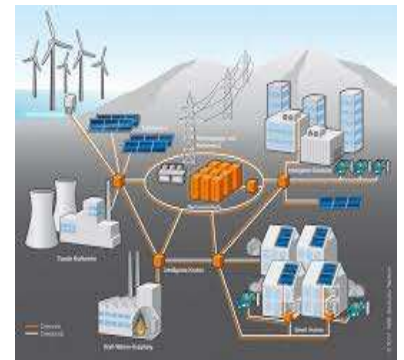


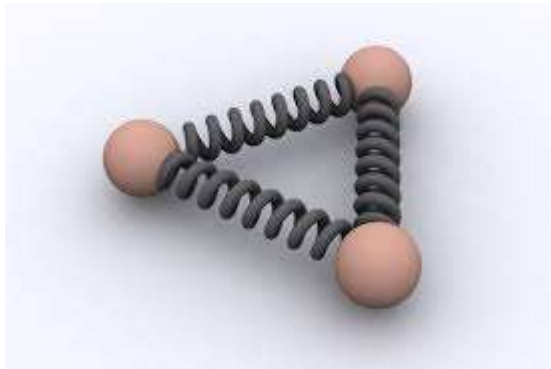
Customer Assets – A New Era in the Electricity Industry



Oct 2015



Life During my PAI Years



Slow
Fast
Decoupling
Singular Perturbations
Manifolds

••



$$-k_1 x_1 + k_2(x_2 - x_1) = m_1 \frac{d^2 x_1}{dt^2}$$

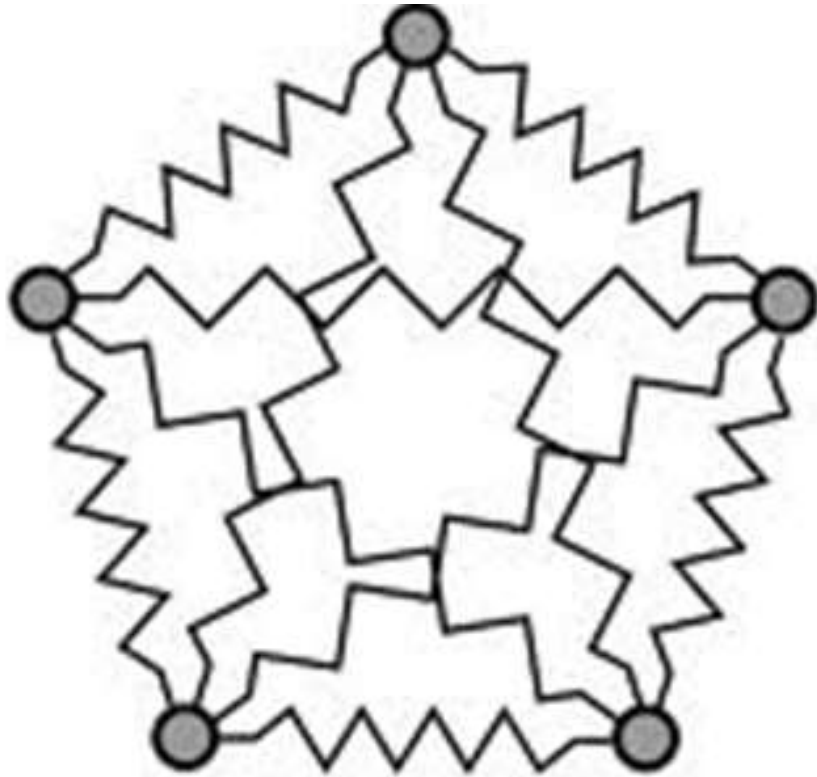
$$-k_1 x_1 + k_2 x_2 - k_2 x_1 = m_1 \frac{d^2 x_1}{dt^2}$$

$$-(k_1 + k_2)x_1 + k_2 x_2 = m_1 \frac{d^2 x_1}{dt^2}$$

$$-m_1 \frac{d^2 x_1}{dt^2} - (k_1 + k_2)x_1 + k_2 x_2 = 0$$

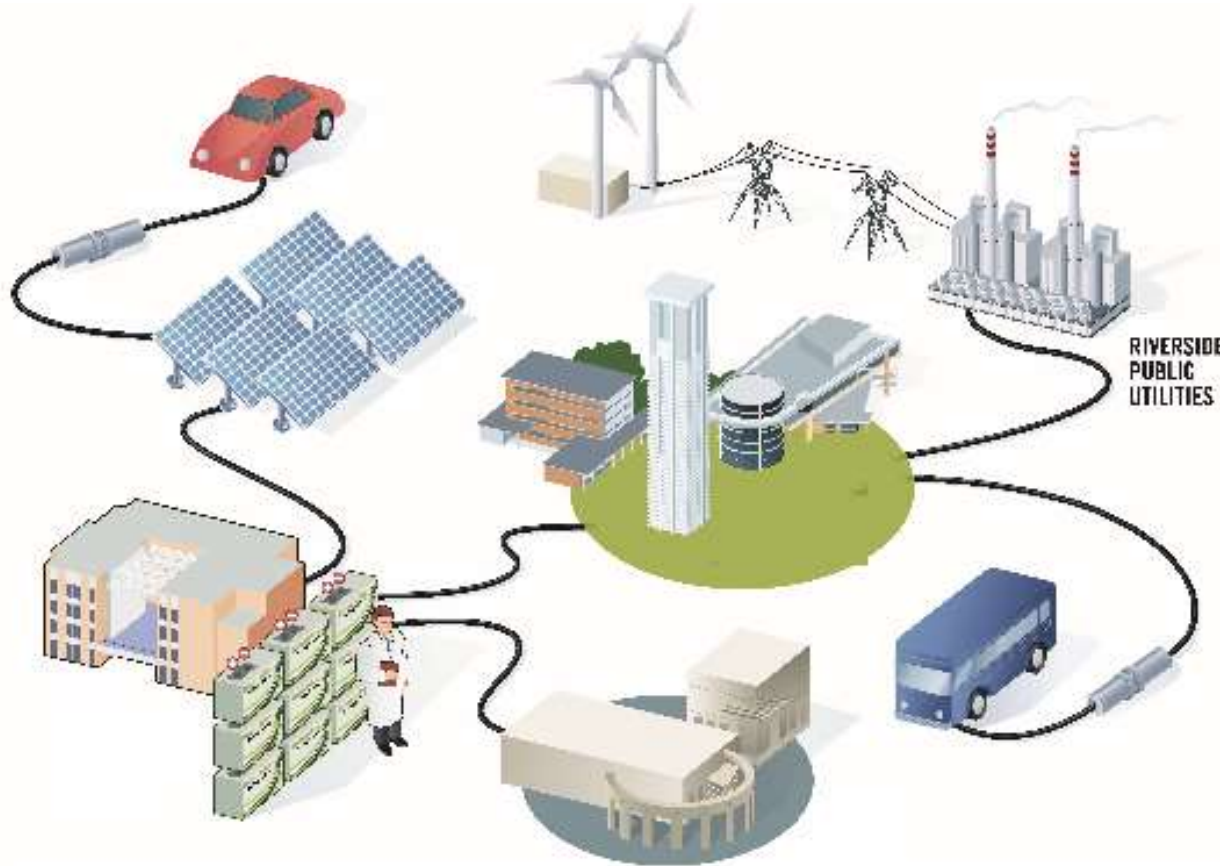
$$m_1 \frac{d^2 x_1}{dt^2} + (k_1 + k_2)x_1 - k_2 x_2 = 0$$

Life During my GE Years



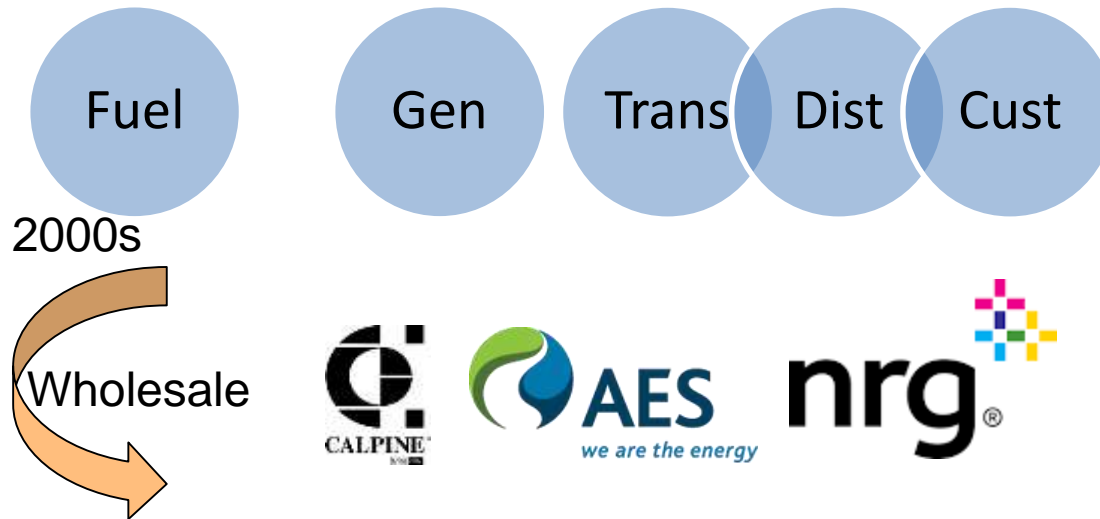
DEC vt100
Coherency
Equivalencing
Modes
Mode Shapes
PSS

Life today

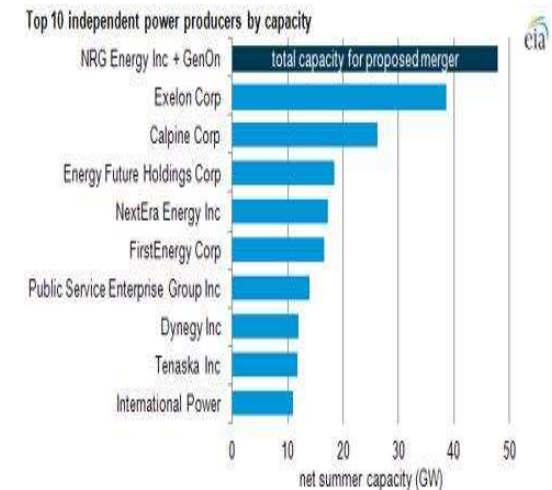


**Distributed
Connected
Renewable
Electronics
Transport/Heat
Responsive
Transactive
Smart
Ownership!**

Fundamental Changes Happened



Changed the Transactional Layer



More Changes Underway



Changing the Transactional and Physical Layers

Changing Landscape

- California on Path to 33% Renewables by 2020
 - 250,000 Rooftop solar PV today; 3GW
- Electric Vehicles 0.4 Million growing exponentially
 - CA target of 1.5 Million Vehicles by 2025
- Battery Sales at 100MW in 2014, Growing to 900MW by 2019.
 - CA mandate of 1,300 MW by 2020.
- NEST Thermostats are selling at 100,000 units / month
- 46 Million Customers (31.5%) on Smart Meters
 - 29 GW potential peak reduction from Demand Response
 - 5 Million Customers on Demand Response programs



Utility Business Model

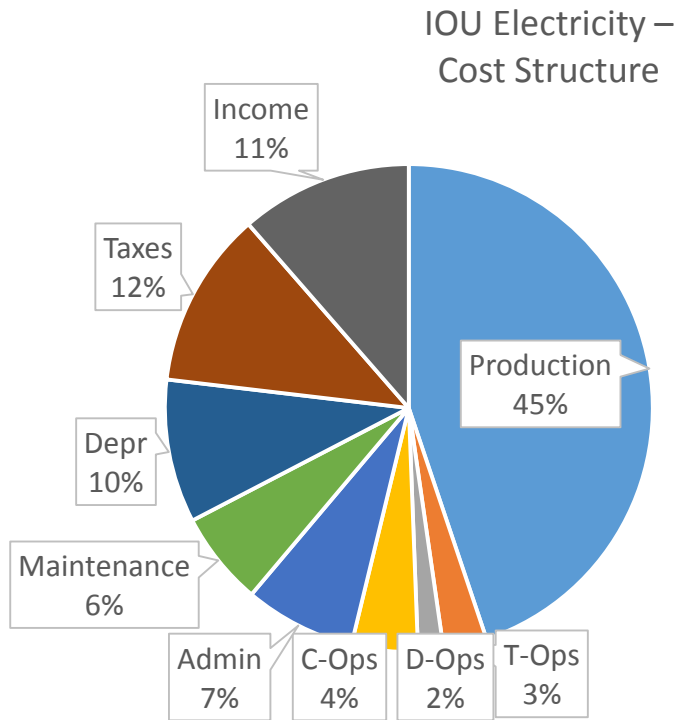
- Challenges Today

- Earn money on capital investments. With a flat demand and already-built grid, where are the next capital investment opportunities?
- Distributed Gen is getting closer to customers and thus squeezing the utility delivery opportunity.
- Grid Defection renders the utility as a backup option that is difficult to value.
- Competitive Transmission Biz.
- Grid Edge – What to do?
- Big Data – Liability? Operational Excellence?

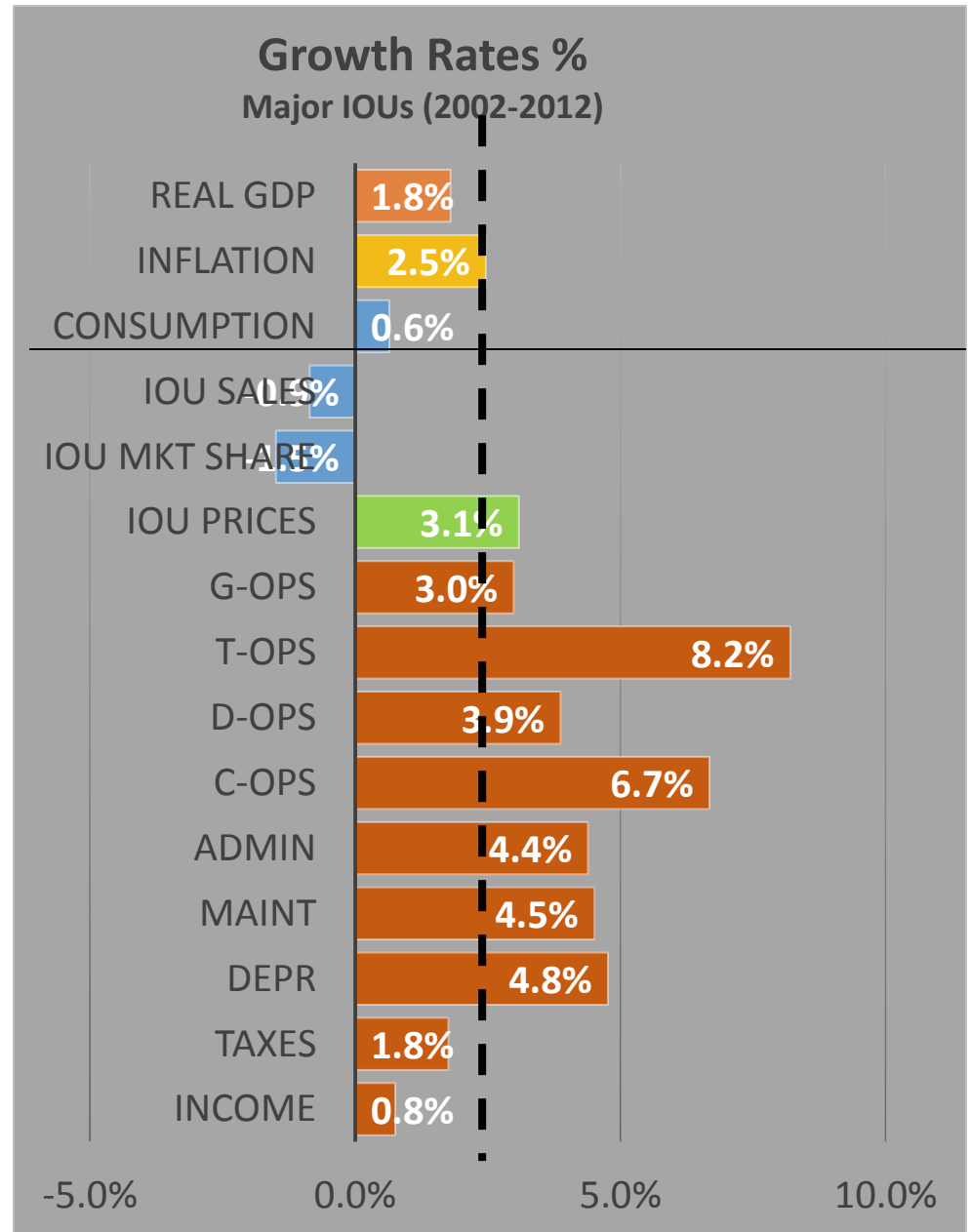
- Opportunities

- Extracting value out of Poles and Wires business.
- Smart Grid data analytics to drive operational decisions and customer service.
- Leveraging beyond the meter assets (smart inverters, home controls, EV, storage) to lower utility service costs or increase service revenues.
- Grid of Things - adaptable to new technology
- Customer Experience and Value Add

Can the Utilities Compete?



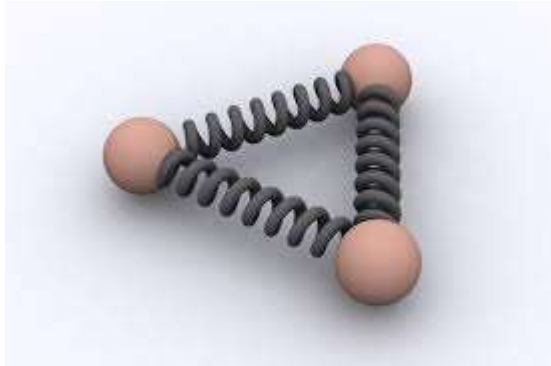
How to transition from analog mindset to the digital age?
 How to explore outside the golden cage?
 How to leverage the aging assets?



Customer Energy Assets

- Customer Assets
 - Smart Load Controls
 - Energy Efficient Lighting and Appliances
 - Solar PV
 - Battery Storage
 - Genset
 - Electric Vehicle or Plug-In Hybrid
 - Smart Inverters
- Enable Customers to Sell Grid Services
 - Reduce Demand, thus accommodating other customers on the same utility infrastructure.
 - Reduce/Increase/Shift Energy Consumption
 - Produce and Sell Energy
 - Regulate Energy Flow, dynamically
 - Voltage Support
 - Backup Power , Black Start capability
 - Generate Harmonic Current
 - End of Line Monitoring driving predictive asset maintenance programs and workforce optimization.

Life in future Years



Unbundled Prices
Demand Flexibility
Differentiated Reliability
Production Intermittency
Diminishing Thermal Fleet
Prosumers
Integrated Services
Smart Buildings
Energy Apps

Multi-Disciplinary:

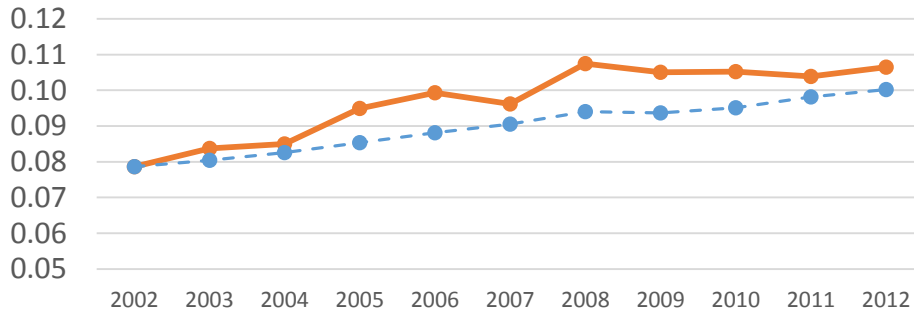
- Energy
- Electronics
- Software
- Communication
- Finance
- Customer Service

SUPPORTING SLIDES

Can the Utilities Compete?

Cost

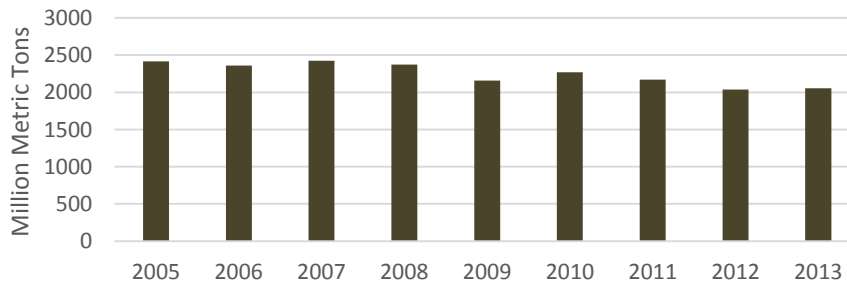
Prices \$/kWh (Major IOUs)



- 150 million Customers
- 3,300 Utilities
- 7,000 Power Plants
- 5 million mile Lines
- \$1 Trillion Net Assets,
- \$7,000 per customer

Environmental Footprint

CO2 Emissions



Outages



Consulting Opportunities – Takeaways

- Landscape includes more than Utilities – OEMs, Integrators, Retailers, Investors, Commerce Platforms, ...
- All layers are Changing – Transactional, Informational, Physical
- Technology Changes will bring cost savings and new liabilities/risks, and will require continuous product/service innovations
- Consulting landscape is also crowded, requiring focus on core expertise and collaboration within ecosystem.

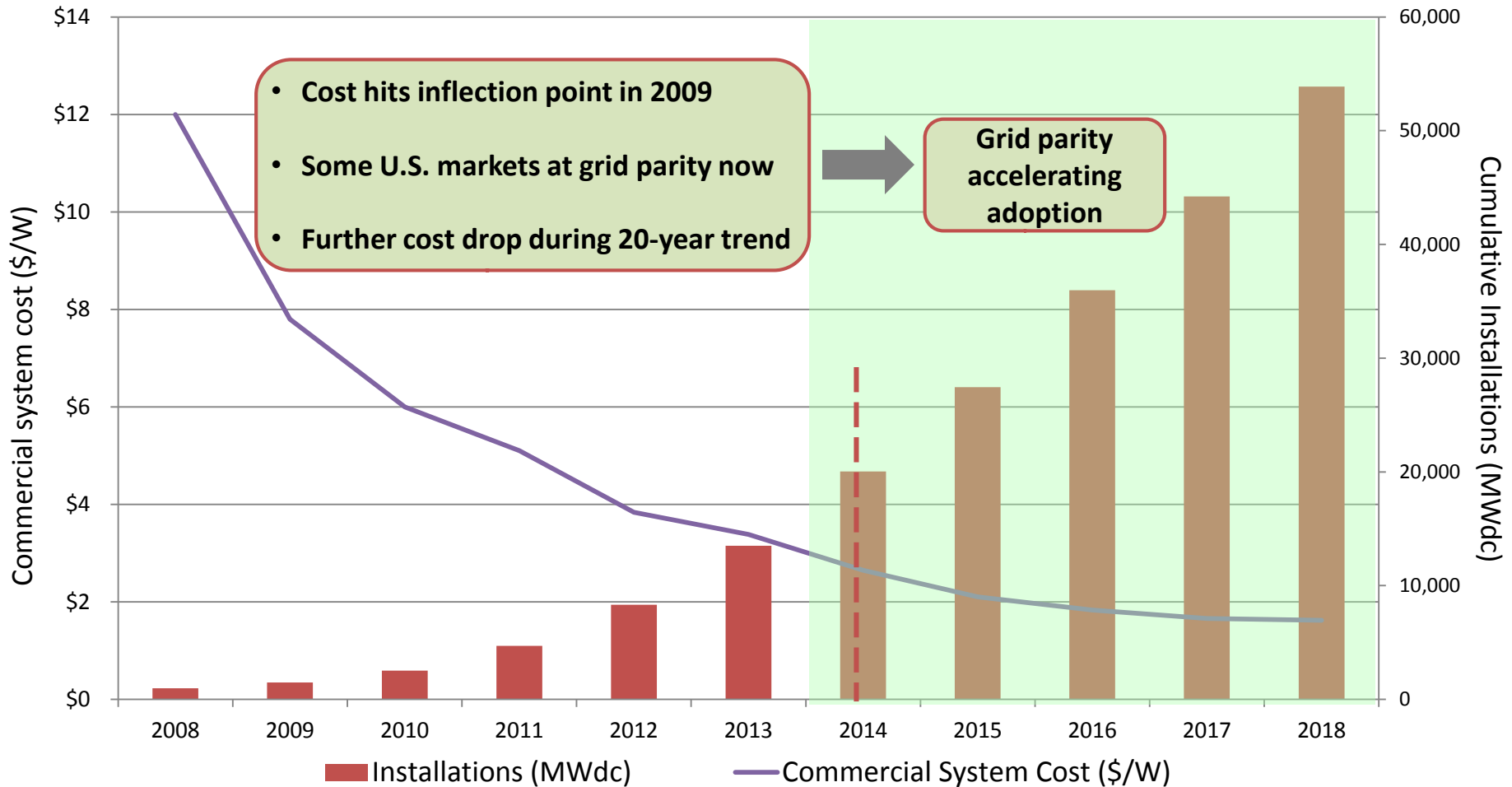
RTOs



Key Innovations – Distributed Solar



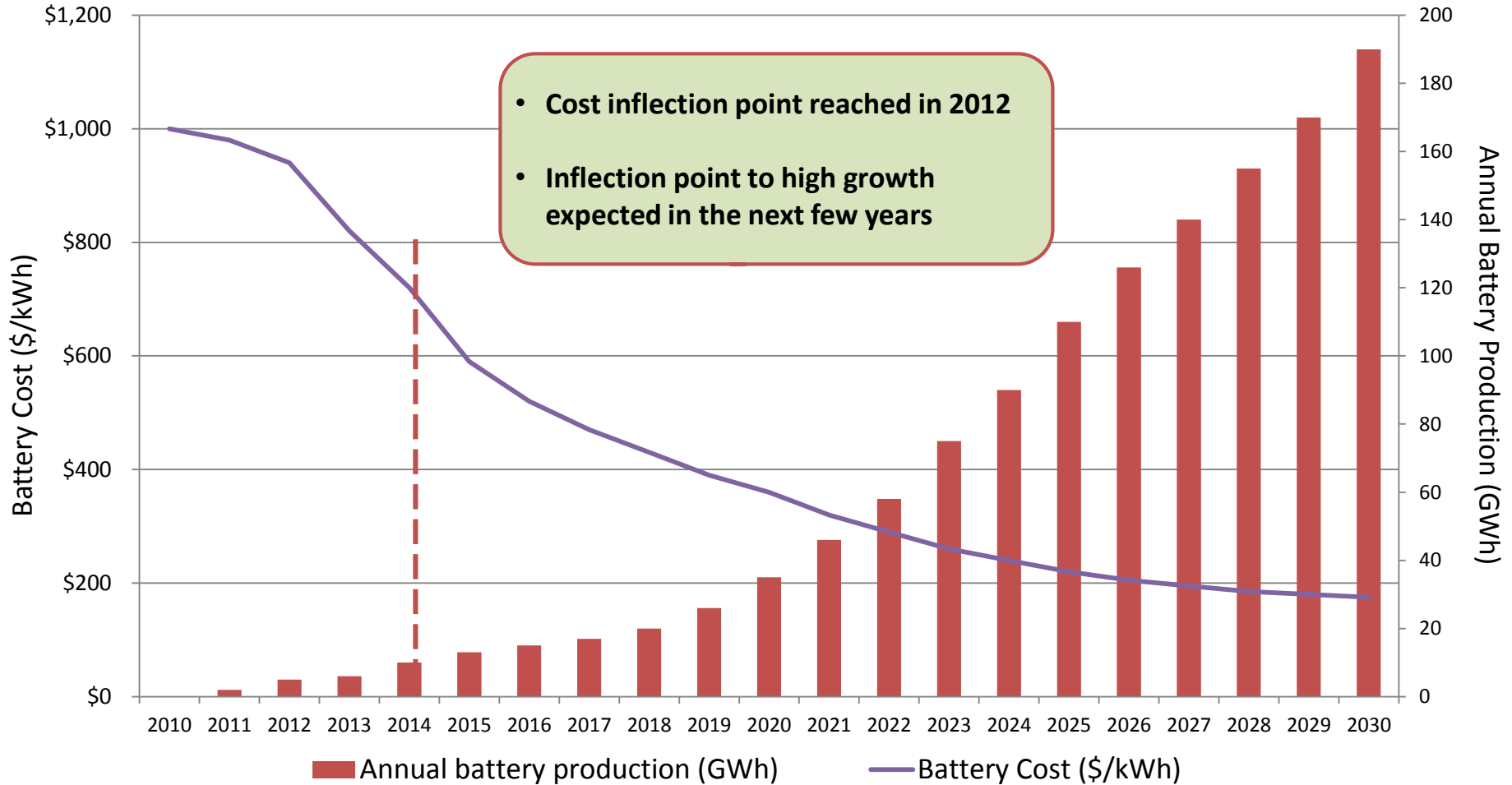
USA Solar Growth



Key Innovations: Distributed Storage



Storage Cost and Volume Trend

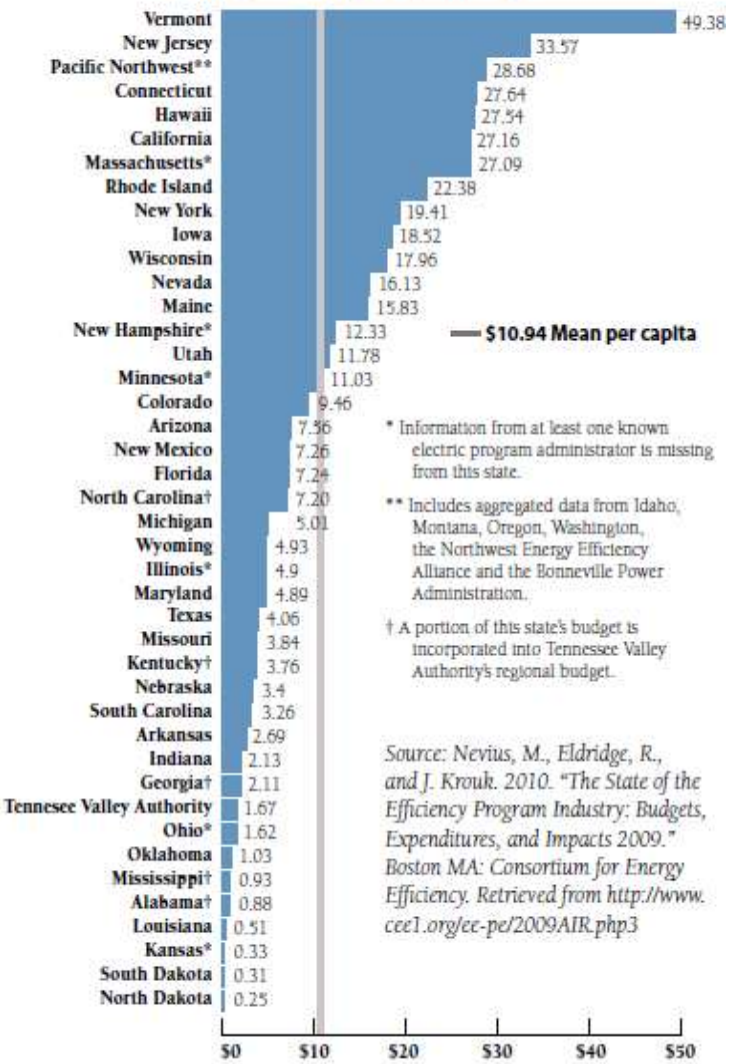


Source: Goldie-Scot, L.. (2014) "European End-User Storage: A Battery In Every Home?", BNEF.

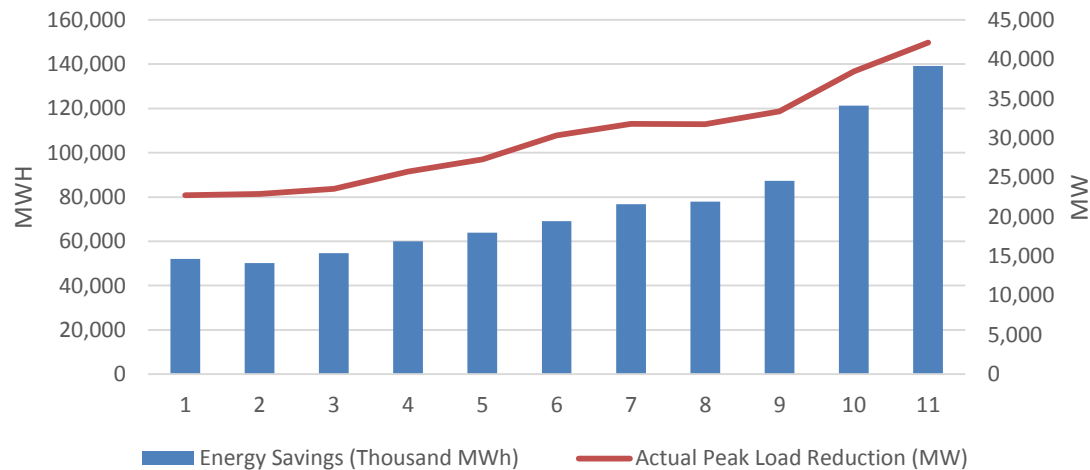
Key Innovations - Energy Efficiency



Annual Per-Capita Utility Investment in Energy Efficiency Programs by State



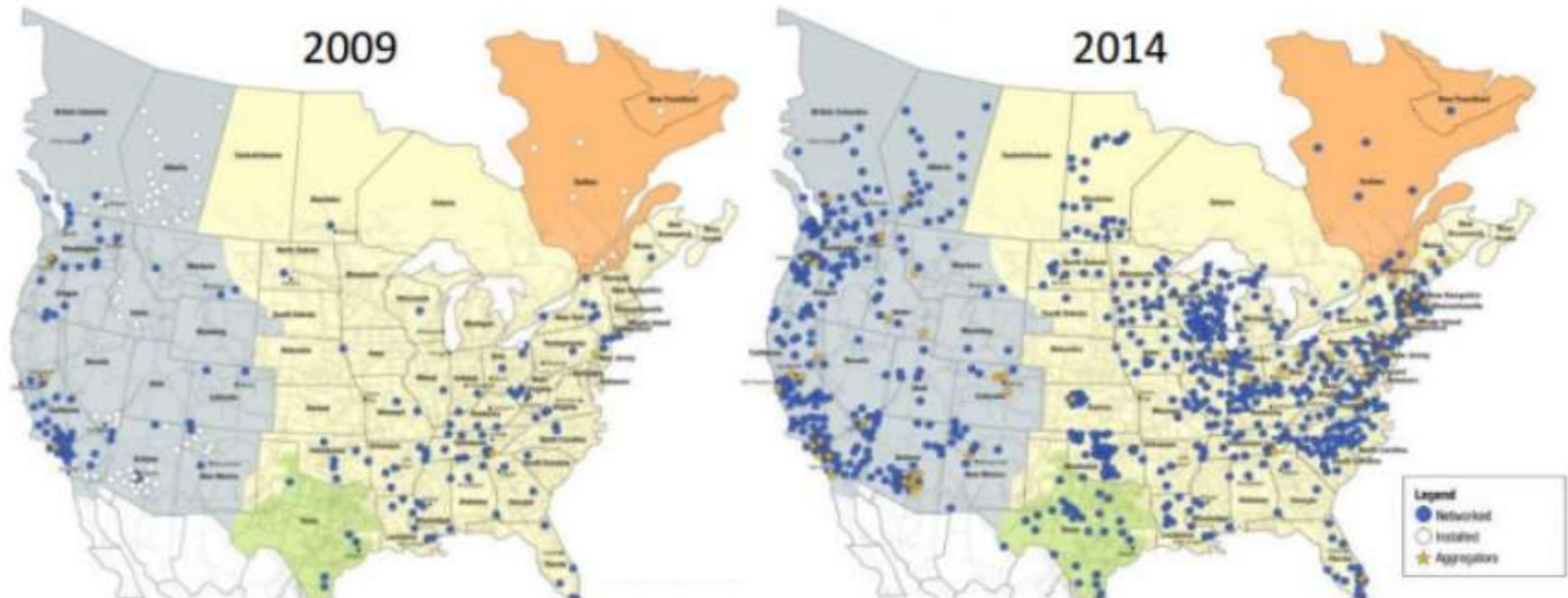
Impact of Energy Efficiency and Load Management



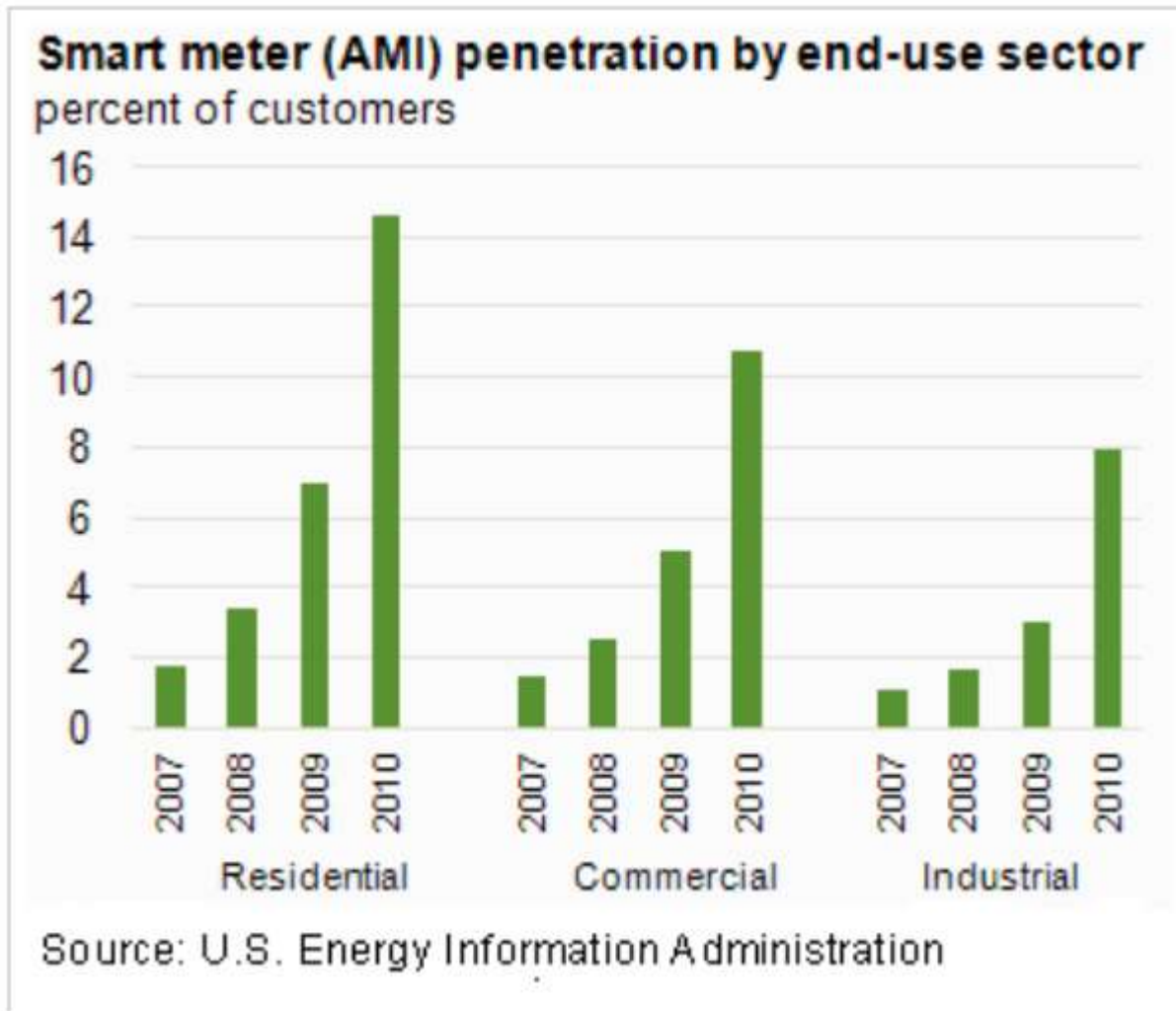
Proliferation of PMUs



Phasor Measurement Units across North America



Smart Meters



Some energy you
can't control.

Some you can.

Start reducing your bill with Smart Energy Solutions.
Take control at: nationalgrid.com/smartenergy



Behind the Meter Assets

- SCE Dec 2014 Local Capacity Requirement RFO Results:
 - CC Gas Plant 68%
 - Peaking Gas Plant 5%
 - Ahead of Meter Storage 5%
 - Behind the Meter Storage 8%
 - Behind the Meter Renewables 2%
 - Demand Response 4%
 - Energy Efficiency 7%

Energy Efficiency	102.5
Energy Efficiency	11.0
Energy Efficiency	16.7
Demand Response	75.0
Behind-the-Meter Renewable	44.0
Behind-the-Meter Thermal Energy Storage	25.6
Behind-the-Meter Battery Energy Storage	50.0
Behind-the-Meter Battery Energy Storage	85.0
In-Front-of-Meter Battery Energy Storage	100.0
Combined Cycle Gas Fired Generation	1284.0
Peaking Gas Fired Generation	98.0
TOTAL:	1891.8

27% of the Capacity is Addressed by non-generation Technologies!
Can we push it higher??

NY Drive Towards Consumer Participation

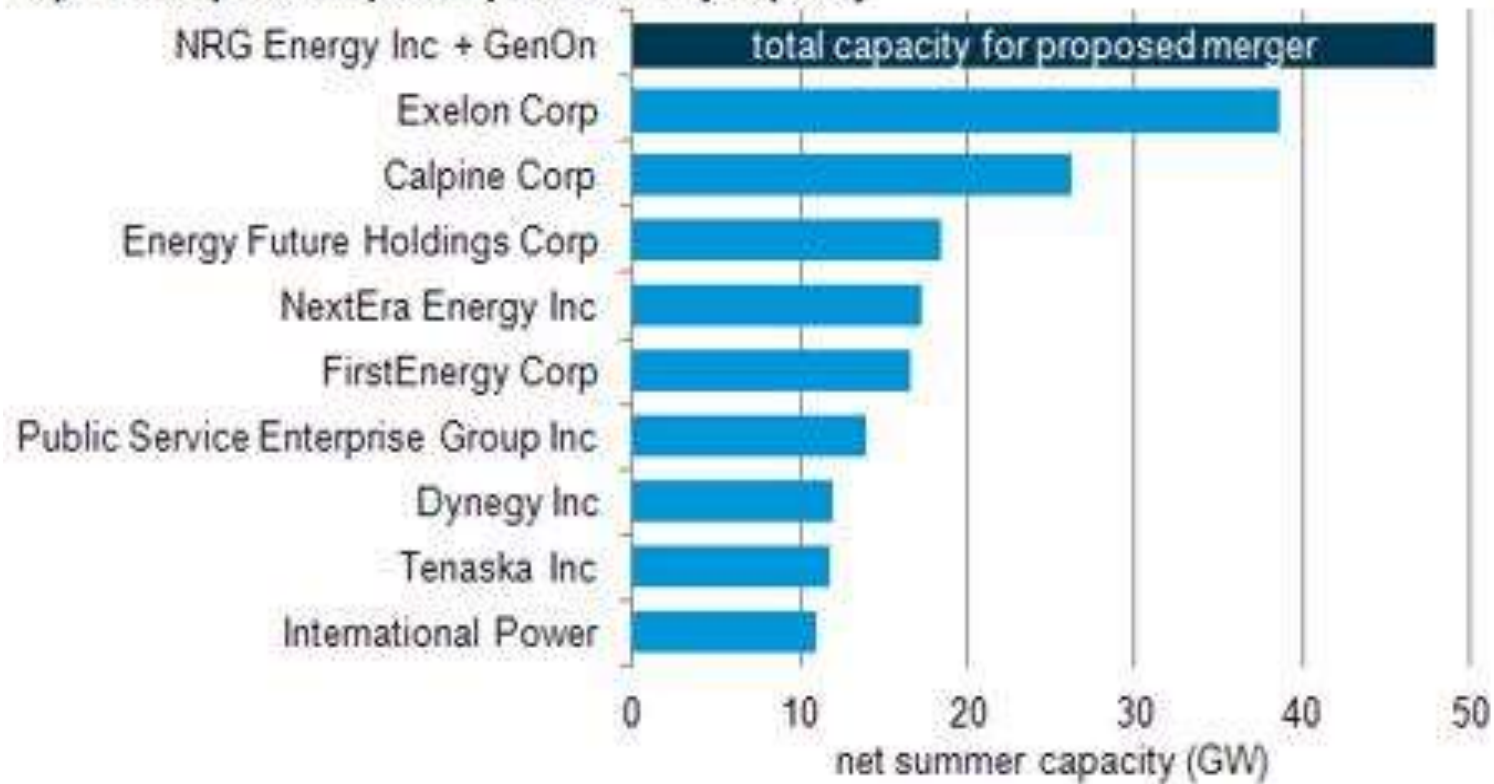
- Drivers:
 - Peak Demand Outstripped Supplies in Constrained Areas.
 - Aging Infrastructure requires Billions in Investments
 - Price Volatility due to demand inelasticity and lack of fuel diversity
- Objectives:
 - Enable consumer participation to promote efficiency and resiliency
- How:
 - Market-Based Signals
 - Clean and Distributed Technologies

New York REV Order Poised to Deliver More Clean Energy, a Stronger Grid & Lower Bills for New Yorkers



IPPs

Top 10 independent power producers by capacity



Almost 20% of USA capacity held by 10 IPPs

Impact of Customer Energy Assets

- Value Creation

- Enable existing utility grids to serve more customers without additional capital investments.
- Increase grid reliability and resiliency.
- Enable optimization of bulk generation plants thus reducing energy cost and volatility.
- Reduce Grid Losses.

- Business Models

- Grids Buy/Sell from/to customers.
- Customers buy/sell to each others.
- Aggregators/Retailers buy/sell from/to Customers and interact with Grids.