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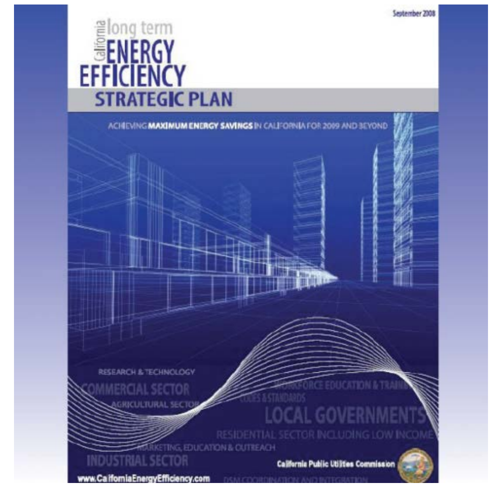
Grid Integration Costs of Residential Zero Net Energy Buildings: CPUC Staff Perspectives

CEC Staff Workshop on 2019 Building Energy Efficiency Standards

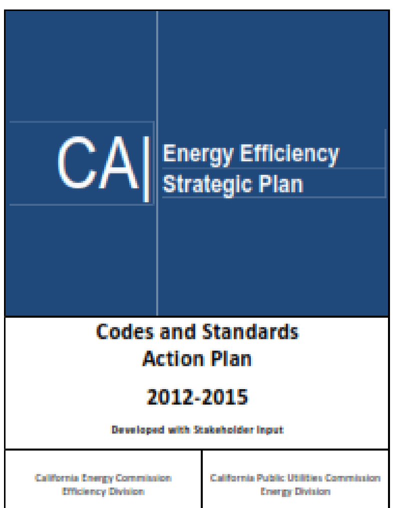
August 22, 2017

Simon Baker, Deputy Director
Energy Division, CPUC

Policy Context: Big Bold EE Goals



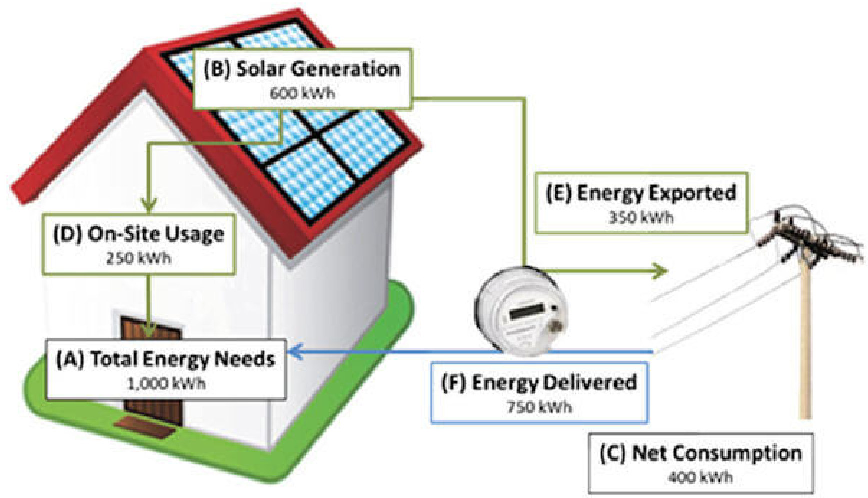
- 2006: AB32 climate goals
- 2007: Big Bold Energy Efficiency Strategies (D.07-10-032)
- **By 2020, residential new construction will achieve zero net energy**



- 2008: EE Strategic Plan seeks to animate market transformation
- IOU programs: new construction, codes & standards, emerging tech, research
- 2012: Codes and Standards Action Plan
- 2015 Residential ZNE Action Plan

Policy Context: Net Energy Metering

- Net Energy Metering (NEM) is an incentive wherein a customer pays only for the net cost of electricity from the grid over what is produced by their solar system.



Source: NowGoSolar.com

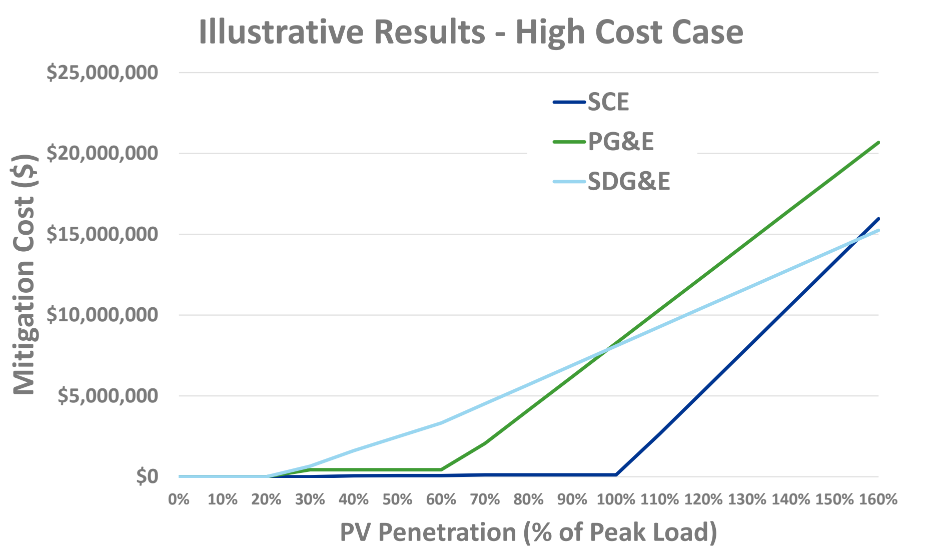
- 2016: NEM “2.0” (for <1MW systems):
  - Customer pays one-time interconnection fee
  - Grid integration costs covered by all ratepayers
    - Costs tracked: ~ $25 million for Jun 2015-Jun 2016
- 2019: CPUC will revisit NEM policy

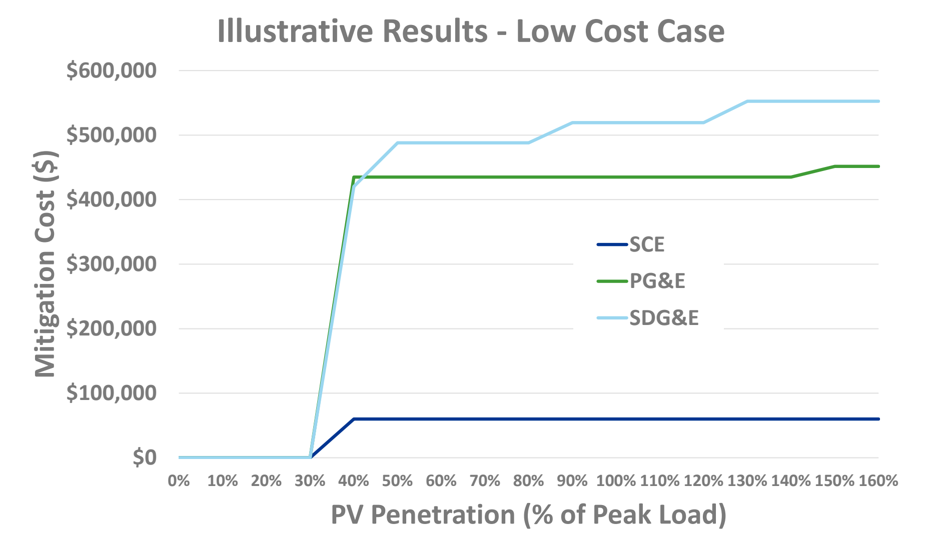
ZNE Grid Integration Cost Study

- Study objectives:
  - Inform residential ZNE policy determinations
  - Inform NEM policy determinations
- Evaluate two cases (2016-2025):
  - Base case: PV growth trajectory (IEPR mid case forecast)
  - Residential ZNE case: Incremental PV growth due to a ZNE building standard mandate (IEPR ZNE sensitivity case)
- Not a benefit-cost study

DNV-GL Methodology

- **Mapped annual PV growth** to distribution circuits, using a geographic allocation method.
- Assumed **2kW system size** per home
- Categorized into **representative circuits**
- Performed flow studies on 75 **sample circuits** assuming up to 160% penetration
- Evaluated **technical criteria:** voltage, thermal, reverse power flow
- Added **mitigation measures:** traditional measures, energy storage, smart inverters, optimal location
- Examined 2 scenarios:
  - **High Cost case** - all ZNE homes lumped together in one place
  - **Low Cost case** – ZNE homes distributed throughout feeder





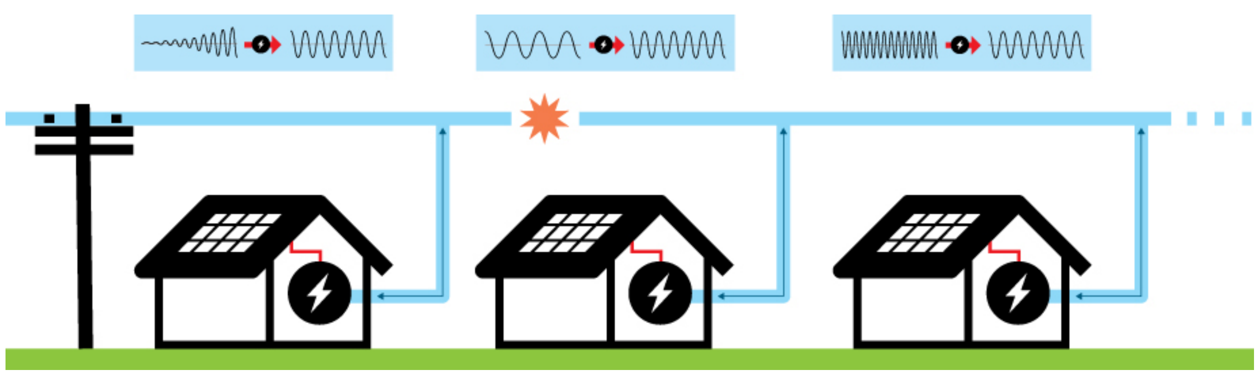
Results: High Cost Scenario

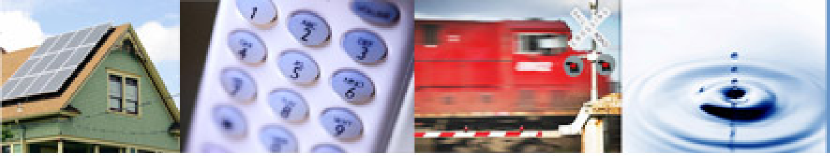
Grid Integration Costs for new PV between 2016 and 2026

High Cost Case	PG&E		SCE		SDG&E	
	Total Cost	Cost Per Ratepayer	Total Cost	Cost Per Ratepayer	Total Cost	Cost Per Ratepayer
Without ZNE	$850 M	$157	$134 M	$27	$605 M	$432
With ZNE	$1,473 M	$273	$179 M	$36	$698 M	$498
Difference	$623 M	$116	$45 M	$9	$93 M	$66

Smart Inverter Sensitivity Case

- Use of smart inverter functions (i.e., Volt / Var control) as mitigation measure
- Assumptions:
  - Used IOUs' Volt / Var curves
  - **Reactive power priority** assumed.
  - Where smart inverters absorbed reactive power, a **capacitor bank** was assumed to be installed on the feeder. Functionality is assumed autonomous, so **no other costs were added**.
  - **Real power losses <u>not</u> been included** (max loss is 5% at any time; total energy loss would be significantly lower than this).
- Affects **high cost case only**. The low cost case results remain the same, as there was no requirement for energy storage to mitigate problems in that case.





Results: Smart Inverter Sensitivity Case

Grid Integration Costs for new PV between 2016 and 2026

Smart Inverter Study	PG&E		SCE		SDG&E	
	Total Cost	**Cost Per Ratepayer**	**Total Cost**	**Cost Per Ratepayer**	**Total Cost**	**Cost Per Ratepayer**
Without ZNE	$262 M	$48	$92 M	$18	$252 M	$180
With ZNE	$510 M	$94	$116 M	$23	$289 M	$206
Difference	$248 M	$46	$24 M	$5	$36 M	$26

1/3 to 2/3 lower than High Cost Scenario

Results: Low Cost Scenario

Grid Integration Costs for new PV between 2016 and 2026

Low Cost Case	PG&E		SCE		SDG&E	
	Total Cost	Cost Per Ratepayer	Total Cost	Cost Per Ratepayer	Total Cost	Cost Per Ratepayer
Without ZNE	$75 M	$14	$51 M	$10	$38 M	$27
With ZNE	$117 M	$21	$36 M	$7	$43 M	$31
Difference	$42 M	$7	$15 M	$3	$6 M	$4

80% – 95% lower than High Cost Scenario

Reasons for the Cost Differences

- Average PV penetration
  - PG&E has the highest
- Number of homes projected per feeder
  - PG&E has the highest home : feeder ratio
- Distance from substation to end of circuit. Longer circuits are more sensitive to voltage issues
  - PG&E circuits are generally the longest

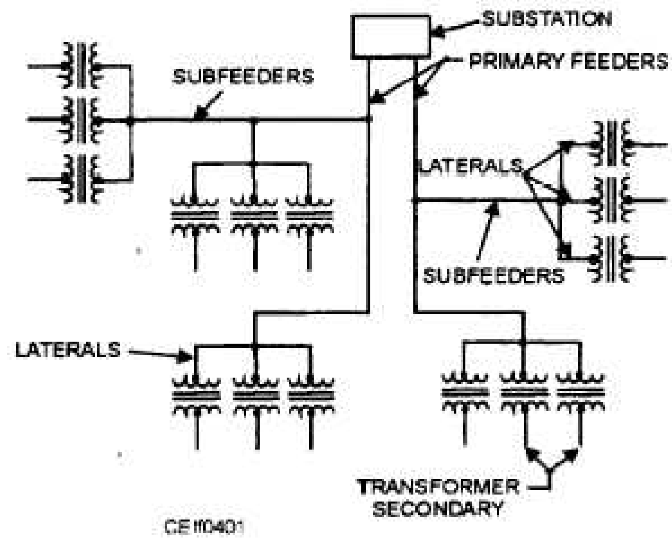


Image: Integrated Publishing

Staff Conclusions

- **Integration costs** of high penetration PV – whether driven by ZNE policy or NEM policy alone – **can be high if not mitigated**.
- **Mitigation measures are available** to reduce grid upgrade costs to more acceptable levels
  - **Smart inverters:** CPUC should update required smart inverter settings.
  - **Optimal location:** IOUs Integration Cost Analysis (ICA) tool should be helpful to indicate low cost locations.
- **Most likely case** is probably in the range indicated by the Smart Inverter Sensitivity Case
  - Effective Sept 2017 : Smart Inverter Phase 1 capabilities will be required
  - CPUC staff proposal to modify Rule 21 to require reactive power priority (in Volt / Var settings)
  - Debatable whether realistic to assume that PV will be installed throughout a circuit

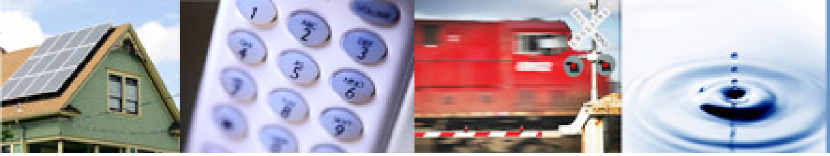
Sample Stakeholder Comments

- **PG&E:** system-level grid integration costs not included; 2kW system size per home too low; start date for 2019 code update too early
- **SCE:** Not all costs included, MF housing starts should be included, NEM variations (VNEM, NEM-FC, etc.) should be included
- **SDG&E**: More likely case is High Cost (b/c new housing starts are highly clustered), smart inverter implementation costs not included
- **SEIA:** Benefits not considered; costs will be reduced when ZNE mandate is incorporated into distribution planning, storage costs too high and storage provides other benefits

The Future of NEM

- CPUC will revisit NEM policy in 2019.
- CPUC will consider an export compensation rate that takes into account locational and time-differentiated values (D.16-01-044)
  - Methodology being developed in the Distribution Resource Plans proceeding (R.14-08-013)

- AB 2514 NEM evaluation (Bradford, 2013) required a review from the non-participant ratepayer perspective
- Current law (P.U. Code 2827.1) requires CPUC to ensure that
  - BTM renewable DG “continues to grow sustainably”
  - “Total benefits to all customers and the electrical system are approximately equal to costs.”
- NEM 2.0 proceeding examined broad range of compensation structures. Expect the 2019 review to do the same.



Draft DNV-GL study available at: https://pda.energydataweb.com/#/

Questions?

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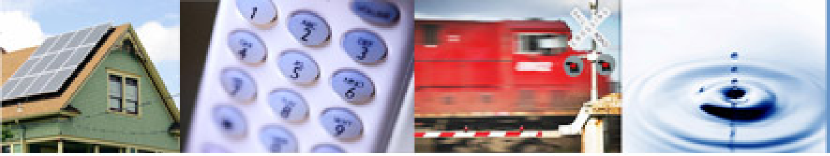

APPENDICES

Forecast Assumptions

	PG&E	SCE	SDG&E	Statewide
Number of New Homes	1,140,515	724,488	15,178	1,880,181
Number of Feeders	2,821	5,687	1,032	9,540
Total PV Capacity (MW) **without** ZNE by 2026 (new and existing)	5,717	5,174	1,280	12,171
Total PV Capacity (MW) **with** ZNE by 2026 (new and existing)	6,402	5,709	1,371	13,482
Difference (MW)	685	535	91	1,311

Mitigation Measures and Assumed Costs

Technical Limit	Mitigation Measure	Cost
Voltage	New voltage regulator	$150,000
Voltage (if not mitigated by voltage regulator)	Energy storage	$460/kW + $450/kWh + $1500/100kW for installation. Assume 4 hours of storage required
Thermal Loading	Re-conductoring	$190/ft (average of overhead and underground re-conductoring costs)
Reverse Power Flow at Regulator	Enable co-generation mode	$60,000
Reverse Power Flow at Substation Transformer	Enable co-generation mode	$60,000
Reverse Power Flow at Re-Closer	Implement re-close blocking	$145,000

Smart Inverter Phase 1 Functions

Function Name	Description of Function	Impact on Integration Costs
Anti-Islanding	Support anti-islanding to trip off under extended anomolous conditions, coordinated with the following functions.	Could be used to offset re-close blocking costs which are triggered when there is potential reverse power flow at a re-closer, although IOU's have not considered anti-islanding functions to-date when specifying re-close blocking requirements.
Voltage Ride-Through	Provide ride-through of low/high voltage excursions beyond normal limits.	No impact on integration costs in this study – inverters were assumed to remain connected throughout the study.
Frequency Ride-Through	Provide ride-through of low/high frequency excursions beyond normal limits.	No impact on integration costs in this study as system frequency variations were not studied. Improved ride-through in practice would likely not have an impact on upgrade costs included in this study, but may have an impact on improved reliability for customers on a circuit.
Volt/Var Control	Provide volt/var control through dynamic reactive power injection through autonomous responses to local voltage measurements.	Could be used to offset energy storage costs which are triggered when variable output of PV systems could potentially cause voltage violations.
Ramp Rate Control	Define default and emergency ramp rates as well as high and low limits.	No impact on integration costs in this study, as ramp rates would likely have to be too slow to mitigate variable voltage violations.
Fixed Power Factor	Provide reactive power by a fixed power factor.	Could be used to mitigate static voltage violations, but less effective than volt/var control for variable voltage violations.
Soft-Start	Reconnect by "soft-start" methods (e.g. ramping and/or random time within a window).	No impact on integration costs in this study, as start-up and re-connection events were not included.