Feasibility Study of Economics and Performance of Solar Photovoltaics at the Ft. Hood Military Base Outside Killeen, Texas

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

Jesse Geiger, Lars Lisell, 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-11-01836 and Task No. WFM2.1001.

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Technical Report
NREL/TP-6A10-60398
October 2013

Contract No. DE-AC36-08GO28308

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Special thanks go to Africa Welch-Castle for hosting the site visit.

Executive Summary

The U.S. Environmental Protection Agency (EPA), in accordance with the RE-Powering America's Land initiative through the Region 6 contract, selected Ft. Hood Army Base in Killeen, Texas, for a feasibility study of renewable energy production. The National Renewable Energy Laboratory (NREL) provided technical assistance for this project. The purpose of this study is to assess the site for possible photovoltaic (PV) system installations 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 does not assess environmental conditions at the site.

Ft. Hood Army Base is located just north and west of Killeen, Texas, and 70 miles north of Austin. The military base has been in operation since 1942 and is the largest active-duty armored post. Home of the III Corps, the base, capable of housing two full armored divisions, currently has 79,640 people on post with more returning from deployments. The site has many construction projects on and around the base as buildings are upgraded regularly. Any future renewable energy projects will need to fit into the existing build-out plans. The base has two operating PV systems on site: the solar carports outside of the engineering offices and a 700-kW system in a residential neighborhood just south of the main cantonment.

The suitability of a PV system before considering economic factors is dependent on 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 future development of the base impact the feasibility of a PV system. After an assessment of these factors, we concluded that Ft. Hood is suitable for deployment of a large-scale PV system.

The Ft. Hood site is approximately 159,000 acres; 52 acres of this were investigated for ground-mounted PV, with the additional potential to incorporate PV systems on top of existing and new buildings. To the north of the main cantonment (MC) is a vast open space used for military exercises and not considered for renewable energy development. There are currently 28.6 acres designated for a ground-mounted PV system on the western side of the MC and 23.7 acres available for a ground-mounted system in West Ft. Hood.

There are approximately 50 acres available for potential carport roof-mounted PV systems as well. The entire area does not need to be developed at one time, due to the feasibility of staging installation as land or funding becomes available, so calculations for this analysis reflect the solar potential of the roof-mounted PV systems at $750,000 and $1 million funding levels as well as if entire designated land areas are used for the ground-mounted systems. It should be noted that the purpose of this report is not to determine how to develop the site but to investigate options and present the results in an unbiased manner.

The economics were analyzed using the average Oncor Energy retail rate provided during the site visit of $0.0593/kWh, and all power produced was considered to offset purchased power. Four incentives were included in the economic analysis of systems installed and owned by a third-party developer (taxable entity). Table ES-1 shows the current incentives considered.

Table ES-1. Summary of Incentives Evaluated

Incentive Title	Modeled Value	Expected End
1. Solar and Wind Energy Business Franchise Tax Exemption	100% of corporate tax	N/A
2. Renewable Energy Systems Property Tax Exemption	100% of property tax	N/A
3. Oncor Electric Delivery - PV Incentive Program	Non-residential: $1.50/W DC-STC; Maximum: 100 kW	N/A
4. Federal Investment Tax Credit	30% of total investment	12/31/2015

Of the 12 scenarios considered, none had a positive net present value and 2 had a payback in the analysis period. Without other factors beyond utility savings, such as grid independence and price guarantees, PV systems would not be recommended for the site at the current utility price. Table ES-2 summarizes the system performance and economics of potential systems that were modeled at Ft. Hood. The table shows the annual energy output from each system along with the number of average American households that could be powered off such a system and corresponding estimated job creation. This includes the current cost of energy, expected installation cost, site solar resource, and existing incentives for the proposed PV system.

Table ES-2. Ft. Hood PV System Summary

System Type	PV System Size[a] (kW)	Array Tilt (deg)	Annual Output (kWh/year)	Houses Powered[b]	Jobs Created[c] (job-year)	Jobs Sustained[d] (job-year)
Carport Systems						
Carport System - <$750k	222	20	312,399	28	6.7	0.1
Carport System - <$1million	296	20	416,532	38	8.9	0.1
Carport System - Total Area	8,710	20	12,256,733	1110	261	2.6
Carport System - <$750k Microinverters	204	20	287,069	26	6.7	0.1
Carport System - Total Area w/ Microinverters	8,710	20	382,759	35	8.9	0.1
Carport System - Best Economic Case	100	20	140,720	13	2.6	0.0
MC Area						
Fixed Tilt Ground System - MC Area	4,982	20	7,010,682	635	109.7	1.5
1-Axis Ground System - MC Area	4,109	20	7,319,777	663	121.4	1.2
West Ft. Hood Area						
Fixed Tilt Ground System - West Ft. Hood Area	4,134	20	5,817,375	527	91.0	1.2
1-Axis Ground System - West Ft. Hood Areas	3,409	20	6,072,796	550	100.7	1.0
1-Axis Ground System - Best Economic Case	100	20	178,140	16	3.4	0.0
Fixed Axis - Net Zero	260,061	20	463,272,951	41963	7,680.8	76.5

System Type	System Cost	Maximum Base Incentives	PPA ¢/kWh	NPV ($)	Annual O&M ($/year)	Payback Period with Incentives (years)
Carport Systems						
Carport System - <$750k	$ 748,251	$ 374,475	11.76	$ (183,527)	$ 6,660	N/A
Carport System - <$1million	$ 997,668	$ 449,300	12.90	$ (274,099)	$ 8,880	N/A
Carport System - Total Area	$ 27,959,100	$ 8,537,730	16.22	$ (13,118,831)	$ 401,096	N/A
Carport System - <$750k Microinverters	$ 747,558	$ 374,267	12.41	$ (224,300)	$ 4,080	N/A
Carport System - Total Area w/ Microinverters	$ 30,397,900	$ 9,269,370	16.87	$ (14,359,674)	$ 326,190	N/A
Carport System - Best Economic Case	$ 337,050	$ 251,115	6.16	$ (77,900)	$ 3,000	22.6
MC Area						
Fixed Tilt Ground System - MC Area	$ 13,899,780	$ 4,319,934	14.25	$ (5,698,891)	$ 149,460	N/A
1-Axis Ground System - MC Area	$ 13,765,150	$ 4,279,545	13.24	$ (4,919,981)	$ 123,270	N/A
West Ft. Hood Area						
Fixed Tilt Ground System - West Ft. Hood Area	$ 12,110,553	$ 3,783,166	14.21	$ (4,709,342)	$ 124,020	N/A
1-Axis Ground System - West Ft. Hood Areas	$ 12,025,247	$ 3,757,574	13.20	$ (4,062,283)	$ 102,270	N/A
1-Axis Ground System - Best Economic Case	$ 351,750	$ 255,525	5.37	$ (51,344)	$ 3,000	19.0
Fixed Axis - Net Zero	$ 917,365,177	$ 275,359,553	11.92	$ -	$ 7,801,830	N/A

a *Data assume a maximum usable area of 102 acres*

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.

Table of Contents

1 Study and Site Background ... 1
2 Development of a PV System on an Army Base ... 2
3 PV Systems Technology ... 4
3.1 PV Overview ... 4
3.2 Major System Components ... 5
3.2.1 PV Module ... 5
3.2.2 Inverter ... 7
3.2.3 Balance-of-System Components ... 8
3.2.4 Operation and Maintenance ... 10
3.3 Siting Considerations ... 10
4 Proposed Installation Location Information ... 12
4.1 Ft. Hood Site PV System ... 12
4.2 Carport-Mounted PV Systems ... 12
4.3 Ground-Mounted Systems ... 13
4.4 Utility-Resource Considerations ... 17
4.5 Useable Acreage for PV System Installation ... 18
4.6 PV Site Solar Resource ... 18
4.7 Ft. Hood Energy Usage ... 20
5 Economics and Performance ... 21
5.1 Assumptions and Input Data for Analysis ... 21
5.2 SAM-Forecasted Economic Performance ... 23
5.2.1 Solar Investor Versus Developer Owned ... 25
5.2.2 Fixed Plate Versus Single-Axis Tracking ... 26
5.2.3 Possible Ways to Improve the Economics Not Modeled ... 26
5.3 Job Analysis and Impact ... 27
5.4 Financing Opportunities ... 28
5.4.1 Owner and Operator Financing ... 28
5.4.2 Third-Party Developers with Power Purchase Agreements ... 29
5.4.3 Third-Party “Flip” Agreements ... 29
5.4.4 Hybrid Financial Structures ... 30
5.4.5 Solar Services Agreement and Operating Lease ... 30
5.4.6 Sales/Leaseback ... 30
6 Conclusions and Recommendations ... 31
Appendix A. Assessment and Calculations Assumptions ... 32
Appendix B. Results of the System Advisor Model ... 35
Appendix C. Results of the Jobs and Economic Development Impact Model ... 49

List of Figures

Figure 1. Generation of electricity from a PV cell....4
Figure 2. Ground-mounted array diagram....5
Figure 3. Mono- and multi-crystalline solar panels....6
Figure 4. Thin-film solar panels installed on (left) solar energy cover and (middle/right) fixed-tilt mounting system....6
Figure 5. String inverter....8
Figure 6. Aerial view of the areas evaluated for PV carports (comprises only a small section of the space available for carports at the MC)....13
Figure 7. Aerial view of the area evaluated for ground-mounted PV on the MC at Ft. Hood....14
Figure 8. Ground view of the 28.6-acre area evaluated for ground-mounted PV on the west side of the MC....15
Figure 9. Aerial view of the two sites evaluated for ground-mounted PV at the West Ft. Hood site....16
Figure 10. Ground view of the area evaluated for ground-mounted PV at the West Ft. Hood site....16
Figure 11. Location of onsite substation near the MC area evaluated for a ground-mounted system....17
Figure 12. Location of onsite substation near the West Ft. Hood area evaluated for a ground-mounted system....18
Figure B-1. Monthly output for the $750,000 carport system....35
Figure B-2. Annual cash flow for the $750,000 carport system....36
Figure B-3. Monthly output for the $1,000,000 carport system....37
Figure B-4. Annual cash flow for the $1,000,000 carport system....38
Figure B-5. Monthly output for the total carport system....39
Figure B-6. Annual cash flow for the total carport system....40
Figure B-7. Monthly output for the fixed-tilt ground-mounted system in the MC....41
Figure B-8. Annual cash flow for the fixed-tilt ground-mounted system in the MC....42
Figure B-9. Monthly output for the single-axis tracking ground-mounted system in the MC....43
Figure B-10. Annual cash flow for the single-axis tracking ground-mounted system in the MC.44
Figure B-11. Monthly output for the fixed-tilt ground-mounted system in West Ft. Hood....45
Figure B-12. Annual cash flow for the fixed-tilt ground-mounted system in West Ft. Hood....46
Figure B-13. Monthly output for the single-axis tracking ground-mounted system in West Ft. Hood....47
Figure B-14. Annual cash flow for the single-axis tracking ground-mounted system in West Ft. Hood....48

List of Tables

Table ES-1. Summary of Incentives Evaluated v
Table ES-2. Ft. Hood PV System Summary vi
Table 1. Ground-Mounted Energy Density by Panel and System 9
Table 2. Rooftop Energy Density by Panel 9
Table 3. Site Identification Information and Specifications 19
Table 4. Performance Results for 20-Degree Fixed-Tilt PV 19
Table 5. Performance Results for 20-Degree Single-Axis PV 20
Table 6. Installed System Cost Assumptions 22
Table 7. Summary of Incentives Evaluated 23
Table 8. PV System Summary 24
Table 9. Breakeven (NPV>$0) Price Points 27
Table 10. JEDI Analysis Assumptions 28
Table A-1. Cost, System, and Other Assessment Assumptions 32
Table A-2. Modeling Assumptions 33
Table C-1. Photovoltaic Project Data Summary 16-kW Roof-Mounted System 49
Table C-2. Local Economic Impacts—Summary Results 50
Table C-3. Detailed PV Project Data Costs 51
Table C-4. PV System Annual Operations and Maintenance Costs 52

1 Study and Site Background

The U.S. Environmental Protection Agency (EPA), in accordance with the RE-Powering America's Land initiative through the Region 6 contract, selected the Ft. Hood Army base near Killeen, Texas, for a feasibility study of renewable energy production. The National Renewable Energy Laboratory (NREL) provided technical assistance for this project. The purpose of this study 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.

Ft. Hood is located northwest of Killeen, Texas, which is located 70 miles north of Austin and 160 miles southwest of Dallas. Ft. Hood has a population of 79,640 on post, with many more personnel living off base. Ft. Hood experiences summers that are warm and humid with high temperatures typically in the 100°F range. Winters are cool and cloudy with low temperatures in the 40°F range. Ft. Hood has on average 187 days of sunshine each year. Oncor Energy is the utility that provides electricity to Ft. Hood and is a deregulated utility.

The total site area at Ft. Hood is approximately 158,700 acres. The base is split into four main areas: the main cantonment (MC), West Fort Hood, North Fort Hood, and Belton Lake. The MC is where the majority of the on-base personnel resides and works and is the area targeted for PV development. Currently a small onsite demonstration of PV-covered car ports and a ground-mounted 700-kW system are being used to prove the feasibility of PV on base. There are a number of areas available for PV arrays on base; however, a few areas have been suggested for PV development by site engineers. A preferred dual-purpose development plan would be to build carports in the main parking areas for barracks and motor pools. West Fort Hood also has an area near a substation suggested for PV development. The major limiting factor for feasibility at the Ft. Hood site will not be available area but available funding for energy and energy security projects. The ability of developers who can offer PPA prices competitive with grid electrical rates will also be a consideration.

The base has three major electrical substations on site and a large number of meters around the MC. The areas adjacent to substations are ideal locations for a large PV system. A detailed interconnection study will have to be performed through local electric utility Oncor Energy to determine the feasibility of utilizing the onsite substation as a tie-in point for a PV system. The site has a large load, 465,272 MWh in 2011, some of which could be offset using PV.

Feasibility assessment team members from NREL, the Ft. Hood Directorate of Public Works Energy Management Office, and EPA conducted a site visit on Monday and Tuesday, September 17 and 18, 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 an Army Base

Ft. Hood is an active military base that is interested in increased energy savings and energy security onsite. The community of Ft. Hood is planned through the Army's master planning process. PV and other onsite generation options will need to be integrated with the site plan as funding allows. The purpose of this study is to analyze plausible options so that an informed decision can be made on how to best utilize the site.

Understanding opportunities studied and realized by other similar sites demonstrates the potential for PV system development.

Developing onsite renewable energy supplies can reduce energy cost risk and may become an increasingly important strategic opportunity. Renewable energy technologies can contribute to enhancing security of the energy supplied to the site while allowing for predictable and potentially decreased energy costs and responsiveness to energy-related federal or U.S. Department of Defense (DoD) mandates.

The Army is currently working on a pilot initiative to find pathways to have typical installations generate energy onsite equivalent to annual use. Army has partnered with NREL to assess opportunities for increasing energy security through increased energy efficiency (EE) and optimized renewable energy strategies at select installations across the Army's portfolio.

The Army's vision is to "appropriately manage our natural resources with the goal of net zero installations."[1] Although Ft. Hood is not currently generating a large portion of their energy needs, a move toward energy efficiency and onsite energy generation could position the installation to become a leader within DoD and improve their strategic capabilities.

Ft. Hood has potential renewable energy and energy security prospects beyond the solar PV systems proposed in this report. Any potential PV installation should align with the master plan and should work to enhance the overall utility of the base. Aside from PV, there is opportunity to build up biomass-based fuel production onsite and biomass power production. There are also opportunities to build on- and off-site wind turbines that could have the ability to directly power the base. Further development of these and other energy opportunities at the site could be pursued.

There are many compelling reasons to consider moving toward renewable energy sources for power generation instead of fossil fuels, including:

- Renewable energy sources offer a grid-independent energy option in the broader energy portfolio
- Deployment of renewable energy bolsters national energy independence and increases domestic energy security

[1] Office of the Assistant Secretary of the Army (Installations, Energy & Environment), "Army Vision for Net Zero," February 2010. Accessed January 2012: http://army-energy.hqda.pentagon.mil/netzero/.

- Fluctuating electric costs can be mitigated by locking in electricity rates through long-term power purchase agreements (PPAs) linked to renewable energy systems
- Renewable energy can have a net positive effect on human health and the environment.

3 PV Systems Technology

3.1 PV Overview

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

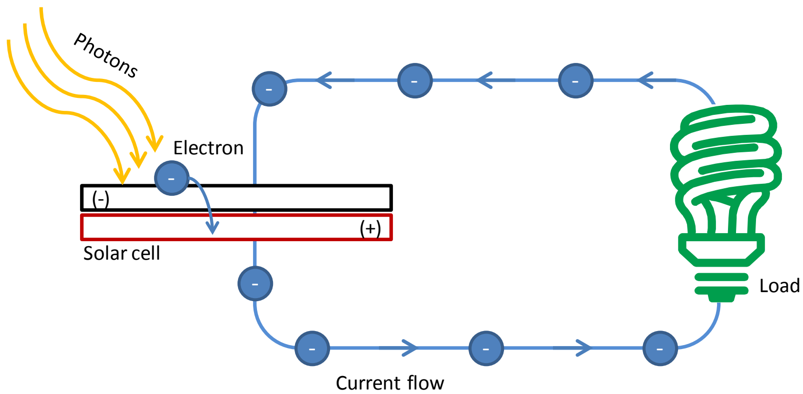

Figure 1. Generation of electricity from a PV cell

Source: EPA

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

3.2 Major System Components

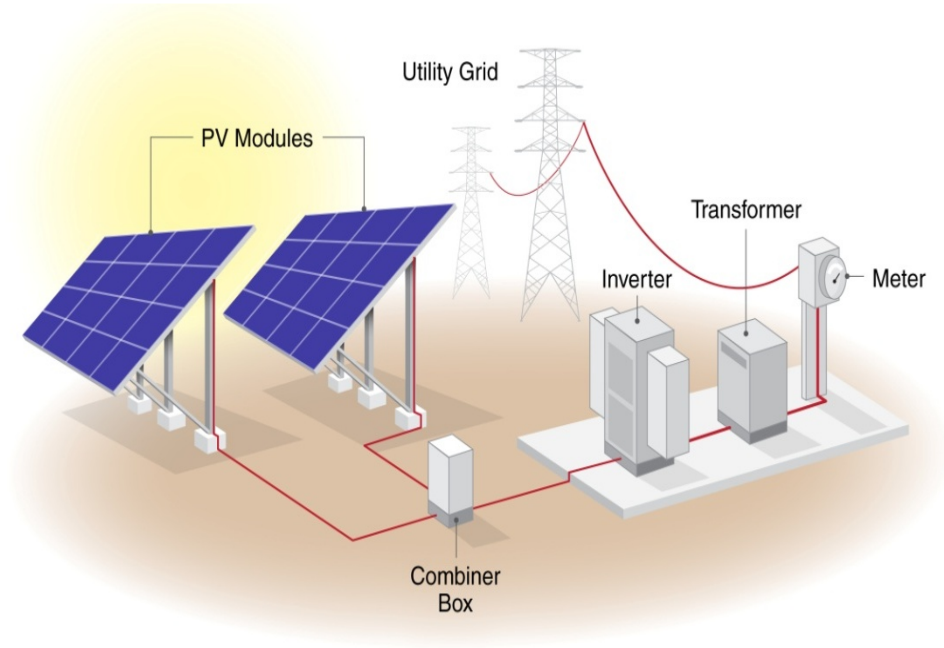

Figure 2. Ground-mounted array diagram

Source: NREL

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

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

These, along with other PV system components, are discussed in turn 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 range of 25–30 years but can keep producing energy beyond this range.

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

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

3.2.1.2 Thin Film

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

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

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

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

3.2.2 Inverter

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

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

There are two primary types of inverters for grid-connected systems: string and micro-inverters. Each type has strengths and weaknesses and 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 years. On larger units, extended warranties up to 25 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 a 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 10–25 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. Shading impacts only that shaded panel if micro-inverters are used. Figure 5 shows a string inverter.

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

3.2.3 *Balance-of-System Components*

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

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

3.2.3.1 Mounting Systems

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

3.2.3.1.1 Ground-Mounted Systems

For ground-mounted systems, the mounting system can be either directly anchored into the ground (via driven piers or concrete footers) or ballasted on the surface without ground penetration. Mounting systems must withstand local wind loads, which range from 90–120 mph 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 brownfield applications, mounting system designs will be primarily driven by these considerations coupled with settlement concerns.

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

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

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

System Type	Fixed-Tilt Energy Density (DC-Watts/ft^2)	Single-Axis Tracking Energy Density (DC-Watts/ft^2)
Crystalline Silicon	4.0	3.3

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 might 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.

3.2.3.1.2 Roof-Mounted Systems

Installing PV on rooftops has many of the same considerations as installing ground-mounted PV systems. Factors, such as available area for an array, solar resource, shading, distance to transmission lines, and distance to major roads at the site, are just as important in roof-mounted systems as in ground-mounted systems. Rooftop systems can be ballasted or fixed to the roof, and it is recommended that the roof be relatively new (less than 5 years old) to avoid having to move the PV system in order to repair or replace the roof.

The development plan for roof-mounted PV systems at Ft. Hood is to include PV on any newly constructed car ports. There are many relatively easy low-cost/no-cost measures that can be taken during the design phase so that the carports are optimally built for rooftop PV systems. Design strategies such as orienting the buildings so that the southern exposure is maximized and reducing the amount of mechanical equipment on the roof are examples of measures that can be taken to optimize rooftop PV systems. A solar-ready design guide was published in order to help design teams optimize rooftop PV systems when designing buildings.[2]

Table 2. Rooftop Energy Density by Panel

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

[2] Lisell, L.; Tetreault, T.; Watson, A. *Solar Ready Buildings Planning Guide*, December 2009. Accessed October 2012: http://www.nrel.gov/docs/fy10osti/46078.pdf.

3.2.3.2 Wiring for Electrical Connections

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

In most traditional applications, wiring from (1) the arrays to inverters and (2) inverters to point of interconnection is generally run as direct burial through trenches. In brownfield applications, this wiring might 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 can also use this data to identify required maintenance, shade on panels, and accumulating dirt on panels, for example. Monitoring system data can also be used for outreach and education. This can be achieved with publicly available, online displays; wall-mounted systems; or even smart phone applications.

3.2.4 Operation and Maintenance

PV panels typically have a 25-year performance warranty. String inverters, which come standard with a 10-year warranty (extended warranties are available), would be expected to last 10–15 years. Micro-inverters are known to have warranties as long as 25 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, which is based on the historical O&M costs of installed fixed-axis grid-tied PV systems. In addition, the system should expect a replacement of system inverters in year 15 at a cost of $0.25/W.

3.3 Siting Considerations

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

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

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

4 Proposed Installation Location Information

This section summarizes the findings of the NREL solar assessment site visit on September 17–18, 2012.

4.1 Ft. Hood Site PV System

In order to get the most from ground area available, it is important to consider whether the site 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 Ft. Hood site is approximately 158,706 acres, and much of the site that could house a PV installation is already designated for use and future buildout. The vast majority of the base is used for field training and is not an acceptable building site for PV arrays. Due to the lack of electrical infrastructure outside of the cantonment, any PV arrays will be built in and near the cantonments. The cantonments could incorporate a large number of small and medium-sized ground-mounted and roof systems, with only a few spaces available to large systems.

The PV systems would be built through dual-use applications, such as roof-mounted PV systems on top of carports for the motor pools and barracks parking. The potential carport option would serve as shaded cover for personal vehicles while producing power near the barracks loads without sacrificing unused land. Another reason this option is preferred is because the systems could be built out in small sections as funding becomes available.

The areas that could be used for large ground-mounted PV arrays consist of gently sloping hills, which is good for packing systems together. The ground-mounted systems will cost less per installed capacity than the carport systems, and there is the potential for larger system sizes in ground systems.

4.2 Carport-Mounted PV Systems

Figure 6 shows an aerial view of some of the potential areas for PV carports at Ft. Hood taken from Google Earth; the feasible area for the carports is shaded in red. Each of the parking lots between Old Ironsides Avenue and Hell on Wheels Avenue were measured to have adequate solar access. None of the surrounding buildings or trees will result in significant shading for a raised PV system.

Figure 6. Aerial view of the areas evaluated for PV carports (comprises only a small section of the space available for carports at the MC)

Illustration done in Google Earth

4.3 Ground-Mounted Systems

Three areas on the MC were also evaluated for ground-mounted PV systems—a 28.6-acre site, a 17.6-acre site, and a 6.13-acre site. Figure 7 shows an aerial view of the 28.6-acre site taken from Google Earth. The site is near the substation on the west side of the MC and just south of Tank Destroyer Boulevard. The hill is south-facing on a gentle slope, as seen in Figure 8.

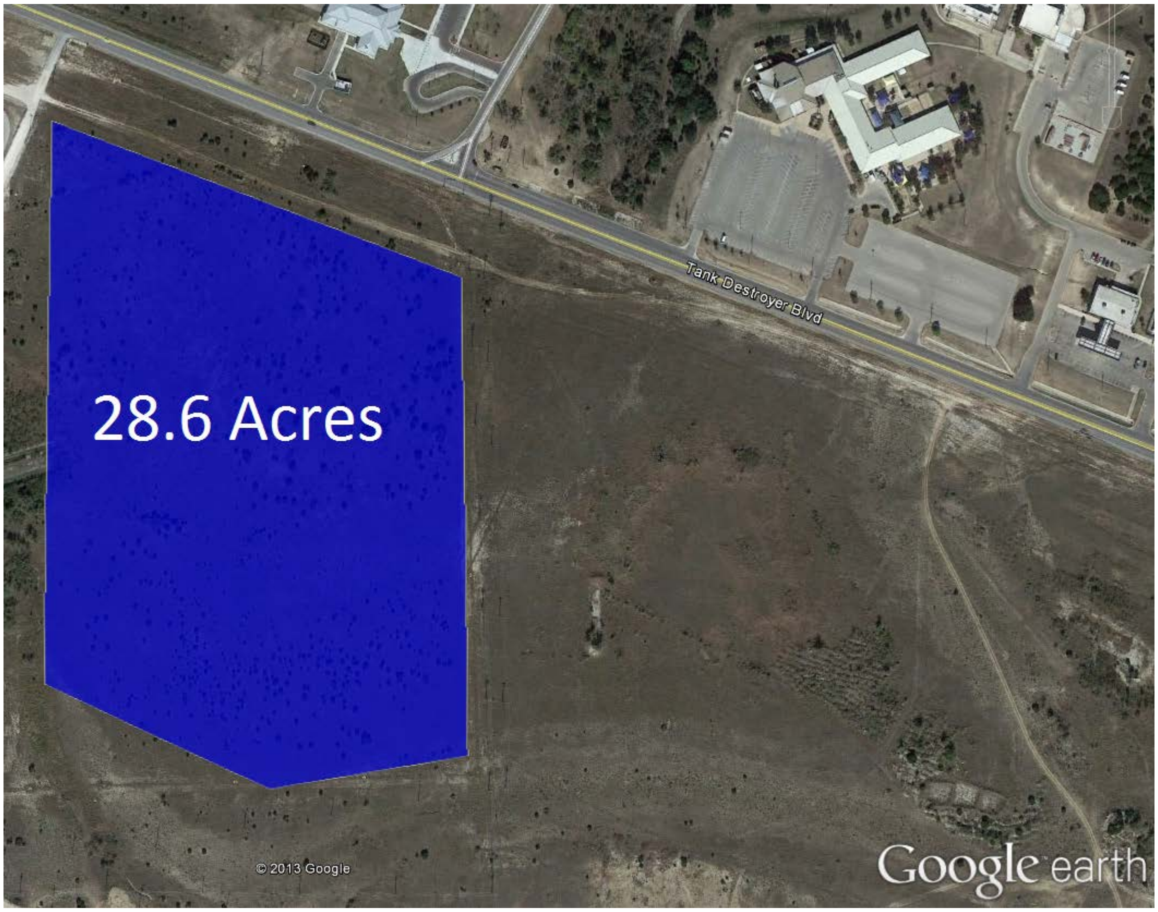

Figure 7. Aerial view of the area evaluated for ground-mounted PV on the MC at Ft. Hood

Illustration done in Google Earth

Figure 8. Ground view of the 28.6-acre area evaluated for ground-mounted PV on the west side of the MC

Photo by Jesse Geiger, NREL

Figures 9 and 10 show the final suggested ground-mounted PV sites southwest of the MC in West Ft. Hood. The system is near the West Ft. Hood substation on a hill that faces east. This area will require more landscape work than the area mentioned above.

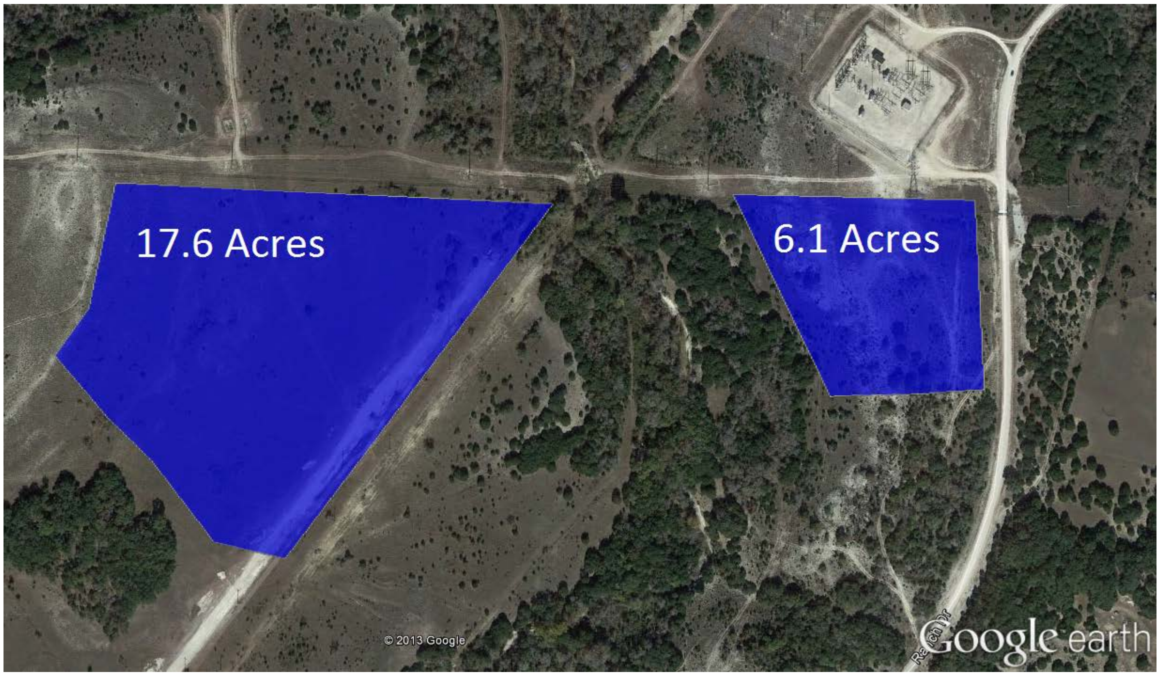

Figure 9. Aerial view of the two sites evaluated for ground-mounted PV at the West Ft. Hood site

Illustration done in Google Earth

Figure 10. Ground view of the area evaluated for ground-mounted PV at the West Ft. Hood site. ***Photo by Jesse Geiger, NREL***

4.4 Utility-Resource Considerations

The carport rooftop systems should be sized to interconnect with the nearby barracks and motor pool meters. The carports should not require a major electrical tie-in, but confirmation from Oncor will be needed. The ground-mounted systems will require connections to substations onsite. The substations are located next to each ground-mounted system. The locations of the two substations (in relation to the ground-mounted systems) are shown in Figure 11 and Figure 12. A detailed interconnection study will have to be performed through Oncor and Reliant Energy to determine the feasibility of utilizing the onsite substations as tie-in points for PV systems. The base has plans to expand the current number of buildings, but current onsite electric customers will be able to use the electricity produced by a PV system.

Figure 11. Location of onsite substation near the MC area evaluated for a ground-mounted system

Illustration done in Google Earth

Figure 12. Location of onsite substation near the West Ft. Hood area evaluated for a ground-mounted system

Illustration done in Google Earth

4.5 Useable Acreage for PV System Installation

Typically, a minimum of 2 useable acres is recommended to site commercial-scale 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/or unused paved areas (e.g., a parking lot or industrial site space and existing building rooftops).

4.6 PV Site Solar Resource

The Ft. Hood site has been evaluated to determine the adequacy of the solar resource available using both onsite data and industry tools.

The assessment team for this feasibility study collected multiple Solmetric SunEye data and found a solar access of 90% or higher. All data gathered using this tool is available in Appendix C.

The predicted array performance was found using PVWatts Version 2 for Killeen, Texas.[3] Table 3 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 below. It is scaled linearly to match the proposed system size.

[3] National Renewable Energy Laboratory. "PVWatts." Accessed October 17, 2013: http://www.nrel.gov/rredc/pvwatts/.

Table 3. Site Identification Information and Specifications

Station Identification	
Cell ID	0213391
State	Texas
Latitude	31.0° N
Longitude	97.9° 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	20°
Array Azimuth	180°
Energy Specifications	
Cost of Electricity	$0.06/kWh

Table 4 shows the performance results for a 20-degree fixed-tilt PV system in Killeen, Texas, as calculated by PVWatts.

Table 4. Performance Results for 20-Degree Fixed-Tilt PV

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)
1	3.90	94
2	4.45	95
3	5.37	125
4	5.99	131
5	5.93	131
6	6.24	132
7	6.50	139
8	6.43	138
9	5.66	121
10	5.25	118
11	4.21	94
12	3.72	88
Year	5.31	1,408

Table 5 shows the performance results for a 20-degree single-axis tracking PV system in Killeen, Texas, as calculated by PVWatts.

Table 5. Performance Results for 20-Degree Single-Axis PV

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)
1	4.74	116
2	5.44	117
3	6.71	158
4	7.40	163
5	7.33	164
6	7.93	171
7	8.36	183
8	8.18	178
9	7.17	155
10	6.67	152
11	5.14	117
12	4.52	109
Year	6.64	1,782

4.7 Ft. Hood Energy Usage

The Ft. Hood site currently has buildings on the site that use electricity. There are future plans to build a significant number of buildings on the site. 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. The onsite electrical provider is Oncor Energy, and the power producer is Reliant Energy. The average onsite electrical utility cost is currently $0.0593/kWh annually. The contract with the power provider is up for renewal this coming year and will be constant for 2013–2014.

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). [4]

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

The 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 in 2011, the average cost for utility-scale ground-mounted systems have declined from \$4.80/W in the first quarter of 2010 to \$2.79/W in the first quarter of 2012. With an increasing demand and supply, potential of further cost reduction is expected as market conditions evolve. The installed system cost assumptions are summarized in Table 6. For this analysis, the installed cost of the baseline fixed-tilt ground-mounted systems was assumed to be \$2.79/W, and the installed cost of single-axis tracking was assumed to be \$3.34/W. For the carport systems a system cost addition will be required. This will add 15% to the baseline scenario for this scenario, by conservative estimate. Micro-inverters will also be evaluated for the carport scenarios to decrease ground space required. This will increase the installed cost by 10% but decrease the O&M costs for this scenario. The carport systems will only be able to use fixed-axis mounting.

[4] For additional information on SAM, see https://sam.nrel.gov/cost.

Table 6. Installed System Cost Assumptions

System Type	Fixed Tilt ($/Wp)	Single-Axis Tracking ($/Wp)
Ground-Mounted System	2.79	3.34
+ Carports (15%)	+0.42	N/A
+ Micro-Inverters (10%)	+0.28	N/A
Full Carport Installation (PV Only)	3.49	N/A

These prices include the PV array and the BOS components for each system, including the inverter and electrical equipment, as well as the installation cost. 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 and state incentives are received for taxable entities. 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 30% 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. 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 25-year life, although the systems can be reasonably expected to continue operation past this point. A full list of standard assumptions can be found in Appendix A-2. For the purposes of modeling how much PV could cover carports, it was assumed that coverage could be 4 W/ft^2. PVWatts Version 2 was used to calculate expected energy performance for the system.

Incentives were investigated for the Ft. Hood site using the DSIRE website, which summarizes renewable energy incentives at the state level.[5] Four incentives were found that should apply to the Ft. Hood site if PV development on base were done through third-party developers. The list of incentives used in this study can be found in Table 7. Any incentives that were not immediately and obviously applicable to the Ft. Hood site were not considered in the analysis.

[5] DSIRE: Database of State Incentives for Renewables & Efficiency, http://www.dsireusa.org/.

Table 7. Summary of Incentives Evaluated

Incentive Title	Modeled Value	Expected End
1. Solar and Wind Energy Business Franchise Tax Exemption	100% of corporate tax	N/A
2. Renewable Energy Systems Property Tax Exemption	100% of property tax	N/A
3. Oncor Electric Delivery - Solar Photovoltaic Standard Offer Program	$0.539/W DC-STC and $0.41/kWh AC; Maximum: 20% of total budget	Annually funded: 2013: $4.43 million
4. Federal Investment Tax Credit	30% of total investment	Through 2015

5.2 SAM-Forecasted Economic Performance

Using varied inputs and the assumptions summarized in Section 5.1, SAM predicts net present value (NPV), PPA, and levelized cost of energy (LCOE). Because of the unique funding options, scenarios were run to determine: the system size at different price points; carport space and ground space utilization; fixed and single-axis tracking for the ground portion; and third-party developer versus Ft. Hood ownership. There are multiple factors that go into choosing which scenario(s) beyond NPV, PPA, and LCOE including funding and multi-purpose structure. The following systems were evaluated:

1. Carport systems
   A. A system under $750,000 installed cost
   B. A system under $1 million installed cost
   C. Total proposed carport-PV area
   D. A system under $750,000 installed cost with micro-inverters
   E. Total proposed carport-PV area with micro-inverters
   F. Best payback case for carport systems (100 kW)
2. MC ground-mounted system (28.6 acres)
   A. Fixed-tilt PV covering the entire area
   B. Single-axis PV covering the entire area
3. West Ft. Hood ground-mounted system (17.6 + 6.1 acres)
   A. Fixed-tilt PV covering the entire area
   B. Single-axis PV covering the entire area
   C. Best economic case for ground-mounted systems
4. A theoretical model to determine size and cost of using PV to turn Ft. Hood into a net-zero installation.

Table 8 shows the SAM results from these scenarios.

Table 8. PV System Summary

System Type	PV System Size[a] (kW)	Array Tilt (deg)	Annual Output (kWh/year)	Houses Powered[b]	Jobs Created[c] (job-year)	Jobs Sustained[d] (job-year)
Carport Systems						
Carport System - <$750k	222	20	312,399	28	6.7	0.1
Carport System - <$1million	296	20	416,532	38	8.9	0.1
Carport System - Total Area	8,710	20	12,256,733	1110	261	2.6
Carport System - <$750k Microinverters	204	20	287,069	26	6.7	0.1
Carport System - Total Area w/ Microinverters	8,710	20	382,759	35	8.9	0.1
Carport System - Best Economic Case	100	20	140,720	13	2.6	0.0
MC Area						
Fixed Tilt Ground System - MC Area	4,982	20	7,010,682	635	109.7	1.5
1-Axis Ground System - MC Area	4,109	20	7,319,777	663	121.4	1.2
West Ft. Hood Area						
Fixed Tilt Ground System - West Ft. Hood Area	4,134	20	5,817,375	527	91.0	1.2
1-Axis Ground System - West Ft. Hood Areas	3,409	20	6,072,796	550	100.7	1.0
1-Axis Ground System - Best Economic Case	100	20	178,140	16	3.4	0.0
Fixed Axis - Net Zero	260,061	20	463,272,951	41963	7,680.8	76.5

System Type	System Cost	Maximum Base Incentives	PPA ¢/kWh	NPV ($)	Annual O&M ($/year)	Payback Period with Incentives (years)
Carport Systems						
Carport System - <$750k	$ 748,251	$ 374,475	11.76	$ (183,527)	$ 6,660	N/A
Carport System - <$1million	$ 997,668	$ 449,300	12.90	$ (274,099)	$ 8,880	N/A
Carport System - Total Area	$ 27,959,100	$ 8,537,730	16.22	$ (13,118,831)	$ 401,096	N/A
Carport System - <$750k Microinverters	$ 747,558	$ 374,267	12.41	$ (224,300)	$ 4,080	N/A
Carport System - Total Area w/ Microinverters	$ 30,397,900	$ 9,269,370	16.87	$ (14,359,674)	$ 326,190	N/A
Carport System - Best Economic Case	$ 337,050	$ 251,115	6.16	$ (77,900)	$ 3,000	22.6
MC Area						
Fixed Tilt Ground System - MC Area	$ 13,899,780	$ 4,319,934	14.25	$ (5,698,891)	$ 149,460	N/A
1-Axis Ground System - MC Area	$ 13,765,150	$ 4,279,545	13.24	$ (4,919,981)	$ 123,270	N/A
West Ft. Hood Area						
Fixed Tilt Ground System - West Ft. Hood Area	$ 12,110,553	$ 3,783,166	14.21	$ (4,709,342)	$ 124,020	N/A
1-Axis Ground System - West Ft. Hood Areas	$ 12,025,247	$ 3,757,574	13.20	$ (4,062,283)	$ 102,270	N/A
1-Axis Ground System - Best Economic Case	$ 351,750	$ 255,525	5.37	$ (51,344)	$ 3,000	19.0
Fixed Axis - Net Zero	$ 917,365,177	$ 275,359,553	11.92	$ -	$ 7,801,830	N/A

a *Data assume a maximum usable area of 102 acres*

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.

A net-zero scenario was done to determine the maximum appropriate PV installation onsite and not as a currently feasible scale project. Ft. Hood would need to build 260,061 kW in solar capacity to become a net-zero facility if electricity usage were to remain constant from 2011. This capacity should be seen as a ceiling for onsite renewable energy production, and when coupled with extensive energy storage systems, could maintain continuous operations on Ft. Hood during an extended outage of grid power.

Only the 100-kW single-axis tracking system, which maximizes the potential Oncor Energy incentive, has a PPA price below the current utility cost for energy. The site has suitable solar resource, but combined with few incentives, prices for larger-scale solar energy onsite are higher than that for grid electricity. The prices may be overcome with changing utility prices, energy security price add-ons, and decreases to PV installation cost. All of the different options investigated have pros and cons that will play in deciding the path forward.

5.2.1 Solar Investor Versus Developer Owned

Using a solar investor to develop a PC system is a more attractive option for Ft. Hood from an economic perspective. The choice between going with a solar investor or developer ownership will depend on the desire for equipment ownership by Ft. Hood and the Army or ownership by a third party. A solar investor would build and finance the project and inherit the risk and profit, and Ft. Hood in turn would receive power from the PV system at a rate agreed upon by the site and the investor. The major benefits for a solar investor are the potential tax incentives and the ability of the developer to finance the project, requiring no upfront capital from the site. As a non-taxable entity, Ft. Hood will not be able to take advantage of the many different tax benefits that will drive down costs for the PV systems without a private developer partner. The primary benefit to ownership of the system to Ft. Hood will be full control over the systems; however, contracts can be structured with the solar investor to ensure power delivery to the base for energy security purposes. For these reasons, it is the suggestion of the feasibility team to pursue a solar investor.

For the remainder of the analysis, options will be presented from the perspective that a solar investor with a tax incentive appetite will own and operate the PV systems.

Federal Prison Industries (FPI) UNICOR provides services, including solar PV development activities. Due to the nature of the work force and established process in which UNICOR can develop projects, UNICOR can oftentimes offer a lower PPA price than other developers. The federal government in general and Ft. Hood specifically may benefit from the overall increased efficiency of federal government operations.

The reasons that FPI increases the overall efficiency for installing renewable energy systems are:

- FPI has the proper contracting authority for contracting for these systems.
- FPI is staffed and resourced to provide turnkey renewable energy systems as it is consistent with FPI mission in general and with its renewable energy device manufacturing in particular because this directly enhances FPI's ability to train and educate inmates.
- FPI has established a Multiple Award Contract with 20 renewable energy integrators.
- FPI has teaming agreements with many of the large U.S. Department of Energy (DOE) energy services companies/integrators as well as with small businesses and service disabled veterans to provide integration services.
- FPI has the expertise in the renewable energy field to ensure the requesting agency is getting a best value system.
- FPI has established sources of third-party financing for these projects.

5.2.2 Fixed Plate Versus Single-Axis Tracking

For the carport systems, the system must be fixed tilt. For the ground-mounted simulations, the single-axis tracking modules are the preferred option because they will produce more energy and have a lower PPA. The single-axis tracking system will produce over 20% more energy than a fixed-axis system of the same capacity. When space is a limiting factor, single-axis tracking is often the more attractive option. Fluctuations in prices at the local level can switch the favorability of the system type. For the 2.5-MW system on the west side of the MC, the installed price of single-axis tracking modules would need to increase to $0.0362/kW for a fixed-axis system to have more favorable economics.

5.2.3 Possible Ways to Improve the Economics Not Modeled

The economics for a PV system at Ft. Hood could be feasible under lower installed prices, slightly higher value for electricity produced onsite, or more incentives. One incentive that could allow for lower prices from a solar investor would be an exemption from sales taxes for solar equipment. This would reduce PPA prices for all PV systems by approximately $0.05/kWh. The price for energy security should also be considered for determining PV system feasibility. The ability to accept a higher price for secure onsite electricity than what Oncor is charging for energy will improve the chances for such a project to move forward. Also, the upcoming contract renewal with Oncor Energy could be an opportunity to negotiate onsite renewable energy systems, secure further incentives for PV, and improve the utility cooperation for projects on base.

Sensitivity studies were done for the modeled systems to each scenario to determine when a system would be economically viable. Table 9 shows the panel installed cost and the utility price points that would make each scenario become economically feasible with Ft. Hood ownership. Each variable was varied independently. The price point for a panel installed cost is similar to the price for a third-party developer to offer a PPA price at the $0.0593/kWh current utility price.

Table 9. Breakeven (NPV>$0) Price Points

Case	Installed Cost [$/W]	Utility Price [$/kWh]
Carport System - <$750,000	1.94	0.102
Carport System - <$1 million	1.78	0.107
Carport System - Total area	1.54	0.113
Carport System - <$750,000 w/ micro-inverters	2.19	0.101
Carport System - Total area w/ micro-inverters	2.03	0.107
Fixed-Tilt Ground System – MC area	1.44	0.103
Single-Axis Ground System - MC area	1.94	0.96
Fixed-Tilt Ground System – West Ft. Hood area	1.44	0.103
Single-Axis Ground System – West Ft. Hood area	1.94	0.95

The results graphs and summary of inputs to SAM is available in Appendix B.

5.3 Job Analysis and Impact

To evaluate the impact on employment and economic impacts of the PV project associated with this analysis, the NREL Jobs and Economic Development Impact (JEDI) models are used.[6] JEDI estimates 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.

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

For this analysis, inputs, including the estimated installed project cost ($/kW), targeted year of construction, system capacity (kW), O&M costs ($/kW), and location, were entered into the

[6] JEDI has been used by DOE, the U.S. Department of Agriculture, NREL, and the Lawrence Berkeley National Laboratory, as well as a number of universities. For information on JEDI, see http://www.nrel.gov/analysis/jedi/about_jedi.html.

model to predict the jobs and economic impact. It is important to note that JEDI does not predict or incorporate any displacement of related economic activity or alternative jobs due to the implementation of the proposed project. As such, the JEDI results are considered gross estimates as opposed to net estimates.

For the Ft. Hood site, the values in Table 10 were assumed from a $750,000 limited project.

Table 10. JEDI Analysis Assumptions

Input	Assumed Value
Capacity	204 kW
Placed In Service Year	2013
Installed System Cost	$734,316
Location	Ft. Hood, TX

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

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

As indicated in the results of the JEDI analysis provided in Appendix D, the total proposed system is estimated to support 6.9 direct and indirect jobs per year for the duration of the procurement and construction period. Total wages paid to workers during the construction period are estimated to be $327,200, and total economic output is estimated to be $889,000. The annual O&M of the new PV system is estimated to support 0.1 FTE per year for the life of the system. The jobs and associated spending are projected to account for approximately $3,300 in earnings and $6,100 in economic activity each year for the next 25 years.

5.4 Financing Opportunities

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

5.4.1 Owner and Operator Financing

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

For public entities that choose to finance, own, and operate a solar project, funding can be raised as part of a larger, general obligation bond; as a standalone tax credit bond; through a tax-exempt lease structure, bank financing, grant and incentive 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

Because 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, higher lease payment) while not directly receiving them. The term of a PPA typically varies from 20–25 years.

5.4.3 Third-Party "Flip" Agreements

The most common use of this model is a site host working with a third-party developer who then partners with a tax-motivated investor in an 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 each investor's return is met.

5.4.4 Hybrid Financial Structures

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

5.4.5 Solar Services Agreement and Operating Lease

The solar services agreement (SSA) and operating lease business models have been predominately used in the municipal and cooperative utility markets due to the 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 work-around to this issue. One model is the SSA, wherein a private party sells solar services [i.e., energy and renewable energy certificates (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 can purchase the services in annual installments. The municipality can buyout 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 sales/leaseback. Under the sales/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 Sales/Leaseback

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

6 Conclusions and Recommendations

Under current utility and PV cost conditions studied, the inclusion of PV is not attractive solely for cost savings; however, deciding whether or not to pursue solar power should also include energy security, prices, and the duel benefit of solar and carport construction. There is also an opportunity to lower costs through an agreement with UNICOR as described in Section 5.2. As summarized in Section 5, the current PPA prices that could be attained from solar investors at a 15% internal rate of return would be near $0.1176/kWh. Because Ft. Hood may be able to obtain better costs and PPA prices than what is found in this study, it is suggested that this report be used as a starting point for acquiring and comparing quotes from vendors. Table 10 lists some cost conditions that would make solar energy an economically attractive option.

The option with the highest likelihood to succeed identified in this study would be to incrementally build carport systems at the various funding limits allowed. Multiple factors make this the best option: many different small systems can maximize the capacity-based credit offered by Oncor; the multipurpose carports have a better chance to overcome poor economics; and the PV systems would be able to tie into meters already in place at the barracks. Considering all of these factors, the carports are the closest to becoming viable projects.

Appendix A. Assessment and Calculations Assumptions

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

Cost Assumptions			
Variable	**Quantity of Variable**	**Unit of Variable**	
Cost of Site Electricity	0.0593	$/kWh	
Annual O&M (fixed)	20	$/kW/year	
Inverter Replacement	10 for 15 years	$/kW/year	
System Assumptions			
System Type	**Annual energy kWh/kW**	**Installed Cost ($/W)**	**Energy Density (W/sq. ft.)**
Ground Fixed	1,408	$2.79	4.0
Ground Single-Axis	1,782	$3.35	3.3
Carport-Mounted PV Systems	1,408	$3.21	4.0
Carport-Mounted PV With Micro-Inverters	1,408	$3.49	4.0
Other Assumptions			
	1 acre	43,560 ft^2	
	1 MW	1,000,000 W	
	Ground utilization	90% of available area	

Table A-2. Modeling Assumptions

Item	PPA/Investor	Municipal Purchase	Notes
Analysis period (years)	25	25	
Inflation	2.50%	2.50%	
Real discount rate	5.85%	3%	
Federal tax rate	35%	0%	
State tax rate	8%	0%	
Insurance (% of installed cost)	0.50%	0.50%	
Property tax	0	0	
Construction loan	0	0	
Loan term	15	25	25-year bonds
Loan rate	6%	6%	May be lower for bonds
Debt fraction	55%	100%	45%-60% PPA, 100% municipal ownership, DSCR of ~1.3 (>1.2)
Minimum IRR	15.00%	15.00%	
PPA escalation rate	1.50%	1.50%	
Federal depreciation	5-year MACRS w/ 50% 1st-year bonus	N/A	N/A for municipal ownership
State depreciation	5-year MACRS	N/A	N/A for municipal ownership
Federal ITC	30%	N/A	N/A for municipal ownership
Payment incentives	0	0	
Degradation	0.50%	0.50%	
Availability	100%	100%	
Cost - fixed axis per KW	\$2.79 - \$3.20	\$2.79 - \$3.20	
Cost - single-axis tracking per kW	\$3.35 - \$3.84	\$3.35 - \$3.84	
Cost - landfill ballasted per kW	\$3.49 - \$4.00	\$3.49 - \$4.00	
Grid interconnection cost	\$ -	\$ -	
Land cost	\$ -	\$ -	

O&M	$30/kW/yr first 15 yrs & $20 yrs 16-25	$30/kW/yr first 15 yrs & $20 yrs 16-26	
Derate factor	0.8	0.8	
Fixed tilt	20°	20°	
Single-axis tilt	0°	0°	
Acres per MW fixed	5.74	5.74	
Acres per MW tracking	6.96	6.96	

Appendix B. Results of the System Advisor Model

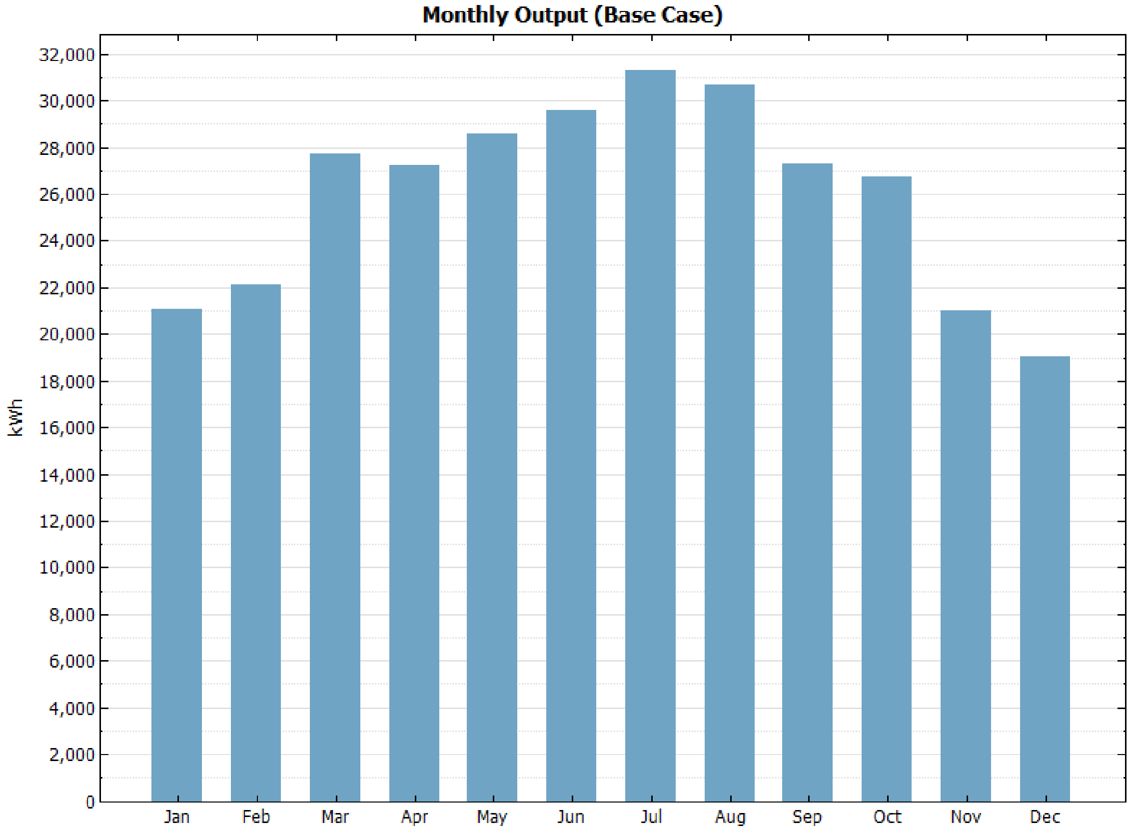

Figure B-1. Monthly output for the $750,000 carport system

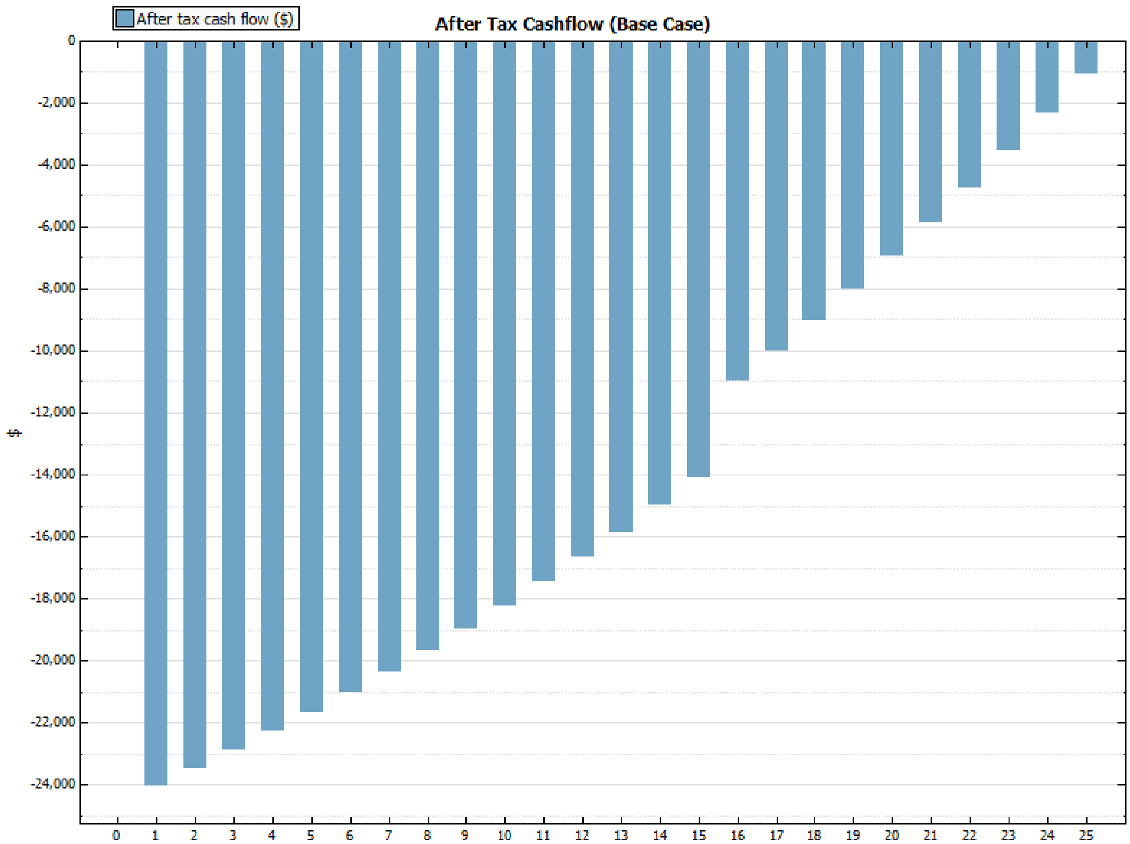

Figure B-2. Annual cash flow for the $750,000 carport system

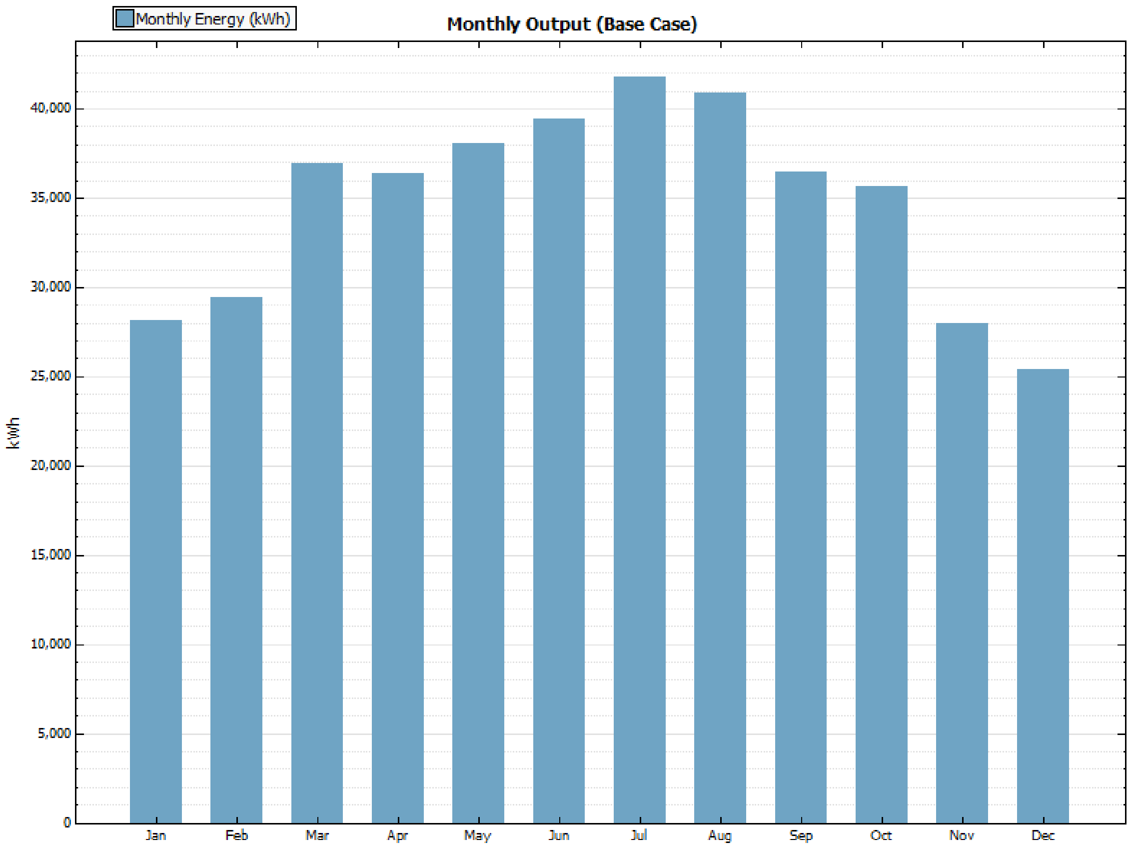

Figure B-3. Monthly output for the $1,000,000 carport system

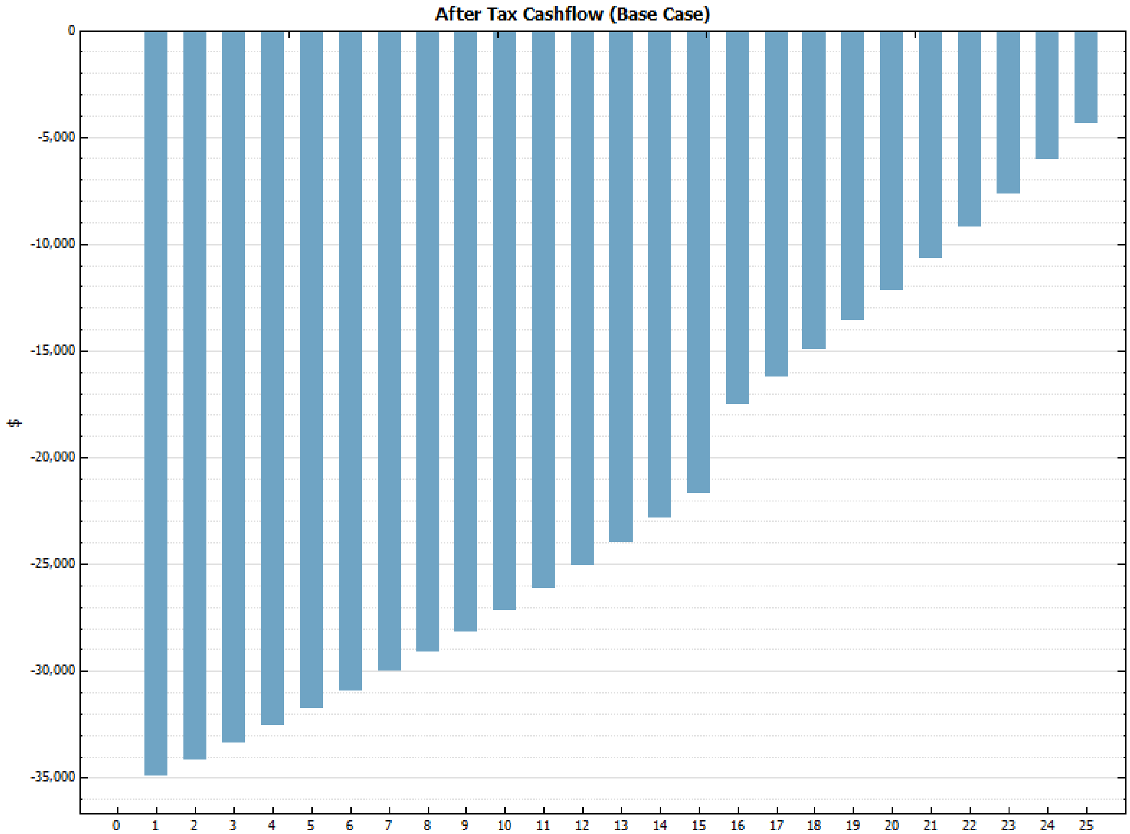

Figure B-4. Annual cash flow for the $1,000,000 carport system

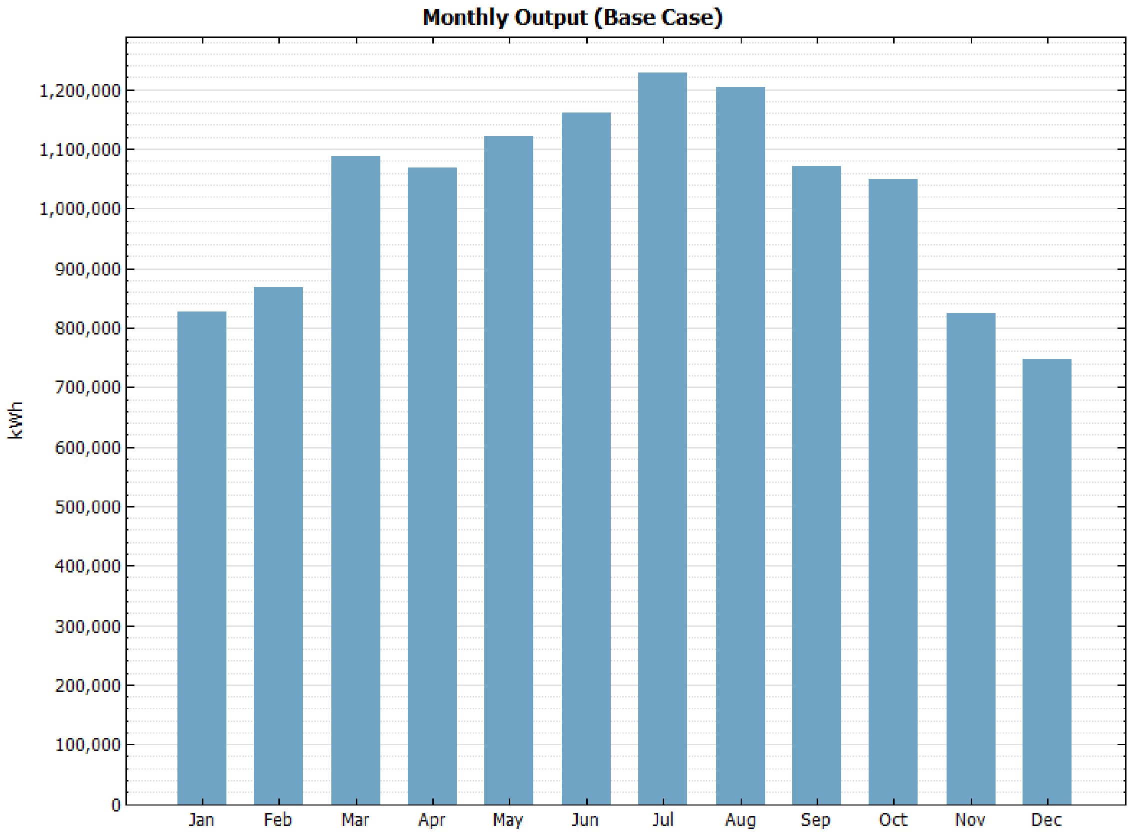

Figure B-5. Monthly output for the total carport system

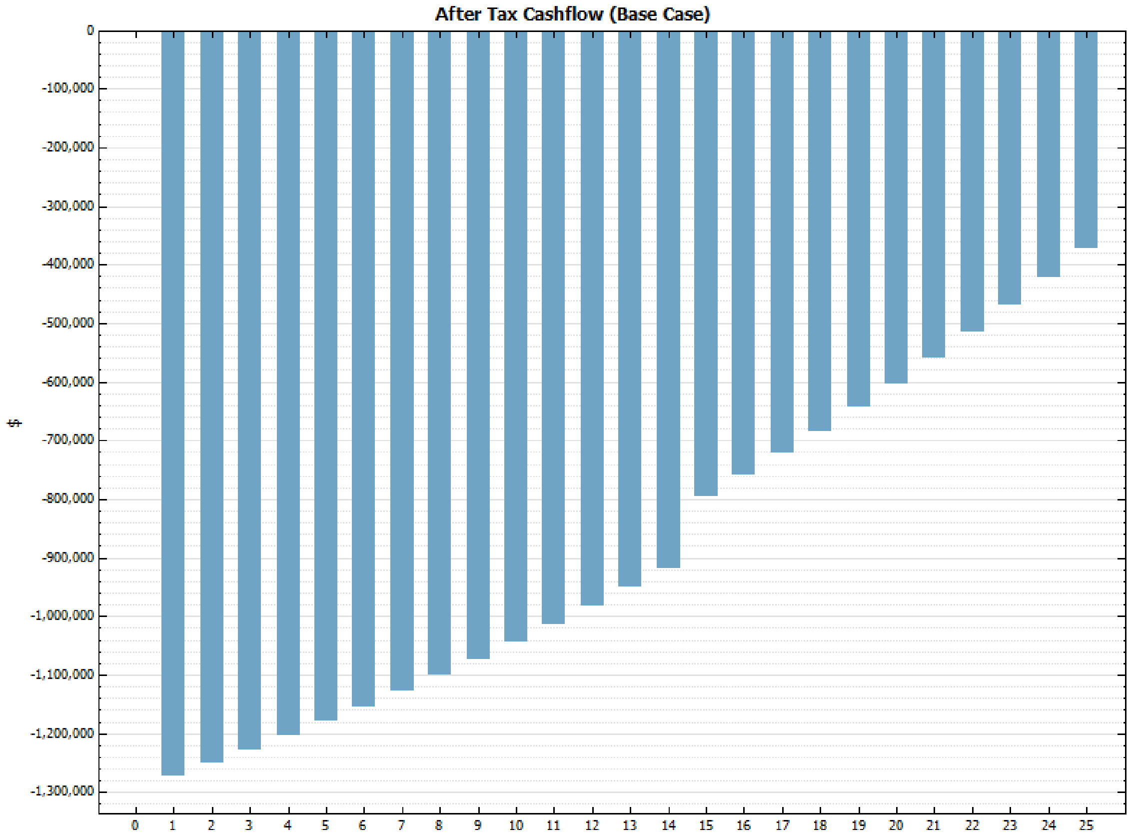

Figure B-6. Annual cash flow for the total carport system

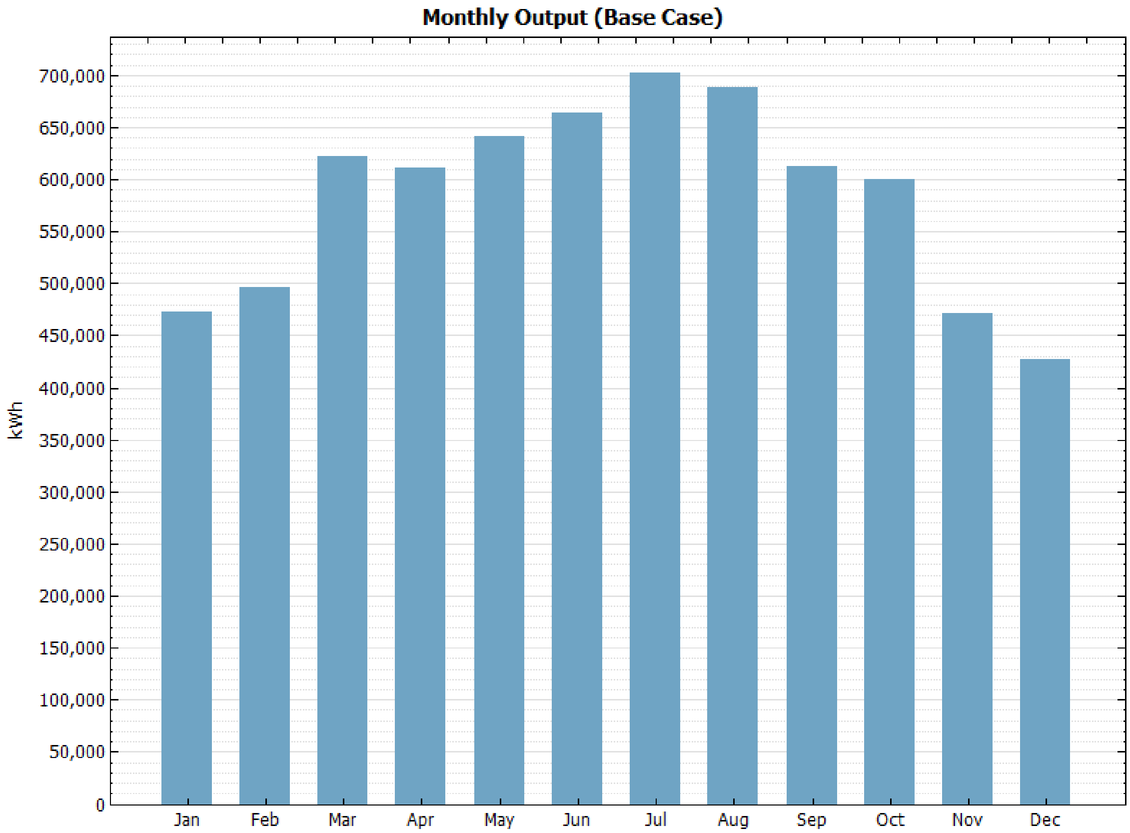

Figure B-7. Monthly output for the fixed-tilt ground-mounted system in the MC

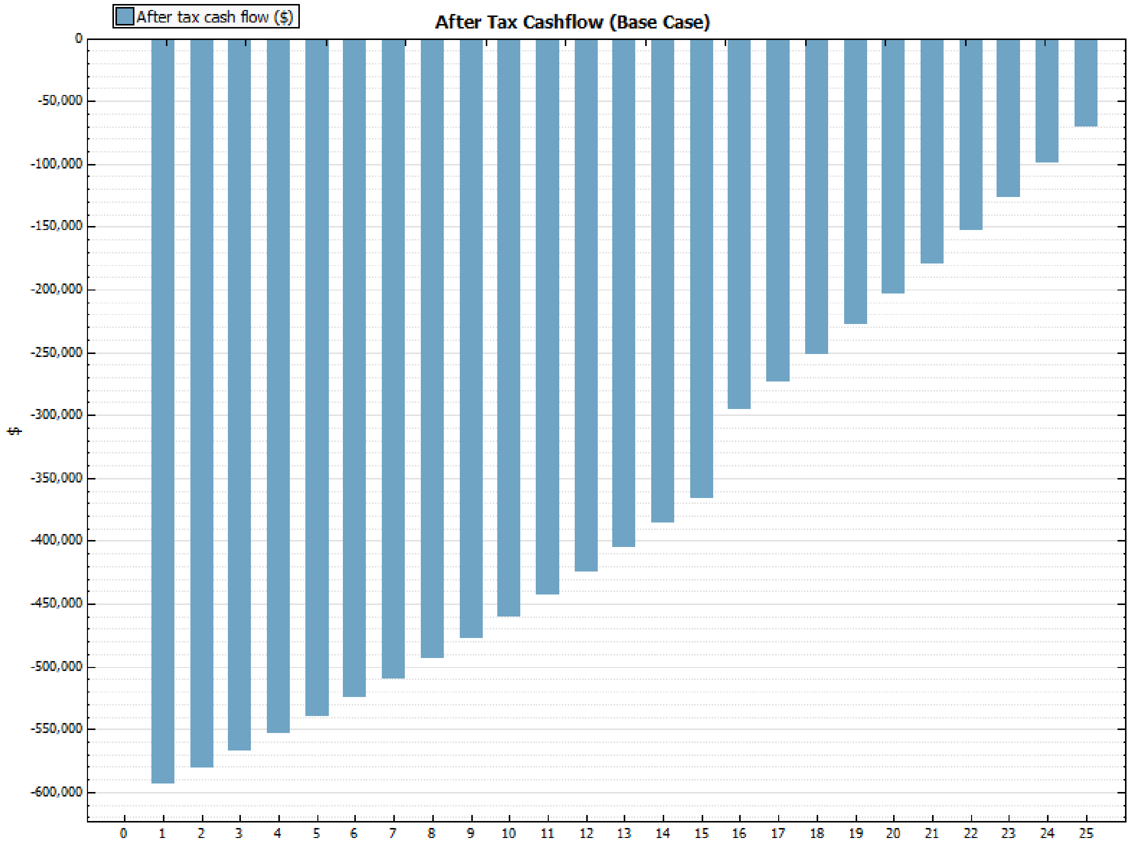

Figure B-8. Annual cash flow for the fixed-tilt ground-mounted system in the MC

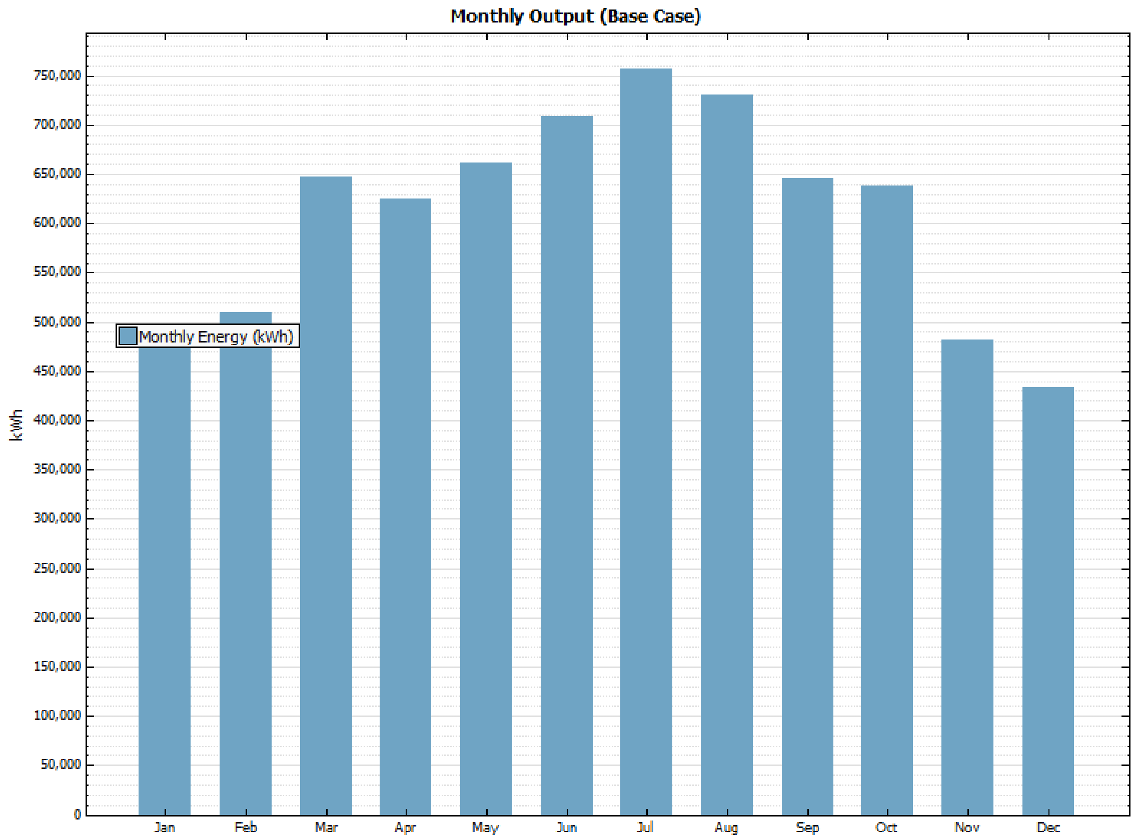

Figure B-9. Monthly output for the single-axis tracking ground-mounted system in the MC

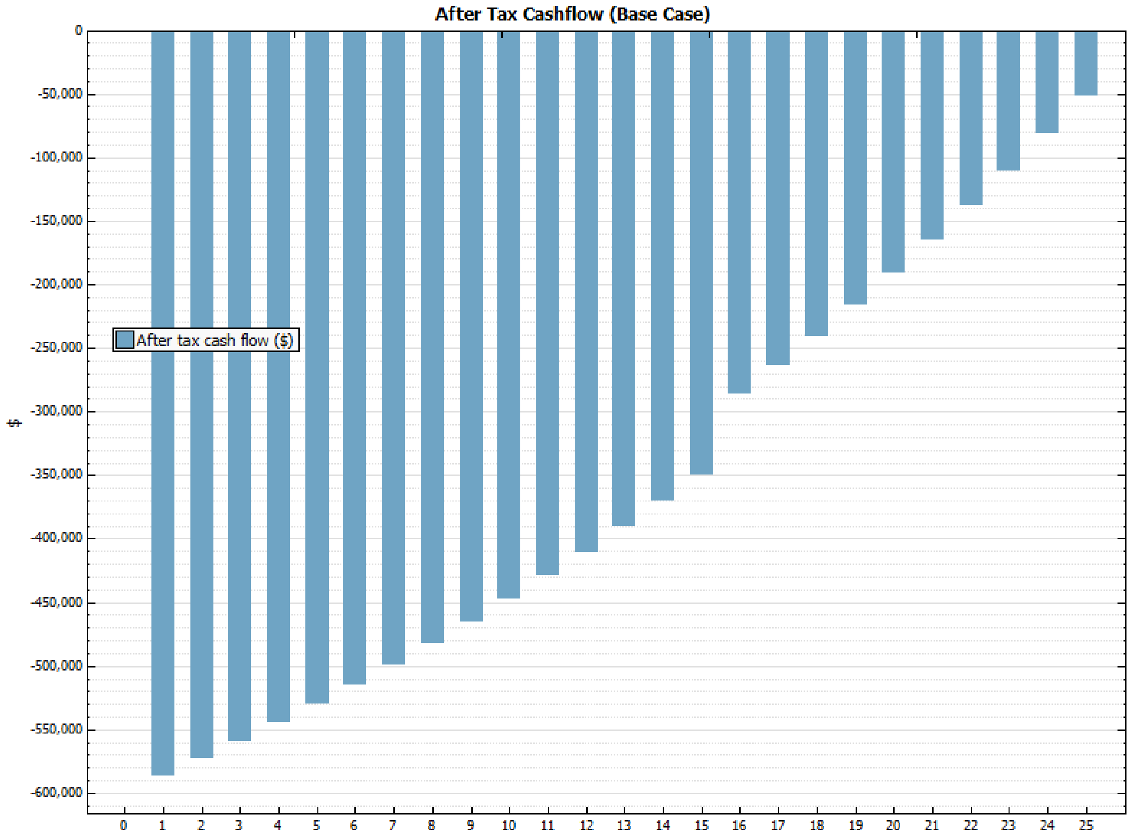

Figure B-10. Annual cash flow for the single-axis tracking ground-mounted system in the MC

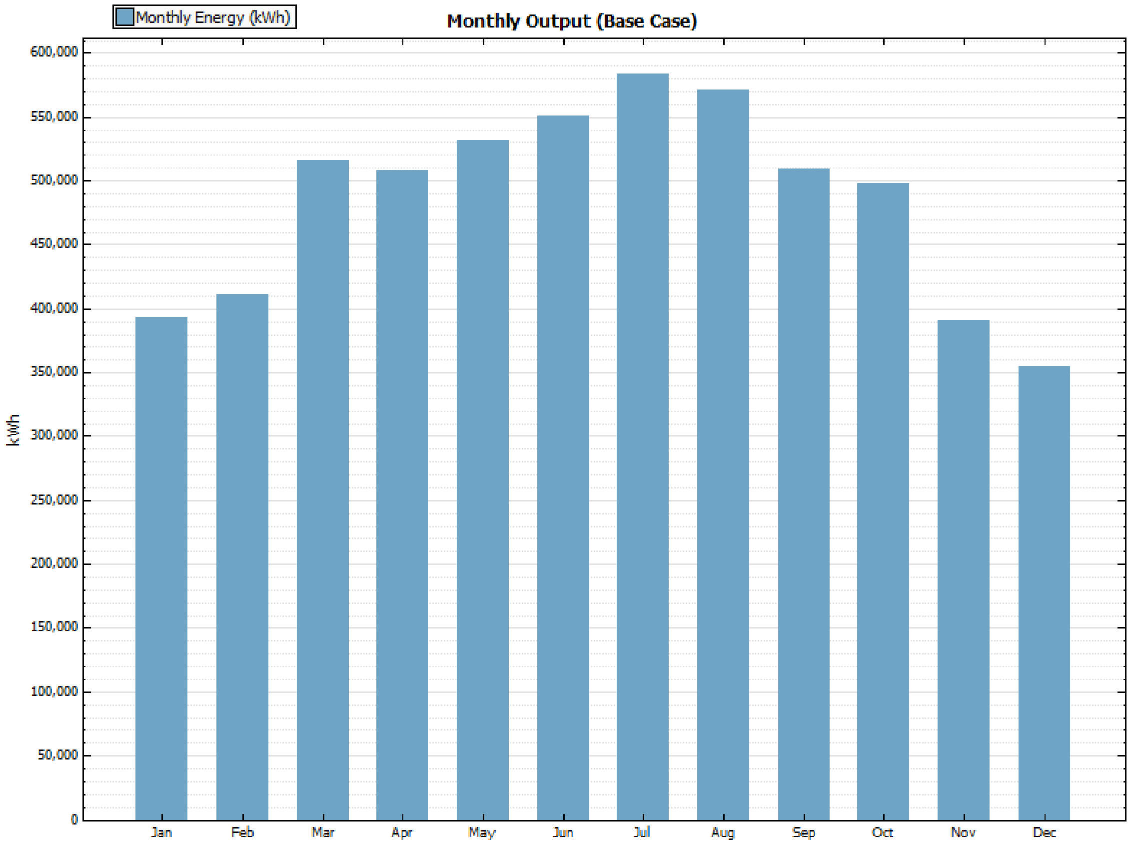

Figure B-11. Monthly output for the fixed-tilt ground-mounted system in West Ft. Hood

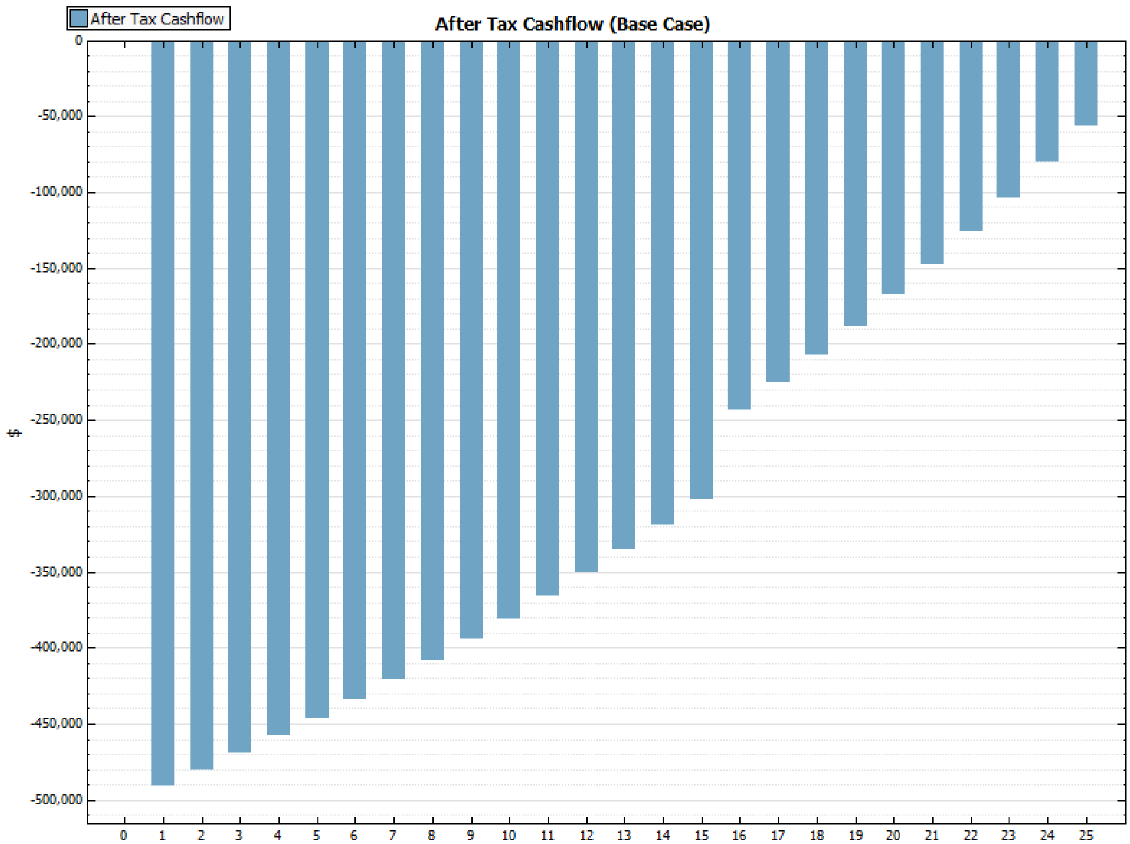

Figure B-12. Annual cash flow for the fixed-tilt ground-mounted system in West Ft. Hood

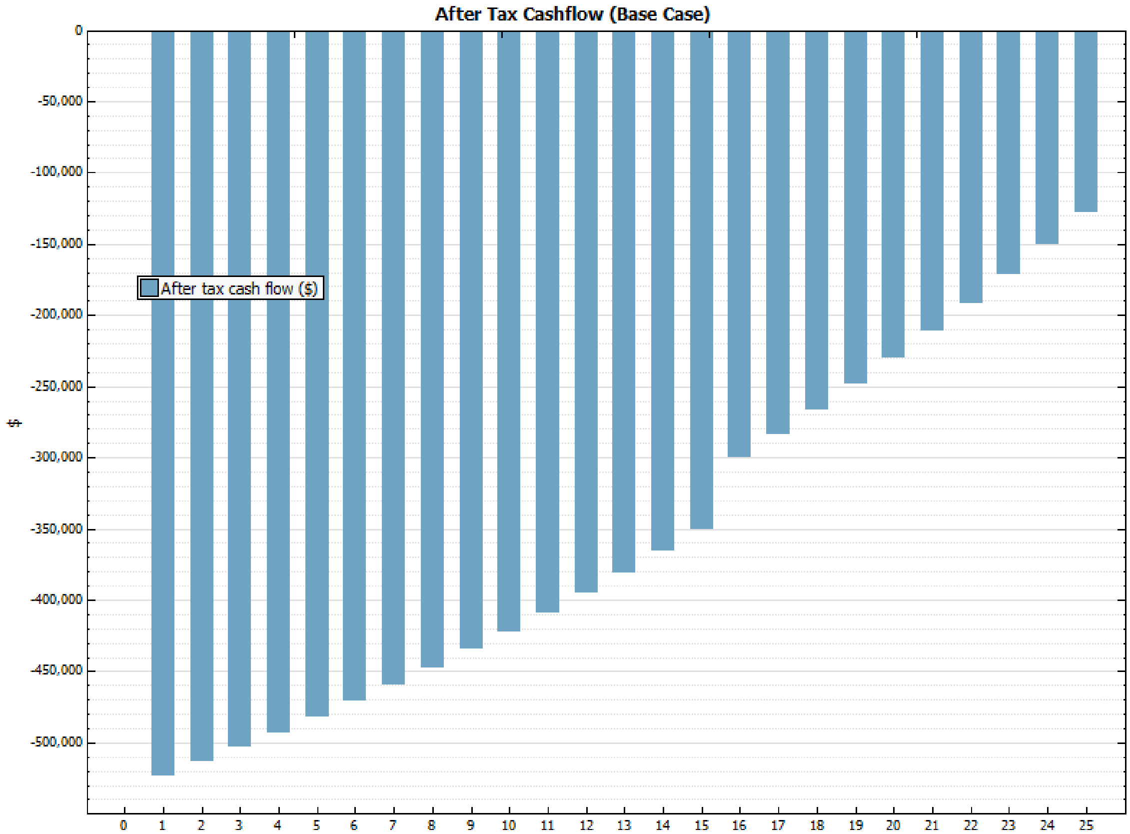

Figure B-13. Monthly output for the single-axis tracking ground-mounted system in West Ft. Hood

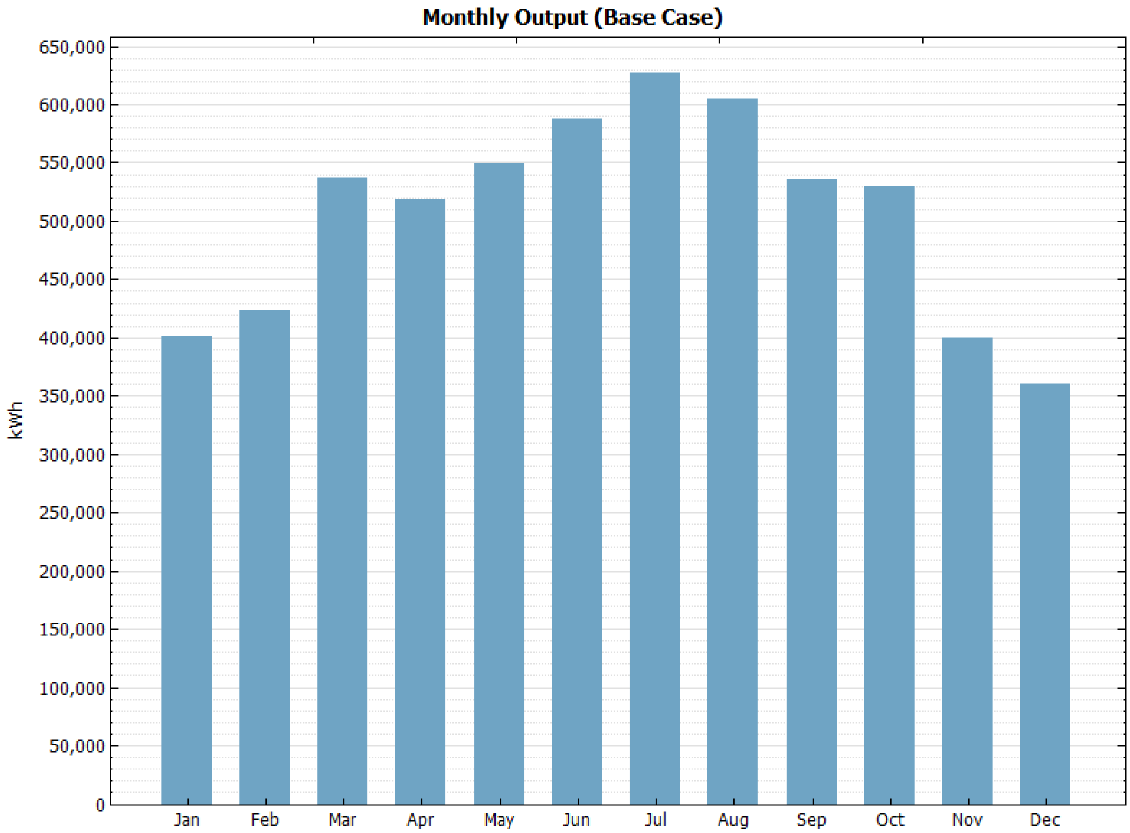

Figure B-14. Annual cash flow for the single-axis tracking ground-mounted system in West Ft. Hood

Appendix C. Results of the Jobs and Economic Development Impact Model

Appendix C shows the JEDI results from installing a 204-kW single-axis system. Other PV system sizes will be relative to this.

Table C-1. Photovoltaic Project Data Summary 16-kW Roof-Mounted System

Project Location	Texas
Year of Construction or Installation	2013
Average System Size - DC Nameplate Capacity (kW)	204.0
Number of Systems Installed	1
Project Size - DC Nameplate Capacity (kW)	204.0
System Application	Large Commercial
Solar Cell/Module Material	Crystalline Silicon
System Tracking	Single Axis
Total System Base Cost ($/kW$_{DC}$)	$3,430
Annual Direct Operations and Maintenance Cost ($/kW)	$20.00
Money Value – Current or Constant (Dollar Year)	2012
Project Construction or Installation Cost	$699,637
Local Spending	$465,690
Total Annual Operational Expenses	$83,220
Direct Operating and Maintenance Costs	$4,080
Local Spending	$3,754
Other Annual Costs	$79,140
Local Spending	$102
Debt Payments	$0
Property Taxes	$0

Table C-2. Local Economic Impacts—Summary Results

During Construction and Installation Period	Jobs	Earnings $000 (2012)	Output $000 (2012)
Project Development and Onsite Labor Impacts			
Construction and Installation Labor	0.9	$55.2	
Construction- and Installation-Related Services	1.6	$79.5	
Subtotal	2.5	$134.7	$249.0
Module and Supply Chain Impacts			
Manufacturing Impacts	0.0	$0.0	$0.0
Trade (Wholesale and Retail)	0.5	$31.3	$94.7
Finance, Insurance, and Real Estate	0.0	$0.0	$0.0
Professional Services	0.5	$20.1	$73.0
Other Services	0.5	$34.9	$129.0
Other Sectors	1.1	$37.8	$83.4
Subtotal	2.6	$124.1	$380.1
Induced Impacts	1.8	$68.3	$260.0
Total Impacts	**6.9**	**$327.2**	**$889.0**
During Operating Years	**Annual Jobs**	**Annual Earnings $000 (2012)**	**Annual Output $000 (2012)**
Onsite Labor Impacts			
PV Project Labor Only	0.0	$2.3	$2.3
Local Revenue and Supply Chain Impacts	0.0	$0.7	$2.3
Induced Impacts	0.0	$0.4	$1.5
Total Impacts	**0.1**	**$3.3**	**$6.1**

Notes: Earnings and output values are thousands of dollars in year 2012 dollars. Construction and operating period jobs are full-time equivalent for one year (1 FTE = 2,080 hours). Economic impacts "during operating years" represent impacts that occur from system/plant operations/expenditures. Totals might not add up due to independent rounding.

Table C-3. Detailed PV Project Data Costs

Installation Costs	New Mexico Cost	Purchased Locally (%)	Manufactured Locally (Y or N)
Materials and Equipment			
Mounting (rails, clamps, fittings, etc.)	$37,203	100%	N
Modules	$211,088	100%	N
Electrical (wire, connectors, breakers, etc.)	$6,044	100%	N
Inverter	$38,099	100%	N
Subtotal	$292,433		
Labor			
Installation	$55,229	100%	
Subtotal	$55,229		
Subtotal	$347,663		
Other Costs			
Permitting	$89,718	100%	
Other Costs	$36,620	100%	
Business Overhead	$207,360	100%	
Subtotal	$333,697		
Subtotal	$681,360		
Sales Tax (materials and equipment purchases)	$18,277	100%	
Total	$699,637		

Table C-4. PV System Annual Operations and Maintenance Costs

	Cost	Local Share	Manufactured Locally (Y or N)
Labor			
Technicians	$2,448	100%	
Subtotal	$2,448		
Materials and Services			
Materials and Equipment	$1,632	100%	N
Services	$0	100%	
Subtotal	$1,632		
Sales Tax (materials and equipment purchases)	$102	100%	
Average Annual Payment (interest and principal)	$79,038	0%	
Property Taxes	$0	100%	
Total	$83,220		
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)	100%		
Local Property Taxes	$0	100%	
Local Sales Tax Rate	6.25%	100%	
Sales Tax Exemption (percent of local taxes)	0%		
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%	