NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Feasibility Study of Economics and Performance of Solar Photovoltaics at the Stringfellow Superfund Site in Riverside, California

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

Otto VanGeet and Gail Mosey

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

Technical Report
NREL/TP-6A20-48770
December 2010

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Prepared under Task No. WFD4.1000

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

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Executive Summary

The U.S. Environmental Protection Agency (EPA), in accordance with the RE-Powering America's Land initiative, selected the Stringfellow Superfund Site in Riverside, California for a study of solar photovoltaic (PV) feasibility. The National Renewable Energy Laboratory (NREL) was contacted to provide technical assistance for this project. The purpose of this report is to assess the site for possible PV 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. The economics of the potential systems were analyzed using an electric rate of $0.13/kWh, and incentives that are offered by Southern California Edison (SCE) under the California Solar Initiative (CSI). NREL recommends the installation of ground-mounted PV. Because of the high cost of energy, dropping cost of PV, excellent solar resource and excellent SCE incentives a government owned PV system provides a reasonable payback, is easy to implement, and is therefore recommended. If funding is not available then a third party ownership arrangement Power Purchase Agreement (PPA) is the most plausible way for a system to be financed on this site.

Table ES-1.Stringfellow Superfund Site Summary

Tie-in Location	Array Tilt (Deg)	Area (ft^2) Required	PV System Size (kW)	Annual Output kWh/yr	Annual Cost Savings after O&M ($/year)	Total System Cost with No Incentives ($)	CSI Incentive $0.26/kWh for 5 years, ($) after 5 years	Cost ($) after 5 years of CSI incentives	Payback Period after CSI Incentive (years)
Ground-mounted; Treatment Plant only = 430,000 kWh annual									
Treatment plant	20	71,192	285	430,000	53,479	1,543,841	559,000	984,841	18
Treatment plant	Single axis	73,410	242	430,000	53,429	1,573,521	559,000	1,014,521	19
Stringfellow site with virtual net metering = 648,000 kWh annual									
Site	20	107,285	429	648,000	80,592	2,155,695	842,400	1,313,295	16
Site	Single axis	110,627	365	648,000	80,516	2,200,423	842,400	1,358,023	17

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1 Study Location

Industrial wastes were disposed of on the Stringfellow Superfund Site[1] (the site) from 1956 to 1972. During this period, up to 20 unlined surface impoundments for liquid wastes were located in the 17-acre disposal area. Approximately 34 million gallons of liquid wastes containing spent acids, solvents, pesticide-manufacturing byproducts, heavy metals, and various organic and inorganic compounds were discharged into the surface impoundments during the operational period.

In 1983, the site was listed as a Superfund site on the National Priorities List as California's highest priority hazardous waste site. The California Department of Toxic Substances Control is responsible for monitoring and operating remediation systems at the site. These systems include three groundwater extraction and treatment systems extending from the waste disposal site into Glen Avon, California.

Assessment team members from NREL, the State of California and the U.S. Environmental Protection Agency (EPA) conducted a site assessment visit on December 17, 2009 to determine whether PV is feasible for the site. Team members and their contact information are included in Appendix A.

[1] For more information about the site, see http://yosemite.epa.gov/r9/sfund/r9sfdocw.nsf/3dec8ba3252368428825742600743733/0c1b8f989b2c080288257007005e9440!opendocument.

2 Photovoltaic (PV) Systems

Photovoltaics (PV) are semiconductor devices that convert sunlight directly into electricity. They do so without any moving parts and without generating any noise or pollution. They must be mounted in unshaded locations: rooftops, carports and ground-mounted arrays are common mounting locations. PV systems are well suited to the sunny Riverside, California 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 5 $kWh/m^2/day$, which is excellent.

This number, however, is not the amount of energy that can be produced by a PV panel in this location. The amount of energy produced by a panel depends on the several factors, including the type of collector, the tilt and azimuth of the collector, the module temperature, the level of sunlight and the weather conditions. An inverter is required to convert the direct current (DC) to alternating current (AC) of the desired voltage compatible with building and utility power systems. The balance of the system consists of conductors/conduit, switches, disconnects and fuses. Grid-connected PV systems feed power into the facility's electrical system and do not include batteries. Figure 1 shows the major components of a grid-connected PV system and illustrates how these components are interconnected.

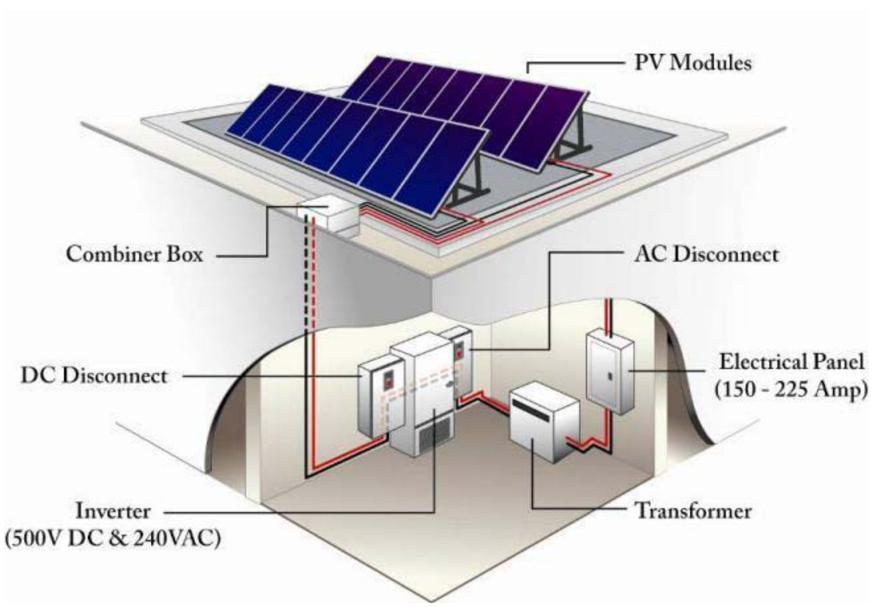

Figure 1. Major components of grid-connected photovoltaic (PV) system

PV panels are very sensitive to shading. When shade falls on a panel, that portion of the panel is unable to collect the high-energy beam radiation from the sun. PV panels are made up of many individual cells that all produce a small amount of current and voltage. These individual cells are connected in series to produce a larger current. 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™ 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.

If a site is found to have much potential for a PV system, the next step is to determine the size of the system. System size depends highly on the average energy use of the facilities on the site. It is generally not advisable to provide more energy than the site will use due to the economics of most net metering agreements.

2.1 Types of PV Systems

2.1.1 Ground-Mounted Systems

Ground-mounted PV systems are usually the lowest cost option to install on a $/DC-Watt basis. There are several mounting options available, each having different benefits for different ground conditions. Table 1 outlines the energy density values that can be expected from each of the different system types. Due to the lack of hybrid HE panels as a significant portion of the commercial market, they were not included in the financial analysis. Installing panel types that do not hold a significant portion of the commercial market would not be feasible for a large-scale solar generation plant.

Table 1. Energy Density by Panel and System

System Type	Fixed Tilt Energy Density (DC-Watts/Sq. Ft)	Single Axis Tracking Energy Density (DC-Watts/Sq. Ft)
Crystalline Silicon	4	3.3
Thin Film	3.3	2.7
Hybrid HE	4.8	3.9

For the purposes of this analysis, it was assumed that crystalline silicon PV panels are used. 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. When considering a ground-mounted system, an electrical tie in location should be identified to determine how the energy would be fed back into the grid. For this report, only fixed axis ground-mounted systems and single axis tracking systems will be considered. Fixed tilt systems are installed at a specified tilt, and are fixed at that tilt for the life of the system. Single axis tracking systems have a fixed tilt (horizontal in this case) on one axis and a variable tilt on the other axis. The system is designed to follow that sun in its path through the sky. This allows the solar radiation to strike the panel at an optimum angle for a larger part of the day than can be achieved with a fixed axis system. A zero tilt (horizontal) single axis tracking system will collect about 18% more electricity per capacity (kW) than a fixed-tilt (non-tracking) system at Stringfellow. The drawbacks include increased operation and maintenance (O&M) costs, less capacity per unit area to avoid self-shading (DC-Watt/ft2), and greater installed cost ($/DC-Watt). The annual energy production per unit area (kWh/ft2) is slightly less with single axis tracking, but adequate land should be available at Stringfellow, so this is not an issue. The performance specifications will allow either fixed tilt or single axis tracking at any tilt; the evaluation criteria will include O&M costs.

2.1.2 Roof-Mounted Systems

In many cases, the roof is the best location for a PV system. On this site, no roof area is available, so roof-mounted analysis will not be conducted.

2.2 PV System Components

The PV system considered here has these components:

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

2.2.1 PV Array

The primary component of a PV system, the PV array, converts sunlight to electrical energy; all other components simply condition or control energy use. Most PV arrays consist of interconnected PV modules that range in size from 50 peak DC-Watts to 300 peak DC-Watts. Peak watts are the rated output of PV modules at standard operating conditions of 25°C (77F) and insolation of 1,000 Watts/m². Because these standard operating conditions are nearly ideal, the actual output would be less under typical environmental conditions. PV modules are the most reliable components in any PV system. They have been engineered to withstand extreme temperatures, severe winds and impacts. ASTM E1038-05[2] subjects modules to impacts from one-inch hail balls at terminal velocity (55 mph) at various parts of the module. PV modules have a life expectancy of 20–30 years, and manufacturers warranty them against power degradation for 25 years. The array is usually the most expensive component of a PV system; it accounts for approximately two-thirds the cost of a grid-connected system. A large choice of PV manufacturers is available.[3]

2.2.2 Inverters

PV arrays provide direct current power at a voltage that depends on the configuration of the array. This power is converted to alternating current at the required voltage and number of phases by the inverter. Inverters enable the operation of commonly used equipment such as appliances, computers, office equipment and motors. Existing inverter technology provides true sine wave power at a quality often better than that of the serving utility. The locations of both the inverter and the balance of the system equipment are important. Inverters are available that include most or all of the control systems required for

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

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

operation, including some metering and data-logging capability. Inverters must provide several operational and safety functions for interconnection with the utility system. The Institute of Electrical and Electronic Engineers, Inc (IEEE) maintains standard *"P929 Recommended Practice for Utility Interface of Photovoltaic (PV) Systems,"*[4] which allows manufacturers to write "Utility-Interactive" on the listing label if an inverter meets the requirements of frequency and voltage limits, power quality, and non-islanding inverter testing. Underwriters Laboratory maintains "*UL Standard 1741, Standard for Static Inverters and Charge Controllers for Use in Photovoltaic Power Systems,"*[5] which incorporates the testing required by IEEE P929 and includes design (type) testing and production testing. A large choice of inverter manufacturers is available.[6]

2.2.3 Operation and Maintenance

The PV panels come with a 25-year performance warranty. The inverters, which come standard with a five-year or ten-year warranty (extended warranties available), would be expected to last 10-15 years. System performance should be verified on a vendor provided web site. Wire and rack connections should be checked annually. This economic analysis uses an annual O&M cost computed as 0.17% of the total installed cost, which is based on the historical operation and maintenance (O&M) costs of installed fixed-axis grid tied PV systems. For the case of single-axis tracking, the analysis uses an annual O&M cost of 0.35% of total installed cost based on the historical costs existing single-axis tracking systems.

2.3 PV Size and Performance

The PV arrays must be installed in unshaded locations on the ground or on building roofs that have an expected life of at least 25 years. For this assessment, the predicted array performance was determined using PVWatts, ™ a performance calculator for grid-connected PV systems created by NREL's Renewable Resource Data Center.[7] The performance data was used to calculate the amount of revenue that could be expected each year. The project economics were based on this analysis; the calculations can be found in Appendix B.

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

[5] Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources: UL 1741 (http://ulstandardsinfonet.ul.com/scopes/1741.html)

[6] Go Solar California approves inverters.

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

3 Photovoltaic (PV) Sites

3.1 PV Size and Performance

PV arrays must be installed in un-shaded locations on the ground or on building roofs that have an expected life of at least 25 years. The site has excellent annual solar access of 96% based on solar access measurements taken during the site visit; see Appendix C for details. The predicted array performance was found using PVWatts Version 2 for Riverside, California.[8] Table 2 shows the station identification information, PV system specifications, and energy specifications for the site.

Table 2. Site Identification Information and Specifications

Station Identification	
Cell ID	176362
State	California
Latitude	34.0° N
Longitude	117.3° W
PV System Specifications	
DC Rating	1.00 kW
DC to AC Derate Factor	0.77
AC Rating	0.77 kW
Array Type	Fixed Tilt
Array Tilt	20.0°
Array Azimuth	180.0°
Energy Specifications	
Cost of Electricity	13.0 ¢/kWh

[8]PV Watts is a performance calculator for grid-connected PV systems. It was created by NREL's Renewable Resources Data Center. For more information, see http://rredc.nrel.gov/solar/calculators/PVWATTS/version2/

Table 3 shows the performance results in kWh/kW for 20-degree fixed-tilt PV from PVWatts for Riverside.

Table 3. Performance Results for 20-degree fixed-tilt PV

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	4.22	94	12.22
2	4.80	98	12.74
3	5.64	126	16.38
4	6.40	135	17.55
5	7.02	152	19.76
6	7.70	157	20.41
7	7.59	158	20.54
8	7.45	154	20.02
9	6.55	132	17.16
10	5.39	116	15.08
11	4.61	99	12.87
12	4.00	89	11.57
Year	5.95	1510	196.30

Table 4 shows the performance results for 0-tilt single-axis tracking PV from PVWatts for Riverside.

Table 4. Performance Results for 0-degree single-axis PV

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	4.14	95	12.35
2	5.16	107	13.91
3	6.43	146	18.98
4	7.86	170	22.10
5	8.80	193	25.09
6	9.54	196	25.48
7	9.72	204	26.52
8	9.15	192	24.96
9	7.61	157	20.41
10	5.80	128	16.64
11	4.63	101	13.13
12	3.87	88	11.44
Year	6.90	1775	230.75

3.1.1 Energy Use

The site has nine different Southern California Edison (SCE) meters. The majority of the energy use, 430,512 kWh annually from May 2007 through April 2008, is for the treatment plant, meter ID 3-029-1238-11, the last meter listed in Table 5. Table 6 and Table 7 describe seasonal and time-of-use energy rates during the summer season.[9]

Table 5. Meters and Rates Schedules

Meter ID	Rate Schedule	Peak (kW) Apr' 08	Total Annual Energy Consumption (kWh)	Mean Monthly Energy Consumption (kWh)
3-029-1236-34	PA-2	12	46,296	3,858
3-029-1236-54	PA-2	5	22,785	1,899
3-029-1236-63	GS-2	16	15,313	1,276
3-029-1237-60	PA-2	9	56,798	4,733
3-029-1237-80	PA-2	2	17,670	1,473
3-029-1237-89	PA-2	4	34,290	2,858
3-029-1237-97	PA-2	3	23,129	1,927
3-029-1238-05	PA-2	1	1,826	152
3-029-1238-11	PA-2	165	430,512	35,876
Annual Site Total (kWh)			648,619	

[9] Detailed rate schedule is available at http://www.sce.com/NR/sc3/tm2/pdf/ce43-12.pdf. This detailed rate schedule does not contain information on different on and off-peak rates as described above. The electric bills were annualized, and it was determined that the rates are higher in the summer season, but on- and off-peak rates are not currently being charged. Rate schedule PA-2, an "agricultural and pumping" rate, is used for most of the site. For more information, see http://www.sce.com/NR/rdonlyres/7E7A46DB-7DDD-468F-A3C8-8F187C68F06C/0/081212_Power_Agriculture_2.pdf.

Tables 6, 7, and 8 show the time-of-use (TOU) PA- rate PA-2 and TOU-PA rate schedules. The PA-2 schedule is a seasonal rate (winter and summer) that includes a periodic demand charge based upon the peak electrical load realized in any 15-minute interval during the billing period. The current demand charge is approximately one-third of cost billed to the pump and treat plant (PTP) account. An analysis of the 15-minute interval data by DTSC indicates that the peak demand during the last 12 months was 192 kW. If the PTP demand increases to 200 kW, the utility would require that DTSC switch the PTP to the time-of-use rate schedule, TOU-PA. Schedule TOU-PA has energy rates for off-peak, mid-peak, and on-peak periods during summer and winter months. In addition, schedule TOU-PA includes a service charge or demand charge, depending upon which of two options, "Rate A" or "Rate B," is elected under the schedule. According to a SCE rate analyst[10], Rate A likely would be the better option for the PTP.[11] NREL recommends consideration of TOU PA Rate B because most motors at the treatment plant are on variable speed drives which limit demand kW as compared to Rate A based on motor name plate HP. Rate B has lower On-Peak and Mid-Peak Rates. NREL did not conducted detailed rate analysis for the Stringfellow site but has analyzed similar TOU rates in San Diego and determined that the combination of low demand charges, low off-peak rates and low energy use during peak hours (due to the PV system's contribution) results in the lowest cost.[12]

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[10] Telephone conversation between Judy Zimmerman of SCE and Mikos Fabersunne of DTSC, November 19, 2010. Zimmerman recommended that DTSC switch from PA-2 to TOU-PA as soon as possible and estimated that the annual savings for operating the PTP, without the PV system, would be approximately $5000.

[11] Tables 6 and 7 come from http://www.sce.com/NR/rdonlyres/7E7A46DB-7DDD-468F-A3C8-8F187C68F06C/0/081212_Power_Agriculture_2.pdf.

[12] See Doris, Ong, and Van Geet (July 2009). "Rate Analysis of Two Photovoltaic Systems in San Diego." NREL/TP-6A2-43537 Golden, CO: National Renewable Energy Laboratory. http://www.nrel.gov/docs/fy09osti/43537.pdf.

Table 6. Summer Rate Schedule TOU PA: Off-Peak, Mid-Peak and On-Peak Energy Rates[a]

<table>
<tr><th>Monday</th><th>Tuesday</th><th>Wednesday</th><th>Thursday</th><th>Friday</th><th>Saturday</th><th>Sunday</th></tr>
<tr><td colspan="5">Mid-Peak Energy Rate[b]</td><td colspan="2" rowspan="4">Off-Peak Energy Rate[e]</td></tr>
<tr><td colspan="5">On-Peak Energy Rate[c]</td></tr>
<tr><td colspan="5">Mid-Peak Energy Rate[d]</td></tr>
<tr><td colspan="5">Off-Peak Energy Rate[e]</td></tr>
</table>

[a] Summer season begins 12:00 a.m., June 1 and continues until 12:00 a.m., October 1.
[b] 8:00 a.m. - 12:00 a.m. weekdays except holidays
[c] 12:00 a.m. - 6:00 p.m. weekdays except holidays
[d] 6:00 p.m. - 11:00 p.m. weekdays except holidays
[e] all other hours

Table 7. Winter Rate Schedule TOU PA: Off-Peak, Mid-Peak and On-Peak Energy Rates[a]

<table>
<tr><th>Monday</th><th>Tuesday</th><th>Wednesday</th><th>Thursday</th><th>Friday</th><th>Saturday</th><th>Sunday</th></tr>
<tr><td colspan="5">Mid-Peak Energy Rate[b]</td><td colspan="2" rowspan="2">Off-Peak Energy Rate[c]</td></tr>
<tr><td colspan="5">Off-Peak Energy Rate[c]</td></tr>
</table>

[a] Winter season begins 12:00 a.m., October 1 and continues until 12:00 a.m., June 1.
[b] 8:00 a.m. - 9:00 p.m. weekdays except holidays
[c] 9:00 p.m. - 8:00 a.m. weekdays and all day on weekends including holidays

Table 8. Comparison Rate Schedule TOU PA, PA-A and PA-B

Rate	$/kW	$/HP	Summer ($/kWh on peak)	Summer ($/kWh mid peak)	Summer ($/kWh off peak)	Winter ($/kWh mid peak)	Winter ($/kWh off peak)
PA-2	8.06	--	0.11582	0.11582	0.11582	0.05944	0.05944
PA- A	--	4.89	0.229858	0.0925	0.03646	0.07782	0.03444
PA-B	7.83	--	0.10745	0.0615	0.03648	0.06096	0.03446

3.1.2 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, [13] under Sec. 1251, all public electric utilities are required upon request to make net metering available to their customers.[2]:

> (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 offset electric energy provided by the electric utility to the electric consumer during the applicable billing period.

California's net-metering law,[14] which took effect in 1996, requires utilities to offer net metering to all customers with solar and wind-energy systems up to 1 megawatt (MW).

Net excess generation (NEG) is carried forward to a customer's next bill. Under prior law, any NEG remaining at the end of each 12-month period was granted to the customer's utility. In 2009, California Assembly Bill 920 (AB920)[15] gave net metering customers two additional options for the NEG remaining after a 12-month period. They can roll over any remaining NEG from month-to-month indefinitely, or they can receive financial compensation from their utility for the remaining NEG. By January 1, 2011, the California Public Utilities Commission (CPUC) must develop a compensation valuation for the remaining NEG if customers choose the financial compensation option. The rate-making authorities of publicly-owned utilities must develop their own compensation methods for the remaining NEG through public proceedings. By January 31, 2010, utilities must notify all of their net metering customers of these new options. If the customer makes no affirmative election for either option, the utility will be granted their NEG at the end of the 12-month period with no compensation to the customer.

Renewable energy certificates (RECs)[16], 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 NEG remaining after a 12-month period, the utility will be granted the RECs associated with only that surplus they purchase.

[13] For a summary of this bill and its full text, see http://frwebgate.access.gpo.gov/cgi-in/getdoc.cgi?dbname=109_cong_bills&docid=f:h6enr.txt.pdf.
[14] For more information about California's net metering law, see http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=CA02R&re=1&ee=1.
[15] http://www.leginfo.ca.gov/pub/09-10/bill/asm/ab_0901-0950/ab_920_bill_20091011_chaptered.pdf
[16] For a description of RECs, see http://apps3.eere.energy.gov/greenpower/markets/certificates.shtml.

California does not allow any new or additional demand charges, standby charges, customer charges, minimum monthly charges, interconnection charges, or other charges that would increase an eligible customer-generator's costs beyond those of other customers in the rate class to which the eligible customer-generator would otherwise be assigned. The CPUC has explicitly ruled that technologies eligible for net metering (up to 1 MW) are exempt from interconnection application fees, as well as from initial and supplemental interconnection review fees.

Publicly owned utilities may elect to provide co-energy metering, which is the same as net metering, except that it incorporates a time-of-use (TOU) rate schedule. Customer-generators with systems sized between 10 kW and 1 MW, who are subject to time-of-use rates, are entitled to return electricity to the system for the same TOU (including real-time) price that they pay for power purchases. However, TOU customers who choose to co-energy meter must pay for the metering equipment capable of making such measurements. Customer-generators retain ownership of all RECs associated with the generation of electricity they use on site.

3.1.3 Virtual Net Metering

California Assembly Bill 2466 (AB 2466), [17] codified as Section 2830 of the Public Utilities Code, was signed into law by Governor Schwarzenegger in September 2008 and became effective on January 1, 2009. The law allows a local government to install renewable generation of up to 1 MW at one location within its geographic boundary and to generate credits that can be used to offset charges at one or more other locations within the same geographic boundary. This billing arrangement is called virtual net metering (VNM). [18]

The California State Legislature defined local government to include cities, counties, school districts, special districts, political subdivisions or other local public agencies that are authorized to generate electricity. The legislature decided that the tariff would **not** be available for the state, any agency or department of the state, or any joint powers authority. Because the site is a state site, it probably does not qualify under AB2466 for VNM. However, SCE could allow VNM if they choose to. The SCE customer representative for the site customer should be asked if VNM whether an option.

IF SCE were to allow VNM, energy use for the entire site could be offset by a larger system. This would also allow a lower installation cost because all PV could be fed into the closest SCE connection point rather than having to tie into the treatment plant distribution panel, which is about 400 feet away. The connection point could also be used for the future plant. A new transformer may be required. A "feed in" meter would be installed and would credit the other meters on site. The cost of a new meter and tie-in is assumed to be $10,000 for this economic analysis.

Because it is unknown whether SCE will allow VNM, these options were analyzed:

[17] http://www.leginfo.ca.gov/pub/09-10/bill/asm/ab_2451-2500/ab_2466_bill_20100428_amended_asm_v98.pdf
[18] For more information about VNM, see http://www.pge.com/b2b/newgenerator/ab2466/.

- Size the installed PV system to offset the annual load of the existing treatment plant, which is about 430,000 kWh. Tie the PV system into the existing plant after the meter, which would require about 400 feet of new overhead transmission line at 480V. Recent case studies have quoted the costs of new transmission lines at $1.5 Million per mile installed.[19] Therefore, the new transmission will add an estimated $120,000.
- Size the installed PV system to offset the annual load of the existing treatment plant, which is about 648,000 kWh. Tie the PV system into the existing SCE distribution at the closest available location and feed a new meter for VNM. The cost of the SCE tie-in was assumed to be $10,000.

[19] http://news.cnet.com/Shrinking-the-cost-for-solar-power/2100-11392_3-6182947.html

Table 9. Stringfellow Superfund Site Summary

Tie-in Location	Array Tilt (Deg)	Area (ft^2) Required	PV Syst. Size (kW)	Annual Output (kWh/yr)	Annual Cost Savings after O&M ($/year)	Electrical Tie-in Cost ($)	Total System Cost with No Incentives ($)	Payback Period with No Incentive (years)	CSI Incentive $0.26/kWh for 5 Years, $ after 5 Years	Cost $ after 5 years of CSI incentives	Payback Period after CSI Incentive (years)
	Ground-mounted; Treatment Plant only = 430,000 kWh annual										
Treatment plant	20	71,192	285	430,000	53,479	120,000	1,543,841	29	559,000	984,841	18
Treatment plant	Single axis	73,410	242	430,000	53,429	120,000	1,573,521	29	559,000	1,014,521	19
	Stringfellow Superfund Site with virtual net metering = 648,000 kWh annual										
Site	20	107,285	429	648,000	80,592	10,000	2,155,695	27	842,400	1,313,295	16
Site	Single axis	110,627	365	648,000	80,516	10,000	2,200,423	27	842,400	1,358,023	17

3.1.4 PV Location

The proposed PV system would be located in the existing truck parking area, which is visible in the bottom center of Figure 2. The center of parking lot NE of PTP is:

Latitude: 34.026850 (34° 1' 36.660" N)
Longitude: -117.455430 (118° 32' 40.452" W)

Figure 2. Aerial photograph showing proposed treatment plant and PV location

The existing plant is located in the bottom center of the image.
Credit: California Department of Toxic Substances Control

Figures 3 and 4 show the proposed treatment plant location and the existing site plan, respectively. Figure 5 depicts the proposed PV location, and Figure 6 depicts an SCE meter and electrical distribution panels serving the existing plant.

Figure 3. Site plan showing proposed treatment plant location

Credit: California Department of Toxic Substances Control and Tetra Tech Inc.

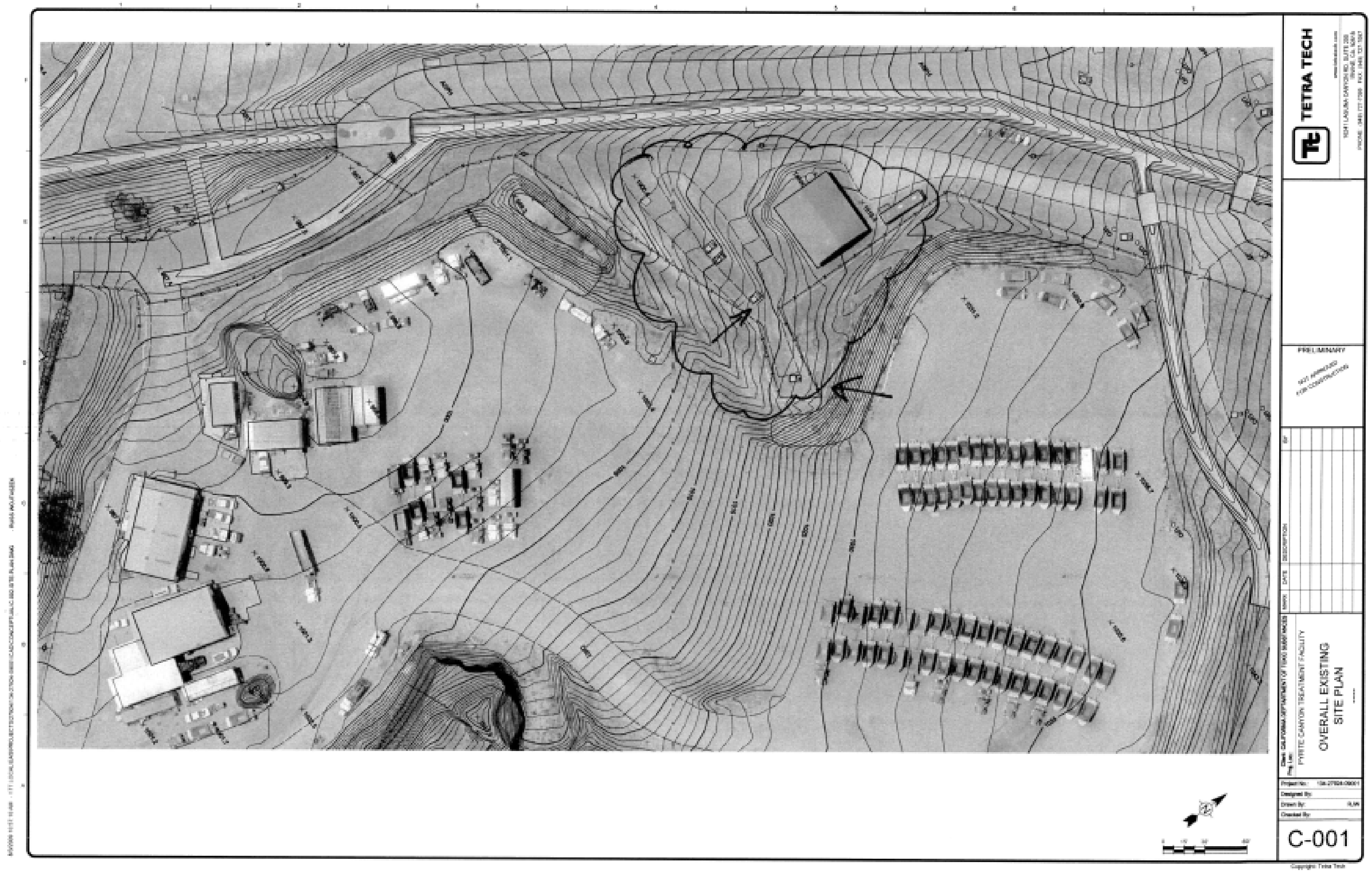


Figure 4. Existing site plan showing topographic contours and proposed PV location in center and east portion of truck parking area

Credit: California Department of Toxic Substances Control and Tetra Tech Inc.

a) Truck parking area looking south, PV proposed in center and east portion of area, new treatment plant on west (right side of picture). Arrow shows existing SCE overhead electrical distribution on west edge of parking area. Credit: Otto Van Geet, NREL

b) Closer view of flat truck parking area that is well suited for PV. Credit: Otto Van Geet, NREL

c) West side of truck parking area looking southwest, new treatment plant on west (right side of picture); arrow shows existing SCE overhead electrical distribution on west edge of parking area. Credit: Otto Van Geet, NREL

d) Closer view of SCE overhead electrical distribution and possible PV tie-in location if virtual net metering were allowed by SCE. Credit: Otto Van Geet, NREL

e) Existing treatment plant looking east. Credit: Otto Van Geet, NREL

f) SCE overhead electrical distribution serving existing plant. Credit: Otto Van Geet, NREL

Figure 5. Photographs of proposed PV in center and east portion of truck parking area

a) SCE main meter 3-029-1238-11 in main distribution & metering panel “MDP” at existing treatment plant located in center of plant.

b) Electrical distribution panels serving existing plant.

c) Electrical distribution panels serving existing plant.

Figure 6. Photographs of SCE meter and electrical distribution panels serving existing plant

4 Economics and Performance

4.1 Assumptions and Input Data for Analysis

For this analysis, the following input data were used. The installed cost of fixed tilt ground-mounted systems was assumed to be $5/W, and the installed cost of a single-axis was assumed to be $6/W. These prices include the PV array and the balance-of-system (BOS) components for each system, including the inverter and electrical equipment, as well as the installation cost. The economics of grid-tied PV depend on incentives, the cost of electricity, the solar resource, and panel tilt and orientation. For this analysis, the cost of electricity was assumed to be $0.13 as reported by the State of California based on electric bills for the site.

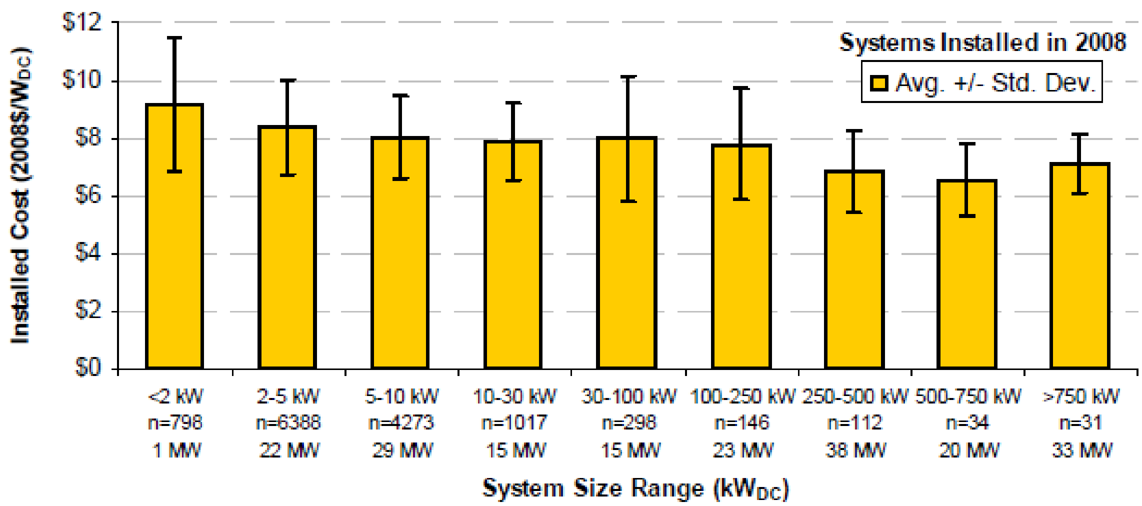


Figure 7. PV Costs[20]

A system DC to AC conversion of 77% was assumed. This included losses in the inverter, wire losses, PV module losses, and losses due to temperature effects, and other losses. Figure 7 summarizes average system installation costs for grid-tied U.S. PV systems in 2008; however, the costs have dropped significantly since 2008. PVWATTS Version 2 was used to calculate energy performance.

It was assumed for this analysis that federal incentives are received. It is important to find incentives or grants to make PV cost effective. If the PV system is owned by a private tax-paying entity, this entity may qualify for a 30% federal tax credit and accelerated depreciation on the PV system, which is worth about 15%. The total potential tax benefits to the tax-paying entity are about 45% of the system cost. Because the state and federal governments do not pay taxes, private ownership of the PV system would be required to capture tax incentives.

[20] Wiser, R.; Barbose, G.; Peterman, C.; Darghouth, N. (2009). "Tracking the Sun II: The Installed Cost of Photovoltaics in the U.S. from 1998-2008." LBNL-2674E. Berkeley, CA: Lawrence Berkeley National Laboratory.

4.2 Other Incentives and Financing Opportunities

The Database of State Incentives for Renewable Energy (DSIRE) provides a summary of net metering, interconnection and incentives available to customers. The utility for the site is SCE.

Net Metering Agreement—California's net-metering law, which took effect in 1996, requires all utilities, to offer net metering to all customers for solar and wind-energy systems up to 1 megawatt (MW).

Interconnection—Net metering in California applies to renewable-energy systems up to 1 MW in capacity and includes provisions for TOU net metering. Net-metered systems up to 1 MW are exempt from paying costs associated with the interconnection studies, distribution system modifications or application review fees discussed below.[21]

Performance-based incentives (PBI) for systems that are 30 kW and larger began in 2007 at $0.39/kWh for the first five years for taxable entities and at $0.50/kWh for the first five years for government entities and nonprofits. The incentive levels decline as the aggregate capacity of PV installations increases. PBI will be paid monthly based on the actual amount of energy produced over five years. Residential and small commercial projects under the 30-kW threshold can also choose to opt in to the PBI rather than the upfront Expected Performance-Based Buydown approach. However, all installations of 30 kW or larger must take the PBI.[22] The program is managed by Southern California Edison (SCE).[23]

Current incentives are $0.15/kWh for commercial customer-generators and $0.26/kWh for government and non-profit customer-generators. Locking in at the existing incentive level—when Step 7 is reached for SCE the incentives drop to $0.09/kWh for commercial customer-generators and to $0.19/kWh for government and non-profit customer-generators— is strongly recommended.

NREL also evaluated the SCE CREST program.[24] CREST is a PPA, not a net metering agreement like CSI. A Net Generation Output Meter ("NGOM") where SCE pays the owner for the energy generated. Stringfellow would still buy energy from SCE under the current rate. The CREST program uses a Season Period Energy Adjustment Factor (EAF) multiplied by the base rate for 25 years:

[21] For details, see http://www.dsireusa.org/incentives/index.cfm?re=1&ee=1&spv=0&st=0&srp=1&state=CA.
[22] For current incentive levels (Step) for each utility, see http://www.csi-trigger.com/.
[23] For more information, see http://www.csi-trigger.com/details.aspx?Administrator.=SCE
[24] For more information, see http://www.sce.com/EnergyProcurement/renewables/crest.htm

- On-Peak weekday summer, noon-6 pm, 3.13 x \$0.10442 = \$0.326/kWh
- Mid-Peak weekday summer, 8-noon, 6 - 11 pm, 1.35 x \$0.10442 = \$0.14/kWh
- Summer: June-September Off-Peak
- All other times 0.75 x \$0.10442 = \$0.078/kWh

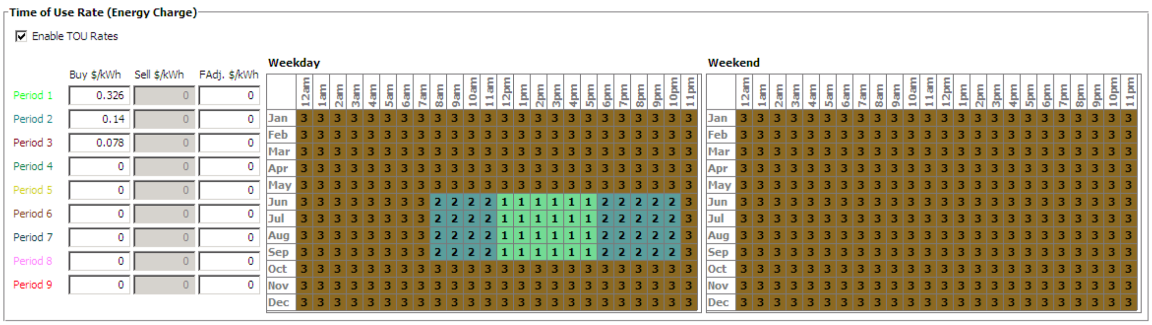


Figure 8. SAM input used to evaluate the economics of CREST versus CSI Steps 6 and 7

The NREL Solar Advisor Model (SAM) was used to evaluate the economics of CREST versus CSI Steps 6 and 7, and the SAM input is shown above. The result is that CSI Steps 6 and 7 has far better economics that CREST, and most future Step in CSI will still have better economics. This is because the CREST program provides so little high revenue. On Peak and Mid Peak times, and the cost paid during off peak are poor. Participation in the current CREST program is not recommended. For detailed results, see Appendix D.

Several options are available for getting solar PV systems financed. One potentially feasible financing option is third-party ownership under a power purchase agreement (PPA). The PPA works by having a solar contractor install, finance, and operate the system while there is a contract in place for a utility company to purchase the electricity generated by the system. The system is financed by the solar contractor, and the payments are paid by the electricity that is sold to the utility. In this arrangement, the land that the solar system occupies must be leased to the owner of the system for the duration of the contract.

5. Conclusions and Recommendations

The site locations considered for a solar PV system in this report are excellent areas in which to implement solar PV systems. Using land that cannot be used for other purposes would minimize the environmental impact of a solar generation plant. Installing a PV system on the compromised land at the site would reduce the amount of energy used to run the Stringfellow treatment plant.

It is recommended that the site facilitator, the state of California, contact SCE and attempt to set up a VNM agreement for the site. When the system goes out to bid, a design-build contract should be issued that requests the best annual output (kWh/yr) at the best price and which lets the vendors optimize system configuration, including slope and the option for single-axis tracking. For multiple reasons—the high cost of energy, the dropping cost of PV, the existence of an excellent solar resource and excellent SCE incentives—a government-owned PV system provides a reasonable payback, is easy to implement, and is therefore recommended. If funding is not available, a third- party ownership PPA arrangement is the most feasible way for a system to be financed on this site.

Appendix A. Contacts and Assessment Team Members

Environmental Protection Agency (EPA)

Lura Matthews
Center for Program Analysis
Office of Solid Waste and Emergency Response
U.S. Environmental Protection Agency
matthews.lura@epamail.epa.gov
202-566-2539

Charnjit Bhullar,
Remedial Project Manager
Region 9
U.S. Environmental Protection Agency
Bhullar.Charnjit@epamail.epa.gov
707-315-5532

State of California

Mikos Fabersunne, P.E.
Legacy Landfill and RCRA Corrective Action Office
Brownfields and Environmental Restoration Program
Department of Toxic Substances Control
8810 Cal Center Drive
Sacramento, California 95826
mfabersu@dtsc.ca.gov
916-255-6543

Allen Wolfenden, Performance Manager
San Joaquin and Legacy Landfill Office
Department of Toxic Substances Control
AWolfend@dtsc.ca.gov
916-255-6540

Tej Pahwa, P.E., Supervising Hazardous Substances Engineer I
Legacy Landfill and RCRA Corrective Action Office
Department of Toxic Substances Control
TPahwa@dtsc.ca.gov
916-255-6548

National Renewable Energy Laboratory (NREL)

Otto VanGeet, P.E.
Senior Mechanical Engineer
303-384-7369
otto.vangeet@nrel.gov

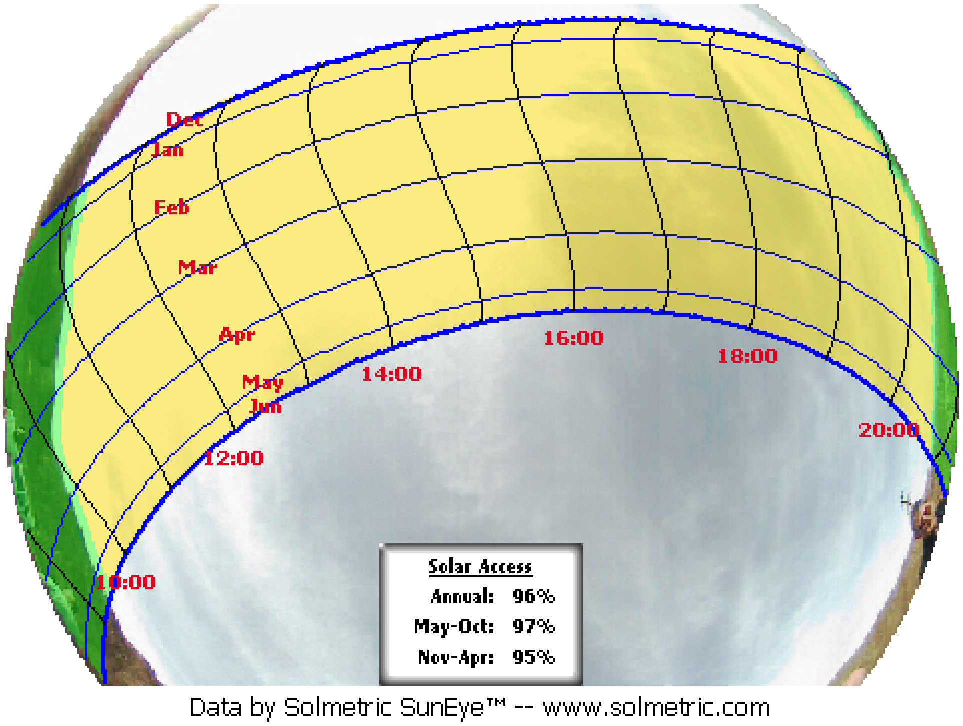
Gail Mosey, Project Manager
303-384-7356
Gail.Mosey@nrel.gov

Appendix B. Assessment Assumptions and Assumptions for Calculations

Table B-1. Cost, System, and other Assessment Assumptions

Cost Assumptions			
Variable	**Quantity of Variable**	**Unit of Variable**	
Cost of Site Electricity	0.13	$/kWh	
Annual O&M (fixed)	0.17%	% of installed cost	
Annual O&M (tracking)	0.35%	% of installed cost	
System Assumptions			
System Type	**Annual energy kWh/kW**	**Installed Cost ($/W)**	**Energy Density (W/sq. ft.)**
Ground fixed 5 acre/MW 20 degrees	1510	$5.00	4.0
Ground single-axis tracking 6 acre/MW	1775	$6.00	3.3
Other Assumptions			
	1 acre	43,560 sq ft.	
	1 MW	1,000,000 W	
	Ground Utilization	90% of available area	

Appendix C. Solar Access Measurements



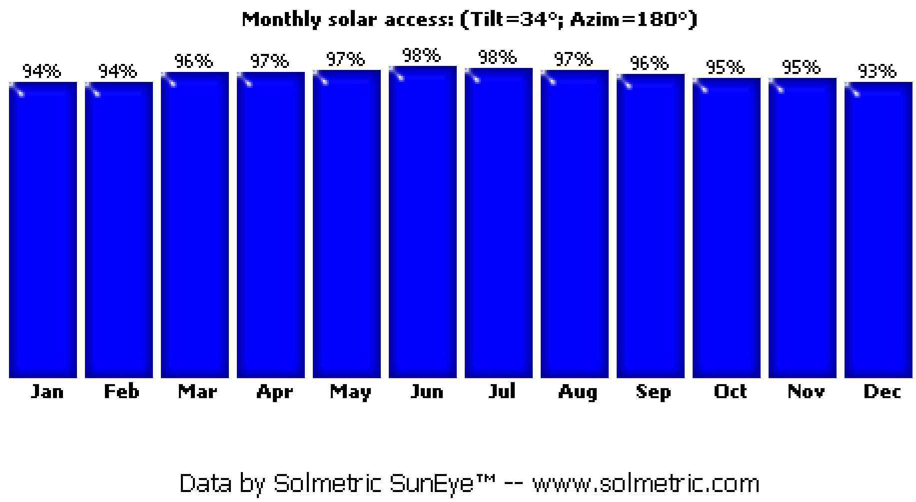


Figure B-1. Solar access measurements for proposed PV site

Appendix D. Comparison of SCE CREST to CSI Steps 6 and 7 Using the Solar Advisor Model

Year	Annual Revenue ($) Case1 (CREST)	Annual Revenue ($) Case2 (CSI6)	Annual Revenue ($) Case2 (CSI7)	NPV ($) Case1	NPV ($) Case2	NPV ($) Case3
1	81,531	259,215	212,689	77,649	246,872	202,561
2	81,531	259,215	212,689	73,951	235,116	192,916
3	81,531	259,215	212,689	70,430	223,920	183,729
4	81,531	259,215	212,689	67,076	213,257	174,980
5	81,531	259,215	212,689	63,882	203,102	166,648
6	81,531	86,405	86,405	60,840	64,477	64,477
7	81,531	86,405	86,405	57,943	61,406	61,406
8	81,531	86,405	86,405	55,184	58,482	58,482
9	81,531	86,405	86,405	52,556	55,697	55,697
10	81,531	86,405	86,405	50,053	53,045	53,045
11	81,531	86,405	86,405	47,670	50,519	50,519
12	81,531	86,405	86,405	45,400	48,114	48,114
13	81,531	86,405	86,405	43,238	45,822	45,822
14	81,531	86,405	86,405	41,179	43,640	43,640
15	81,531	86,405	86,405	39,218	41,562	41,562
16	81,531	86,405	86,405	37,351	39,583	39,583
17	81,531	86,405	86,405	35,572	37,698	37,698
18	81,531	86,405	86,405	33,878	35,903	35,903
19	81,531	86,405	86,405	32,265	34,193	34,193
20	81,531	86,405	86,405	30,728	32,565	32,565
21	81,531	86,405	86,405	29,265	31,014	31,014
22	81,531	86,405	86,405	27,872	29,538	29,538
23	81,531	86,405	86,405	26,544	28,131	28,131
24	81,531	86,405	86,405	25,280	26,791	26,791
25	81,531	86,405	86,405	24,076	25,516	25,516
Total	2,038,287	3,024,177	2,791,548	1,149,100	1,965,965	1,764,533

Appendix E. Electrical Single-Line Diagrams

Figure E-1 and E-2 show electrical single-line diagrams for the site and possible PV tie in locations.

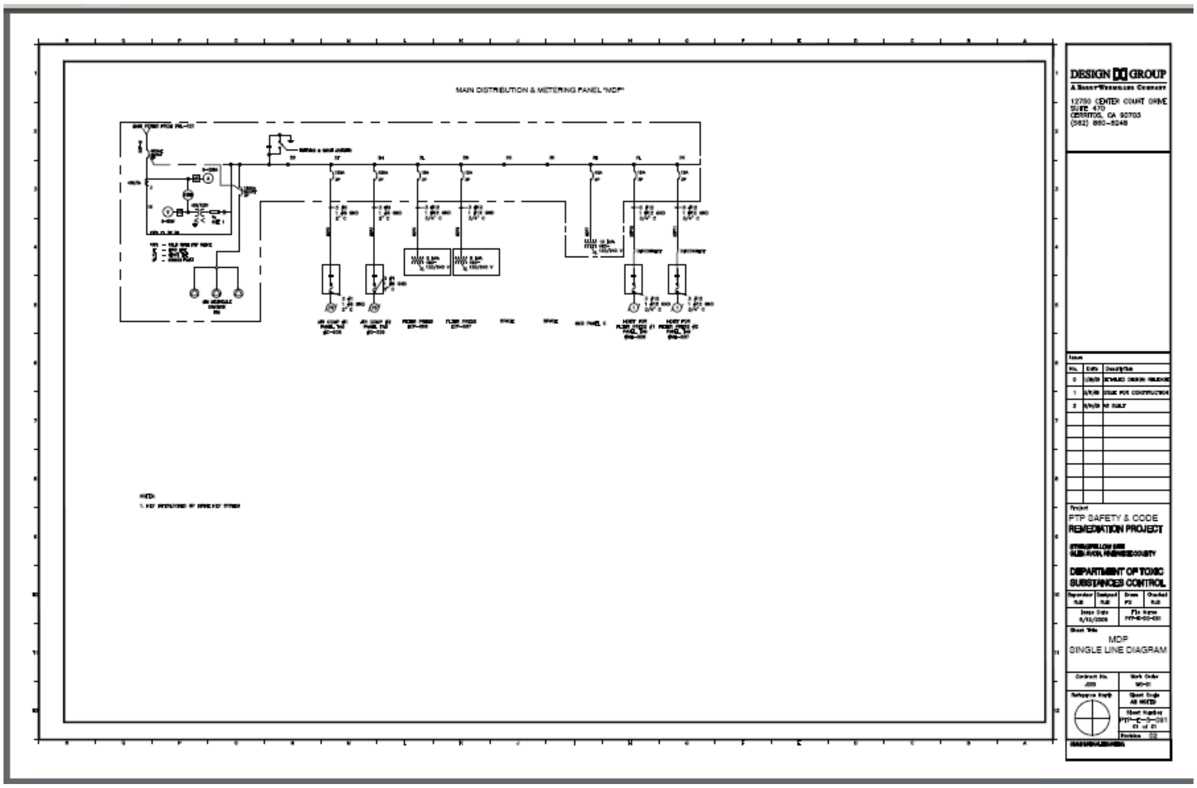


Figure E-1. The 1200-amp main distribution and metering panel "MDP" at the existing treatment plant—with spaces for possible PV tie-in

Credit: State of California

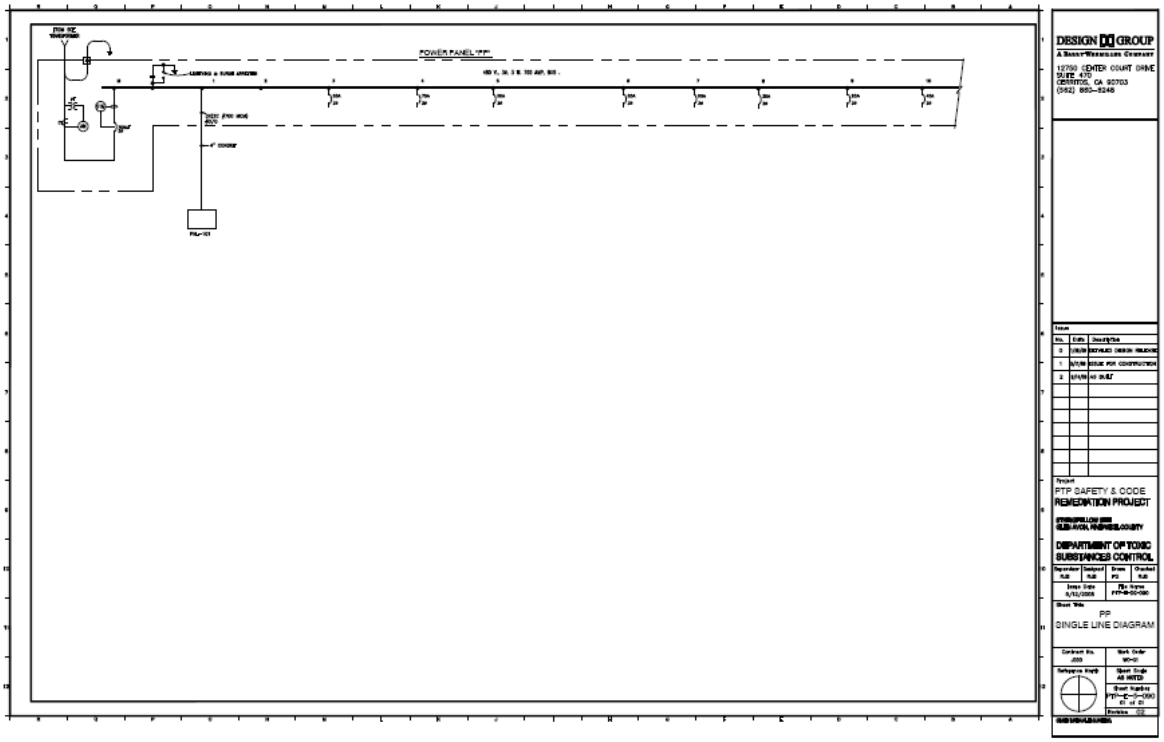


Figure E-2. The 800-amp panel "PP" at the existing treatment plant—with spaces for possible PV tie-in

Credit: State of California

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14. ABSTRACT *(Maximum 200 Words)*
This report presents the results of an assessment of the technical and economic feasibility of deploying a photovoltaics (PV) system on the Stringfellow Superfund Site in Riverside, California. The site was assessed for possible PV installations. The cost, performance, and site impacts of different PV options were estimated. The economics of the potential systems were analyzed using an electric rate of \$0.13/kWh and incentives offered by Southern California Edison under the California Solar Initiative. According to the assessment, a government-owned, ground-mounted PV system represents a technically and economically feasible option. The report recommends financing options that could assist in the implementation of such a system.

15. SUBJECT TERMS
feasibility study; solar photovoltaics; PV system; ground-mounted PV; Stringfellow Superfund Site; brownfields; cost; performance; site impacts; financial incentives; financing options; Southern California Edison; California Solar Initiative

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