APPENDIX N

Renewable Energy Feasibility Study

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Feasibility Study of Economics and Performance of Solar Photovoltaics at the Brisbane Baylands Brownfield Site in Brisbane, 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

James Salasovich, Jesse Geiger, Victoria Healey, and Gail Mosey

Produced under direction of the Environmental Protection Agency (EPA) by the National Renewable Energy Laboratory (NREL) under Interagency Agreement IAG-08-0719 and Task No. WFD3.1001.

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

Technical Report
NREL/TP-7A40-57357
April 2013
Contract No. DE-AC36-08GO28308

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List of Acronyms

AC	alternating current
BOS	balance of system
CEC	California Energy Commission
CPUC	California Public Utilities Commission
CREBL	Committee for Renewable Energy on the Baylands
DC	direct current
DOE	U.S. Department of Energy
DTSC	Department of Toxic Substances Control
ECM	energy conservation measures
EPA	U.S. Environmental Protection Agency
FTE	full-time equivalent
HVAC	heating, ventilation, air conditioning
ITC	investment tax credit
LCOE	levelized cost of energy
JEDI	Jobs and Economic Development Impact
NEG	net excess generation
NPV	net present value
NREL	National Renewable Energy Laboratory
O&M	operations and maintenance
PG&E	Pacific Gas and Electric
PPA	power purchase agreement
PV	photovoltaic
REC	renewable energy certificates
RWQCB	Regional Water Quality Control Board
SAM	System Advisor Model
SPE	special purpose entity
SSA	solar services agreement
TOU	time of use
UPC	Universal Paragon Corporation
VNM	virtual net metering
VOC	volatile organic compounds

Executive Summary

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

The Brisbane Baylands site is located in the western part of San Francisco Bay and the site is divided into two areas. The west side of the site was used by the Southern Pacific Railroad for freight rail operations from 1914 to 1960, and the east side of the site was used as a municipal landfill for household waste from the 1930s until its closure in 1967. Since the landfill closure, the site has been used as a clean fill operation for construction sites in the area.[1] The City of Brisbane and the owner of the property understand that on-site renewable energy generation will be integral to the development of the land.[2]

The feasibility of a PV system installed is highly impacted by the available area for an array, solar resource, distance to transmission lines, and distance to major roads. In addition, the operating status, ground conditions, and restrictions associated with redevelopment of the brownfield site impact the feasibility of a PV system. Based on the current assessment of these factors, the Brisbane Baylands is suitable for deployment of a large-scale PV system.

The Brisbane Baylands site is approximately 684 acres, and there are two options for developing the site that include the Universal Paragon Corporation's (UPC) "Developer Option" and the Committee for Renewable Energy on the Baylands' (CREBL) "Renewable Energy Alternative." The Developer Option has more area allotted for rooftop PV and the Renewable Energy Alternative has more area allotted for ground-mounted PV. The Developer Option has approximately 24.7 acres appropriate for installation of a ground-mounted PV system and 257.4 acres appropriate for constructing buildings, which is derived from the pre-design drawings provided by the UPC. Of the 257.4 acres available for buildings, 50% is assumed to be useable for the installation of roof-mounted PV, and the remaining 50% is assumed to be used for roads, green space, and rooftop mechanical equipment.

The Renewable Energy Alternative has approximately 134.2 acres appropriate for installation of a ground-mounted PV system and 60.7 acres appropriate for constructing buildings, which is derived from pre-design drawings provided by CREBL. Of the 60.7 acres available for buildings, 38% (1 million square feet) is assumed to be useable for the installation of roof-mounted PV, and the remaining 62% is assumed to be used for roads, green space, and rooftop mechanical equipment.

[1] http://www.brisbanebaylands.com/environmentalcleanup/. Accessed July 2012.
[2] http://www.epa.gov/oswercpa/docs/r09-11-004_brisbane.pdf. Accessed July 2012.

While this entire area does not need to be developed at one time due to the feasibility of staging installation as land or funding becomes available, calculations for this analysis reflect the solar potential if the total feasible area is used for both the Developer Option and the Renewable Energy Alternative. These options are considered the broadest range of PV implementation for the site under the two development scenarios and do not represent all of the intermediate options available. It should also be noted that the purpose of this report is not to determine how to develop the site but to investigate both options and present the results in an unbiased manner.

The economic feasibility of a potential PV system on the Brisbane Baylands site depends greatly on the purchase price of the electricity produced and incentives available to the PV project. The economics of the potential system were analyzed using the average Pacific Gas and Electric Company (PG&E) June 2012 electric rate schedule of $0.1179/kWh for commercial entities. There are currently three incentives available to the project from the state and federal levels. Table ES-1 shows the current incentives considered with the incentive amount and the indicated ending criteria for each incentive.

Table ES-1. Summary of Incentives Evaluated[3]

Incentive Title	Modeled Value	Expected End
California Property Tax Incentive	100% of Property Value	12/31/2016
California Solar Initiative	$0.025/kWh	Re-funded in 12/2011
Business Energy Investment Tax Credit (ITC)	30% of installed cost	12/31/2016

The community net-metering incentive was not included in the feasibility study but will certainly improve economics if developed further. The California Energy Commission's (CEC) New Solar Home Partnership was excluded from the analysis because its applicability is uncertain. If this option were pursued and attained, the economics for each scenario would greatly improve. The combined quantitative amounts for these incentives are applied to each scenario in Table ES-2.

All scenarios considered for the site were economically attractive; the Renewable Energy Alternative scenario with a single-axis tracking PV system for the ground-mounted portion has the highest net present value (NPV). Table ES-2 summarizes the system performance and economics of a potential system that would use all available areas that were surveyed at the Brisbane Baylands site. Each scenario in the table includes the maximum utilized roof area associated with the specified development option and the specified ground-mounted system. The table shows the annual energy output from the system along with the number of average American households that could be powered by such a system and estimated job creation.

As indicated in Table ES-2, the different systems are expected to have a payback of 12.68–13.72 years and an NPV of $1.5 million to $4.1 million for a 23–28 MW PV system producing

[3] DSIRE: Database of State Incentives for Renewables and Efficiency. http://www.dsireusa.org/. Accessed July 2012.

approximately 42.4–45 GWh annually. This includes the current cost of energy, expected installation cost, site solar resource, and existing incentives for the proposed PV system. This savings and payback is deemed reasonable and as such, a solar PV system represents a viable reuse for the site.

Table ES-2. Brisbane Baylands PV System Summary

Tie-In Location	System Type	PV System Size[a] (kW)	Array Tilt (deg)	Annual Output (kWh/year)	Number of Houses Powered[b]	Jobs Created[c] (job-year)	Jobs Sustained[d] (job-year)
	Renewable Energy Alternative Rooftop PV System	4,000	20	6,018,006	1,056	101	1
	Renewable Energy Alternative Fixed Axis Ground Mounted System	23,380	20	35,175,244	6,171	590	7
	Crystalline Silicon (Fixed-Axis Ground System) - Renewable Energy Alternative, Developer Owned	27,380	20	43,129,543	7,567	691	8
	Renewable Energy Alternative Rooftop PV System	4,000	20	6,018,006	1,056	101	1
	Renewable Energy Alternative 1-Axis Ground Mounted System	19,281	20	37,007,662	6,493	649	6
	Crystalline Silicon (1-Axis Ground System) - Renewable Energy Alternative, Developer Owned	23,281	20	44,961,961	7,888	750	7
	Developer Rooftop PV System	23,876	20	35,921,477	6,302	603	7
	Developer Fixed Axis Ground Mounted System	4,303	20	6,473,870	1,136	109	1
	Crystalline Silicon (Fixed-Axis Ground System) - Developer Option, Developer Owned	28,179	20	42,395,347	7,438	711	9
	Developer Rooftop PV System	23,876	20	35,921,477	6,302	603	7
	Developer 1-Axis Ground Mounted System	3,548	20	6,809,978	1,195	119	1
	Crystalline Silicon (1-Axis Ground System) - Developer Option, Developer Owned	27,424	20	42,731,455	7,497	722	8

Tie-In Location	System Type	System Cost	Maximum Incentive Amount	PPA Price ¢/kWh	Net Present Value 2012$	Annual O&M ($/year)	Payback Period with Incentives (years)
	Renewable Energy Alternative Rooftop PV System	$ 13,690,000	$ 4,840,444	13.25	$ 169,556	$ 108,889	13.89
	Renewable Energy Alternative Fixed Axis Ground Mounted System	$ 75,066,000	$ 26,806,783	13.06	$ 1,375,151	$ 636,453	13.69
	Crystalline Silicon (Fixed-Axis Ground System) - Renewable Energy Alternative, Developer Owned	$ 88,756,000	$ 31,883,213	13.09	$ 1,544,707	$ 745,342	13.72
	Renewable Energy Alternative Rooftop PV System	$ 13,690,000	$ 4,840,444	13.25	$ 169,556	$ 109,749	13.89
	Renewable Energy Alternative 1-Axis Ground Mounted System	$ 77,990,992	$ 27,907,606	11.92	$ 3,942,864	$ 529,019	12.43
	Crystalline Silicon (1-Axis Ground System) - Renewable Energy Alternative, Developer Owned	$ 91,680,992	$ 32,984,037	12.11	$ 4,112,420	$ 638,768	12.68
	Developer Rooftop PV System	$ 80,473,360	$ 28,519,938	13.05	$ 1,406,007	$ 620,776	13.69
	Developer Fixed Axis Ground Mounted System	$ 14,708,080	$ 5,201,427	13.23	$ 188,405	$ 111,878	13.87
	Crystalline Silicon (Fixed-Axis Ground System) - Developer Option, Developer Owned	$ 95,181,440	$ 33,721,365	13.08	$ 1,594,412	$ 732,654	13.72
	Developer Rooftop PV System	$ 80,473,360	$ 28,519,938	13.05	$ 1,406,007	$ 620,776	13.69
	Developer 1-Axis Ground Mounted System	$ 14,555,536	$ 5,196,627	12.09	$ 660,859	$ 92,248	12.60
	Crystalline Silicon (1-Axis Ground System) - Developer Option, Developer Owned	$ 95,028,896	$ 33,716,565	12.90	$ 2,066,866	$ 713,024	13.55

a Data assume a maximum usable area of 684 acres

b Number of average American households that could hypothetically be powered by the PV system assuming 5,700 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.

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1 Study and Site Background

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

The Brisbane Baylands is located in Brisbane, California, which is located by the western San Francisco Bay. Brisbane has a population of 4,282 as of the 2010 U.S. Census. Brisbane has a coastal temperate climate with limited temperature variations throughout the day. The summers are mild with temperatures typically in the 60^{o}F range, and the winters are cool with temperatures in the 50^{o}F range. The winters tend to have the most precipitation. Brisbane has on average 261 days of sunshine each year. Pacific Gas & Electric (PG&E) is the utility that provides electricity to Brisbane; it is a regulated utility.

The Brisbane Baylands site is approximately 684 acres and is located to the north of the town and on the west side of the San Francisco Bay with the California State Highway 101 to the east and the Caltrain light rail running down the center of the site. There are two options for developing the site that include the Universal Paragon Corporation's (UPC) "Developer Option" and the Committee for Renewable Energy on the Baylands' (CREBL) "Renewable Energy Alternative." The Developer Option has more area allotted for rooftop PV and the Renewable Energy Alternative has more area allotted for ground-mounted PV.

The west side of the site was used by the Southern Pacific Railroad for freight rail operations from 1914 to 1960, and the east side of the site was used as a municipal landfill for household waste from the 1930s until its closure in 1967. Since the landfill closure, the site has been used as a clean fill operation for construction sites in the area.[4] The City of Brisbane and the owner of the property, UPC, are interested in developing this underused land as a mixed-use community that has adequate access to regional transportation and on-site renewable energy generation.[5]

The area to the west of the Caltrain line that was used by the Southern Pacific Railroad is contaminated with petroleum products, heavy metals, and volatile organic compounds (VOC). The northern portion of this area has VOC groundwater contamination, while the southern portion of this area has contaminated soil caused by petroleum hydrocarbons. The area to the east of the Caltrain line that was used as a household landfill contains no hazardous waste. This area was used for 35 years to dispose of household, commercial, and shipping waste and to also dispose of construction debris and sewage. The San Mateo County Health Services Agency – Environmental Health Division, the California

[4] http://www.brisbanebaylands.com/environmentalcleanup/. Accessed July 2012.
[5] http://www.epa.gov/oswercpa/docs/r09-11-004_brisbane.pdf. Accessed July 2012.

Regional Water Quality Control Board (RWQCB), the Department of Toxic Substances Control (DTSC), and the City of Brisbane have jurisdiction over this area. This area is currently covered with 30 feet of clean fill dirt and is used for the disposal of clean construction debris.[6] All of the seepage that flows through the site flows toward the lagoon is pumped and treated. There is methane gas production at the site, which is currently flared, and the amount of methane gas being produced is declining.

The closest electrical tie-in location is at the PG&E Martin Substation at 3150 Geneva Avenue, Brisbane, California. The substation is located right across the street from the Brisbane Baylands site, which could make it an ideal interconnection location for a PV system. A detailed interconnection study will need to be performed through PG&E to determine the feasibility of utilizing the Martin Substation as a tie-in point for a PV system. The site is planned to have buildings, but the extent of the build-out has not been determined. The buildings on the site are potential off-takers of the electricity produced by a PV system.

Feasibility assessment team members from NREL, the City of Brisbane, UPC, and EPA conducted a site visit on Tuesday, January 31, 2012, to gather information integral to this feasibility study. The team considered information such as solar resource, transmission availability, community acceptance, and ground conditions.

[6] http://www.brisbanebaylands.com/environmentalcleanup/. Accessed August 2012.

2 Development of a PV System on Brownfields

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

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

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

The Brisbane Baylands is owned by UPC, which is interested in potential revenue flows on the site. For many brownfield sites, the local community has significant interest in the redevelopment of the site, and community engagement is critical to match future reuse options to the CREBL vision for the site. For the Brisbane site, the vision of the community group does not completely align with the vision of the developer, but both parties have similar interests in having buildings on the site along with on-site renewable energy generation. The purpose of this study is to analyze both 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. The City Solar project in Chicago, Illinois, is the largest urban PV system in the United States and is built on a brownfield site. The brownfield site is a former industrial site that had been vacant for 30 years. The 41-acre site is owned by the City of Chicago, who leases the land to a solar developer. The City Solar project was completed in 2010 and is a 10-MW single-axis tracking system.[7]

The subject site has potential to be used for other functions beyond the solar PV systems proposed in this report. Any potential use should align with the community's vision for the site and should work to enhance the overall value of the property. There is potential to build residential, commercial, and light industrial buildings on the site as the community sees fit. There is also the potential to create open space areas and parks. The potential to utilize the methane gas for energy production could be investigated. It should be noted that there is a 30-meter tower at the site with an anemometer, and a detailed wind feasibility study was done at the site using over one year's worth of wind data collected at

[7] http://www.exeloncorp.com/PowerPlants/exeloncitysolar/Pages/Profile.aspx. Accessed July 2012.

the site. The study determined that large-scale wind is not feasible at the Brisbane Baylands site.

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

- Renewable energy sources offer a sustainable energy option in the broader energy portfolio
- Renewable energy can have a net positive effect on human health and the environment
- Deployment of renewable energy bolsters national energy independence and increases domestic energy security
- Fluctuating electric costs can be mitigated by locking in electricity rates through long-term power purchase agreements (PPAs) linked to renewable energy systems
- Generating energy without harmful emissions or waste products can be accomplished through renewable energy sources.

3 PV Systems

3.1 PV Overview

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

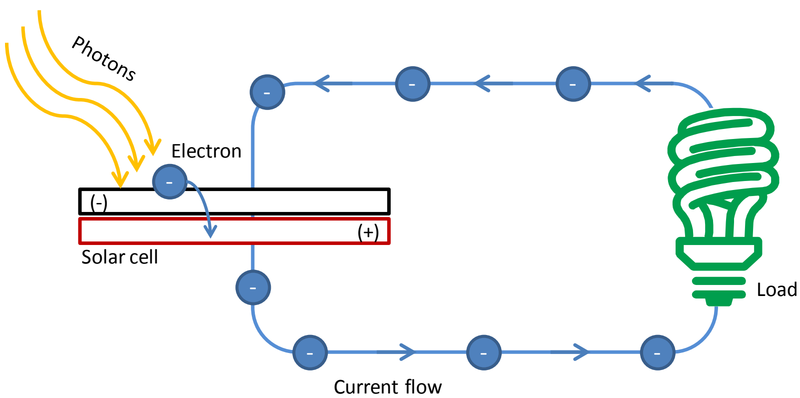

Figure 1. Generation of electricity from a PV cell

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

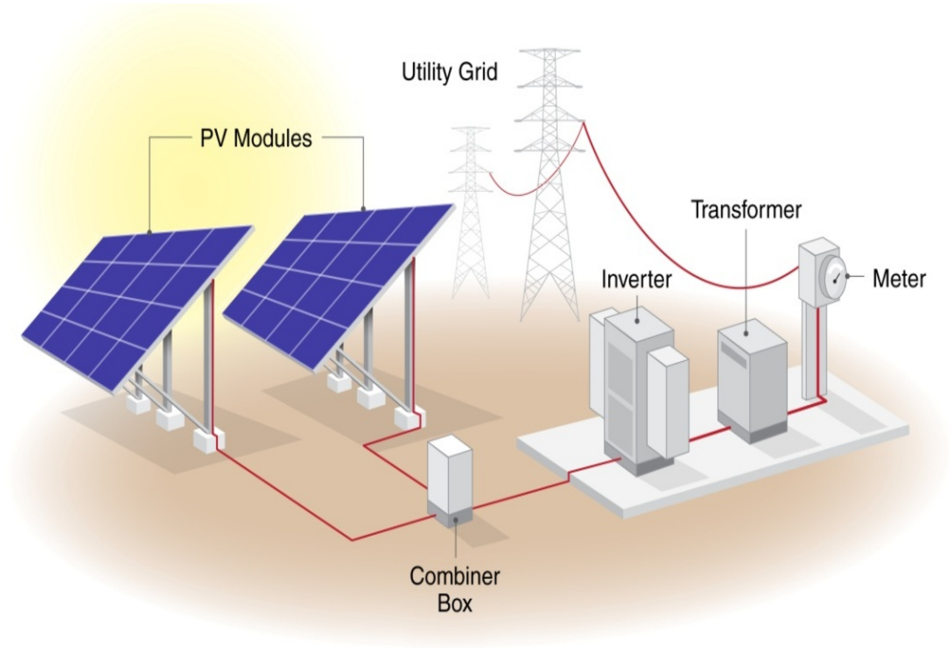

Figure 2. Ground-mounted array diagram

Source: NREL

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

- PV modules
- Inverter
- Balance-of-system (BOS) components (e.g., mounting system and wiring).

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. This technology builds on a strong industry on both material supply (silicon industry) and the product maturity 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 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 by (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 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 systems.

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 by (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 due to a fault condition, 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 could be recommended for different types of installations.

String inverters are most common and typically range in size from 1.5–1,000 kW. These inverters tend to be cheaper on a capacity basis and provide high efficiency and lower operations 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 between 5 and 10 years with 10 years being the current industry standard. On larger units, extended warranties up to 20 years are possible. Given that the expected life of the PV panels is 25–30 years, an operator can expect to replace a string inverter at least one time during the life of the PV system.

Micro-inverters are dedicated to the conversion of a single PV module's power output. The AC output from each module is connected in parallel to create the array. This technology is relatively new to the market and in limited use in larger systems due to 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 10–20 years. Small projects with irregular modules and shading issues typically benefit from micro-inverters.

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

Figure 5. String inverter. ***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 the PV panels are 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. Energy Density by Panel and System

System Type	Fixed-Tilt Energy Density ($DC\text{-}Watts/ft^2$)	Single-Axis Tracking Energy Density ($DC\text{-}Watts/ft^2$)
Crystalline Silicon	4.0	3.3
Thin Film	3.3	2.7
Hybrid High Efficiency	4.8	3.9

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 wind and seismic zones.

3.2.3.1.2 Roof-Mounted Systems

At the Brisbane site, both the Renewable Energy Alternative and the Developer Option have available roof area for PV. 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, 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 at the Brisbane site indicates a significant number of new construction buildings. There are many relatively easy low-cost/no-cost measures that can be taken during the design phase so that the buildings 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, can be taken to optimize rooftop PV systems.[8]

[8] A solar-ready design guide was published in order to help design teams optimize rooftop PV systems when designing buildings, and this guide can be found at http://www.nrel.gov/docs/fy10osti/46078.pdf.

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

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 produced 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 with large-scale PV 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. Inverters, which come standard with a 5-year or 10-year warranty (extended warranties available), would be expected to last 10–15 years. System performance should be verified on a vendor-provided website. Wire and rack connections should be checked annually. This economic analysis uses an annual O&M cost computed as $20/kW/yr, which is based on the historical O&M costs of installed fixed-axis, grid-tied PV systems. In addition, a replacement of system inverters can be expected 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 assessing shading, 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 January 31, 2012.

4.1 Brisbane Baylands Site PV System

As discussed in Section 1, the Brisbane Baylands site is under the jurisdiction of the San Mateo County Health Services Agency - Environmental Health Division, RWQCB, DTSC, and the City of Brisbane.

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

The Brisbane Baylands Site is approximately 684 acres and is relatively flat, but some grading will be necessary in some areas to accommodate a PV system. The entire site could be feasible for PV after any remediation measures are completed. There are two options for developing the site that include UPC's "Developer Option" and CREBL's "Renewable Energy Alternative." The Developer Option has more area allotted for rooftop PV, and the Renewable Energy Alternative has more area allotted for ground-mounted PV. While this entire area does not need to be developed at one time due to the feasibility of staging installation as land or funding becomes available, calculations for this analysis reflect the solar potential if the total feasible area is used for both the Developer Option and the Renewable Energy Alternative. It should be noted that the purpose of this report is not to determine how to develop the site but to investigate both options and present the results in an unbiased manner.

Figure 6 shows an aerial view of the Developer Option for the Brisbane Baylands site. The proposed area for ground-mounted PV is shaded in yellow; the proposed area for commercial and light industrial building rooftop PV is shaded in orange; and the proposed area for residential building rooftop PV is shaded in red. These proposed areas are based on design drawings provided by UPC.

Figure 6. Aerial view of the Developer Option, showing proposed areas for PV at the Brisbane Baylands site (ground-mounted PV in yellow; commercial/retail/light industrial rooftop PV in orange; residential rooftop PV in red)

Illustration done in Google Earth

As shown, there are large expanses of relatively flat, un-shaded land, which makes it a suitable candidate for a ground-mounted PV system. There are also large expanses of possible un-shaded rooftop area, which makes it a suitable candidate for rooftop PV systems. The proposed area of the site for ground-mounted PV has an area of 24.7 acres. The proposed area of the site that is available for commercial/retail/light industrial buildings has an area of 189.5 acres, and the area that is available for residential buildings has an area of 84.6 acres. For the areas that are available for buildings, it is assumed that 50% of the available area would be useable for rooftop PV. The remaining 50% of this area is assumed to be made up of roads, green space, and rooftop mechanical equipment.

Figure 7 shows an aerial view of the Renewable Energy Alternative, as proposed by CREBL, for the Brisbane Baylands site. The proposed area for ground-mounted PV is shaded in yellow; and the proposed area for commercial and light industrial building rooftop PV is shaded in orange. The proposed areas designated for ground-mounted and rooftop PV are based on design drawings provided by CREBL.

Figure 7. Aerial view of the Renewable Energy Alternative feasible area for PV at the Brisbane Baylands site (ground-mounted PV in yellow; commercial and light industrial rooftop PV in orange)

Illustration done in Google Earth

Under the Renewable Energy Alternative development plan, the proposed area of the site for ground-mounted PV has an area of 134.2 acres, while the proposed area of the site for commercial and light industrial buildings has an area of 60.7 acres. For the areas that are available for buildings, it is assumed that 38% of the available area would be useable for rooftop PV, which translates to approximately 1 million square feet of roof area for PV. The remaining 62% of this area is assumed to be made up of roads, green space, and rooftop mechanical equipment.

PV systems are well suited to the Brisbane, 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 5.45 kWh/m^2/day.

Figure 8 shows various views of the Brisbane Baylands site.

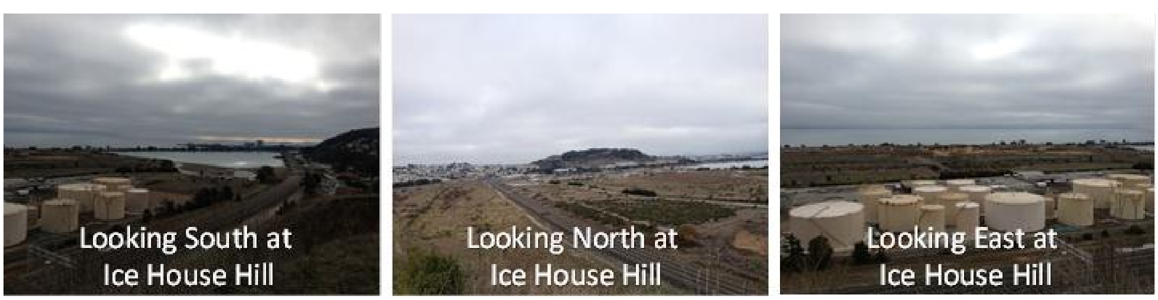

Figure 8. Views of the feasible area for PV at the Brisbane Baylands site. ***Photos by Jimmy Salasovich, NREL***

4.2 Utility Resource Considerations

The closest electrical tie-in location is at the PG&E Martin Substation at 3150 Geneva Avenue, Brisbane, California. The location of the PG&E Martin Substation in relation to the Brisbane Baylands Site is provided in Figure 9. As shown, the substation is located right across the street from the Brisbane Baylands site, which could make it an ideal location for a PV system interconnection. A detailed interconnection study will have to be performed through PG&E to determine the feasibility of utilizing the Martin Substation as a tie-in point for a PV system. The site plans to have buildings, but the extent of the build-out has not been determined. The buildings on the site are potential off-takers of the electricity produced by a PV system.

Figure 9. Location of PG&E Martin Substation in relation to the Brisbane Baylands site

Illustration done in Google Earth

4.3 Useable Acreage for PV System Installation

Typically, a minimum of 2 useable acres is recommended to site large-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 area (e.g., a parking lot or industrial site space, as well as existing building rooftops).

4.4 PV Site Solar Resource

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

The assessment team for this feasibility study collected multiple Solmetric SunEye data points and found a solar access of 90% or higher. Solar access is the amount of un-shaded time at the point of measurement over the course of the year. A 90% solar access number indicates that 10% of the year there will be shading at the point of measurement when the sun is out. The locations for each measurement are intended to capture the highest shading for an entire site. All data gathered using this tool is available in Appendix B.

The predicted array performance was found using PVWatts Version 2[9] for Brisbane, California. 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.

Table 3. Site Identification Information and Specifications

Station Identification	
Cell ID	174347
State	California
Latitude	37.7° N
Longitude	122.4° W
PV System Specifications	
DC Rating	1.00 kW
DC-to-AC Derate Factor	0.8
AC Rating	0.8 kW
Array Type	Fixed Tilt
Array Tilt	20°
Array Azimuth	180°
Energy Specifications	
Cost of Electricity	$0.1179/kWh

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

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

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

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	3.07	72	8.49
2	4.08	87	10.26
3	4.90	116	13.68
4	6.01	137	16.15
5	6.61	158	18.63
6	7.09	161	18.98
7	7.26	170	20.04
8	6.65	155	18.27
9	6.05	135	15.92
10	4.87	113	13.32
11	3.70	83	9.79
12	3.04	71	8.37
Year	5.28	1,459	172.02

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

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

Month	Solar Radiation ($kWh/m^2/day$)	AC Energy (kWh)	Energy Value ($)
1	3.66	87	10.26
2	5.01	109	12.85
3	6.13	148	17.45
4	7.61	176	20.75
5	8.47	205	24.17
6	9.00	207	24.41
7	9.33	221	26.06
8	8.50	201	23.70
9	7.65	174	20.51
10	6.10	143	16.86
11	4.50	103	12.14
12	3.69	89	10.49
Year	6.65	1,863	219.65

4.5 Brisbane Baylands Energy Usage

The Brisbane Baylands 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 aid a full analysis of whether or not energy produced would need to be sold or if it could offset on-site energy use.

4.5.1 Current Energy Use

There are currently buildings on the site that use electricity. No current electricity usage or cost data was available for the site. There are plans to build out the site with office, light industrial, residential, and retail buildings.

4.5.2 Estimated Future Energy Use and Net-Zero Energy Potential

4.5.2.1 Developer Option

The future energy use of the buildings on the site could be estimated by creating building energy models of the various building types, which include commercial, light industrial, retail, and residential. It is important to note that buildings were assumed to be all electric buildings and to be very energy efficient buildings with tight construction, low lighting and equipment energy use, and with air-source heat pump systems. The estimated total building area of the site build-out is 14 million square feet. The breakdown of the building area by building type was estimated to be 56% commercial buildings, 6% light industrial buildings, 7% retail buildings, and 31% residential buildings. Using the energy models of the various building types, the total annual energy use of the site is estimated to be 72,000 MWh/yr. In order for the site to be net-zero, a 50.5-MW, fixed-tilt PV system would have to be installed to offset the energy us of the buildings. This is larger than the available area on the site.

4.5.2.2 Renewable Energy Alternative Option

The future energy use of the buildings on the site could be estimated by creating building energy models of the various building types, which include commercial and light industrial buildings. It is important to note that buildings were assumed to be all electric buildings and to be very energy efficient buildings with tight construction, low lighting and equipment energy use, and with air-source heat pump systems. The estimated total building area of the site build-out is 1 million square feet. The breakdown of the building area by building type was estimated to be 46% commercial building, 46% light industrial buildings, 8% retail buildings, and 0% residential buildings. Using the energy models of the various building types, the total annual energy use of the site is estimated to be 5,800 MWh/yr. In order for the site to be net-zero, a 4.1-MW, fixed-tilt PV system would have to be installed to offset the energy us of the buildings.

4.5.3 Net Metering

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

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

California's net-metering law,[10] which took effect in 1996, requires utilities to offer net metering to all customers with solar and wind-energy systems up to 1 MW.

Renewable energy certificates (RECs),[11] 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 (i.e., renewable electricity). The RECs that are associated with the electricity produced and are used on site remain with the customer-generator. If, however, the customer chooses to receive financial compensation for the net excess generation (NEG) remaining after a 12-month period, the utility will be granted the RECs associated with only that surplus they purchase.

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 California Public Utilities Commission (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 could 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 and are subject to TOU 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.

4.5.4 Virtual Net Metering

Some states and utilities allow for virtual net metering (VNM). This arrangement can allow certain entities, such as a local government, to install renewable generation 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. California Assembly Bill 2466 (AB 2466),[12] 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.[13]

The California State Legislature defined local government to include cities, counties, school districts, special districts, political subdivisions, or other local public agencies that

[10] For the full text of this bill see, http://www.dsireusa.org/incentives/incentive.cfm?Incentive_Code=CA02R&re=1&ee=1.
[11] For a description of RECs, see http://apps3.eere.energy.gov/greenpower/markets/certificates.
[12] California Legislature. Assembly Bill No. 2466. (Apr. 28, 2010). Accessed May 1, 2012: http://www.leginfo.ca.gov/pub/09-10/bill/asm/ab_2451-2500/ab_2466_bill_20100428_amended_asm_v98.pdf.
[13] For more information about VNM, see http://www.pge.com/b2b/newgenerator/ab2466/.

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. However, PG&E could allow VNM if they choose to. The PG&E customer representative for the site customer should be asked if VNM is an option.

If PG&E allows 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 PG&E connection. 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.

5 Economics and Performance

The economic performance of a PV system installed on the site was 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 NREL's System Advisor Model (SAM).[14]

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. 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, solar water heating, wind, and geothermal power systems. SAM also provides economic estimates for distributed energy and central generation projects, economic calculations for both projects that buy and sell power at retail rates, and power projects that sell power through a PPA. The model calculates the cost of generating electricity based on information the user provides about a project's location, installation and operating costs, type of financing, applicable tax credits and incentives, and system specifications.

5.1 Assumptions and Input Data for Analysis

Cost of a PV system depends on the system size and other factors, such as geographic location, mounting structure, and type of PV module. Based on significant cost reductions seen in 2011, the average cost for utility-scale ground-mounted systems have declined from $4.80/W in the first quarter of 2010 to $2.79/W in the first quarter of 2012. With an increasing demand and supply, potential for further cost reduction is expected as market conditions evolve.

The installed system cost assumptions for this analysis are summarized in Table 6. These costs represent high remediation-consideration cost case scenarios for PV installation price on EPA brownfields.

Table 6. Installed System Cost Assumptions

System Type	Fixed-Tilt ($/Wp)	Single-Axis Tracking ($/Wp)
Baseline system	3.20	3.84

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. The site remediation costs are also included. The assumed system costs include estimated taxes and a national-average labor rate but does not include land cost. The cost for electrical tie-in was also

[14] For additional information on the System Advisor Model, see https://sam.nrel.gov/cost.

modeled at $500,000. The economics of grid-tied PV depend on incentives, the cost of electricity, the solar resource, and panel tilt and orientation.

For this analysis, it was assumed that relevant federal 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 could 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. See www.dsireusa.org for the most up to date 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. The electrical utility PG&E is expected to supply energy to the site under the A-10 General Demand rate schedule. This schedule is, on average over the year, $0.11789/kWh as of June 2012. For the sale of electricity, the site is expected to be able to sell the electricity produced over the demand of the site at an average rate of $0.09528/kWh. Because there is no current demand on site, we modeled that all PV generated electricity would be sold to PG&E at the sale rate. Once there is a demand on site, the benefits of a PV system will greater than what is presented below. For the purposes of modeling how much PV could cover rooftops, we assumed that with intentional design, 50% of the developed land space could contain PV. This roof coverage assumption is based on industry experience in new development. PVWatts Version 2 was used to calculate expected energy performance for the system.

The full list of incentives used in this study can be found on Table 7. The California Energy Commission (CEC) - New Solar Homes Partnership and the California community net-metering incentives were not included in this study.

Table 7. Summary of Incentives Evaluated

Incentive Title	Modeled Value	Expected End
California Property Tax Incentive	100% of property value	12/31/2016
California Solar Initiative	$0.025/kWh	Re-funded in 12/2011
Business Energy Investment Tax Credit (ITC)	30% of installed cost	31-Dec-16

5.2 SAM-Forecasted Economic Performance

SAM predicts NPV, PPA target price, and levelized cost of energy (LCOE), among other economic indicators. According to the modeling software with the given assumptions, every scenario for solar development is economically viable. When solely considering the solar options, and no other site development opportunities, the single-axis ground-mounted Renewable Energy Alternative has the highest NPV. Similarly, the single-axis option is the best option with a third-party solar investor. All of the different options have pros and cons, which will play in deciding the correct path forward. These advantages and disadvantages are discussed below. Table 8 shows the results from the different options.

Table 8. Results Summary of Simulations

Cases	LCOE ($/kWh)	NPV	PPA ($/kWh)
Crystalline Silicon (Fixed-Tilt) -Renewable Energy Alternative	$0.0781	$1,544,707	$0.1309
Crystalline Silicon (Single-Axis) -Renewable Energy Alternative	$0.0728	$4,112,420	$0.1211
Crystalline Silicon (Fixed-Tilt) –Developer's Option	$0.0655	$1,594,412	$0.1308
Crystalline Silicon (Single-Axis) – Developer's Option	$0.0771	$2,066,866	$0.1290

A total of eight scenarios were run for the Brisbane development site to encompass the many options available to this site. The independent variables include: CREBL and developer site recommendations; fixed and single-axis tracking for the ground portion; and third-party developer versus site developer ownership. There are multiple factors that go into choosing which scenario to pursue beyond the NPV, PPA, and LCOE.

5.2.1 Fixed-Axis Versus Single-Axis Tracking

For the Brisbane site, there are two area types that could contain solar panels: roof and ground space. Fixed-axis panels will be the system used for all covered roof space regardless of how the ground space is utilized. According to the simulations, single-axis tracking for the ground-mounted system will provide the best payback for a slightly lower LCOE. Installation costs could vary from the model due to availability of installers and equipment and could change the scenario favorability. Under current assumptions, it is the recommendation of the feasibility study to pursue a single-axis system for the ground-mounted portions of the Brisbane development site.

The single-axis tracking system is able to gather a significantly greater portion of the sun's energy but requires a greater amount of land than a fixed-axis system of the same size. The fixed-axis system gathers less solar energy, but more panels can be packed together than single-axis tracking. The fixed-axis tracking system is also economically feasible but not as favorable as the single-axis panels. If the fixed-axis price were to drop to about $0.97 below the single-axis price, the fixed-axis tracking system would become more favorable from a NPV basis.

5.2.2 Solar Investor Versus Developer Owned

The choice between going with a solar investor or developer ownership will depend on the desire for involvement and the risk appetite of the developer. While ownership of the system will bring a high-value payback for the developer, it will also require hiring the contractors to permit, build, and maintain the system. A solar investor inherits that risk and profit, and the developer in turn will purchase a significant portion of the power for the Brisbane development at a lower rate than offered by the utility, PG&E. It is recommended by the feasibility study group for the developer to own the system, considering the high value that could be gained from incentives. The site would need to acquire a PPA price for less than the PG&E utility cost and have the demand to make use of the PV-generated electricity.

5.2.3 Renewable Energy Alternative Versus Developer Option

The site currently has two development options being proposed: the Renewable Energy Alternative and Developer options. The major difference between these two options is the area available for ground-mounted solar PV and substituted for roof space. The annual system production is similar in both cases despite this difference. The applicability of the CEC New Solar Homes incentive to the project would greatly shift the favorability toward the Developer's Option with the fixed-axis tracking ground system.

The entire results and summary of inputs to SAM is provided in Appendix D.

A summary of the results of the economic analysis and the system considered is provided in Table 9.

Table 9. PV System Summary

Tie-In Location	System Type	PV System Size[a] (kW)	Array Tilt (deg)	Annual Output (kWh/year)	Number of Houses Powered[b]	Jobs Created[c] (job-year)	Jobs Sustained[d] (job-year)
	Renewable Energy Alternative Rooftop PV System	4,000	20	6,018,006	1,056	101	1
	Renewable Energy Alternative Fixed Axis Ground Mounted System	23,380	20	35,175,244	6,171	590	7
	Crystalline Silicon (Fixed-Axis Ground System) - Renewable Energy Alternative, Developer Owned	27,380	20	43,129,543	7,567	691	8
	Renewable Energy Alternative Rooftop PV System	4,000	20	6,018,006	1,056	101	1
	Renewable Energy Alternative 1-Axis Ground Mounted System	19,281	20	37,007,662	6,493	649	6
	Crystalline Silicon (1-Axis Ground System) - Renewable Energy Alternative, Developer Owned	23,281	20	44,961,961	7,888	750	7
	Developer Rooftop PV System	23,876	20	35,921,477	6,302	603	7
	Developer Fixed Axis Ground Mounted System	4,303	20	6,473,870	1,136	109	1
	Crystalline Silicon (Fixed-Axis Ground System) - Developer Option, Developer Owned	28,179	20	42,395,347	7,438	711	9
	Developer Rooftop PV System	23,876	20	35,921,477	6,302	603	7
	Developer 1-Axis Ground Mounted System	3,548	20	6,809,978	1,195	119	1
	Crystalline Silicon (1-Axis Ground System) - Developer Option, Developer Owned	27,424	20	42,731,455	7,497	722	8

Tie-In Location	System Type	System Cost	Maximum Incentive Amount	PPA Price ¢/kWh	Net Present Value 2012$	Annual O&M ($/year)	Payback Period with Incentives (years)
	Renewable Energy Alternative Rooftop PV System	$ 13,690,000	$ 4,840,444	13.25	$ 169,556	$ 108,889	13.89
	Renewable Energy Alternative Fixed Axis Ground Mounted System	$ 75,066,000	$ 26,806,783	13.06	$ 1,375,151	$ 636,453	13.69
	Crystalline Silicon (Fixed-Axis Ground System) - Renewable Energy Alternative, Developer Owned	$ 88,756,000	$ 31,883,213	13.09	$ 1,544,707	$ 745,342	13.72
	Renewable Energy Alternative Rooftop PV System	$ 13,690,000	$ 4,840,444	13.25	$ 169,556	$ 109,749	13.89
	Renewable Energy Alternative 1-Axis Ground Mounted System	$ 77,990,992	$ 27,907,606	11.92	$ 3,942,864	$ 529,019	12.43
	Crystalline Silicon (1-Axis Ground System) - Renewable Energy Alternative, Developer Owned	$ 91,680,992	$ 32,984,037	12.11	$ 4,112,420	$ 638,768	12.68
	Developer Rooftop PV System	$ 80,473,360	$ 28,519,938	13.05	$ 1,406,007	$ 620,776	13.69
	Developer Fixed Axis Ground Mounted System	$ 14,708,080	$ 5,201,427	13.23	$ 188,405	$ 111,878	13.87
	Crystalline Silicon (Fixed-Axis Ground System) - Developer Option, Developer Owned	$ 95,181,440	$ 33,721,365	13.08	$ 1,594,412	$ 732,654	13.72
	Developer Rooftop PV System	$ 80,473,360	$ 28,519,938	13.05	$ 1,406,007	$ 620,776	13.69
	Developer 1-Axis Ground Mounted System	$ 14,555,536	$ 5,196,627	12.09	$ 660,859	$ 92,248	12.60
	Crystalline Silicon (1-Axis Ground System) - Developer Option, Developer Owned	$ 95,028,896	$ 33,716,565	12.90	$ 2,066,866	$ 713,024	13.55

a Data assume a maximum usable area of 684 acres

b Number of average American households that could hypothetically be powered by the PV system assuming 5,700 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.

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.[15] JEDI estimates the economic impacts associated with the construction and operation of distributed generation power plants. It is a flexible input-output tool that

[15] The JEDI models have 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.

estimates, but does not precisely predict, the number of jobs and magnitude of economic impacts that can be reasonably created 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 procure and install the complete system.

For this analysis, inputs, including the estimated installed project cost ($/kW), targeted year of construction, system capacity (kW), O&M costs ($/kW), and location, were entered into the model to predict the jobs and economic impact. 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 Baylands site, the values in Table 10 were used from the Renewable Energy Alternative, which has the highest impact on the local economy during construction.

Table 10. JEDI Analysis Assumptions

Input	Assumed Value
Capacity	19,281 kW
Placed-In-Service Year	2013
Installed System Cost	$76,847,002
Location	Brisbane, CA

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 of full-time equivalent (FTE) positions. An FTE is defined as 40 hours per week for one person for one 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 C, the total proposed system is estimated to support 649 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 $32,979,500 and total economic output is estimated to be $88,363,500. The annual O&M of the new PV system is estimated to support 5.8 FTEs per year for the life of the system. The jobs and associated spending are projected to account for approximately $332,600 in earnings and $615,100 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 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 do not 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 to 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 their 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 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 turn-key system cost minus the 30% federal tax credit or can purchase the services in annual installments. The municipality may buy out the system once the third party has accrued the tax credits, but due to IRS regulations, the buyout of the plant cannot be included as part of the SSA (i.e., the SSA cannot be used as a vehicle for a sale and must be a separate transaction).

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

5.4.6 Sale/Leaseback

In the widely accepted sale/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.

5.4.7 Community Solar/Solar Gardens

The concept of "community solar" is one in which the costs and benefits of one large solar project are shared by a number of participants. A site owner may be able to make the land available for a large solar project, which can be the basis for a community solar project. Ownership structures for these projects vary, but the large projects are typically owned or sponsored by a local utility. Community solar gardens are distributed solar projects wherein utility customers have a stake via a prorated share of the project's energy output. This business model is targeted to meet demand for solar projects by customers who rent/lease homes or businesses, do not have good solar access at their site, or do not want to install a solar system on their facilities.

Customer prorated shares of solar projects are acquired through a long-term transferrable lease of one or more panels, or they subscribe to a share of the project in terms of a specific level of energy output or the energy output of a set amount of capacity. Under the customer lease option, the customer receives a billing credit for the number of kilowatt-hours their prorated share of the solar project produces each month; it is also known as VNM. Under the customer subscription option, the customers typically pay a set price for a block of solar energy (i.e., 100 kWh per-month blocks) from the community solar project. Other models include monthly energy outputs from a specific investment dollar amount, or a specific number of panels.

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

There are some states that offer solar incentives for community solar projects, including Washington State (production incentive) and Utah (state income tax credit). Community solar is known as solar gardens depending on the location (e.g., Colorado).

6 Conclusions and Recommendations

The inclusion of PV in the development is an economically feasible project, with many different options that will be practical and match the building plans. Installing a PV system on the Brisbane development site could potentially generate nearly 45,000 MWh annually and represents nearly half of the expected load from the Developer's Option.

As summarized in section 5, the SAM economic analysis predicts an NPV and LCOE of greater than $1.54 million and less than $0.0780/kWh, respectively, for the different cases of developer ownership. In a solar investor/PPA case, the starting year PPA price is modeled to be less than $0.1309/kWh in the first year.

When considering only the economics of installing a PV system, the best scenario economically is the single-axis ground system in the Renewable Energy Alternative, in which the expected payback period is 12.68 years and could produce the majority of electricity needed for the proposed site. This feasibility study does not comment on the viability of other development projects on site. The modeled scenarios do not include the community net-metering incentive or the CEC new solar homes incentive. All systems were favorable without these incentives, and their inclusion will only make the economics better.

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	0.1179	\$/kWh	
Annual O&M (fixed)	20	\$/kW/year	
System Assumptions			
System Type	**Annual energy kWh/kW**	**Installed Cost (\$/W)**	**Energy Density (W/sq. ft.)**
Ground Fixed	1,459	\$3.20	4.0
Ground Single-Axis	1,733	\$3.85	3.3
Other Assumptions			
	1 acre	43,560 ft^2	
	1 MW	1,000,000 W	
	Ground utilization	90% of available area	

Appendix B. Solar Access Measurements

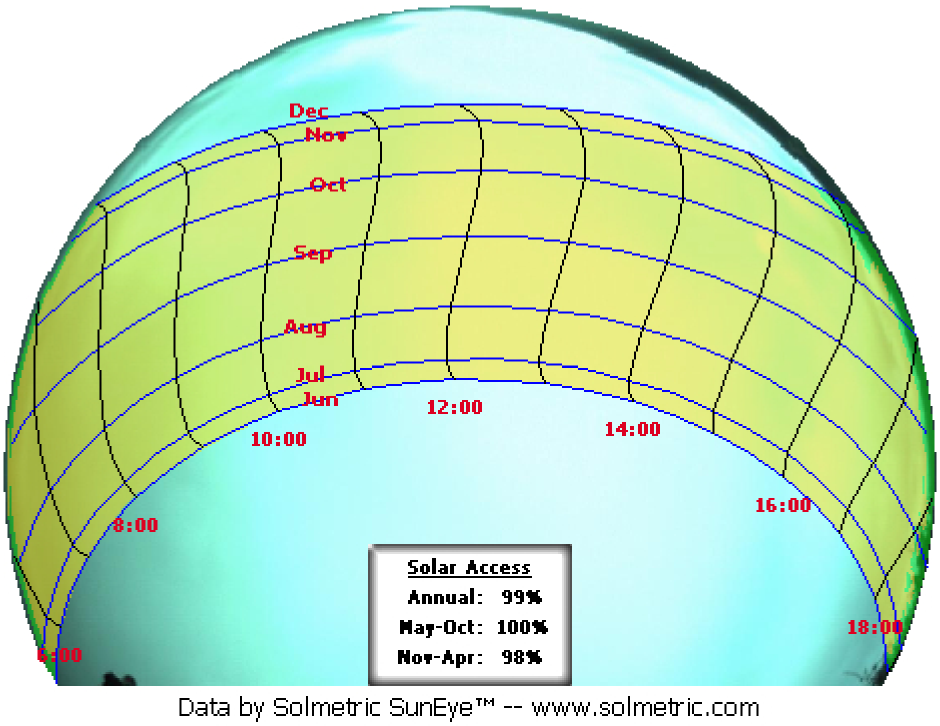

Figure B-1. Solar access measurements for Brisbane Baylands PV site

Appendix C. Results of the JEDI Model

Table C-1. JEDI Project Data Summary

Project Location	CALIFORNIA
Year of Construction or Installation	2013
Average System Size - DC Nameplate Capacity (KW)	19,281.0
Number of Systems Installed	1
Project Size - DC Nameplate Capacity (KW)	19,281.0
System Application	Utility
Solar Cell/Module Material	Crystalline Silicon
System Tracking	Single Axis
Total System Base Cost ($/KW$_{DC}$)	$3,986
Annual Direct Operations and Maintenance Cost ($/kW	$20.00
Money Value - Current or Constant (Dollar Year)	2012
Project Construction or Installation Cost	$76,847,002
Local Spending	$42,811,099
Total Annual Operational Expenses	$8,986,874
Direct Operating and Maintenance Costs	$385,620
Local Spending	$354,770
Other Annual Costs	$8,601,254
Local Spending	$12,725
Debt Payments	$0
Property Taxes	$0

Table C-2. JEDI Local Economic Impacts Summary

	Jobs	Earnings	Output
During construction and installation period		**$000 (2012)**	**$000 (2012)**
Project Development and Onsite Labor Impacts			
Construction and Installation Labor	88.7	$5,742.1	
Construction and Installation Related Services	148.9	$6,986.5	
Subtotal	237.5	$12,728.6	$22,993.8
Module and Supply Chain Impacts			
Manufacturing Impacts	0.0	$0.0	$0.0
Trade (Wholesale and Retail)	30.6	$1,823.5	$5,489.1
Finance, Insurance and Real Estate	0.0	$0.0	$0.0
Professional Services	43.9	$2,209.3	$7,491.0
Other Services	74.2	$5,429.8	$18,810.3
Other Sectors	91.5	$2,966.3	$5,786.8
Subtotal	240.2	$12,429.0	$37,577.4
Induced Impacts	171.4	$7,821.9	$27,792.3
Total Impacts	**649.1**	**$32,979.5**	**$88,363.5**
		Annual	**Annual**
	Annual	**Earnings**	**Output**
During operating years	**Jobs**	**$000 (2012)**	**$000 (2012)**
Onsite Labor Impacts			
PV Project Labor Only	3.6	$214.9	$214.9
Local Revenue and Supply Chain Impacts	1.2	$71.0	$234.4
Induced Impacts	1.0	$46.7	$165.8
Total Impacts	**5.8**	**$332.6**	**$615.1**

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 may not add up due to independent rounding.

Table C-3. JEDI Detailed PV Project Data Costs

	CALIFORNIA	Purchased	Manufactured
Installation Costs	**Cost**	**Locally (%)**	**Locally (Y or N)**
Materials & Equipment			
Mounting (rails, clamps, fittings, etc.)	$3,966,019	100%	N
Modules	$25,332,065	100%	N
Electrical (wire, connectors, breakers, etc.)	$970,486	100%	N
Inverter	$3,767,333	100%	N
Subtotal	$34,035,903		
Labor			
Installation	$5,742,113	100%	
Subtotal	$5,742,113		
Subtotal	$39,778,016		
Other Costs			
Permitting	$403,919	100%	
Other Costs	$8,926,610	100%	
Business Overhead	$24,930,495	100%	
Subtotal	$34,261,024		
Subtotal	$74,039,040		
Sales Tax (Materials & Equipment Purchases)	$2,807,962	100%	
Total	$76,847,002		

Table C-4. JEDI PV System Annual Operation and Maintenance Costs

	Cost	Local Share	Manufactured Locally (Y or N)
Labor			
Technicians	$231,372	100%	
Subtotal	$231,372		
Materials and Services			
Materials & Equipment	$154,248	100%	N
Services	$0	100%	
Subtotal	$154,248		
Sales Tax (Materials & Equipment Purchases)	$12,725	100%	
Average Annual Payment (Interest and Principal)	$8,588,529	0%	
Property Taxes	$0	100%	
Total	$8,986,874		
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	8.25%	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%	

Appendix D. Results of the System Advisor Model

Table D-1. SAM 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 internal rate of return	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 investment tax credit	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	

Item	PPA/Investor	Municipal Purchase	Notes
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 E. Building Energy Modeling

Building energy modeling was used to estimate the energy use of the proposed building types, which include commercial office, light industrial, retail, and residential buildings. Because none of the proposed buildings at the Brisbane Baylands site have been designed, the building geometry, construction, lighting, equipment, and HVAC systems were all assumed. eQUEST was selected as the building simulation software tool to perform the energy modeling of this site. eQUEST is a commercially available interface for the DOE-2 hourly building energy simulation program originally developed by the DOE. The program is capable of evaluating energy and energy cost savings that can be achieved by applying energy conservation measures (ECMs), such as improved envelope components, passive heating and cooling strategies, lighting system improvements, and HVAC system improvements. The software is commonly used to analyze new construction buildings and building retrofits. eQUEST requires a detailed description of the building envelope (for thermal and optical properties), internal loads, operating schedules, lighting and HVAC system requirements, and utility rate schedules. The major benefits of eQUEST include the ease of defining building geometry, space characteristics, schedules, HVAC systems, and running parametric analyses to study design and retrofit options. Another major benefit of eQUEST is the relatively short simulation run-times.

eQUEST building energy models of the four proposed major building types at the Brisbane Baylands site were created. The building construction, lighting, equipment, and operating condition of HVAC systems was modeled assuming that the buildings would have advanced energy efficiency features and each of the buildings would be all-electric buildings that use air-source heat pump systems. The four building types that were modeled, which include commercial office, light industrial, retail, and residential, are described in detail in the sections below.

Brisbane Baylands Commercial Office Building Energy Model

A sample commercial office building was modeled in eQUEST. A graphical representation of the building energy model developed in eQUEST is shown in Figure E-1. The geometry of the building was assumed because none of the commercial office buildings on the Brisbane Baylands site have been designed.

Brisbane Commercial Office Building
Sample Building Energy Model
5 floors - 100,000 ft^2

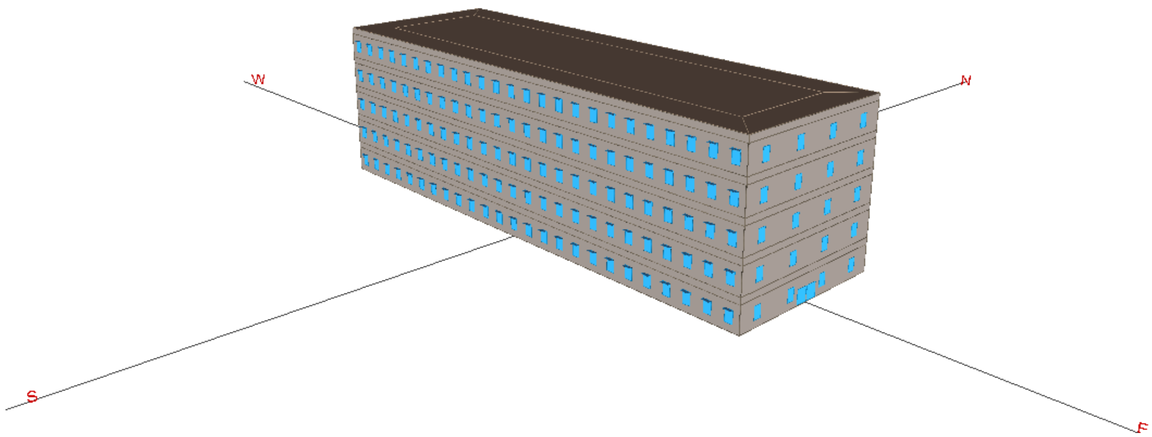

Figure E-1. Brisbane Baylands commercial office-building eQUEST model representation

The NREL team assumed advanced energy-efficient building design to develop the eQUEST model of the sample commercial office building. The general facility characteristics that were modeled are provided in Table E-1.

Table E-1. Brisbane Baylands Commercial Office Building eQUEST Summary Information

Brisbane Baylands commercial office building – Brisbane, CA		
Project		
	Weather Data	TMY2 - San Francisco, CA
	Building Type	Office Building
	Total Number of Buildings Modeled	1
	Building Areas	100,000 ft^2
	Above Grade Floors	5
	Below Grade Floors	0
Building Footprint		
	Building Orientation	Plan North
	Zoning Pattern	Perimeter/core
	Floor-to-Floor Height	15 ft
	Floor-to-Ceiling Height	12 ft
	Roof Pitch	0 deg
Roof		
	Construction	Steel framed
	Roof	Metal
	Insulation	4” Polyisocyanurate (R-28)
Walls		
	Construction	4” Concrete
	Finish	Stone
	Insulation	2” Polystyrene (R-9) continuous R-21 batts
Ground Floor		
	Earth Contact	8” Concrete
Infiltration		
	Perimeter	0.10 (CFM/ft^2)
Floors		
	Interior Finish	Carpet
	Construction	6” Concrete
	Concrete Cap	None
Exterior Doors		
	Door Type	Double pane glass
Exterior Windows		
	Window Type	Double pane glass U-0.28, SHGC 0.6, Tvis 0.6
Building Operation		
	Schedule	8 hours/day, 5 days/week
	Area Type	Office, conference rooms, corridors, restrooms
Power Density		

Brisbane Baylands commercial office building – Brisbane, CA		
	Lighting	0.8 W/ft^2 Daylighting Controls
	Plug Loads	0.35 W/ft^2
HVAC Systems		
	System Type	Air-source heat pump
	System Cooling Source	Heat pump – 14 EER
	Economizer	Temperature/enthalpy based
	Heating System	Heat pump – COP 4.0
	Thermostat	Occupied / Unoccupied Cooling - 73°F / 82°F Heating - 70°F / 64°F
Fan Schedules		
	Operation Schedule	10 hours/day, 5 days/week

Figure E-2 presents the eQUEST output for the Brisbane Baylands commercial office-building energy model. As shown, lighting energy uses the most energy, followed by equipment energy and ventilation fans.

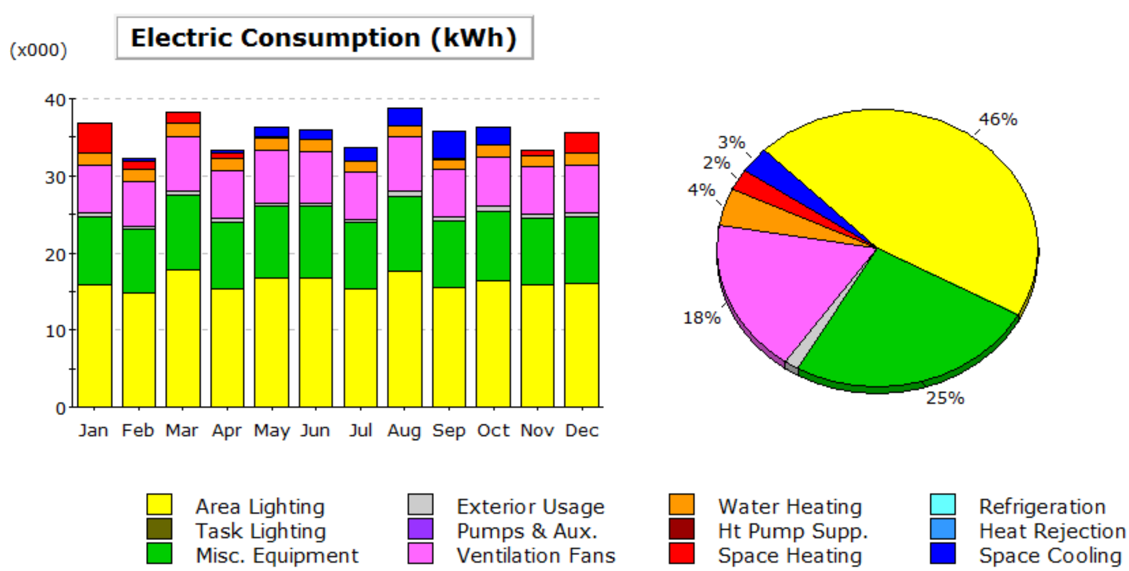

Figure E-2. Brisbane Baylands commercial-office eQUEST results for annual energy use

Brisbane Baylands Light-Industrial Building Energy Model

A sample light industrial building was modeled in eQUEST. A graphical representation of the building energy model developed in eQUEST is shown in Figure E-3. The geometry of the building was assumed because none of the light industrial buildings on the Brisbane Baylands site have been designed.

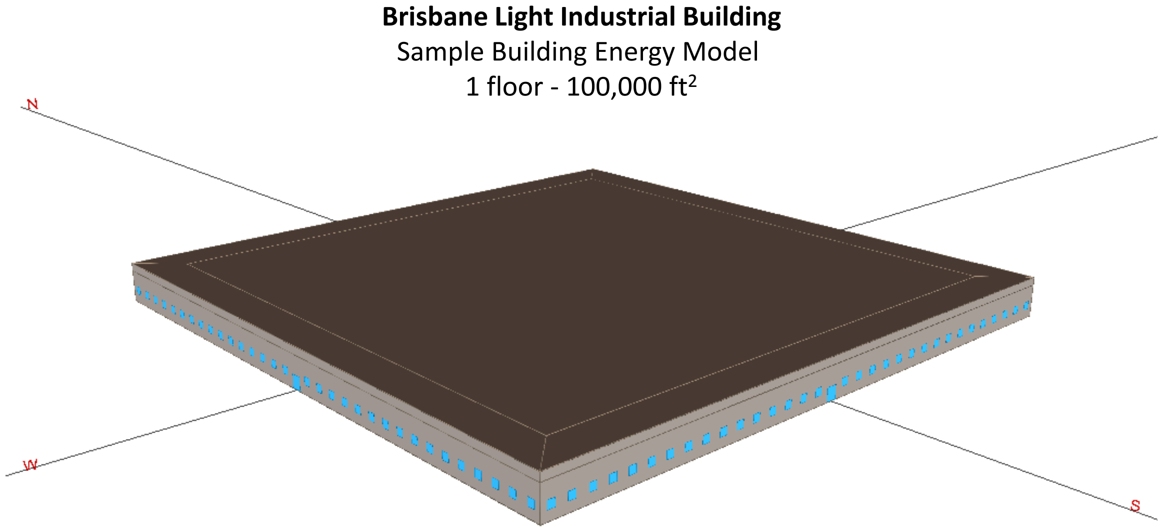

Figure E-3. Brisbane Baylands light-industrial building eQUEST model representation

The NREL team assumed advanced energy-efficient building design to develop the eQUEST model of the sample light industrial building. The general facility characteristics that were modeled are provided in Table E-2.

Table E-2. Brisbane Baylands Light-Industrial Building eQUEST Summary Information

Brisbane Baylands light industrial building – Brisbane, CA		
Project		
	Weather Data	TMY2 - San Francisco, CA
	Building Type	Light industrial building
	Total Number of Buildings Modeled	1
	Building Areas	100,000 ft^2
	Above Grade Floors	1
	Below Grade Floors	0
Building Footprint		
	Building Orientation	Plan North
	Zoning Pattern	Perimeter/core
	Floor-to-Floor Height	20 ft
	Floor-to-Ceiling Height	16 ft
	Roof Pitch	0 deg
Roof		
	Construction	Steel framed
	Roof	Built up roof
	Insulation	4” Polyisocyanurate (R-28)
Walls		
	Construction	Metal frame
	Finish	Metal
	Insulation	2” Polystyrene (R-9) continuous R-21 batts
Ground Floor		
	Earth Contact	8” Concrete
Infiltration		
	Perimeter	0.10 (CFM/ft^2)
Floors		
	Interior Finish	No finish
	Construction	8” Concrete
	Concrete Cap	None
Exterior Doors		
	Door Type	Double pane glass
Exterior Windows		
	Window Type	Double pane glass U-0.28, SHGC 0.6, Tvis 0.6
Building Operation		
	Schedule	8 hours/day, 5 days/week
	Area Type	Light manufacturing, office, corridors, restrooms
Power Density		

Brisbane Baylands light industrial building – Brisbane, CA		
	Lighting	0.8 to 1.5 W/ft^2 Daylighting Controls
	Plug Loads	0.35 to 2.0 W/ft^2
HVAC Systems		
	System Type	Air-source heat pump
	System Cooling Source	Heat pump – 14 EER
	Economizer	Temperature/enthalpy based
	Heating System	Heat pump – COP 4.0
	Thermostat	Occupied / Unoccupied Cooling - 73^{o}F / 82^{o}F Heating - 70^{o}F / 64^{o}F
Fan Schedules		
	Operation Schedule	10 hours/day, 5 days/week

Figure E-4 presents the eQUEST output for the Brisbane Baylands light-industrial building energy model. As shown, lighting energy uses the most energy, followed by equipment energy and ventilation fans.

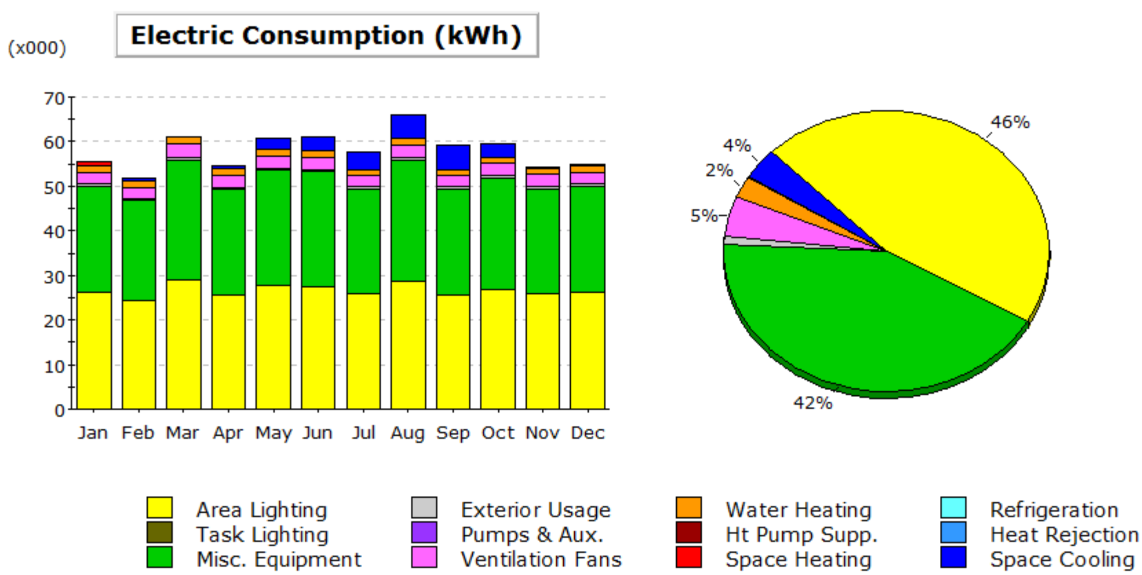

Figure E-4. Brisbane Baylands light-industrial eQUEST results for annual energy use

Brisbane Baylands Retail-Building Energy Model

A sample retail building was modeled in eQUEST. A graphical representation of the building energy model developed in eQUEST is shown in Figure E-5. The geometry of the building was assumed because none of the retail buildings on the Brisbane Baylands Site have been designed.

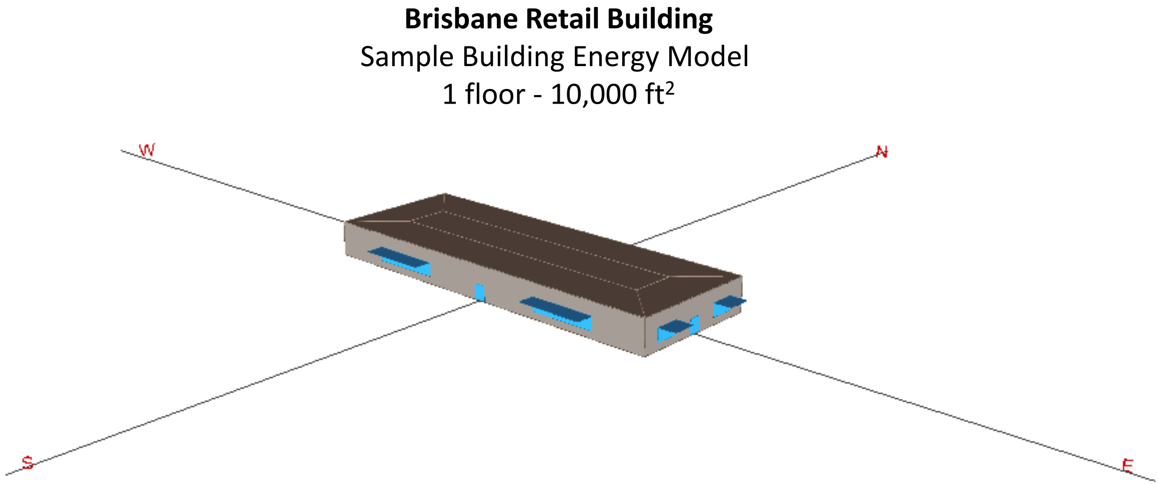

Figure E-5. Brisbane Baylands retail-building eQUEST model representation

The NREL team assumed advanced energy-efficient building design to develop the eQUEST model of the sample retail building. The general facility characteristics that were modeled are provided in Table E-3.

Table E-3. Brisbane Baylands Retail-Building eQUEST Summary Information

Brisbane Baylands retail building – Brisbane, CA		
Project		
	Weather Data	TMY2 - San Francisco, CA
	Building Type	Retail building
	Total Number of Buildings Modeled	1
	Building Areas	10,000 ft^2
	Above Grade Floors	1
	Below Grade Floors	0
Building Footprint		
	Building Orientation	Plan North
	Zoning Pattern	Perimeter/core
	Floor-to-Floor Height	15 ft
	Floor-to-Ceiling Height	15 ft
	Roof Pitch	0 deg
Roof		
	Construction	Steel framed
	Roof	Metal roof
	Insulation	4" Polyisocyanurate (R-28)
Walls		
	Construction	Metal frame
	Finish	Metal
	Insulation	2" Polystyrene (R-9) continuous R-21 batts
Ground Floor		
	Earth Contact	8" Concrete
Infiltration		
	Perimeter	0.10 (CFM/ft^2)
Floors		
	Interior Finish	No finish
	Construction	8" Concrete
	Concrete Cap.	None
Exterior Doors		
	Door Type	Double pane glass
Exterior Windows		
	Window Type	Double pane glass U-0.28, SHGC 0.6, Tvis 0.6
Building Operation		
	Schedule	12 hours/day, 7 days/week
	Area Type	Retail
Power Density		

Brisbane Baylands retail building – Brisbane, CA		
	Lighting	1.2 to 1.6 W/ft^2 Daylighting Controls
	Plug Loads	0.25 W/ft^2
HVAC Systems		
	System Type	Air-source heat pump
	System Cooling Source	Heat pump – 14 EER
	Economizer	Temperature/enthalpy based
	Heating System	Heat pump – COP 4.0
	Thermostat	Occupied / Unoccupied Cooling - 73°F / 82°F Heating - 70°F / 64°F
Fan Schedules		
	Operation Schedule	14 hours/day, 7 days/week

Figure E-6 presents the eQUEST output for the Brisbane Baylands retail-building energy model. As shown, lighting energy uses the most energy, followed by equipment energy and ventilation fans.

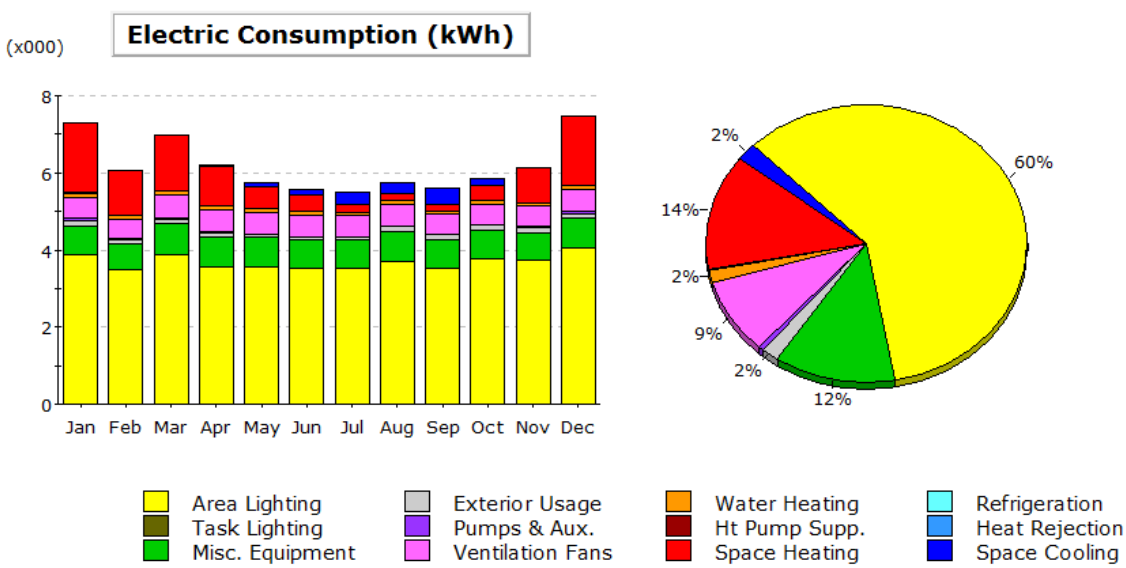

Figure E-6. Brisbane Baylands retail-building eQUEST results for annual energy use

Brisbane Baylands Residential-Building Energy Model

A sample multi-family residential building was modeled in eQUEST. A graphical representation of the building energy model developed in eQUEST is shown in Figure E-7. The geometry of the building was assumed because none of the residential buildings on the Brisbane Baylands Site have been designed.

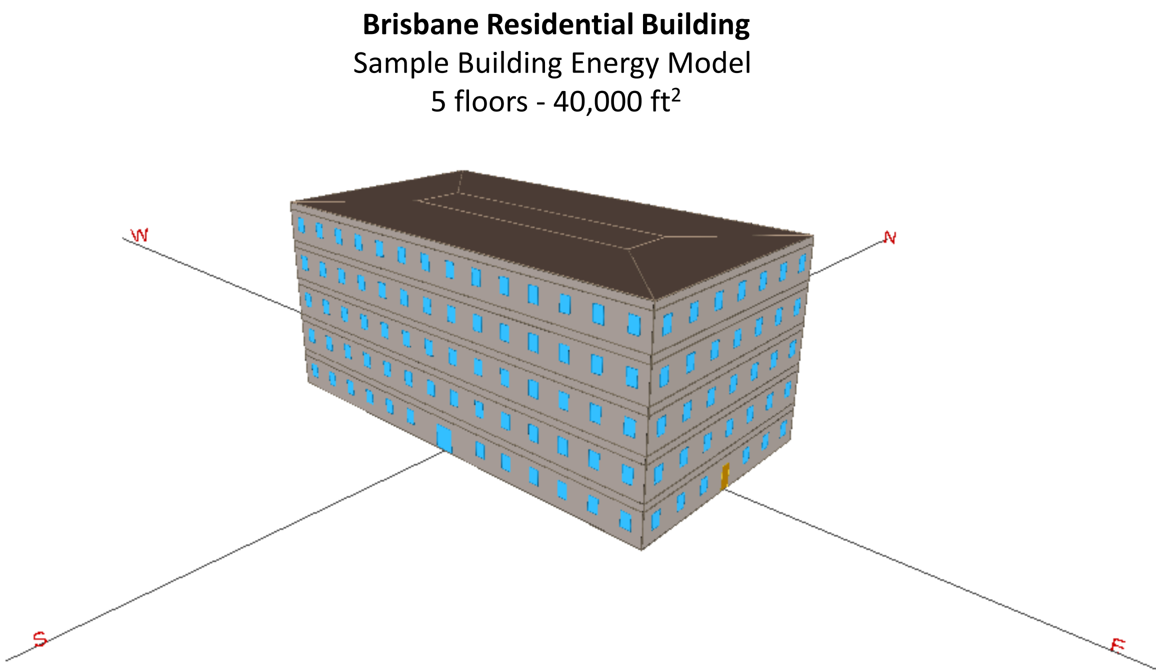

Figure E-7. Brisbane Baylands residential-building eQUEST model representation

The NREL team assumed advanced energy-efficient building design to develop the eQUEST model of the sample multi-family residential building. The general facility characteristics that were modeled are provided in Table E-4.

Table E-4. Brisbane Baylands Residential-Building eQUEST Summary Information

Brisbane Baylands residential building – Brisbane, CA		
Project		
	Weather Data	TMY2 - San Francisco, CA
	Building Type	Multi-family residential building
	Total Number of Buildings Modeled	1
	Building Areas	40,000 ft^2
	Above Grade Floors	5
	Below Grade Floors	0
Building Footprint		
	Building Orientation	Plan North
	Zoning Pattern	Perimeter/core
	Floor-to-Floor Height	11 ft
	Floor-to-Ceiling Height	9 ft
	Roof Pitch	0 deg
Roof		
	Construction	Steel framed
	Roof	Metal roof
	Insulation	4” Polyisocyanurate (R-28)
Walls		
	Construction	Metal frame
	Finish	Metal
	Insulation	2” Polystyrene (R-9) continuous R-21 batts
Ground Floor		
	Earth Contact	8” Concrete
Infiltration		
	Perimeter	0.10 (CFM/ft^2)
Floors		
	Interior Finish	No finish
	Construction	8” Concrete
	Concrete Cap	None
Exterior Doors		
	Door Type	Double pane glass
Exterior Windows		
	Window Type	Double pane glass U-0.28, SHGC 0.6, Tvis 0.6
Building Operation		
	Schedule	14 hours/day, 7 days/week Away from 7:00 am to 5:00 pm
	Area Type	Residential
Power Density		

Brisbane Baylands residential building – Brisbane, CA		
	Lighting	0.5 to 0.8 W/ft^2
	Plug Loads	0.15 to 0.3 W/ft^2
HVAC Systems		
	System Type	Air-source heat pump
	System Cooling Source	Heat pump – 14 EER
	Economizer	Temperature/enthalpy based
	Heating System	Heat pump – COP 4.0
	Thermostat	Occupied / Unoccupied Cooling - 73°F / 82°F Heating - 70°F / 64°F
Fan Schedules		
	Operation Schedule	14 hours/day, 7 days/week

Figure E-8 presents the eQUEST output for the Brisbane Baylands residential-building energy model. As shown, lighting energy uses the most energy, followed by equipment energy and ventilation fans.

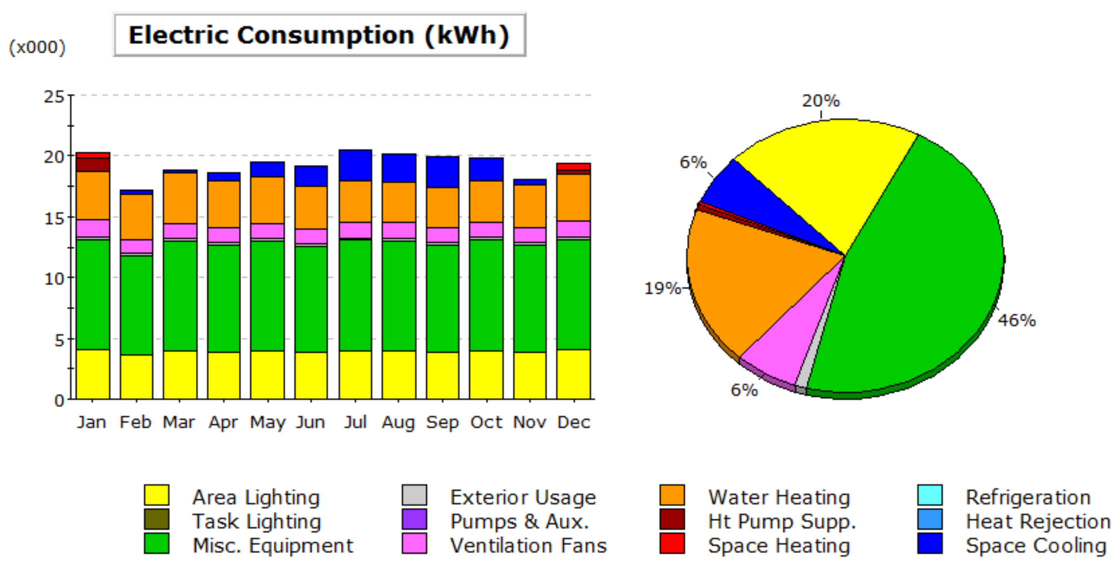

Figure E-8. Brisbane Baylands residential-building eQUEST results for annual energy use