Zero Net Energy: 7,000 kWh/yr to Near Zero in 12 Years Flat

Midwest Building Energy **Codes Conference**

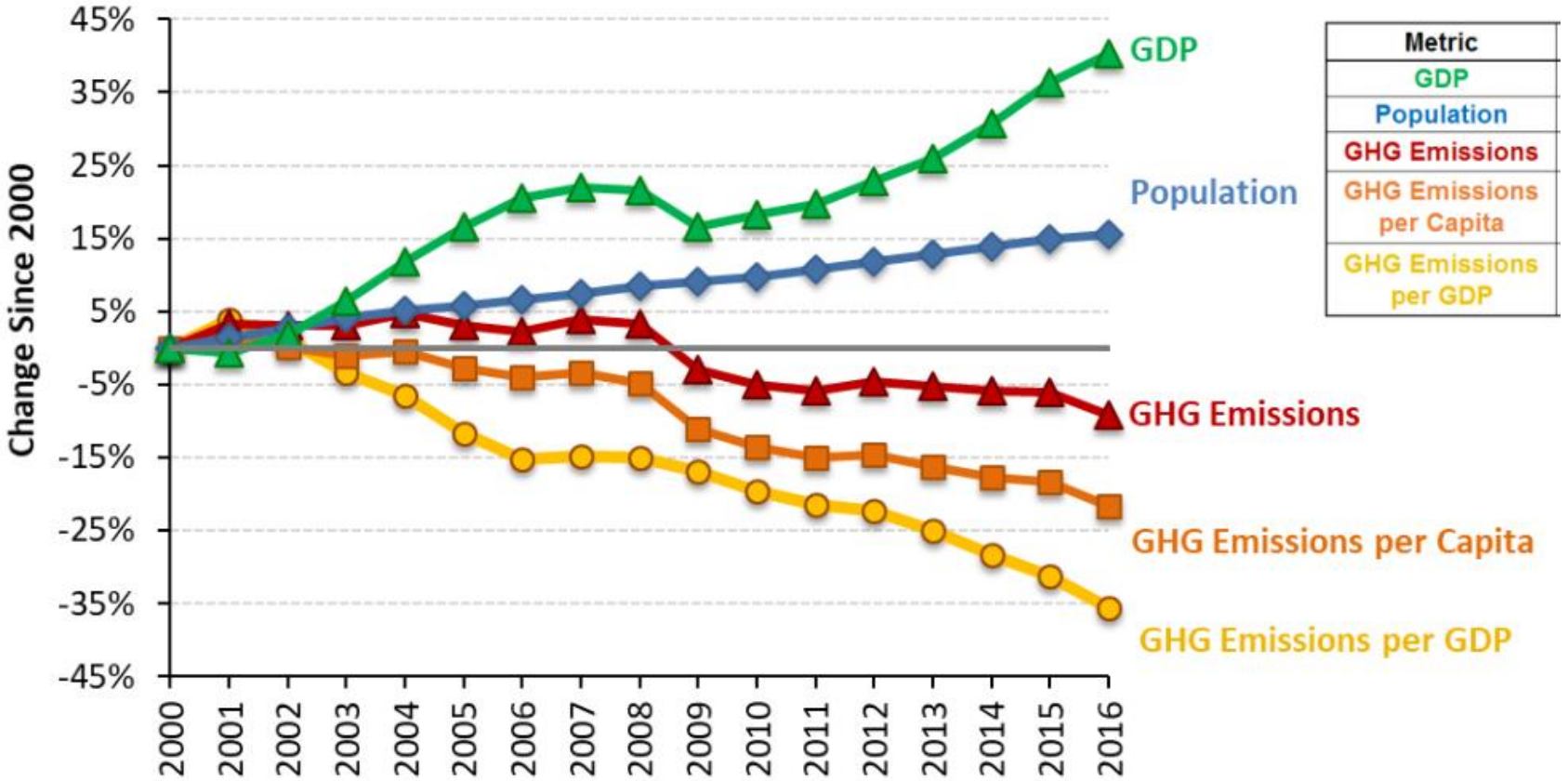
November 29, 2018

Together, Building a Better California

2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018

California's Goal:
Reduce emissions 80 percent under 1990 levels by 2050

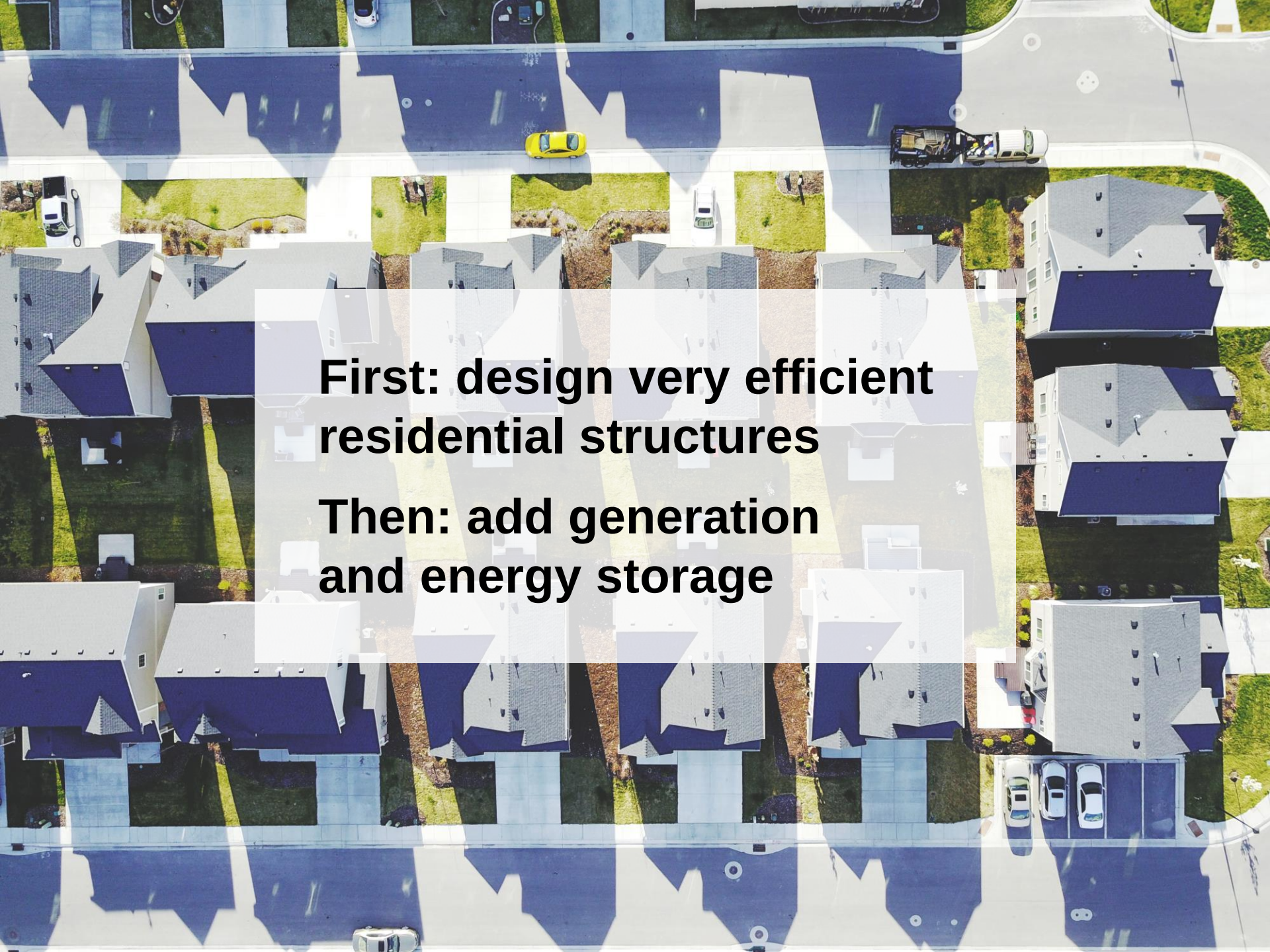
Making Progress on GHG Goals



CARB. 2018. *California Greenhouse Gas Emissions for 2000 to 2016*
https://www.arb.ca.gov/cc/inventory/pubs/reports/2000_2016/ghg_inventory_trends_00-16.pdf

4 Big Bold Strategies (CPUC 2008)

1. **All new residential construction in California will be Zero Net Energy by 2020;**
2. **All new commercial construction in California will be Zero Net Energy by 2030;**
3. **Heating, Ventilation and Air Conditioning (HVAC) will be transformed to ensure that its energy performance is optimal for California's climate; and**
4. **All eligible low-income customers will be given the opportunity to participate in the low income energy efficiency program by 2020.**


First: design very efficient residential structures
Then: add generation and energy storage

**If you have built castles in the air,
your work need not be lost;
that is where they should be.**

**Now put the foundations
under them.**

— Henry David Thoreau (Walden)

Warren-Alquist Act

"The standards adopted or revised…shall be cost-effective when taken in their entirety and when amortized over the economic life of the structure compared with historic practice. When determining cost-effectiveness, the commission shall consider the value of the water or energy saved, impact on product efficacy for the consumer, and the life cycle cost of complying with the standard."

Code and Standards Enhancement

- Life-cycle Cost-effectiveness
- Feasibility
- Enforceability

Single Family Residential Change Log

CZ12 Sacramento

	Strategy *(Baseline is T24 2013 Unless Noted Otherwise)*	kBtu/ft2 savings	TDV$/ft2 (30yr) savings	TDV$ reduction
	Starting EUI:	30.4	18.4	0%
1	Improved Wall Construction: 2x6 walls, R-21 w/ R-4 rigid ext. sheathing. Advanced framing, 24" o.c.	-1.94	-1.15	6%
2	Ceiling Insulation: R-60 blown-in insulation w/ raised heel trusses	-0.43	-0.23	7%
3	Reduced Building Infiltration: 1.8 SLA / 3.15 ACH50	-0.91	-0.24	9%
4	Improved Windows: U-Factor=0.25 / SHGC=0.20	-0.78	-0.16	10%
5	Cool Roof: Reflectivity=0.40 / Emissivity=0.85	0.06	-0.14	10%
6	Additional Thermal Mass	-0.15	-0.20	11%
7	Improved Lighting: High efficacy LED lighting and vacancy controls	-1.32	-2.20	23%
8	High Efficiency Appliances: Clothes washer, Dishwasher, Refrigerator	-1.12	-0.52	26%
9	Reduced Plug Loads & Plug Load Control 20%	-0.71	-1.09	32%
10	Low-Flow Shower & Sinks	-1.84	-0.49	34%
11	Ducts in Conditioned Space	-0.86	-0.54	37%
12	High Efficiency 2-speed AC, SEER 21 w/ Integrated Ventilation Cooling	-0.23	-0.55	40%
13	Condensing Gas Space Heating	-0.78	-0.22	42%
14	Condensing Gas Water Heater	-2.53	-0.85	46%
15	Improved HW Distribution: Compact Design, Insulated HW Pipes	-0.18	-0.06	46%
16	Rooftop PV (see "Solar PV (kW)" in "Building Performance Data" table for PV system sizes)	-16.65	-9.77	100%
	Ending EUI:	0.0	0.00	
	Total TDV$ Savings:		-$18.43	
	Incremental First Cost:		$9.25*	
	Net Life Cycle Cost:		-$9.19*	

http://calmac.org/publications/California_ZNE_Technical_Feasibility_Report_CALMAC_PGE0326.01.pdf

2012

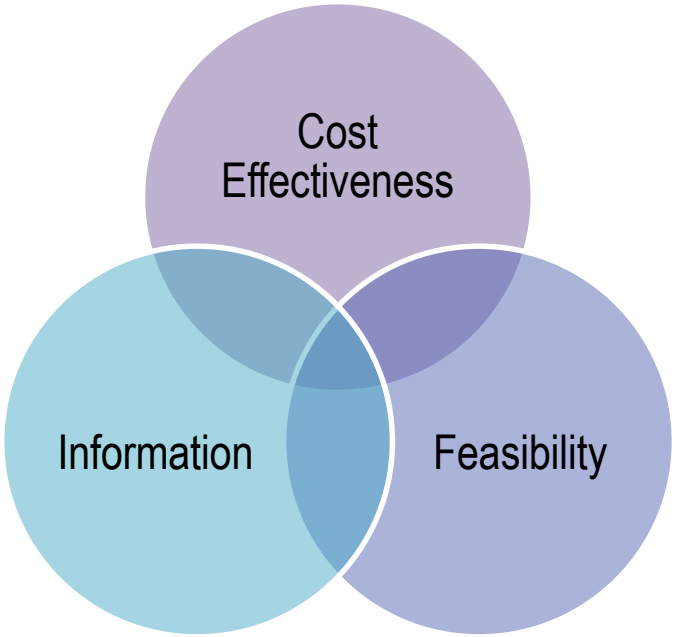
ZNE Technical Feasibility Report: Can ZNE Meet Warren-Alquist Cost-Effectiveness Criteria?

Measures similar to those proposed for 2016 & 2019 Title 24

Incremental Cost = $19,570 for 2,116 ft² home

ZNE Cost-Effective
B/C Ratio = 18.43/9.25 = 2.0
Cost could nearly double and still be > 1.0 (cost-effective)

Removing Code Barriers



COST EFFECTIVENESS

- Measure is not cost effective. Projects need to address commercialization, economies of scale, efficiency optimization, etc.

FEASIBILITY

- Measure is not feasible. Projects need to address uncertainty of unintended consequences, satisfaction or amenity, training, etc.

INFORMATION

- Project may be cost effective and feasible but there's not enough information available to support code adoption or enforcement. Projects need to address ways to collect and highlight information.

Residential Electricity Use Not Covered by T-24

Over half of home electricity consumption not covered by T-24

Electricity End-uses

End-Use	kWh/yr	
Not covered by T-24	**3,612**	
Dryer	187	
Clothes Washer	109	
Dish Washer	73	
First Refrigerator	707	
Additional Refrigerator	313	
Freezer	138	**54%**
Range/Oven	105	
Television	645	
Microwave	122	
Home Office Equipment	17	
Personal Computer	602	
Well Pump	28	
Miscellaneous	568	
T-24 + Preempted	**1,106**	
Conv. Space Heating	37	
Heating	13	
Aux Space Heating	0	**10%**
Central Air Conditioning	876	
Room Air Conditioning	47	
Water Heating	133	
T-24	**1,927**	
Furnace Fan	164	
Attic Fan	14	
Evaporative Cooling	43	
Solar Water Heating	0	**29%**
Pool Pump	234	
Spa	25	
Outdoor Lighting	284	
Spa Electric Heat	28	
Lighting	1,136	
Total	**6,645**	

Natural Gas End-uses

End-Use	Therm/yr	%
Not Covered by T-24	**51.4**	
Dryer	16.2	**14%**
Range/Oven	31.7	
Miscellaneous	3.5	
T-24+ preempted	**309.0**	
Primary Heat	175.8	**83%**
Conv. Gas Water Heat	133.2	
T-24	**10.2**	
Pool Heat	5.6	**3%**
Spa Heat	2.9	
Auxiliary Heat	1.6	
Total	**370.5**	

Not Covered by T-24
Plug loads are installed after building inspection and are not covered by T-24

T-24 + Preempted
T-24 is preempted from requiring higher equipment efficiency but T-24 can impact the loads on equipment (envelope eff, controls etc.)

Covered by T-24
Loads and equipment efficiency can be regulated by T-24

*** 2009 Residential Appliance Saturation Survey**

2019 Title 24: Paths to Zero Net Electricity

Prescriptive Compliance

Energy Efficiency

- Most measures transitioned from prior code cycles
- Incremental changes for 2019 code cycle

Photovoltaics

- KWp equation – coefficients for:
  - Climate zone
  - Number of dwelling units
  - Conditioned floor area

Performance Compliance

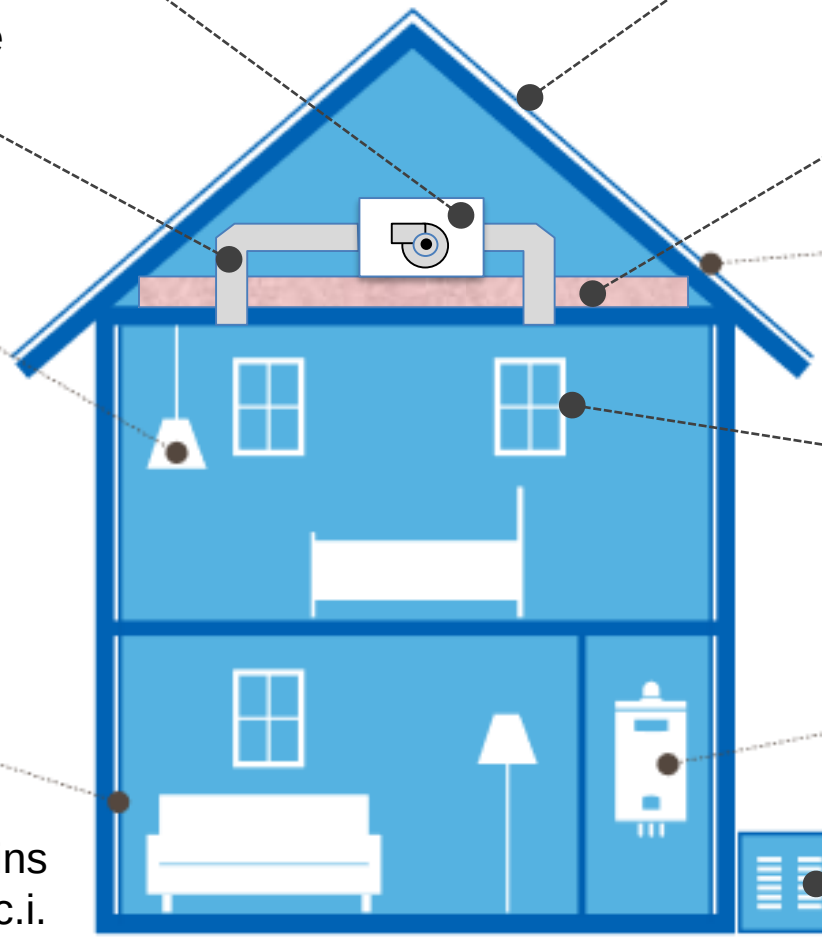
Energy Efficiency EDR

- EDR target based on prescriptive EE measures
- Small battery storage credit and DR credit allowed

Total EDR

- EE EDR – PV EDR = score
- PV EDR target = offsetting electricity in mixed fuel home
  - PV target does not go up in all-elec home
  - Fuel agnostic target
- Increased EE reduces amount of PV required

Energy Efficiency First: Prescriptive Measures



Low W/cfm
Air-handler

Verified low-leakage
R-6 or R-8* ducts

JA8

All high efficacy
High quality lighting

Quality Insulation
Installation Inspection

Walls
6” stud w R-21 cavity ins
R-5 (SF) or R-4 (MF) c.i.

Cool Roof*
($\rho_{solar} \geq 0.2$)

Ceiling Insulation
R-30 or R-38*

R-19* Ins Roof Deck or
Ducts in Cond Space

Windows
U-0.3/S-0.23

Eff Gas Tankless or
Heat Pump DHW
& Insulated pipe

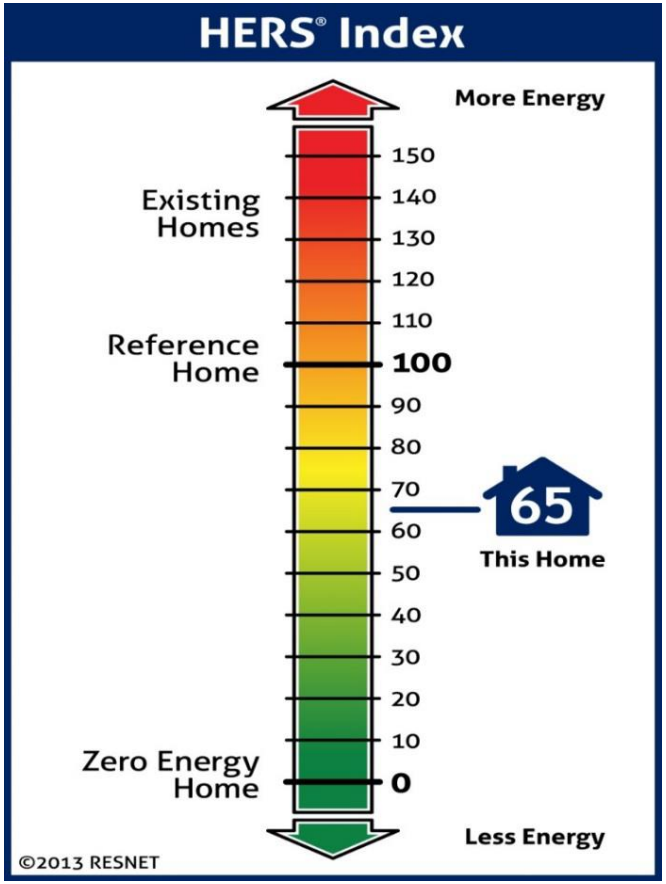
Verified
Refrigerant Charge

* In hot or extreme climates, requirements vary by measure

Energy Design Rating (EDR)

What's in the number?

- Aligned with RESNET
- Reference home is a 2006 IECC compliant home, EDR=100
- Passing scores are CZ-dependent
- Likely to be around 25
- Reach Codes will push to Zero



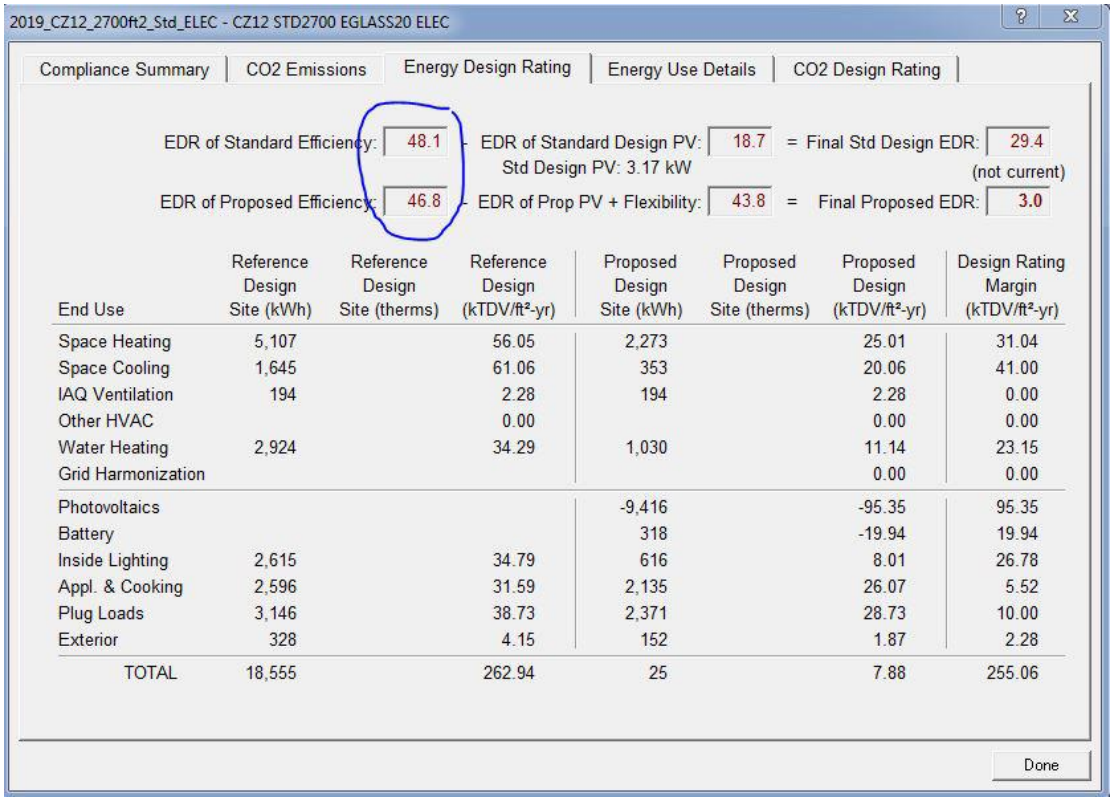
How is it calculated?

- CBECC-Res Compliance Software
- Efficiency measures
- Includes nonregulated loads (e.g. plug loads, white goods)
- PV + storage

Two Energy Design Rating (EDR) Targets

Sample CBECC-res Output Screen

California Building Energy Code Compliance - Residential



2019_CZ12_2700ft2_Std_ELEC - CZ12 STD2700 EGLASS20 ELEC

Compliance Summary | CO2 Emissions | Energy Design Rating | Energy Use Details | CO2 Design Rating

EDR of Standard Efficiency: 48.1 - EDR of Standard Design PV: 18.7 = Final Std Design EDR: 29.4
Std Design PV: 3.17 kW (not current)

EDR of Proposed Efficiency: 46.8 - EDR of Prop PV + Flexibility: 43.8 = Final Proposed EDR: 3.0

End Use	Reference Design Site (kWh)	Reference Design Site (therms)	Reference Design (kTDV/ft²-yr)	Proposed Design Site (kWh)	Proposed Design Site (therms)	Proposed Design (kTDV/ft²-yr)	Design Rating Margin (kTDV/ft²-yr)
Space Heating	5,107		56.05	2,273		25.01	31.04
Space Cooling	1,645		61.06	353		20.06	41.00
IAQ Ventilation	194		2.28	194		2.28	0.00
Other HVAC			0.00			0.00	0.00
Water Heating	2,924		34.29	1,030		11.14	23.15
Grid Harmonization						0.00	0.00
Photovoltaics				-9,416		-95.35	95.35
Battery				318		-19.94	19.94
Inside Lighting	2,615		34.79	616		8.01	26.78
Appl. & Cooking	2,596		31.59	2,135		26.07	5.52
Plug Loads	3,146		38.73	2,371		28.73	10.00
Exterior	328		4.15	152		1.87	2.28
TOTAL	18,555		262.94	25		7.88	255.06

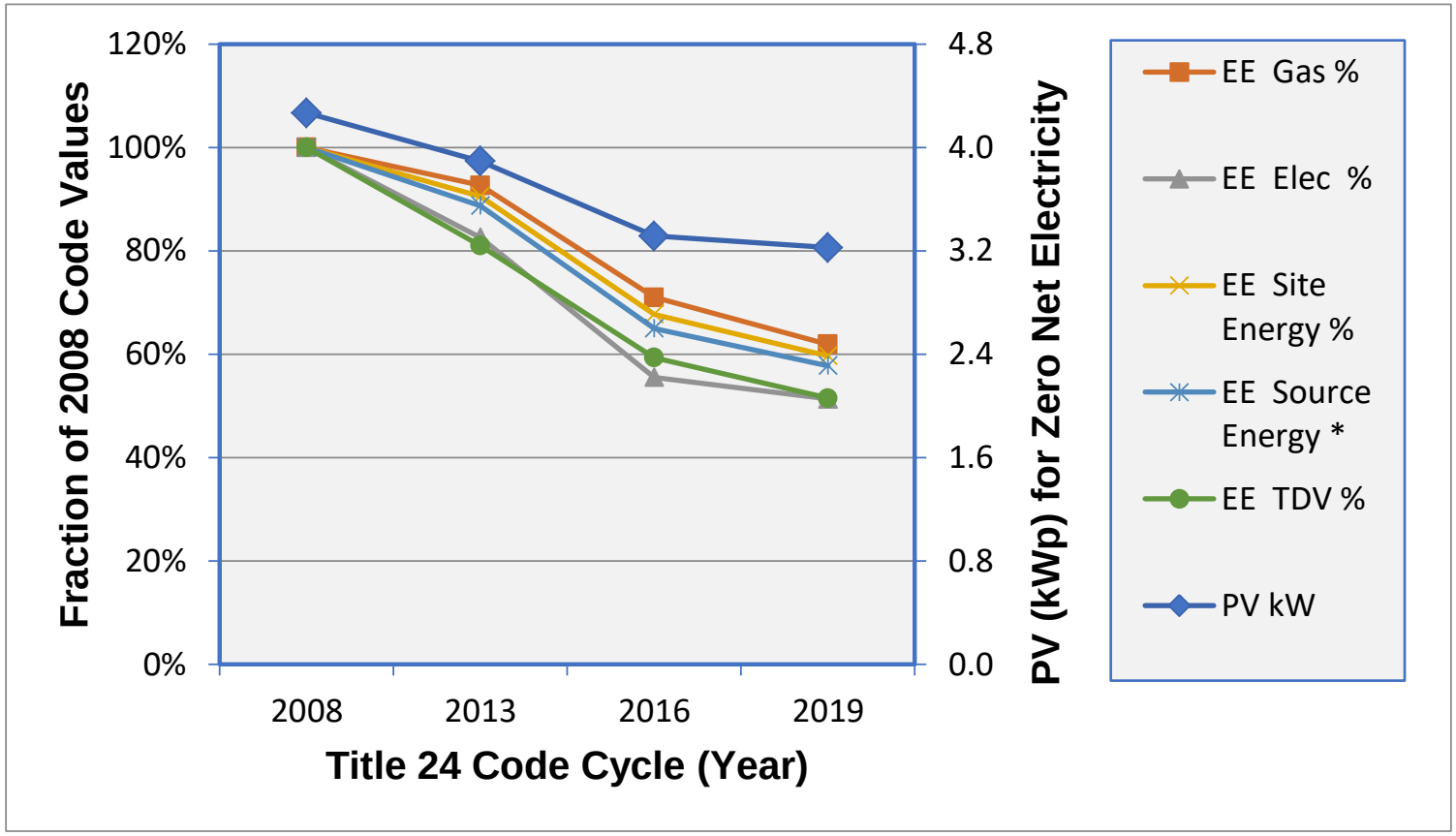
Done

- **Efficiency EDR Target** – based on mandatory and prescriptive efficiency baseline without renewables and storage
- **Final (Total) EDR** – based on EE baseline with renewables and storage sized to offset electricity in mixed fuel home

Source: California Energy Commission

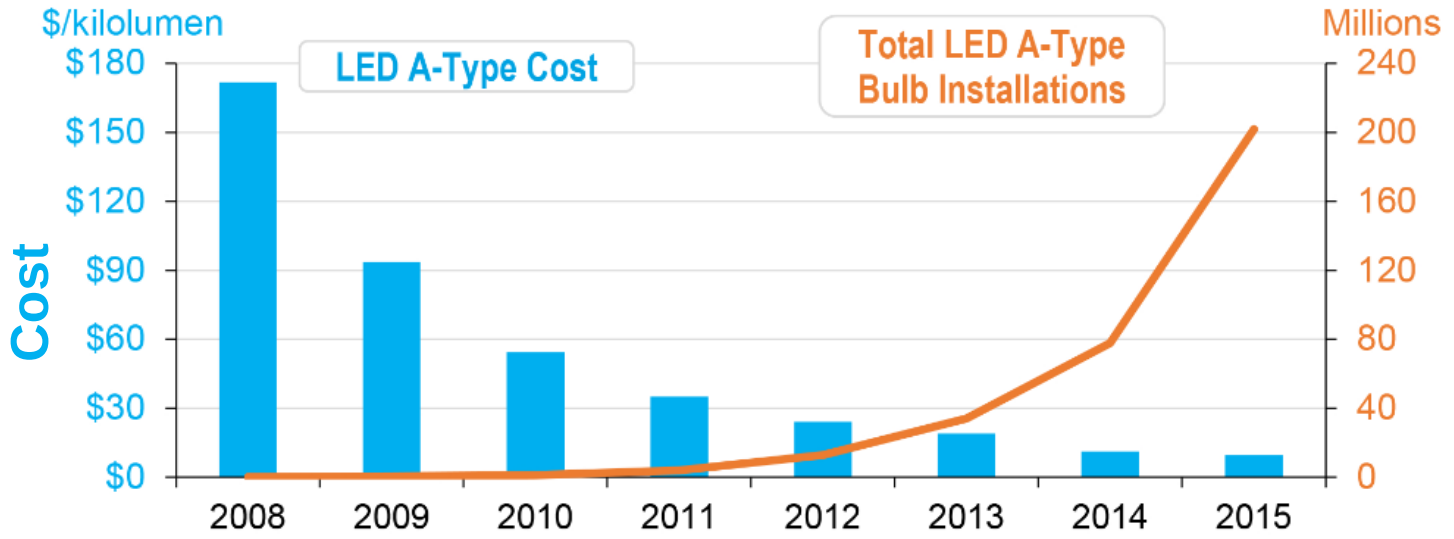
2013, 2016 & 2019 Title 24, Part 6

Regulated Loads % Reduction by Code Cycle
and PV System kW for 2,700 ft2 Mixed Fuel Home
to Offset Electricity Consumption

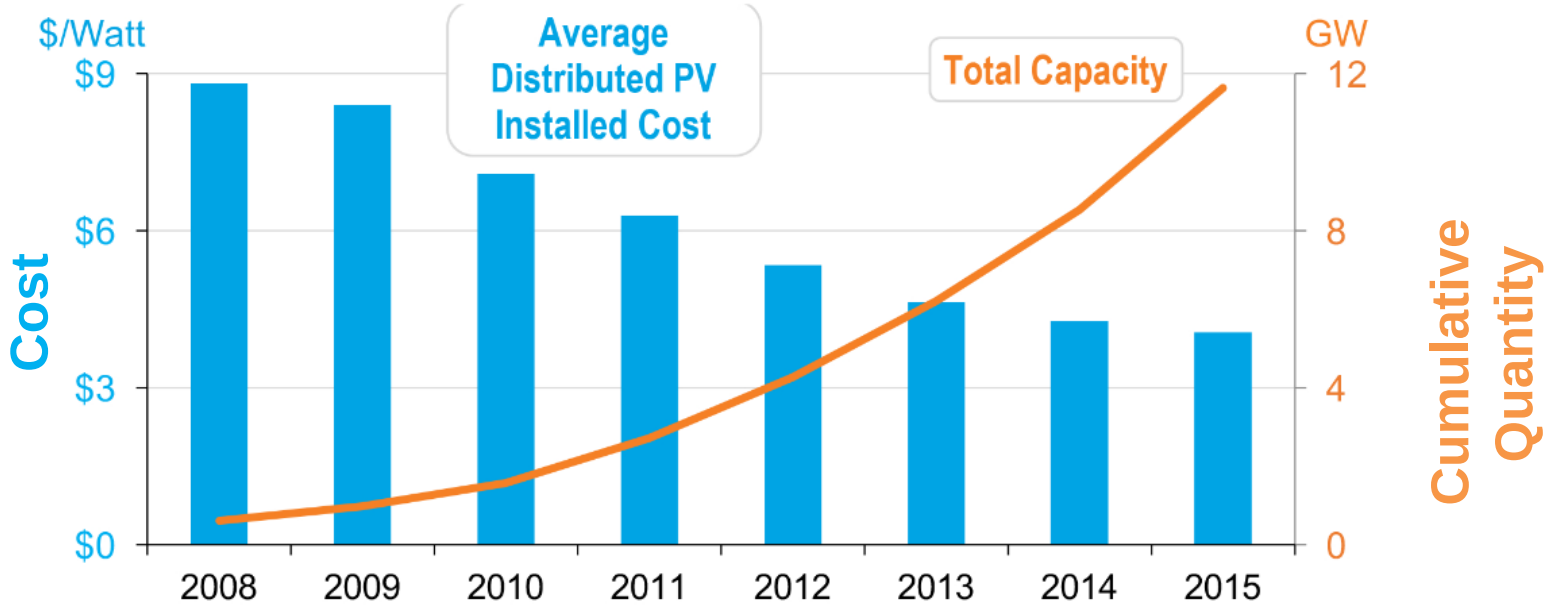


Experience Curves for LEDs and Renewables

LEDs



Rooftop PV



https://www.energy.gov/sites/prod/files/2017/05/f34/Revolution%20Now%202016%20Report_2.pdf

Enhanced Energy Efficiency Expands Nonres Occupancies for ZNE-Capable

CFA Ratio – Collector-to -Floor area Ratio. (Example uses site energy)
Ratio of ZNE Photovoltaic Collector Area to Conditioned Floor Area

- CFR = 1, Enough roof area to serve all loads for 1 story building
- CFR = 0.25, Enough roof area to serve all loads for a 4 story building

ZNE Capable, EE at ASHRAE 90.1-2013 levels

TABLE 6 Minimum CFA ratio needed for ZNE, compliance with Standard 90.1-2013.

	PACIFIC COAST	WARM AND DRY	HOT AND HUMID	WARM AND HUMID	COLD AND DRY	COLD AND HUMID	ARCTIC
Warehouses	0.22	0.21	0.17	0.24	0.28	0.44	0.84
Offices	0.30	0.42	0.46	0.46	0.45	0.56	1.04
Retail	0.49	0.66	0.67	0.72	0.77	0.98	2.07
Schools	0.48	0.62	0.68	0.69	0.69	0.84	1.72
Apartments	0.49	0.64	0.67	0.74	0.76	1.02	1.93
Offices/Data Center	0.85	0.94	0.99	1.02	1.05	1.29	2.25
Hotels	0.78	1.01	1.12	1.13	1.12	1.38	2.55
Health Care	1.40	1.45	1.64	1.68	1.61	2.01	3.57
Restaurants	4.97	5.80	5.81	6.82	7.46	9.60	19.34

The darkest shaded areas represent CFA ratios equal to or greater than 1.00 and represent the building types and climates for which ZNE will be most challenging.

ZNE Capable, EE at max tech levels

TABLE 7 Minimum CFA ratio needed for ZNE, maximum technical potential.

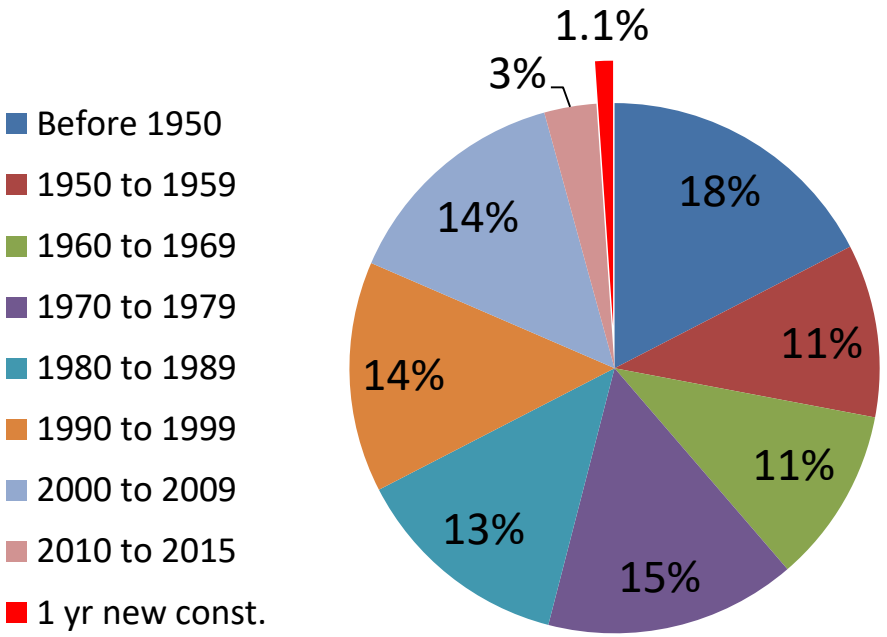
	PACIFIC COAST	WARM AND DRY	HOT AND HUMID	WARM AND HUMID	COLD AND DRY	COLD AND HUMID	ARCTIC
Warehouses	0.08	0.08	0.07	0.09	0.10	0.13	0.19
Offices	0.11	0.14	0.15	0.15	0.15	0.18	0.30
Retail	0.18	0.24	0.25	0.25	0.26	0.32	0.67
Schools	0.22	0.28	0.32	0.32	0.31	0.38	0.66
Apartments	0.33	0.40	0.41	0.44	0.47	0.57	0.90
Offices/Data Center	0.59	0.63	0.66	0.64	0.68	0.77	1.19
Hotels	0.55	0.66	0.69	0.74	0.75	0.90	1.48
Health Care	0.87	0.86	0.96	0.96	0.95	1.15	1.83
Restaurants	3.66	4.35	4.53	4.87	4.99	5.91	9.61

The darkest shaded areas represent CFA ratios equal to or greater than 1.00 and represent the building types and climates for which ZNE will be most challenging.

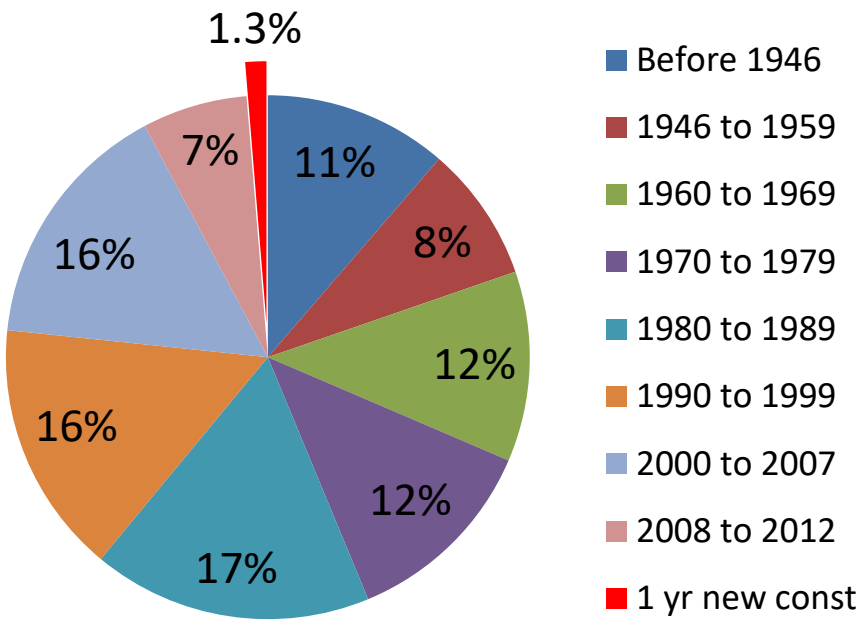
Charles Eley. Feasibility of ZNE by Building Type and Climate ASHRAE Journal July 2017

US New Construction: A Sliver of the Pie

Residential, 119 Million Units
By Year Built



Commercial, 88 Billion sq. ft.
By Year Built



Approximately half of buildings in California
were built before the first Title 24 energy code in 1978

Sources: EIA, RECS 2015 Table HC 10.1, CBECS Table B9, 1 year new const is average post year 2000

Thank you

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