U.S. DEPARTMENT OF
ENERGY

Office of
ENERGY EFFICIENCY &
RENEWABLE ENERGY

EVs, PVs, & Connected Communities: Technologies Beyond Buildings

Building Technologies Office Peer Review

Monday, April 30; 1:30-3:00PM

Agenda

- **Introduction** *Johney Green, NREL*
- **BTO Interest Beyond Buildings** *Joan Glickman, DOE*
- **Keynote** *Robin Roy, Next Energy*
- **Enabling Technologies in Other Sectors**
  - **Connected Communities** *Greg Hale, NYSERDA*
  - **Solar Photovoltaics** *Charlie Gay, DOE*
  - **Electric Vehicles** *Steve Rosenstock, EEI*
- **Moderated Discussion**

BTO Interest in Technologies Beyond Buildings

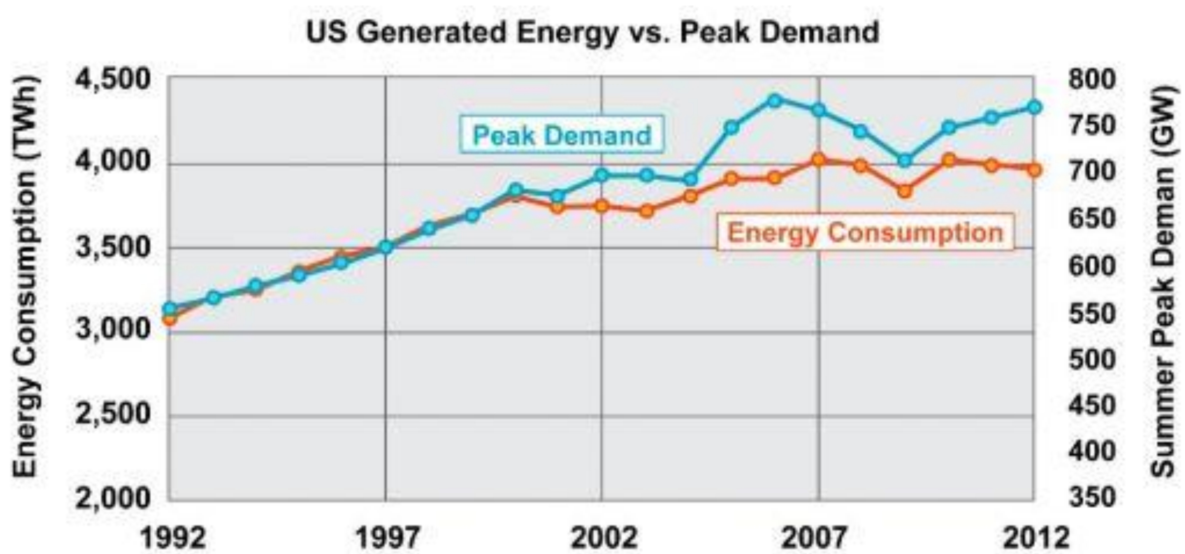
Joan Glickman, DOE

How BTO Traditionally Has Seen Its Role

- Buildings as ***energy consumers***
- Research focused on how to ***improve efficiency***
- Relevant building systems include ***HVAC and enclosure***

Electricity Grid Reality

- Overall demand is relatively flat, but peak demand keeps rising
- Most energy resources & buildouts are aimed to enhance reserve capacity
- DERs & variable energy resource supplies continue to grow



Our Question: What can buildings do to help?

Interest in "GEB"

Grid-interactive Efficient Buildings

"The U.S. Department of Energy's Building Technologies Office defines a grid-interactive efficient building (GEB) as an energy efficient building that can automatically and dynamically change its energy use and demand patterns in response to signals from the grid."

Looking to the Future

Relevant Questions

- What are new areas we should take on?
- How can DOE and national labs' capabilities best contribute to this field?
- How can we best work with other researchers engaged in these issues?
- How do we keep our focus on energy goals?

Keynote

Robin Roy, Next Energy

BTO's Connected Role in a

Clean, Abundant, Resilient, & Economic Energy Future

BTO Peer Review
April 30, 2018

Robin Roy, Ph.D.
Next Energy US
RRoy@NextEnergyUS.com

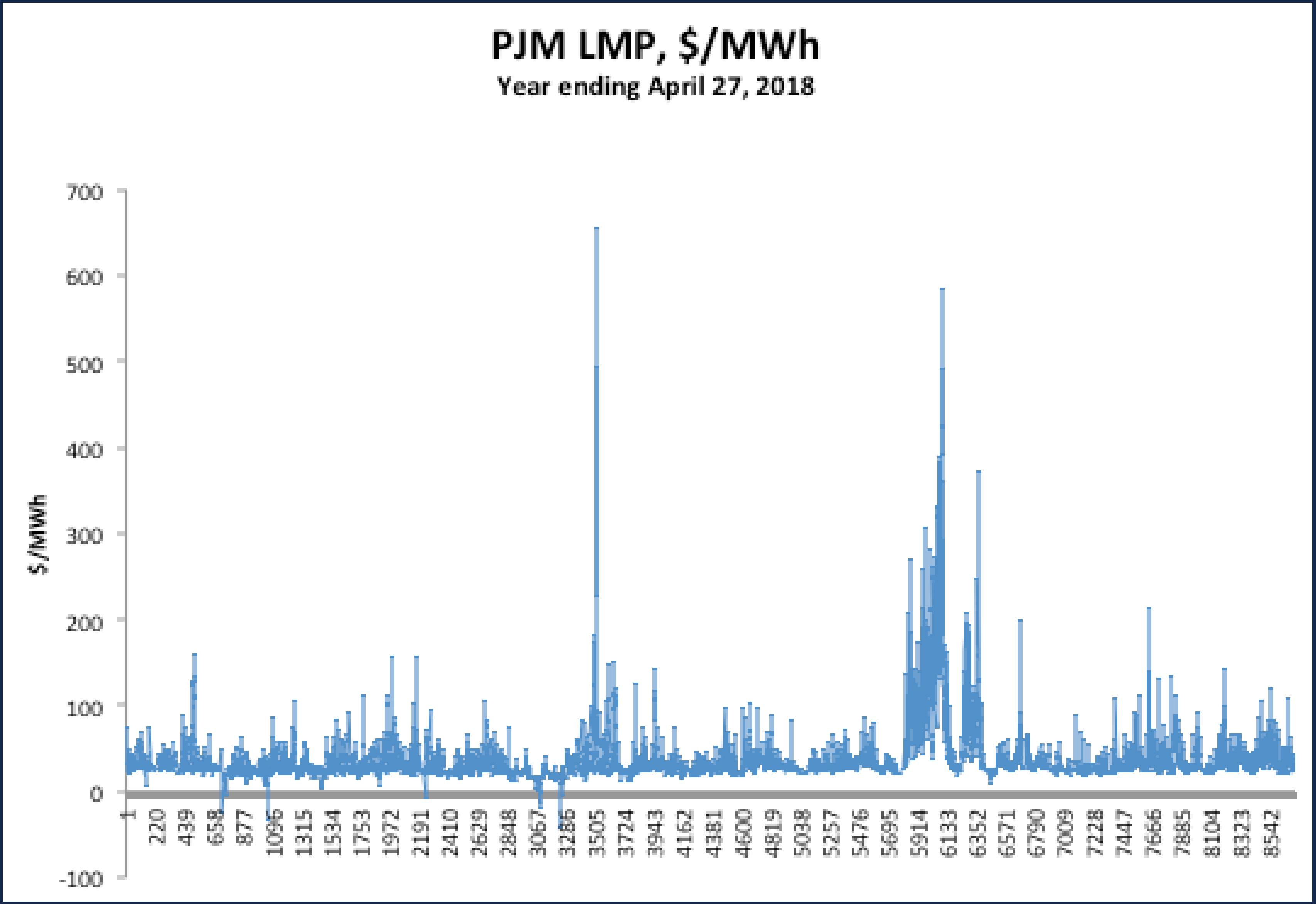
Evolving Context for BTO – Beyond EE

Abundant Energy Resources

Evolving Context for BTO – Beyond EE

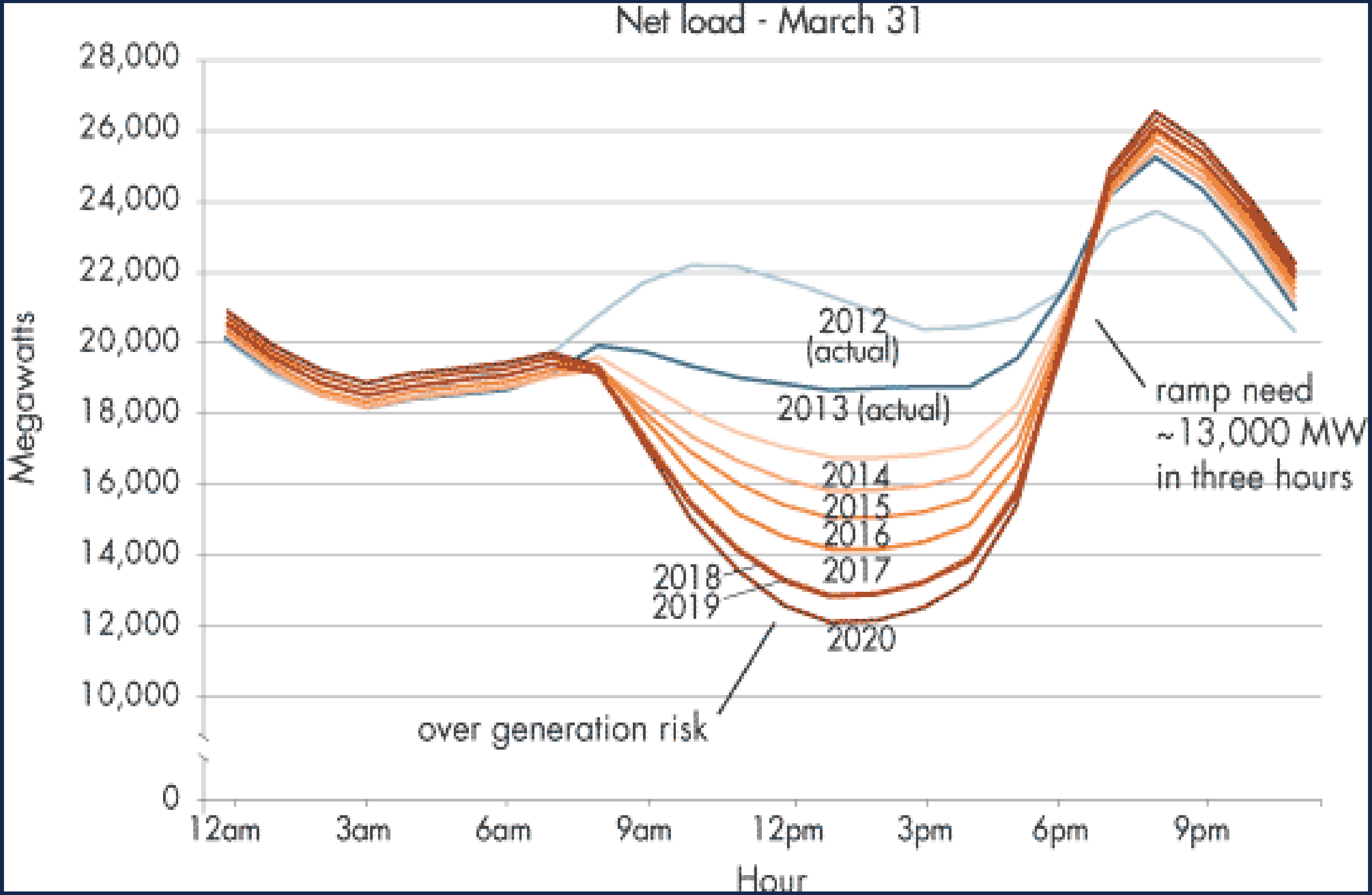
Abundant Energy Resources

… but highly time-varying grid conditions (cost, resilience, emissions)

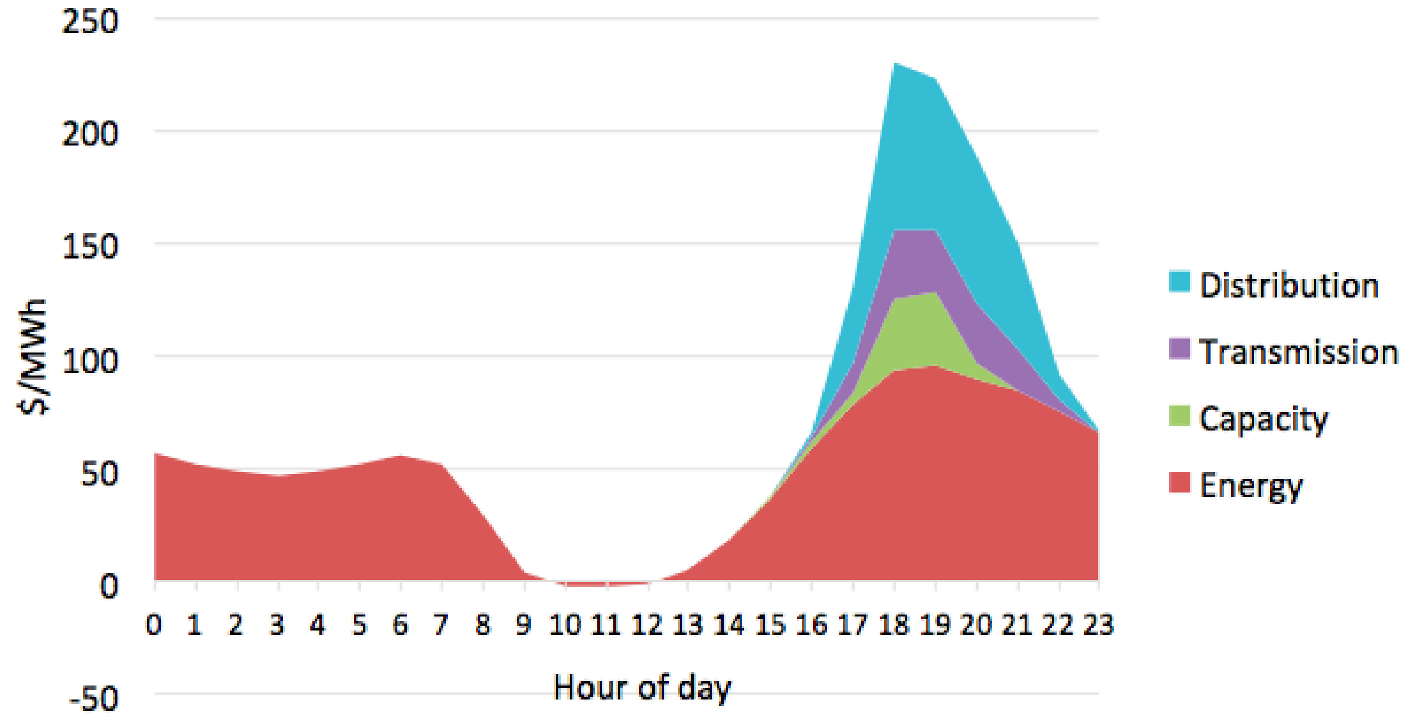


PJM LMP, $/MWh
Year ending April 27, 2018
$/MWh
700
600
500
400
300
200
100
0
-100
1
220
439
658
877
1096
1315
1534
1753
1972
2191
2410
2629
2848
3067
3286
3505
3724
3943
4162
4381
4600
4819
5038
5257
5476
5695
5914
6133
6352
6571
6790
7009
7228
7447
7666
7885
8104
8323
8542

The Duck Curve



Hourly Marginal Costs (PG&E 2024) – Annual Average



Source: NRDC "HPWH Demand Flexibility Study Preliminary Results" March 2018

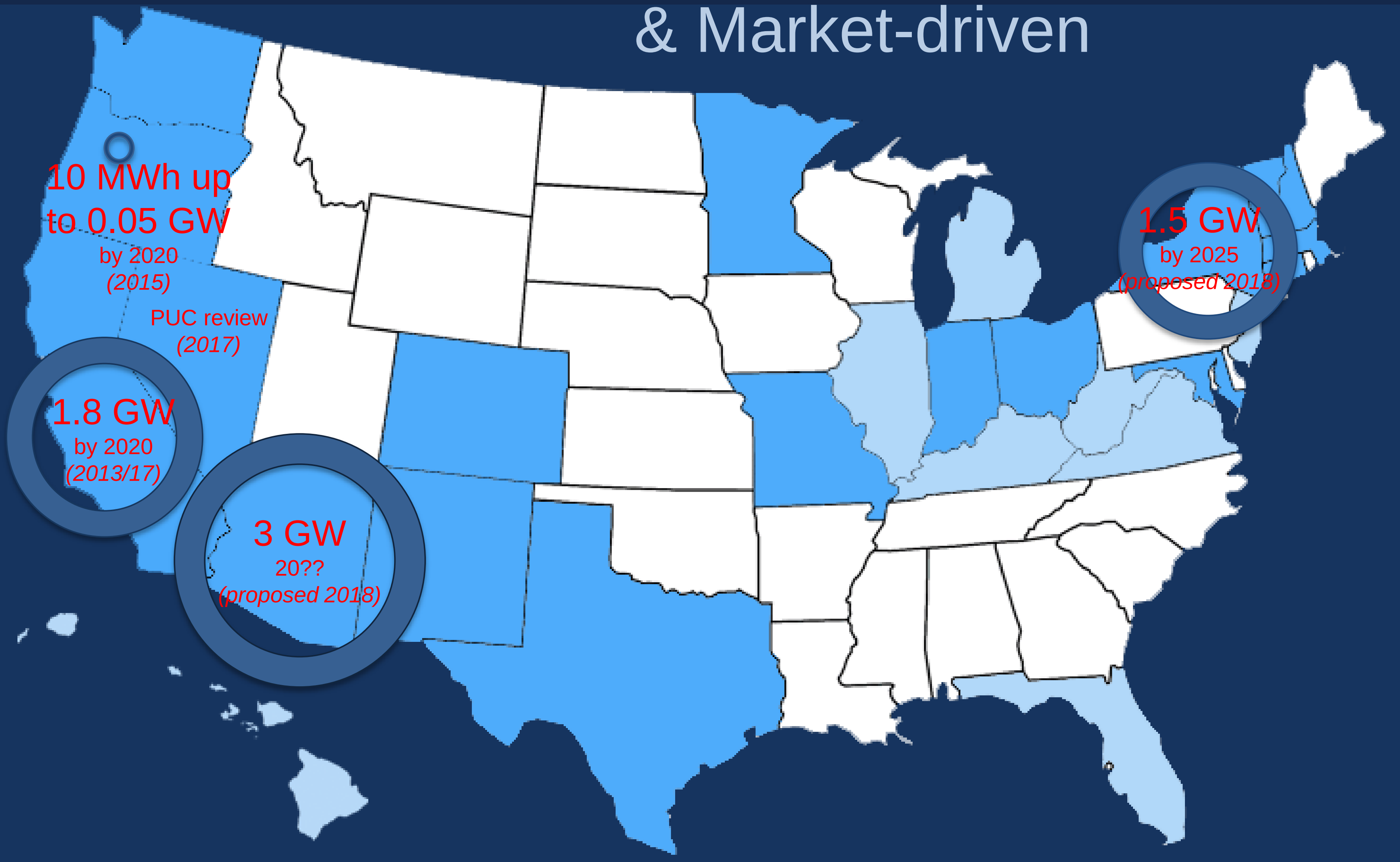
Evolving Context for BTO – Beyond EE

Abundant Energy Resources

… but highly time-varying grid conditions (cost, resilience, emissions)

Energy Storage – rapidly growing role

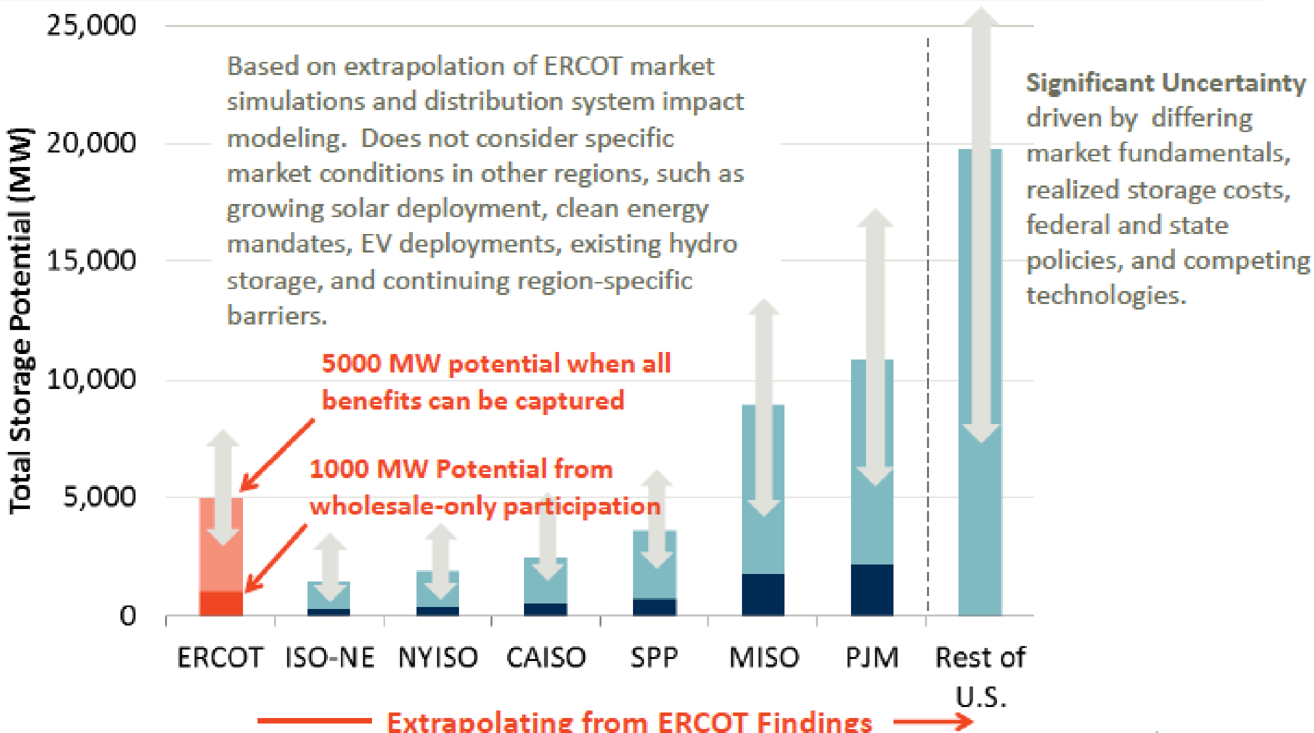
Storage Mandates, Other State Policy, & Market-driven



Activities beyond mandates from Brattle Group, "Battery Storage Development" Jan 18, 2018

U.S.-Wide Storage Potential

At a cost of $350/kWh (installed), Order 841 could unlock 7,000 MW based solely on wholesale-market participation in RTOs. This increases to 50,000 MW US-wide if all benefits can be captured, but requires states to unlock T&D and customer benefits.



Evolving Context for BTO – Beyond EE

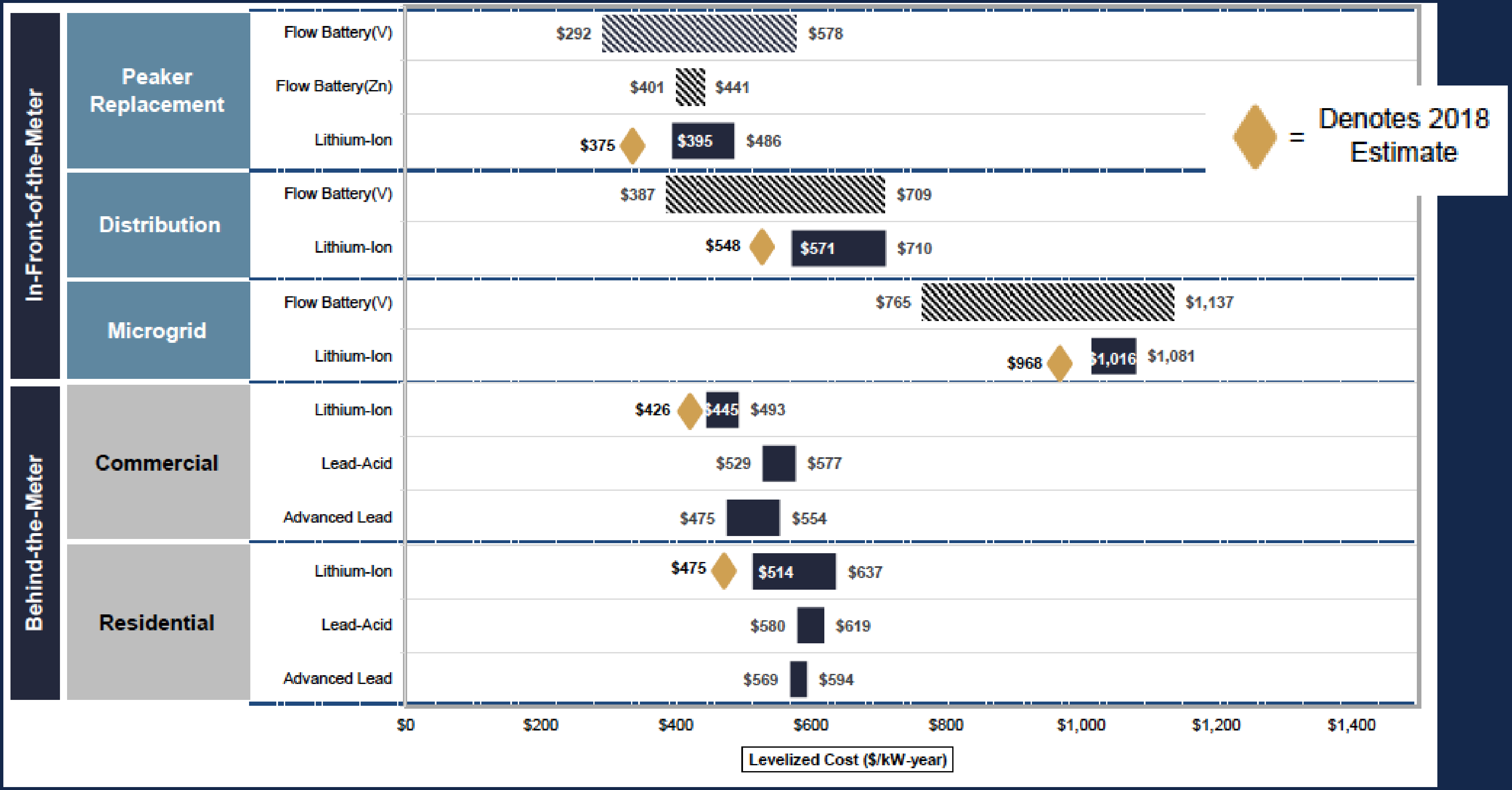
Abundant Energy Resources

… but highly time-varying grid conditions (cost, resilience, emissions)

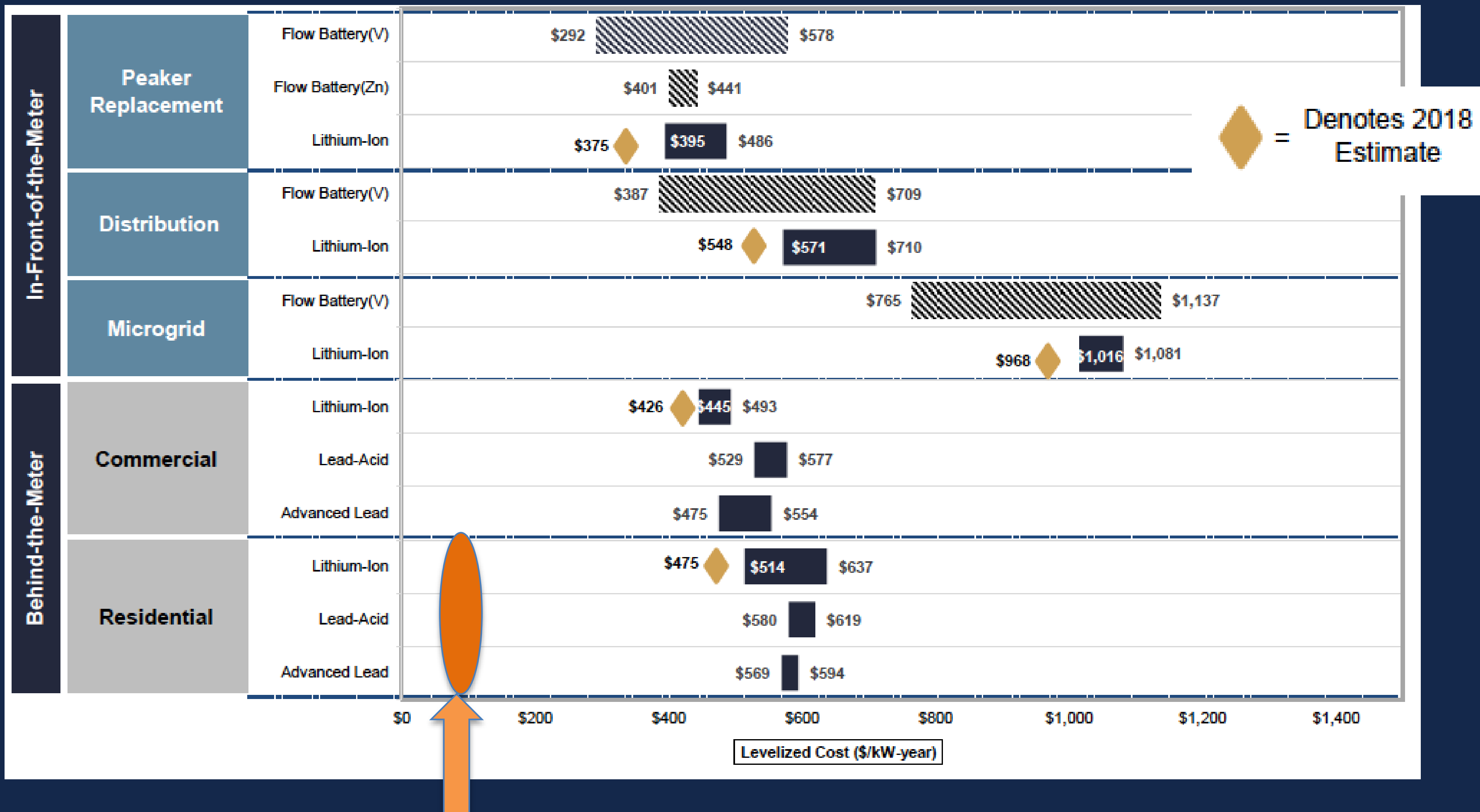
Energy Storage – rapidly growing role

Responsive loads - great potential in legacy DR, consumer IOT, advanced tech

Unsubsidized Levelized Cost of Storage Comparison—$/kW-year



Unsubsidized Levelized Cost of Storage Comparison—$/kW-year



Connected water heating

The Hidden Battery

Opportunities in Electric Water Heating

PREPARED FOR

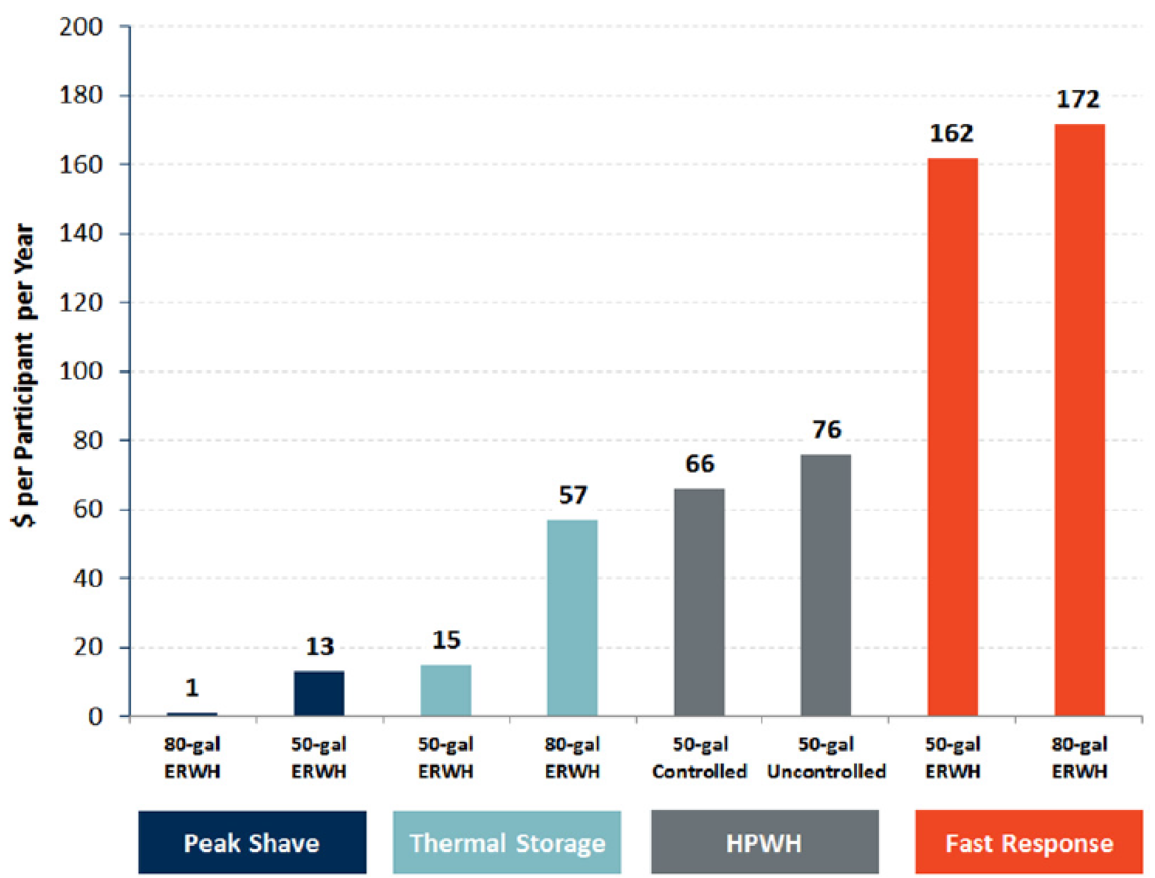
NRECA

NRDC

NATURAL RESOURCES DEFENSE COUNCIL

PLMA

Figure ES-1: Annualized Net Benefits of Water Heating Strategies (PJM 2014)



Evolving Context for BTO – Beyond EE

Abundant Energy Resources

… but highly time-varying grid conditions **(cost, resilience, emissions)**

Energy Storage **– a rapidly growing role**

Responsive loads **- great potential in legacy DR, consumer IOT, advanced tech**

Enormous stakeholder interest in responsive loads

Interest in Advanced Electric Water Heaters

- **Manufacturers**
- **Utilities**
- **FERC** and **some states**
- **CEE, NEEA** and **Energy Star**
- **ARPA-E**
- **Consumers?**

Evolving Context for BTO – Beyond EE

Abundant Energy Resources

… but highly time-varying grid conditions (cost, resilience, emissions)

Energy Storage – rapidly growing role

Responsive loads - great potential in legacy DR, consumer IOT, advanced tech

Enormous stakeholder interest in responsive loads

Beneficial electrification ←→ Responsive loads

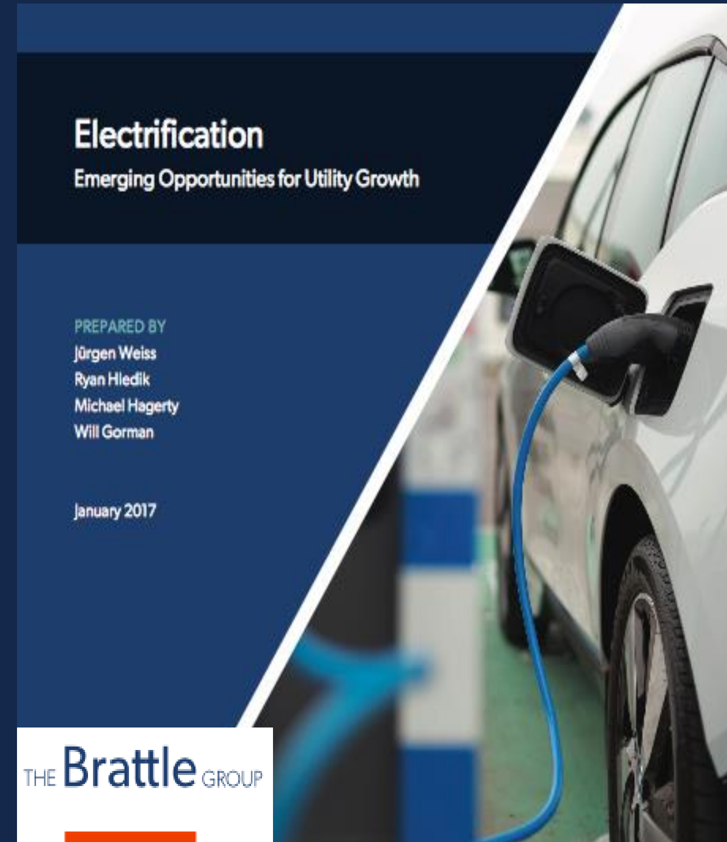
The Electricity Journal

Volume 29, Issue 6, July 2016, Pages 52–58

Environmentally beneficial electrification: The dawn of ‘emissions efficiency’ ☆ ☆☆

AMERICA'S ELECTRIC COOPERATIVES

RAP®



EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Agenda Industries Location Registration Sponsors

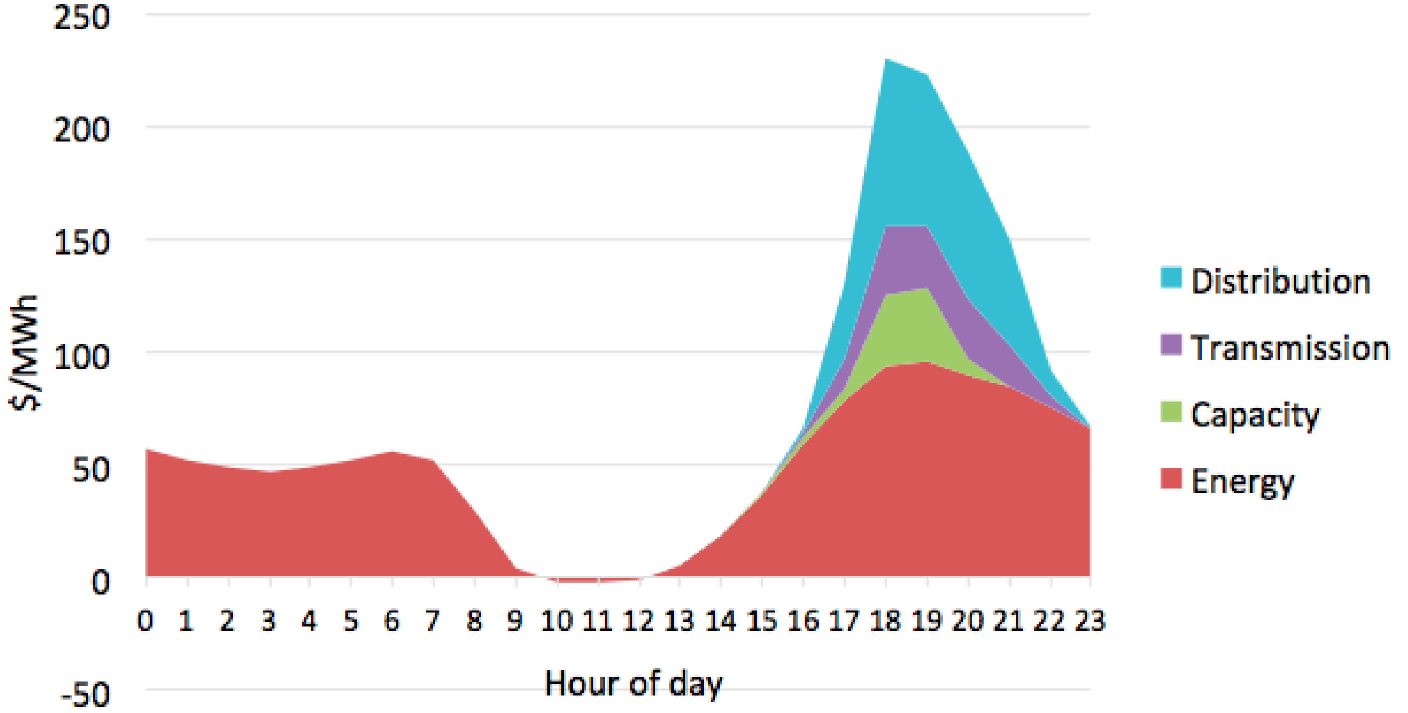
ELECTRIFICATION 2018

INTERNATIONAL CONFERENCE & EXPOSITION

AUGUST 20-23, 2018

LONG BEACH, CALIFORNIA

Hourly Marginal Costs (PG&E 2024) – Annual Average



Source: NRDC "HPWH Demand Flexibility Study Preliminary Results" March 2018

Evolving Context for BTO – Beyond EE

Abundant Energy Resources

… but highly time-varying grid conditions (cost, resilience, emissions)

Energy Storage – rapidly growing role

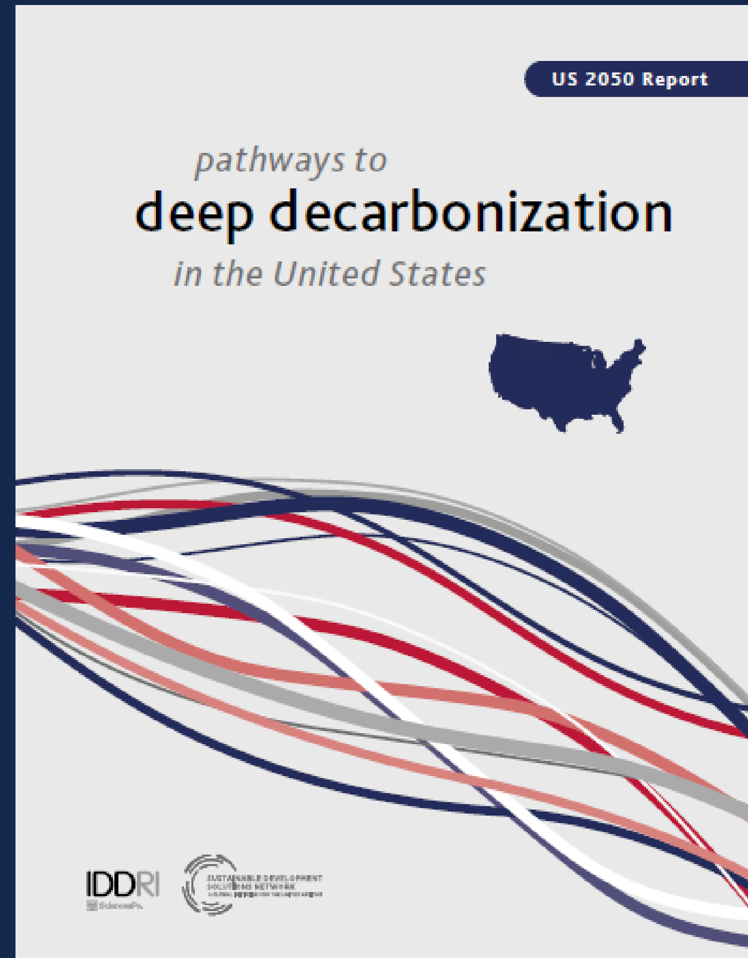
Responsive loads - great potential in legacy DR, consumer IOT, advanced tech

Enormous stakeholder interest in responsive loads

Beneficial electrification ←→ Responsive loads

Managing carbon pollution ←→ Responsive loads


NRDC
SEPTEMBER 2017
R: 16-06-A
REPORT
AMERICA'S CLEAN ENERGY FRONTIER:
THE PATHWAY TO A SAFER CLIMATE FUTURE


US 2050 Report
pathways to
deep decarbonization
in the United States
IDDRI


A BETTER LIFE WITH
A HEALTHY PLANET
PATHWAYS TO NET-ZERO EMISSIONS
A NEW LENS SCENARIOS SUPPLEMENT

Implications for BTO

Great value in BTO's connected work

An energy saving goal/metric doesn't mesh with the opportunities of responsive loads (nor of other DERs)

Need a **responsive loads road map**

Lexicon

Goals & metrics other than 'saving energy'

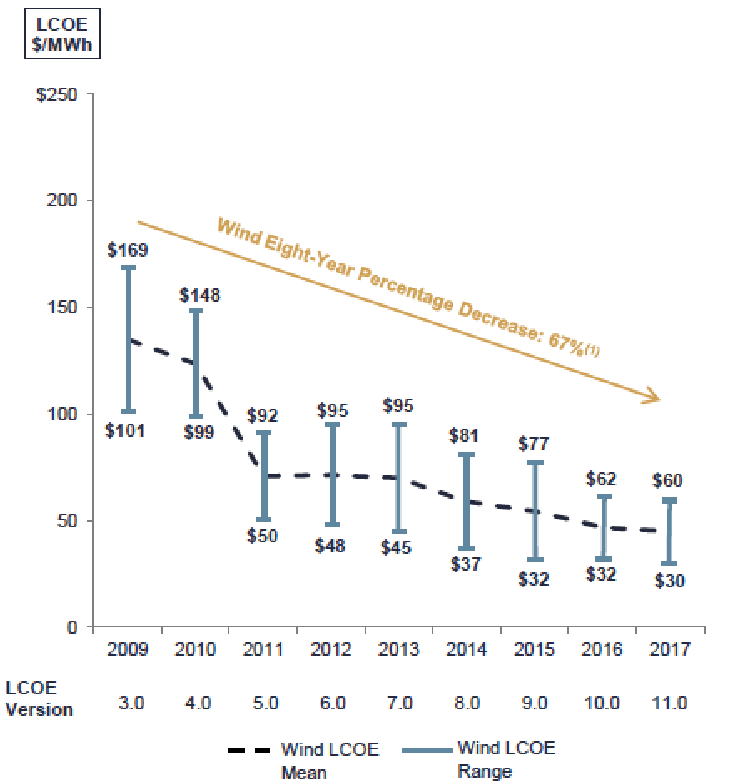
Total potential

Policy tools & options

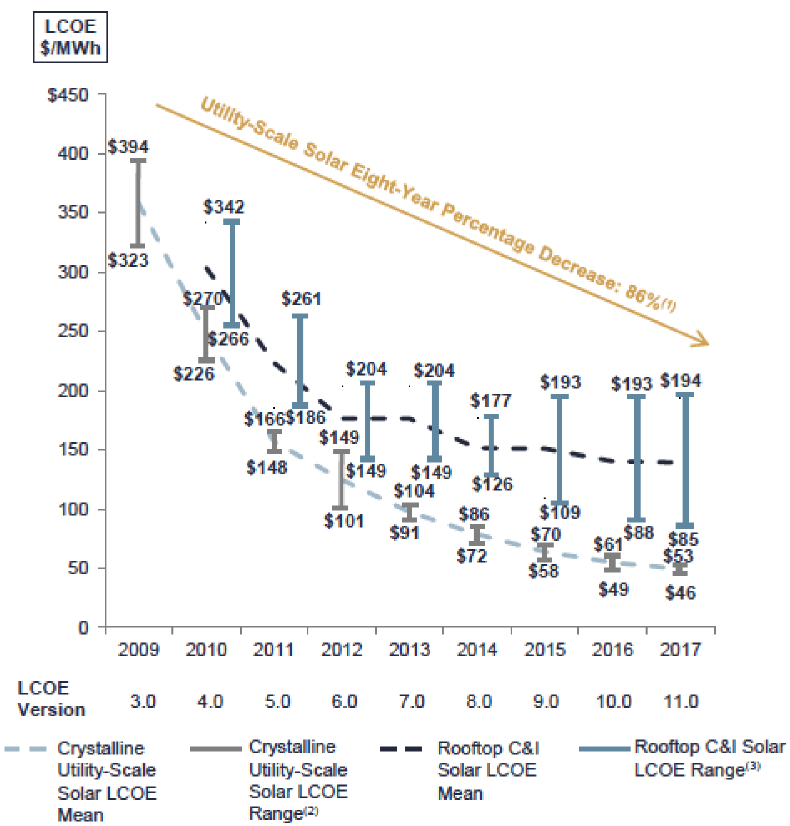
Evolving from historic EE focus

Unsubsidized Levelized Cost of Energy—Wind & Solar PV (Historical)

Wind LCOE



Solar PV LCOE



LAZARD

Enabling Technologies in Other Sectors

Panel Discussion

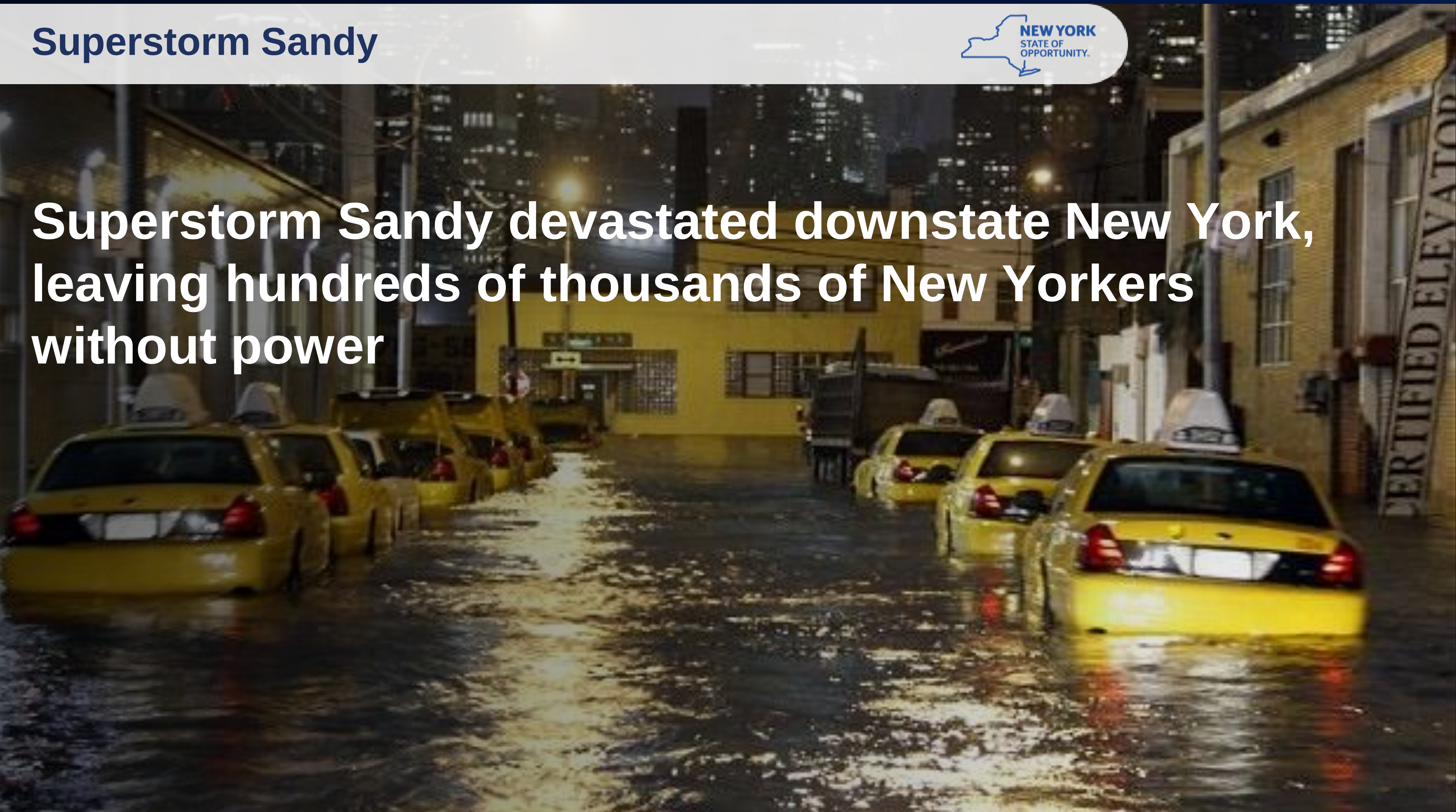
NEW YORK
STATE OF
OPPORTUNITY.™

Reforming the Energy Vision:
New York State's Approach

DOE Building Technology Office Peer Review Conference

April 30, 2018

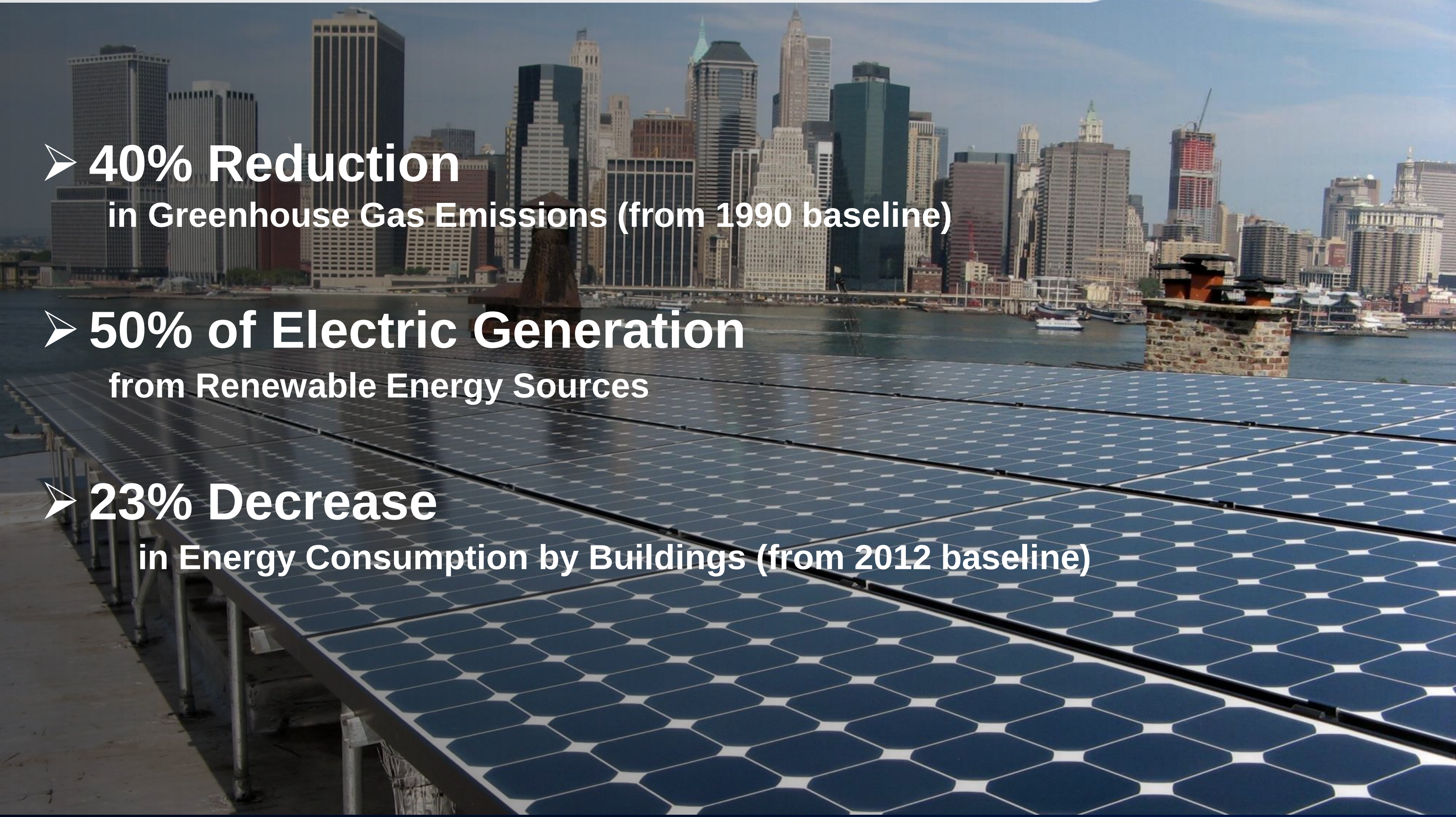
Superstorm Sandy



Superstorm Sandy devastated downstate New York, leaving hundreds of thousands of New Yorkers without power

NYS Energy Plan: 2030 Goals

NEW YORK STATE OF OPPORTUNITY.

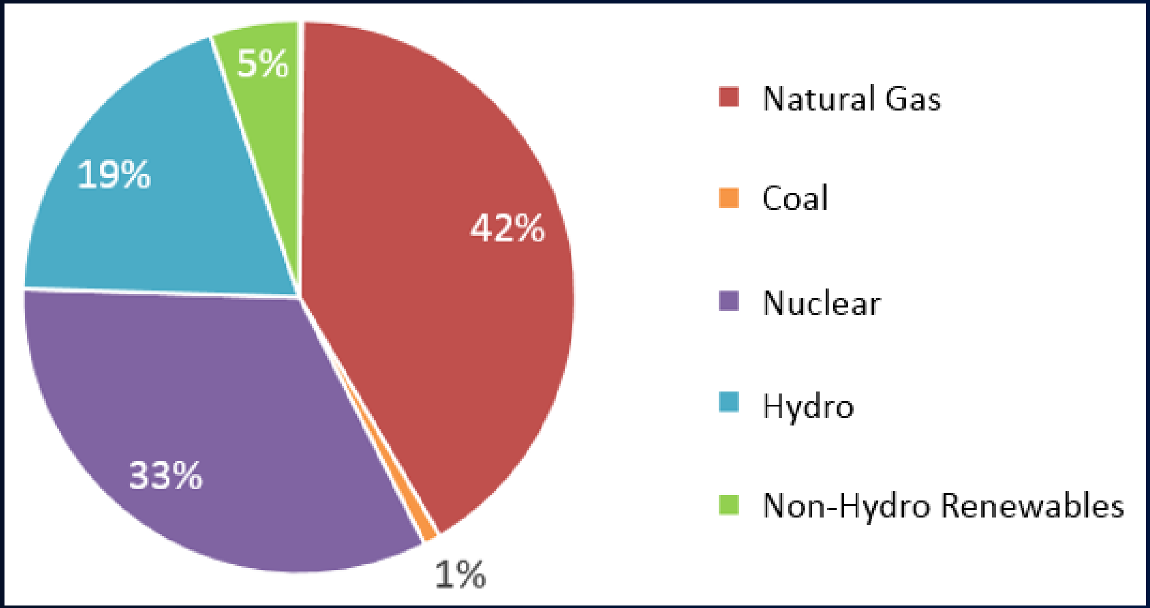


- **40% Reduction**
  in Greenhouse Gas Emissions (from 1990 baseline)

- **50% of Electric Generation**
  from Renewable Energy Sources

- **23% Decrease**
  in Energy Consumption by Buildings (from 2012 baseline)

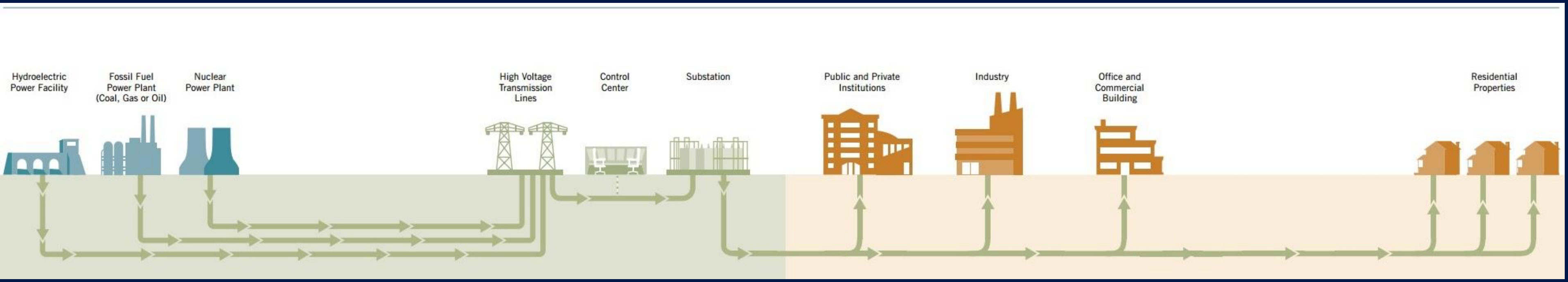
Background: New York State Electricity Mix



Regulated and Deregulated Markets

- Utilities in New York State **do not** own power plants
- Electricity **generation** is a competitive business, and financial returns come from market prices, not from a regulated rate of return
- Electric utilities just own transmission and distribution – the “wires”
- Utility compensation was based upon a pass through of operating costs plus a regulated rate of return on invested capital

Background: The Grid of Yesterday



Background: 20^{th} Century Grid

- Electrons flow in one direction from large power plants often over hundreds of kilometers to cities
- Supply is determined on a given day by a fixed estimate of demand

Background: Uncoordinated Distributed Energy Resources

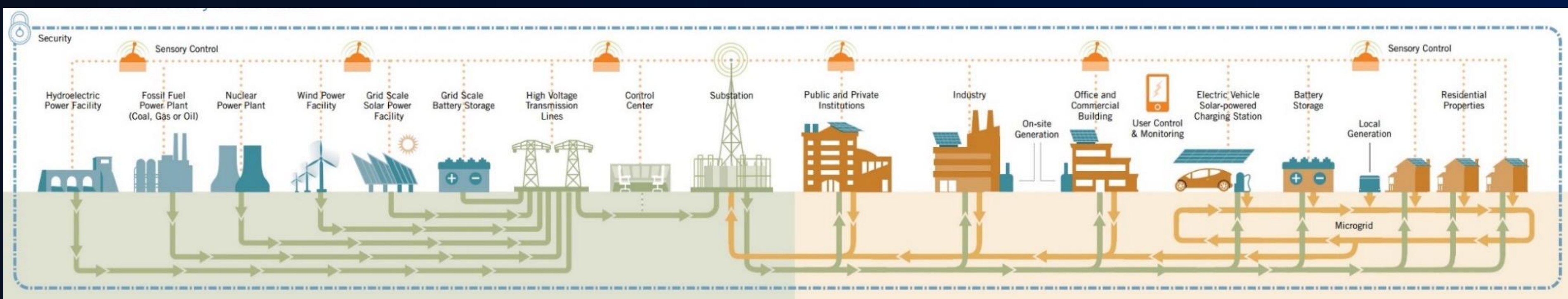
Good for DER host customers…

but good for all?

Challenge: Meeting the 50 Percent Mandate

- We cannot achieve the 50 percent renewable mandate by continuing to "bolt on" Distributed Energy Resources (DER) and renewable energy to a grid architecture that wasn't designed for those types of resources

Challenge: Creating the Grid of Tomorrow



Challenge: Creating the Grid of Tomorrow

Features of the 21st Century Grid:

- A mix between large power plants and DER
- Electrons flow in more than one direction
- Supply and demand are dynamic
- Intermittency of renewable resources are paired with storage and adjustable load

Challenge: Underutilized Assets

Capacity utilization of New York's electric grid is 54%

Other capital-intensive industries have seen increases to the mid-80% range

The Challenge

Low capacity utilization – the problem:
The grid is built for the hottest hours or days of the year, but customers pay all year long

Low capacity utilization – the opportunity:
Because the current grid is so financially inefficient, in New York State we can largely build the new grid within the “cost envelope” of the existing utility bill

REFORMING THE ENERGY VISION (REV)

Governor Cuomo's comprehensive strategy to build a clean, resilient and affordable energy system for all New Yorkers.

- Reforming the Utility Regulatory System
- Evolution of NYS Clean Energy Programs
  - Clean Energy Fund
- Leading by Example with the State's Assets

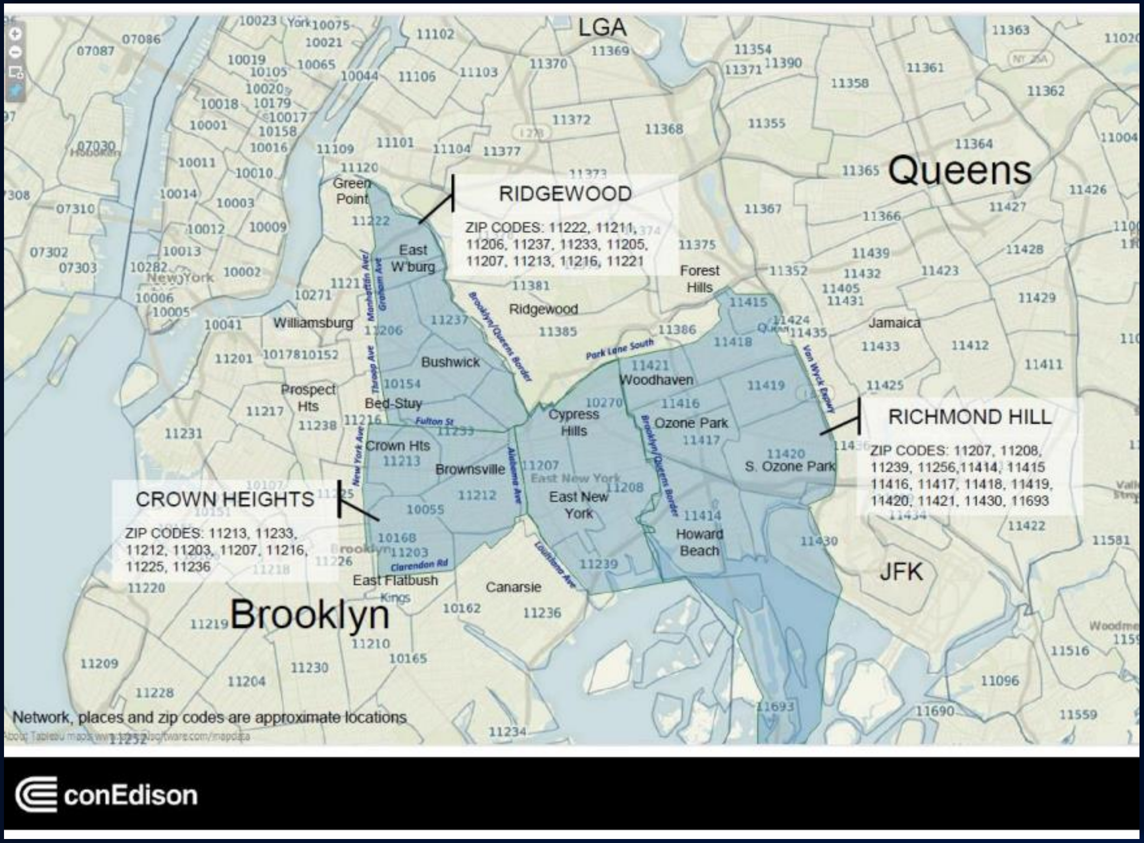
Traditional Utility Business Model:

- Through rates, utilities recover costs of providing service plus a regulated return on capital deployed (known as *rate based regulation*)
- The more capital deployed, the greater the profit
- The more capital deployed, higher rates unless there are more customers to share costs

Methods of Changing Compensation:

- “Performance Based Regulation”: determining rates of return based on achieving certain targets
- “Shared savings” models (Earnings Adjustment Mechanisms)
- “Non-Wires Alternatives” (and Non-Pipes Alternatives)

Four Ideas: Changing Utility Procurement Processes



Changing Utility Procurement Processes

- Under business-as-usual, the New York City utility (ConEd) would have built a $1.2 billion dollar substation to meet growing demand in Brooklyn and Queens.

- Under REV's reformed financial incentives, ConEd allowed third-party innovators to propose DER solutions like solar, storage, combined heat and power (CHP), and efficiency to meet demand.

- The portfolio of DER solutions selected by ConEd will meet the growing demand, defer the need for a new substation, and cost in aggregate $200 million, saving all ConEd customers money because less capital is deployed and system peak is reduced.

CLEAN ENERGY FUND (CEF)

- 10-year, $5 billion State funding commitment to support REV
- Reshapes New York’s clean energy programs
  - Incentive based ⟶ Market Transformation
- Reduce the market cost of deploying clean energy solutions
- Accelerate the market’s rate of adoption
- Mobilize private investment in clean energy
  - New York Green Bank
  - NY Sun

High Performance Buildings

NEW YORK STATE OF OPPORTUNITY.

- To reach scale, we must capture all available economics:
- Grid Benefits
  - Permanent – long term load reduction through ultra low load profiles
  - Temporary – Demand Response
- Rate Design – Behavior
- Carbon Benefits – social cost of carbon
  - Heat pumps absorbing excess capacity
- Health Benefits – Medicaid Redesign
- Microgrids ⇨ Innovation Districts
- Net Zero Buildings ⇨ Net Zero Communities ⇨ Net Zero NY State

SOLAR ENERGY
TECHNOLOGIES OFFICE
U.S. Department Of Energy

BTO Peer Review

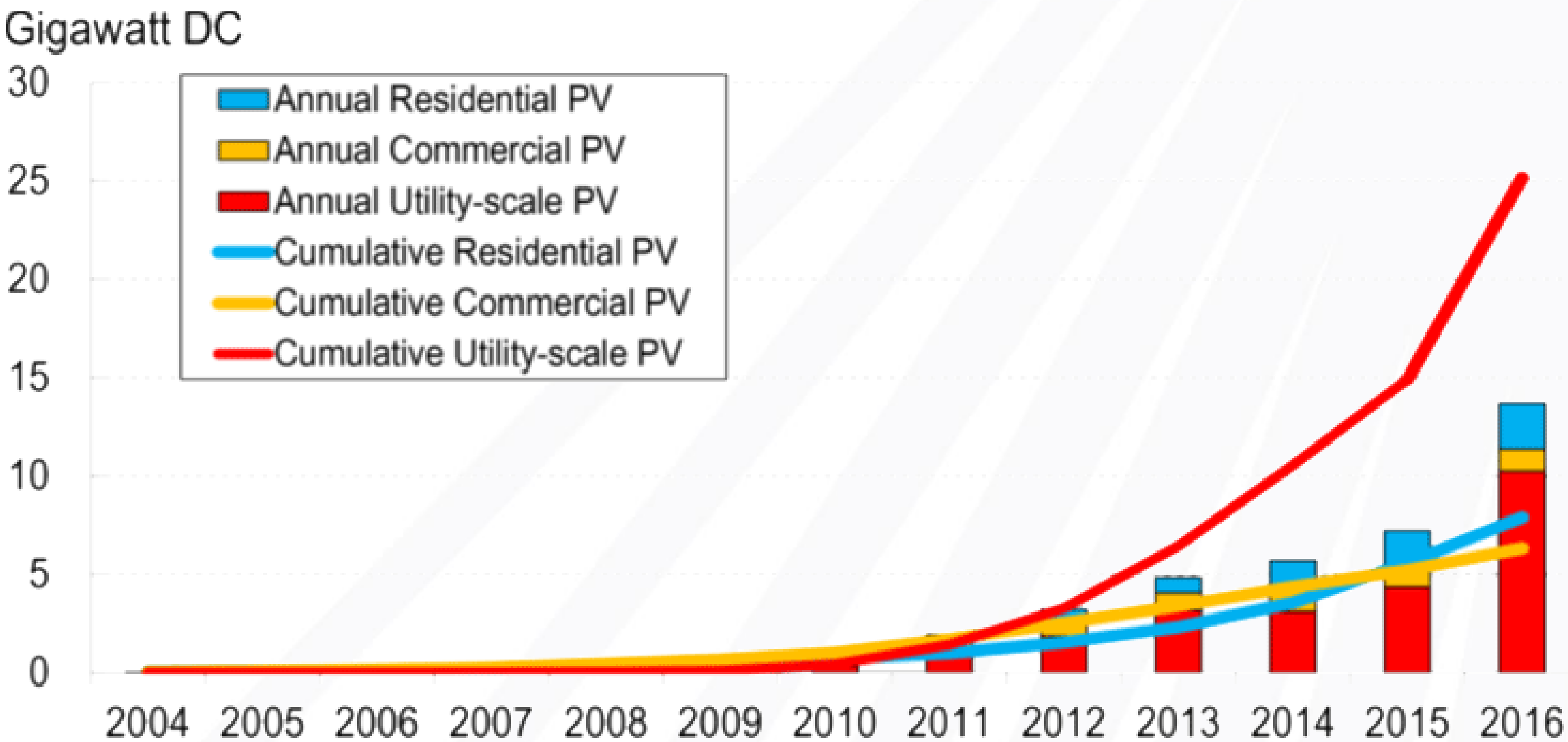
Solar Photovoltaics for Better Functioning and more Resilient Buildings and Grid

Charlie Gay
Director
30 April 2018

US PV Market

- Annual U.S. PV installations grew 100x from 2006 to 2017, with over 50 GW-DC of cumulative installations
  - In 2017 PV represented 29 % of all new U.S. generating capacity
- The U.S. energy market consists of many different state, regional, and local markets
  - PV is much more competitive in certain areas and penetration levels vary dramatically California, which has represented approximately ½ of the U.S. market, received approximately 16% of its electric generation from solar in 2017.

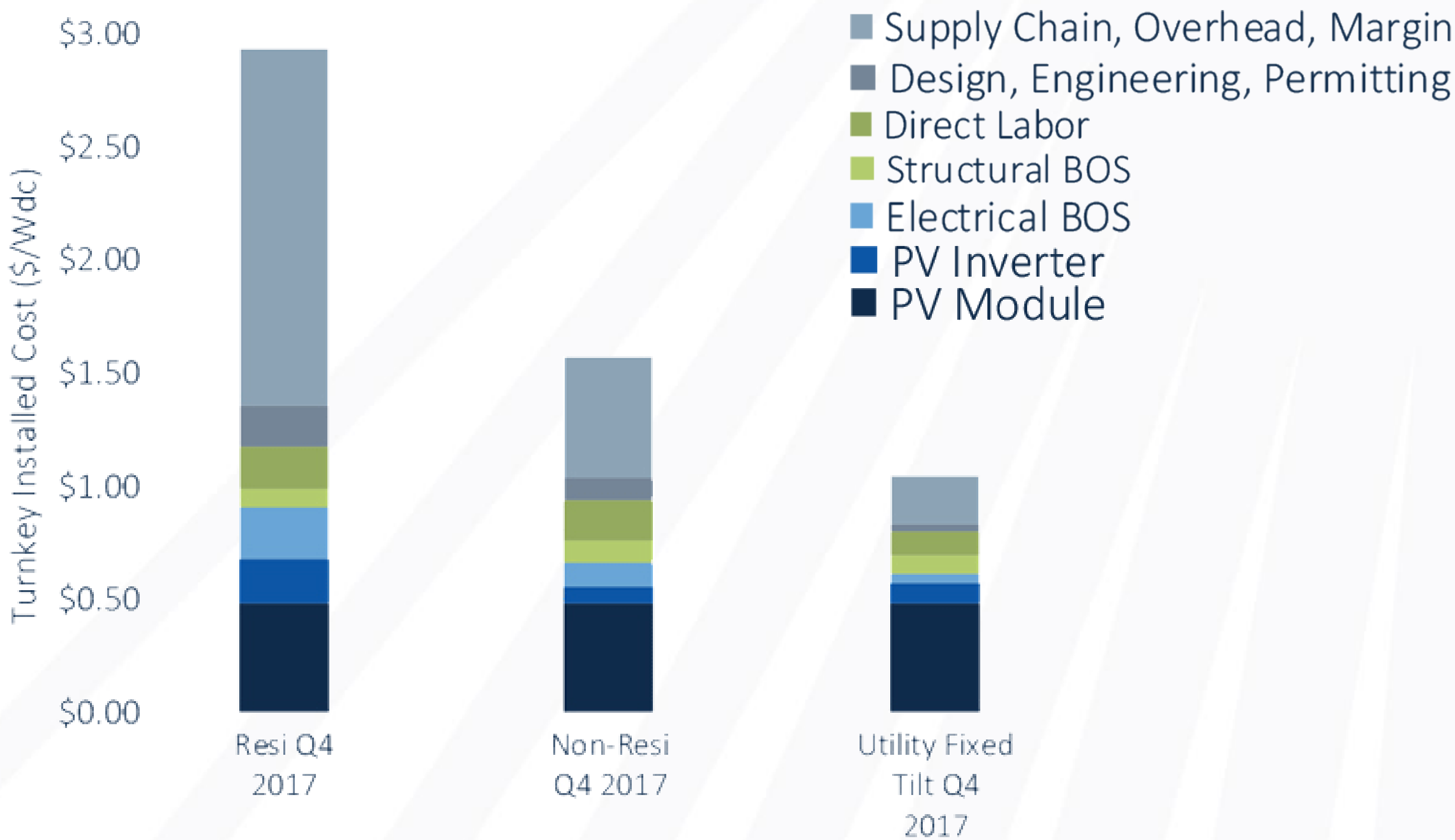
US Solar PV Market Growth



U.S. PV market growth, 2004–2016, in gigawatts of direct-current (DC) capacity (Bloomberg 2017)

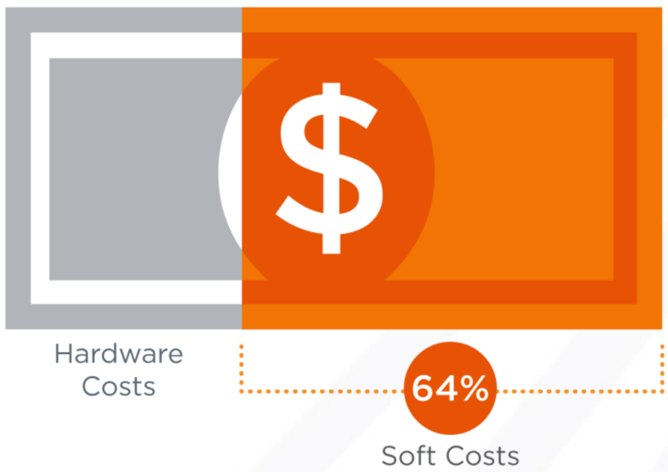
Source: NREL/PR-6A20-68580

Modeled U.S. National Average System Costs by Market Segment, Q4 2017



Source: GTM

Balance of Systems (Soft Costs)



4%
Permitting, Inspection, Interconnection (and associated fees)

9%
Marketing/Customer Acquisition

11%
Labor

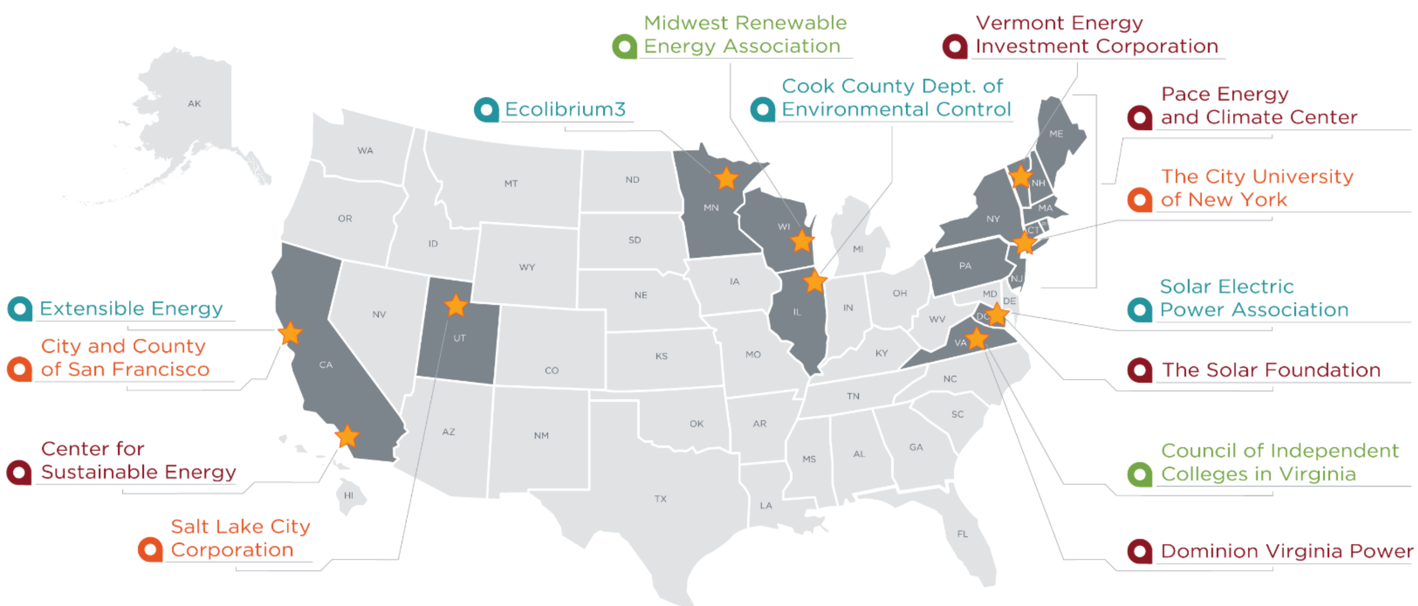
11% -%
Financing

30%
Supply chain, overhead, margin ("Corporate Costs & Profit")

Solar Market Pathways

The Solar Market Pathways Program brings together 14 diverse teams under a single goal:

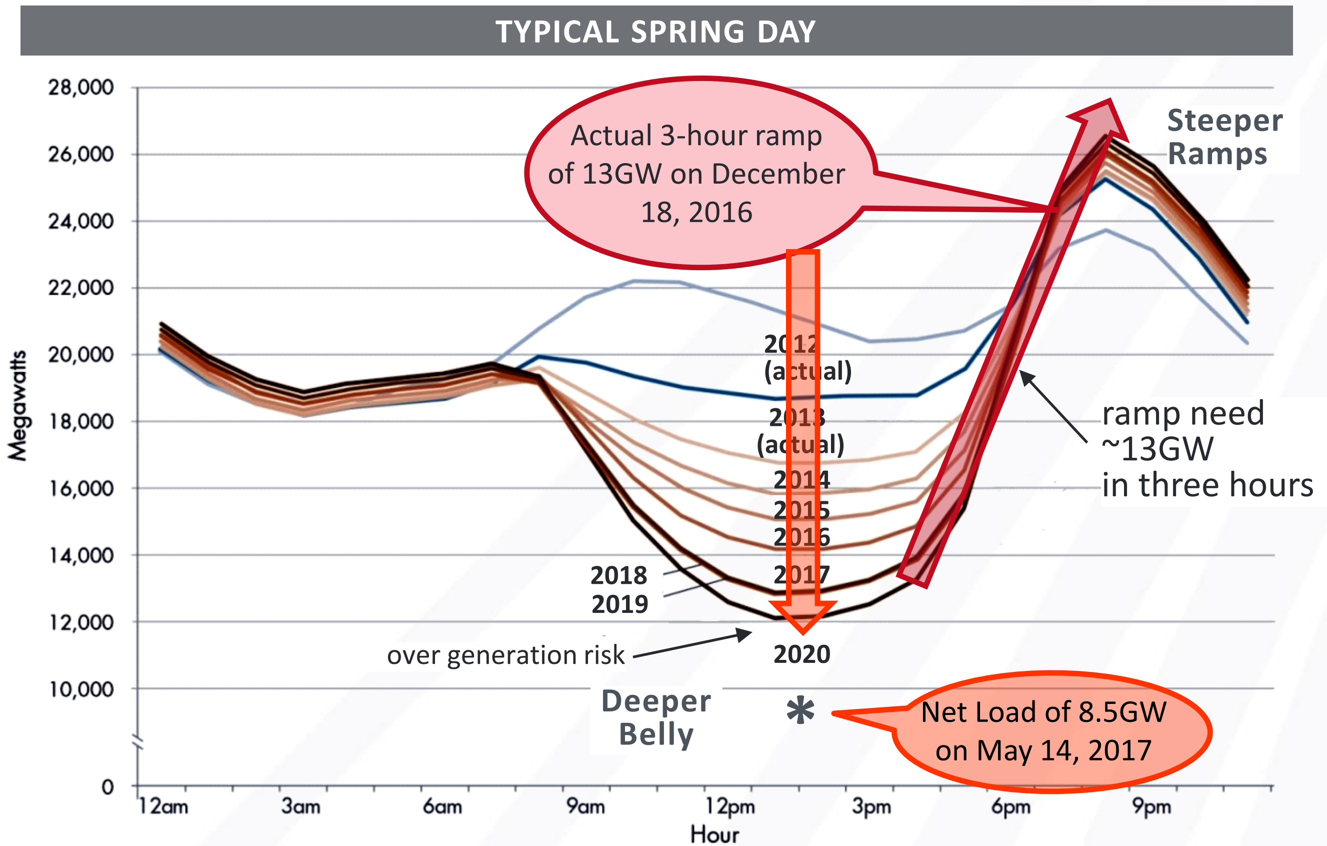
SHARE BEST PRACTICES TO REDUCE SOLAR'S SOFT COSTS.



Program Strategies:

- Expanding Community Solar
- Enhancing Resiliency
- Deploying Solar on Campuses
- Supporting Strategic Planning

Inflexible Solar Saturation Already Evident on the CAISO Grid



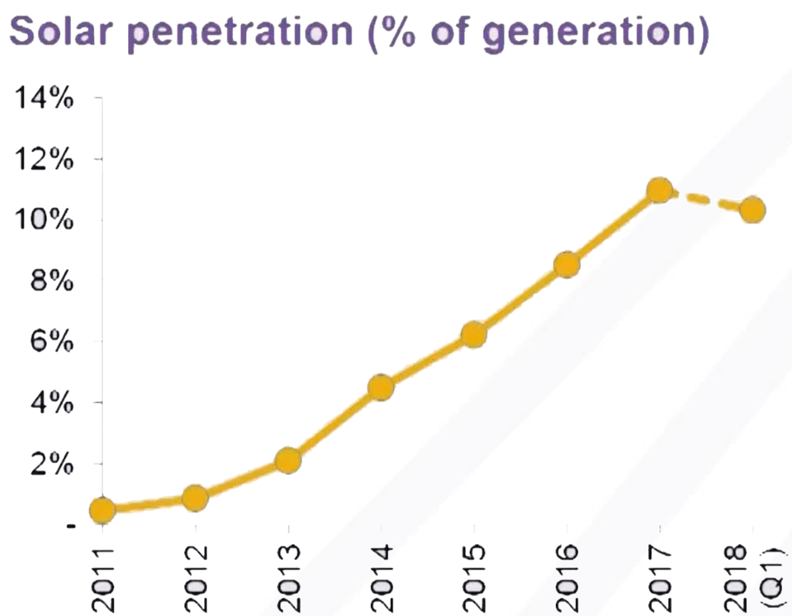
- The "duck" chart elegantly captures oversupply misperception
- Two Concerns:
  - Low Net Load: flexibility to reduce must-run generation resources is limited
  - High Ramp Rates in Evening: flexibility of other generation to ramp up is limited

SOLAR ENERGY TECHNOLOGIES OFFICE U.S. Department Of Energy

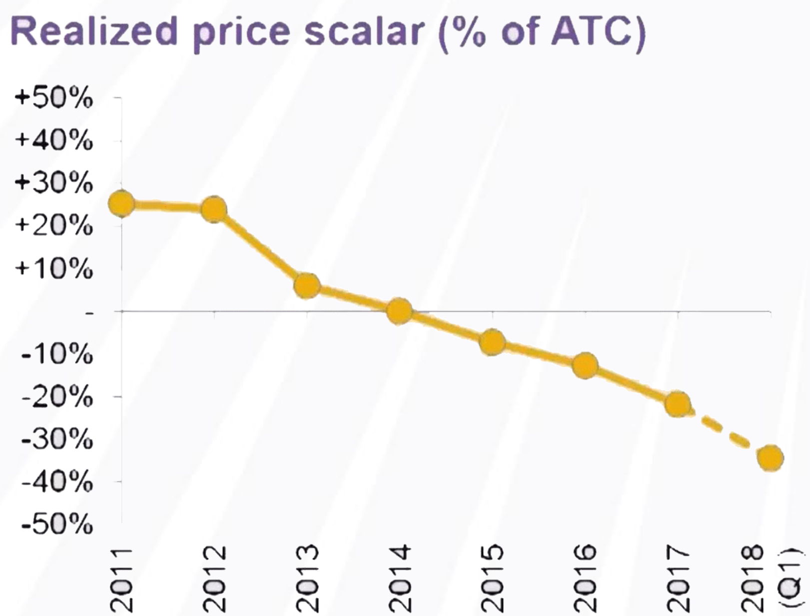
SOLAR ENERGY TECHNOLOGIES OFFICE U.S. Department Of Energy

Challenges : Curtailment

California Independent System Operator Data



Includes utility-scale solar only. Does not include behind-the-meter.

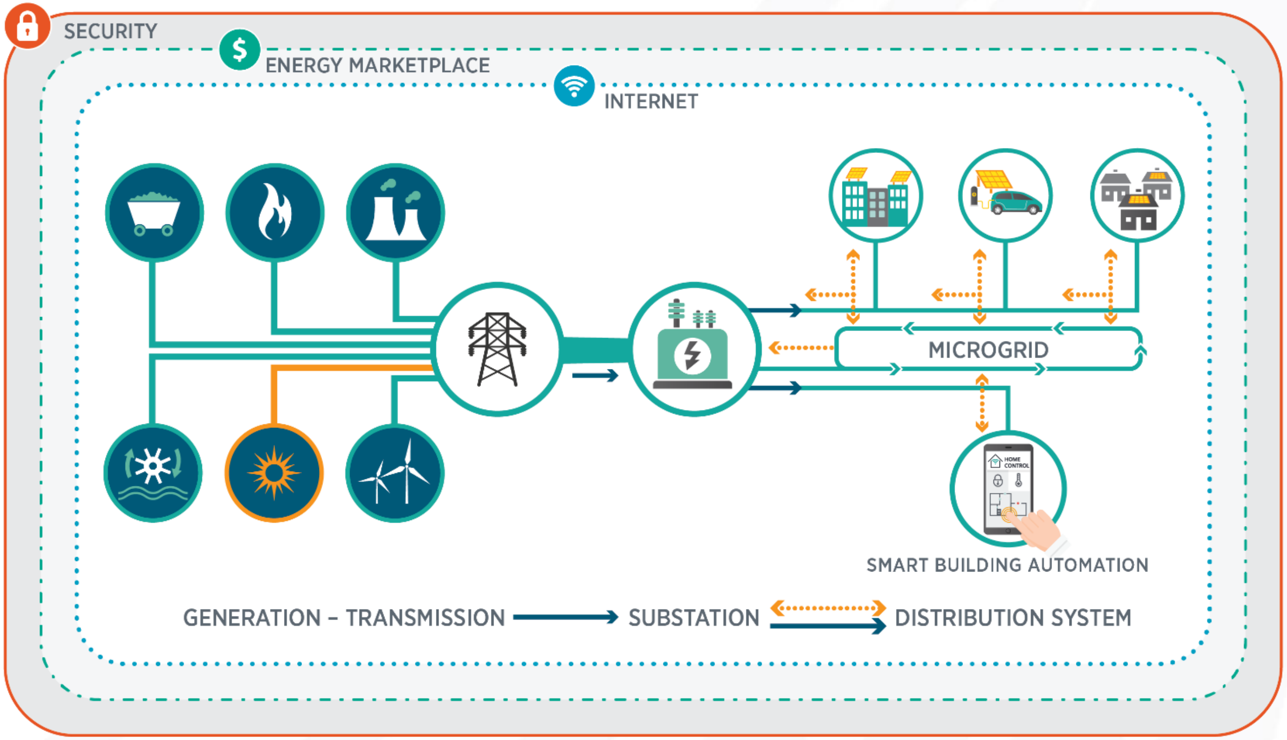


Measured against Day-Ahead, SP15 power prices.

SOLAR ENERGY TECHNOLOGIES OFFICE
U.S. Department Of Energy

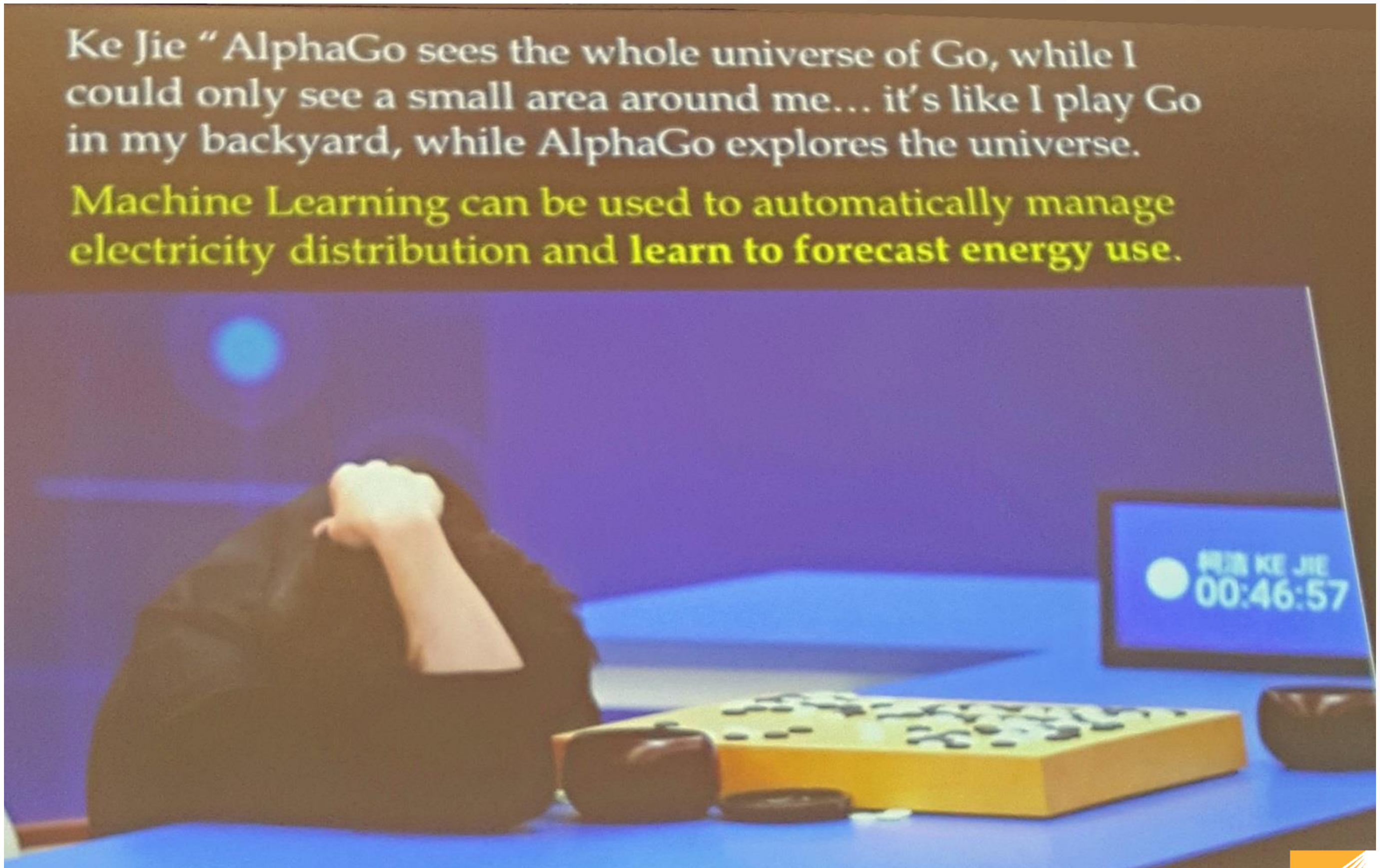
SOLAR ENERGY TECHNOLOGIES OFFICE
U.S. Department Of Energy

Modern Electric Grid: Two Way Energy and Data Flow



Goal: Centralized and distributed generation optimized with finely tuned, 2-way load balancing

Role of Artificial Intelligence



SOLAR ENERGY
TECHNOLOGIES OFFICE
U.S. Department Of Energy

Connections : Why we Need Each Other

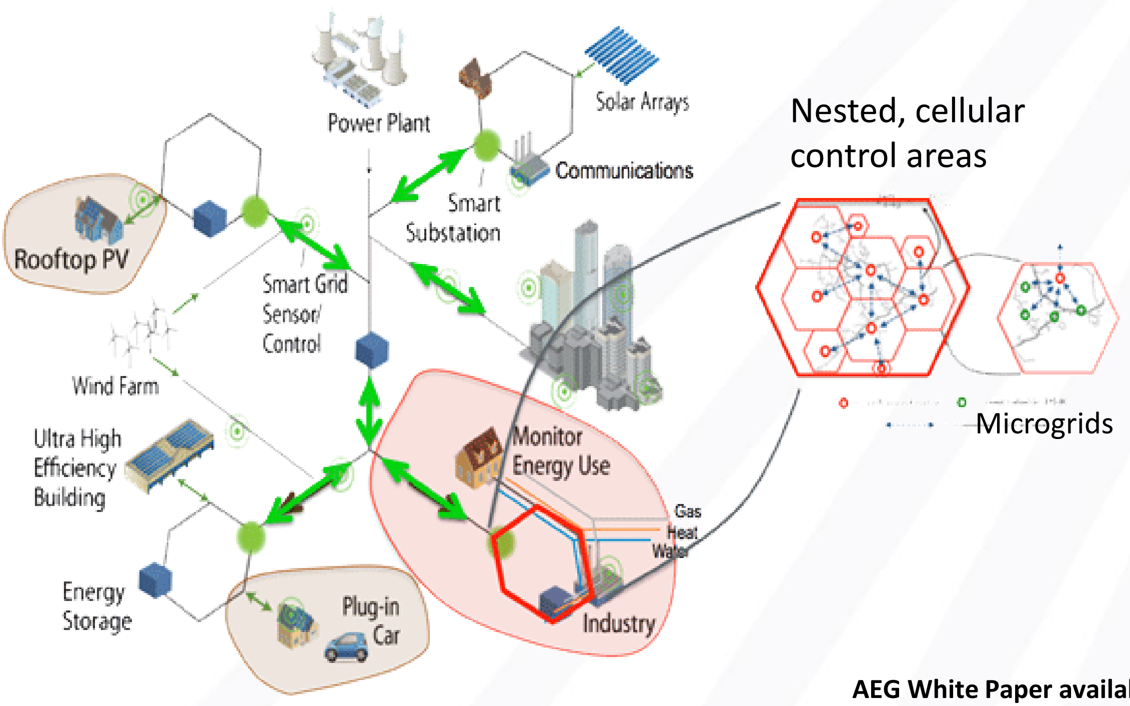
- Electricity is not easily stored in native form
- Need to convert to some other form (chemical, mechanical, thermal) to store energy

- There are alternatives to energy storage
  - Generator ramping (constrained by min/max operational levels and ramp speed)
  - Load ramping (constrained by customer needs)
  - Geographic electricity moving/shifting (transmission)

SOLAR ENERGY TECHNOLOGIES OFFICE U.S. Department Of Energy

Autonomous Energy Grids (AEGs)

Optimized for secure, resilient and economic operations



Key Features of AEGs

- **Autonomous** – Makes decisions without operators
- **Resilient** – Self-reconfiguring, cellular building blocks, able to operate with and without communications
- **Secure** – Incorporates cyber and physical security against threats
- **Reliable and Affordable** - Self optimizes for both economics and reliability
- **Flexible** – Able to accommodate energy in all forms including variable renewables

AEG White Paper available at:
https://www.nrel.gov/docs/fy18osti/68712.pdf

Edison Electric INSTITUTE

EV's and Grid-interactive Efficient Buildings (GEB)

DOE 2018 Building Technologies Office Peer Review

April 30, 2018

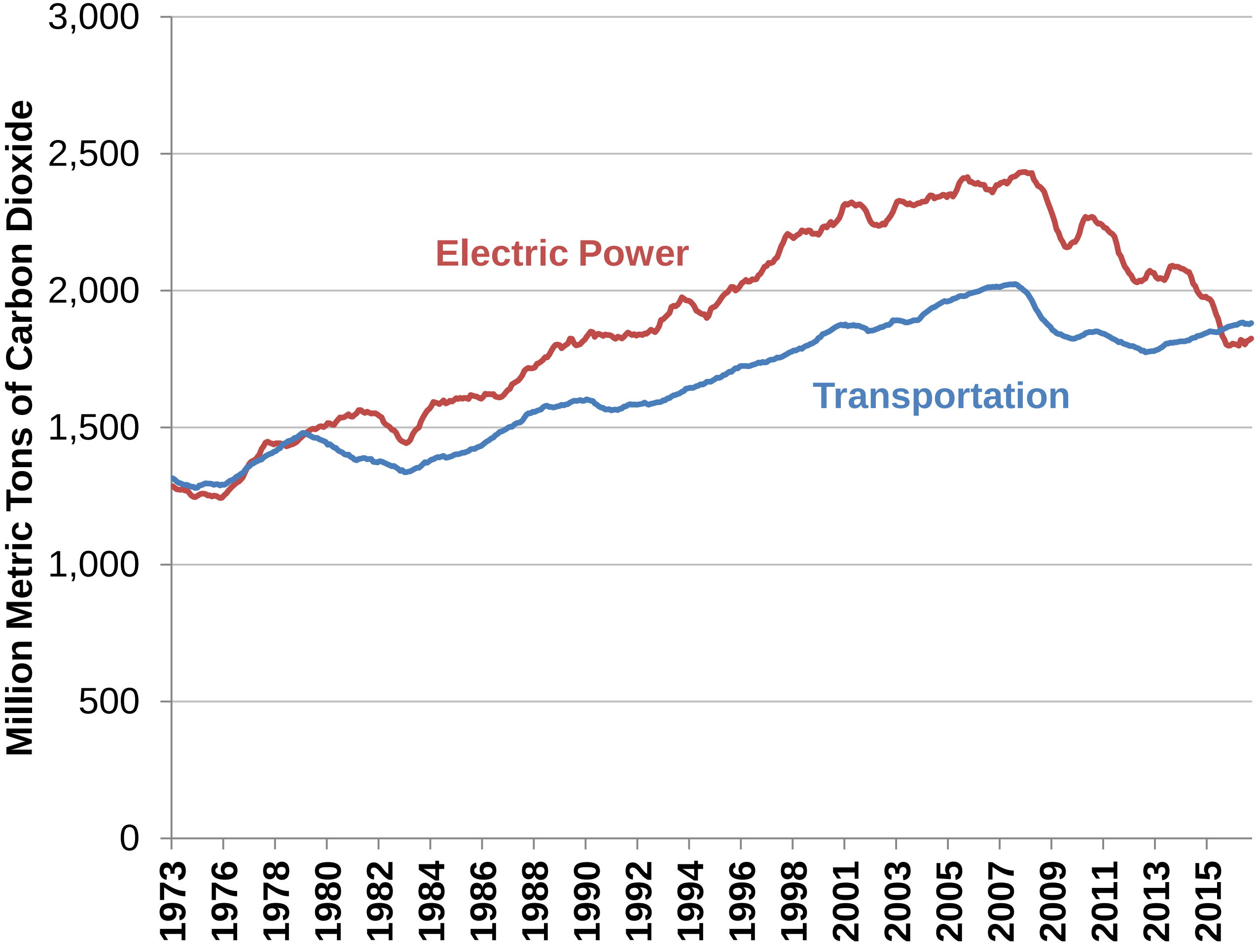
Arlington, VA

Steve Rosenstock, P.E.

Overview

- Status of US electric vehicle market today
- Strategies for EV's at GEBs
- Impacts of Different Strategies

CO_2 Emissions



Electric Power

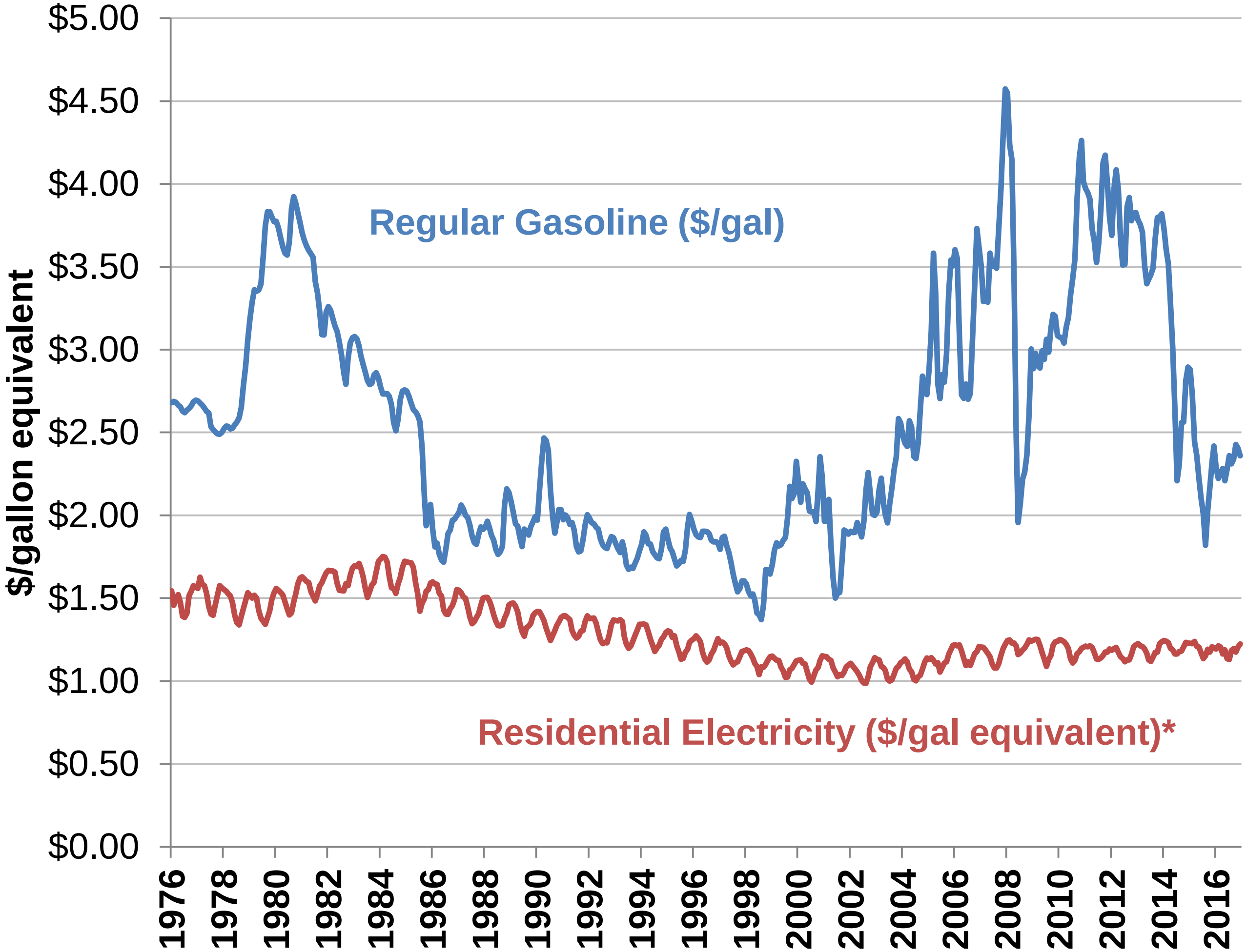
27% reduction from 2005 levels by end of 2017

Transportation

decreased 10% 2005-2012, but increased 7% from 2012 through 2017

SOURCE: EIA, *August 2017 Monthly Energy Review*

Fuel Costs



Electric Power

approx. **2X** price advantage

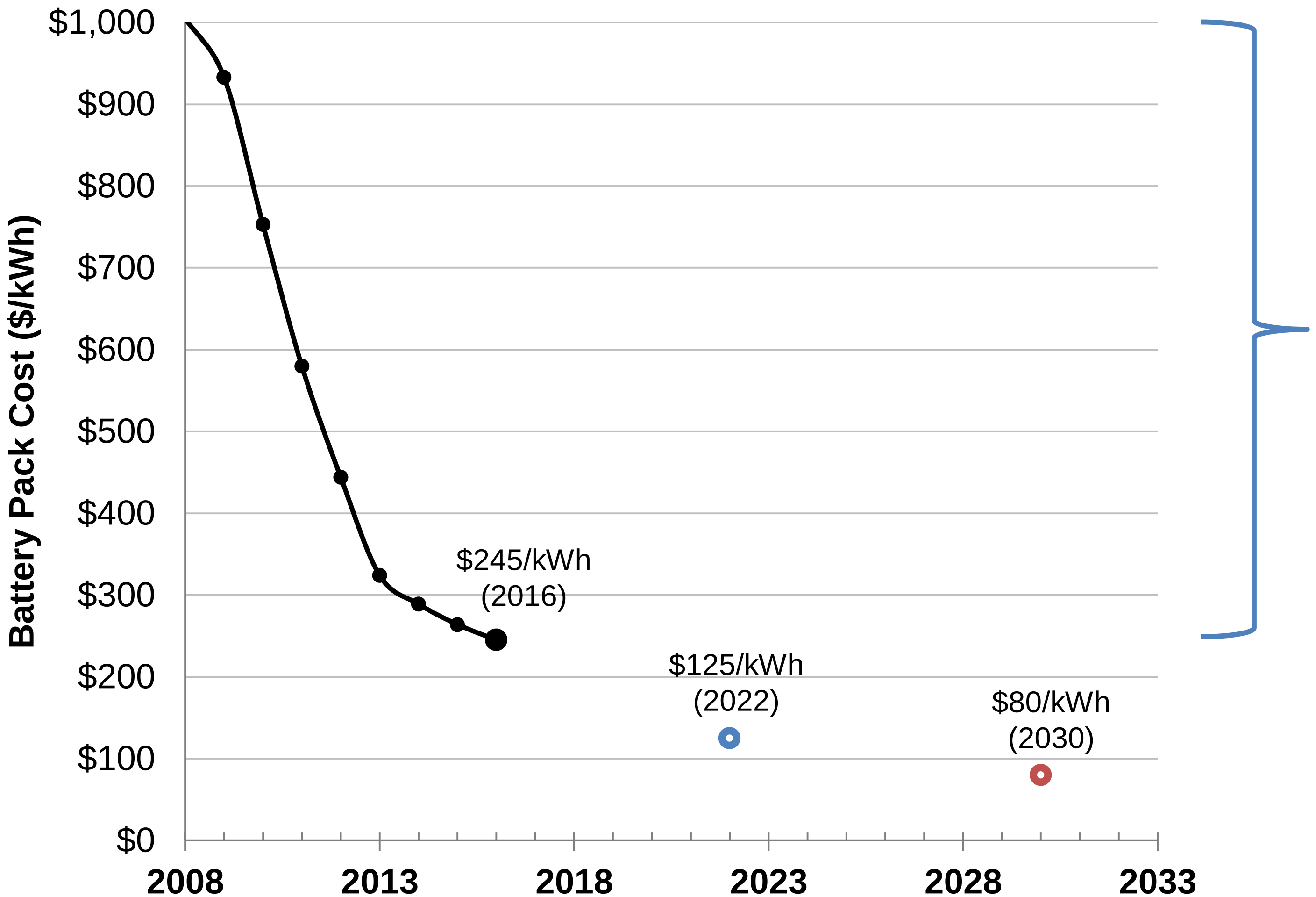
Gasoline

volatile, global commodity

*Equivalent electricity price assumes average vehicle fuel economy of 27.9 mpg, PEV efficiency of 0.33 kWh/mi

SOURCE: EIA, *Short-Term Energy Outlook, September 2017*

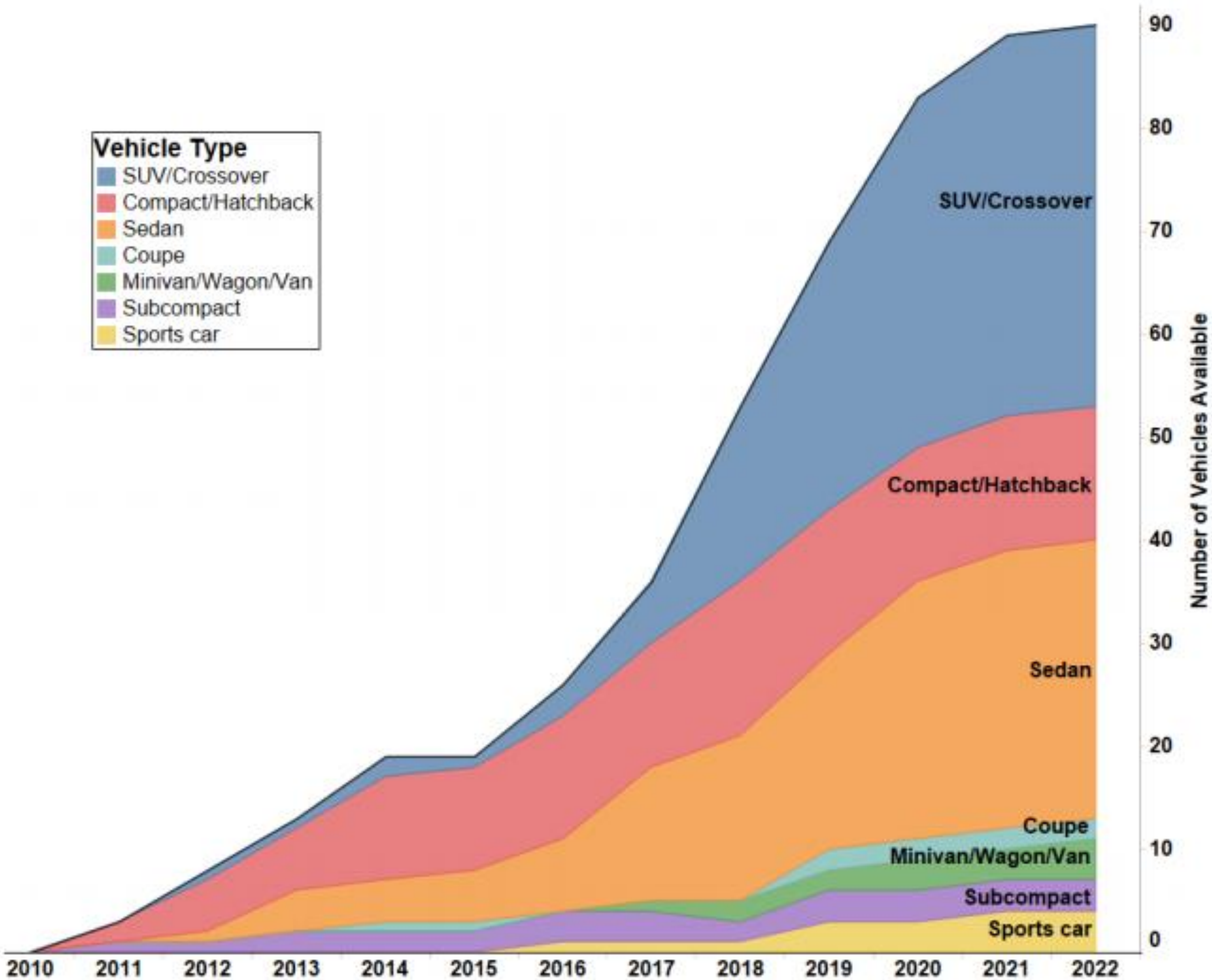
Battery Cost



75%
modeled battery pack cost reduction (2008-2016)

SOURCE: U.S. Department of Energy, Vehicles Technology Office

Growth in EV Models



The number and variety of electric vehicle models continues to grow. By the end of 2018, about 53 different models are expected to be available. By 2022, at least 90 models are projected.

SOURCE: EPRI, *A U.S. Consumer's Guide to Electric Vehicles.*

Inside EV's: As of March 2018, there are 53 models for sale in at least some parts of the US.

Sales Progress

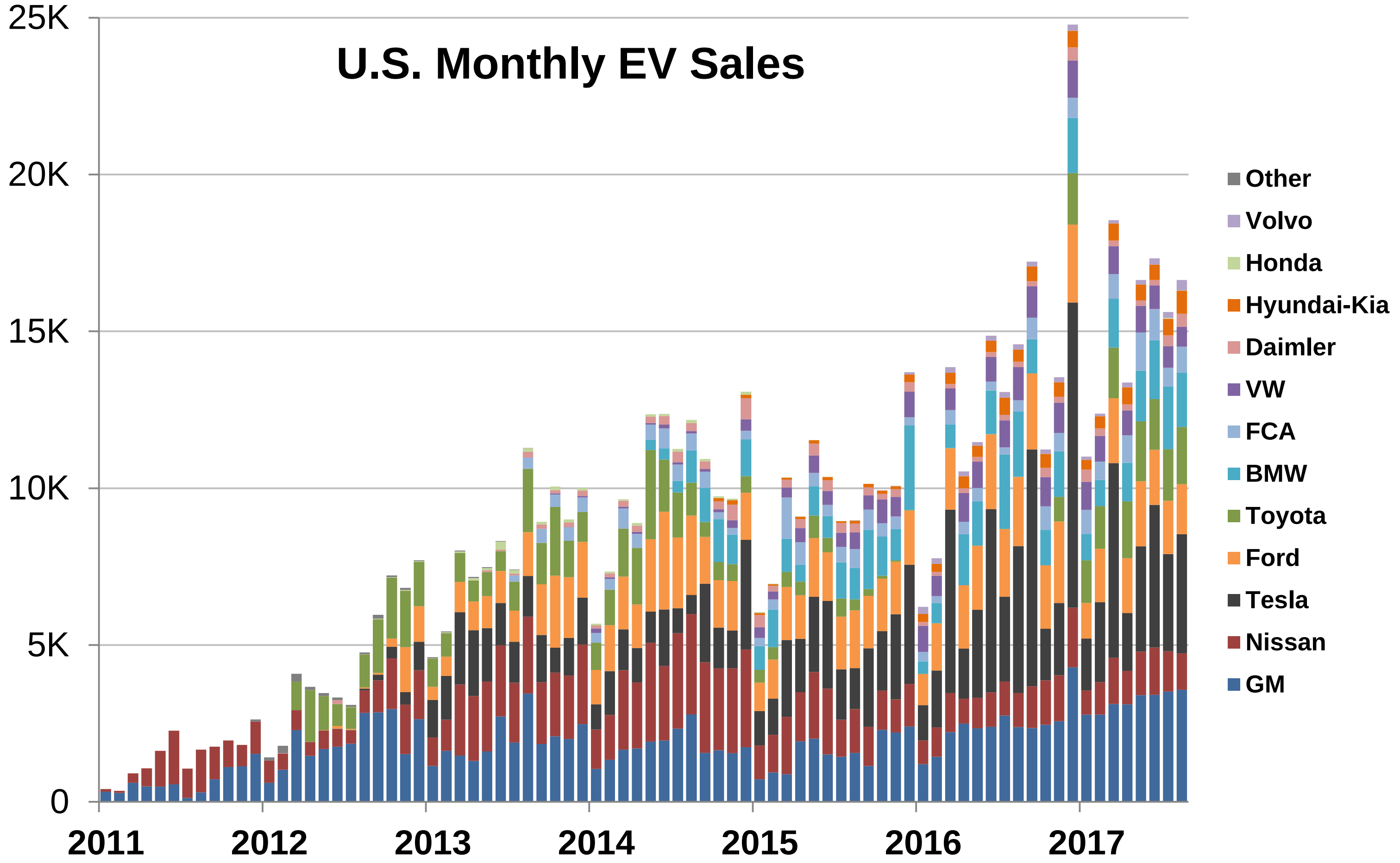
764,000+
sales since Dec. 2010

+32%
2018 sales YTD vs. '17

March 2018: over **26,300** sold/leased

53
PEV models

20
auto brands



SOURCE: Sales data from InsideEVs.com and HybridCars.com

EV Forecast

If these companies meet their stated EV sales goals…

…how many EVs would these companies need to sell to meet the forecast?

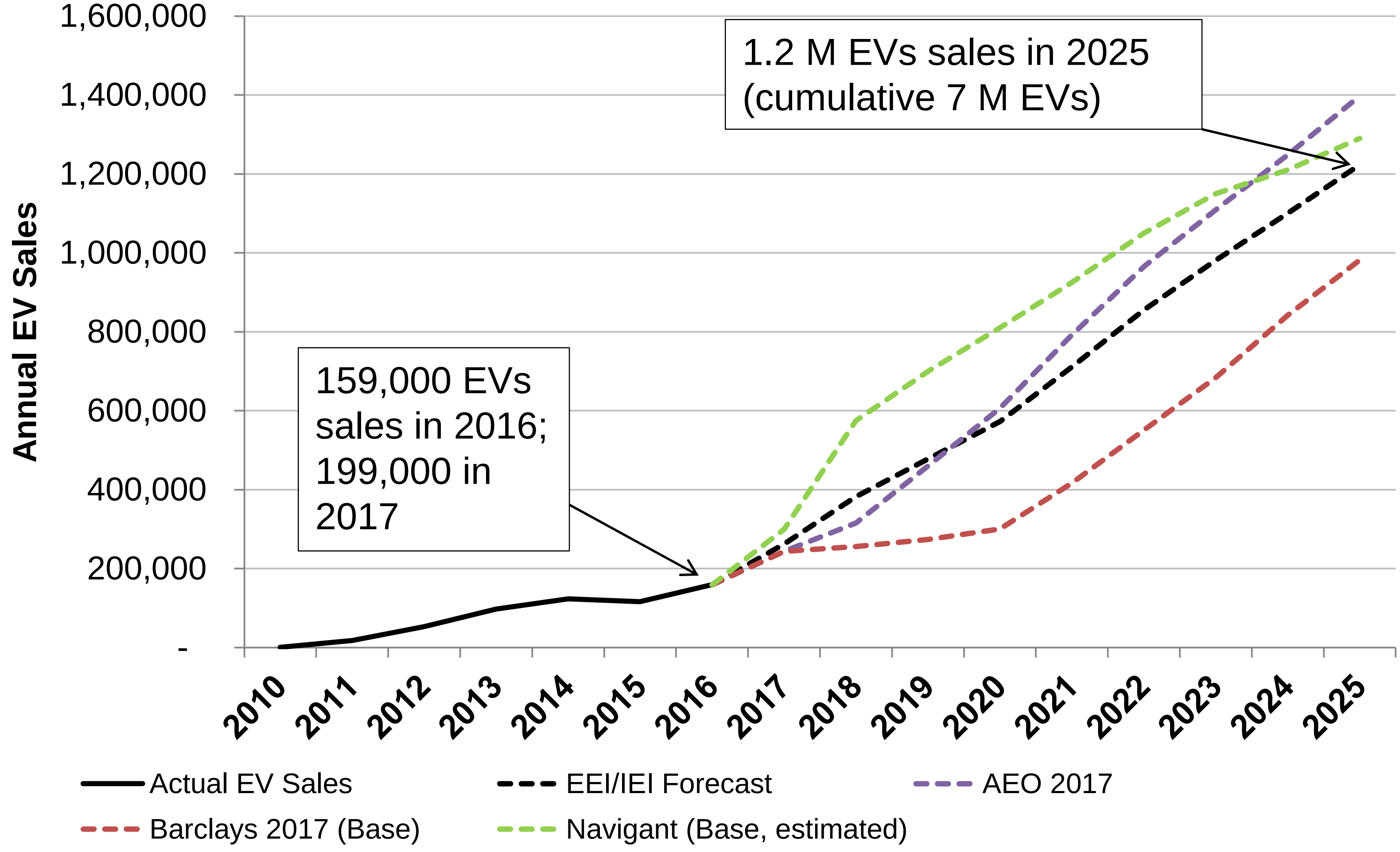
	EV % in 2016	EV % in 2025	EV Sales in 2025	Total Sales in 2025
Tesla, BMW, Mercedes-Benz, Volkswagen, Volvo	5.5%	30+ %	520 K	1.8 M
Fiat-Chrysler, Ford, General Motors, Honda, Hyundai-Kia, Nissan, Toyota	0.5%	~ 5 %	710 K	14.8 M
	1.0%	7%	**1.2 M**	**16.6 M**

SOURCE: IEI and EEI, *Plug-in Electric Vehicle Sales Forecast Through 2025 and the Charging Infrastructure Required*

Recent EV Announcements

GM plans 20 new all-electric models by 2023	Wired: *General Motors is Going All Electric*
Ford creates “Team Edison” to lead EV development	CNBC: *Ford creates team to ramp up electric vehicle development*
VW to invest $24 B by 2030; 80 new EVs by 2025	Reuters: *Volkswagen spends billions more on electric cars in search for mass market*
BMW plans 12 all-electric models by 2020	CNBC: *BMW readies mass production of electric cars, 12 models by 2020*
Mercedes-Benz to invest $1 B in Alabama plant; 50 hybrid or electric vehicles by 2022	USA Today: *Mercedes-Benz makes a $1B bet it can take down Tesla*
Volvo: all new models in 2019+ hybrid or electric	NY Times: *Volvo, Betting on Electric, Moves to Phase Out Conventional Engines*
Jaguar-Land Rover plans all new models in 2020+ to be available as hybrid or electric	Reuters: *All new Jaguar Land Rover cars to have electric option from 2020*
Nissan-Renault plans 12 all-electric models by 2022	Bloomberg: *A Spark for the Electric Car Revolution*
China phasing in EV quotas, ~ 5% of sales by 2020	Bloomberg: *China Gives Automakers More Time in World’s Biggest EV Plan*
France, Britain plan to end ICE sales by 2040	NY Times: *Britain to Ban New Diesel and Gas Cars by 2040*

EV Forecast



SOURCE: IEI and EEI, *Plug-in Electric Vehicle Sales Forecast Through 2025 and the Charging Infrastructure Required*

Strategies for EV's in GEBs

- **What are you trying to do?**
- *Managed charging* (G2V or Bldg Renewable Electric to Vehicle, BRE2V). Also known as demand response or load management.
- *Emergency backup power* – Enable the export of vehicle power to assist in building or grid outages and even disaster-recovery efforts. V2B or V2G or V2RE
- *Local power quality* – Enhance local power quality and improve grid stability in scenarios with a high concentration of renewables. V2G Ancillary Services
- *Bi-directional power flow* – Integrated V2B or V2G systems for reducing building peak power demands or assisting the grid.

Strategies for EV's in GEBs (1)

- *Managed charging*
- Reduce (or increase) charging rate during key times
  - From 5% to 100%
- Advantages:
  - Easy to accomplish
  - Lowest installation / operation / control costs
  - Vehicle gets at least some charging before event
  - No impact on battery life (all vehicles can handle Level 1 charge at 1.6 kW or Level 2 charge at 3.3, 6.6, or 19.2 kW)
- Disadvantages:
  - Lower / lowest coincidence factor (battery full before event)
  - Possible complaints if vehicle owner is paying per charge

Strategies for EV's in GEBs (2)

- *Emergency Backup Power*
- Export vehicle power to assist in building / grid outages
- Advantages:
  - Provide critical power that is mobile
  - Backup to on-site emergency generation
- Disadvantages:
  - Higher installation / operation infrastructure costs
  - Vehicle may have low / no charge after event
  - Third party vehicle owner concerns
  - Discharge rate may be too low for certain equipment
  - Battery capacity may be too low (6 to 100 kWh)
  - Limited time of operation

Strategies for EV's in GEBs (3)

- *Local Power Quality*
- Enhance local power quality and improve grid stability
- Advantages:
  - Applications can be temporary (lasting only minutes)
  - Quick response
  - Helps with more variable generation sources
- Disadvantages:
  - Higher installation / operation infrastructure costs
  - Higher number of charging or discharging events, may impact battery life if # of events (not depth) is an issue
  - Third party vehicle owner concerns
  - Vehicle may have low / no charge after event
  - Discharge rate may be too low at certain times
  - Limited time of operation for use of EV battery

Strategies for EV's in GEBs (4)

- ***Bi-Directional Power Flow***
- Reduce building peak kW demand or assist the grid
- Advantages:
  - Possible economic "win-win" for building and vehicle owner
  - Help reduce building "spike" peak kW demands
- Disadvantages:
  - Higher installation / operation infrastructure costs
  - Vehicle may have low / no charge after event
  - Third party vehicle owner concerns
  - Discharge rate may be too low for certain equipment
  - Battery capacity may be too low (6 to 100 kWh)
  - Limited time of operation for use of EV battery
  - Much higher number of charging or discharging events, may impact battery life and capacity

The Edison Electric Institute (EEI) is the association that represents the U.S. investor-owned electric industry. Our members provide electricity for 220 million Americans, operate in all 50 states and the District of Columbia, and directly employ more than 500,000 workers. Safe, reliable, affordable, and clean electricity powers the economy and enhances the lives of all Americans.

The EEI membership also includes dozens of international electric companies as International Members, and hundreds of industry suppliers and related organizations as Associate Members.

Since 1933, EEI has provided public policy leadership, strategic business intelligence, and essential conferences and forums for the energy industry.

For more information, visit our Web site at www.eei.org.

Kellen Schefter
kschefter@eei.org

EEI
Edison Electric Institute
701 Pennsylvania Avenue, NW
Washington, D.C. 20004-2696
202-508-5000 | www.eei.org

Q & A

Moderated & Open Discussion