



CALIFORNIA
ENERGY
CODES & STANDARDS

A STATEWIDE UTILITY PROGRAM

2019 New Construction Cost-effectiveness Studies

**Mid-Rise Multifamily Residential
Cost-effectiveness Study
PRELIMINARY Results**

Appendices added March 30, 2020

March 11, 2020

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Agenda – Midrise Multifamily Residential New Construction

- Welcome and Introductions
- Overview
- Methodology, Measures, and Assumptions
- Analysis Results
 - Mixed Fuel
 - All-Electric
- Summary
- Q&A

Overview



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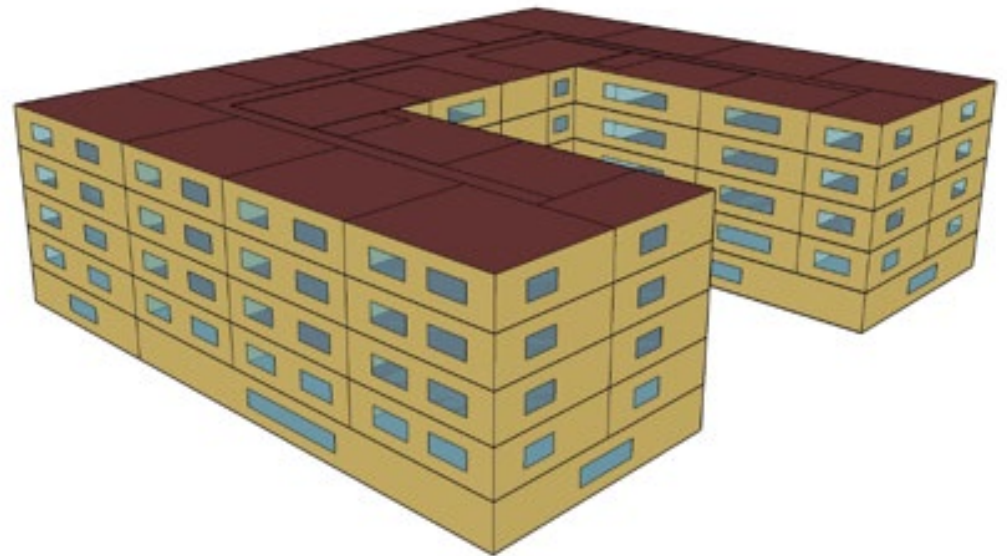
Overview and Timeline

- Four new multifamily prototypes: two low-rise, mid-rise and high-rise.
- August 2019: Initial mid-rise prototype design. One climate zone, not calibrated for compliance
 - December 2019: Notification of new prescriptive compliance option for central HPWH water heating system
 - March 2020: CBECC-Com updated to enable modeling for prescriptive central HPWH system

Methodology, Measures, and Assumptions

Analysis Methodology

- 5-story mid-rise multifamily prototype
- EnergyPro v8 / CBECC-Com 2019 v1.2 (3/1 release)
- All 16 climate zones
- Basecase meets 2019 prescriptive standard
- Mixed fuel and all-electric cases



Prototype Characteristics

Characteristic	Multifamily Mid-Rise
Conditioned Floor Area	113,100 ft ² Total: 33,660 ft ² Nonresidential & 79,440 ft ² Residential
Num. of Stories	6 Stories Total: 1 Story Parking Garage 1 Story of Nonresidential Space 4 Stories of Residential Space
Num. of Units / Bedrooms	(8) studios (40) 1-bed units, (32) 2-bed units, & (8) 3-bed units.
Window-to-Wall Area Ratio	22.5%
Baseline HVAC System	Split heat pumps at apartments
Baseline Water Heater	Gas central boiler with solar thermal

- Baseline space heating system based on market data indicating heat pumps are most common system type. ACM assumes furnace/AC.

Residential Efficiency Measures

Measure	Performance Level
Window U-factor	0.25 vs 0.36
Window SHGC	0.22 vs 0.25
Exterior Wall Insulation	Add 1-inch
HERS Verified Pipe Insulation	HERS verified pipe insulation vs no verification
Low Pressure Drop Duct Design	0.25 W/cfm vs 0.35 W/cfm
PV System	1 kW per Dwelling Unit

- ❖ Packages vary based on climate zone / package
- ❖ Measures analyzed but not included:
Drain water heat recovery, solar thermal
- ❖ Additional measures to evaluate:
Battery storage

Nonresidential Efficiency Measures

Measure	Performance Level
Window SHGC	0.22 vs 0.25
VAV box minimum airflow	20% of max flow
Reduced LPD	10% reduction
Institutional tuning	5% reduction in daylit areas 10% reduction in other areas

- ❖ Applied the same measures used in the 2019 NR reach code analysis
 - ❖ Medium Retail for retail spaces
 - ❖ Small Hotel - Common Spaces for other areas

Cost Effectiveness

- Evaluate residential apartments only
- 2 methodologies
 - Time Dependent Valuation (TDV) per CEC methodology
 - On-bill customer based
 - IOU rates based on region.
 - TOU utility rates. Reflect rate schedules for 2019*
- 30 year evaluation period
- Benefit-to-Cost Ratio (BCR)

$$BCR = \frac{NPV \text{ of benefit}}{NPV \text{ of cost}}$$

**To be updated with 2020 rates*

Residential Efficiency Measure Costs

Measure	Performance Level	Incremental Cost (2020 PV\$)	Notes
Window U-factor	0.25 vs 0.36	\$28,301	\$6.95/ft ² window area
Window SHGC	0.22 vs 0.25	\$0	No cost impact
Exterior Wall Insulation	Add 1-inch	\$14,058	\$0.86/ft ² exterior wall
HERS Verified Pipe Insulation	HERS verified pipe insulation vs no verification	\$7,260	\$83 per apartment for a HERS rater to conduct verification of pipe insulation.
Low Pressure Drop Duct Design	0.25 W/cfm vs 0.35 W/cfm	\$12,654	\$145 per apartment (1-1.5 hour labor) for upgrades to duct system.
PV System	1 kW per Dwelling Unit	\$3.17/W-DC	\$2.90/W-DC reduced by 16% for the solar investment tax credit (average credit over years 2020-2022). Includes inverter replacement at year 11 and 21 and annual maintenance costs.

Mixed Fuel Analysis

Mixed Fuel Efficiency Measure Packages

Climate Zone	Window U-value	Window SHGC	Exterior Wall Ins.	Duct Design	HERS pipe insulation
CZ01			+ 1-inch	0.25 W/cfm	
CZ02		0.22		0.25 W/cfm	
CZ03		0.22		0.25 W/cfm	
CZ04		0.22		0.25 W/cfm	
CZ05		0.22		0.25 W/cfm	
CZ06		0.22		0.25 W/cfm	
CZ07		0.22		0.25 W/cfm	
CZ08		0.22		0.25 W/cfm	
CZ09		0.22		0.25 W/cfm	
CZ10		0.22		0.25 W/cfm	
CZ11	0.25	0.22	+ 1-inch	0.25 W/cfm	
CZ12	0.25	0.22	+ 1-inch	0.25 W/cfm	
CZ13	0.25	0.22	+ 1-inch	0.25 W/cfm	
CZ14	0.25	0.22	+ 1-inch	0.25 W/cfm	
CZ15	0.25	0.22	+ 1-inch	0.25 W/cfm	
CZ16	0.25	0.22	+ 1-inch	0.25 W/cfm	

Mixed Fuel Package Results

SAVINGS PER APARTMENT – 30-yr Period

Climate Zone	Elec Utility	Gas Utility	Comp. Margin	Utility Cost Savings (NPV)	TDV Savings (NPV)	Incremental Cost	TDV B/C Ratio	On-Bill B/C Ratio
CZ01	PGE	PGE	5.8%	\$135	\$105	\$304	0.3	0.4
CZ02	PGE	PGE	5.9%	\$322	\$285	\$144	2.0	2.2
CZ03	PGE	PGE	6.7%	\$289	\$226	\$144	1.6	2.0
CZ04	PGE	PGE	6.6%	\$392	\$331	\$144	2.3	2.7
CZ05	PGE	PGE	6.7%	\$271	\$206	\$144	1.4	1.9
CZ05	PGE	SCG	6.7%	\$271	\$206	\$144	1.4	1.9
CZ06	SCE	SCG	7.1%	\$354	\$351	\$144	2.4	2.5
CZ07	SDGE	SDGE	7.6%	\$625	\$374	\$144	2.6	4.3
CZ08	SCE	SCG	7.0%	\$408	\$420	\$144	2.9	2.8
CZ09	SCE	SCG	6.5%	\$399	\$441	\$144	3.1	2.8
CZ10	SCE	SCG	6.5%	\$347	\$427	\$144	3.0	2.4
CZ10	SDGE	SDGE	6.5%	\$581	\$427	\$144	3.0	4.0
CZ11	PGE	PGE	6.8%	\$653	\$635	\$625	1.0	1.0
CZ12	PGE	PGE	7.3%	\$627	\$661	\$625	1.1	1.0
CZ13	PGE	PGE	7.3%	\$818	\$779	\$625	1.2	1.3
CZ14	SCE	SCG	6.8%	\$473	\$602	\$625	0.96	0.8
CZ14	SDGE	SDGE	6.8%	\$672	\$602	\$625	0.96	1.1
CZ15	SCE	SCG	6.8%	\$629	\$802	\$625	1.3	1.0
CZ16	PGE	PGE	7.4%	\$655	\$563	\$625	0.9	1.0

Compliance margin >5% in all climate zones.

Meets CALGreen Tier 1

Mixed Fuel Package Results with 88kW PV System SAVINGS PER APARTMENT – 30-yr Period

Climate Zone	Elec Utility	Gas Utility	Comp. Margin	Utility Cost Savings (NPV)	TDV Savings (NPV)	Incremental Cost	TDV B/C Ratio	On-Bill B/C Ratio
CZ01	PGE	PGE	5.8%	\$7,611	\$5,029	\$3,469	1.4	2.2
CZ02	PGE	PGE	5.9%	\$9,133	\$6,203	\$3,309	1.9	2.8
CZ03	PGE	PGE	6.7%	\$9,145	\$6,079	\$3,309	1.8	2.8
CZ04	PGE	PGE	6.6%	\$9,525	\$6,483	\$3,309	2.0	2.9
CZ05	PGE	PGE	6.7%	\$9,650	\$6,482	\$3,309	2.0	2.9
CZ05	PGE	SCG	6.7%	\$9,650	\$6,482	\$3,309	2.0	2.9
CZ06	SCE	SCG	7.1%	\$5,778	\$6,534	\$3,309	2.0	1.7
CZ07	SDGE	SDGE	7.6%	\$9,708	\$6,739	\$3,309	2.0	2.9
CZ08	SCE	SCG	7.0%	\$5,757	\$6,861	\$3,309	2.1	1.7
CZ09	SCE	SCG	6.5%	\$5,514	\$6,948	\$3,309	2.1	1.7
CZ10	SCE	SCG	6.5%	\$5,427	\$6,697	\$3,309	2.0	1.6
CZ10	SDGE	SDGE	6.5%	\$9,284	\$6,697	\$3,309	2.0	2.8
CZ11	PGE	PGE	6.8%	\$9,665	\$6,846	\$3,791	1.8	2.5
CZ12	PGE	PGE	7.3%	\$9,526	\$6,786	\$3,791	1.8	2.5
CZ13	PGE	PGE	7.3%	\$9,587	\$6,709	\$3,791	1.8	2.5
CZ14	SCE	SCG	6.8%	\$5,989	\$7,859	\$3,791	2.1	1.6
CZ14	SDGE	SDGE	6.8%	\$10,193	\$7,859	\$3,791	2.1	2.7
CZ15	SCE	SCG	6.8%	\$5,809	\$7,342	\$3,791	1.9	1.5
CZ16	PGE	PGE	7.4%	\$10,221	\$6,836	\$3,791	1.8	2.7

Cost effective everywhere

~\$3,200 incremental cost / apt for PV

All Electric Analysis

Electric Water Heating Equipment

Clustered Design

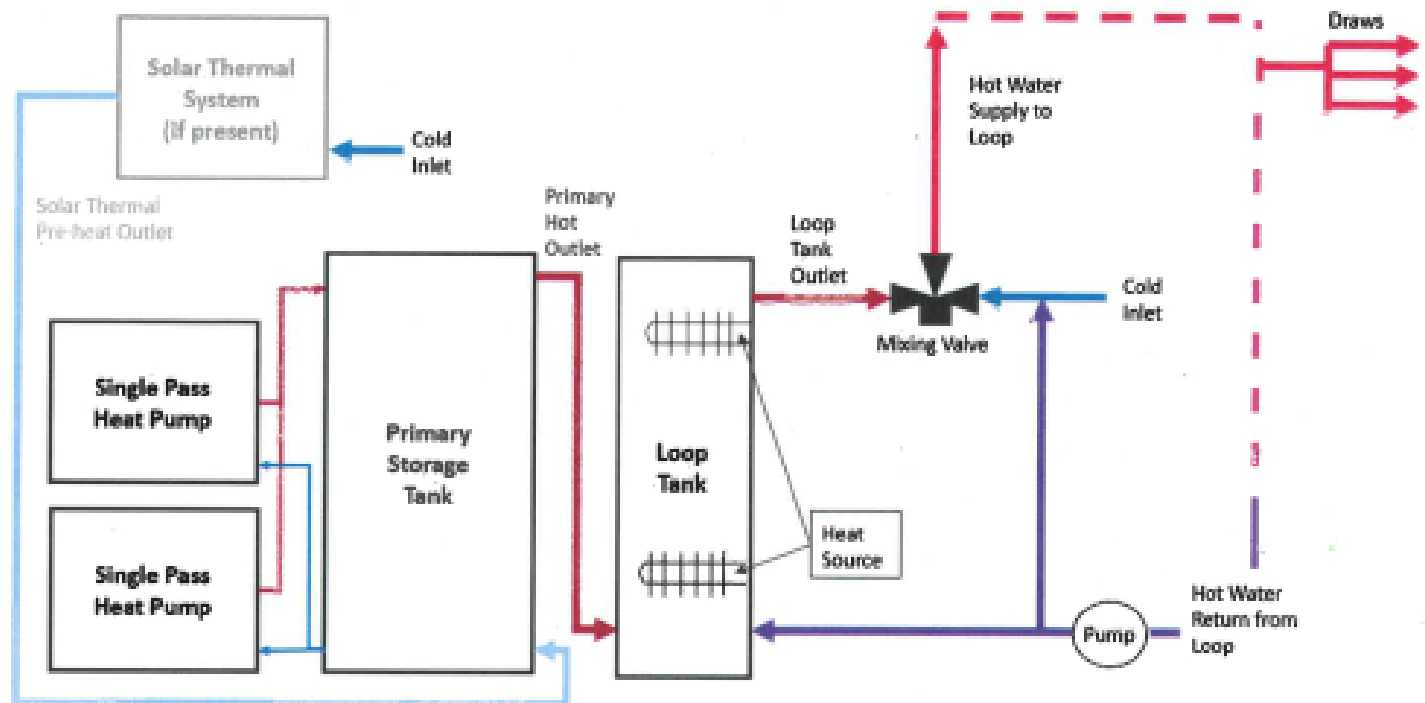
- 1 residential 80-gallon HPWH per 4-5 bedrooms (32 total)
- Located in interior closets throughout the building
- Designed for short plumbing runs – no HW recirculation



Electric Water Heating Equipment

Prescriptive Central HPWH Design

- Spec based on Sanden HPWH
- 15 compressors required for mid-rise prototype
- 80 gallon storage per compressor
- Either solar thermal OR 0.1 kW PV / apartment



Nonresidential Electric Heating Equipment

- Applied the same measures used in the 2019 NR reach code analysis
 - Packaged heat pump & VAV with electric resistance reheat
 - Electric resistance storage service water heater

Costs for Gas versus Electric Water Heating Equipment

	Central Gas Boiler (CZs 1-9)	Central Gas Boiler (CZs 10-16)	Clustered HPWH	Central HPWH
System Quantity/Description	1 boiler recirc		32 units 80 gal. each no recirc	15 units 1,200 gal total recirc
Total Equipment Cost	\$106,105		\$126,778	\$213,364
Solar Thermal	\$35,073 (20% SF)	\$61,611 (35% SF)	-	-
Solar PV	-	-	-	\$23,580 (88 kW)
Total First Cost	\$141,178	\$167,716	\$126,778	\$236,944
Maintenance / Replacement Cost (NPV)	\$80,594	\$80,594	\$77,305	\$120,683
Total Cost (NPV)	\$221,771	\$248,309	\$204,083	\$357,627
Incremental Cost (NPV)			(\$44,226) - (\$17,688)	\$109,318 - \$135,855)

- 15-year lifetime for boiler & HPWH equipment
 - 5% reduction in cost for clustered HPWH
 - 15% reduction in cost for central HPWH

Gas Infrastructure Costs

Item	Total	Non-Residential Portion	Residential Portion
Natural Gas Plan Review	\$2,316	\$689	\$1,627
Service Extension	\$10,331	\$3,869	\$6,462
Meter	\$7,200	\$3,600	\$3,600
Plumbing Distribution	\$1,266	\$633	\$633
Total First Cost	\$21,113	\$8,791	\$12,322

- Costs data from PG&E, Palo Alto, 2019 NR reach code
- Building level costs split between Res/NR based on floor area
- Electric infrastructure costs included in water heating equipment costs

All Electric Efficiency Measure Packages

Climate Zone	Window U-value	Window SHGC	Exterior Wall Ins.	Duct Design	HERS pipe insulation
CZ01			+ 1-inch	0.25 W/cfm	Verified
CZ02		0.22		0.25 W/cfm	Verified
CZ03		0.22		0.25 W/cfm	Verified
CZ04		0.22		0.25 W/cfm	Verified
CZ05		0.22		0.25 W/cfm	Verified
CZ06		0.22		0.25 W/cfm	Verified
CZ07		0.22		0.25 W/cfm	Verified
CZ08		0.22		0.25 W/cfm	Verified
CZ09		0.22		0.25 W/cfm	Verified
CZ10		0.22		0.25 W/cfm	Verified
CZ11	0.25	0.22	+ 1-inch	0.25 W/cfm	Verified
CZ12	0.25	0.22	+ 1-inch	0.25 W/cfm	Verified
CZ13	0.25	0.22	+ 1-inch	0.25 W/cfm	Verified
CZ14	0.25	0.22	+ 1-inch	0.25 W/cfm	Verified
CZ15	0.25	0.22	+ 1-inch	0.25 W/cfm	Verified
CZ16	0.25	0.22	+ 1-inch	0.25 W/cfm	Verified

Clustered HPWH design

All Electric Package Results Clustered HPWH SAVINGS PER APARTMENT – 30-yr Period

Climate Zone	Elec Utility	Gas Utility	Comp. Margin	Utility Cost Savings (NPV)	TDV Savings (NPV)	Incremental Cost	TDV B/C Ratio	On-Bill B/C Ratio
CZ01	PGE	PGE	-0.4%	-\$971	\$199	\$45	4.4	0
CZ02	PGE	PGE	1.6%	-\$578	\$528	-\$115	>1	0.2
CZ03	PGE	PGE	1.1%	-\$616	\$390	-\$115	>1	0.2
CZ04	PGE	PGE	3.4%	-\$438	\$625	-\$115	>1	0.3
CZ05	PGE	PGE	1.3%	-\$679	\$391	-\$115	>1	0.2
CZ05	PGE	SCG	1.3%	-\$1,073	\$391	-\$115	>1	0.1
CZ06	SCE	SCG	3.7%	\$382	\$612	-\$115	>1	>1
CZ07	SDGE	SDGE	4.8%	\$513	\$665	-\$115	>1	>1
CZ08	SCE	SCG	3.9%	\$436	\$693	-\$115	>1	>1
CZ09	SCE	SCG	3.8%	\$427	\$739	-\$115	>1	>1
CZ10	SCE	SCG	1.8%	\$19	\$396	-\$416	>1	>1
CZ10	SDGE	SDGE	1.8%	\$2	\$396	-\$416	>1	>1
CZ11	PGE	PGE	2.0%	-\$453	\$430	\$65	6.6	0
CZ12	PGE	PGE	2.0%	-\$589	\$380	\$65	5.8	0
CZ13	PGE	PGE	2.6%	-\$266	\$505	\$65	7.8	0
CZ14	SCE	SCG	2.0%	\$125	\$458	\$65	7.0	1.9
CZ14	SDGE	SDGE	2.0%	\$55	\$458	\$65	7.0	0.8
CZ15	SCE	SCG	4.4%	\$474	\$832	\$65	12.8	7.3
CZ16	PGE	PGE	-5.8%	-\$883	\$127	\$65	2.0	0

Code compliant everywhere except CZ 1 & 16

Cost effective in all climate zones

All Electric Package Results Clustered HPWH with 88kW PV System

SAVINGS PER APARTMENT – 30-yr Period

Climate Zone	Elec Utility	Gas Utility	Comp. Margin	Utility Cost Savings (NPV)	TDV Savings (NPV)	Incremental Cost	TDV B/C Ratio	On-Bill B/C Ratio
CZ01	PGE	PGE	-0.4%	\$6,505	\$5,123	\$3,210	1.6	2.0
CZ02	PGE	PGE	1.6%	\$8,233	\$6,446	\$3,051	2.1	2.7
CZ03	PGE	PGE	1.1%	\$8,240	\$6,242	\$3,051	2.0	2.7
CZ04	PGE	PGE	3.4%	\$8,695	\$6,777	\$3,051	2.2	2.9
CZ05	PGE	PGE	1.3%	\$8,701	\$6,667	\$3,051	2.2	2.9
CZ05	PGE	SCG	1.3%	\$8,307	\$6,667	\$3,051	2.2	2.7
CZ06	SCE	SCG	3.7%	\$5,806	\$6,796	\$3,051	2.2	1.9
CZ07	SDGE	SDGE	4.8%	\$9,596	\$7,030	\$3,051	2.3	3.1
CZ08	SCE	SCG	3.9%	\$5,785	\$7,133	\$3,051	2.3	1.9
CZ09	SCE	SCG	3.8%	\$5,543	\$7,247	\$3,051	2.4	1.8
CZ10	SCE	SCG	1.8%	\$5,099	\$6,666	\$2,749	2.4	1.9
CZ10	SDGE	SDGE	1.8%	\$8,706	\$6,666	\$2,749	2.4	3.2
CZ11	PGE	PGE	2.0%	\$8,559	\$6,641	\$3,230	2.1	2.6
CZ12	PGE	PGE	2.0%	\$8,310	\$6,505	\$3,230	2.0	2.6
CZ13	PGE	PGE	2.6%	\$8,503	\$6,435	\$3,230	2.0	2.6
CZ14	SCE	SCG	2.0%	\$5,640	\$7,716	\$3,230	2.4	1.7
CZ14	SDGE	SDGE	2.0%	\$9,576	\$7,716	\$3,230	2.4	3.0
CZ15	SCE	SCG	4.4%	\$5,654	\$7,371	\$3,230	2.3	1.8
CZ16	PGE	PGE	-5.8%	\$8,683	\$6,399	\$3,230	2.0	2.7

Cost effective in all climate zones

~\$3,200 incremental cost / apt for PV

Summary

Legal Requirements for Local Energy Ordinances

- Compliant with local requirements for ordinances
- Compliant with all state laws
- Updated for each new Building Code cycle
- Filed with the State
- Accessible to the public
- **More stringent than state requirements**
- **Cost effective**
- **May not preempt federal regulations (effectively, may not specifically require high efficiency HVAC and DHW equipment or any other appliances for which there is a federal standard)**

Mixed Fuel Design Results

- Energy Efficiency Only
 - Compliance Margin meets CALGreen Tier 1 ($\geq 5\%$)
 - Cost-effective in all climate zones EXCEPT 1, 14, 16
 - Incremental cost: approximately \$13k - \$55k
- Energy Efficiency plus PV (1kW per dwelling unit)
 - No change to compliance margin (CALGreen Tier 1)
 - Cost-effective in all climate zones
 - Both on-bill and TDV metrics
 - Incremental cost: approximately \$291k - \$334k

All-Electric Design Results

- Energy Efficiency Only
 - Compliance only (no Tier 1)
 - Cost-effective in all climate zones depending on metric
 - TDV – all climate zones
 - On-Bill – Only climate zones 6-10, 15
 - Incremental cost: approximately +\$6k cost to -(\$37k) savings
- Energy Efficiency plus PV (1kW per dwelling unit)
 - No change to compliance margin
 - Cost-effective in all climate zones
 - Both on-bill and TDV metrics
 - Incremental cost: approximately \$242k - \$284k

Ordinance Structures Supported

- Electric-Preferred
 - Mixed Fuel = CALGreen Tier 1
 - All-Electric = Comply only
 - EE Only: All climate zones except 1, 16
 - EE + PV: All climate zones
- All-Electric
 - EE Only: All climate zones except 1, 16 if TDV
CZ 6-10, 15 only if On-Bill
 - EE + PV: All climate zones

Questions?

Thank you!

Contact us at Info@localenergycodes.com for additional information

LocalEnergyCodes.com

Appendices

- ❖ CBECC-Com Modeling Limitations
- ❖ Mixed Fuel PV System Analysis
- ❖ All-Electric PV System Analysis

CBCECC-Com Compliance Software Modeling Limitations

- Mid-rise and high-rise prototypes are new and have not been publicly released by the CEC. The Standard Design files for the prototypes have not been created and models must be “tweaked” to create compliance-neutral design in each climate zone.
- Highrise residential is expected to undergo a dramatic baseline change. The HVAC Standard Design will change from a 4-pipe fan coil to individual split furnace / AC systems in the dwelling units. This can be simulated in the current version of CBCECC-Com but may not be used yet for compliance.
- New ability to model central HPWH in CBCECC-Com. (Released 2/29/2020)
 - Limited flexibility with prescriptive approach
 - Only Sanden product available in model (two more to be added Q2 2020)
 - Currently unable to model PV for compliance with the prescriptive requirements (0.1 kW PV/dwelling unit), resulting in a compliance penalty unless there is a solar thermal system.
 - Limited testing completed by the Statewide Team
- New version of software adds solar thermal performance modeling capabilities. While this improves accuracy of system performance relative to hourly TDV, cannot specify solar thermal fraction. Must create a system which requires partial design and multiple iterations to achieve compliance-neutral system.

Mixed Fuel PV System Analysis

Mixed Fuel Design: Summary of PV Sensitivity Analysis

- Adding PV system is cost-effective in all climate zones and utility territories.
- PV production is not optimally matched to residential usage patterns
 - Most production is during off-peak hours
 - Residential usage peaks during early morning and evening hours
- Efficiency-Only vs Efficiency Plus PV
 - Climate Zones 1-5, 11-16
 - PV system improves On-Bill cost-effectiveness
 - Climate Zones 6-10
 - Combined package remains cost-effective, but PV system reduces ratio

Mixed Fuel Package Results

SAVINGS PER APARTMENT – 30-yr Period

Climate Zone	Elec Utility	Gas Utility	Comp. Margin	Utility Cost Savings (NPV)	TDV Savings (NPV)	Incremental Cost	TDV B/C Ratio	On-Bill B/C Ratio
CZ01	PGE	PGE	5.8%	\$135	\$105	\$304	0.3	0.4
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CZ06	SCE	SCG	7.1%	\$354	\$351	\$144	2.4	2.5
CZ07	SDGE	SDGE	7.6%	\$625	\$374	\$144	2.6	4.3
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CZ09	SCE	SCG	6.5%	\$399	\$441	\$144	3.1	2.8
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CZ15	SCE	SCG	6.8%	\$629	\$802	\$625	1.3	1.0
CZ16	PGE	PGE	7.4%	\$655	\$563	\$625	0.9	1.0

Compliance margin >5% in all climate zones.

Meets CALGreen Tier 1

Mixed Fuel Package Results with 0.1kW PV System / Apartment SAVINGS PER APARTMENT – 30-yr Period

Climate Zone	Elec Utility	Gas Utility	Comp. Margin	Utility Cost Savings (NPV)	TDV Savings (NPV)	Incremental Cost	TDV B/C Ratio	On-Bill B/C Ratio
CZ01	PGE	PGE	5.8%	\$901	\$597	\$620	0.96	1.5
CZ02	PGE	PGE	5.9%	\$1,223	\$877	\$460	1.9	2.7
CZ03	PGE	PGE	6.7%	\$1,198	\$812	\$460	1.8	2.6
CZ04	PGE	PGE	6.6%	\$1,327	\$947	\$460	2.1	2.9
CZ05	PGE	PGE	6.7%	\$1,236	\$834	\$460	1.8	2.7
CZ05	PGE	SCG	6.7%	\$1,236	\$834	\$460	1.8	2.7
CZ06	SCE	SCG	7.1%	\$956	\$969	\$460	2.1	2.1
CZ07	SDGE	SDGE	7.6%	\$1,736	\$1,010	\$460	2.2	3.8
CZ08	SCE	SCG	7.0%	\$1,017	\$1,064	\$460	2.3	2.2
CZ09	SCE	SCG	6.5%	\$940	\$1,091	\$460	2.4	2.0
CZ10	SCE	SCG	6.5%	\$871	\$1,054	\$460	2.3	1.9
CZ10	SDGE	SDGE	6.5%	\$1,471	\$1,054	\$460	2.3	3.2
CZ11	PGE	PGE	6.8%	\$1,571	\$1,256	\$942	1.3	1.7
CZ12	PGE	PGE	7.3%	\$1,533	\$1,273	\$942	1.4	1.6
CZ13	PGE	PGE	7.3%	\$1,710	\$1,372	\$942	1.5	1.8
CZ14	SCE	SCG	6.8%	\$1,042	\$1,327	\$942	1.4	1.1
CZ14	SDGE	SDGE	6.8%	\$1,646	\$1,327	\$942	1.4	1.7
CZ15	SCE	SCG	6.8%	\$1,156	\$1,456	\$942	1.5	1.2
CZ16	PGE	PGE	7.4%	\$1,634	\$1,191	\$942	1.3	1.7

~\$317 incremental cost / apt for PV

Mixed Fuel Package Results with 0.2kW PV System / Apartment SAVINGS PER APARTMENT – 30-yr Period

Climate Zone	Elec Utility	Gas Utility	Comp. Margin	Utility Cost Savings (NPV)	TDV Savings (NPV)	Incremental Cost	TDV B/C Ratio	On-Bill B/C Ratio
CZ01	PGE	PGE	5.8%	\$1,668	\$1,090	\$937	1.2	1.8
CZ02	PGE	PGE	5.9%	\$2,125	\$1,469	\$777	1.9	2.7
CZ03	PGE	PGE	6.7%	\$2,108	\$1,397	\$777	1.8	2.7
CZ04	PGE	PGE	6.6%	\$2,261	\$1,562	\$777	2.0	2.9
CZ05	PGE	PGE	6.7%	\$2,201	\$1,461	\$777	1.9	2.8
CZ05	PGE	SCG	6.7%	\$2,201	\$1,461	\$777	1.9	2.8
CZ06	SCE	SCG	7.1%	\$1,558	\$1,587	\$777	2.0	2.0
CZ07	SDGE	SDGE	7.6%	\$2,734	\$1,647	\$777	2.1	3.5
CZ08	SCE	SCG	7.0%	\$1,626	\$1,708	\$777	2.2	2.1
CZ09	SCE	SCG	6.5%	\$1,466	\$1,742	\$777	2.2	1.9
CZ10	SCE	SCG	6.5%	\$1,394	\$1,681	\$777	2.2	1.8
CZ10	SDGE	SDGE	6.5%	\$2,361	\$1,681	\$777	2.2	3.0
CZ11	PGE	PGE	6.8%	\$2,488	\$1,877	\$1,258	1.5	2.0
CZ12	PGE	PGE	7.3%	\$2,440	\$1,886	\$1,258	1.5	1.9
CZ13	PGE	PGE	7.3%	\$2,601	\$1,965	\$1,258	1.6	2.1
CZ14	SCE	SCG	6.8%	\$1,612	\$2,053	\$1,258	1.6	1.3
CZ14	SDGE	SDGE	6.8%	\$2,621	\$2,053	\$1,258	1.6	2.1
CZ15	SCE	SCG	6.8%	\$1,684	\$2,110	\$1,258	1.7	1.3
CZ16	PGE	PGE	7.4%	\$2,612	\$1,818	\$1,258	1.4	2.1

Cost effective in all climate zones

~\$633 incremental cost / apt for PV

Mixed Fuel Package Results with 0.3kW PV System / Apartment SAVINGS PER APARTMENT – 30-yr Period

Climate Zone	Elec Utility	Gas Utility	Comp. Margin	Utility Cost Savings (NPV)	TDV Savings (NPV)	Incremental Cost	TDV B/C Ratio	On-Bill B/C Ratio
CZ01	PGE	PGE	5.8%	\$2,434	\$1,582	\$1,253	1.3	1.9
CZ02	PGE	PGE	5.9%	\$3,026	\$2,061	\$1,093	1.9	2.8
CZ03	PGE	PGE	6.7%	\$3,017	\$1,982	\$1,093	1.8	2.8
CZ04	PGE	PGE	6.6%	\$3,195	\$2,177	\$1,093	2.0	2.9
CZ05	PGE	PGE	6.7%	\$3,166	\$2,089	\$1,093	1.9	2.9
CZ05	PGE	SCG	6.7%	\$3,166	\$2,089	\$1,093	1.9	2.9
CZ06	SCE	SCG	7.1%	\$2,160	\$2,206	\$1,093	2.0	2.0
CZ07	SDGE	SDGE	7.6%	\$3,635	\$2,283	\$1,093	2.1	3.3
CZ08	SCE	SCG	7.0%	\$2,228	\$2,352	\$1,093	2.2	2.0
CZ09	SCE	SCG	6.5%	\$1,992	\$2,393	\$1,093	2.2	1.8
CZ10	SCE	SCG	6.5%	\$1,918	\$2,308	\$1,093	2.1	1.8
CZ10	SDGE	SDGE	6.5%	\$3,251	\$2,308	\$1,093	2.1	3.0
CZ11	PGE	PGE	6.8%	\$3,405	\$2,498	\$1,575	1.6	2.2
CZ12	PGE	PGE	7.3%	\$3,347	\$2,498	\$1,575	1.6	2.1
CZ13	PGE	PGE	7.3%	\$3,492	\$2,558	\$1,575	1.6	2.2
CZ14	SCE	SCG	6.8%	\$2,182	\$2,779	\$1,575	1.8	1.4
CZ14	SDGE	SDGE	6.8%	\$3,595	\$2,779	\$1,575	1.8	2.3
CZ15	SCE	SCG	6.8%	\$2,211	\$2,764	\$1,575	1.8	1.4
CZ16	PGE	PGE	7.4%	\$3,590	\$2,445	\$1,575	1.6	2.3

Cost effective in all climate zones

~\$950 incremental cost / apt for PV

Mixed Fuel Package Results with 1kW PV System / Apartment SAVINGS PER APARTMENT – 30-yr Period

Climate Zone	Elec Utility	Gas Utility	Comp. Margin	Utility Cost Savings (NPV)	TDV Savings (NPV)	Incremental Cost	TDV B/C Ratio	On-Bill B/C Ratio
CZ01	PGE	PGE	5.8%	\$7,611	\$5,029	\$3,469	1.4	2.2
CZ02	PGE	PGE	5.9%	\$9,133	\$6,203	\$3,309	1.9	2.8
CZ03	PGE	PGE	6.7%	\$9,145	\$6,079	\$3,309	1.8	2.8
CZ04	PGE	PGE	6.6%	\$9,525	\$6,483	\$3,309	2.0	2.9
CZ05	PGE	PGE	6.7%	\$9,650	\$6,482	\$3,309	2.0	2.9
CZ05	PGE	SCG	6.7%	\$9,650	\$6,482	\$3,309	2.0	2.9
CZ06	SCE	SCG	7.1%	\$5,778	\$6,534	\$3,309	2.0	1.7
CZ07	SDGE	SDGE	7.6%	\$9,708	\$6,739	\$3,309	2.0	2.9
CZ08	SCE	SCG	7.0%	\$5,757	\$6,861	\$3,309	2.1	1.7
CZ09	SCE	SCG	6.5%	\$5,514	\$6,948	\$3,309	2.1	1.7
CZ10	SCE	SCG	6.5%	\$5,427	\$6,697	\$3,309	2.0	1.6
CZ10	SDGE	SDGE	6.5%	\$9,284	\$6,697	\$3,309	2.0	2.8
CZ11	PGE	PGE	6.8%	\$9,665	\$6,846	\$3,791	1.8	2.5
CZ12	PGE	PGE	7.3%	\$9,526	\$6,786	\$3,791	1.8	2.5
CZ13	PGE	PGE	7.3%	\$9,587	\$6,709	\$3,791	1.8	2.5
CZ14	SCE	SCG	6.8%	\$5,989	\$7,859	\$3,791	2.1	1.6
CZ14	SDGE	SDGE	6.8%	\$10,193	\$7,859	\$3,791	2.1	2.7
CZ15	SCE	SCG	6.8%	\$5,809	\$7,342	\$3,791	1.9	1.5
CZ16	PGE	PGE	7.4%	\$10,221	\$6,836	\$3,791	1.8	2.7

Cost effective in all climate zones

~\$3,200 incremental cost / apt for PV

All Electric PV System Analysis

All-Electric Design: Summary of PV Sensitivity Analysis

- Compliance in all Climate Zones EXCEPT 1 and 16
- Adding PV system is cost-effective in all remaining climate zones and utility territories.
- PV production is not optimally matched to residential usage patterns
 - Most production is during off-peak hours
 - Residential usage peaks during early morning and evening hours
- Efficiency-Only vs Efficiency Plus PV
 - Climate Zones 2-5, 11-15
 - PV system improves On-Bill cost-effectiveness, but reduces TDV ratio
 - Climate Zones 6-10
 - Efficiency-Only: Negative incremental cost results in immediate savings
 - Efficiency Plus PV: Combined package remains cost-effective (TDV and On-Bill)

All Electric Package Results Clustered HPWH SAVINGS PER APARTMENT – 30-yr Period

Climate Zone	Elec Utility	Gas Utility	Comp. Margin	Utility Cost Savings (NPV)	TDV Savings (NPV)	Incremental Cost	TDV B/C Ratio	On-Bill B/C Ratio
CZ01	PGE	PGE	-0.4%	-\$971	\$199	\$45	4.4	0
CZ02	PGE	PGE	1.6%	-\$578	\$528	-\$115	>1	0.2
CZ03	PGE	PGE	1.1%	-\$616	\$390	-\$115	>1	0.2
CZ04	PGE	PGE	3.4%	-\$438	\$625	-\$115	>1	0.3
CZ05	PGE	PGE	1.3%	-\$679	\$391	-\$115	>1	0.2
CZ05	PGE	SCG	1.3%	-\$1,073	\$391	-\$115	>1	0.1
CZ06	SCE	SCG	3.7%	\$382	\$612	-\$115	>1	>1
CZ07	SDGE	SDGE	4.8%	\$513	\$665	-\$115	>1	>1
CZ08	SCE	SCG	3.9%	\$436	\$693	-\$115	>1	>1
CZ09	SCE	SCG	3.8%	\$427	\$739	-\$115	>1	>1
CZ10	SCE	SCG	1.8%	\$19	\$396	-\$416	>1	>1
CZ10	SDGE	SDGE	1.8%	\$2	\$396	-\$416	>1	>1
CZ11	PGE	PGE	2.0%	-\$453	\$430	\$65	6.6	0
CZ12	PGE	PGE	2.0%	-\$589	\$380	\$65	5.8	0
CZ13	PGE	PGE	2.6%	-\$266	\$505	\$65	7.8	0
CZ14	SCE	SCG	2.0%	\$125	\$458	\$65	7.0	1.9
CZ14	SDGE	SDGE	2.0%	\$55	\$458	\$65	7.0	0.8
CZ15	SCE	SCG	4.4%	\$474	\$832	\$65	12.8	7.3
CZ16	PGE	PGE	-5.8%	-\$883	\$127	\$65	2.0	0

Code compliant everywhere except CZ 1 & 16

Cost effective in all climate zones

All Electric Package Results Clustered HPWH with 0.1kW PV System / Apartment SAVINGS PER APARTMENT – 30-yr Period

Climate Zone	Elec Utility	Gas Utility	Comp. Margin	Utility Cost Savings (NPV)	TDV Savings (NPV)	Incremental Cost	TDV B/C Ratio	On-Bill B/C Ratio
CZ01	PGE	PGE	-0.4%	-\$205	\$692	\$362	1.9	0.0
CZ02	PGE	PGE	1.6%	\$323	\$1,120	\$202	5.5	1.6
CZ03	PGE	PGE	1.1%	\$294	\$975	\$202	4.8	1.5
CZ04	PGE	PGE	3.4%	\$496	\$1,240	\$202	6.1	2.5
CZ05	PGE	PGE	1.3%	\$286	\$1,018	\$202	5.0	1.4
CZ05	PGE	SCG	1.3%	-\$108	\$1,018	\$202	5.0	0.0
CZ06	SCE	SCG	3.7%	\$984	\$1,231	\$202	6.1	4.9
CZ07	SDGE	SDGE	4.8%	\$1,624	\$1,302	\$202	6.4	8.0
CZ08	SCE	SCG	3.9%	\$1,045	\$1,337	\$202	6.6	5.2
CZ09	SCE	SCG	3.8%	\$969	\$1,390	\$202	6.9	4.8
CZ10	SCE	SCG	1.8%	\$543	\$1,023	-\$100	>1	>1
CZ10	SDGE	SDGE	1.8%	\$892	\$1,023	-\$100	>1	>1
CZ11	PGE	PGE	2.0%	\$464	\$1,052	\$382	2.8	1.2
CZ12	PGE	PGE	2.0%	\$318	\$992	\$382	2.6	0.8
CZ13	PGE	PGE	2.6%	\$625	\$1,098	\$382	2.9	1.6
CZ14	SCE	SCG	2.0%	\$694	\$1,183	\$382	3.1	1.8
CZ14	SDGE	SDGE	2.0%	\$1,030	\$1,183	\$382	3.1	2.7
CZ15	SCE	SCG	4.4%	\$1,002	\$1,485	\$382	3.9	2.6
CZ16	PGE	PGE	-5.8%	\$96	\$754	\$382	2.0	0.3

~\$317 incremental cost / apt for PV

All Electric Package Results Clustered HPWH with 0.2kW PV System / Apartment SAVINGS PER APARTMENT – 30-yr Period

Climate Zone	Elec Utility	Gas Utility	Comp. Margin	Utility Cost Savings (NPV)	TDV Savings (NPV)	Incremental Cost	TDV B/C Ratio	On-Bill B/C Ratio
CZ01	PGE	PGE	-0.4%	\$562	\$1,184	\$678	1.7	0.8
CZ02	PGE	PGE	1.6%	\$1,225	\$1,712	\$518	3.3	2.4
CZ03	PGE	PGE	1.1%	\$1,203	\$1,560	\$518	3.0	2.3
CZ04	PGE	PGE	3.4%	\$1,431	\$1,855	\$518	3.6	2.8
CZ05	PGE	PGE	1.3%	\$1,251	\$1,646	\$518	3.2	2.4
CZ05	PGE	SCG	1.3%	\$857	\$1,646	\$518	3.2	1.7
CZ06	SCE	SCG	3.7%	\$1,586	\$1,849	\$518	3.6	3.1
CZ07	SDGE	SDGE	4.8%	\$2,622	\$1,938	\$518	3.7	5.1
CZ08	SCE	SCG	3.9%	\$1,653	\$1,981	\$518	3.8	3.2
CZ09	SCE	SCG	3.8%	\$1,495	\$2,040	\$518	3.9	2.9
CZ10	SCE	SCG	1.8%	\$1,067	\$1,650	\$217	7.6	4.9
CZ10	SDGE	SDGE	1.8%	\$1,782	\$1,650	\$217	7.6	8.2
CZ11	PGE	PGE	2.0%	\$1,382	\$1,673	\$698	2.4	2.0
CZ12	PGE	PGE	2.0%	\$1,224	\$1,605	\$698	2.3	1.8
CZ13	PGE	PGE	2.6%	\$1,517	\$1,691	\$698	2.4	2.2
CZ14	SCE	SCG	2.0%	\$1,264	\$1,909	\$698	2.7	1.8
CZ14	SDGE	SDGE	2.0%	\$2,004	\$1,909	\$698	2.7	2.9
CZ15	SCE	SCG	4.4%	\$1,529	\$2,139	\$698	3.1	2.2
CZ16	PGE	PGE	-5.8%	\$1,074	\$1,381	\$698	2.0	1.5

~\$633 incremental cost / apt for PV

All Electric Package Results Clustered HPWH with 0.3kW PV System / Apartment SAVINGS PER APARTMENT – 30-yr Period

Climate Zone	Elec Utility	Gas Utility	Comp. Margin	Utility Cost Savings (NPV)	TDV Savings (NPV)	Incremental Cost	TDV B/C Ratio	On-Bill B/C Ratio
CZ01	PGE	PGE	-0.4%	\$1,328	\$1,676	\$995	1.7	1.3
CZ02	PGE	PGE	1.6%	\$2,126	\$2,304	\$835	2.8	2.5
CZ03	PGE	PGE	1.1%	\$2,113	\$2,146	\$835	2.6	2.5
CZ04	PGE	PGE	3.4%	\$2,365	\$2,470	\$835	3.0	2.8
CZ05	PGE	PGE	1.3%	\$2,216	\$2,274	\$835	2.7	2.7
CZ05	PGE	SCG	1.3%	\$1,822	\$2,274	\$835	2.7	2.2
CZ06	SCE	SCG	3.7%	\$2,187	\$2,467	\$835	3.0	2.6
CZ07	SDGE	SDGE	4.8%	\$3,522	\$2,575	\$835	3.1	4.2
CZ08	SCE	SCG	3.9%	\$2,255	\$2,625	\$835	3.1	2.7
CZ09	SCE	SCG	3.8%	\$2,021	\$2,691	\$835	3.2	2.4
CZ10	SCE	SCG	1.8%	\$1,590	\$2,277	\$533	4.3	3.0
CZ10	SDGE	SDGE	1.8%	\$2,672	\$2,277	\$533	4.3	5.0
CZ11	PGE	PGE	2.0%	\$2,299	\$2,294	\$1,015	2.3	2.3
CZ12	PGE	PGE	2.0%	\$2,131	\$2,217	\$1,015	2.2	2.1
CZ13	PGE	PGE	2.6%	\$2,408	\$2,284	\$1,015	2.3	2.4
CZ14	SCE	SCG	2.0%	\$1,833	\$2,635	\$1,015	2.6	1.8
CZ14	SDGE	SDGE	2.0%	\$2,979	\$2,635	\$1,015	2.6	2.9
CZ15	SCE	SCG	4.4%	\$2,056	\$2,793	\$1,015	2.8	2.0
CZ16	PGE	PGE	-5.8%	\$2,052	\$2,009	\$1,015	2.0	2.0

Cost effective in all climate zones

~\$950 incremental cost / apt for PV

All Electric Package Results Clustered HPWH with 1kW PV System / Apartment SAVINGS PER APARTMENT – 30-yr Period

Climate Zone	Elec Utility	Gas Utility	Comp. Margin	Utility Cost Savings (NPV)	TDV Savings (NPV)	Incremental Cost	TDV B/C Ratio	On-Bill B/C Ratio
CZ01	PGE	PGE	-0.4%	\$6,505	\$5,123	\$3,210	1.6	2.0
CZ02	PGE	PGE	1.6%	\$8,233	\$6,446	\$3,051	2.1	2.7
CZ03	PGE	PGE	1.1%	\$8,240	\$6,242	\$3,051	2.0	2.7
CZ04	PGE	PGE	3.4%	\$8,695	\$6,777	\$3,051	2.2	2.9
CZ05	PGE	PGE	1.3%	\$8,701	\$6,667	\$3,051	2.2	2.9
CZ05	PGE	SCG	1.3%	\$8,307	\$6,667	\$3,051	2.2	2.7
CZ06	SCE	SCG	3.7%	\$5,806	\$6,796	\$3,051	2.2	1.9
CZ07	SDGE	SDGE	4.8%	\$9,596	\$7,030	\$3,051	2.3	3.1
CZ08	SCE	SCG	3.9%	\$5,785	\$7,133	\$3,051	2.3	1.9
CZ09	SCE	SCG	3.8%	\$5,543	\$7,247	\$3,051	2.4	1.8
CZ10	SCE	SCG	1.8%	\$5,099	\$6,666	\$2,749	2.4	1.9
CZ10	SDGE	SDGE	1.8%	\$8,706	\$6,666	\$2,749	2.4	3.2
CZ11	PGE	PGE	2.0%	\$8,559	\$6,641	\$3,230	2.1	2.6
CZ12	PGE	PGE	2.0%	\$8,310	\$6,505	\$3,230	2.0	2.6
CZ13	PGE	PGE	2.6%	\$8,503	\$6,435	\$3,230	2.0	2.6
CZ14	SCE	SCG	2.0%	\$5,640	\$7,716	\$3,230	2.4	1.7
CZ14	SDGE	SDGE	2.0%	\$9,576	\$7,716	\$3,230	2.4	3.0
CZ15	SCE	SCG	4.4%	\$5,654	\$7,371	\$3,230	2.3	1.8
CZ16	PGE	PGE	-5.8%	\$8,683	\$6,399	\$3,230	2.0	2.7

Cost effective in all climate zones

~\$3,200 incremental cost / apt for PV