.82	-64,569.63	-70,220.84	-76,134.44	-82,324.16	-88,804.48	-95,590.71	-98,156.79	-100,789.49	-103,490.52
Tax Effect on Equity (Federal)										
Federal Depreciation Schedule (%)	0	0	0	0	0	0	0	0	0	0
Federal Depreciation	0	0	0	0	0	0	0	0	0	0
Federal Income Taxes	204,128.97	222,765.21	242,261.89	262,663.83	284,018.36	306,375.47	329,787.95	338,640.92	347,723.75	357,042.31
Federal Tax Savings	-204,128.97	-222,765.21	-242,261.89	-262,663.83	-284,018.36	-306,375.47	-329,787.95	-338,640.92	-347,723.75	-357,042.31
After Tax Cashflow	-190,801.49	-187,343.08	-184,278.54	-181,647.39	-179,491.93	-177,857.44	769,505.23	790,162.15	811,355.43	833,098.72
PreTax Debt Service Coverage Ratio	1.08	1.11	1.14	1.17	1.2	1.23	0	0	0	0

	20	21	22	23	24	25
Energy (kWh)	7,532,796	7,495,132	7,457,657	7,420,368	7,383,266	7,346,350
Energy Price ($/kWh)	0.21	0.217	0.223	0.23	0.237	0.244
Energy Value ($)	1,585,056.45	1,624,445.10	1,664,812.56	1,706,183.15	1,748,581.80	1,792,034.06
Operating Expenses						
Fixed O&M Annual	0	0	0	0	0	0
Fixed O&M	145,917.32	148,106.08	150,327.67	152,582.58	154,871.32	157,194.39
Variable O&M	0	0	0	0	0	0
Insurance	110,868.87	112,531.91	114,219.89	115,933.18	117,672.18	119,437.26
Property Assessed Value	0	0	0	0	0	0
Property Taxes	0	0	0	0	0	0
Net Salvage Value	0	0	0	0	0	1,671,032.24
Total Operating Expenses	256,786.19	260,637.98	264,547.55	268,515.77	272,543.50	-1,394,400.58
Operating Income	1,328,270.26	1,363,807.12	1,400,265.01	1,437,667.39	1,476,038.30	3,186,434.64
Financing						
Debt Balance	0	0	0	0	0	0
Debt Interest Payment	0	0	0	0	0	0
Debt Repayment	0	0	0	0	0	0
Debt Total Payment	0	0	0	0	0	0
Federal ITC						
Tax Effect on Equity (State)						
State Depreciation Schedule (%)	0	0	0	0	0	0
State Depreciation	0	0	0	0	0	0
State Income Taxes	106,261.62	109,104.57	112,021.20	115,013.39	118,083.06	254,914.77
State Tax Savings	-106,261.62	-109,104.57	-112,021.20	-115,013.39	-118,083.06	-254,914.77
Tax Effect on Equity (Federal)						
Federal Depreciation Schedule (%)	0	0	0	0	0	0
Federal Depreciation	0	0	0	0	0	0
Federal Income Taxes	366,602.59	376,410.76	386,473.14	396,796.20	407,386.57	879,455.96
Federal Tax Savings	-366,602.59	-376,410.76	-386,473.14	-396,796.20	-407,386.57	-879,455.96
After Tax Cashflow	855,406.04	878,291.78	901,770.66	925,857.80	950,568.67	2,052,063.91
PreTax Debt Service Coverage Ratio	0	0	0	0	0	0