

TECHNICAL POTENTIAL FOR ROOFTOP PHOTOVOLTAICS IN THE SAN DIEGO REGION

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ABSTRACT

This paper estimates the technical potential for rooftop photovoltaics in San Diego County and describes the methods used to derive the estimates. The commercial estimate was derived using Geographical Information Systems (GIS) to map actual rooftops in the City of San Diego. This estimate for the City of San Diego was used to extrapolate an estimate for the entire County of San Diego. The residential estimate was developed using a simple model that incorporates estimated roof space and housing growth trends.

1. INTRODUCTION

With among the highest levels of solar insolation in U.S., San Diego is well suited for solar technologies, particularly rooftop photovoltaics. As the number and capacity of installed systems rise, there is much speculation about how much photovoltaics could contribute to the energy needs of the San Diego region. This paper seeks to establish a fact-based estimate for how much rooftop photovoltaics is technically feasible in the region. Our estimate only considers the physical limitations like roof area and expected building growth and does not take into account economic or policy considerations.

In addition to the technical potential, this paper also briefly addresses the effect that large amounts of photovoltaics would have on San Diego Gas & Electric's (SDG&E) peak demand.

2. TOTAL TECHNICAL POTENTIAL

Given the existing building stock, the current technical potential for roof top photovoltaics in the San Diego region is just over 4,100 MW (8,947 GWh). By 2020 as the building stock expands, the technical potential is projected

to grow to about 4,691 MW (10,224 GWh). Given the relatively small commercial industrial sector in the region, the residential sector represents about 63% (2,965 MW) of the technical potential for photovoltaics in 2020. The commercial sector accounts for the remaining 37% (1,726 MW) of photovoltaic potential.

To put these results into perspective, in 2005 San Diego Gas & Electric (SDG&E) had a peak demand of 4,058 MW and total sales of 19,214 GWh. Therefore, the technical potential represents over 100% of peak demand and 53% of energy needs. As of January 2006, a total of 18.1 MW was installed in SDG&E's service territory, which represents 0.4% of 2005 peak demand and 0.1% of total sales.

For further perspective, consider the potential impacts of the California Solar Initiative, a financial incentive program for solar energy, including photovoltaics, which was adopted by the California Public Utilities Commission (CPUC) in January 2006. The program allocates \$2.5 billion over 10 years and has a goal of installing 3,000 megawatts of solar capacity. (1) Taking the funds allocated for the San Diego region, we estimate that the total amount of photovoltaics that would be installed is approximately 218 MW by 2016, assuming all of the funding available is spend. Of this total, approximately 50% or 109 MW would be generating energy during SDG&E's forecasted peak demand of approximately 5,500 MW, which corresponds to 1.9% of the peak.

The following sections describe in detail the commercial and residential estimates and the methodologies used to derive each.

3. COMMERCIAL SECTOR TECHNICAL POTENTIAL

The technical potential for commercial-scale photovoltaic systems in the San Diego region is 1,726 MW and 3,468 GWh in 2020. These numbers represent the amount of

capacity and energy that could be realized if all available commercial rooftop space identified were to be covered with photovoltaic panels.

3.1 Commercial Estimate Methodology

To determine the total potential for commercial rooftop photovoltaic systems in the San Diego region, we used data from a project conducted by the San Diego Regional Energy Office (SDREO) and the City of San Diego, which identifies all the large commercial rooftops within the City of San Diego boundaries. Results from this project were compared to the overall regional commercial building stock to extrapolate the total roof area for San Diego County.

The project, which was based on a similar study done in Marin County, used Solar Analyst software to determine if there were any areas of the region that were not suitable for photovoltaic systems (e.g., canyons or valleys)(2). The results of the Solar Analyst model were overlaid on a satellite image of the entire City of San Diego. Given the terrain, minimal tree cover, and dispersed development within San Diego, there were few if any areas of commercial development that had significantly less sunlight than others; therefore, we determined that the entire City of San Diego had strong solar insolation.

Using Geographical Information Systems (GIS), we then identified and digitized all buildings with a footprint of over 3,000 square feet in the following non-residential land classifications: industrial, office, commercial, educational (including schools and universities), hospital, hotel, and other. Each building was classified based on the estimated amount of roof area available for solar photovoltaic equipment.

Three classifications were created depicting the percentage of area available for photovoltaic systems:

- Class 1 represents buildings with approximately 80 percent of the total roof space suitable for a photovoltaic installation,
- Class 2 represents approximately 60 percent suitable roof space
- Class 3 represents approximately 20 percent suitable roof space.

Because there were over 15,000 rooftops to digitize, this classification system simplified and expedited the actual digitization process, which is very time consuming. Alternatively, we could have digitized the total roof area and all roof obstructions and taken the difference between the two as the usable space. This approach would have been more accurate but would have been much more time-consuming. We opted for the simpler approach that

balanced accuracy and time-to-complete knowing there was an element of subjectivity in the classification process.

Once all the rooftops were digitized and classified, an estimate the total square footage available for photovoltaic equipment could be developed. One concern was how to account for shading by rooftop equipment and parapet walls. To address this, we reduced the amount of available roof space by 20%. Then we estimated that for each 100 square feet of roof space 1 kW DC of photovoltaic capacity could be installed. This was used to calculate an estimate of the total possible capacity (MW DC) and energy production for all identified buildings in the City of San Diego. We employed a method developed by the California Energy Commission (CEC) to determine MW AC, a more accurate measure of the useable capacity of a photovoltaic system (3).

To derive energy production estimates, we used actual data from systems installed in the San Diego region and CEC estimates that photovoltaic systems in the San Diego region generate approximately 1400-1700 kWh annually for each kW DC of installed capacity (4). Recognizing microclimate variations in the Region, we assigned each jurisdiction a production value from actual system data and the CEC's range, with coastal communities having lower production and inland communities having higher production. For the commercial photovoltaics energy production estimates, we further assumed that all systems would be installed flat, which reduces energy production by about 11 percent according to the CEC. (4)

3.2 Capacity and Energy Results for the City of San Diego

Using the method described above, we derived capacity and energy generation estimates for the 15,157 buildings identified in the City of San Diego. The estimated technical potential for photovoltaic system capacity is 769 MW AC and energy production is 1,532 GWh annually.

3.3 Extrapolating Results to the Entire San Diego Region

The next step was to extrapolate the results from the City of San Diego to determine technical potential for the entire County of San Diego. To do this, we compared the total useable roof area in the City of San Diego with the total existing developed acreage. According to data from the San Diego Association of Governments (SANDAG), in 2005 the City of San Diego will have a total of 1,135,955,502 square feet (26,078 acres) of non-residential developed land. The GIS analysis of non-residential rooftops in the City of San Diego identified approximately 143,489,645 square feet (3,294 acres) of useable roof area. We determined the ratio of total useable roof area to total developed land.

$[3,294 \text{ acres of total useable area}] / [26,078 \text{ acres of total developed land}] = 12.6\%$

For the City of San Diego, the total roof area suitable for photovoltaic systems was about 12.6% of total developed land area. To determine an estimate of useable roof area of the other jurisdictions in the region, we applied this ratio to the total developed non-residential land area. We assumed that all other jurisdictions would have a similar ratio of total developed land to usable roof area. This ratio was applied to the jurisdictions outside the City of San Diego to derive an estimated technical potential for the remaining portions of the County of San Diego.

The total estimate of useable area in 2005 for all the jurisdiction in the County of San Diego is 235,047,321 square feet (5,396 acres), which translates into a capacity of approximately 1,726 MW AC, using our method.

3.4 Assumptions

In developing our technical potential estimates for the commercial sector, we used a range of assumptions. We only assessed commercial rooftops larger than 3,000 square feet. The rationale for this was that the Self-Generation Incentive Program, the primary commercial incentive program in California, has a minimum system size eligibility criterion of 30 kW. Rooftops of 3,000 square feet and greater likely could accommodate a 30 kW system.

In determining the energy production of the technical potential, we assumed all systems would be installed flat. As discussed above, flat systems generate about 89 percent of the energy output that systems with optimum orientation and tilt would produce. While there are fixed tilt commercial installations in the San Diego region, we chose to simplify the process by assuming all systems are flat.

In addition, we did not account for the potential for covered parking and other potential applications like ground-mounting. Lack of detailed GIS data made it impossible to do a detailed analysis of the structured parking. However, we recognize there is a significant potential for these applications, in particular covered parking.

3.5 Interpreting the Results

The results of our analysis yield technical potential for commercial photovoltaics. Given the uncertainty in actual development of this technical potential, we calculated the results using market penetration rates of 1%, 5%, and 10%. Table 1 shows the capacity and values of the San Diego region assuming these market penetration rates are realized.

TABLE 1: COMMERCIAL ESTIMATE AT VARIOUS PENETRATION RATES

Market Penetration Rate	Capacity (MW)			Energy (GWh)		
	2005	2010	2020	2005	2010	2020
1%	16	16	17	32	33	35
5%	79	81	86	158	163	173
10%	157	162	173	317	326	347

4. RESIDENTIAL SECTOR

Based on the model described below, San Diego County has a technical potential of 2,539 MW from existing single and multifamily homes, 2,772 MW from existing plus new homes built between 2005 and 2010, and 2,965 MW from existing plus new homes built through 2020. Applying the location differentiated energy production factors (kWh/kW) described above, the energy potential for residential photovoltaics is estimated to be 5,782 GWh for existing homes, 6,310 GWh for all homes in 2010, and 6,756 GWh for all homes in 2020.

4.1 Residential Estimate Methodology

To derive an estimate of the technical potential for residential photovoltaics, we constructed a simple model, which included estimated roof area and data related to projected housing growth in San Diego County.

The model included the following steps:

1. Determine the average single family and multifamily square footage.
2. Estimate the average roof space available to site a photovoltaics array.
3. Develop a factor to determine the number of housing units with appropriate characteristics, such as orientation and shading.
4. Divide the remaining square footage by 100 to determine the total kW DC rating of photovoltaics. (6)
5. Multiply by a roof pitch adjustment factor.
6. Multiply by the DC to AC conversion factor.
7. Estimate the existing and projected new housing units classified by photovoltaic capacity potential for current and future years for that sub segment.
8. Sum the numbers to derive the capacity estimate for each individual city within the region as well as for the whole region.

Once the photovoltaics capacity potential was determined, we multiplied the capacity value appropriate location-differentiated energy production factors (kWh/kW) described above to determine the energy potential (kWh).

4.2 Assumptions

In determining the residential rooftop photovoltaic technical potential estimate, we made a range of assumptions, including the size of homes, available roof space, number of suitable homes, roof pitch, and energy production per kilowatt of installed capacity. Table 2 below lists the assumptions used to derive the estimate for residential rooftop photovoltaics.

TABLE 2: SINGLE FAMILY RESIDENTIAL ASSUMPTIONS

Category	Assumption
2003 Avg Sq Ft	2,000
2003 – 2010 Avg Sq Ft	2,500
% Sq Ft Roof	50%
% Homes Suitable	50%
Roof Pitch 30 Deg	99%
1 kWdc Required Sq Ft	100
DC to AC conversion	67%

We assumed that smaller residential system performance would be similar to the actual data from large systems that we used in part to develop energy production estimates. Also, we assumed that all photovoltaics installed would be crystalline; therefore, the factors we used for the amount of space required for a kilowatt of capacity reflect these assumptions.

4.3 Interpreting the Results

The results of this analysis yield technical potential for residential photovoltaics. Recognizing the unlikelihood of all homes having photovoltaics, we calculated the results for market penetration rates of 1%, 5%, and 10%. Table 3 shows the capacity and energy values of the San Diego region assuming these market penetration rates are realized.

TABLE 3: RESIDENTIAL ESTIMATE AT VARIOUS PENETRATION RATES

Market Penetration Rate	Capacity			Energy		
	2003	2010	2020	2003	2010	2020
1%	25	28	30	58	63	68
5%	127	139	148	289	316	338
10%	254	277	296	578	631	676

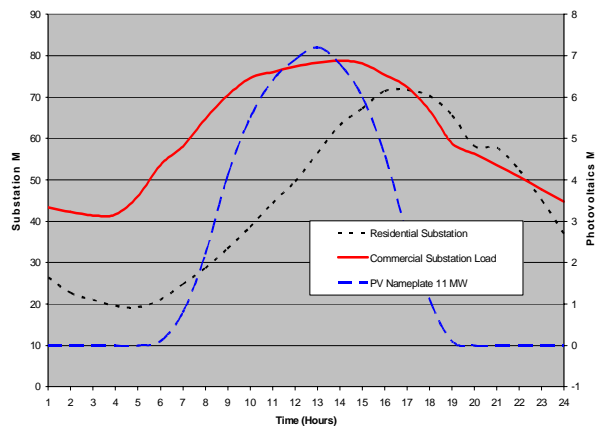
5. EFFECTS OF PHOTOVOLTAICS ON PEAK DEMAND

In addition to the estimate of the total potential for rooftop photovoltaics, we also analyzed the potential effect that varying amounts of photovoltaics would have on the peak demand of the San Diego Gas & Electric system.

SDG&E’s system peak typically occurs at approximately 3 p.m. in the late summer (late August, early September). As more photovoltaics capacity is added to the system, the system peak would decrease and would shift in time. Our analysis shows that as additional photovoltaics are added to the system and the system peak shifts later in time, the ability of photovoltaics to reduce the system peak diminishes. This is because each photovoltaics system will be producing less energy later in time.

In addition, our analysis showed that the typical solar energy production profile does not match the needs of residential substations in our region, but matches fairly well the needs of commercial substations. Figure 1 graphically demonstrates this point. This suggests that strategic placement and/or orientation of photovoltaics could maximize peak demand reduction in the San Diego region.

Fig 1 Impacts of 11 MW of Photovoltaics on SDG&E Substations



6. CONCLUSION

The San Diego region has tremendous technical potential for rooftop photovoltaics. Without considering economics, policy, and adoption rates, the total technical potential in capacity terms exceeds the existing peak demand for the region. While it is unlikely that all of this potential will be developed over time, photovoltaics can play an important but limited role in a diverse mix of energy resources, including fossil-fuel generation, energy efficiency and demand response, and other renewable energy sources like wind and geothermal.

Photovoltaics can up to a point provide important peak power and is best matched to the usage patterns of commercial substations, whose peak usage periods coincide fairly well with the photovoltaic energy production cycle.

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