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Building Energy Efficiency Standards

Proposed 2019 Building Energy Efficiency Standards ZNE Strategy

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Countdown to 2020

August 30, 2017

2019 ZNE Strategy

Content

1. Proposed ZNE Strategy – Parts 6 and 11
2. CBECC-Res Software Tools for ZNE

2019 Standards Goals – Path to the Future

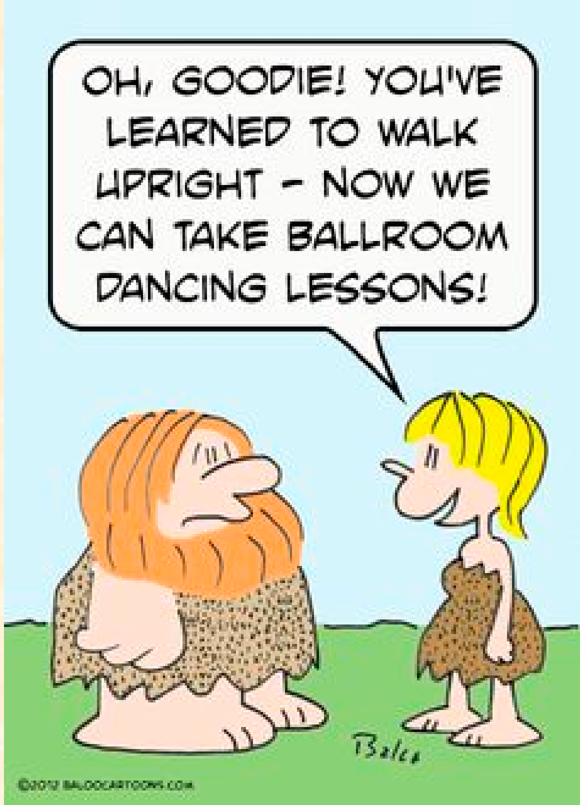
1. Increase building energy efficiency cost effectively
2. For Part 6, make **progress toward the ZNE** goal as possible within the **confines of NEM and life cycle costing rules**, while recognizing that Part 6 is an important but not the only tool for achieving ZNE
3. Contribute to the State's GHG reduction goals
4. **Promote self-utilization of the PV generation** by encouraging or requiring **demand flexibility and grid harmonization strategies**
5. Provide **independent compliance path** for both mixed-fuel and all electric homes
6. Achieve the above goals while ensuring real benefits for the building occupants with **positive benefit to cost ratios** for all efficiency and generation measures
7. Provide the tools for local governments to adopt **ordinances to achieve ZNE through** Part 11 Reach Codes, and other beyond code practices

The proposed 2019 Standards strategy will accomplish all seven goals listed above

ZNE Goals – Grid Harmonization

Grid harmonization strategies (GHS) must be coupled with customer owned PV systems to bring maximum benefits to the grid, environment, and the home owner

GHSs are strategies that maximize self-utilization of the PV array output and minimize exports back to the grid; examples of GHS include but are not limited to battery storage, demand response, thermal storage, and for some homeowners, EV grid integration.



ZNE Goals – 2019 Standards Approach

The 2019 Standards will recognize the following priority for efficiency and generation resources:

1. Envelope efficiency, 2. Appropriately sized PVs, and 3. Grid harmonization strategies that maximize self-utilization of the PV output and limit exports to the grid

Further, the standards must be framed in a way to **encourage competition, innovation, and flexibility** to foster new solutions as the grid and technologies evolve.

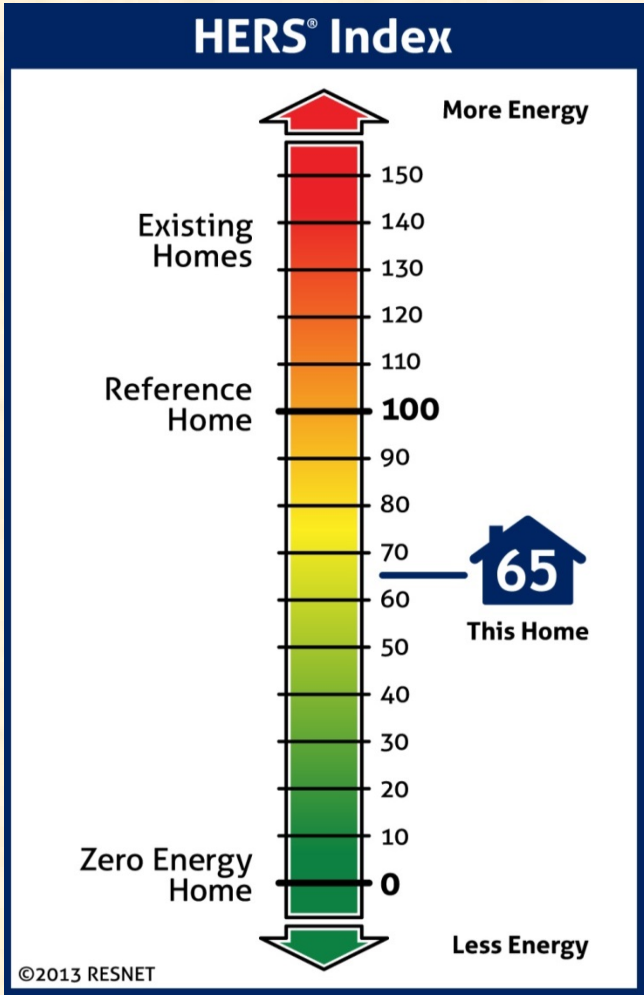
Standards and PV Sizing

- For Part 6, PV is sized to net out the buildings annual kWh; larger PV array may be installed but will not receive additional compliance credit
- For Part 11 compliance, CBECC allows PV array coupled with a 6 kWh battery storage system to be oversized by a factor of 1.6; this PV size:
  - Provides additional flexibility for the grid; the battery enables the increased PV capacity to be used by the utility to meet high demand during critical peak periods
  - Promotes self-utilization on peak since PV is coupled with battery storage
  - The 1.6 cap ensures a greater than 1.0 benefit to cost ratio for the building owner even if hourly exports are compensated only at avoided cost
- CBECC provides a size limit bypass checkbox that once checked allows exceeding the 1.6 times size limit, with a warning that this option may violate NEM sizing rules

Builds on Commission's Energy Design Rating Tool

- **Energy Design Rating (EDR) score show how close a home is to the ZNE target**
  - Aligned with RESNET
  - Reference home is a 2006 IECC compliant home, EDR=100
  - A score of zero means the house is a ZNE building

- **CEC's CBECC-Res software has the capability to calculate EDR scores for EE and PV**
- **Builders can use a combination of envelope energy efficiency features, better appliances, PVs, and other strategies to get to the target EDR**



Download CBECC-Res here for free:

http://www.bwilcox.com/BEES/BEES.html

Proposed 2019 Standards Approach

Energy Design Rating (EDR) targets for each climate zone:

1. An EDR level for energy efficiency features based on 2019 prescriptive measures – This EDR target can only be met using energy efficiency measures, i.e., no PV tradeoff
2. An EDR Contribution for the PV system that is sized to displace the home's annual kWhs
3. Subtract the PV EDR Contribution from the energy efficiency EDR to determine the final target EDR

Proposed 2019 Standards Approach

1. Maximize envelope efficiency as allowed by LCC and calculate EE EDR
   - i. HPA to R19 in severe CZs – Currently R13
   - ii. HPW to 0.043 ~ 0.046 U-factor in severe CZs – Currently 0.051
   - iii. Windows U-factor of 0.30 and SHGC of 0.23 – Currently 0.32 and 0.25
   - iv. QII as a prescriptive requirement

Establish an Energy Design Rating (EDR) for energy efficiency in each CZ **that can only be met with efficiency measures (no PV tradeoff against EE)**

2. Calculate EDR of PV system as follows:
   - i. Calculate the PV size required to displace the kWh in each CZ
   - ii. Calculate the EDR contribution of the PV array

3. Subtract the PV EDR contribution from the EE EDR contribution to **establish the final EDR that the building must meet to comply in each CZ**

Note: Examples are presented in later slides

Target EDR's Many Advantages

1. A target EDR establishes a **performance benchmark that the building must meet to comply**; consistent with the Warren-Alquist Act performance standards expectation to provide builders with compliance flexibility
2. Target EDR allows the builder **to use more efficiency and less PV to get to the target**; such as **high performance glazing, Energy Star appliances, and higher than minimum HVAC systems** that we are prevented from requiring because of preemption issues
3. The EDR concept can be used to **right size the PV system for low EDR and ZNE goals by taking advantage of grid harmonization strategies including battery storage, thermal storage, and demand response and flexibility strategies**
4. Target EDR is fully **compatible with setting reach codes**, local jurisdiction simply identifies a lower target EDR (or zero) that can be met with a combination of additional EE, PV, demand response/flexibility, EV integration, or storage
5. Target EDR works well with **varying building sizes** – static PV size does not

Target EDR Advantages - Example

Here is an example of how CBECC-Res calculates the Target EDR for both EE and PV in CZ12 for the 2,700 sf house:

2019_CZ12_2700ft2 - v30 12 S27 G20 M01

Compliance Summary | Energy Design Rating | Energy Use Details

EDR of Proposed Efficiency: 41.9 - EDR of Prop PV + Flexibility: 19.1 = Final Proposed EDR: **22.8**

EDR of Standard Efficiency: 43.2 - EDR of Minimum Required PV: 18.5 = Final Std Design EDR: 24.7

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	584	486.0	45.09	187	217.2	19.51	25.58
Space Cooling	1,729		59.71	317		17.22	42.49
IAQ Ventilation	194		1.99	194		1.99	0.00
Other HVAC			0.00			0.00	0.00
Water Heating		176.3	13.03		119.9	8.86	4.17
Photovoltaics				-5,022		-43.51	43.51
Battery						0.00	0.00
Inside Lighting	2,615		30.42	616		6.98	23.44
Appl. & Cooking	989	73.4	15.65	1,040	45.1	14.46	1.19
Plug Loads	3,267		35.06	2,371		25.03	10.03
Exterior	328		3.54	152		1.61	1.93
TOTAL	9,705	735.7	204.49	-146	382.3	52.15	152.34

Done

Parallel Prescriptive Paths

There will be two parallel prescriptive paths for compliance, one for each of:

1. **Mixed Fuel Homes**
2. **All-Electric Homes**

This allows the all-electric and mixed fuel homes to have their own prescriptive paths,

NEEA Tier 3 HPWH models can easily be used to meet or exceed standard design using the performance path

All-Electric Homes and GHG Goals

Home electrification when combined with PVs and demand flexibility strategies can result in environmental benefits as well as grid, and occupant benefits

Extreme Efficiency and ZNE

Can extreme energy efficiency regardless of cost achieve full ZNE (EDR of 0)?

- Even if we eliminate all heating, cooling, hot water, and IAQ loads, we'll still end up with an EDR score of 25-30, the theoretical limit for efficiency EDR!
- That is because in most climate zones plug loads are now the dominant loads and they are unaffected by efficiency measures, extreme or not
- 2019 Standards efficiency EDRs are in the 43-48 range depending on the CZ
- "Practical" efficiency measures – without renewables and demand flexibility - can move the EDR score by no more than 7-9 points in severe CZs, less in milder CZs to ~34-41 range!

Conclusions:

1. Limited opportunity for regulated loads to lower EDR in the future
2. Need PV + demand flexibility to achieve low EDR scores or ZNE

Calgreen Tiers and Target EDR Scores

- 2016 Standards have efficiency EDR scores in mid 50s in most CZs
- 2016 Calgreen has three tiers
  - Tier 1 - 15% better than Part 6
  - Tier 2 - 30% better than Part 6
  - And a ZNE tier with EDR score of zero
- 2019 Standards final EDR scores including PVs are in mid 20s in most CZs
- No need (room) for three Calgreen tiers anymore; two tiers may be sufficient
  - A tier 1 that will get halfway to EDR 0 established based on default battery controls and PV oversizing factor of ~ 1.3 or less
  - A second tier with EDR score of zero established based on advanced battery controls and PV oversizing factor of ~ 1.4 or less

Builders may use a combination of PV, efficiency measures including higher appliances efficiencies, and demand flexibility measures to reach these target EDRs most cost effectively

Note for following slides: each EDR point is ~ 170 watts of PV, roughly about half a PV panel

Target EDR Examples by Climate Zone

Here is are examples of how Target EDRs might look for different scenarios

2700 sf Prototype, Mixed Fuel

	Part 6			Tier 1				Tier 2		Recommended EDR Scores For	
CZ	2019 Efficiency EDR	Part 6 PV Size, kW DC	2019 EDR with Part 6 PV	EDR with 1.3 OS Factor and Basic Battery	EDR with 1.2 OS Factor and Basic Battery	EDR with 1.1 OS Factor and Basic Battery	EDR with 1.0 OS Factor and Basic Battery	Tier 2 PV Size with Adv Battery & EDR=0, kW DC	Tier 2 OS Factor	**Tier 1**	**Tier 2**
1	48.0	3.4	26.5	15.5	17.9			4.5	1.3	**16.0**	**0.0**
2	44.6	2.9	23.8	13.1	15.1			3.6	1.2	**12.0**	**0.0**
3	42.7	2.5	22.4	11.8	14.2			2.8	1.1	**12.0**	**0.0**
4	43.6	2.9	22.4	9.4	11.5	13.6		3.0	1.0	**12.0**	**0.0**
5	40.1	2.3	20.9	10.5	12.1	14.6		2.5	1.1	**12.0**	**0.0**
6	48.7	2.9	22.6	6.5		11.8	14.7	3.1	1.1	**12.0**	**0.0**
7	47.5	2.7	19.6	4.5		9.6	12.8	2.4	0.9	**12.0**	**0.0**
8	45.2	3.0	20.3	4.2		8.9	11.4	3.0	1.0	**12.0**	**0.0**
9	46.4	3.1	23.4	6.2		9.9	12.5	3.6	1.1	**12.0**	**0.0**
10	45.3	3.3	23.5	4.6		9.3	11.7	3.8	1.2	**12.0**	**0.0**
11	42.5	4.0	22.6	6.5	8.5	10.5	12.9	5.2	1.3	**12.0**	**0.0**
12	42.7	3.2	24.0	9.0	11.3	13.3	15.4	4.4	1.4	**12.0**	**0.0**
13	43.9	4.1	23.7	7.3	10.1	11.9		5.9	1.4	**12.0**	**0.0**
14	44.1	3.5	23.6	7.2	9.7	11.8		5.0	1.4	**12.0**	**0.0**
15	46.7	5.8	20.4	4.8	7.2	10.1	13.1	7.5	1.3	**12.0**	**0.0**
16	46.6	2.9	27.8	16.6	11.0			5.1	1.8	**16.0**	**0.0**

Target EDR Examples by Climate Zone

Here is are examples of how Target EDRs might look for different scenarios

2100 sf Prototype, Mixed Fuel

	Part 6			Tier 1				Tier 2		Recommended EDR Scores For	
CZ	2019 Efficiency EDR	Part 6 PV Size, kW DC	2019 EDR with Part 6 PV	EDR with 1.3 OS Factor and Basic Battery	EDR with 1.2 OS Factor and Basic Battery	EDR with 1.1 OS Factor and Basic Battery	EDR with 1.0 OS Factor and Basic Battery	Tier 2 PV Size with Adv Battery & EDR=0, kW DC	Tier 2 OS Factor	**Tier 1**	**Tier 2**
3	47.7	2.2	25.0	13.7	16.4		20.1	2.4	1.1	**12.0**	**0.0**
7	49.5	2.3	20.7		7.8	11.6	14.1	2.0	0.9	**12.0**	**0.0**
10	46.9	2.7	24.5			9.8	12.6	2.7	1.0	**12.0**	**0.0**
12	45.0	2.7	25.3	10.5	12.5			3.2	1.2	**12.0**	**0.0**
13	46.6	3.5	25.6	6.1	8.8	11.2	15.0	4.4	1.3	**12.0**	**0.0**
15	49.9	5.2	21.8	0.6		7.4	10.8	6.1	1.2	**12.0**	**0.0**
16	49.3	2.3	30.2	16.9				4.1	1.8	**16.0**	**0.0**

Target EDR Examples by Climate Zone

Here is are examples of how Target EDRs might look for different scenarios

2700 sf Prototype, All Electric

	Part 6			Tier 1					Tier 2		Recommended EDR Scores For	
CZ	2019 Efficiency EDR	Part 6 PV Size, kW DC	2019 EDR with Part 6 PV	EDR with 1.4 OS Factor and Basic Battery	EDR with 1.3 OS Factor and Basic Battery	EDR with 1.2 OS Factor and Basic Battery	EDR with 1.1 OS Factor and Basic Battery	EDR with 1.0 OS Factor and Basic Battery	Tier 2 PV Size with Adv Battery & EDR=0, kW DC	Tier 2 OS Factor	**Tier 1**	**Tier 2**
3	50.9	2.8	28.8	14.3	17.3				4.0	1.4	**14.0**	**0.0**
7	51.3	2.9	23.3			13.2	13.2	16.4	3.0	1.0	**14.0**	**0.0**
10	47.3	3.4	26.2			12.3	12.3	15.2	4.3	1.3	**14.0**	**0.0**
12	45.6	3.3	27.4	10.4		13.9	16.7		5.1	1.5	**14.0**	**0.0**
13	46.5	4.3	26.8		9.4	11.8	15.0	18.4	6.7	1.6	**14.0**	**0.0**
15	48.0	6.1	22.4		4.6		10.6	13.8	8.1	1.3	**14.0**	**0.0**
16	61.4	3.2	44.3	32.2	34.3	36.9	38.9	40.8	8.0	2.5	**22.0??**	**0.0**

Note: There may not a cost effective or practical way to get to EDR score of zero in CZ16, especially for all-electric homes; winters are too cold with too much resistance heating for HP water and space heating. EDR score of 22 requires a 6.1 kW PV system, an oversizing factor of 1.9, exceeding the 1.6 limit; EDR score of zero requires oversizing factor of 2.5!

Target EDR Examples by Climate Zone

Here is are examples of how Target EDRs might look for different scenarios in different CZs for the 2,700 sf Mixed Fuel Homes:

Note: At this time these numbers are examples only and may change as our tools evolve

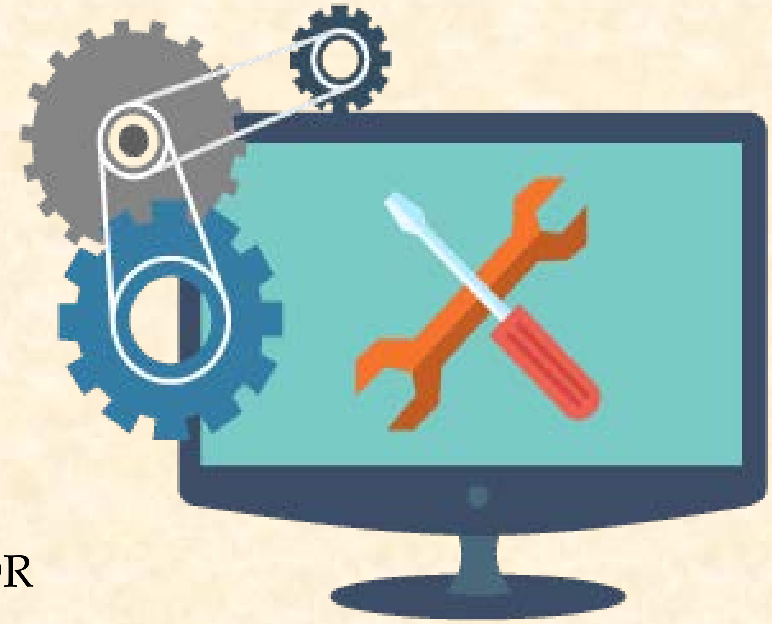
NEM = Net Energy Metering; GH = Grid Harmonization; Dumb PV = No Battery Storage

1	2	3	4	5	6	7	8	9	10	11
CZ	Efficiency EDR without PV, based on 2019 Efficiency Measures	Target Design Rating Score for Displacing kWh Elect with PV from Col 4	PV Sized to Displace Annual kWh Electric – Cool with NEM, not so Cool with GH	Dumb PV Sized to Zero EDR – Violates NEM, Not Cool with GH	PV Size for Zero EDR with Basic Battery Controls – May Violate NEM, OK with GH	PV Size for Zero EDR with Optimum Battery Controls – Cool with NEM and GH	Similar to Col 7 But With 95 Furn, 0.95 WH – Real Cool with NEM and GH	Col 6 to 4 Ratio	Col 7 to 4 Ratio	Col 8 to 4 Ratio
1	48.0	26.5	3.4	7.7	6.9	4.6	4.1	2.0	1.4	1.2
2	41.2	18.0	2.9	6.1	5.5	3.1	2.8	1.9	1.1	1.0
3	46.9	22.7	2.8	5.8	5.3	3.2	2.9	1.9	1.1	1.0
6	48.0	20.9	2.9	5.3	4.5	2.9	2.8	1.6	1.0	1.0
7	48.0	14.9	2.7	4.6	3.9	2.4	2.3	1.4	0.9	0.9
8	43.0	14.6	2.9	5.3	4.3	2.7	2.6	1.5	0.9	0.9
11	43.3	23.4	3.8	8.5	6.5	4.4	4.2	1.7	1.2	1.1
12	43.1	24.5	3.1	7.0	5.8	3.8	3.5	1.9	1.2	1.1
13	44.8	22.1	4.0	9.0	6.2	4.9	4.6	1.6	1.2	1.2
14	44.6	21.3	3.4	7.4	5.4	4.4	4.1	1.6	1.3	1.2
15	48.0	17.9	5.7	10.5	8.1	6.9	6.8	1.4	1.2	1.2
16	46.3	27.5	3.0	7.6	6.5	4.8	4.3	2.2	1.6	1.4

2. Software Tools

The CBECC-Res Compliance Software May Be Used For:

- Part 6 Compliance, and
- Part 11 (*CAL***Green**, Reach Codes, etc)

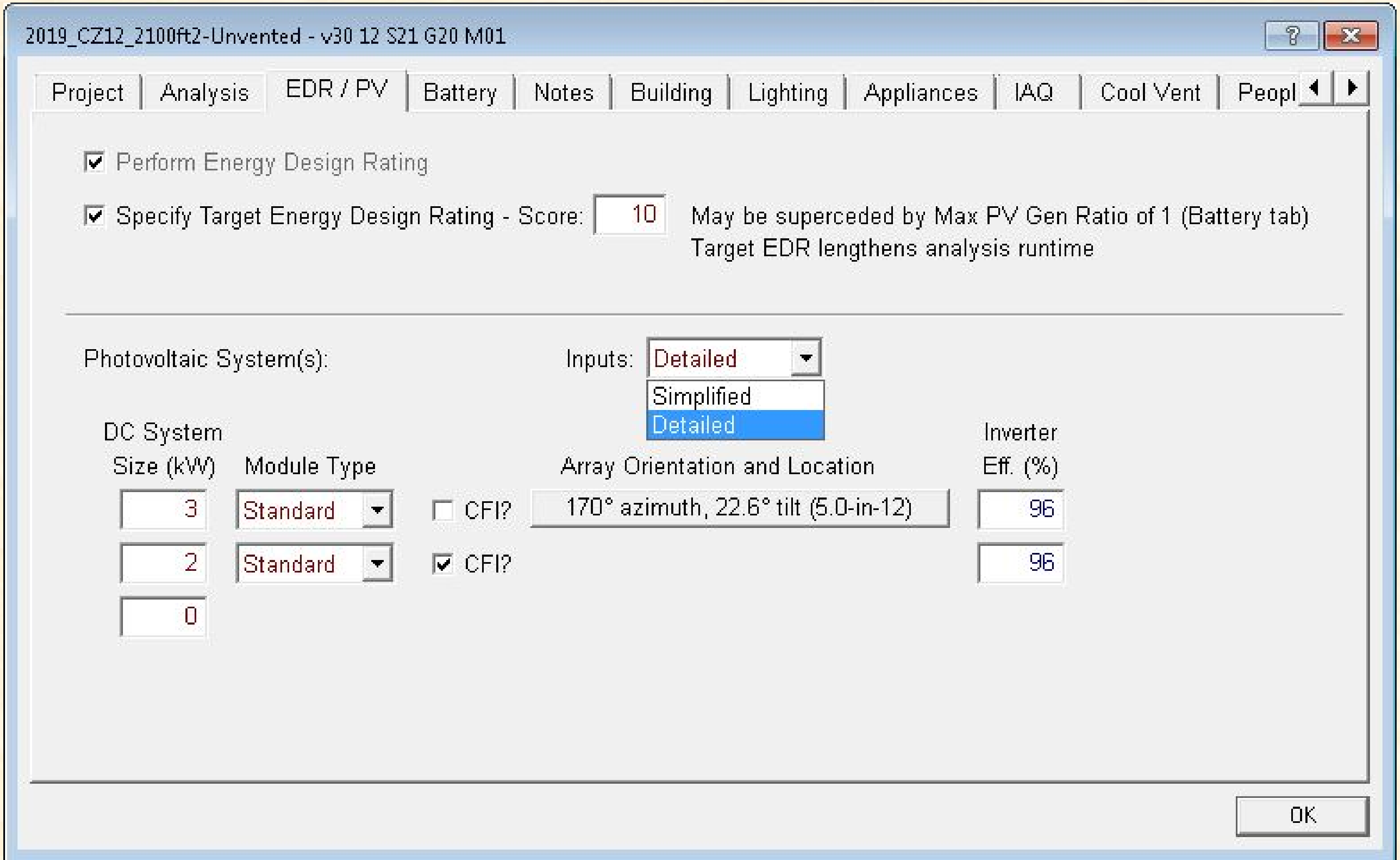


The Software can be used to:

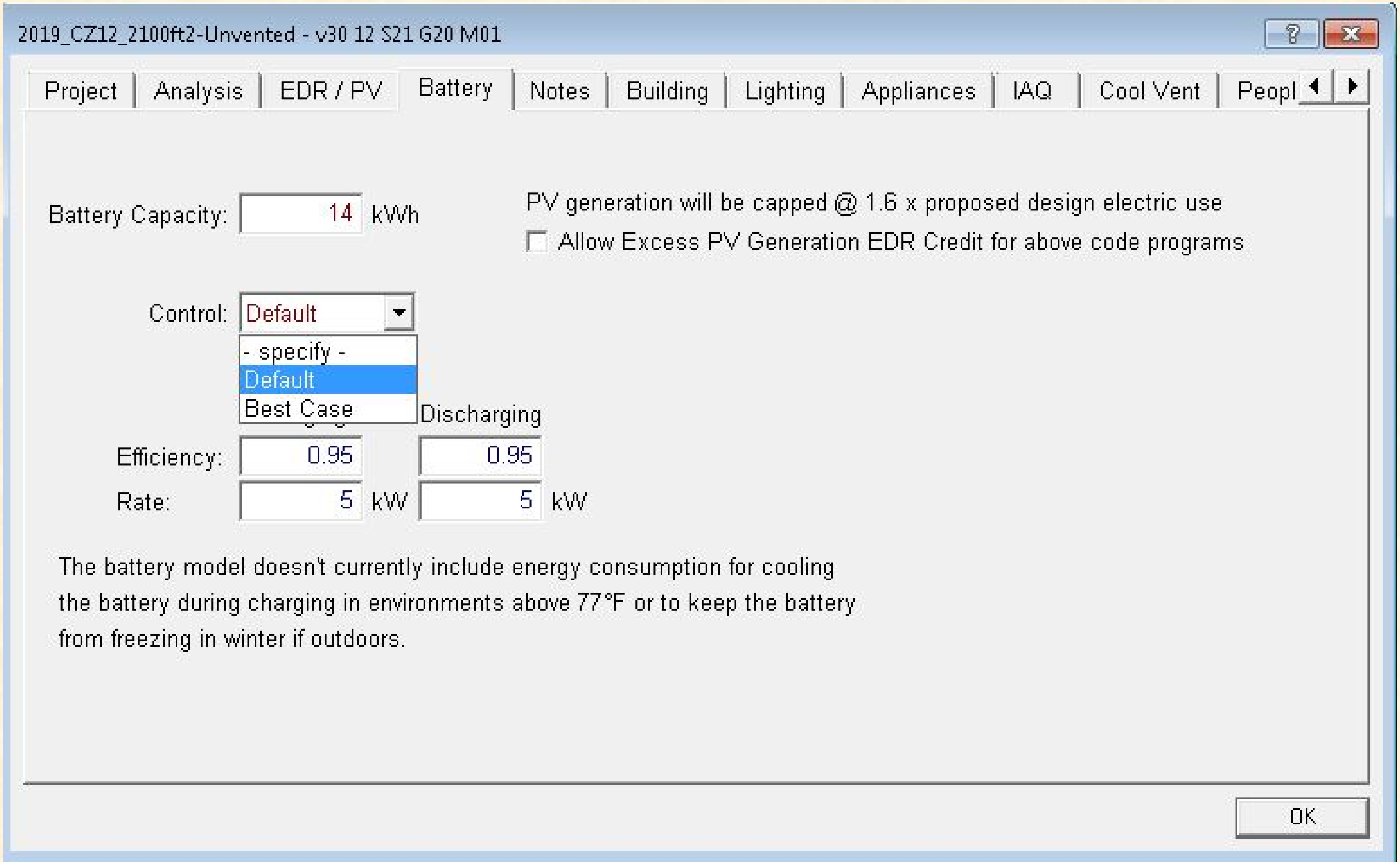
- Size PV for Part 6 compliance or lower target EDRs for Reach Codes
- Assess the impact of battery storage on lowering EDR
- Assess the impact of precooling and other DR strategies on lowering EDR
- Assess the impact of HPWH DR on lowering EDR
- And other options

Software Tools – Input Screens

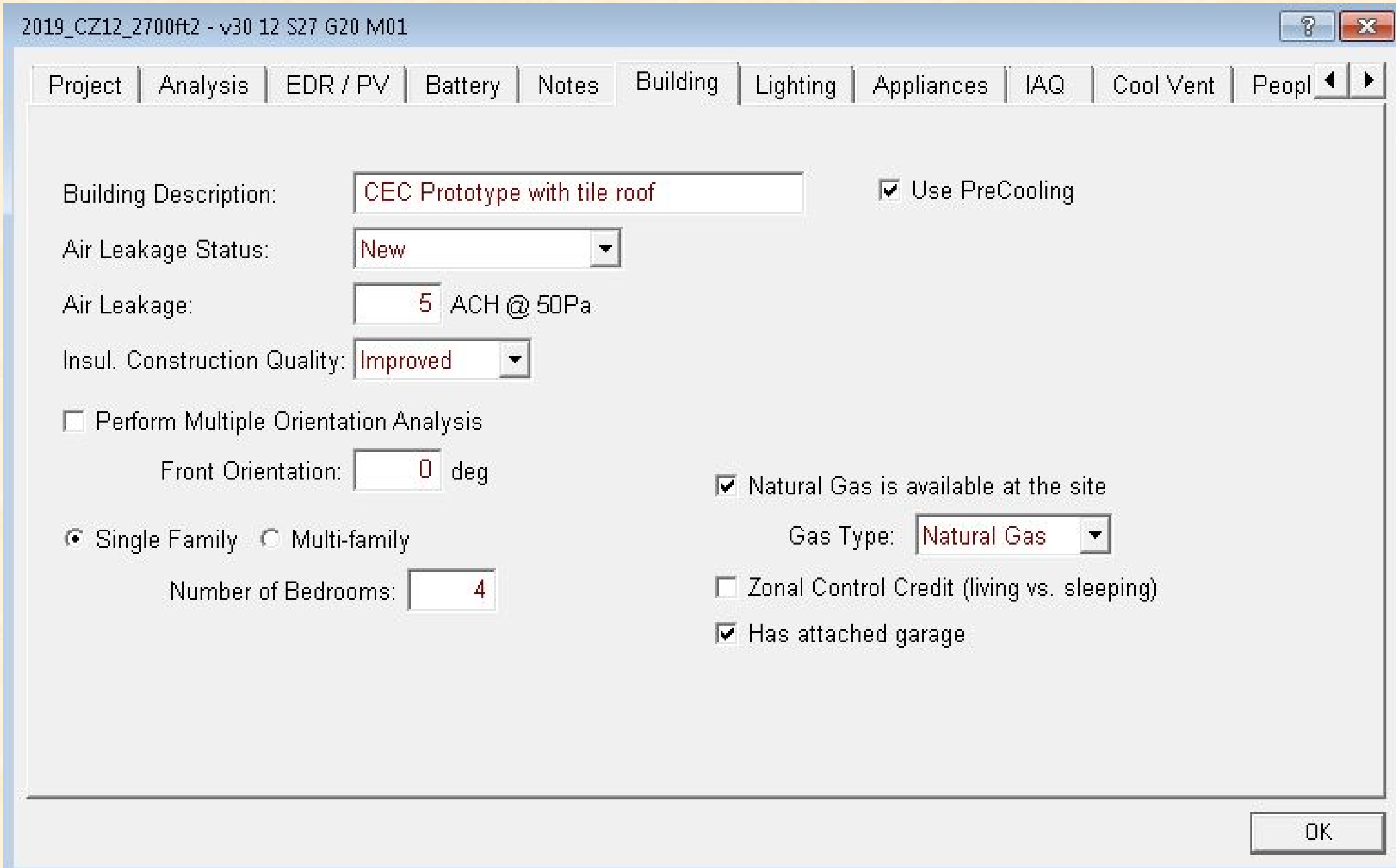
This screen can be used to specify an EDR target that may be required by reach codes to size the PV system



Software Tools – Input Screens



Software Tools – Input Screens



Software Tools – Results Screens

For Compliance for Part 6 and Part 11

2019_CZ12_2700ft2 - v30 12 S27 G20 M01

Compliance Summary | Energy Design Rating | Energy Use Details

EDR of Proposed Efficiency:	41.9	-	EDR of Prop PV + Flexibility:	19.1	=	Final Proposed EDR:	**22.8**
EDR of Standard Efficiency:	43.2	-	EDR of Minimum Required PV:	18.5	=	Final Std Design EDR:	24.7

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	584	486.0	45.09	187	217.2	19.51	25.58
Space Cooling	1,729		59.71	317		17.22	42.49
IAQ Ventilation	194		1.99	194		1.99	0.00
Other HVAC			0.00			0.00	0.00
Water Heating		176.3	13.03		119.9	8.86	4.17
Photovoltaics				-5,022		-43.51	43.51
Battery						0.00	0.00
Inside Lighting	2,615		30.42	616		6.98	23.44
Appl. & Cooking	989	73.4	15.65	1,040	45.1	14.46	1.19
Plug Loads	3,267		35.06	2,371		25.03	10.03
Exterior	328		3.54	152		1.61	1.93
TOTAL	9,705	735.7	204.49	-146	382.3	52.15	152.34

Done

Software Tools – Results Screens

Compliance Pass/Fail

2019_CZ12_2700ft2 - v30 12 S27 G20 M01

Compliance Summary | Energy Design Rating | Energy Use Details

	Energy Design Ratings: Efficiency[1] (EDR)	Energy Design Ratings: Final[2] (EDR)	Compliance Margins: Efficiency[1] (EDR)	Compliance Margins: Final[2] (EDR)
Standard Design	43.2	24.7		
Proposed Design	41.9	22.8	1.3	1.9

Result[3]: **COMPLIES**

(not current)

[1] Efficiency measures include improvements like a better building envelope and more efficient equipment

[2] Final EDR includes efficiency, photovoltaics and batteries

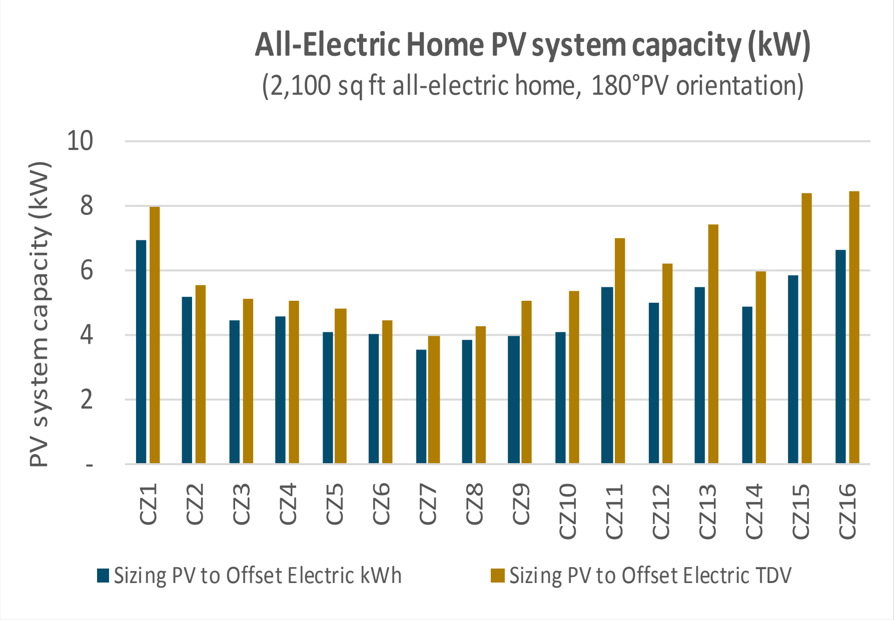
[3] Building complies when all efficiency and final margins are greater than or equal to zero

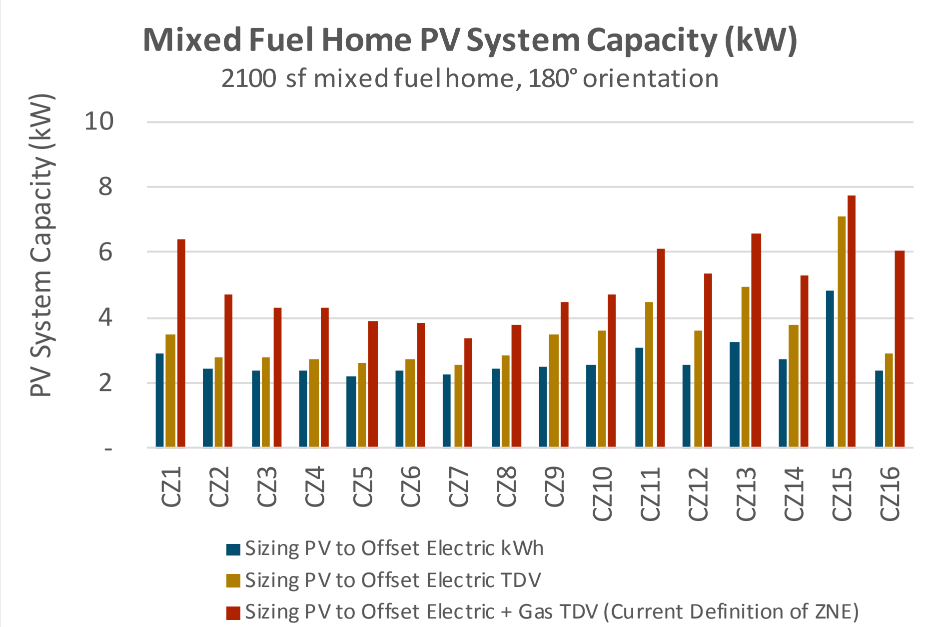
Done

Questions?

TDV ZNE requires a larger PV system than Site ZNE

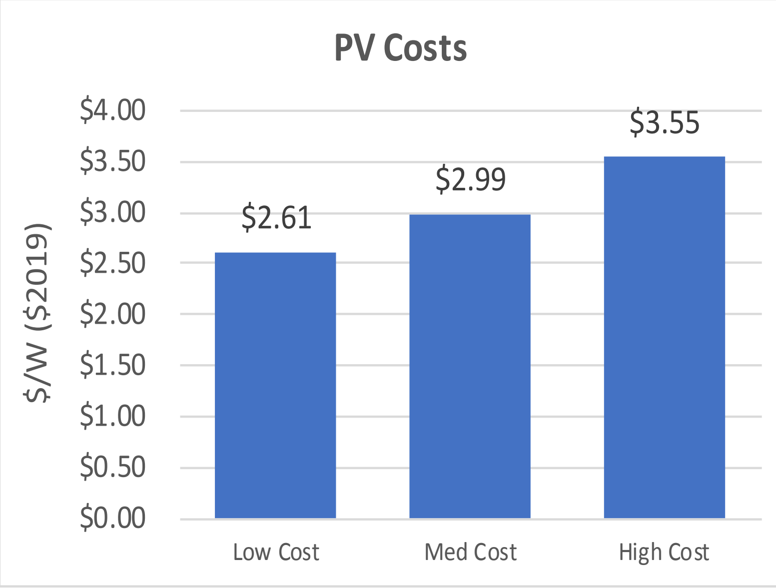
- **Solar production occurs during low TDV hours, and households demand energy during high TDV hours**
  - PV must be sized larger to reach TDV ZNE vs. Site ZNE (which doesn't account for the changing value of kWh)
- **For a 2,100 ft² home with 180° PV orientation, TDV ZNE requires 7% - 44% larger PV capacity than Site ZNE (average: 21%)**
- **Because PV interconnection rules limit sizing to electric kWh, this presentation focuses on that size**



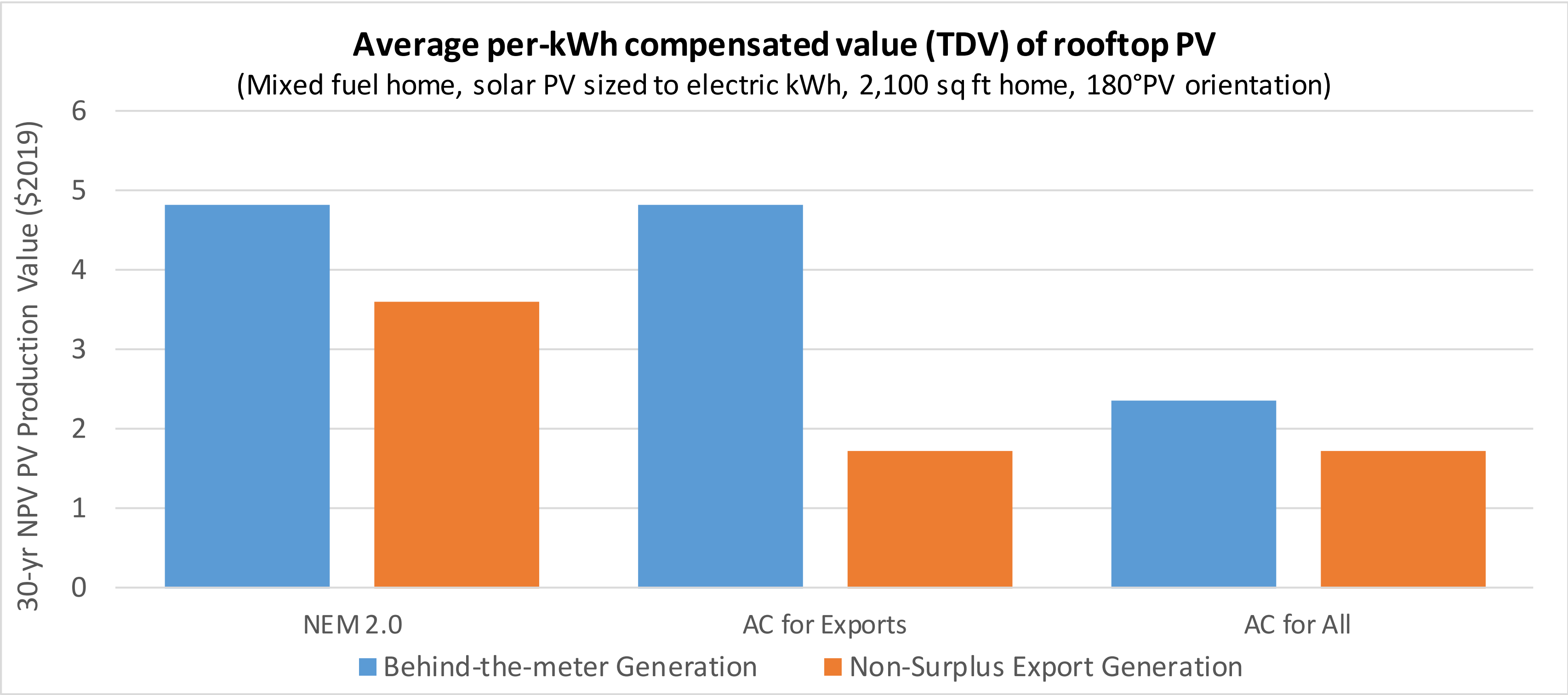


PV Costs

- **No ITC Assumed - The ITC is scheduled to step down throughout the 2020-2022 building standard cycle (26%, 22%, 20%) and then to 0% for residential systems beginning in 2023**
- **All costs assume a 30-yr panel life and inverter replacements after 10 and 20 years (comprises ~$0.40/W in the costs)**
- **Price based on NREL 2016 Installer Price**
  - Low cost case:
    - 30% cost reduction 2016 – 2020 (GreenTech Media)
  - Medium cost case:
    - 18% cost reduction 2016 – 2020 (Bloomberg)
  - High cost case:
    - No cost reduction 2016 - 2020



Three solar compensation policies

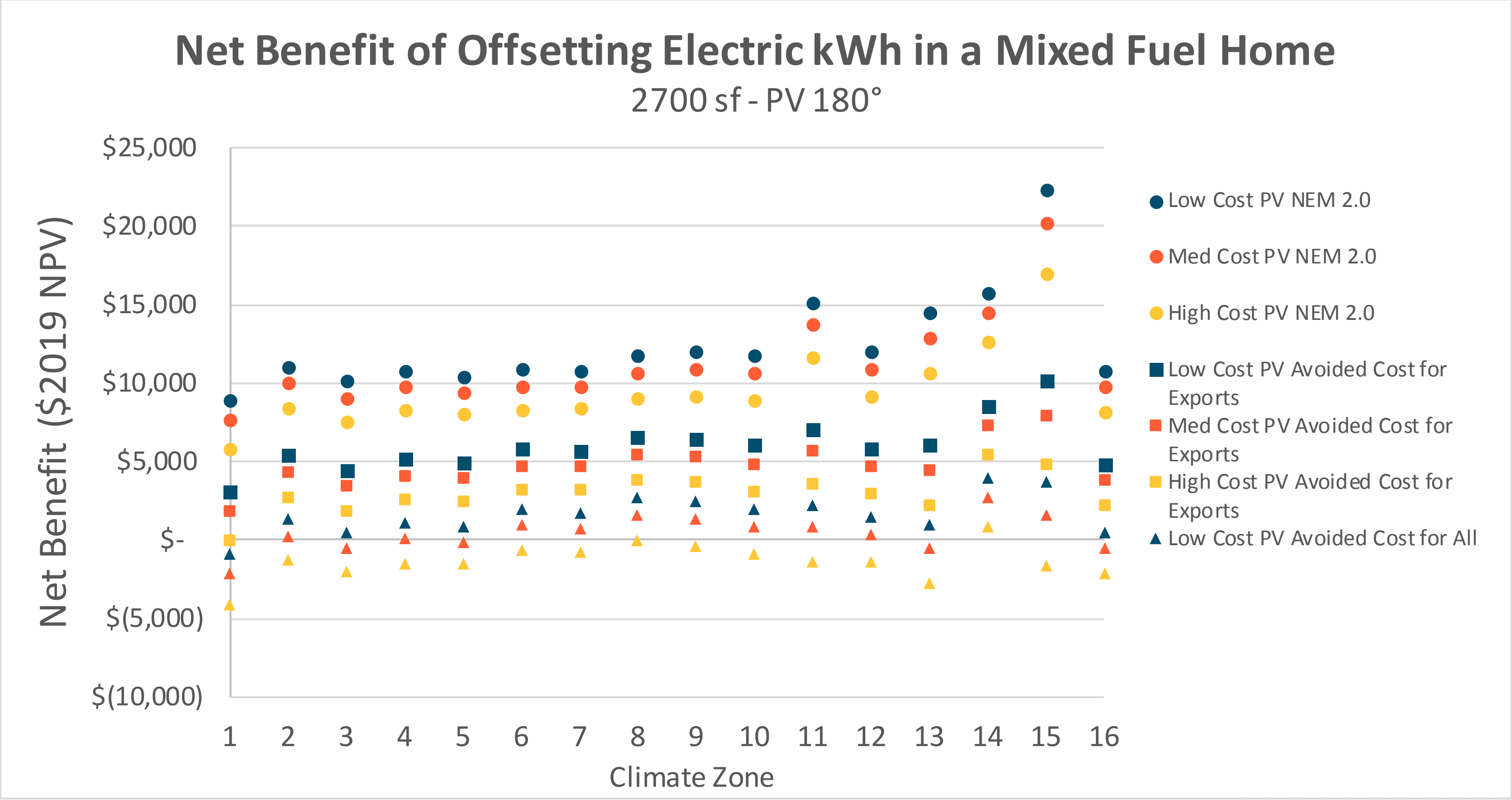


AC = Avoided Costs

Non-surplus Export Generation are the hourly exports

Cost-Effectiveness of Offsetting Elec kWh in a Mixed Fuel Home

+ **Offsetting electric kWh with solar PV is cost-effective except under the most aggressive NEM reform scenarios**



CZ	PV kW
1	2.89
2	2.46
3	2.38
4	2.36
5	2.22
6	2.38
7	2.26
8	2.46
9	2.51
10	2.58
11	3.10
12	2.58
13	3.28
14	2.73
15	4.83
16	2.37

Energy+Environmental Economics

3 - Strategies for Reach Codes

NEM Rules and Oversizing PV – DRAFT

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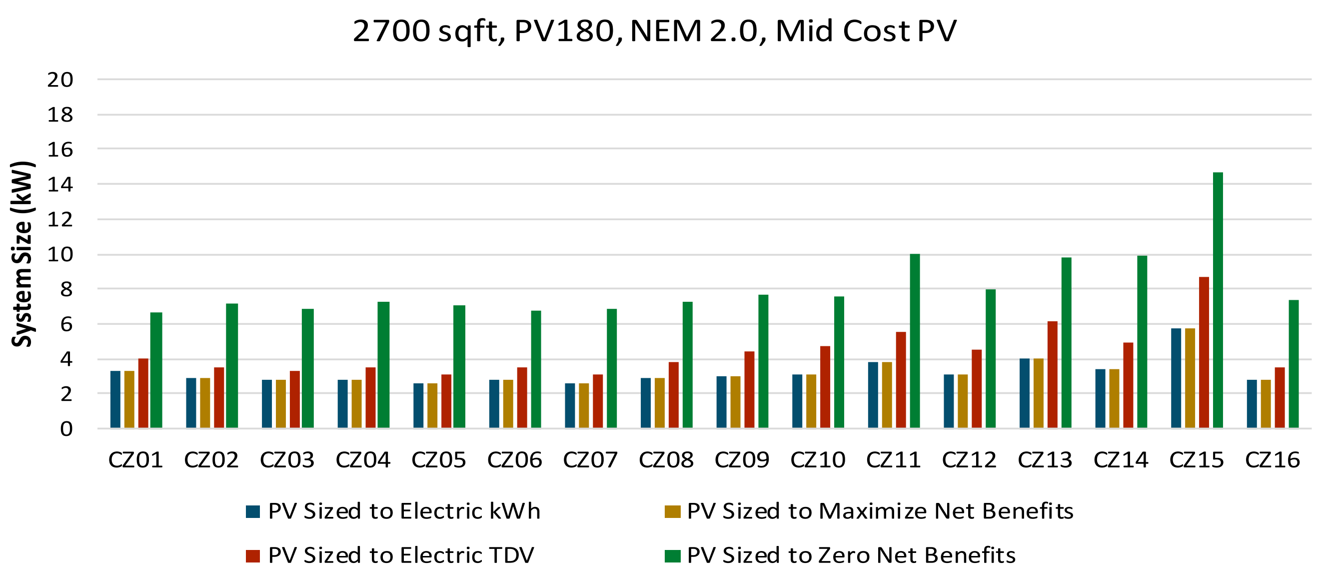
PV Sizing Methods

+ **Electric kWh**
  - PV scaled such that annual generation = annual electric load
+ **Maximize Net Benefits**
  - PV scaled to maximize net TDV benefit to customer
    - Practically, this is the same capacity as sizing to kWh, i.e., further generation will only receive Net Surplus Compensation (NSC)
+ **Electric TDV**
  - PV scaled such that annual TDVs generated = annual TDV of electric load
+ **Zero Net Benefits (Breakeven Point)**
  - PV scaled to point at which a larger system will not be cost-effective
  - Cost of PV system = Revenue from PV generation

Sizing Comparison

NEM 2.0, Mid Cost PV

- **PV sized to max net benefits is smaller than sized to electric TDV**
  - Sizing to TDV does not reflect lower compensation for exports from NEM 2.0
- **At sizes beyond max net benefits, incremental kW only receive NSC**
  - Large net benefit and small marginal net cost (PV cost – NSC) at the point of maximum net benefits require much larger systems to zero out net benefits
  - Retail for self-use and exports, NSC for net surplus – NEM2

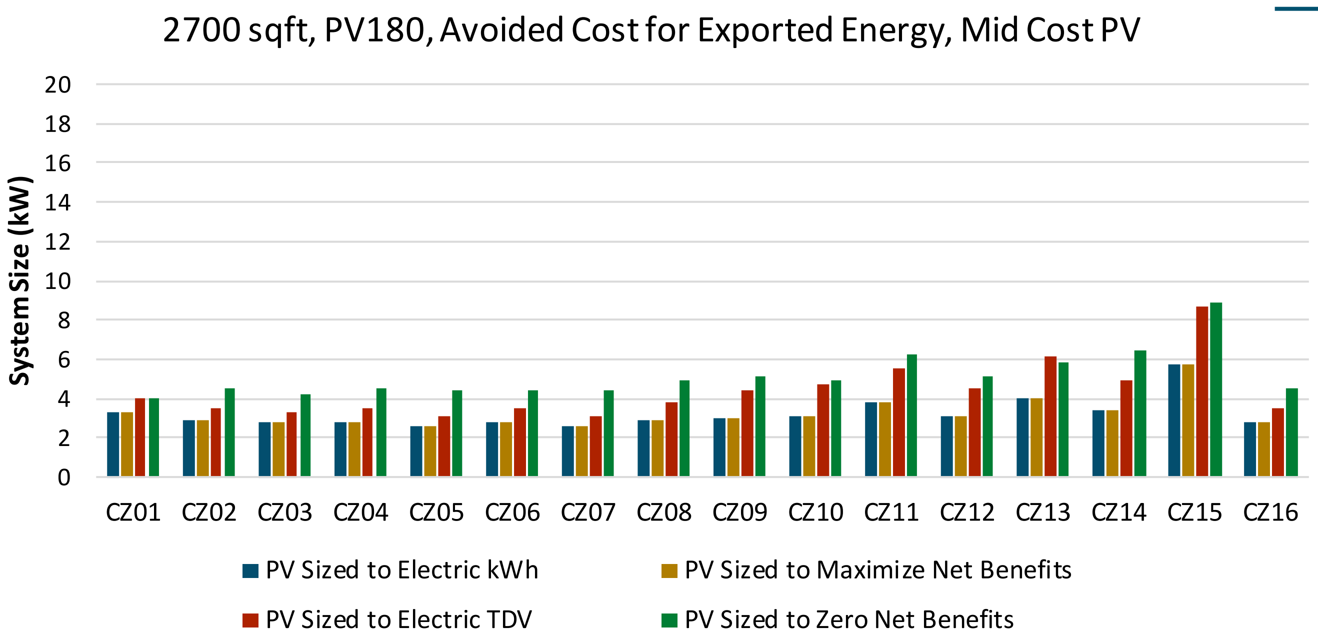


Ratio of PV Sized to Zero Net Benefits / PV Sized to Electric kWh

CZ1	1.98
CZ2	2.51
CZ3	2.49
CZ4	2.62
CZ5	2.76
CZ6	2.42
CZ7	2.61
CZ8	2.49
CZ9	2.55
CZ10	2.43
CZ11	2.65
CZ12	2.59
CZ13	2.43
CZ14	2.96
CZ15	2.55
CZ16	2.61

Sizing Comparison
AC for Exports, Mid Cost PV

- **Valuing export PV generation at avoided cost reduces cost-effectiveness of PV sized to offset kWh**
  - Smaller net benefits for systems sized to offset kWh means less kW at marginal net cost are needed to zero out net benefits
  - Retail for self-use, AC for exports, NSC for net surplus, NEM”3”

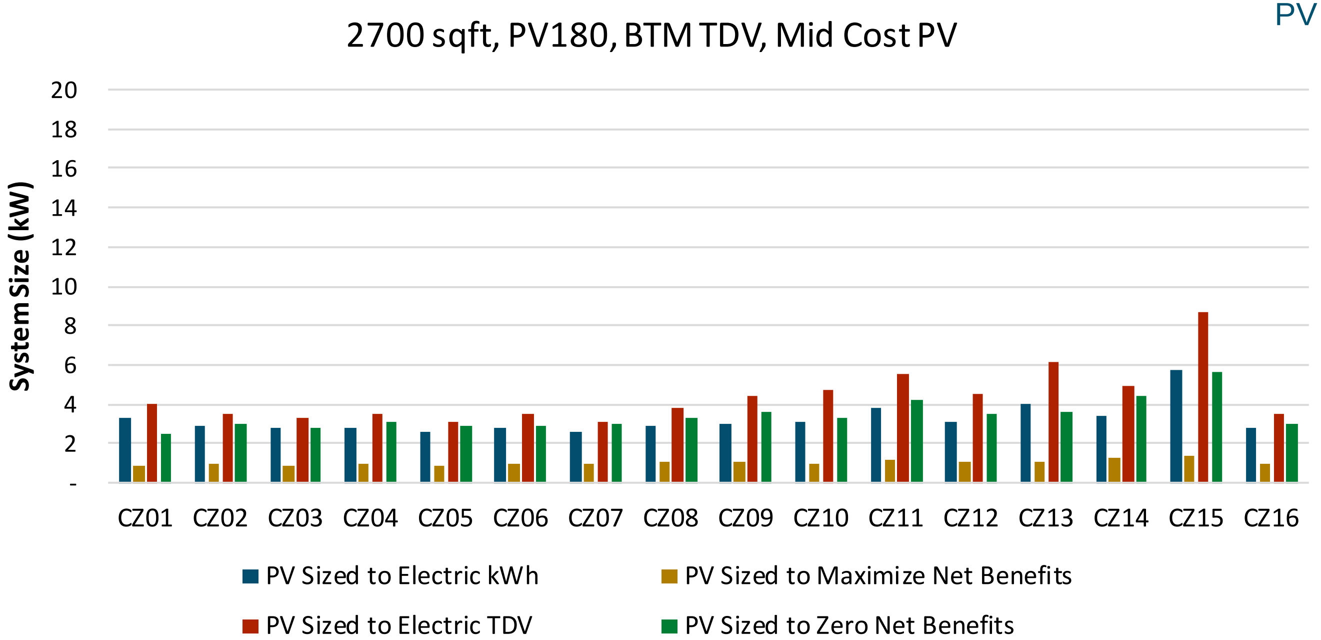


Ratio of PV Sized to Zero Net Benefits / PV Sized to Electric kWh

CZ01	1.21
CZ02	1.57
CZ03	1.52
CZ04	1.64
CZ05	1.71
CZ06	1.58
CZ07	1.67
CZ08	1.67
CZ09	1.69
CZ10	1.57
CZ11	1.65
CZ12	1.64
CZ13	1.45
CZ14	1.91
CZ15	1.55
CZ16	1.60

Sizing Comparison
BTM TDV, Mid Cost PV

- **BTM TDV means**
  - All PV production consumed behind-the-meter (BTM) receives full TDV value
  - All PV production exported to the grid as well as all net surplus above a system sized to annual kWh receives net surplus compensation (NSC)
- **PV sized to electric kWh and electric TDV are unchanged from previous rate structures**
- **PV sized to maximize net benefits and PV sized to zero net benefits are substantially reduced**
- Retail for self-use, NSC for exports and annual surplus



Ratio of PV Sized to Zero Net Benefits / PV Sized to Electric kWh

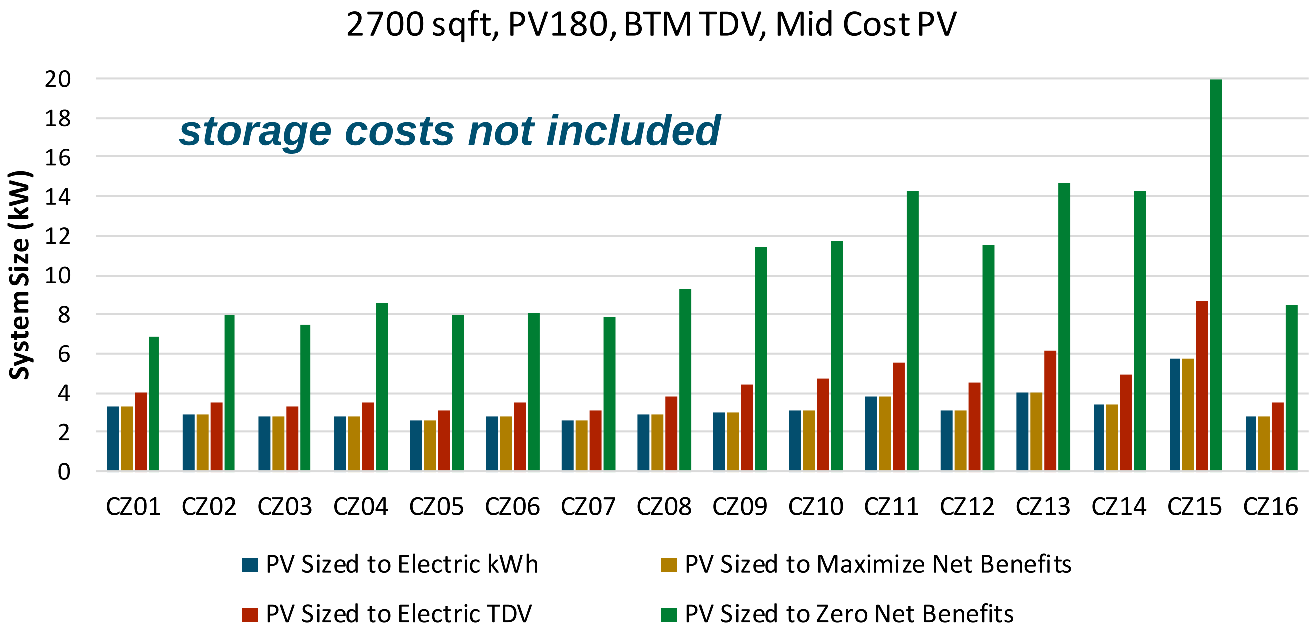
CZ1	0.74
CZ2	1.05
CZ3	1.01
CZ4	1.11
CZ5	1.14
CZ6	1.04
CZ7	1.12
CZ8	1.11
CZ9	1.18
CZ10	1.05
CZ11	1.11
CZ12	1.14
CZ13	0.89
CZ14	1.30
CZ15	0.98
CZ16	1.07

Storage Overview

- **E3 analyzed the additional value of a battery storage system to an existing PV system of a 2700 sf, mixed fuel home**
- **BTM TDV rate scenario**
  - BTM generation receives full TDV value (~$0.20/kWh); exported generation receives net surplus compensation value (~$0.03/kWh)
- **Battery assumptions**
  - 14 kWh
  - 5 kW
  - 90% round trip efficiency
  - $500/kWh fully installed

Sizing Comparison
BTM TDV With Storage, Mid Cost PV

- Installing storage (without accounting for the **storage** costs) increases the benefits to the homeowner, allowing them to install more solar
- The Generous Santa option: Demonstrates how PV value increases if coupled with storage at no cost
- Retail for self-use, and NSC for exports and annual surplus



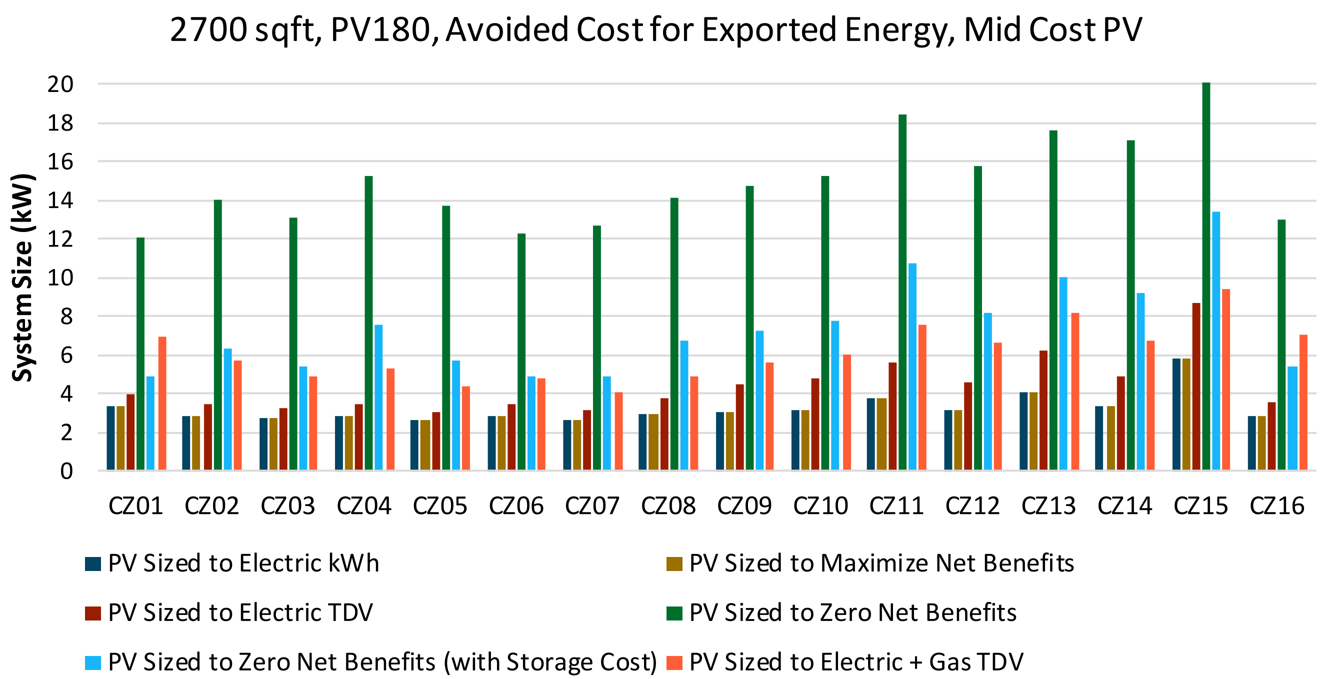
Ratio of PV Sized to Zero Net Benefits / PV Sized to Electric kWh

CZ1	2.05
CZ2	2.78
CZ3	2.70
CZ4	3.09
CZ5	3.09
CZ6	2.89
CZ7	2.97
CZ8	3.17
CZ9	3.77
CZ10	3.75
CZ11	3.76
CZ12	3.71
CZ13	3.66
CZ14	4.26
CZ15	3.47
CZ16	3.02

Sizing Comparison
Avoided Cost for Exported Energy With Storage, Mid Cost PV

NEW

- **Changing the rate structure to avoided cost for exported energy increases the net benefits of solar + storage and therefore increases the amount of solar that can be installed before net benefits are reduced to zero; annual surplus at NSC**
- The Stingy Santa option – Demonstrates the impact on the PV if Santa charges you for the storage
- Retail for self-use, AC for exports, and NSC for annual surplus – NEM"3"

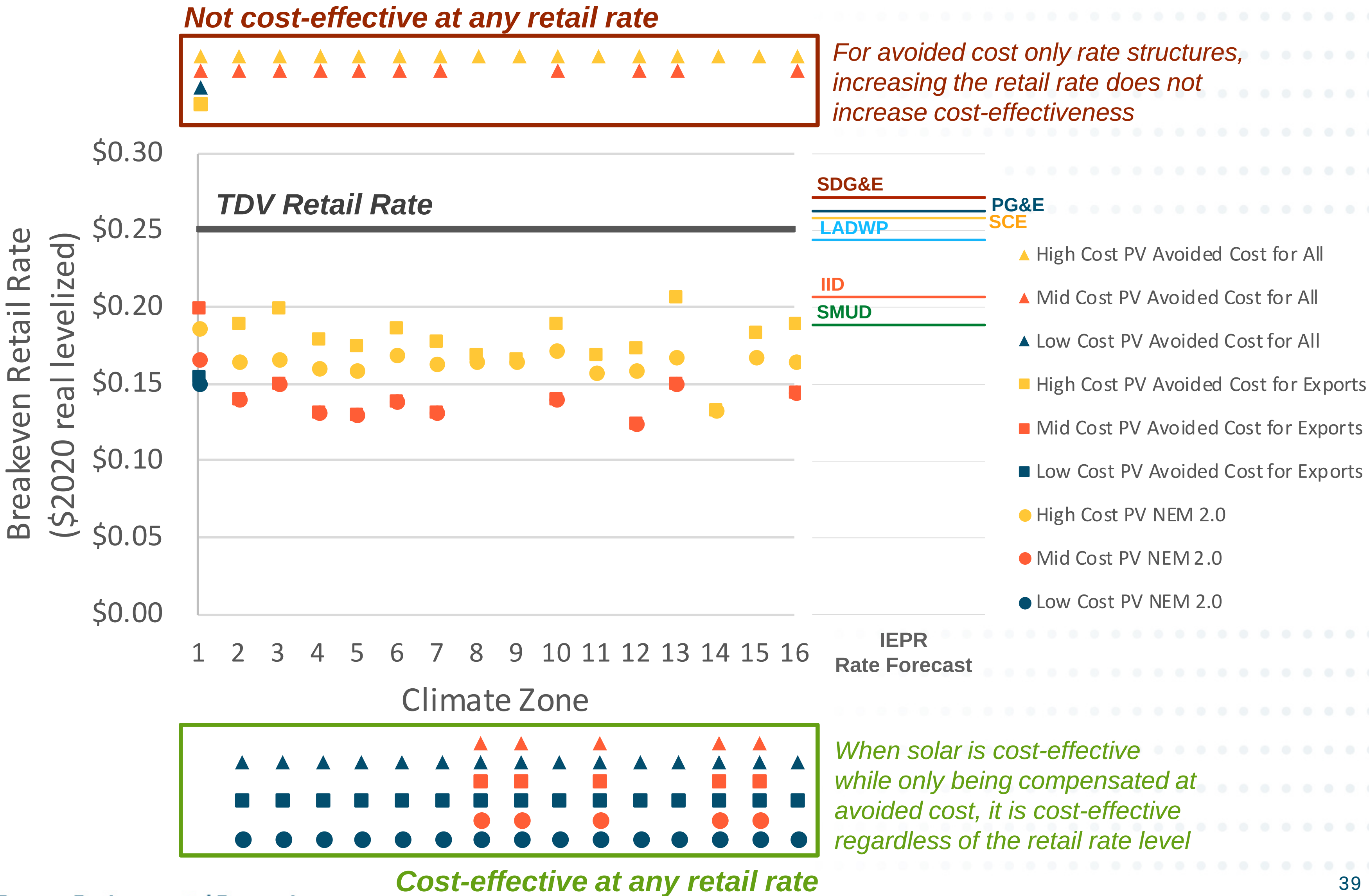


Ratio of PV Sized to Zero Net Benefits (with Storage Costs)

PV Sized to Electric kWh

CZ1	1.48
CZ2	2.21
CZ3	1.96
CZ4	2.71
CZ5	2.23
CZ6	1.73
CZ7	1.87
CZ8	2.29
CZ9	2.39
CZ10	2.47
CZ11	2.82
CZ12	2.63
CZ13	2.49
CZ14	2.73
CZ15	2.33
CZ16	1.90

POU PV Cost / Benefit Breakeven Analysis



For avoided cost only rate structures, increasing the retail rate does not increase cost-effectiveness

When solar is cost-effective while only being compensated at avoided cost, it is cost-effective regardless of the retail rate level

Limited Impact of Standards PV Requirements Compared to Other Forecasted PV Development