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CALIFORNIA ENERGY CODES & STANDARDS

A STATEWIDE UTILITY PROGRAM

2016 Title 24, Part 6
Local Energy Efficiency Ordinances

Cost Effectiveness Study:
Statewide Nonresidential PV Cost Effectiveness Analysis
(New Construction and Retrofits)

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Table of Contents

List of Figures

1 Introduction

The California Building Energy Efficiency Standards Title 24, Part 6 (Title 24) (CEC, 2016b) is maintained and updated every three years by two state agencies, the California Energy Commission (CEC) and the Building Standards Commission (BSC). In addition to enforcing the code, local jurisdictions have the authority to adopt local energy efficiency ordinances, or reach codes, that exceed the minimum standards defined by Title 24 (as established by Public Resources Code Section 25402.1(h)2 and Section 10-106 of the Building Energy Efficiency Standards). Local jurisdictions must demonstrate that the requirements of the proposed ordinance are cost-effective and do not result in buildings consuming more energy than is permitted by Title 24. In addition, the jurisdiction must obtain approval from the CEC and file the ordinance with the BSC for the ordinance to be legally enforceable.

The goal of this study is to evaluate on-bill cost effectiveness of installing photovoltaic (PV) panels on nonresidential buildings for all sixteen climate zones in California. This investigation is in response to jurisdictions' interest in incorporating PV in the nonresidential Title 24 code:

1) Applicability
   a) All nonresidential new construction
   b) All high-rise multifamily residential new construction
   c) All nonresidential redevelopment at least 10,000 ft^2
2) Requirements
   a) Expand solar zone requirement for new nonresidential to include buildings with four to ten habitable stories
   b) Require PV systems with a capacity of either
      i) 80% of the building's modelled annual electric load
      ii) 15 DC watts per square foot of solar zone[1]

At the time of this memo, utility rate modeling and related energy cost calculations are finalized for PG&E and SCE territories. The utility rate modeling for SDG&E territory is being reviewed by the utility for all prototypes. **The analysis for SDG&E territory, including climate zones 7, 10 and 14, is excluded from this memo until full clarification is received from the utility.**

2 Methodology and Assumptions

2.1 Building Prototypes

TRC selected nonresidential new construction building types intended to represent boundary conditions for utility bill cost effectiveness analysis when accounting under net energy metering 2.0 (NEM 2.0). In other words, a large building and small building are likely to have different utility rate structures because they will have high and low energy usage, respectively. Thus they represent the boundaries that other building types would fall in between. If

[1] 2016 Title 24, Part 6, Section 110.10(b)1B: For high-rise multifamily (ten habitable stories or fewer) and nonresidential (three habitable stories or fewer), The solar zone shall be located on the roof or overhang of the building or on the roof or overhang of another structure located within 250 feet of the building or on covered parking installed with the building project and have a total area no less than 15 percent of the total roof area of the building excluding any skylight area.

both buildings are proven to be cost effective, then all buildings in between can be assumed to be cost effective. For the large building, TRC used High-Rise Multifamily prototype to represent multistory mixed-use new construction.

TRC modeled a retail strip mall of 9,375 ft^2 for the nonresidential redevelopment scenario to support cost effectiveness for alterations greater than 10,000 ft^2. TRC chose the retail strip mall prototype because it was the DOE prototype with a floor area closest to 10,000 ft^2. TRC assumed that the >10,000 ft^2 threshold in the proposed ordinance was chosen to ensure that 'large-enough' alterations projects would be subject to the ordinance – projects that have a high nominal cost. Because savings potential increases with building size, TRC assumed that demonstrating cost-effectiveness for an approximately 10,000 ft^2 prototype shows that the PV installations are economical for projects >10,000 ft^2.

TRC developed a total of 64 prototypes -- four building types in 16 climate zones. The four building types, based on the prototype selection include the following, described in more detail in Figure 1:

- New construction, large nonresidential building – three-story Medium Office - 53,628 ft^2
- New construction, small nonresidential building – single-story Small Office - 5,502 ft^2
- New construction high-rise residential building – twelve-story High-Rise Multifamily - 94,088 ft^2
- Existing (pre-1978 code), nonresidential – single-story Retail Strip Mall - 9,375 ft^2

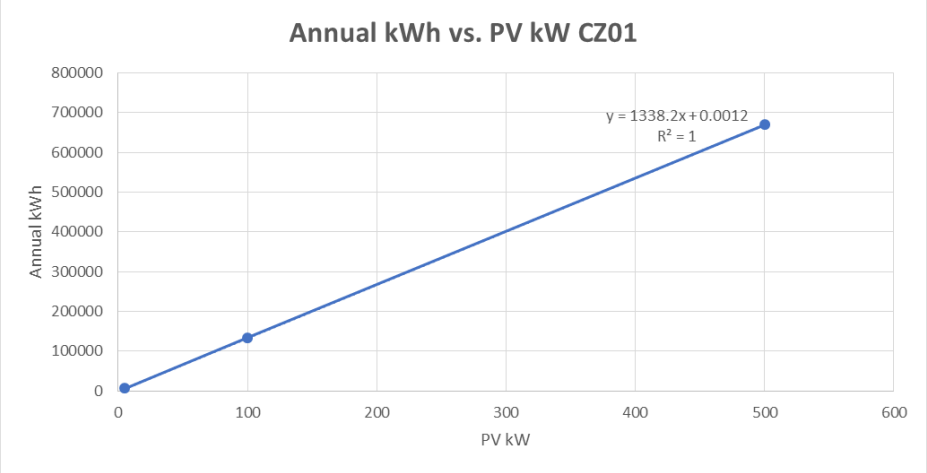
Figure 1. Prototype Characteristics Summary

Building Type	Medium Office	Small Office	High-Rise Multifamily	Retail Strip Mall
Area (ft^2)	53,628	5,502	94,088	9,375
Roof Area (ft^2)	17,876	5,502	8,512	9,375
# of floors	3	1	12 (9-residential floors, 75-dwelling units)	1
Window-to-Floor Area Ratio	13%	11%	27.35%	8.21%
HVAC Distribution System	3x Packaged Variable Air Volume with VAV Hot Water Reheat	5x Packaged Single Zone Air Conditioners	*Common Areas:* PVAV *Dwelling Units:* Four-pipe fan coil	Single Zone Air Conditioner
Cooling System	Direct Expansion, 9.8 EER	Direct Expansion, 13 SEER	*Common areas:* Direct expansion *Dwelling Units:* Chilled Water	Direct Expansion, 13 SEER
Heating System	Boiler, 80% Thermal Efficiency	Furnace, 78% AFUE	Boiler, 80% Thermal Efficiency	Furnace, 78% AFUE
Conditioned Thermal Zones	18	5	40	4
Domestic Water Heating	Natural Gas Storage, 24 Gallon Tank, EF = 0.64	8x Natural Gas Storage, 2 Gallon Tank, EF = 0.71	Natural Gas Storage, 100 Gallon Tank, EF = 0.8	Natural Gas Small Storage, 14 Gallon Tank, EF = 0.65
Lighting Power Density (LPD)	0.75 W/ft^2	0.75 W/ft^2	Dwelling units – 0.5 W/ft^2; Corridor – 0.6 W/ft^2; Nonresidential areas – 0.7-1.2 W/ft^2	2.2 W/ft^2

2.2 Energy Simulations

TRC used CBECC-Com software version 2016.3.0 SP1 to simulate all the building prototypes and obtain the hourly consumption data without PV. CBECC-Com software does not have the capability to model PV in buildings. Hence, TRC simulated a residential building prototype in CBECC-Res software version 2016.3.0 (934 SP1) to obtain hourly PV generation output for each of the sixteen climate zones. TRC simulated three different PV system sizes covering a wide range of output (e.g., 5 to 500 kW) to obtain a relationship between PV system size and kWh generation for each building type. The analysis results in a linear relationship used to scale the PV generation for the desired PV sizes, an example shown in Figure 2 below.

Figure 2. Linear curve between annual PV generation (kWh) and installed PV size (kW) in Climate Zone 1



In summary, TRC performed the following simulations:

- CBECC-Com: All four prototypes under 16 climate zones, total 64 simulations
- CBECC-Res: One prototype, three PV system sizes and 16 climate zones, total 48 simulations

The final results overlay the scaled PV generation output to the hourly consumption output from CBECC-Com simulations to determine the net hourly consumption for the two desired PV definitions and four building types.

In other words,

Net hourly kWh consumption = Hourly kWh consumed (CBECC_Com) - Hourly kWh generated (CBECC_Res)

2.3 Cost Effectiveness

This section discusses how on-bill cost effectiveness is determined for the solar PV and solar ready measures.

2.3.1 Solar PV

TRC evaluated cost effectiveness of PV using the net present value (NPV) metric over 30 years, assuming a 3% discount rate and a 2% energy escalation rate. The analysis included benefit-to-cost (B/C) ratio and discounted payback metrics, defined as follows:

- **Net present value (NPV):** Present value of total benefits from utility bill savings minus present value of all costs including maintenance and replacement over 30 years. The criteria for cost effectiveness is NPV greater than 0.

- **Benefit-to-cost ratio (B/C): Ratio of present value of all benefits over present value of all costs over 30 years. The criteria for cost effectiveness is B/C greater than 1.0.**
- **Discounted payback:** Number of years it takes to break even from undertaking the initial expenditure, by discounting future cash flows and accounting for the time value of money.

Solar PV on-bill energy benefits and installation costs are estimated as discussed below.

2.3.1.1 Energy Cost Benefits

The on-bill cost-effectiveness methodology evaluates savings based on the customer's utility bills using rate structures of California's three major Investor Owned Utility (IOU) including Net Energy Metering (NEM) 2.0, shown in Figure 3 below.[2,3] Because climate zones 10 and 14 overlap with both SCE and SDG&E territory, TRC evaluated cost effectiveness under both utility rate structures in these climate zones.

Figure 3. IOU distribution by climate zone

IOU	Climate zones
Pacific Gas & Electric (PG&E)	1-5, 11-13, 16
Southern California Edison (SCE)	6, 8-10, 14, 15
San Diego Gas & Electric (SDG&E)	7, 10, 14

The specific electricity rate schedules within IOU territory are applied to each of the 64 prototypes based on the climate zone, estimated monthly peak load and annual kWh consumption (Figure 4). Utility territories and climate zones boundaries do not perfectly align; one utility territory contains multiple climate zones, and one climate zone can contain multiple utility territories. A prototype simulated in different climate zones will have different monthly peak loads, and may consequently fall under a different utility rate structure. For example, SCE rate TOU-GS-2-A may apply to the medium office prototype in one climate zone, while TOU-GS-3-A may apply in another climate zone.

Figure 4. Applicable rate schedules by building type

Building type	PG&E	SCE	SDG&E[4]
Small office	A-1 TOU	TOU-GS-1-A; TOU-GS-2-A	-
Medium office	A-10	TOU-GS-2-A; TOU-GS-3-A	-
HRMF	E-TOU A	TOU-D-T	-
Retail strip mall	A-10	TOU-GS-2-A	-

[2] More information on NEM available at: http://www.cpuc.ca.gov/General.aspx?id=3800

[3] The distribution of IOUs across sixteen climate zones is aligned with: Residential Retrofit High Impact Measure (HIM) Evaluation Report, *Prepared for California Public Utilities Commission (CPUC) Energy Division, February 8, 2010*

[4] The applicable rate schedules for SDG&E are still being reviewed and are subject to change.

For high-rise multifamily building utility bill calculations, two simplifying assumptions were necessary:

1. TRC approximated that each dwelling unit had the same energy consumption profile, because energy simulation software aggregates residential energy usage for all individual dwelling units. [5]
2. TRC performed energy calculations at an hourly level, even though utilities may determine bill amounts based on sub-hourly billing intervals for simplification.

TRC does not expect these assumptions to significantly affect the overall results.

2.3.1.2 PV Installation Costs

TRC sourced the PV cost information from nationwide studies done by NREL and LBNL[6,7]. As shown in Figure 5 below, the cost includes the system cost, installation and inverter costs accounting for inflation rate and federal tax credits for nonresidential buildings. TRC applied savings from the federal income tax credit (ITC), although because it is scheduled to be phased out between 2020 and 2022, an average ITC of 16% is used for residential systems and 19% for commercial systems. TRC assumed inverter replacements at years 11 and 21. The cost for a PV retrofit is an additional $0.25/W, resulting in a total $1.97/W only for the retail strip mall prototype existing construction scenario. The federal incentive is applied to the combined system and retrofit cost.

Figure 5. Nonresidential New construction PV costs summary

Cost type	$/W
First Cost	1.72
System Cost	*2.13*
Federal Income Tax Credit	*19.2%*
Inverter Replacement at year 11	0.15
Inverter Replacement at year 21	0.12
Annual Maintenance	0.02

2.3.2 Solar Ready

Because the 'solar ready' measure is an enabling measure, rather than a requirement to install a solar system, there are no associated direct energy savings. Solar-ready measures include:

- Roof area be reserved for solar equipment

[5] Aggregated energy data impacts how utility bills are calculated. As an example in PG&E territory, the baseline allocation and minimum customer charge per unit is multiplied for 75 units of the building. So, the aggregated energy consumption of the building is compared to 75 times the baseline allocation for individual unit to calculate energy costs. Aggregation does not account for real-world variations in energy usage across the dwelling units.

[6] F. Ran et al. (September 2016) U.S. Solar Photovoltaic System Cost Benchmark: Q1 2016. National Renewable Energy Laboratory. Available at: https://www.nrel.gov/docs/fy16osti/66532.pdf

[7] Barbose, G. and Darghouth, N. (September 2017) Tracking the Sun 10. Lawrence Berkeley National Laboratory. Available at: http://eta-publications.lbl.gov/sites/default/files/tracking_the_sun_10_report.pdf

- A pathway for piping and/or conduit be indicated on plans
- Roof structural design loads be shown on plans
- Adequate electrical capacity be provided
- Spare electric breaker space be provided

Costs for reserving roof area, reserving a pathway for piping/conduit, and structural design load calculations are design costs, which are excluded in the CEC's LCC methodology, though realizing these measures will require additional attention from architects and designers. In summary, because a conventional cost-effectiveness analysis would compare zero energy savings to zero costs, no cost effectiveness analysis was performed.

3 Results

Results are provided in Figure 6 through Figure 13 in the following pages. To account for the multiple utilities within climate zones 10 and 14, there is an additional row added in each of the figures below to show cost effectiveness under both rate structures. 10-1 and 14-1 are for SCE utility rate results, and 10-2 and 14-2 are for SDG&E utility rate results (which are still under review by SDG&E, and are thus not presented).

Cost effectiveness results are evaluated for both the proposed PV system size definitions:

- **PV Measure Definition 1**: Generation equating to 80% of the total annual electric consumption
- **PV Measure Definition 2**: 15 Watts DC per square foot of solar zone

Both PV measure definitions are cost-effective for all four building types. Medium office and high-rise multifamily buildings have less roof space available than the single story buildings, resulting in smaller PV system sizes per Definition 2. Smaller PV systems result in lower costs as well as lower bill savings than Definition 1 for these prototypes, as seen when comparing Figure 8 vs. Figure 9 or Figure 10 vs. Figure 11.

The 'kWh savings' are similar across all climate zones for a particular prototype and PV definition because they are only attributable to the PV system generation. However, the 'life cycle bill savings' are influenced by both kWh savings and utility rate schedules. 'Life cycle bill savings' are similar across climate zones when under the same rate schedule, but differ when there are different rate schedules and/or utility territories.

As an example, in Figure 7, both CZ3 (under PG&E territory) and CZ6 (under SCE territory) show similar kWh savings but have significantly different bill savings of $117,445 and $78,957, respectively. TRC compared the PG&E rate to the SCE rate, and found that the SCE rates have lower volumetric charges but higher monthly fixed charges – thus the volumetric savings resulting from PV have a smaller impact on the bill when compared to minimum fixed charges

Even for the same building type within the same IOU territory, differences may occur across different climate zones because of climatic impacts on building energy consumption. Climate-dependent energy consumption, primarily space heating and space cooling, informs the on-peak and off-peak energy consumption along with the peak kW demand. These variabilities dictate both utility rate schedule selection and corresponding energy costs. For example, climate zones within SCE territory can follow under TOU-GS-1, TOU-GS-2 or TOU-GS-3 depending on their monthly loads, and each of these rate schedules have different structures.

High rise multifamily follows a residential rate schedule as opposed to commercial rates applied to the other three prototypes. Residential and commercial rate schedules are structured differently, the major difference being the peak load demand charges included in commercial rates only. PG&E's residential rate plan also includes a credit awarded for usage up to their baseline allocation. As a result, life cycle bill savings of high-rise multifamily building cannot be easily compared against the other prototypes of similar size or energy consumption.

TRC has attempted to model utility rates as accurately as possible and in coordination with the utilities, but has not identified an exhaustive set of causalities for any trends across the buildings, utilities, and climate zones.

Key takeaways include:

- Solar PV is cost effective with both sizing methods, across all building types, utility territories, and climate zones analyzed in this study. Benefit to cost ratios across all results range from 1.5 to 7.4. While TRC could not analyze all possible permutations of building sizes and rates, this suggests that these sizing methods are appropriate in the majority of possible cases.
- The Small Office has similar B/C Ratios using both PV Definitions for sizing PV systems.
- The Medium Office and HRMF prototypes have generally higher B/C Ratios with smaller PV systems (PV Definition 2) as compared to PV Definition 1. However, larger PV systems have higher NPV savings over 30 years.
- The Retail Strip Mall has higher B/C ratios with a larger PV system (PV Definition 1) as compared to PV Definition 2.

Figure 6. Cost effectiveness results – Small office – PV definition 1

Climate zone	Utility	Rate schedule	PV size	kWh savings	Life cycle Costs	Life cycle bill savings	Net savings (NPV)	B/C ratio	Discounted payback (yrs.)
1	PG&E	A-1	29.3	39,217	$70,289	$230,936	$160,647	3.3	7
2	PG&E	A-1	28.4	44,422	$68,087	$262,268	$194,181	3.9	6
3	PG&E	A-1	26.6	42,035	$63,875	$247,967	$184,092	3.9	6
4	PG&E	A-1	28.0	45,152	$67,254	$266,207	$198,954	4.0	6
5	PG&E	A-1	25.0	42,133	$60,080	$247,451	$187,372	4.1	6
6	SCE	TOU-GS-1	28.9	45,664	$69,371	$180,640	$111,269	2.6	10
7	SDG&E	-	-	-	-	-	-	-	-
8	SCE	TOU-GS-2	30.1	47,559	$72,098	$220,008	$147,910	3.1	8
9	SCE	TOU-GS-2	29.6	48,277	$70,892	$223,082	$152,190	3.1	8
10-1	SCE	TOU-GS-2	30.8	50,202	$73,866	$226,056	$152,190	3.1	8
10-2	SDG&E	-	-	-	-	-	-	-	-
11	PG&E	A-1	31.5	50,149	$75,540	$295,240	$219,699	3.9	6
12	PG&E	A-1	30.0	47,102	$71,989	$277,602	$205,613	3.9	6
13	PG&E	A-1	32.5	50,256	$77,997	$295,612	$217,615	3.8	6
14-1	SCE	TOU-GS-2	28.5	51,180	$68,326	$224,963	$156,637	3.3	7
14-2	SDG&E	-	-	-	-	-	-	-	-
15	SCE	TOU-GS-2	35.6	59,568	$85,408	$243,624	$158,216	2.9	9
16	PG&E	A-1	27.7	47,016	$66,388	$276,326	$209,938	4.2	6

Figure 7. Cost effectiveness results – Small office – PV definition 2

Climate zone	Utility	Rate schedule	PV size	kWh savings	Life cycle Costs	Life cycle bill savings	Net savings (NPV)	B/C ratio	Discounted payback (yrs.)
1	PG&E	A-1	12.4	16,567	$29,693	$99,717	$70,024	3.4	7
2	PG&E	A-1	12.4	19,372	$29,693	$116,592	$86,899	3.9	6
3	PG&E	A-1	12.4	19,540	$29,693	$117,445	$87,752	4.0	6
4	PG&E	A-1	12.4	19,935	$29,693	$119,760	$90,067	4.0	6
5	PG&E	A-1	12.4	20,823	$29,693	$124,345	$94,652	4.2	6
6	SCE	TOU-GS-1	12.4	19,546	$29,693	$78,957	$49,265	2.7	9
7	SDG&E	-	-	-	-	-	-	-	-
8	SCE	TOU-GS-2	12.4	19,587	$29,693	$59,942	$30,249	2.0	15
9	SCE	TOU-GS-2	12.4	20,221	$29,693	$60,906	$31,213	2.1	15
10-1	SCE	TOU-GS-2	12.4	20,180	$29,693	$60,206	$30,513	2.0	15
10-2	SDG&E	-	-	-	-	-	-	-	-
11	PG&E	A-1	12.4	19,712	$29,693	$118,521	$88,828	4.0	6
12	PG&E	A-1	12.4	19,428	$29,693	$116,843	$87,150	3.9	6
13	PG&E	A-1	12.4	19,132	$29,693	$115,046	$85,353	3.9	6
14-1	SCE	TOU-GS-2	12.4	22,241	$29,693	$63,850	$34,157	2.2	14
14-2	SDG&E	-	-	-	-	-	-	-	-
15	SCE	TOU-GS-2	12.4	20,710	$29,693	$57,101	$27,408	1.9	17
16	PG&E	A-1	12.4	21,029	$29,693	$126,070	$96,377	4.2	6

Figure 8. Cost effectiveness results – Medium office - PV definition 1

Climate zone	Utility	Rate schedule	PV size	kWh savings	Life cycle Costs	Life cycle bill savings	Net savings (NPV)	B/C ratio	Discounted payback (yrs.)
1	PG&E	A-10	226.4	303,042	$543,148	$1,368,713	$825,566	2.5	10
2	PG&E	A-10	222.4	348,075	$533,510	$1,615,140	$1,081,630	3.0	8
3	PG&E	A-10	206.3	325,611	$494,786	$1,504,648	$1,009,862	3.0	8
4	PG&E	A-10	220.5	355,050	$528,839	$1,623,929	$1,095,090	3.1	8
5	PG&E	A-10	194.8	327,649	$467,219	$1,493,119	$1,025,900	3.2	8
6	SCE	TOU-GS-2	230.2	363,468	$552,169	$1,110,412	$558,243	2.0	16
7	SDG&E	-	-	-	-	-	-	-	-
8	SCE	TOU-GS-2	237.4	375,540	$569,306	$1,159,835	$590,529	2.0	15
9	SCE	TOU-GS-3	233.4	381,176	$559,732	$1,320,521	$760,789	2.4	13
10-1	SCE	TOU-GS-3	237.9	387,771	$570,554	$1,314,698	$744,144	2.3	13
10-2	SDG&E	-	-	-	-	-	-	-	-
11	PG&E	A-10	244.2	388,810	$585,670	$1,760,419	$1,174,749	3.0	8
12	PG&E	A-10	235.8	370,084	$565,629	$1,683,325	$1,117,696	3.0	8
13	PG&E	A-10	254.7	393,559	$610,802	$1,772,341	$1,161,539	2.9	8
14-1	SCE	TOU-GS-3	217.4	390,525	$521,362	$1,297,029	$775,667	2.5	10
14-2	SDG&E	-	-	-	-	-	-	-	-
15	SCE	TOU-GS-3	280.1	468,546	$671,793	$1,495,913	$824,121	2.2	14
16	PG&E	A-10	199.8	339,442	$479,299	$1,516,862	$1,037,563	3.2	8

Figure 9. Cost effectiveness results – Medium office - PV definition 2

Climate zone	Utility	Rate schedule	PV size	kWh savings	Life cycle Costs	Life cycle bill savings	Net savings (NPV)	B/C ratio	Discounted payback (yrs.)
1	PG&E	A-10	40.2	53,825	$96,472	$353,359	$256,887	3.7	6
2	PG&E	A-10	40.2	62,941	$96,472	$408,113	$311,641	4.2	6
3	PG&E	A-10	40.2	63,487	$96,472	$397,970	$301,498	4.1	6
4	PG&E	A-10	40.2	64,769	$96,472	$410,637	$314,165	4.3	6
5	PG&E	A-10	40.2	67,654	$96,472	$430,527	$334,055	4.5	5
6	SCE	TOU-GS-2	40.2	63,503	$96,472	$346,995	$250,523	3.6	7
7	SDG&E	-	-	-	-	-	-	-	-
8	SCE	TOU-GS-2	40.2	63,637	$96,472	$355,618	$259,146	3.7	6
9	SCE	TOU-GS-3	40.2	65,697	$96,472	$391,040	$294,568	4.1	6
10-1	SCE	TOU-GS-3	40.2	65,566	$96,472	$393,515	$297,043	4.1	6
10-2	SDG&E	-	-	-	-	-	-	-	-
11	PG&E	A-10	40.2	64,045	$96,472	$417,553	$321,081	4.3	5
12	PG&E	A-10	40.2	63,121	$96,472	$406,773	$310,300	4.2	6
13	PG&E	A-10	40.2	62,160	$96,472	$408,211	$311,738	4.2	6
14-1	SCE	TOU-GS-3	40.2	72,262	$96,472	$411,201	$314,729	4.3	5
14-2	SDG&E	-	-	-	-	-	-	-	-
15	SCE	TOU-GS-3	40.2	67,285	$96,472	$426,125	$329,653	4.4	5
16	PG&E	A-10	40.2	68,322	$96,472	$412,717	$316,245	4.3	5

Figure 10. Cost effectiveness results – High-rise multifamily - PV definition 1

Climate zone	Utility	Rate schedule	PV size	kWh savings	Life cycle Costs	Life cycle bill savings	Net savings (NPV)	B/C ratio	Discounted payback (yrs.)
1	PG&E	E-TOU	238.4	322,852	$571,845	$2,025,220	$1,453,375	3.5	7
2	PG&E	E-TOU	225.6	371,193	$541,137	$2,187,767	$1,646,630	4.0	6
3	PG&E	E-TOU	210.5	344,653	$504,938	$2,040,935	$1,535,997	4.0	6
4	PG&E	E-TOU	221.9	376,983	$532,167	$2,226,673	$1,694,506	4.2	6
5	PG&E	E-TOU	197.6	348,463	$473,866	$2,011,233	$1,537,367	4.2	6
6	SCE	TOU-D-T	226.5	300,595	$543,263	$2,060,969	$1,517,706	3.8	6
7	SDG&E	-	-	-	-	-	-	-	-
8	SCE	TOU-D-T	233.3	312,666	$559,574	$2,143,444	$1,583,870	3.8	6
9	SCE	TOU-D-T	231.4	323,601	$555,088	$2,199,218	$1,644,131	4.0	6
10-1	SCE	TOU-D-T	235.7	330,150	$565,263	$2,235,530	$1,670,267	4.0	6
10-2	SDG&E	-	-	-	-	-	-	-	-
11	PG&E	E-TOU	249.0	421,808	$597,311	$2,400,718	$1,803,407	4.0	6
12	PG&E	E-TOU	237.4	397,092	$569,400	$2,230,664	$1,661,264	3.9	6
13	PG&E	E-TOU	256.3	425,413	$614,846	$2,354,303	$1,739,457	3.8	6
14-1	SCE	TOU-D-T	220.5	339,752	$528,831	$2,305,881	$1,777,050	4.4	5
14-2	SDG&E	-	-	-	-	-	-	-	-
15	SCE	TOU-D-T	275.4	403,210	$660,453	$2,719,247	$2,058,794	4.1	6
16	PG&E	E-TOU	211.1	377,068	$506,410	$2,290,624	$1,784,213	4.5	5

Figure 11. Cost effectiveness results – High-rise multifamily - PV definition 2

Climate zone	Utility	Rate schedule	PV size	kWh savings	Life cycle Costs	Life cycle bill savings	Net savings (NPV)	B/C ratio	Discounted payback (yrs.)
1	PG&E	E-TOU	19.2	25,630	$45,937	$273,401	$227,464	6.0	4
2	PG&E	E-TOU	19.2	29,970	$45,937	$320,775	$274,838	7.0	3
3	PG&E	E-TOU	19.2	30,231	$45,937	$313,753	$267,816	6.8	3
4	PG&E	E-TOU	19.2	30,841	$45,937	$329,443	$283,506	7.2	3
5	PG&E	E-TOU	19.2	32,215	$45,937	$328,745	$282,808	7.2	3
6	SCE	TOU-D-T	19.2	30,238	$45,937	$286,837	$240,900	6.2	4
7	SDG&E	-	-	-	-	-	-	-	-
8	SCE	TOU-D-T	19.2	30,302	$45,937	$290,631	$244,694	6.3	4
9	SCE	TOU-D-T	19.2	31,283	$45,937	$299,840	$253,903	6.5	4
10-1	SCE	TOU-D-T	19.2	31,221	$45,937	$300,028	$254,091	6.5	4
10-2	SDG&E	-	-	-	-	-	-	-	-
11	PG&E	E-TOU	19.2	30,496	$45,937	$340,273	$294,336	7.4	3
12	PG&E	E-TOU	19.2	30,056	$45,937	$328,635	$282,698	7.2	3
13	PG&E	E-TOU	19.2	29,599	$45,937	$319,894	$273,957	7.0	3
14-1	SCE	TOU-D-T	19.2	34,409	$45,937	$322,608	$276,671	7.0	3
14-2	SDG&E	-	-	-	-	-	-	-	-
15	SCE	TOU-D-T	19.2	32,039	$45,937	$329,110	$283,173	7.2	3
15	PG&E	E-TOU	19.2	32,039	$45,937	$340,897	$294,960	7.4	3

Figure 12. Cost effectiveness results – Existing Retail strip mall – PV definition 1

Climate zone	Utility	Rate schedule	PV size	kWh savings	Life cycle Costs	Life cycle bill savings	Net savings (NPV)	B/C ratio	Discounted payback (yrs.)
1	PG&E	A-10	84.0	112,424	$218,442	$510,358	$291,916	2.3	13
2	PG&E	A-10	84.6	132,460	$220,099	$611,335	$391,237	2.8	9
3	PG&E	A-10	77.0	121,554	$200,239	$561,986	$361,746	2.8	9
4	PG&E	A-10	83.0	133,623	$215,763	$609,041	$393,279	2.8	9
5	PG&E	A-10	71.9	120,997	$187,046	$551,377	$364,331	2.9	8
6	SCE	TOU-GS-2	86.7	136,919	$225,491	$418,301	$192,811	1.9	17
7	SDG&E	-	-	-	-	-	-	-	-
8	SCE	TOU-GS-2	90.0	142,367	$233,969	$439,701	$205,731	1.9	17
9	SCE	TOU-GS-2	88.3	144,288	$229,691	$444,818	$215,127	1.9	16
10-1	SCE	TOU-GS-2	92.6	150,878	$240,662	$461,482	$220,820	1.9	17
10-2	SDG&E	-	-	-	-	-	-	-	-
11	PG&E	A-10	91.9	146,301	$238,904	$658,800	$419,896	2.8	9
12	PG&E	A-10	88.8	139,284	$230,777	$626,075	$395,299	2.7	9
13	PG&E	A-10	96.4	149,044	$250,763	$664,580	$413,816	2.7	10
14-1	SCE	TOU-GS-2	82.6	148,433	$214,824	$446,955	$232,131	2.1	15
14-2	SDG&E	-	-	-	-	-	-	-	-
15	SCE	TOU-GS-2	107.0	178,916	$278,095	$528,901	$250,806	1.9	17
16	PG&E	A-10	78.5	133,261	$203,988	$593,882	$389,894	2.9	9

Figure 13. Cost effectiveness results – Existing Retail strip mall - PV definition 2

Climate zone	Utility	Rate schedule	PV size	kWh savings	Life cycle Costs	Life cycle bill savings	Net savings (NPV)	B/C ratio	Discounted payback (yrs.)
1	PG&E	A-10	21.1	28,229	$54,848	$141,450	$86,602	2.6	10
2	PG&E	A-10	21.1	33,009	$54,848	$169,518	$114,670	3.1	8
3	PG&E	A-10	21.1	33,295	$54,848	$171,209	$116,361	3.1	8
4	PG&E	A-10	21.1	33,968	$54,848	$172,320	$117,472	3.1	8
5	PG&E	A-10	21.1	35,481	$54,848	$183,129	$128,281	3.3	7
6	SCE	TOU-GS-2	21.1	33,304	$54,848	$84,760	$29,912	1.5	26
7	SDG&E	-	-	-	-	-	-	-	-
8	SCE	TOU-GS-2	21.1	33,374	$54,848	$86,054	$31,205	1.6	25
9	SCE	TOU-GS-2	21.1	34,455	$54,848	$88,645	$33,796	1.6	24
10-1	SCE	TOU-GS-2	21.1	34,386	$54,848	$87,635	$32,787	1.6	24
10-2	SDG&E	-	-	-	-	-	-	-	-
11	PG&E	A-10	21.1	33,588	$54,848	$163,366	$108,518	3.0	8
12	PG&E	A-10	21.1	33,103	$54,848	$161,184	$106,336	2.9	8
13	PG&E	A-10	21.1	32,600	$54,848	$157,723	$102,875	2.9	9
14-1	SCE	TOU-GS-2	21.1	37,898	$54,848	$94,785	$39,936	1.7	19
14-2	SDG&E	-	-	-	-	-	-	-	-
15	SCE	TOU-GS-2	21.1	35,287	$54,848	$86,315	$31,467	1.6	25
16	PG&E	A-10	21.1	35,831	$54,848	$173,246	$118,398	3.2	8