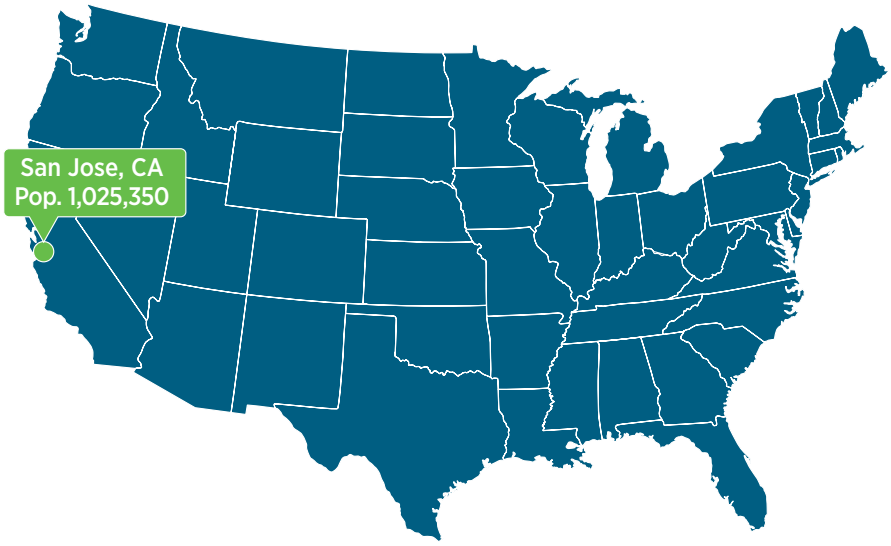
U.S. DEPARTMENT OF ENERGY

Office of ENERGY EFFICIENCY & RENEWABLE ENERGY

CITY ENERGY: FROM DATA TO DECISIONS

San Jose, California: Evaluating Local Solar Energy Generation Potential



The City of San Jose partnered with the Energy Department and the National Renewable Energy Laboratory (NREL) to demonstrate how data and analysis can inform more strategic energy decisions. NREL based its analysis in-part on the City Energy Profiles on the State and Local Energy Data (SLED) website (*eere.energy.gov/sled*). The profiles contain data compiled by SLED and the Cities Leading through Energy Analysis and Planning (Cities-LEAP) program. Cities across the country can follow the same approach and use data-driven analysis in their own energy planning.

> "The Cities-LEAP analysis will help the City of San Jose make critical decisions in developing renewable energy programs, moving toward its renewable energy and energy efficiency goals, and ultimately allowing San Jose to reach its greenhouse gas reduction targets."
>
> *— Ken Davies, Sustainability and Compliance Manager, City of San Jose*

City Energy Goals

The City of San Jose, California, was interested in data and analysis to inform the development of its environmental sustainability plan, programs under its new community-choice aggregation organization, and initiatives under a city energy project grant.

As part of these efforts, the city was seeking data and analysis to understand the extent to which rooftop solar photovoltaic (PV) energy generation could contribute toward its 100% renewable electricity goal.

Data and Analysis

The foundation for this analysis comes from estimated city energy data on SLED, supplemental data from publicly available sources (including the U.S. Census Bureau), and data inputs obtained directly from the City of San Jose.

Total Rooftop Technical Potential

An estimate of total rooftop technical potential from Google Project Sunroof

Total Rooftop PV Market Potential in San Jose

By following the conceptual framework in Figure 1, NREL estimated that 51% of 2015 electricity consumption in San Jose could be met with residential and commercial rooftop solar, based on existing PV technology.[1, 2]

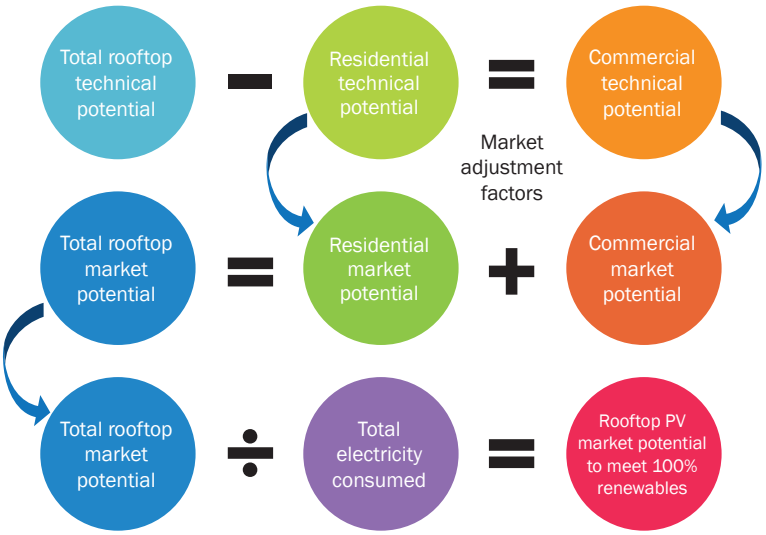


Figure 1. Conceptual framework for estimating rooftop PV market potential to meet 100% renewable goals (Source: NREL)

[1] The framework does not address technical issues related to existing electricity infrastructure (including distribution systems), the role of electricity storage, the need to balance electricity supply and demand, and considerations related to system reliability, solar valuation, or other challenges associated with implementing large amounts of rooftop PV (such as two-way information and energy transfer on existing grid infrastructure).

[2] NREL research shows that, nationwide, more than 80% of load could be met with renewables by 2050 (http://www.nrel.gov/analysis/re_futures).

indicates that San Jose has a technical potential[3] to install 3,400 megawatts (MW) of PV capacity and generate 5 million megawatt-hours (MWh) of electricity annually on 201,000 roofs (see Figure 2).[4]

This analysis uses Cities-LEAP estimates for small building rooftop PV potential available on SLED to approximate residential rooftop technical potential (see Figure 3). These estimates are limited to buildings with a footprint of 5,000 square feet or less, which are assumed to be primarily residential buildings. Using this approach, NREL estimates that San Jose has a residential rooftop technical potential of approximately 1,639 MW of installed capacity and 2,420,600 MWh of annual electricity generation on 194,900 roofs.

Subtracting the residential rooftop technical potential from the total rooftop technical potential leaves an estimated 1,761 MW (52%) of PV capacity and 2,579,400 MWh of annual generation potential from an estimated 6,100 commercial-sector rooftops.

These technical potential estimates model shading, roof azimuth (angle) and tilt, rooftop area available, and solar resource, but do not take market factors into consideration. To adjust the technical potential to reflect market factors such as building ownership and the ability of the rooftop area to meet a sufficient percentage of occupant load, different approaches are applied to the residential and commercial sectors.

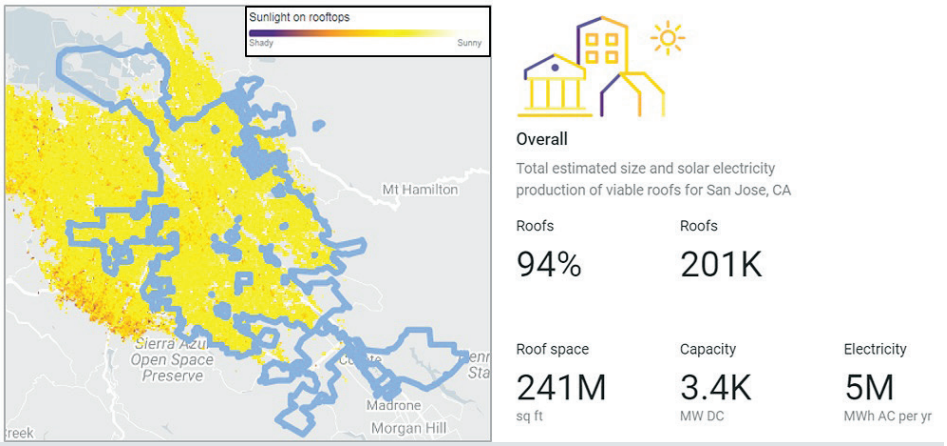


Figure 2. Rooftop PV technical potential for San Jose, California, from the Google Project Sunroof data explorer (October 2016)

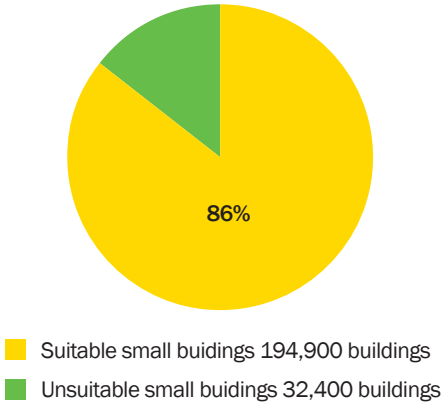
Residential Technical and Market Potential

In an analysis of potential community solar customers, Feldman et al. (2015) assumes that residential customers who do not own their residences, live in a building with more than three stories, or live in a building with insufficient rooftop space for a PV system cannot host PV systems.[5] Feldman et al. use a Housing and Urban Development analysis indicating that 63% of U.S. households are owner occupied and have less than four stories.[6]

To customize this approach for the City of San Jose, the analysis begins with the number of owner-occupied units in structures with less than five units, as revealed in the U.S. Census American Community Survey (see data outlined in red in Table 1),[7] excluding mobile homes, which are assumed to lack the structural capacity necessary for rooftop PV.

With housing unit data from the U.S. Census American Community Survey,[7] NREL applied the percentage of technically suitable small buildings derived from SLED (86%; see Figure 3) to the number of residential buildings with suitable conditions to approximate the market potential of residential rooftops in San Jose (see Table 2).

The estimated number of suitable residential rooftops is then multiplied by the average residential installation capacity (5 kW)[8], to determine a residential market potential of 691 MW of PV capacity. NREL's PVWatts Calculator tool (*pvwatts.nrel.gov*) estimates that each 5-kW system will generate



Suitable area	11,518,500 m^2
Capacity potential	1,638,500 kW
Energy generation potential	2,420,600 MWh

Figure 3. Small building/residential rooftop PV technical potential in San Jose, California (Source: SLED)

[3] Google Project Sunroof data explorer includes solar panels "that generate at least 75% as much energy as an ideally oriented and unshaded panel." The technical potential is limited to roofs with sufficient area for at least a 2-kilowatt (kW) PV system and four adjacent solar panels. https://static.googleusercontent.com/media/www.google.com/en//get/sunroof/assets/data-explorer-methodology.pdf.

[4] Google Project Sunroof data explorer (October 2016): https://www.google.com/get/sunroof/data-explorer/place/ChIJ9T_5iuTKj4ARe3GfygqMnbk/.

[5] D. Feldman, A. Brockway, E. Ulrich, and R. Margolis, Shared Solar: Current Landscape, Market Potential, and the Impact of Federal Securities Regulation, NREL (2015), http://www.nrel.gov/docs/fy15osti/63892.pdf.

[6] D. Feldman et al., Shared Solar: Current Landscape, Market Potential, and the Impact of Federal Securities Regulation.

[7] U.S. Census 2011–2015 American Community Survey 5-Year Estimates.

[8] Data provided by the City of San Jose and based on state data: http://californiadgstats.ca.gov/downloads.

Table 1. Physical Housing Characteristics for Occupied Housing Units in San Jose, California

Housing type	Occupied housing units	Owner-occupied housing units	Renter-occupied housing units
	Estimate	Estimate	Estimate
Occupied housing units	314,297	179,809	134,488
Units in structure			
1, detached	54.6%	77.4%	24.0%
1, attached	10.9%	11.7%	9.9%
2 apartments	1.8%	0.3%	3.8%
3 or 4 apartments	5.2%	1.3%	10.8%
5 to 9 apartments	5.1%	1.4%	10.0%
10 or more apartments	19.0%	2.9%	40.6%

Data from the U.S. Census 2011–2015 American Community Survey 5-Year Estimates.

7.7 MWh annually for a total of 1,063,963 MWh per year (see Table 2). With 16,098 residential PV systems totaling 73 MW of residential capacity installed as of 2016, San Jose has deployed PV systems on an estimated 12% of the suitable residential rooftops and has realized 10.6% of the estimated residential rooftop market potential capacity.

Commercial Technical and Market Potential

The size and capacity of solar installations in the commercial sector (including government, nonprofit, industrial, and educational buildings) vary widely across building types and uses. Some commercial buildings have significant roof space available, while others host equipment, like air conditioners, that leave little space for solar panels. In addition, one solar installation may supply power to a complex of buildings.

Feldman et al. estimate commercial rooftop PV market potential by assuming that non-residential customers are unable to host a PV system if they meet any of the following criteria: (1) businesses in buildings with more than five establishments (e.g., malls); (2) businesses in buildings of less than 10,000 square feet with two to five establishments; and (3) businesses in single-establishment buildings less than 10,000 square feet with insufficient roof space to host a PV system of adequate size. Based on these criteria, Feldman et al. estimate that 52% of non-residential customers can host a PV system.

Applying this percentage to the estimated technical rooftop PV potential for the commercial sector in San Jose results in a market potential of 916 MW of capacity and 1.3 million MWh of annual generation on 3,172 rooftops. With 51 MW of installed commercial rooftop PV on 344 rooftops, San Jose has reached 5.6% of the estimated commercial rooftop PV market potential capacity.

Of the installed capacity through 2016 in San Jose, 41% is commercial and 59% is residential. The market potential reflects higher commercial potential (57%) than residential (43%). Only 2% of existing installations (rooftops) are commercial, possibly reflecting the slower adoption rates of PV in the commercial and industrial sectors. The average capacity of commercial installations in San Jose through 2016 is 149 kW, while installed capacity for residential rooftops averages 5 kW.

Rooftop PV Contributions toward 100% Renewable Goal

The estimated rooftop PV market potential is equivalent to 51% of the 4,702,567 MWh consumed in in San Jose in 2015. This estimate is in line with a state-level finding from NREL research that estimates rooftop generation could meet 43.6% of annual electricity consumption in California overall.[9] If an energy efficiency goal is applied—for this analysis

Table 2. Residential Rooftop Market Potential Estimates for San Jose, California

Owner-occupied housing type	Housing units	Structures
1, detached	139,172	139,172
1, attached	21,038	21,038
2 apartments	539	270
3 or 4 apartments	2,338	668
Total	163,087	161,147

Market potential at Cities-LEAP/SLED 86% suitable small buildings (0.86 x total structures)	138,177 rooftops
Market potential at 5 kW per rooftop (number rooftops x 5 kW)	691 MW
Market potential at generation of 7.7 MWh per 5 kW (number rooftops x 7.7 MWh)	1,063,963 MWh

Data derived using data outlined in red in Table 1.

Table 3. Summary of Estimated Rooftop PV Potential in San Jose, California

		Residential	Commercial	Total
Technical potential	number rooftops	194,900	6,100	201,000
	MW	1,639	1,761	3,400
	MWh	2,420,600	2,579,400	5,000,000
Market potential	number rooftops	138,177	3,172	141,349
	MW	691	916	1,607
	MWh	1,063,963	1,341,288	2,405,251
Total installed capacity (2016)*	number rooftops	16,098	344	16,442
	MW	73	51	124
Unrealized market potential	MW	618	864	1,482

*Data provided by the City of San Jose & based on state data: *californiadgstats.ca.gov/downloads*.

a 10% reduction in electricity consumption is used—the total market potential rooftop generation could meet 57% of the reduced consumption.

Renewable energy credits for rooftop solar generation are generally sold to a utility and therefore counted toward the state renewable energy portfolio standard (RPS). If the city considers the state RPS as a baseline for a goal of 100% combined city and state renewable generation, rooftop generation then contributes to the state RPS side of this equation.

Rooftop PV is by no means the only option, nor the most cost-effective option available to cities seeking high-penetration renewable goals. Washington, D.C., for example, plans to purchase all of the generation from a 45-MW wind energy facility, which will supply 35% of the government's electricity consumption and save $45 million over 20 years.[10] The city of Riverside, California, purchases geothermal electricity from the Imperial Valley.[11]

Other renewable energy sources, as well as community- and utility-scale PV, can also be less expensive—costing one third or one half less than rooftop solar energy generation.[12] For comparison to other renewable energy generation options, meeting the 43% of remaining San Jose electricity demand (after rooftop PV and energy efficiency reductions) would require approximately 922 MW of ground-mounted, community- and utility-scale single-axis tracking PV capacity.[13]

Resources

The following resources may be useful to guide further actions for increasing solar generation:

PV System Cost Analysis

- Google Project Sunroof: *https://www.google.com/get/sunroof/data-explorer* – Estimate rooftop solar potential for state, county, city, zip code, or individual property.
- NREL PVWatts Calculator: *http://pvwatts.nrel.gov/* – Estimate energy production and costs of grid-connected PV systems.

Planning for Solar

- Solar Powering Your Community: A Guide for Local Governments: *https://www1.eere.energy.gov/solar/pdfs/47692.pdf*
- Planning for Solar Energy: Promoting Solar Energy Use Through Local Policy and Action: *http://www.growsolar.org/wp-content/uploads/2014/10/Planning-for-Solar-Energy-2014_PAS-575.pdf*
- Local Solar: What Do Leading Solar Communities Have in Common? It May Not Be What You Expect: *http://www.nrel.gov/docs/fy16osti/64883.pdf*
- Expanding Midscale Solar: Examining the Economic Potential, Barriers, and Opportunities at Offices, Hotels, Warehouses, and Universities: *http://www.nrel.gov/docs/fy16osti/65938.pdf*
- Are Cities Codifying Clean Energy Policy? The Answer is Yes: *https://www.nrel.gov/tech_deployment/state_local_governments/blog/are-cities-codifying-clean-energy-policy-the-answer-is-yes*.

Find additional resources in the SLED Local Energy Action Toolbox: *http://apps1.eere.energy.gov/sled/cleap.html*.

Cities-LEAP is a project funded by the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE). It is part of an effort by EERE's Strategic Priorities and Impact Analysis Team to empower state and local decision makers with data-driven analysis. ■

[9] P. Gagnon, et al., *Rooftop Solar Photovoltaic Technical Potential in the United States: A Detailed Assessment*, NREL (2016), http://www.nrel.gov/docs/fy16osti/65298.pdf.

[10] "Mayor Bowser Announces Groundbreaking Wind Power Purchase Agreement," July 14, 2015, https://mayor.dc.gov/release/mayor-bowser-announces-groundbreaking-wind-power-purchase-agreement.

[11] "Riverside Public Utilities Signs Historic Salton Sea Geothermal Power Agreement with CalEnergy LLC," Green Riverside, June 20, 2013, http://www.greenriverside.com/article/riverside-public-utilities-signs-historic-salton-sea-geothermal-power-agreement-with-calenergy-llc.

[12] "Q4 2016/Q1 2017 Solar Industry Update," NREL (2017), http://www.nrel.gov/docs/fy17osti/68425.pdf.

[13] Solar Electric Power Alliance, *Utility-Scale Solar: The Path to High-Value, Cost-Competitive Projects*, 2016, https://sepapower.org/resource/utility-scale-solar-the-path-to-high-value-cost-competitive-projects. Generation potential based on a limited analysis using PVWatts, suggesting that utility-scale, single-axis PV generates approximately 1,980 MWh per MW installed in the San Jose region. These calculations do not take into consideration technical integration issues and non-PV renewable energy resources, which must be part of any implementation plan.

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DOE/EE-1625 • September 2017