Emerging Technologies Summit

MAKING THE CONNECTION:

From Energy Efficiency Innovation to Delivery

April 19 – 21, 2017

Facilitating Choices: Integration of Deep Energy Efficiency and Renewables with the Grid

CATHY HIGGINS, KEN NICHOLS, TOM WILLIARD, ROBERT SHERICK, RAM NARAYANAMURTHY

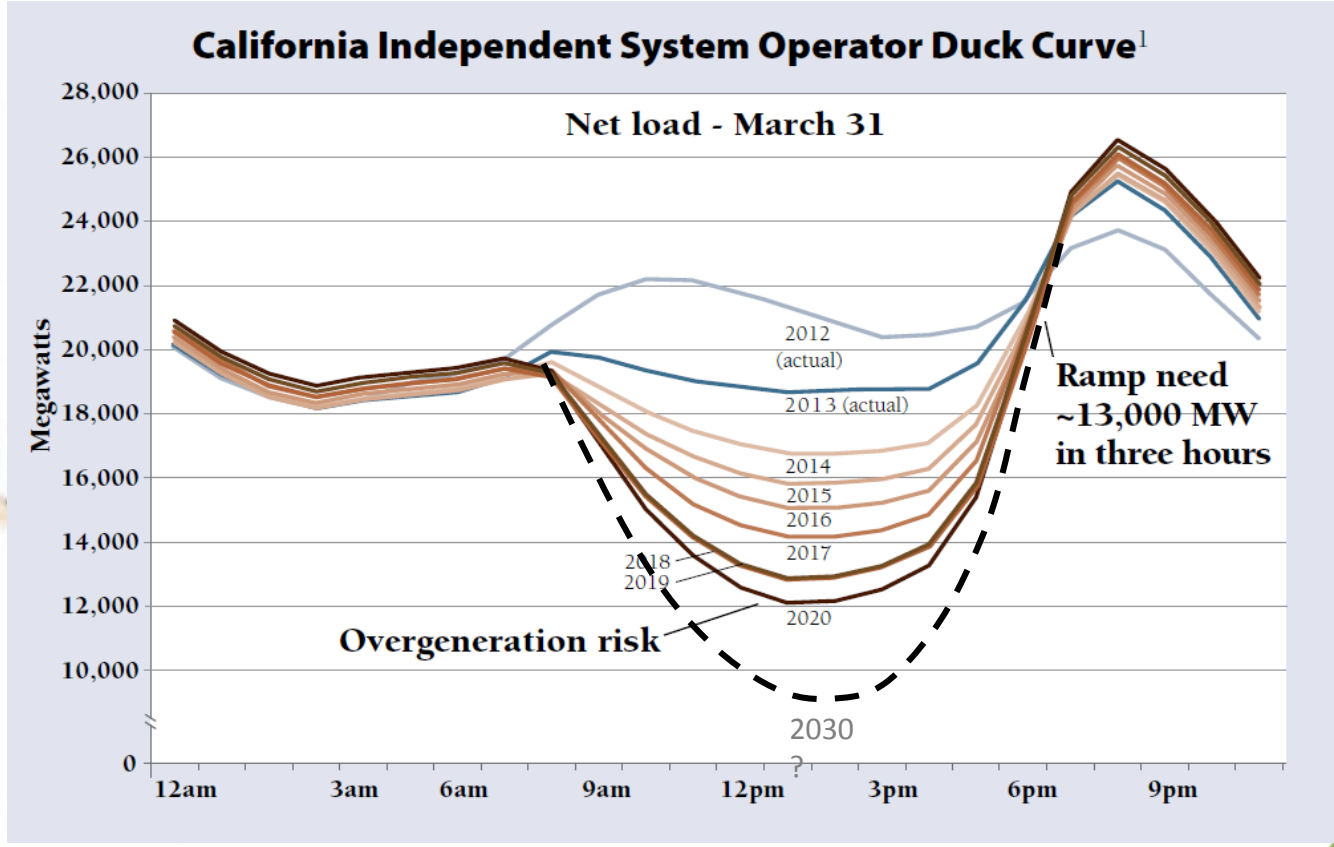
Welcome to

Facilitating Choices: Integration of Deep Energy Efficiency and Renewables with the Grid

Cathy Higgins, Research Director
New Buildings Institute

1. **Ken Nichols**, Principal, EQL Energy
2. **Tom Williard**, Principal and CEO, Sage Renewable Energy Consulting
3. **Robert Sherick**, Principal Manager Renewable Integration, SCE
4. **Ram Narayanamurthy,** Principal Technical Leader, EPRI

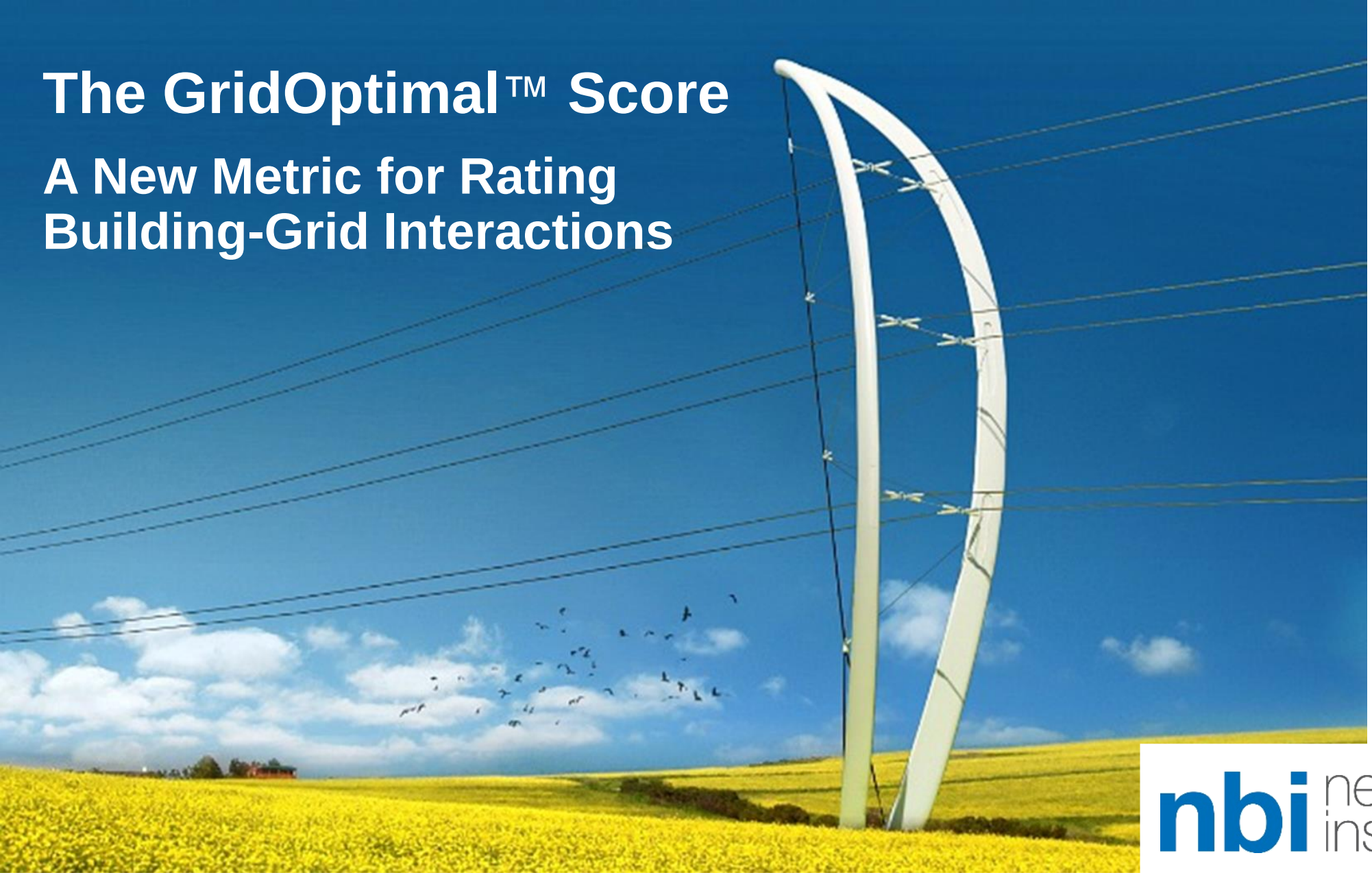
The Duck Issue



Source: Jim Lazar, 2016

The GridOptimal™ Score

A New Metric for Rating Building-Grid Interactions



nbi new buildings institute

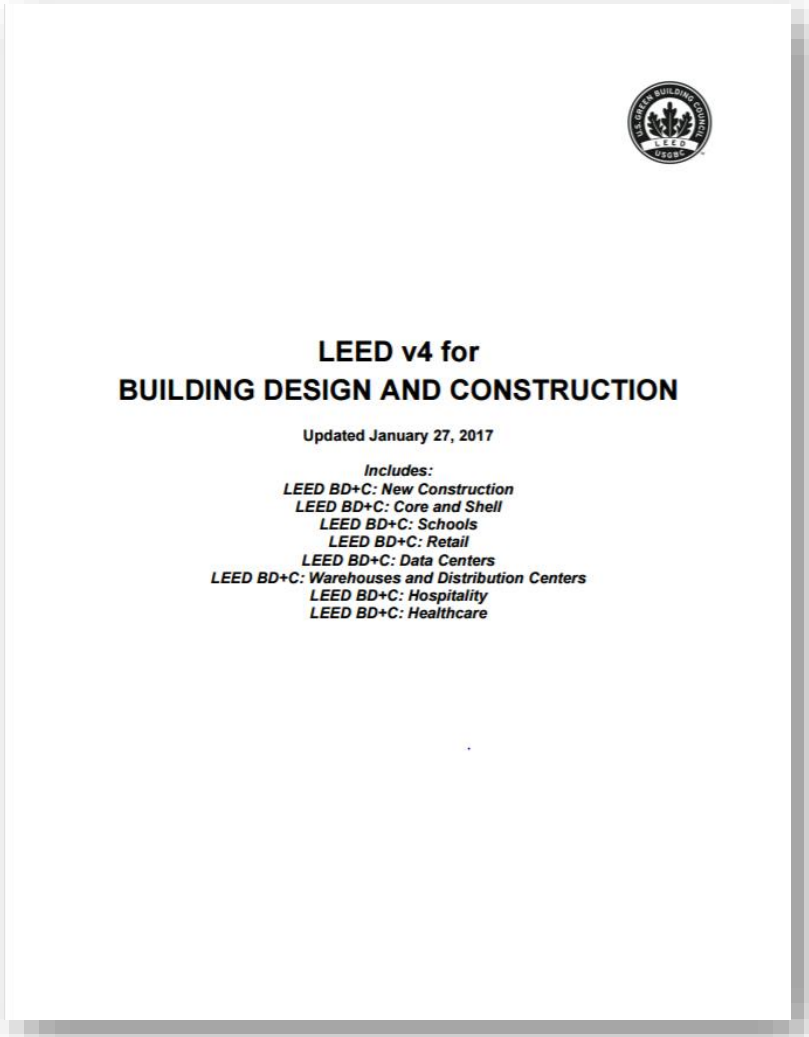
GridOptimal™: Why is it Needed?

Currently no metrics that define
building-level grid citizenship
or **rate building-grid interaction** quality

- Different players have **different language** to discuss the topic
- Grid operators and utilities are struggling to **integrate renewable energy ++** onto the grid
- **Guide** optimal **building design and operations**

(Conference Paper: ASHRAE Winter Conference, January 2017) (Alexi Miller, PE & Jim Edelson, NBI)

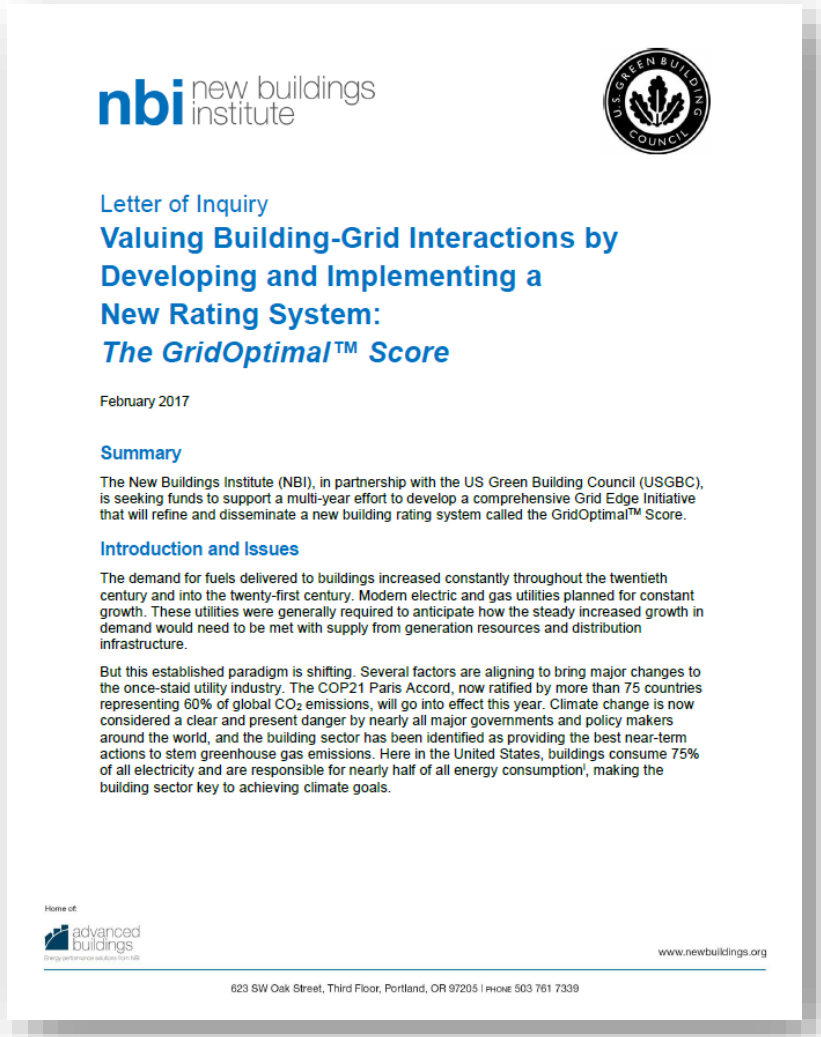
GridOptimal™: Critical Bridge Between Buildings and the Grid



LEED v4 for
BUILDING DESIGN AND CONSTRUCTION

Updated January 27, 2017

Includes:
LEED BD+C: New Construction
LEED BD+C: Core and Shell
LEED BD+C: Schools
LEED BD+C: Retail
LEED BD+C: Data Centers
LEED BD+C: Warehouses and Distribution Centers
LEED BD+C: Hospitality
LEED BD+C: Healthcare



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Letter of Inquiry

Valuing Building-Grid Interactions by Developing and Implementing a New Rating System:
The GridOptimal™ Score

February 2017

Summary

The New Buildings Institute (NBI), in partnership with the US Green Building Council (USGBC), is seeking funds to support a multi-year effort to develop a comprehensive Grid Edge Initiative that will refine and disseminate a new building rating system called the GridOptimal™ Score.

Introduction and Issues

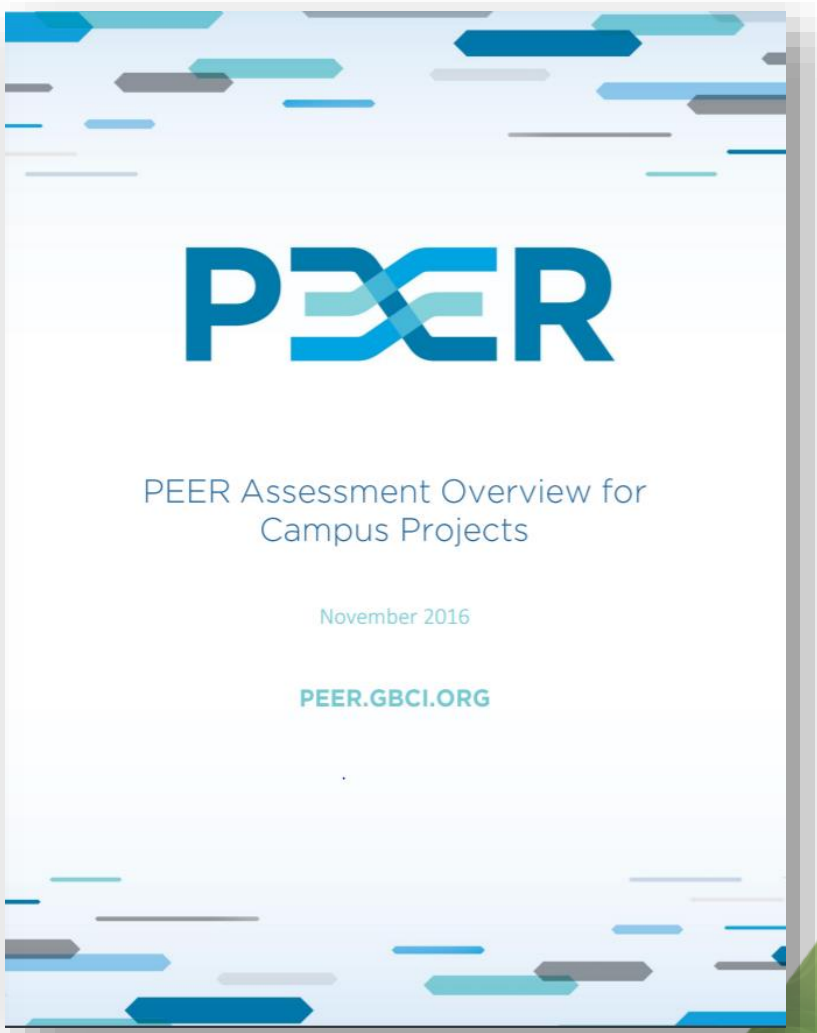
The demand for fuels delivered to buildings increased constantly throughout the twentieth century and into the twenty-first century. Modern electric and gas utilities planned for constant growth. These utilities were generally required to anticipate how the steady increased growth in demand would need to be met with supply from generation resources and distribution infrastructure.

But this established paradigm is shifting. Several factors are aligning to bring major changes to the once-staid utility industry. The COP21 Paris Accord, now ratified by more than 75 countries representing 60% of global CO_2 emissions, will go into effect this year. Climate change is now considered a clear and present danger by nearly all major governments and policy makers around the world, and the building sector has been identified as providing the best near-term actions to stem greenhouse gas emissions. Here in the United States, buildings consume 75% of all electricity and are responsible for nearly half of all energy consumption[1], making the building sector key to achieving climate goals.

Home of advanced buildings

www.newbuildings.org

623 SW Oak Street, Third Floor, Portland, OR 97205 | PHONE 503 761 7339



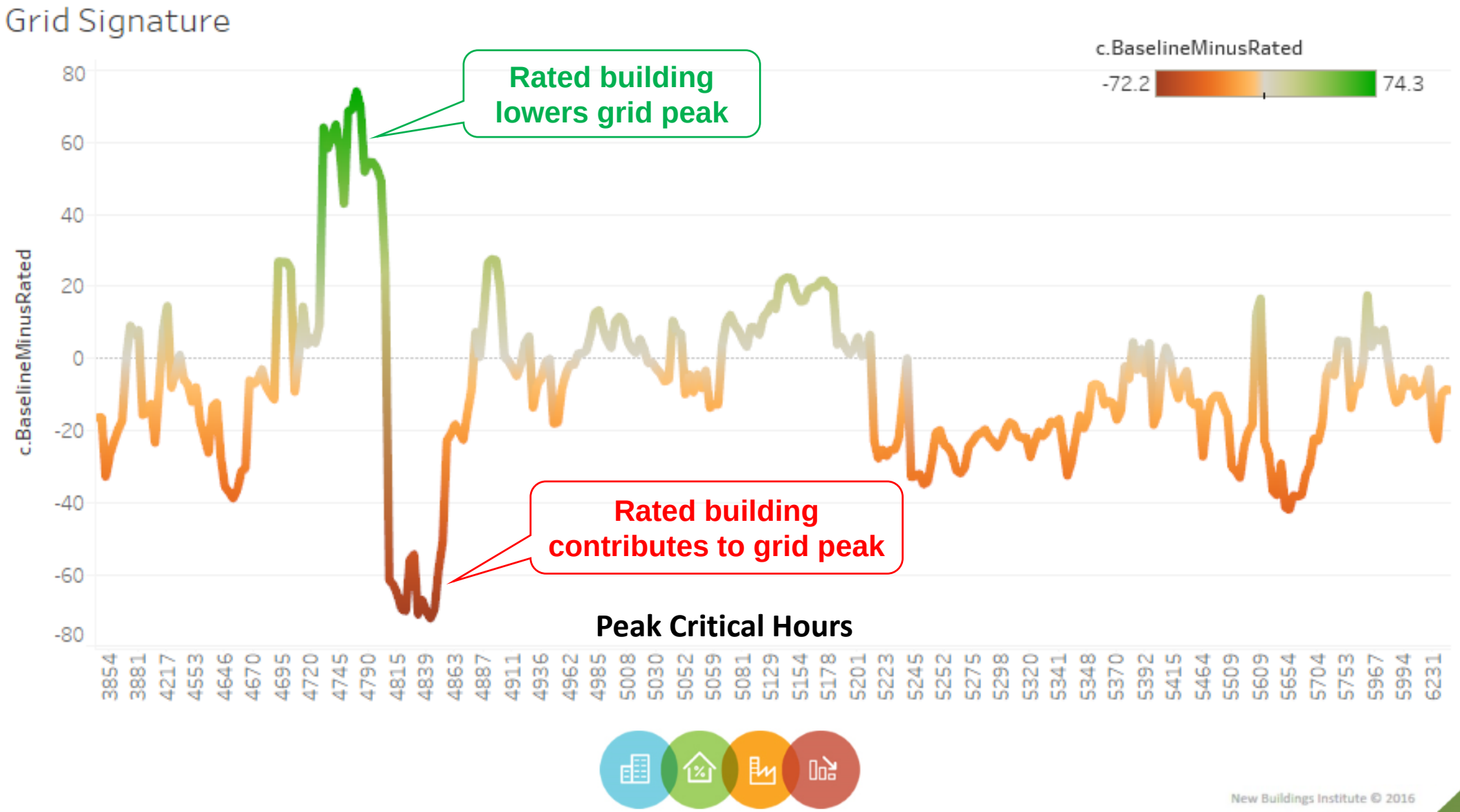
PEER

PEER Assessment Overview for Campus Projects

November 2016

PEER.GBCI.ORG

GridOptimal™: Grid Signature



GridOptimal™: Rating Building-Grid Interactions

Key Benefits:

- Provide a clear, consistent way to measure **grid citizenship**
- Allow utilities to provide incentives by referencing a common, transparent, **reliable standard**
- Ensure that **building staff are engaged** in energy AND grid performance
- Create common language and **consistent metrics**
- Encourage **grid-sensitive and responsive building design AND operations**

New Buildings Institute © 2016

GridOptimal™: How will we do it?

- Bring together **key stakeholders and experts** to develop standards
- Establish **framework for rating system** that will result in program implementation
- Develop the **rating system**, leveraging existing standards
- Identify **pilot projects** and participants
- Outline **incentive programs** and financing mechanisms
- Provide **educational guidance**

Change is Coming

What's Next for the Utility Industry?

- You don't have to figure it out on your own
- We are **assembling the top industry experts** to answer these questions

Join us!

Next Speaker

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Facilitating Choices – Integration of Deep Efficiency and Renewable and the Grid

ZNE and the Distribution System

Ken Nichols

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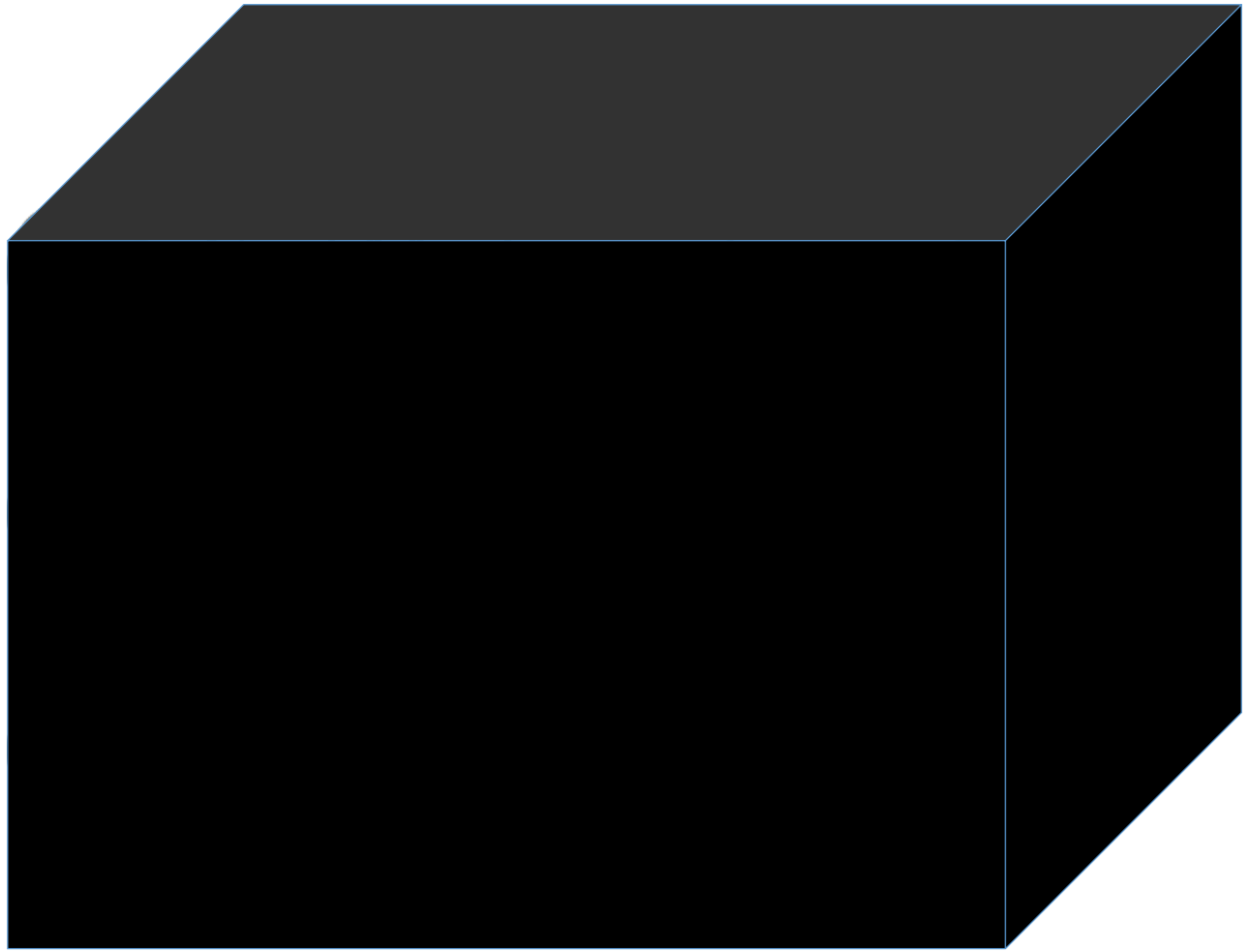
Utilities and Customer DERs

Distribution System Planning

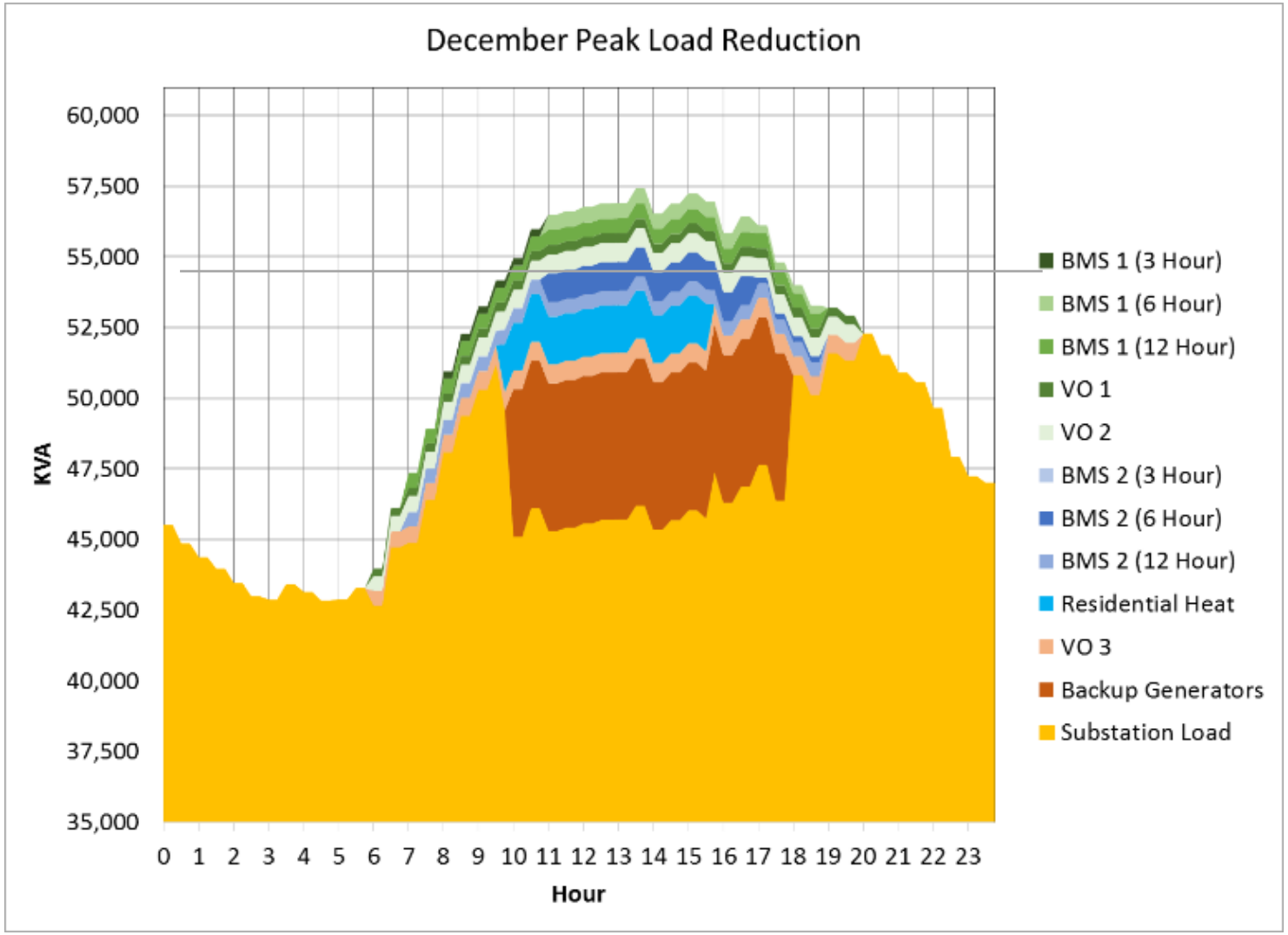


Buildings and Grid Integration:

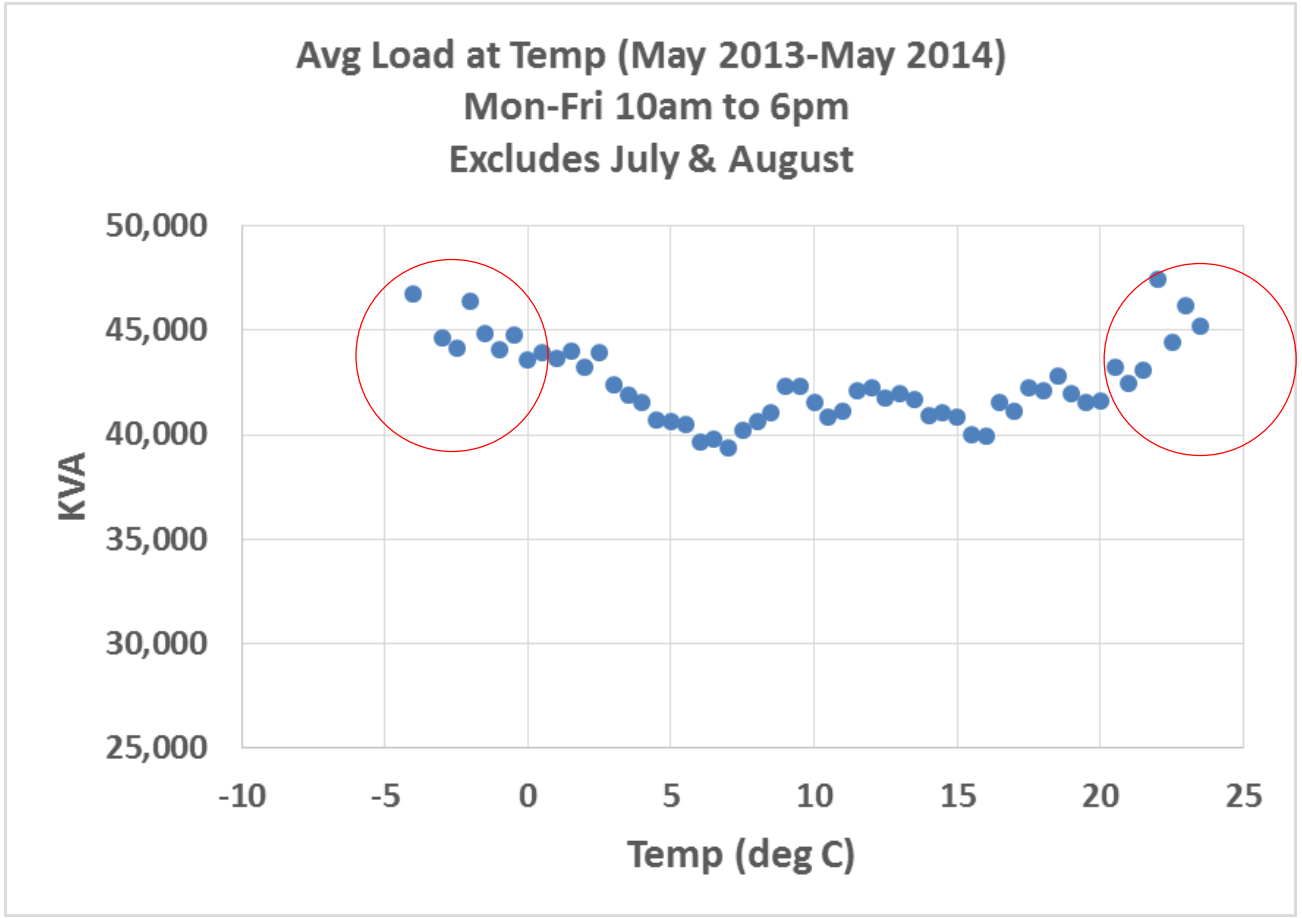
The Good, The Bad, and the Technology

- The Good – Defer costs & Renewable Integration
  - 80 DER projects nationwide displacing T&D, most are Distribution
  - Integrates 8,000MW of behind the meter solar (40% in CA)
  - ZNE impact different for Residential and Commercial feeders
- The Bad – Increase Distribution costs & rates
  - High DG/ZNE can increase distribution costs
  - HECO (2014)$210/kW, SCE 2015 2yr $400-$600MM
  - Lower kwH usage to recover T&D cost >> rate design
- The Technology - solutions
  - Thermal and Chemical storage (CO2 HP,
  - Advanced Inverters to the rescue
  - Distribution Planning add DER critical (feeder snowflakes)
  - Load and DER Management Systems

Campus Load Management defers >$20MM



Weather drives T&D concerns



Measure	Winter KVA Shed Level 1	Winter KVA Shed Level 2	Summer KVA Shed Level 1	Summer KVA Shed Level 2
Command to Low Speed	4		4	
Command VFD to 50% cfm	0	12	0	12
Convert to Variable Flow Loop	0		0	
Curtail Radiant System	8		8	
Disable Fan Coil Unit Fans	0	0	0	0
Install VFD on Lab Exhaust Fans	83	0	83	0
Lock-Out Elevators	0	120	0	120
Lock-Out EV Chargers	50	0	50	0
Pre-Cool Ice Rink	0	500	0	500
Reduce dP Setpoint	19	0	9	0
Reduce Duct Static Pressure Set Point	321	0	321	0
Reduce Velocity Pressure	9	0	9	0
Remove Bypass Flow Control to dP	11	0	11	0
Shut Off AHU	11	117	11	117
Shut Off Chiller	0	66	0	949
Shut Off DW Booster Pumps	71	0	71	0
Shut Off Electric Boiler	40	0	40	0
Shut Off Heat Pumps	0	108	0	0
Shut Off Heat Recovery	0	146	0	0
Shut Off HR Chiller	0	191	0	0
Shut Off Lights	220	0	220	0
Shut Off Pump	12	21	12	21
Temperature Setback	68	0	274	117
Tune VFD Controls	22	0	22	0
Totals	949	1281	1145	1836

BMS measures on 12 buildings

The BAD: Without Integrated DER planning grid Capex could increase dramatically (HECO 2014)

Item	Violation Trigger	Total
Installed DG (MW)		902
Regulator	Feeder Reverse Flow	$308,000
LTC	Substation Transformer Reverse Flow	$1,642,000
Reconductoring	Exceed 50% Backbone Conductor/Cable	$75,588,700
Substation Transformer and Switchgear	Exceed 50% Capacity	$54,766,000
Distribution Transformer	Exceed 100% Loading, % GDML Linear Relationship to % Transformers Upgraded	$15,617,535
Poles and Secondary	Assumed 15% of Distribution Transformer Replacements need poles/secondary	$3,533,342
Grounding Transformers	Exceed 33% GDML (66% in model)	$43,045,200
Total		**$194,500,777**

SCE DRP Capital Expenditure Estimates

Time Period	Capital Expenditures		CPUC Approval Mechanism
2015-2017	Distribution Automation	$40-70 million	• Proposed memorandum account to record associated revenue requirement until expenditures are authorized by CPUC
	Substation Automation	$30-60 million	
	Communications Systems	$7-15 million	
	Technology Platforms and Applications	$130-200 million	
	Grid Reinforcement	$140-215 million	
	Total	**$347-560 million**	
2018-2020	Distribution Automation	$185-320 million	• Request recovery in 2018 GRC
	Substation Automation	$185-320 million	
	Communications Systems	$270-470 million	
	Technology Platforms and Applications	$215-375 million	
	Grid Reinforcement	$550-1,100 million	
	Total	**$1,405-2,585 million**	

SCE anticipates capital spending to continue at least in the range of current forecast levels, although could result in higher spending pending CPUC approval in future GRCs

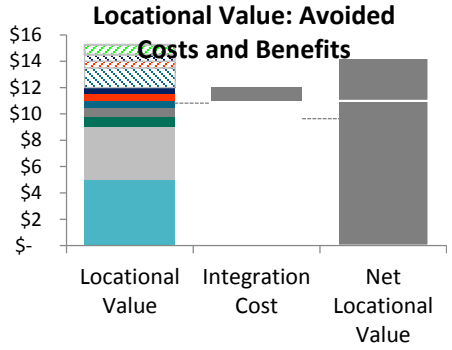
The GOOD: Emerging Technologies and Processes

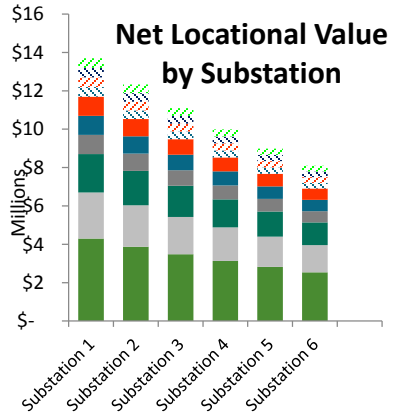
- Distribution Planning tools capable of identifying need and integrating DERs
  - CymeDist V 8.0 (Eaton), SynerGee, PSS, DigSilent, DEW (EDD)
  - Load Forecasting including DERs
- DER tools
  - Target DSM for grid issues
  - Thermal/energy storage and Load management (DR)
  - CTA-2045, EV load control, energy management circuit breaker
  - Solar + Storage, and Storage for customer reliability
- Advanced Inverters
  - CA SIWG Phase 1 - Mandatory Sep 2017
  - Solar and Storage, Sunspec Alliance
  - SIWG, IEEE 1547, UL 1741

Distribution Resource Planning (DRP)

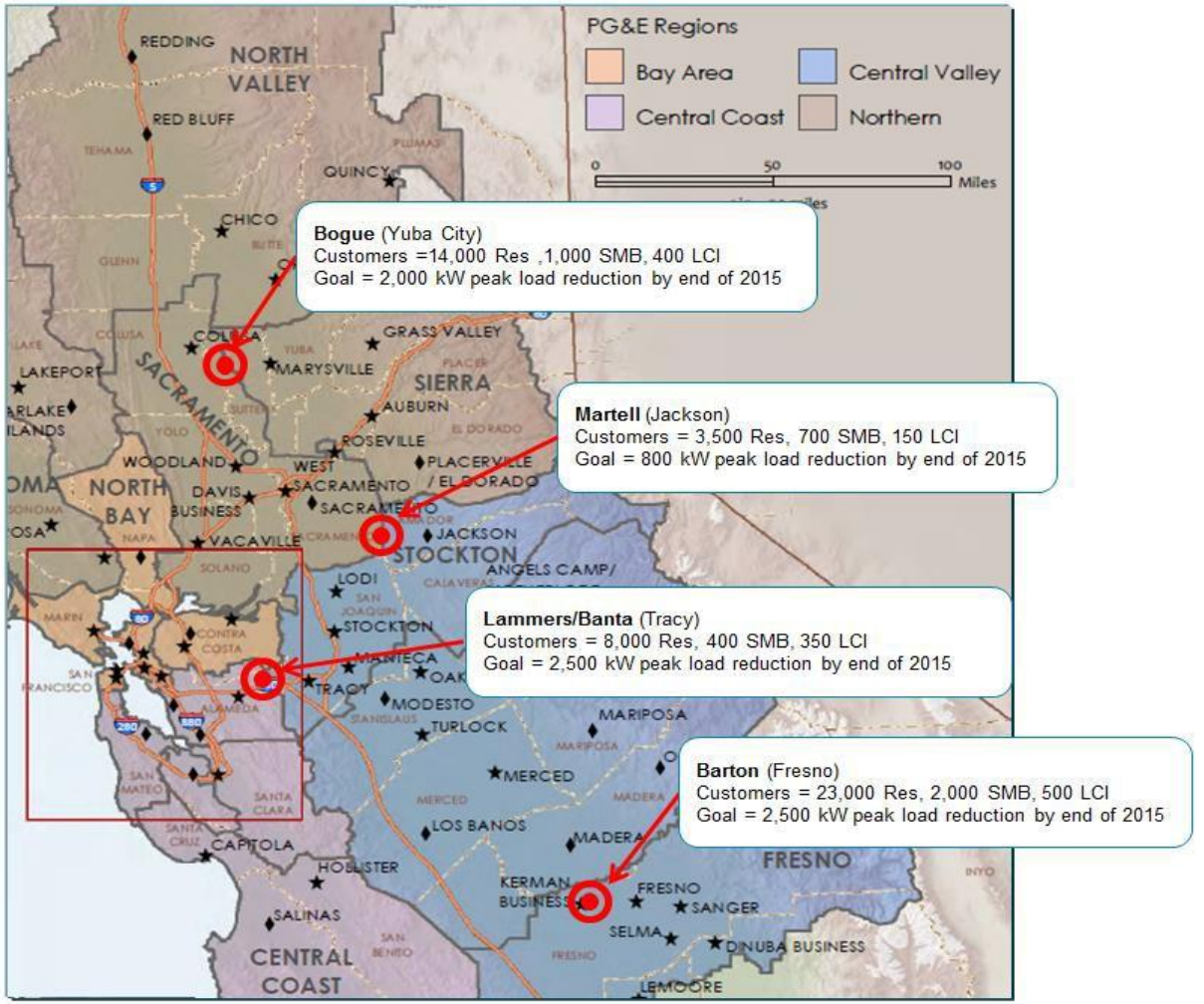
- Distribution planning integrates energy efficiency, DERs, and market incentives
- These factors would then be balanced against the **avoided costs** of ""traditional" distribution investment/operation
- Leads to competitive solicitation for DERs
  - CA discussing, WA in IRP Rulemaking

Identify DPA & Substations → **Perform Planning Analyses** → **Calculate Locational Net Value** → **Rank Substations by Locational Net Value**





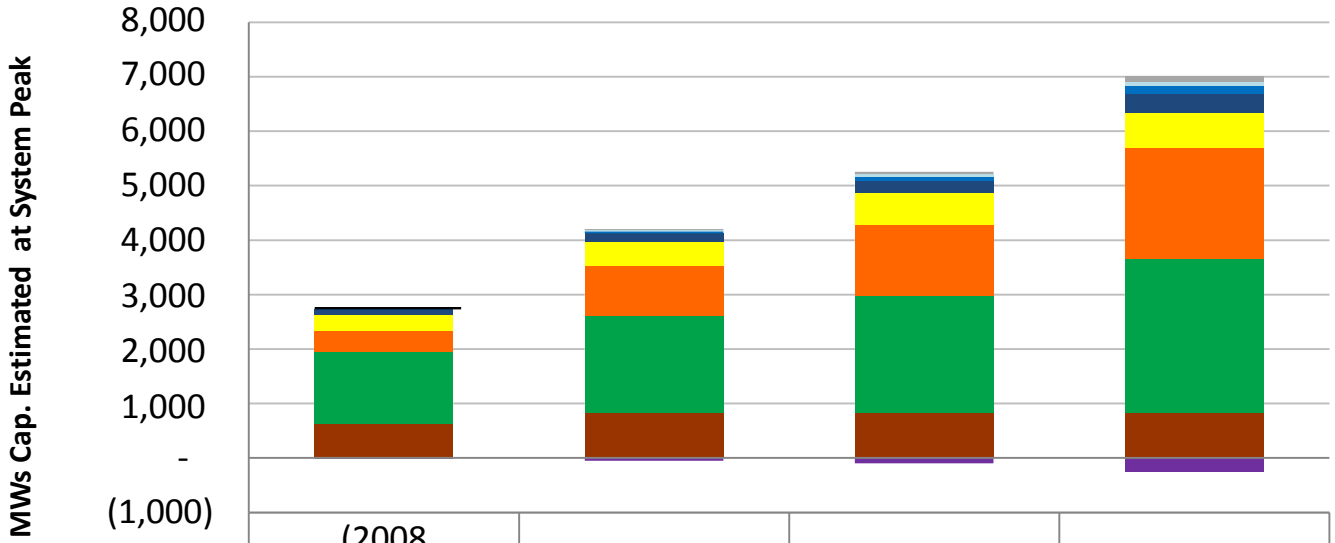
PG&E Targeted IDER projects



http://aceee.org/sites/default/files/pdf/conferences/eer/2015/Richard_Aslin_Session_1B_EER15_9.21.15.pdf

PG&E Estimate of Peak Reduction by DER type

http://aceee.org/sites/default/files/pdf/conferences/eer/2015/Richard_Aslin_Session_1B_EER15_9.21.15.pdf



	(2008 -2014)	2017	2020	2025
Distributed Wholesale Energy Storage	6	6	40	97
CHP from Feed in Tariffs	9.6	30	50	83
Retail Storage	7.4	34	68	156
Retail Non-PV DG	92	153	220	347
Wholesale DG	302	443	590	631
Retail PV	396	916	1,317	2,052
Energy Efficiency	1,318	1,770	2,134	2,809
Demand Response	627	845	834	841
Electric Vehicles	(16)	(48)	(95)	(248)

Advanced Inverters Phase 1: Seven Autonomous DER Functions (CA Mandatory Sep 2017)

- Support ***anti-islanding*** to trip off under extended anomalous conditions, coordinated with the following functions.
- ***Ride-through of low/high frequency*** (56 > f < 64 Hz)
- ***Ride-through of low/high voltage*** (50 > V < 120)
- Provide ***volt/var control*** through dynamic reactive power injection through autonomous responses to local voltage measurements.
- Define default and emergency ***ramp rates*** as well as high and low limits.
- Provide reactive power by a ***fixed power factor***.
- Reconnect by "***soft-start" methods*** (e.g. ramping and/or random time within a window).

- Phase 2 addresses communication and change of settings
- Phase 3 addresses communication and control
- Sunspec Alliance is working with inverter manufacturers to certify both Solar and Storage. (www.sunspec.org)

Emerging Technology Takeaways

- **Customer desire for higher reliability will assist cost effectiveness of solar+ storage, and grid integration**
  - Customer Reliability ex: PGE DSG, STEM, Demand Energy, Blue Pillar
  - Advanced Inverters augment grid support, and reduces utility costs. Utility ownership/control?
- **Thermal/Chemical Storage and Load Management**
  - CO2 heatpumps and H2O storage for water and HVAC
  - Batteries as Premise backup and grid support
  - CTA 2045 – WH, AC, Space heat, pool pumps, etc.
  - Communicating Tstats
- **DERMs needed for utility**
  - AutoGrid, Blue Pillar, ABB, Siemens, etc.

Ken Nichols, 503 438 8223

http://westernenergyboard.org/2015/05/final-report-released-by-eql

Extras

WECC 2022 DER Forecast (less than German PV today)

DER	2022 DER WECC Estimate (GW)	Source
Solar	13	2013 E3 TEPPC study on High DG
CHP	8	2013 E3 TEPPC study on High DG
DR Load Following	2.6	2013 WIEB VER Integration
DR Other	4.7	2013 LBNL 6381, Incorporating Demand Response into Western Interconnection Transmission Planning
Storage	2.1	AB2514 California 2020 mandate , plus 800 MW
Total	30.4	

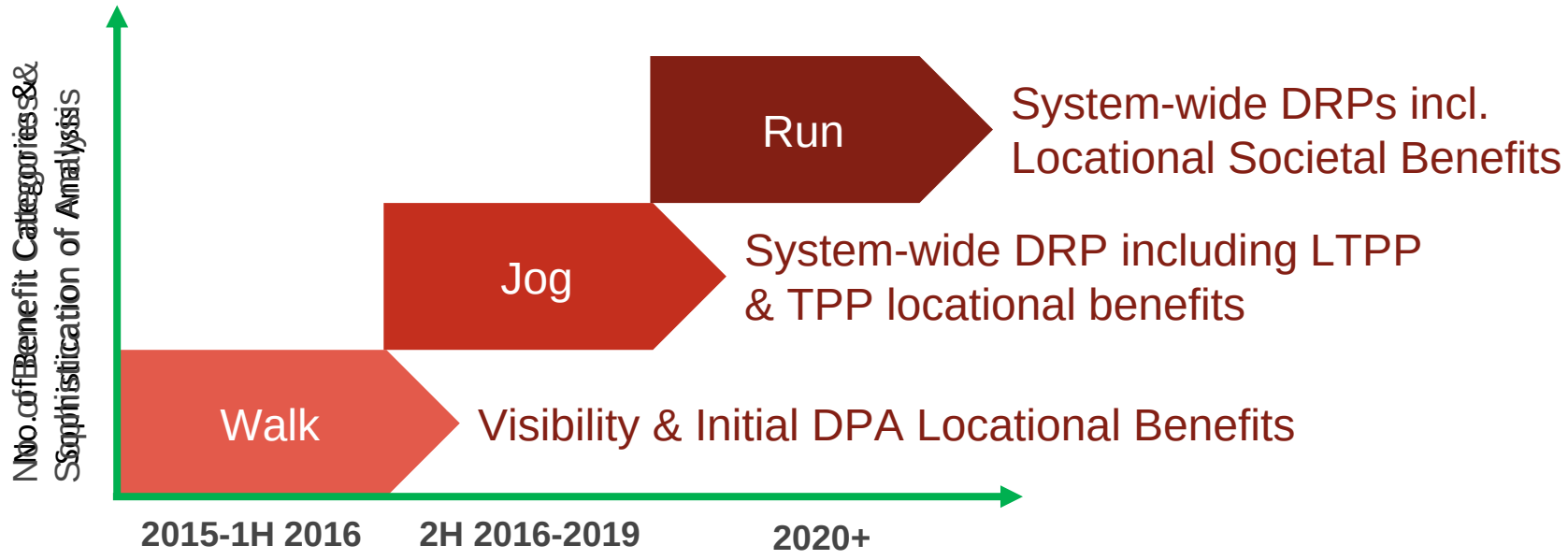
Background: Typical Distribution Planning

- Each distribution feeder is assessed separately
- Maximum load is determined for the next 3 to 5 to 10 years, based on load profiles and expected customer growth
- Additional capacity, about 50%, is added to ensure the feeder can handle reconfiguration scenarios
- Feeder equipment upgrades or additions are determined: distribution transformers, cables, capacitor banks, voltage regulators, load tap changers, substation transformers, reclosers, automated switches, tie switches, even new substations, etc.
- These distribution costs are either just the “cost of doing business” and/or are assessed by regulators for reasonableness

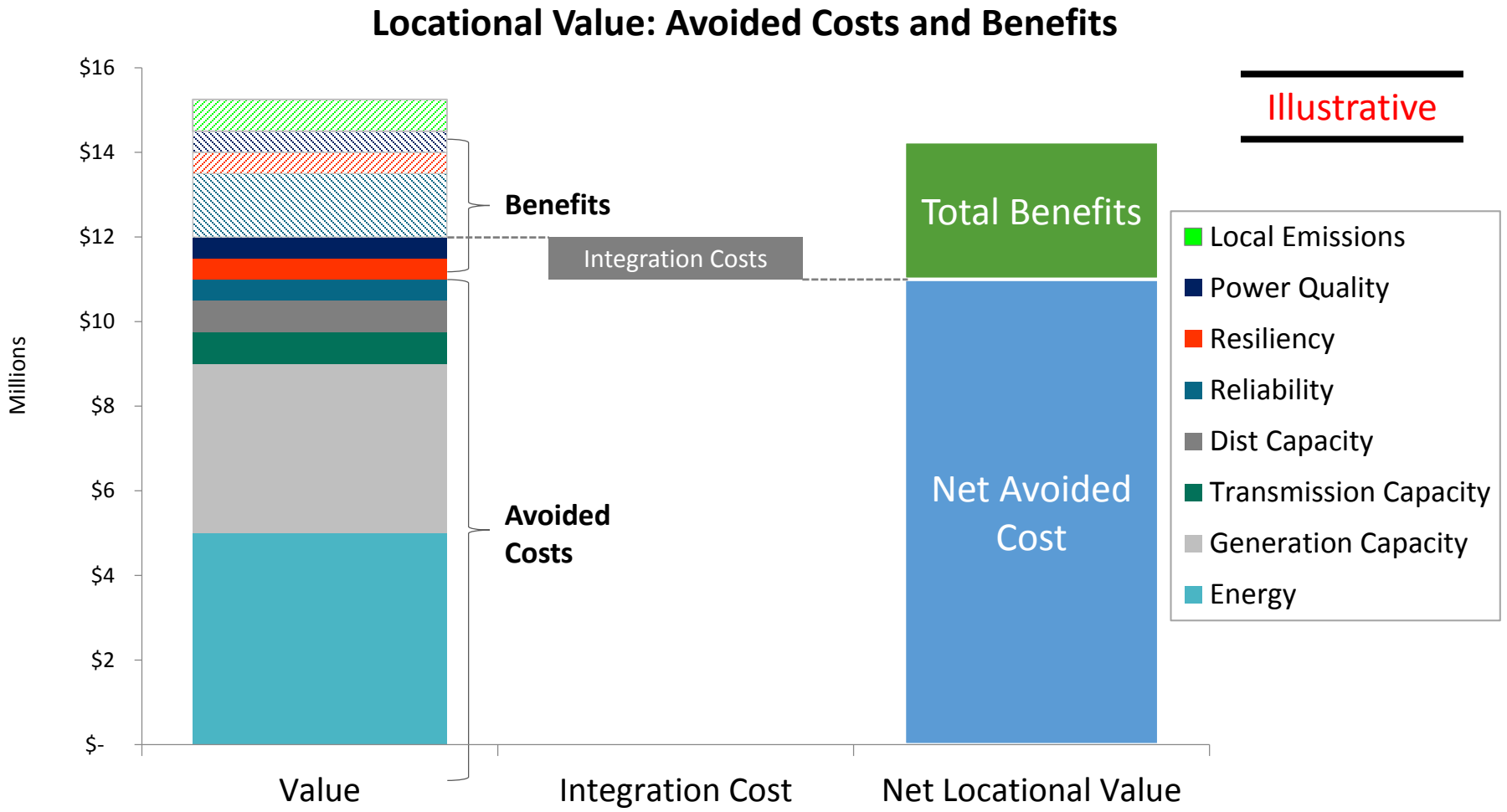
More Than Smart (MTS) Working Group Purpose & Objectives

- Purpose:
  - Provide an open, voluntary stakeholder forum to discuss core issues toward finding common ground regarding the evolution of California's distribution system and the seamless integration of DER to meet customers' needs and public policy. The results of the discussions will be for the benefit of the participants and will be made public without specific participant attribution.
- Objectives:
  - Define common parameters for the development of distribution planning scenarios for utilities to properly stress test plans and to achieve a measure of comparability among the different plans.
  - Identify and define the integrated engineering-economic analysis required to conduct distribution planning in the context of AB 327 requirements.
  - Define the potential grid end-states in the context of existing plans/roadmaps and identify the considerations regarding grid evolution to meet customers' needs and California's policy objectives.
  - Define the scope and parameters of an operational/DER market information exchange to facilitate an open planning process and enable R&D efforts.
  - Define distribution services associated with identified DER values including performance requirements.
  - Define new distribution operational functions (DSO) and related integration technologies (vendor neutral) to create "node-friendly" open grid

Evolution of DRP Optimal Location Benefits Analysis



Value Analysis: Avoided Costs and Benefits



Note: Analysis excludes some avoided costs/benefits that do not have a locational dimension. Therefore, analysis is not intended to estimate full stack of avoided costs and benefits associated with DER

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Tom Williard
Principal and CEO
Sage Renewable Energy Consulting

SAGE RENEWABLES

Key Regulatory and Market Drivers for California Solar and Storage

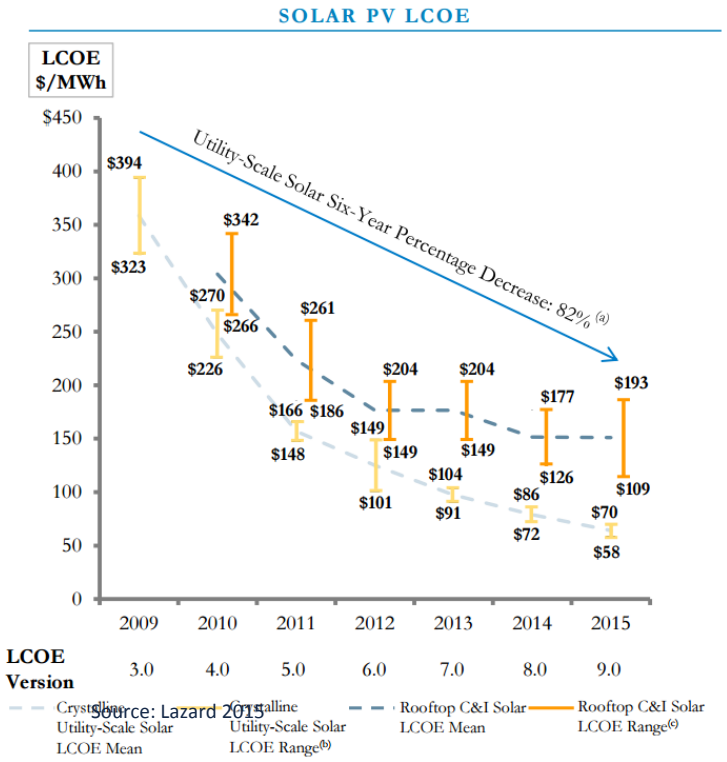
Emerging Technologies Summit
April 20-21, 2017

Key Regulatory and Market Drivers for California Solar and Storage

- California's Changing Distributed Energy Landscape
  - Falling prices vs. regulatory uncertainty
- Utility Retail Tariffs
  - Big changes coming – that don't help solar or storage
- Project Finance Landscape
  - ITC sunset, irregular incentives and decreased competition
  - Storage market nascence

California's Changing Energy Landscape

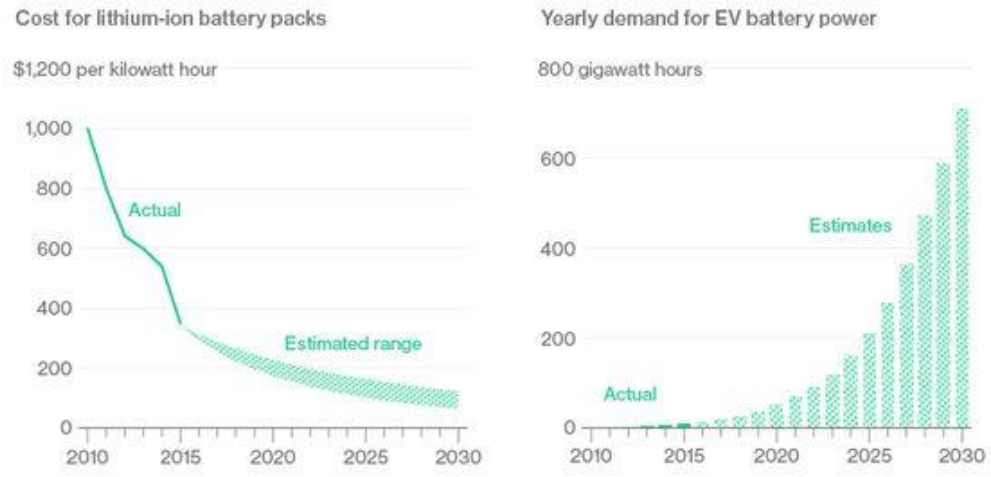
Renewable energy and storage costs declining rapidly



Source: Lazard 2015

+ 50% PV panel price decline 2015-2017 (GTM)

+ 50% Li-Ion battery and BOS cost decline next 5 years (GTM)



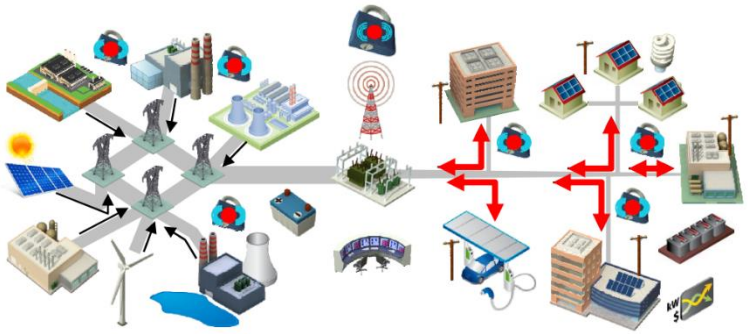
Source: Data compiled by Bloomberg New Energy Finance

Bloomberg

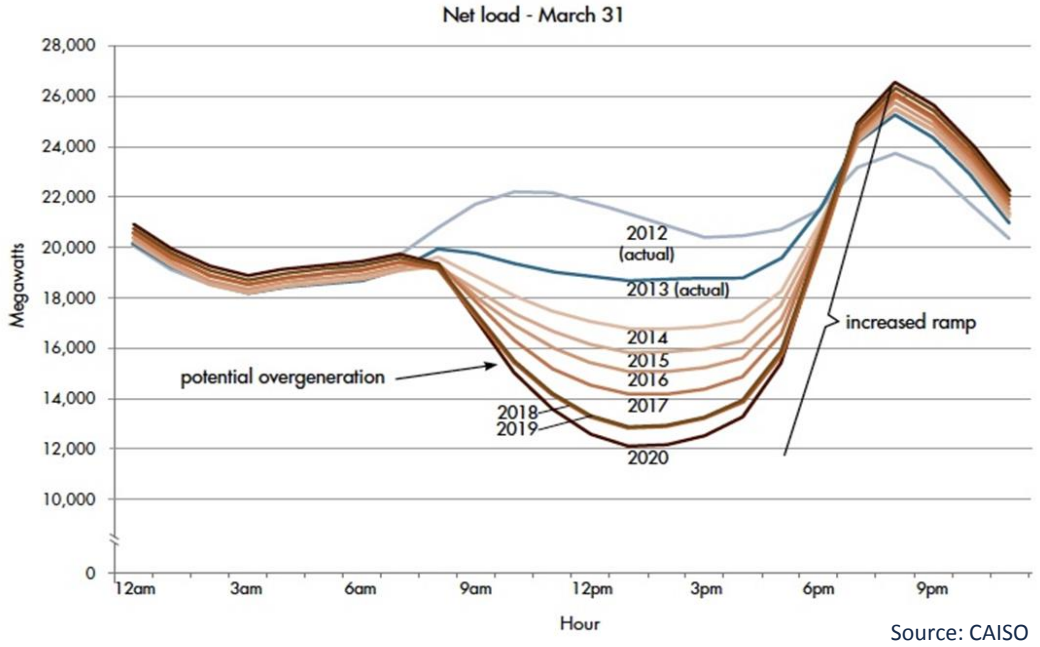
California's Changing Energy Landscape

Grid loading

+ Changing load profile of the grid and rate structures impact the value of distributed solar and storage



The Duck Curve: Overgeneration mid-day in spring and fall above 30% RPS

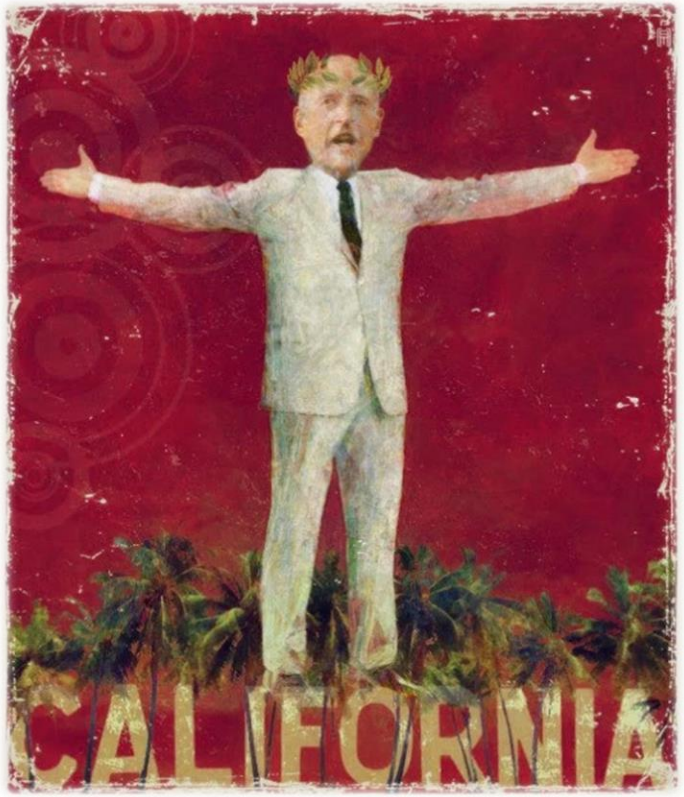


Source: CAISO

+ Distribution resource sharing requires a smart grid

California's Changing Energy Landscape

Legislation and Regulation



Source: Shasta Lantern

- Utilities required to procure 1.3 GW of energy storage by 2020 to support grid optimization and renewables integration
- Utilities are required to submit distribution resource plans (DRPs) that integrate distributed energy resources (DERs) into distribution grid planning
- The Integrated Distributed Energy Resources (IDER) proceeding is actively considering how best to integrate demand-side resources into utility planning and procurement processes

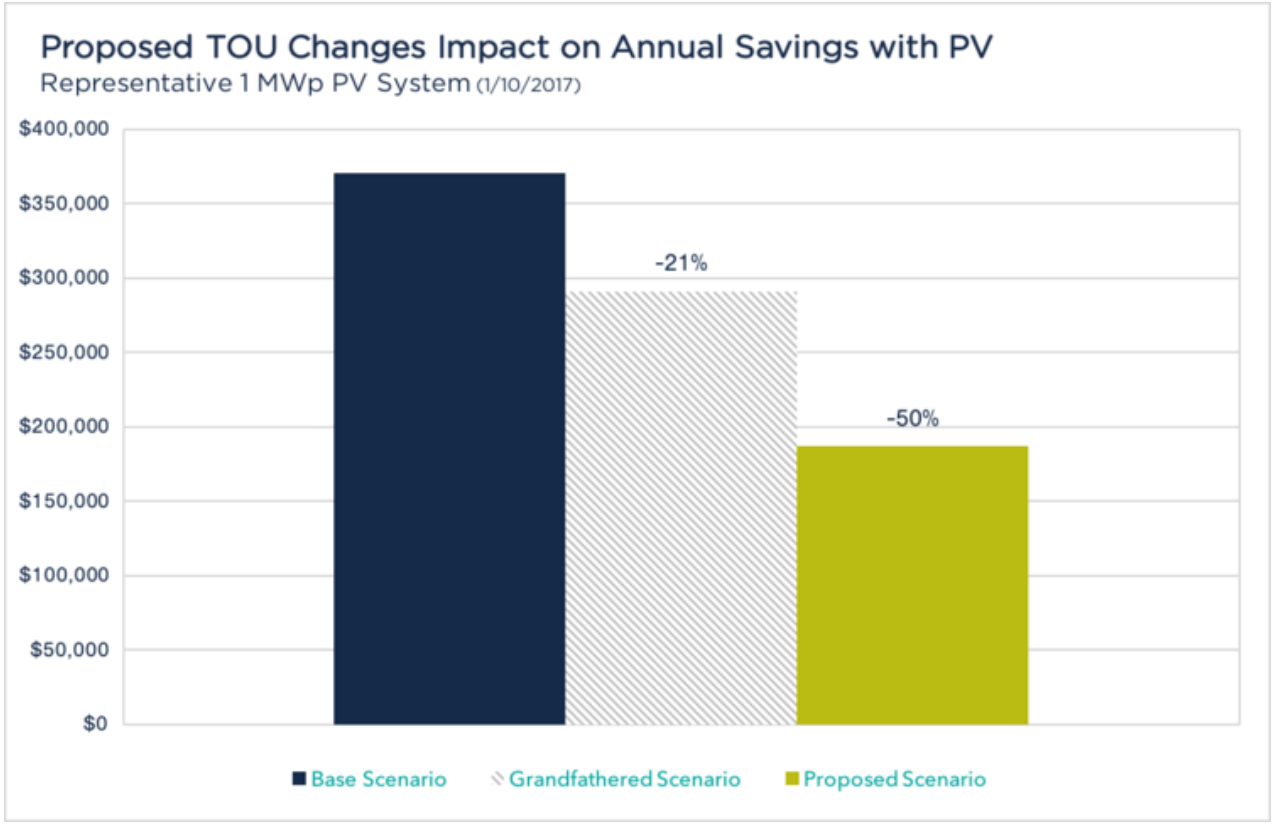
UTILITY TARIFFS

Big Changes and Less Support for DG Customers

- TOU Peak and the Duck Curve: large and abrupt changes to TOU periods have an outsized effect on solar, reducing value significantly in some markets
- Tariffs are *not* stable and CPUC is increasingly reluctant to protect solar customer investments
- Current TOU and associated tariff change proposals do *not* promote DG storage
- Solar and storage tariff requirements at odds
  - Other storage value streams need to be enabled to promote storage with solar

UTILITY TARIFFS

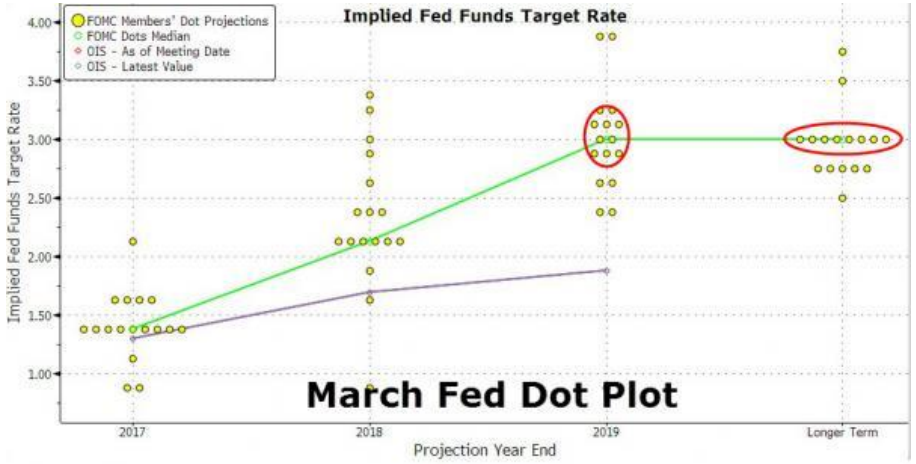
- **Time of Use Periods:** January 2017 CPUC Rulemaking allows utilities to shift time-of-use Peak Periods from afternoon to early evening to better match today's grid loads (Duck Curve).
- This shift has outsized impacts on the value of commercial solar energy – with **losses of 10-40%** for many customers.
- Utility rate proposals flatten the differential between Peak and Off-Peak - loss of solar value and storage arbitrage

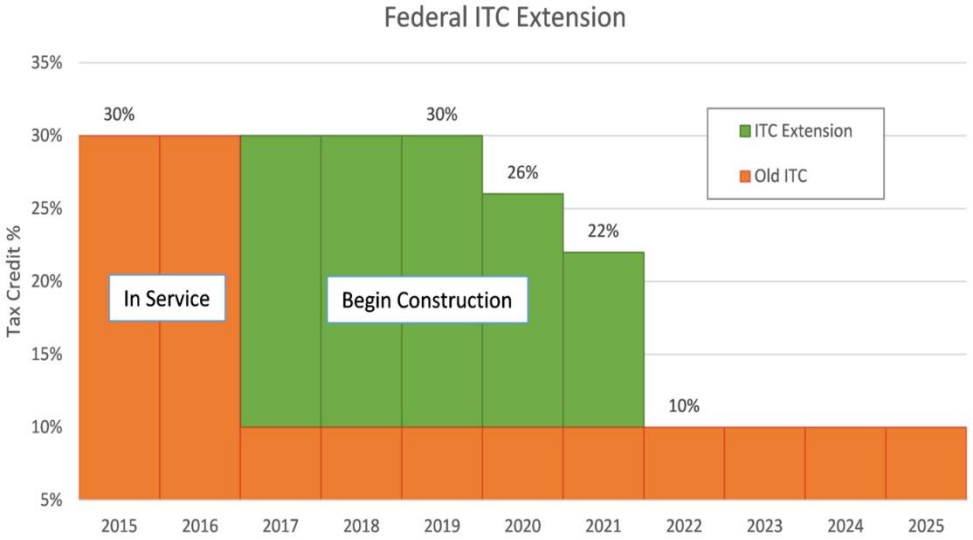


PROJECT FINANCE LANDSCAPE

Solar Project Finance – upward cost pressure

+ 30% ITC extended until the end of 2019
  - 3-year stepdown after 2019
+ Reduced Competition
  - SunEdison Bankruptcy
  - SolarCity acquisition by Tesla





+ Interest Rate and Stock Performance Pressure
  - Fed rate hikes will push up borrowing cost
  - SolarCity, SunPower, First Solar stock performance

PROJECT FINANCE LANDSCAPE

Storage Project Finance – still developing and dependent on incentives

- **+** Market and companies not well established
  - Perceived risk = storage companies must provide customer financing
  - No standardized customer financings yet
- **+** SGIP incentives oversubscribed
  - Some fixes implemented and money allocated, but far less than the market needs
- **+** Savings Difficult to Prove to Customers
- **+** Storage incentivized utility tariffs – not yet

For more information:

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Principal and CEO

O: 415.663.9914

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- **Arindam Maitra, Technical Executive EPRI**

Facilitating Choices – Integration of Deep Efficiency, Renewables, and the Grid

Robert Sherick
Southern California Edison
Advanced Technology – Renewable Integration

Customer Choices

ELECTRIC VEHICLE INTEGRATION

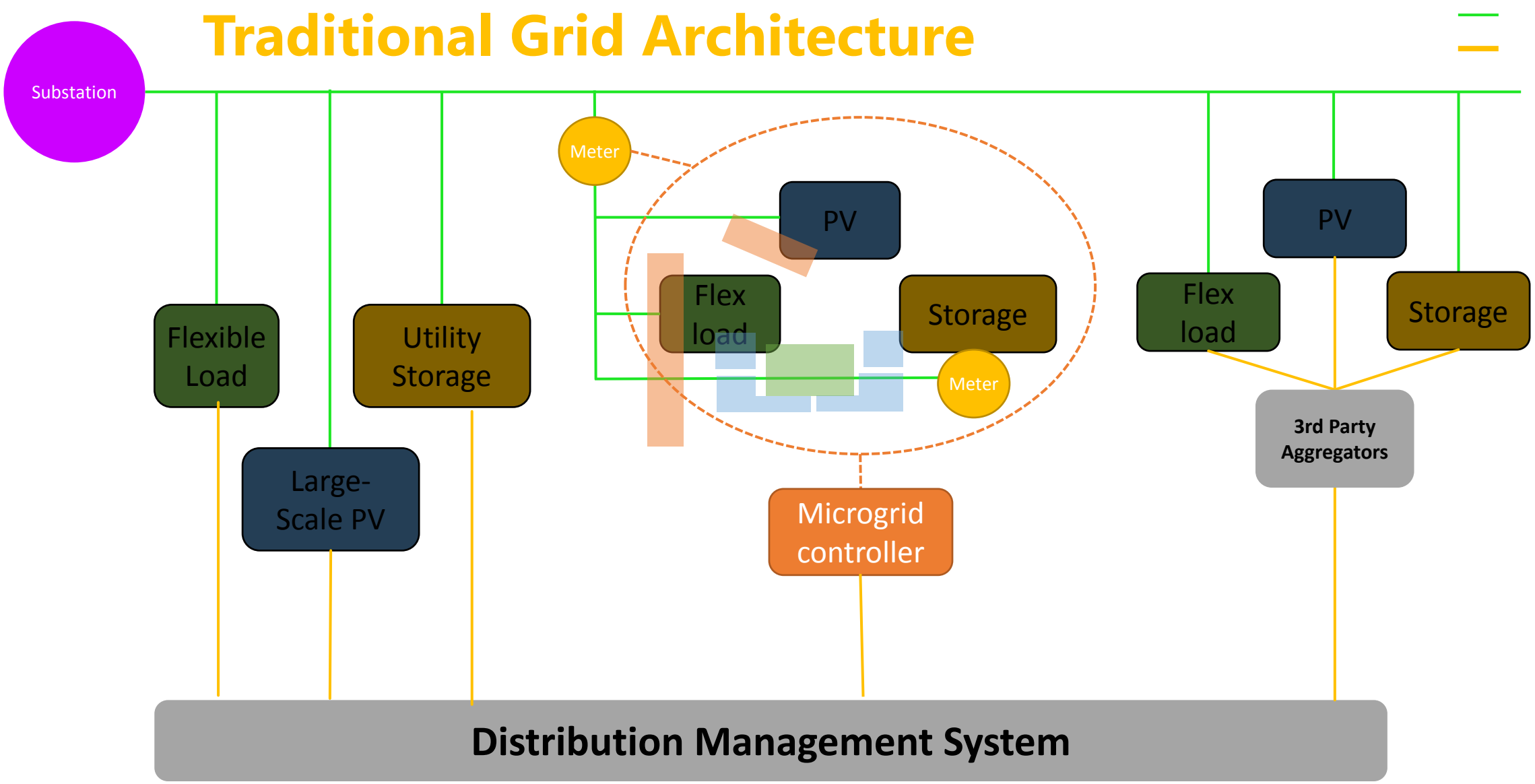
ROOFTOP SOLAR PV

BATTERY ENERGY STORAGE

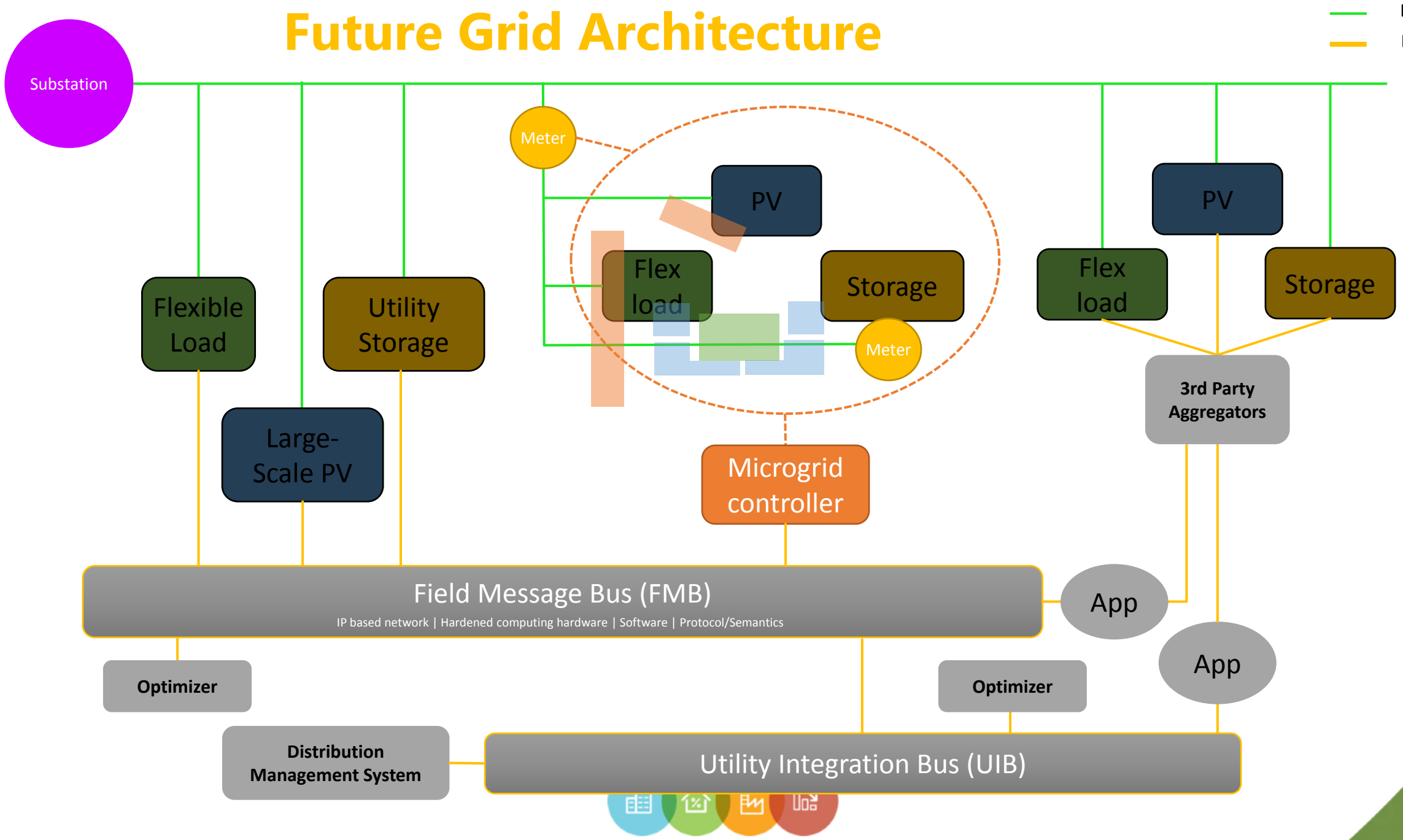
FLEXIBLE LOAD


Resource Integration
Meter
S5187803
S5187804
S5187805
M5350499
B5187967
P5305945
P5305945
PMH2613
PMH2613
600A
600A
FI05251
FI05251
P5605070
GS6141
V5615007
V5615006
POS 1
POS 1
B5187965
B5187964
V5549560
PT
PT
P5605069
URCI6779
S5187807
B5187966
1800
P5531362
P5305946
P5305757
PME3460
Google earth

Traditional Grid Architecture



Future Grid Architecture



Why?

- Beyond interconnecting – optimizing
- Leveraging the resources and flexibility to obtain full value
- Creating an adequate infrastructure to coordinate the grid
- Create efficiency and optimization opportunities for all parties
- Reduce risk of centralization without losing reliability of control
- Enable innovation and new market structures

Next Speaker

- Ken Nichols, Principal, EQL Energy
- Tom Williard, Principal and CEO, Sage Renewable Energy Consulting
- Robert Sherick, Principal Manager
  Renewable Integration, SCE
- **Ram Narayanamurthy, Principal Technical Leader, EPRI**

Grid Integration of Zero Net Energy Communities

Emerging Technologies Summit

Ram Narayanamurthy

Technical Executive

Electric Power Research Institute

April 20, 2017

Community Groundbreaking Event

Itron CSI RD&D Program Manager

PUBLIC UTILITIES COMMISSION · EUREKA · STATE OF CALIFORNIA

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MeritageHomes®

biraenergy
integrated clean energy solutions

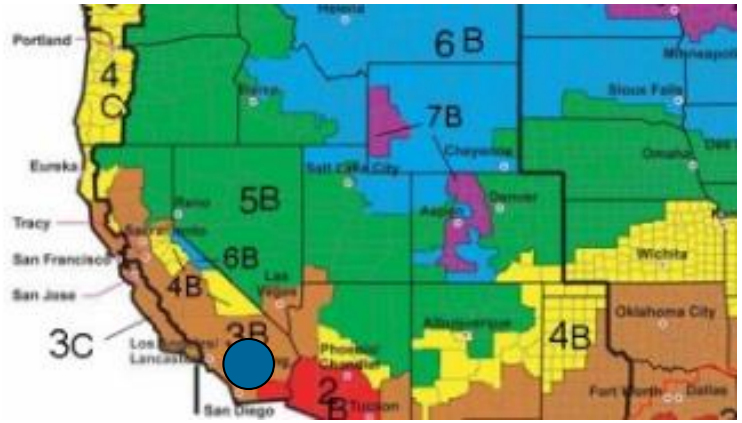
Project Synopsis

Project location: Fontana, CA

California's first ZNE neighborhood

Annual peak temperatures ~ 105 F

NEM Rules + ZNE, along with decarbonization drive electrification



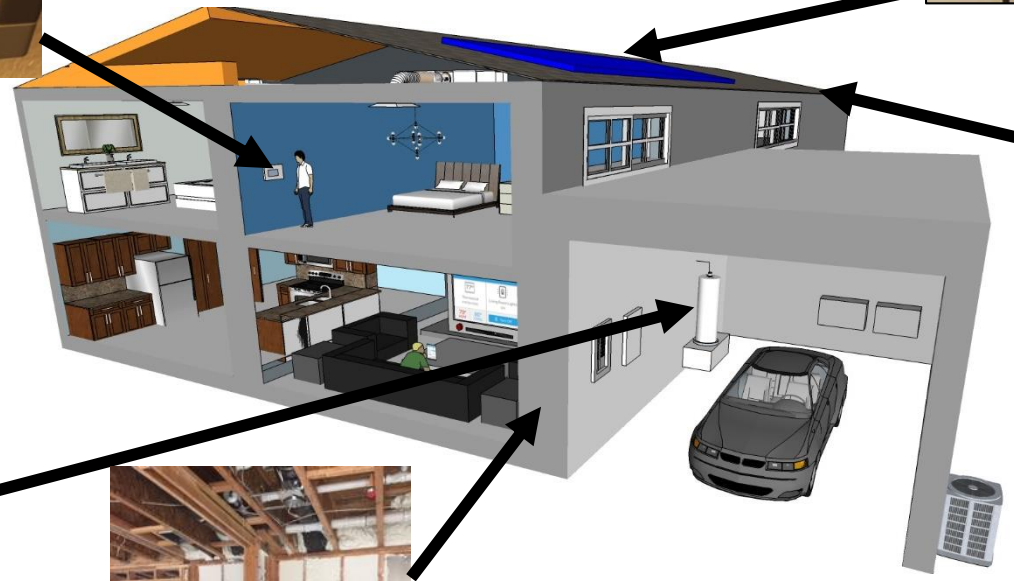
Attained Zero Net Energy @ 4% of home price including PV

Implemented ZNE Measures

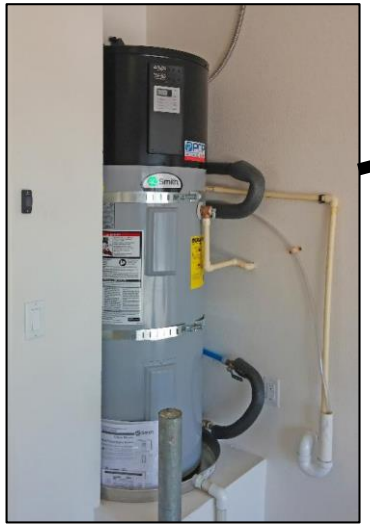
Nexia Thermostats/HEMS

All LED lighting

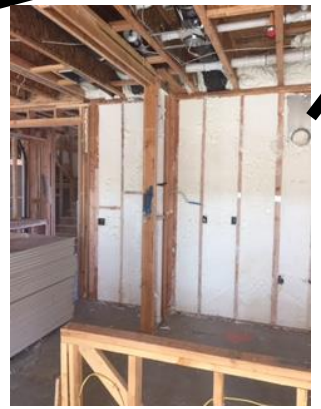
3.5 – 4.5 kW PV



High Performance Envelope



Electric Heating and Water Heating

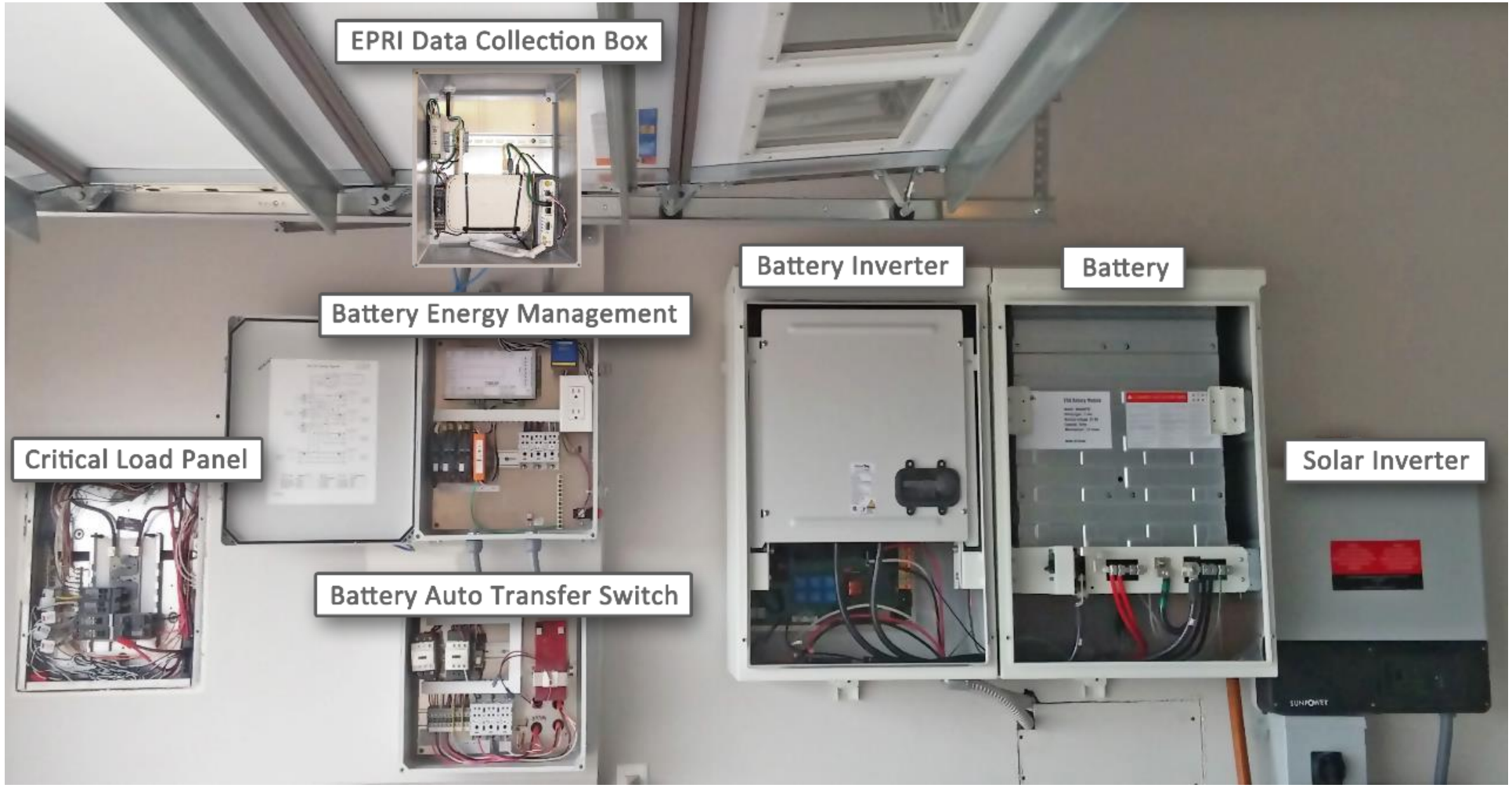


Foam Insulation

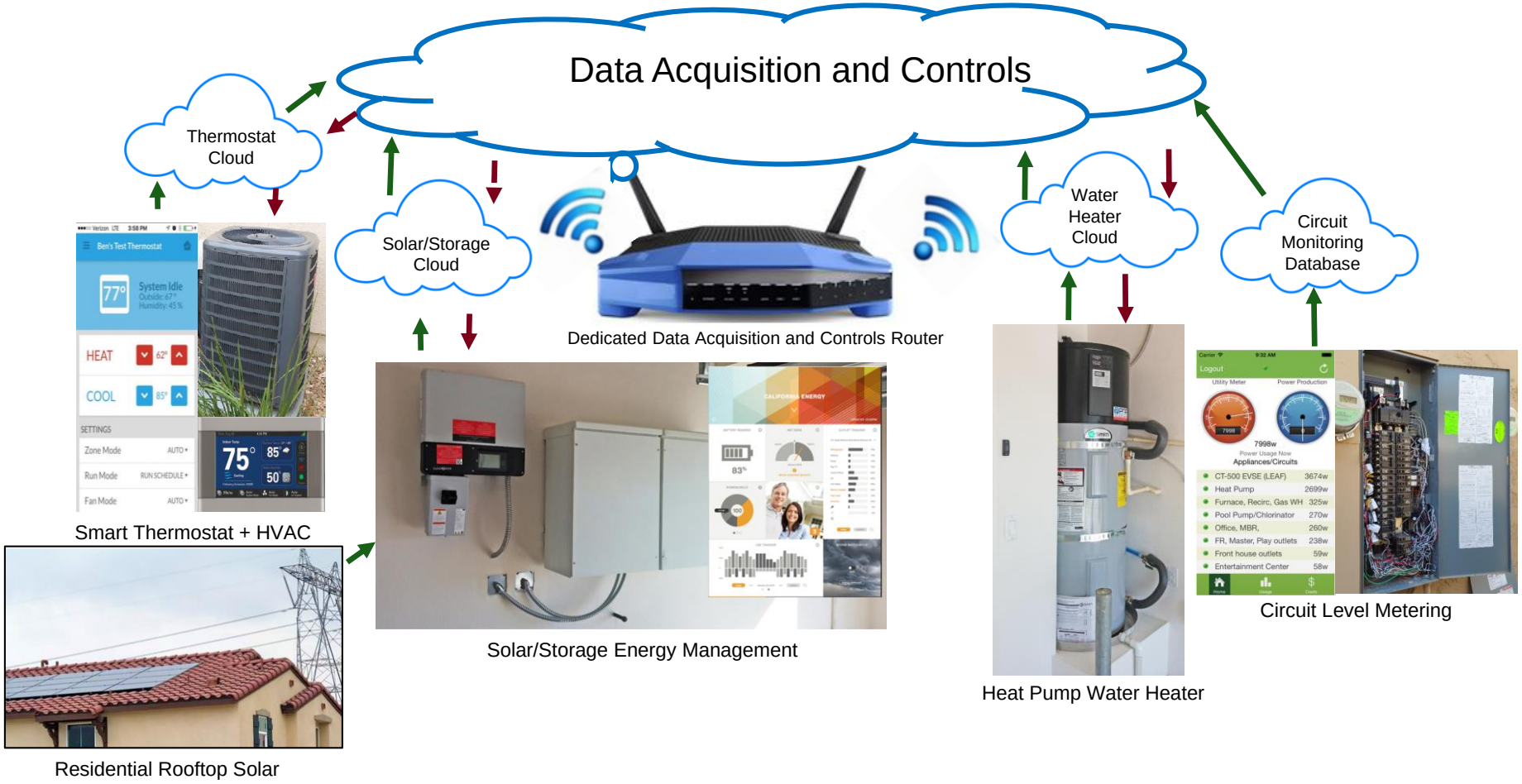
Plus:

- Plug load controllers
- Circuit-level monitoring

Home Energy Management Center



Data Acquisition and Distributed Energy Resource Controls



Objectives:

- Develop and vet “organic” data acquisition system
- Assess control scenarios for load-optimization

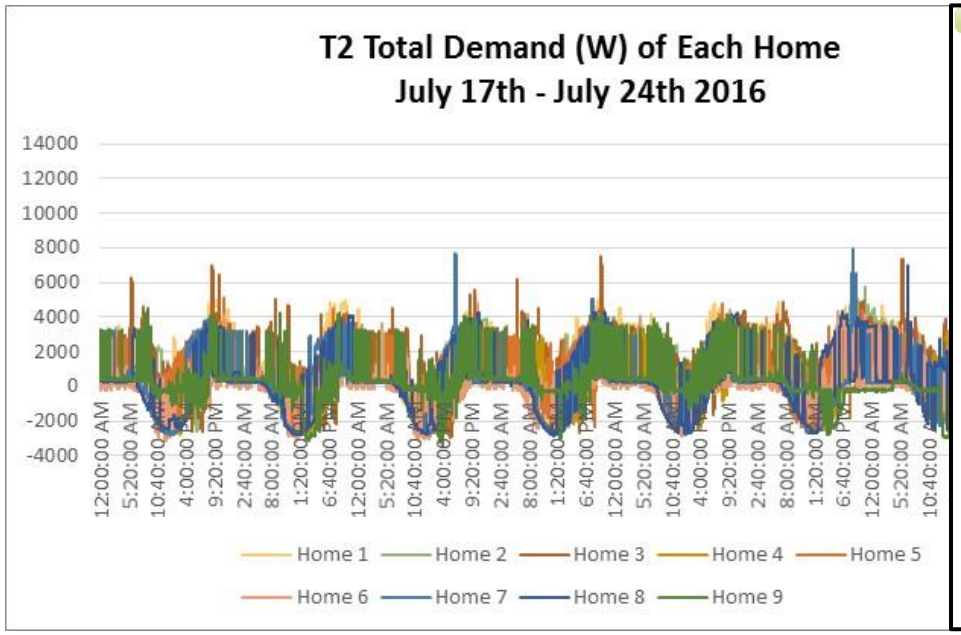
Key

Data Pathway

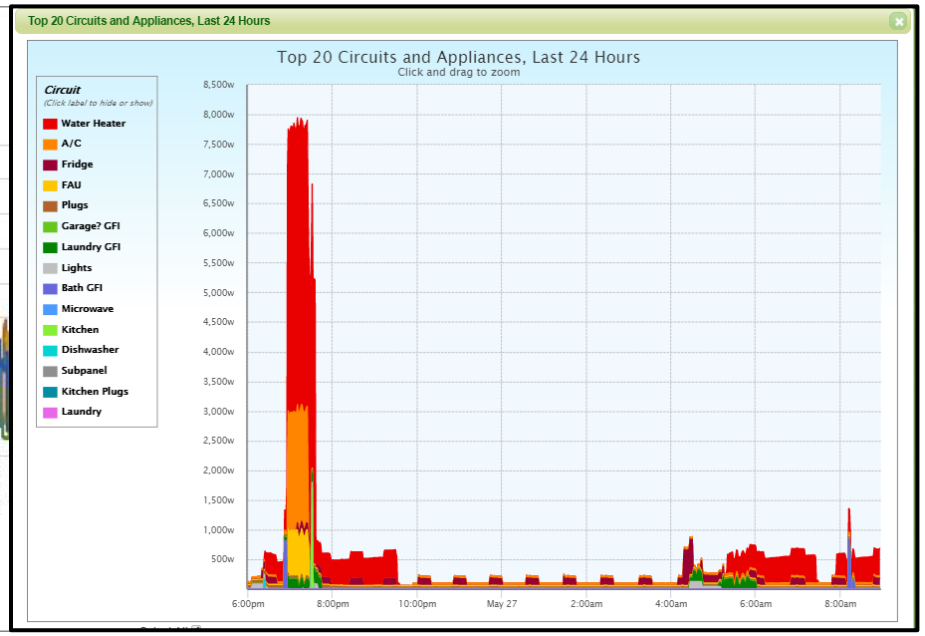
Controls Pathway

EPRI ELECTRIC POWER RESEARCH INSTITUTE

How Are These Homes Performing?



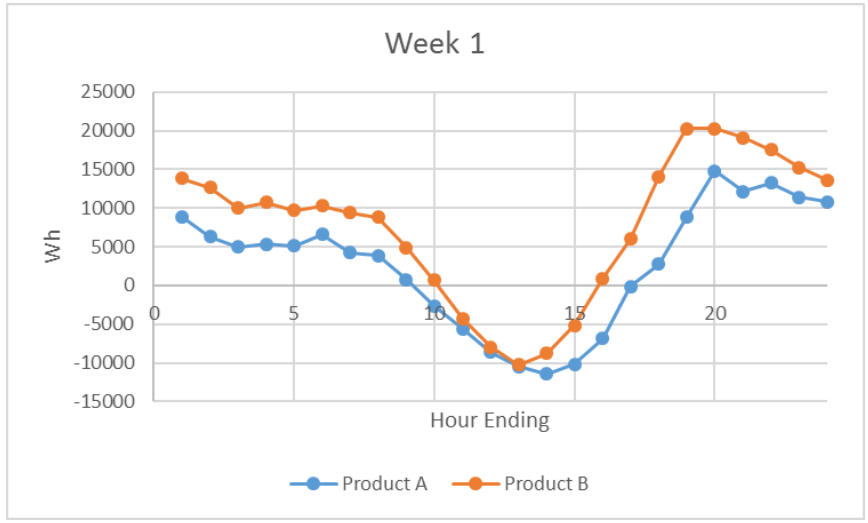
Energy Usage in Watts (1 min interval)

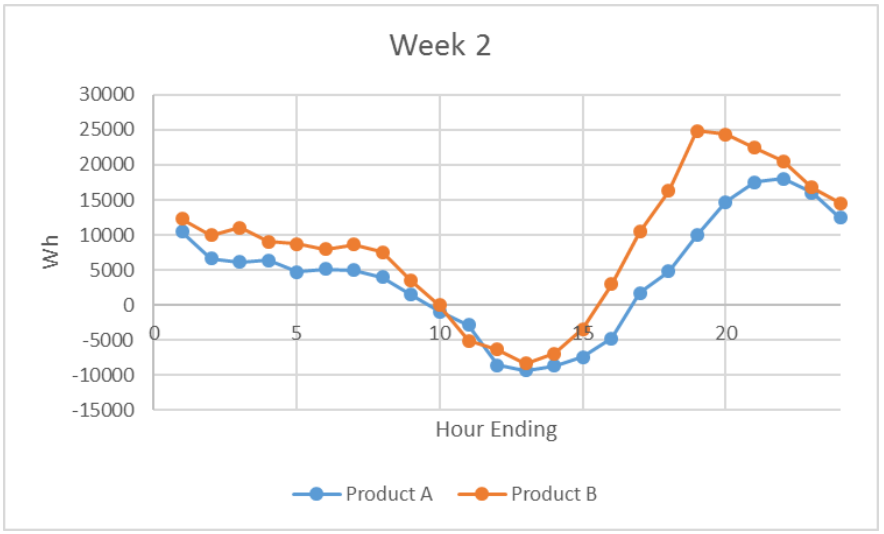


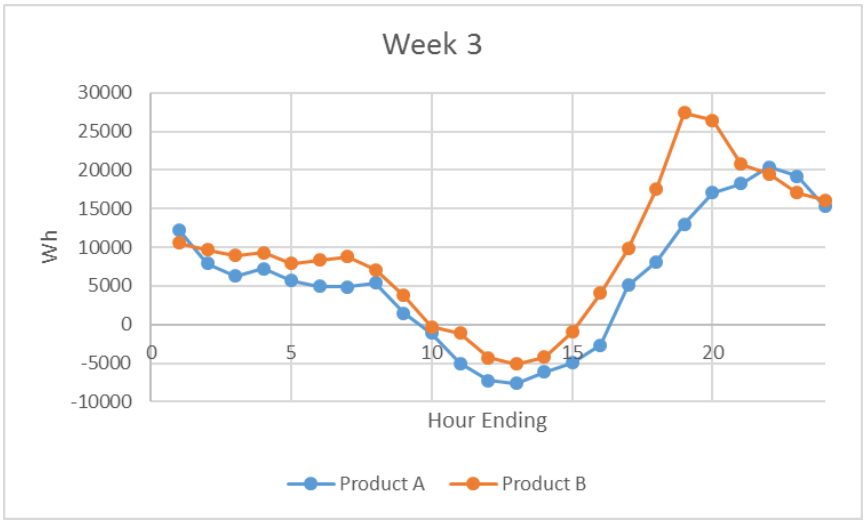
Disaggregated load profile

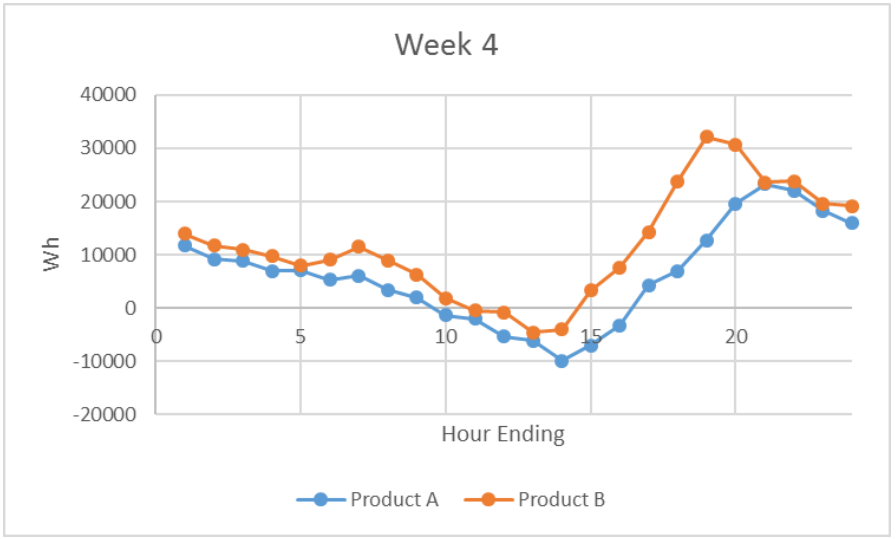
- These ZNE homes are occupied by first time home buyers, not energy enthusiasts
  - Anecdotal - $25 July bill with electric dryer, $0.64 bill in April
- Very erratic load shape with HPWH and appliance driven peaks
- Models: average loads/time-step; actually discrete, intermittent loads
- Intermittent loads coincident → large, unanticipated peaks

What does this mean to the grid?
Transformer load shapes









SCE Distribution Standards

- Transformer sizing is based off of available load information, SCE climate zone, building sq. ft, # of customers, and installed HVAC system
- Distribution planning today is based on worst case scenario of total connected load. Storage is counted as a load

Factors	Xfmr T1 75kVA	Xfmr T2 50kVA
Building Sqft (Adj Ave)	~1800	~1800
Largest A/C (tons)	4	4
Avg A/C (tons)	3.5	3.5
# of customers	**11**	**9**
Peak Demand per lot (kW) *Based on SCE Planning Standard*	**5.0-5.5kW**	**5.0-5.5kW**
	Based on HVAC usage	
Panel Size	200A	200A
Climate Zone	7	7

Rating	# Cust
25 kVA	1-4
50 kVA	5-10
75 kVA	11-15

Residential Transformer Loading Limits @SCE

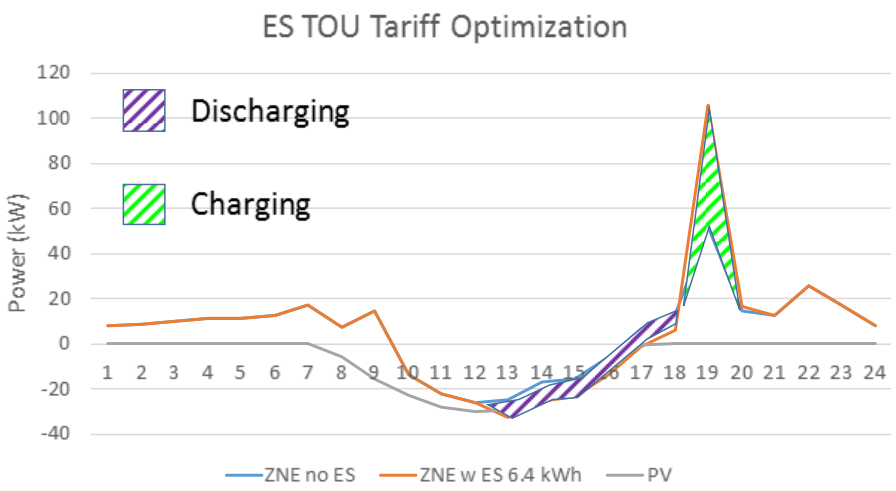
Date	Weekly Measured Xfmr T1	Weekly Measured Xfmr T2
	Peak Demand per lot (KW)	
July 17-24	4.9	3.8
Aug 20-27	4.7	3.6

Could Energy storage Provide a Potential Solution

Controls are key

Operation based on ToU rates Optimization

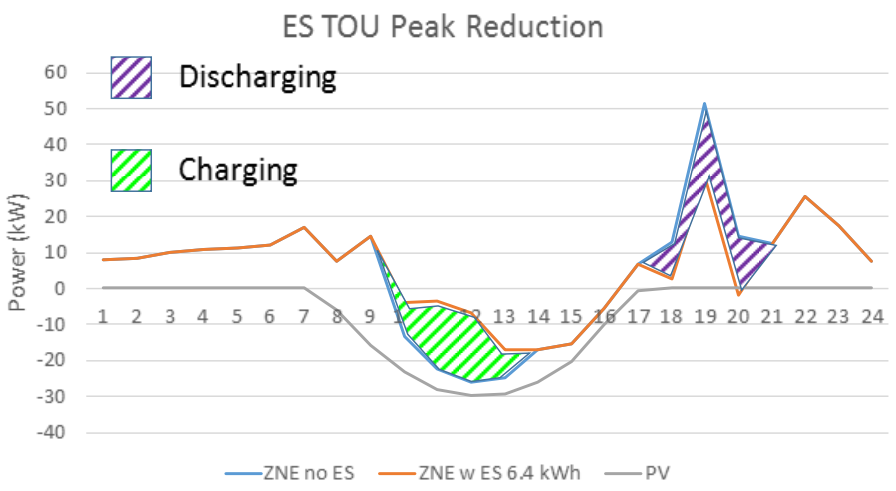
- Energy storage is operated to optimize for current ToU rates
  - Peak is Noon – 6 PM (ES discharge)
  - Off-peak is 6 PM – 6 AM (ES charge)
- 100% SOC maintained overnight



The ES TOU tariff optimization control scheme could potentially cause adverse impacts.

Operation based on ToU Peak Reduction

- Energy storage systems operated with “simulated peak and off-peak”
  - Peak is 5 PM – 8 PM (ES discharge)
  - Off-peak is 9 AM – 12 PM (ES charge)
- 25% SOC maintained overnight



The ES TOU grid balancing control scheme could be beneficial.

Lessons learned – Planning and design

1. Minimize the size of PV arrays for multiple benefits:
   - Neighborhood planning and lot fits
   - Least cost pathways
   - Reduce peak backflow
   - Reduce late evening ramps
2. NEM drives electrification of heating loads
   - TDV (or source) ZNE definition accounts for gas consumption, and gas heating results in excess annual generation at low payback
   - TDV ZNE favors gas heating – lowest first-cost for ZNE_{TDV}
   - → Naïve T24 analyst/designer spec gas despite no gas NEM
3. Neighborhood solar planning could be a big barrier to reaching current ZNE goals
4. Energy efficiency has more capacity benefits than PV
   - PV production is non-coincident with loads

Lessons learned – Grid Impacts and future initiatives

1. In distribution planning, most reliable path forward is to increase transformer and wire sizing for ZNE and high PV penetration
   - 50 year planning horizon cannot rely on controls (including storage)
   - Future loads – EV and electrified heating are not coincident with PV
   - Customer controlled energy storage is not reliable for grid needs.
2. The problem spots for distribution systems is load blocks, and laterals with protection devices and wire sizing
3. Distribution systems will need to manage for load peaks almost as much as high penetration PV (coincident loads)
   - Passive energy storage, demand response and energy storage can provide integrated load management
4. Research community solar and storage options for ZNE

Together…Shaping the Future of Electricity

Questions and Commentary