Interconnected Electricity Systems and Networks – What does the future look like?

Or: "There must be some way outa here" – J. Hendrix, R. Zimmerman

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Think Tank

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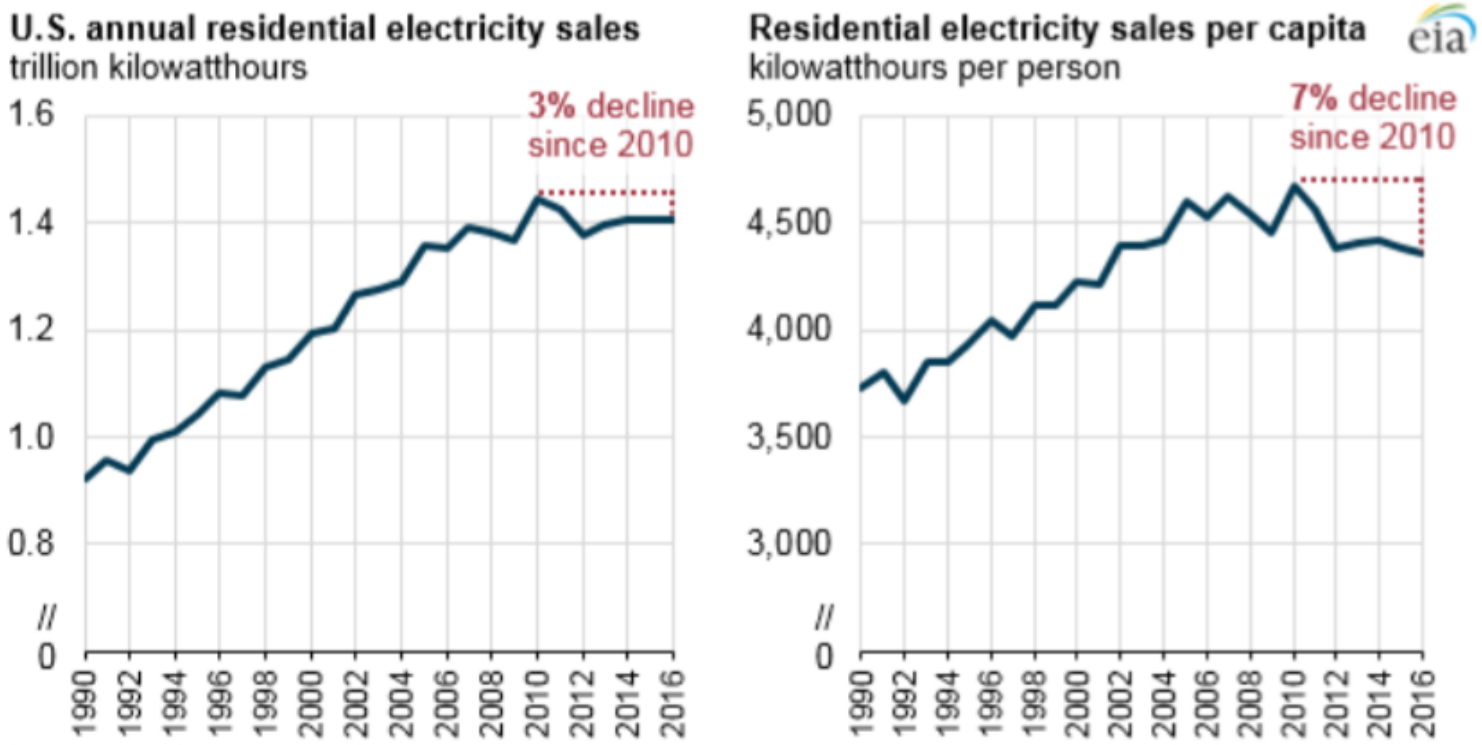
College of Social Sciences
University of Hawaii at Manoa

Trends That Impact Future Utility Business Models in US – "Change" Will Be the "Constant"

- **Cost of electricity will rise due to need to address grid issues and carbon – investment of $1.5 – 2 Trillion by 2030**
- **Utility investment in trouble as electricity sales are flat or declining**
- **Investment (public or private) must be made to address cyber attacks**
- **Investment must address reliability and resiliency in the face of growing number of extreme weather events – hurricanes, wild fires**
- **Grid investments needed as prices for BTM solar and storage decline, creating additional grid instability**
- **Convergence of energy, IT, and communications technologies — intersection of physical power layer (T&D system), data transport and control layer (communications and control), and an applications and services layer (two-way information and power flow between utilities and consumers).**
- **Consumers are becoming more actively engaged - "prosumers"**
- **All of these things are happening simultaneously, so electricity providers must transform business models from a commodity to a service orientation**
- **Services such as data analytics, DG, storage, demand response, energy efficiency, and financing, are provided by utilities and non-utility along the value chain from generation to customer end- use.**

Cost-Effective Efficiency, BTM Generation Drive Electricity Sales Down, and Impact Funding for New Systems – DOE, 2017



Source: U.S. Energy Information Administration, *Electric Power Annual* and U.S. Census Bureau Population estimates

Think Tank Will Consider Systems Interactions and Speed of Change:

- Risk of significant value loss from existing centralized distribution, transmission and generation, with assets becoming stranded.
- Technologies and regulations that lead to greater end-user (Consumer) choice and independence
- Impacts of electric vehicles and other home battery storage solutions.
- State initiatives, distributed or grid connected generation

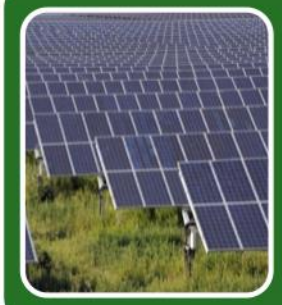
Risk of significant value loss for existing centralized distribution, T&D - with assets being stranded

- In California, current over-generation of BTM solar leads to negative pricing for electricity from thermal plants
  - Thermal plants are not configured to address hour-ahead and day-ahead pricing
- CAISO is developing regional mechanisms to ameliorate pricing issues and promoting increased use of renewable (must take) generation
- System must be managed for future development of increasing intermittent renewables on the grid
- System must link to GHG emissions and their prices – latest auction $14.61/ton of carbon dioxide

Power industry transformation

Wind

- Unpredictable Output
- 4,773 MW Peak – April 24, 2016
- 6,087 MW Installed Capacity



Solar Thermal / Photo Voltaic

- Semi – Predictable Output
- 9,868 MW Peak – April 21, 2017
- ≈ 10,000 MW Installed Capacity

** Simultaneous wind and solar has exceeded 13,000MW on April 23, 2017*

Roof Top Solar

- Semi – Predictable Output
- Behind the meter – Residential
- 5,000+ MW Estimated Capacity

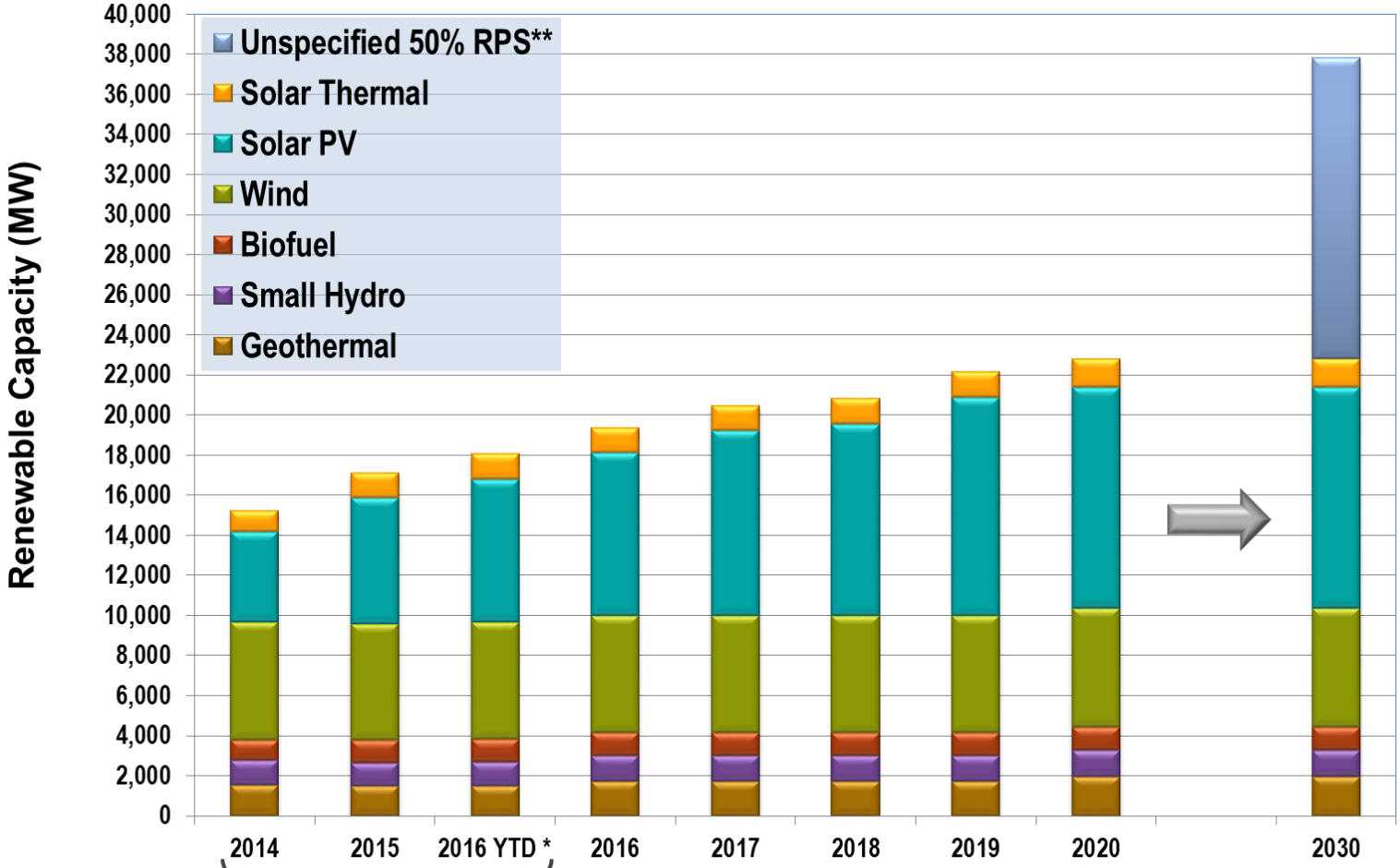
Main Drivers:

- ✓ *California RPS*
- ✓ *GHG reduction*
- ✓ *Once-through-Cooled plants retirement*

Goals:

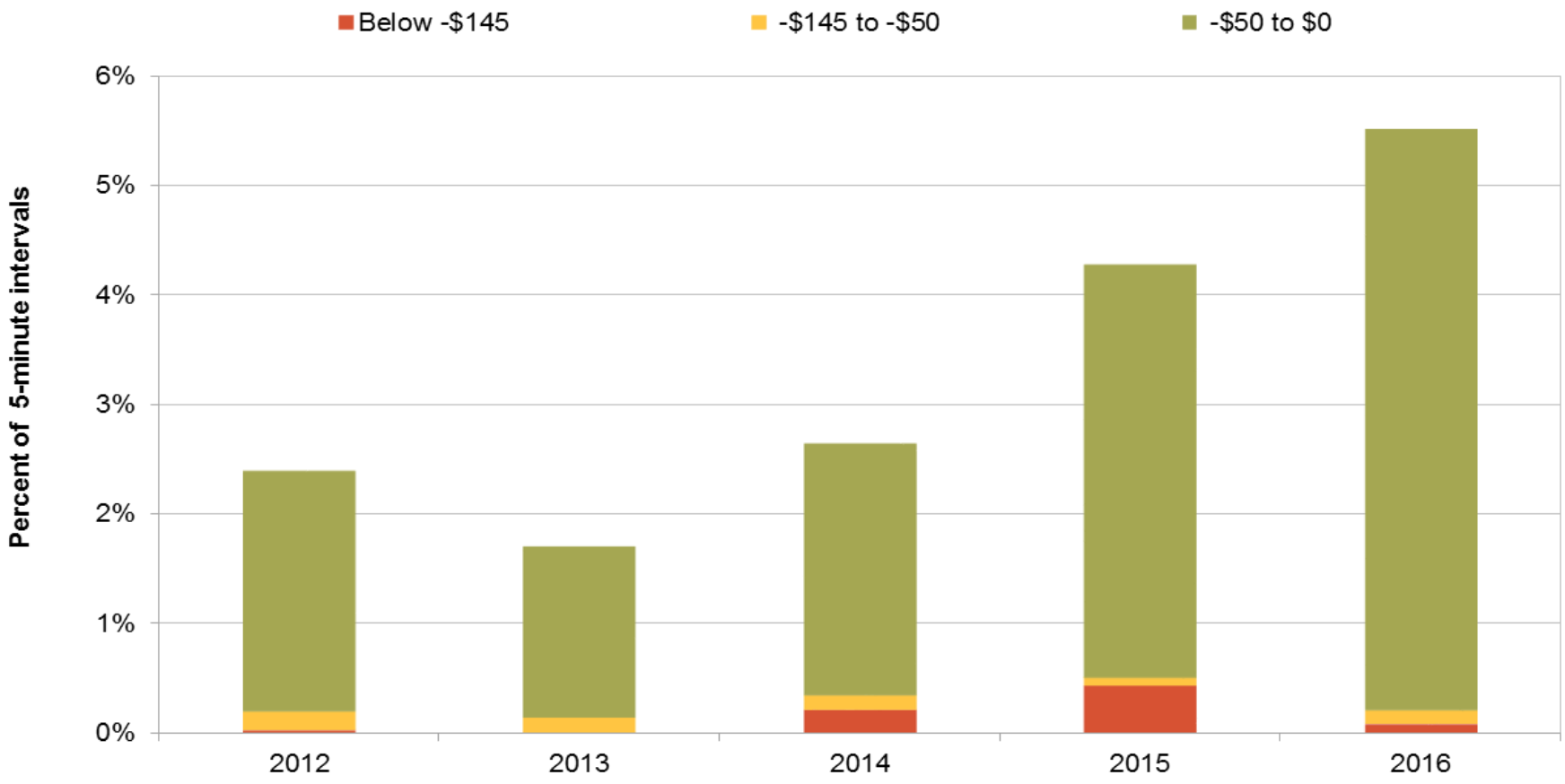
- ✓ *Higher expectation of reliability*
- ✓ *Higher expectation of security*
- ✓ *Smart Grid*
- ✓ *Situational awareness through Visualization*

About 4 GW of utility-scale renewables added by 2020 and 10 to 15 GW more by 2030, does not count BTM – but, impact on grid?



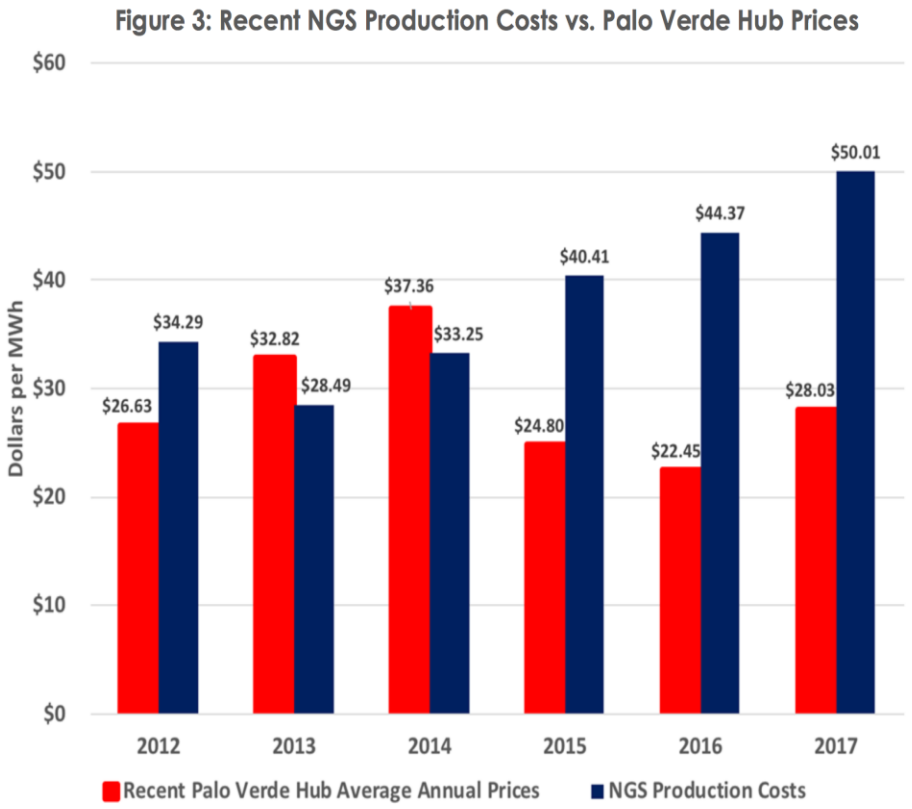
*All online resources that are not in test mode are included in the 2016 YTD amounts, including those yet to achieve full commercial operation.
**Approximate
(IOU data through 2017 and RPS Calculator data 2018-2020)

Frequency of Market Clearing at Negative Prices Is Increasing

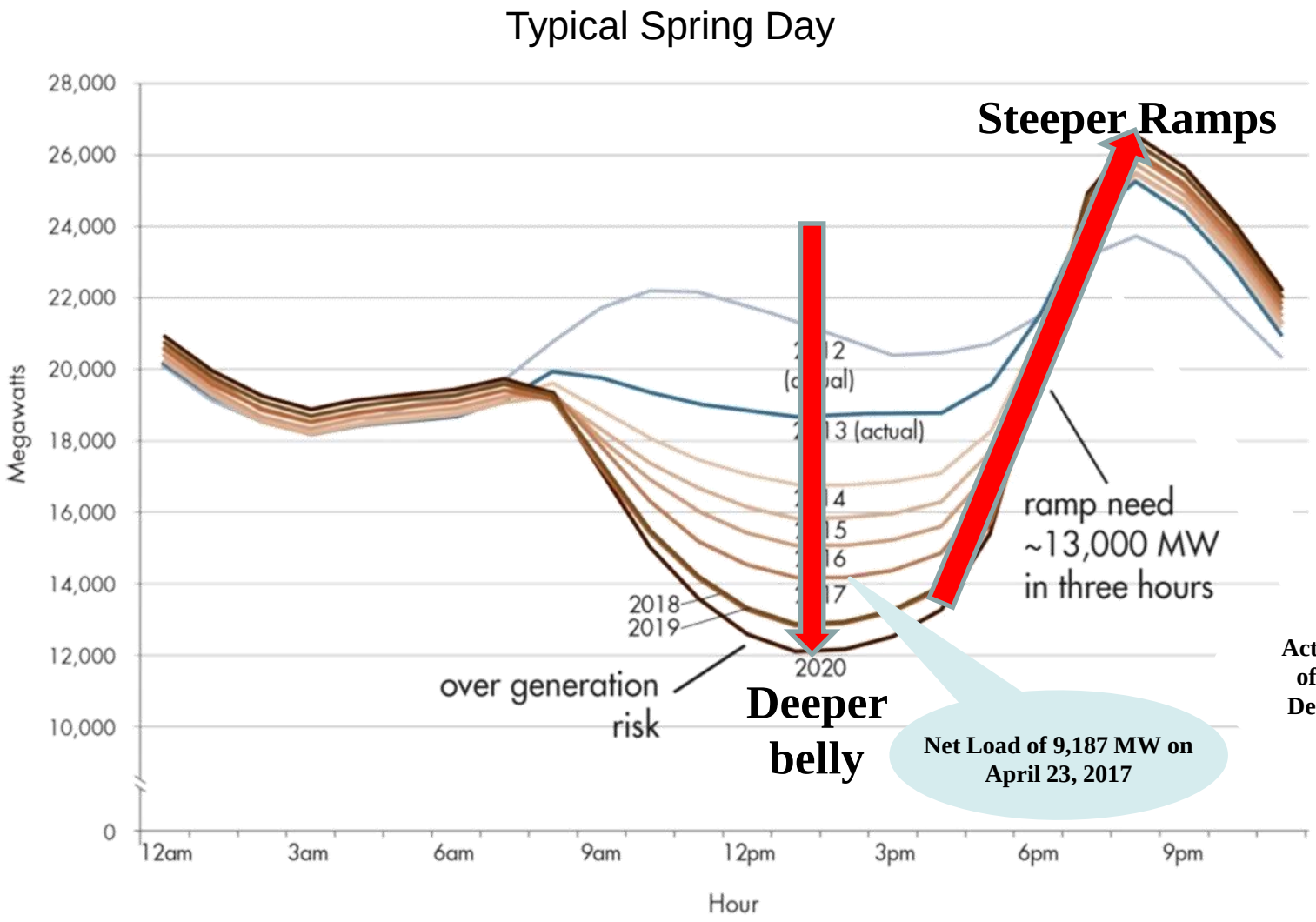


Example - Palo Verde is largest US power plant - production ~3.3 GW – but may no longer be economical

APS operates and owns 29.1% of the plant - other owners include Salt River Project (17.5%), El Paso Electric (15.8%), SCE (15.8%), PNM (10.2%), Southern California Public Power Authority (5.9%), and LADWP (5.7%)



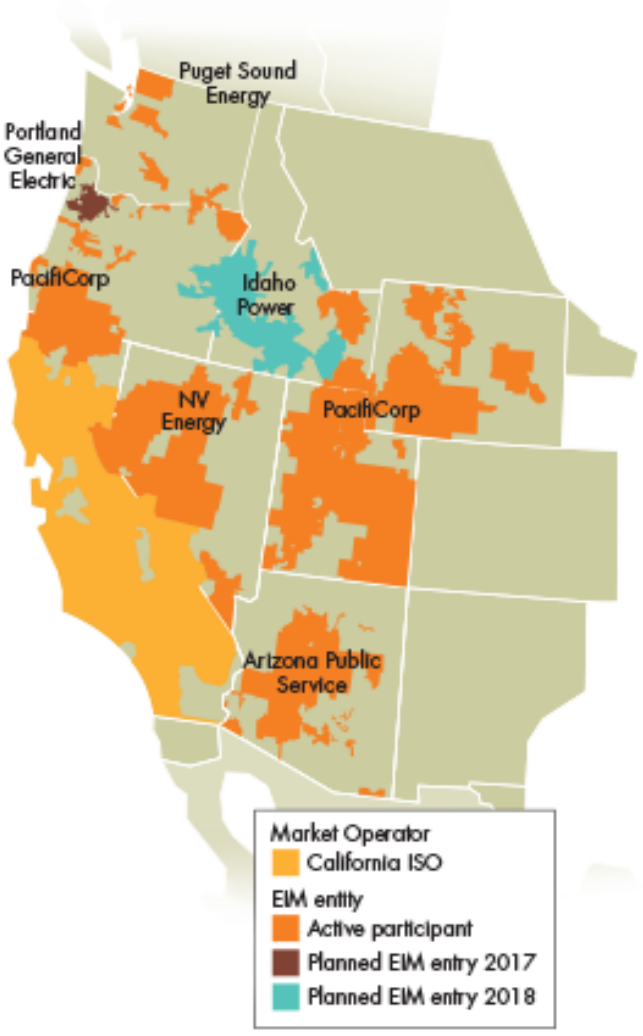
Actual net-load and 3-hour ramps are approximately four years ahead of ISO's original estimate



Addressing the Duck Curve in California - CAISO's Energy Imbalance Market (EIM)

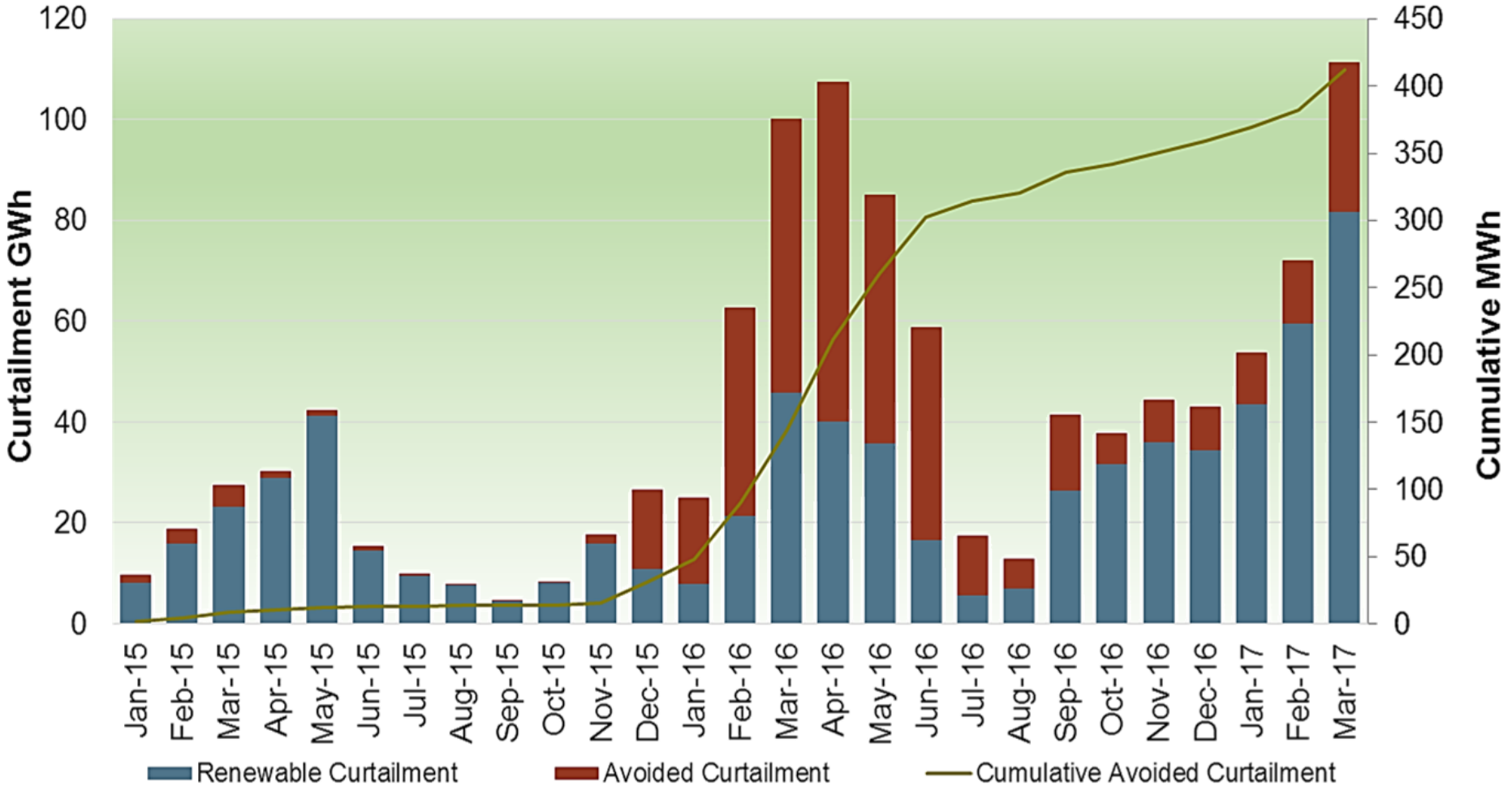
- In 2014, a regional market system launched to increase coordination and interconnection between CAISO and other Western Bas
- Expansion to Southwest Power Pool is planned (March 2017)
- Now have improved forecasting for wind and solar on day-ahead/hour-ahead markets
- EIM enables real-time coordination (15- and 5-minute) and reserve in larger resource base
- Demonstrated benefits during first two years include reductions of system costs, **renewables curtailment**, and GHG emissions

Gross Benefits (Million$)	Curtailment Reductions (MWh)	GHG Emission Reudctions (MMTon CO_2-e)
$114.36	335,930	143,695



Source: CAISO

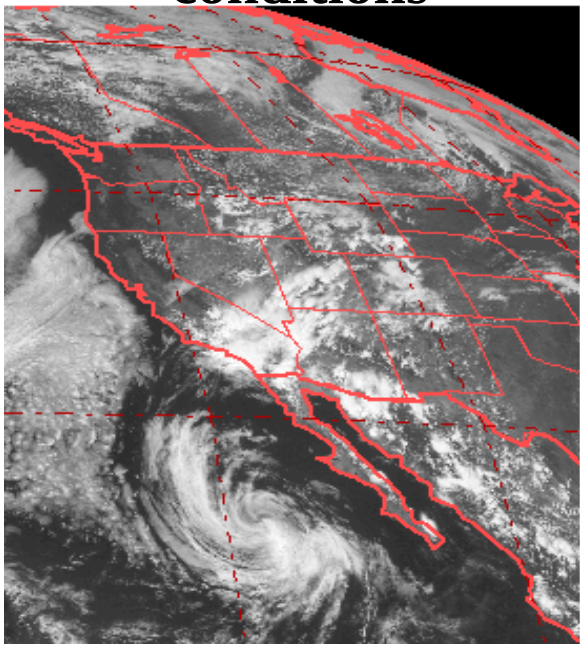
Energy Imbalance Market Helps Avoid Curtailment



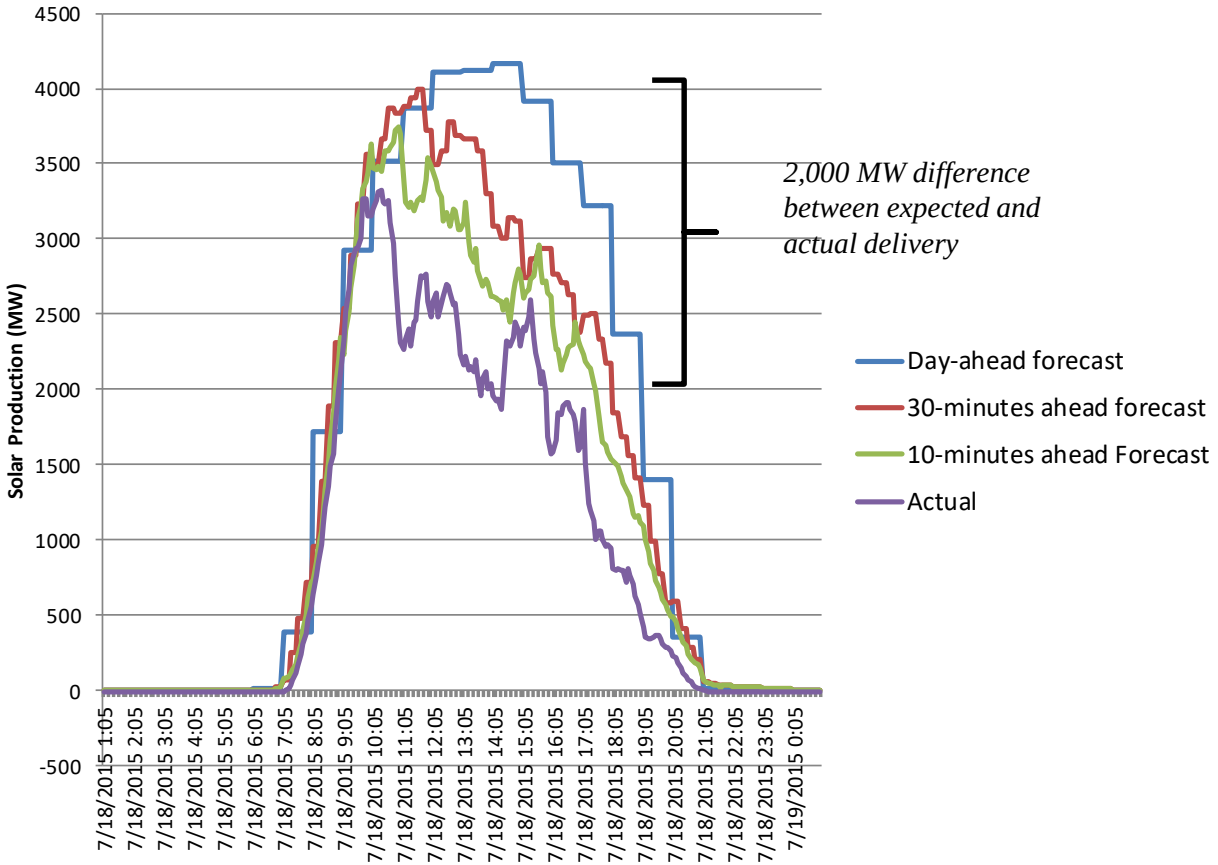
YTD estimated metric tons of CO2 displaced = 176,241, But Multi-state EIM has "Green" Critics

Need Further Improvements in Forecasting to Manage Supply Uncertainty - ~5% Error

Example day with monsoonal conditions



CAISO – Solar Forecast & Actual
July 18, 2015

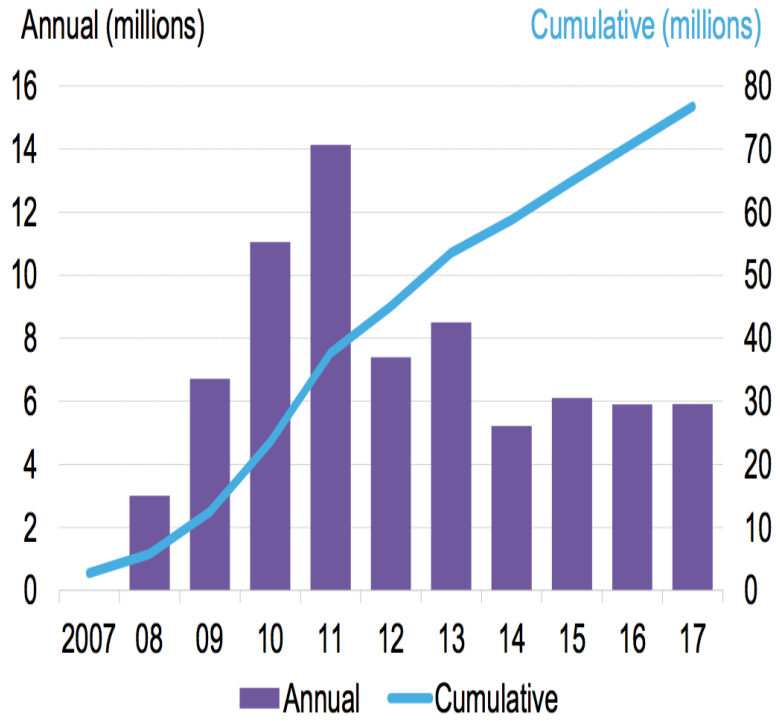


Technologies and Regulations that Led to Greater End-User (Consumer) Choice and Independence

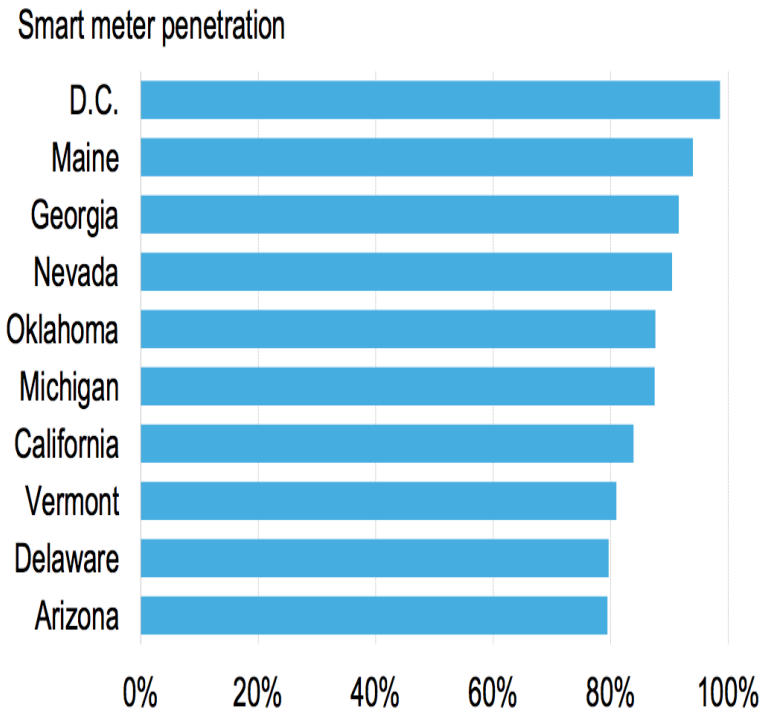
- Two-way smart meters allow for greater choice
- Continued reduction in pricing for BTM solar and storage
  - Includes more flexible means of home-owners obtaining BTM resources
- Automated demand response programs will allow for consumer savings
- Depending on how these resources are used, they can either help or hurt grid operation
- Regulators must develop substantively different time-of-use rates

Over 50% of Electricity Customers Have Smart Meters, with Enormous Regional Variation - Top 10 States Have Penetration Greater than 79%.

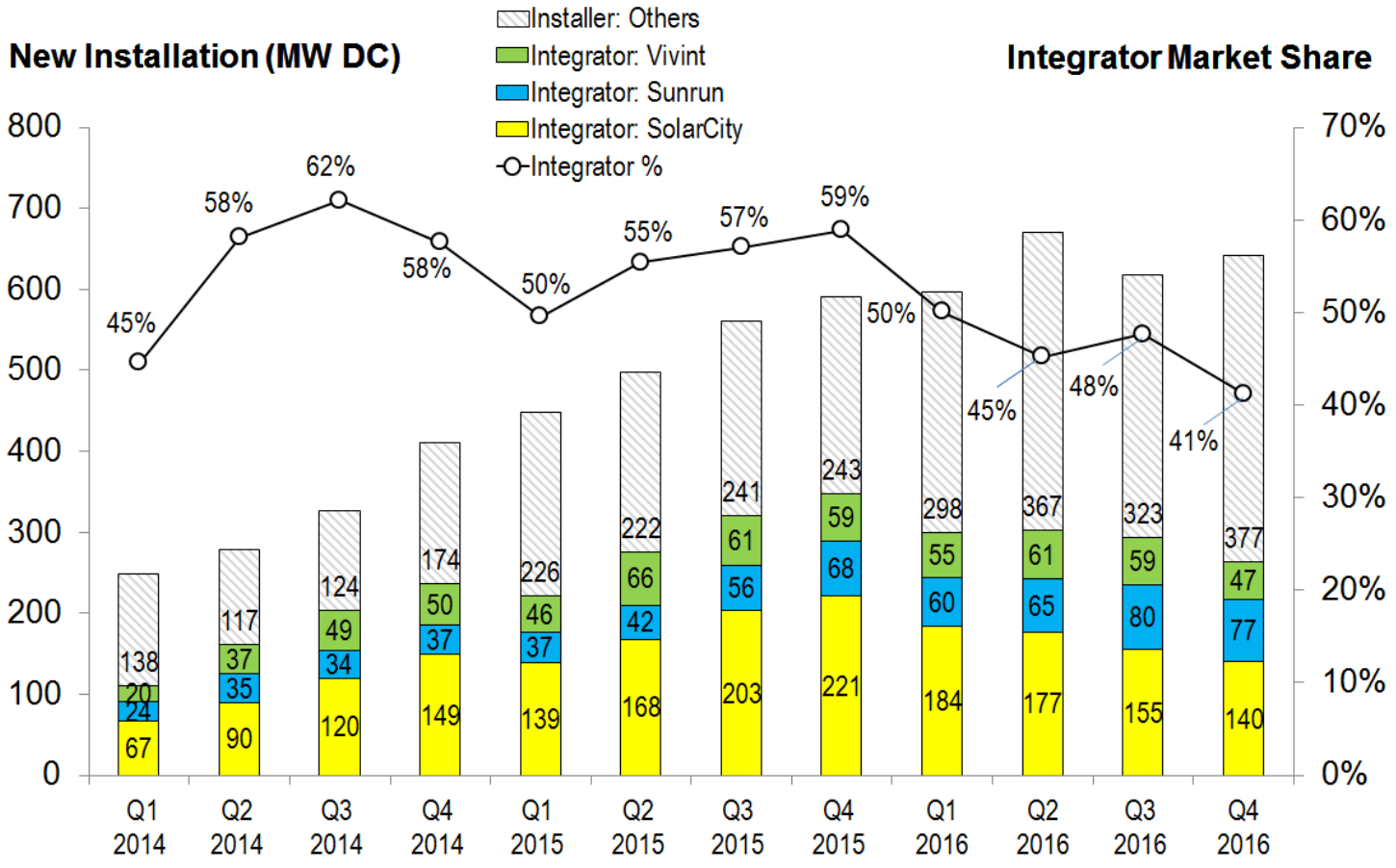
U.S. smart meter deployments



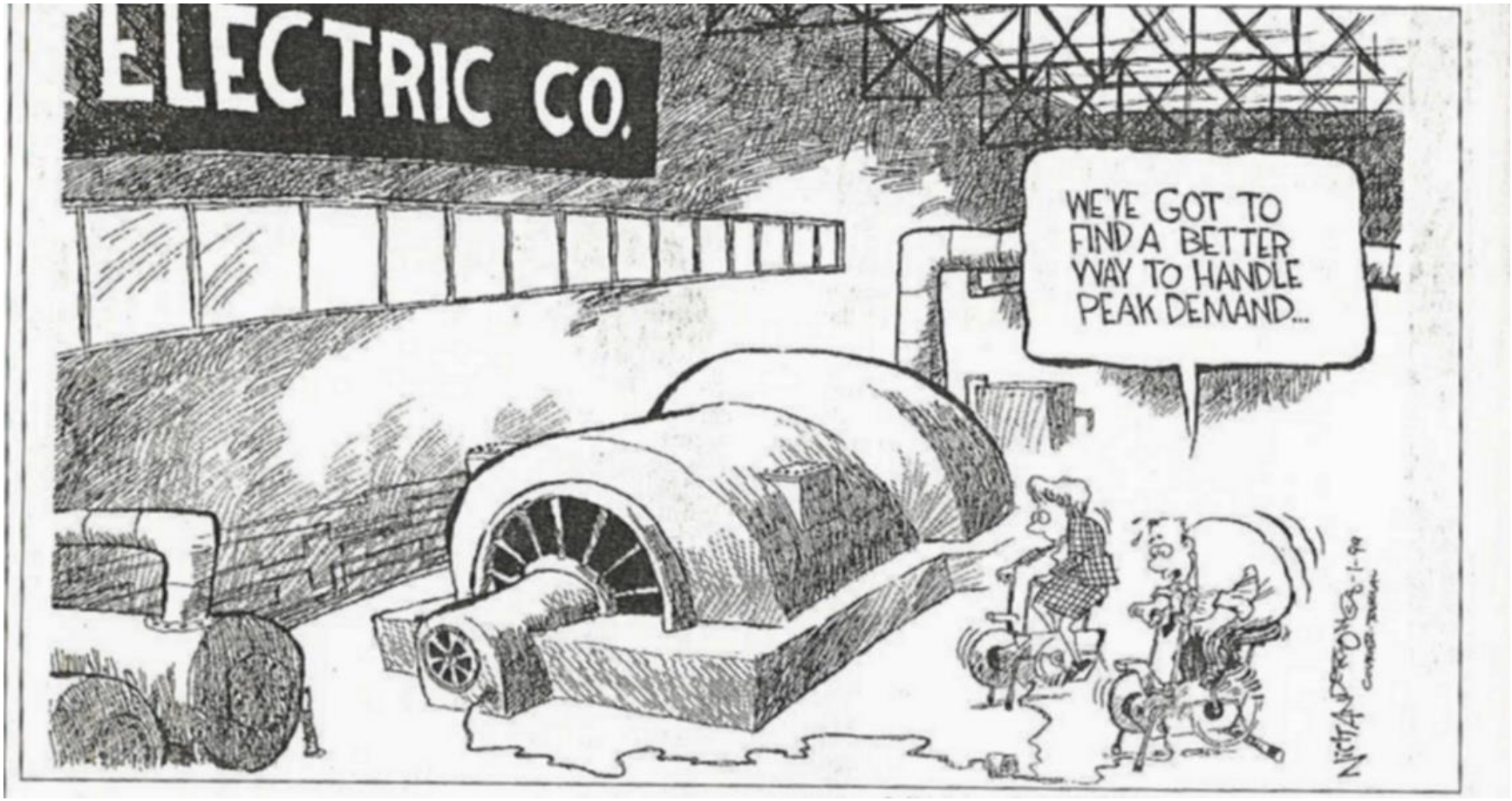
Top 10 states by penetration



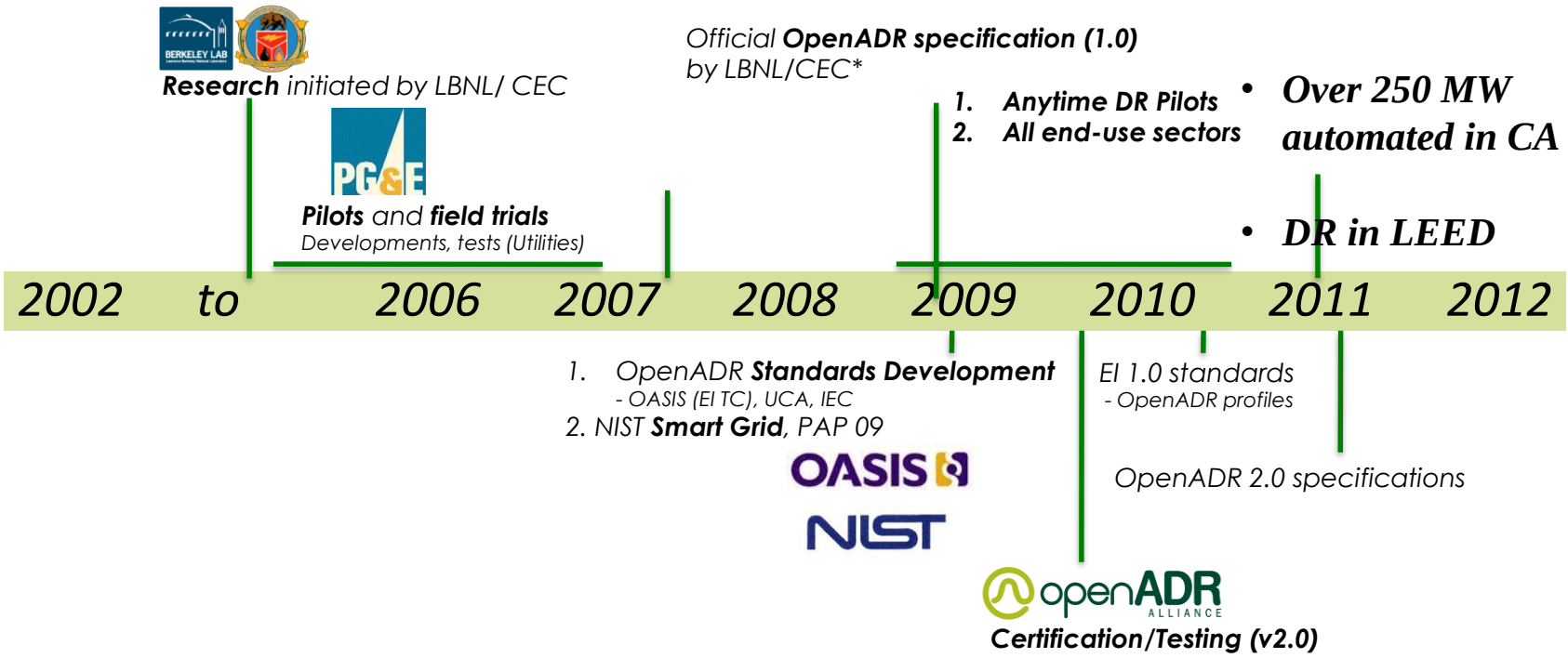
New Business Models for Paying for BTM PV Leads to Increased Installation – Who Gets ITC?



With Advent of New Technology, Automated Demand Response (ADR) Will Be a Tool for Managing the Grid



Timeline Example: OpenADR Interoperability Progress - slow even when all parties want it!



Demand Response (Pricing Load as a Resource): FERC/PJM Case: Won SCOTUS Decision in 2016

21% of U.S. GDP produced in PJM

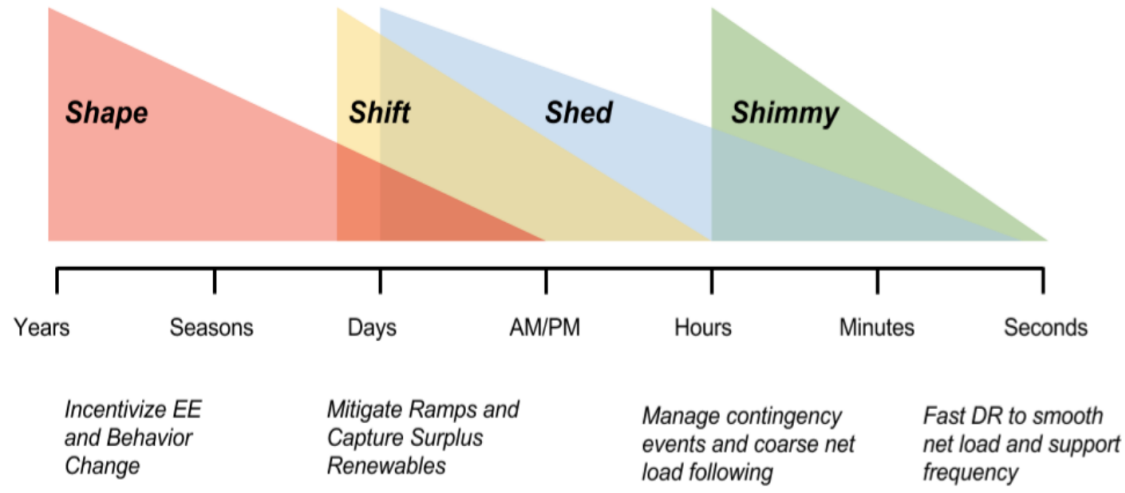
www.pjm.com

KEY STATISTICS

Member companies	*800+*
Millions of people served	*61*
Peak load in megawatts	*165,492*
MWs of generating capacity	*183,604*
Miles of transmission lines	*62,556*
2012 GWh of annual energy	*793,679*
Generation sources	*1,376*
Square miles of territory	*243,417*
States served	*13 + DC*

As of 6/1/2013

Spectrum of Demand Response in Developing Regulatory Market – ALJ Driven Change in California, More than System Aggregators



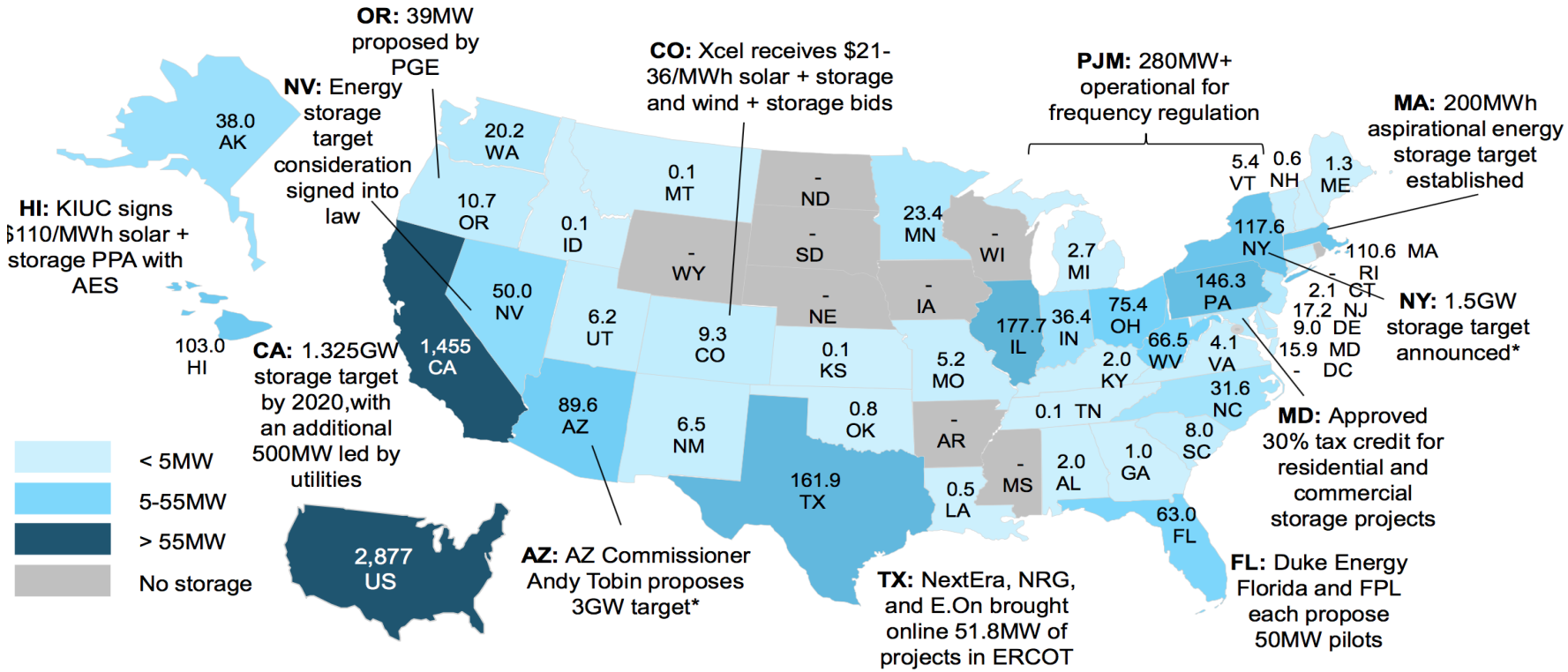
- **Shed:** acts like a **generation** capacity resource
- **Shift**: acts like a **storage** resource
- **Shimmy**: acts like a **regulation**/ ancillary services resource
- **Shape**: **persistent** daily load modifications (**Shed** & **Shift** combinations) arising from changes in behavior

Impacts of Electric Vehicles and Battery Storage Market Penetration

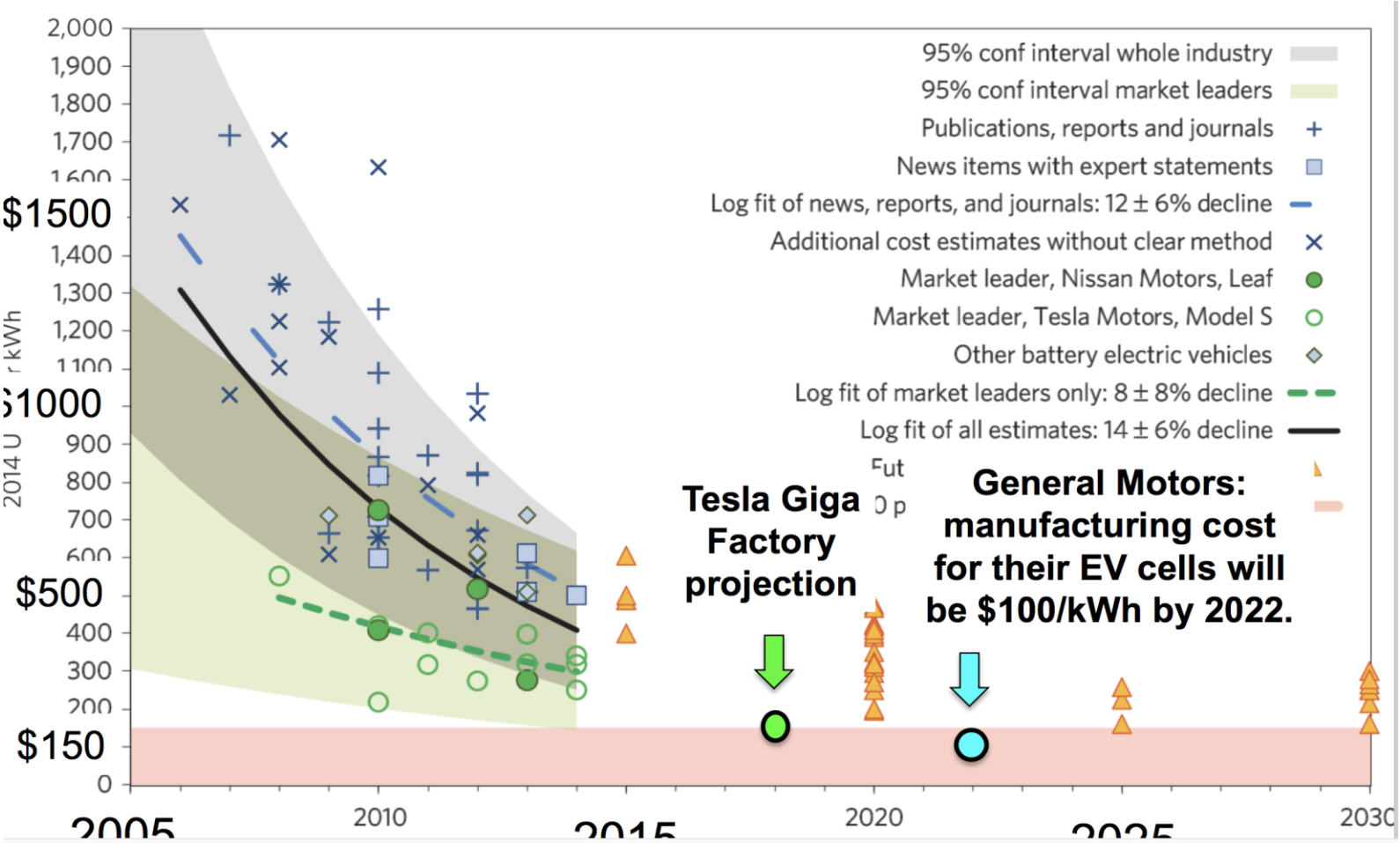
- Storage systems are still expensive, but coming down in price
  - One issue is how does current Li-ion cost advantage may impede other – generally flow – systems that may be more useful in dealing with ramps
- EVs are growing in important, but are still not a major factor
  - Charging times do not necessarily help the grid to deal with either over-generation or peak load issues

Commissioned Storage Capacity Now at 251MW – Landmark Energy Storage Law (AB 2514) in California

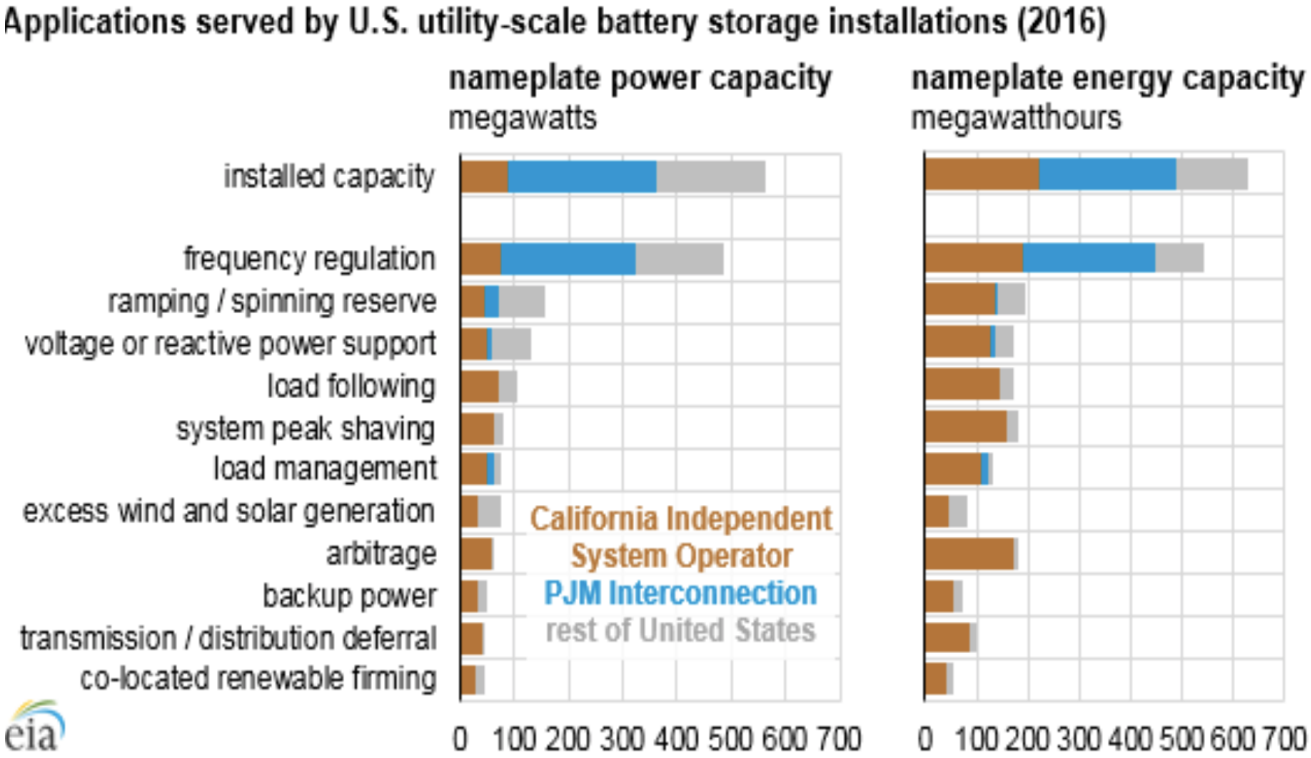
Deployment: U.S. announced and commissioned energy storage projects



Li-Ion Costs Set the Bar for Storage, Although Ramping Needs May Require Other (Flow Batteries) Options

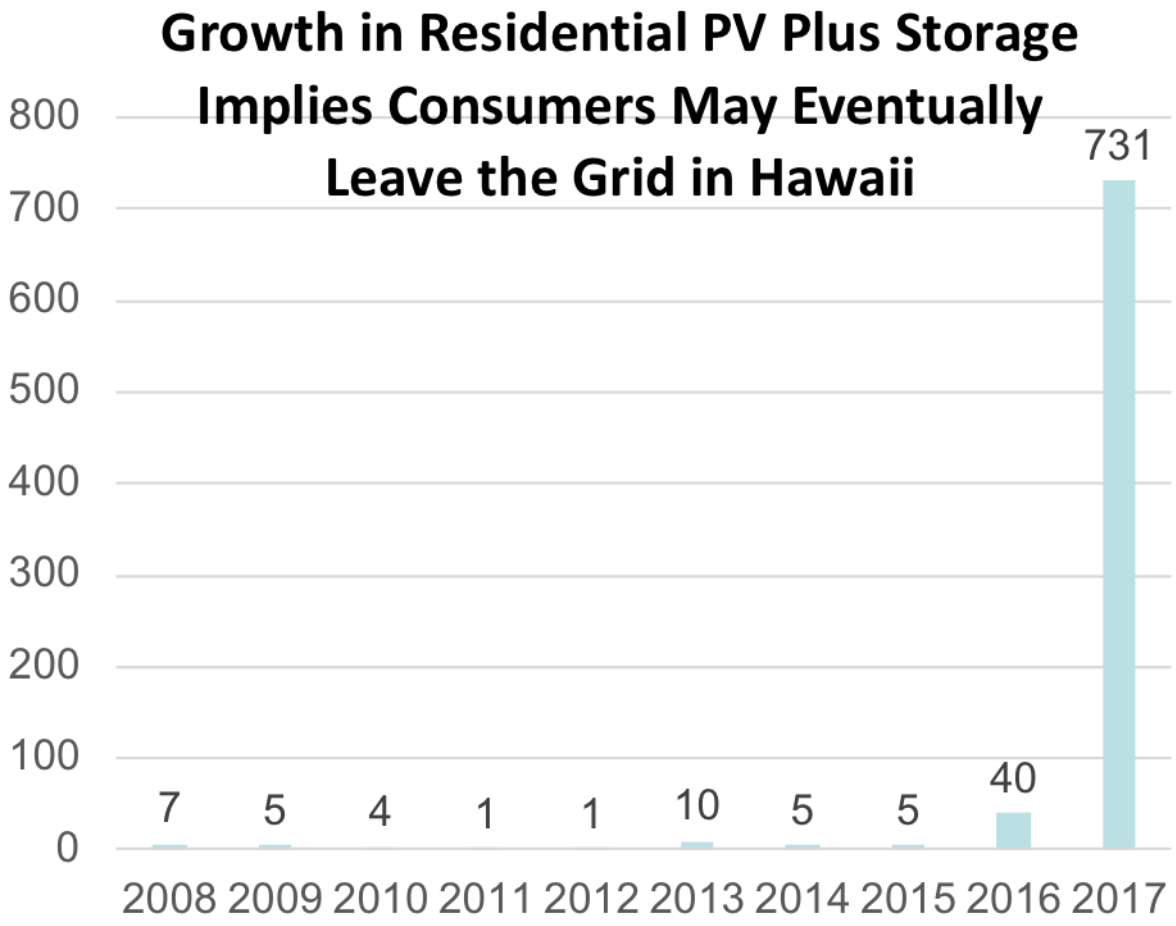


Main Application of Storage Is Frequency Regulation, Although "Duck's Back" Will Lead to Use for Ramping



Source: U.S. Energy Information Administration, Form EIA-860, Annual Electric Generator Report
Note: Several battery systems provide more than one application.

Utility-scale battery storage capacity in other regions has not reached the levels observed in PJM and California, but actic


Growth in Residential PV Plus Storage Implies Consumers May Eventually Leave the Grid in Hawaii
800
700
600
500
400
300
200
100
0
7
5
4
1
1
10
5
5
40
731
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017

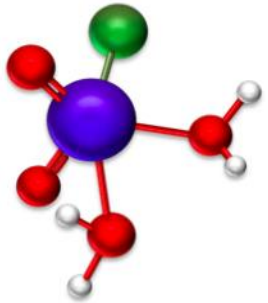
Flow Batteries May be Best Approach for Addressing Ramping Problems – Deployment at NELHA on Big Island

Advanced Vanadium Flow Battery

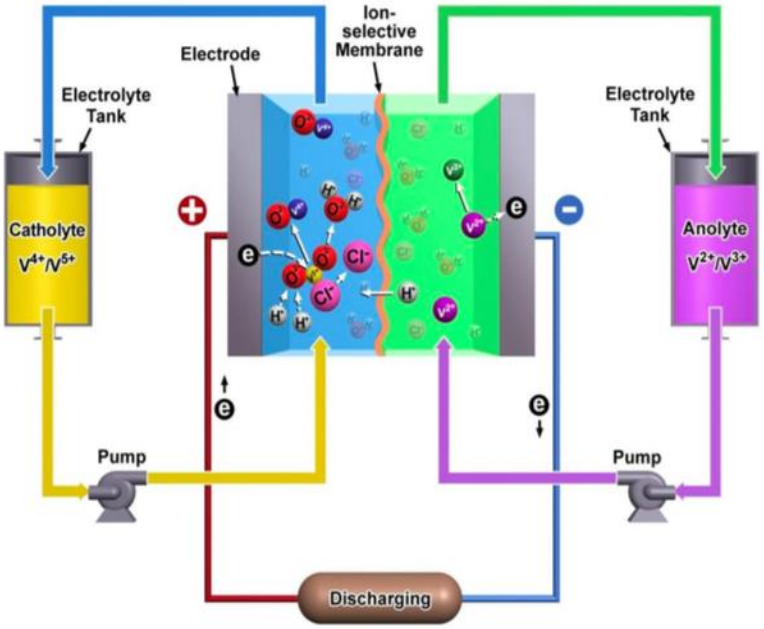
U.S. DEPARTMENT OF ENERGY
Office of Electricity

Pacific Northwest NATIONAL LABORATORY

UET

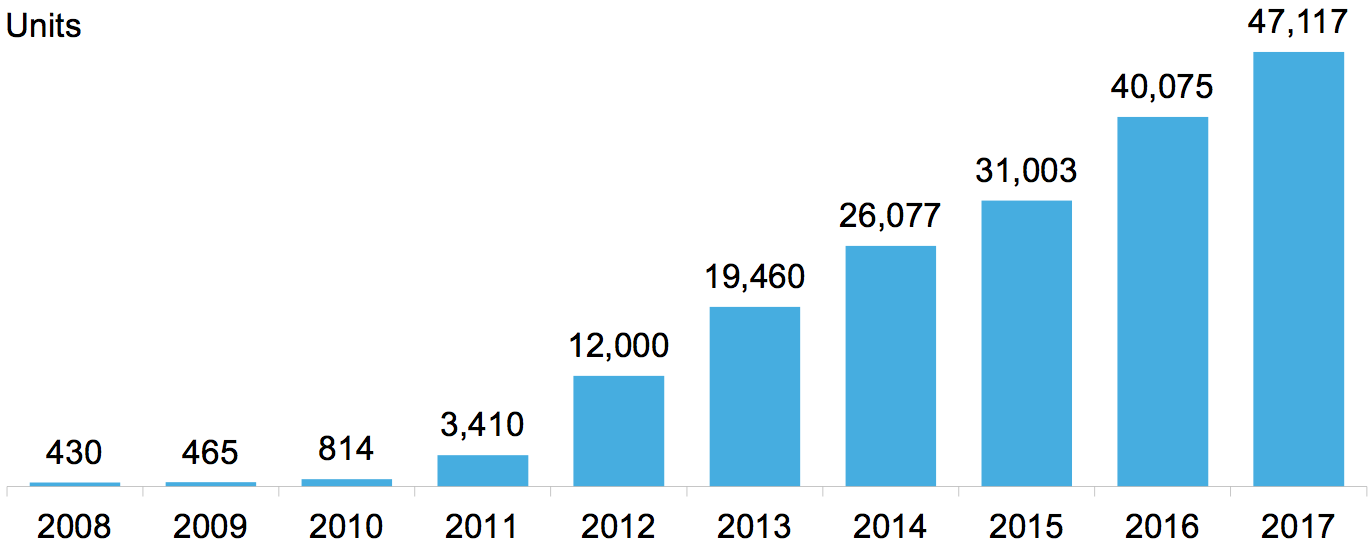


$VO_2Cl(H_2O)_2$

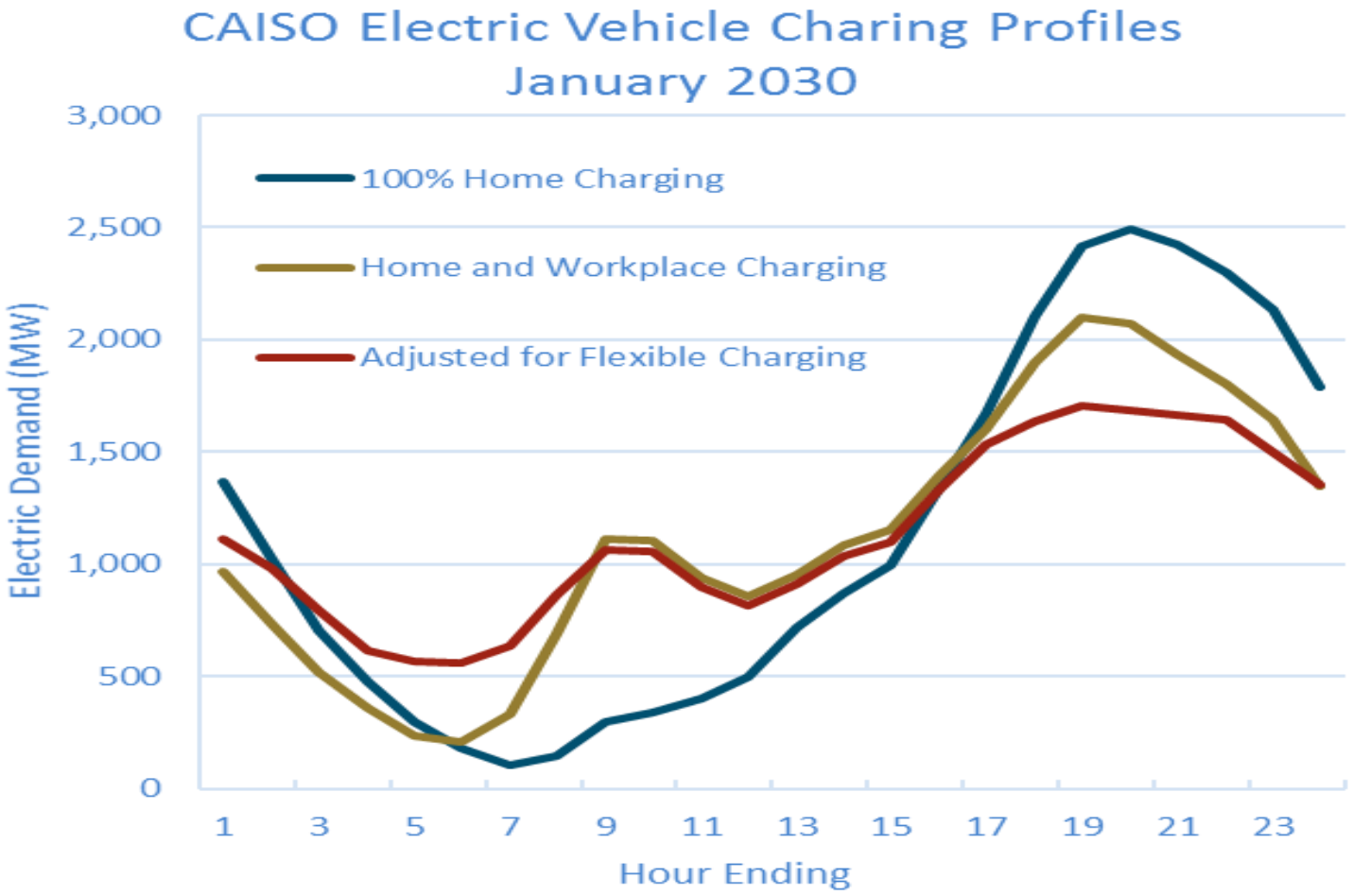


Developed at and licensed from PNNL
Improved and commercialized at UET

EV Charging Stations Are Rapidly Increasing in California



EV charging Not Well Aligned to Help the “Duck” – current model results



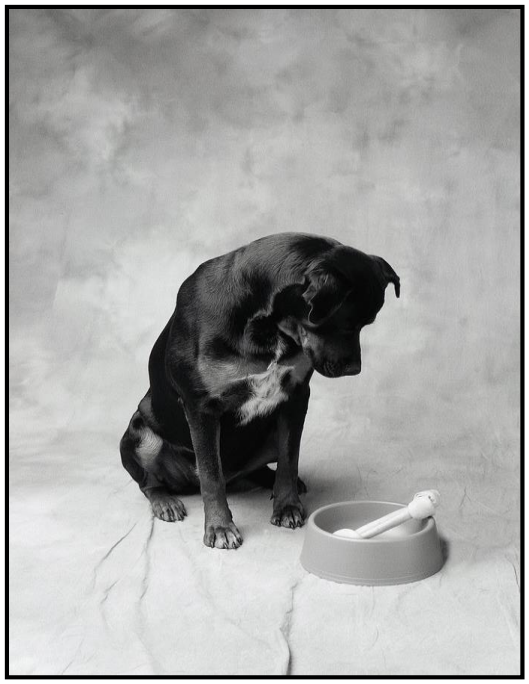
State Initiatives, Distributed Energy Resources that Impact Utility Business

- California Community Choice Aggregators made sense at one point, but now less so – regulators must react to changing technology pricing environment
- DER will impact utility businesses, but can also serve to be a new "services" leader under new business models
  - Southern Co. microgrid in Chattanooga, Tennessee
- Many of these technologies can either benefit the consumer or the utility.
- The key is to determine business models and regulations that will lead to win-win situations
  - Hawaii SB 2939 (2018) requiring development of performance- based standards may be harbinger of the future

Government Policies Must Keep Pace with Technology and the Need to Have an Economically-Viable Electricity Infrastructure

Major technology innovations require regulatory and institutional and barriers to be addressed in addition to technical and financial aspects – Avoid red tape and don't let lawyers pick technology winners!!

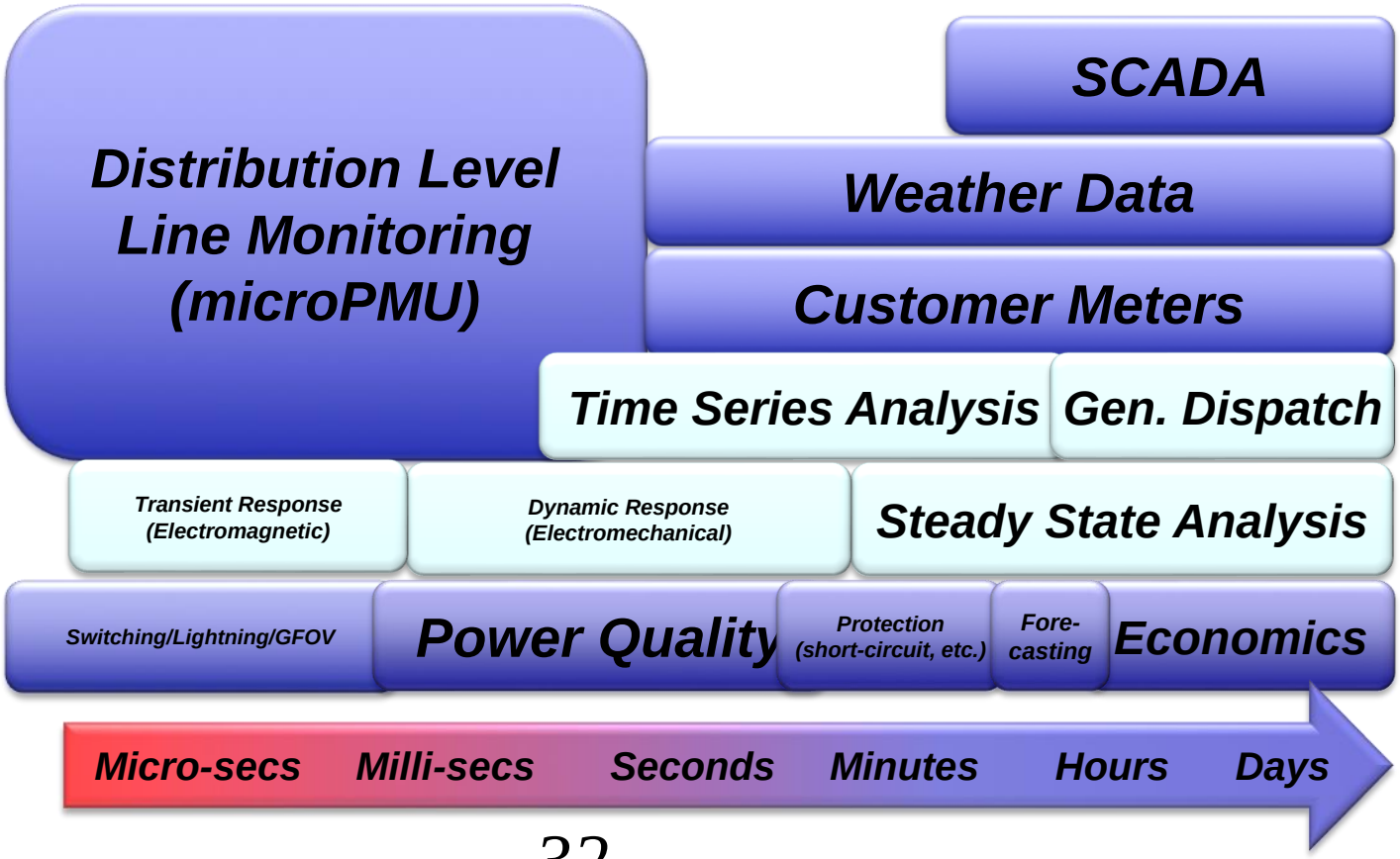
Otherwise, states have been guilty of dog's breakfast of regulations and policies – i.,e., CA conflicted energy/environmental laws



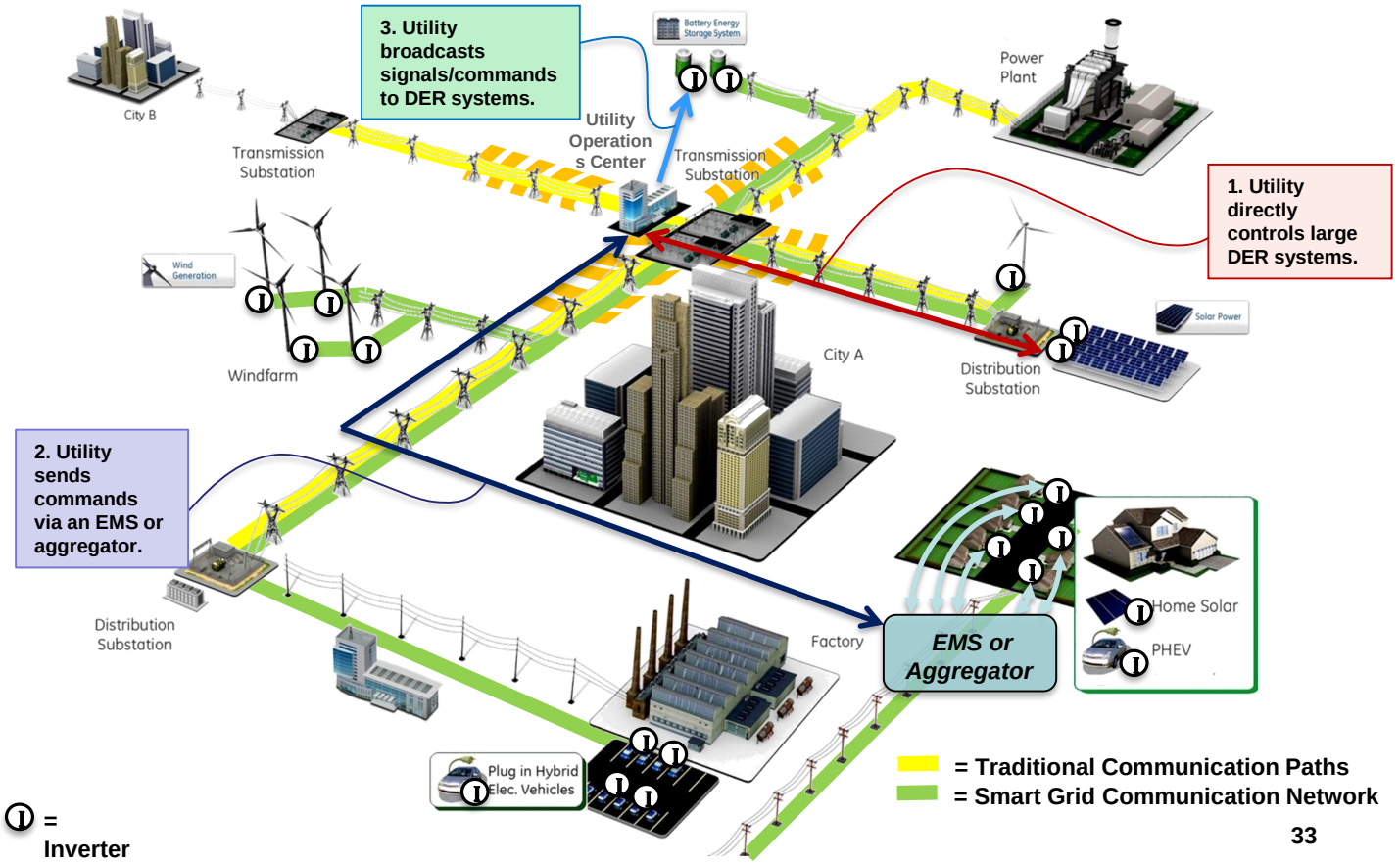
DER - But Not Necessarily BTM - Can Contribute to Meeting Grid Operational Challenges

- Energy storage can help mitigate over-generation
- Load shifting (ADR, storage) can help mitigate conventional resource needs
- DERs may also benefit system by reducing peak demand and thereby avoid need for transmission upgrades
- Controlled load dropping can provide spinning reserve and frequency response benefits
- Electric Vehicles can provide regulation service or balancing needs
  - but not electricity during peak periods – Nissan Leafs could, but Tesla not interested
- Micro grids allows participation in ancillary services markets – concern is will end-users exit market entirely

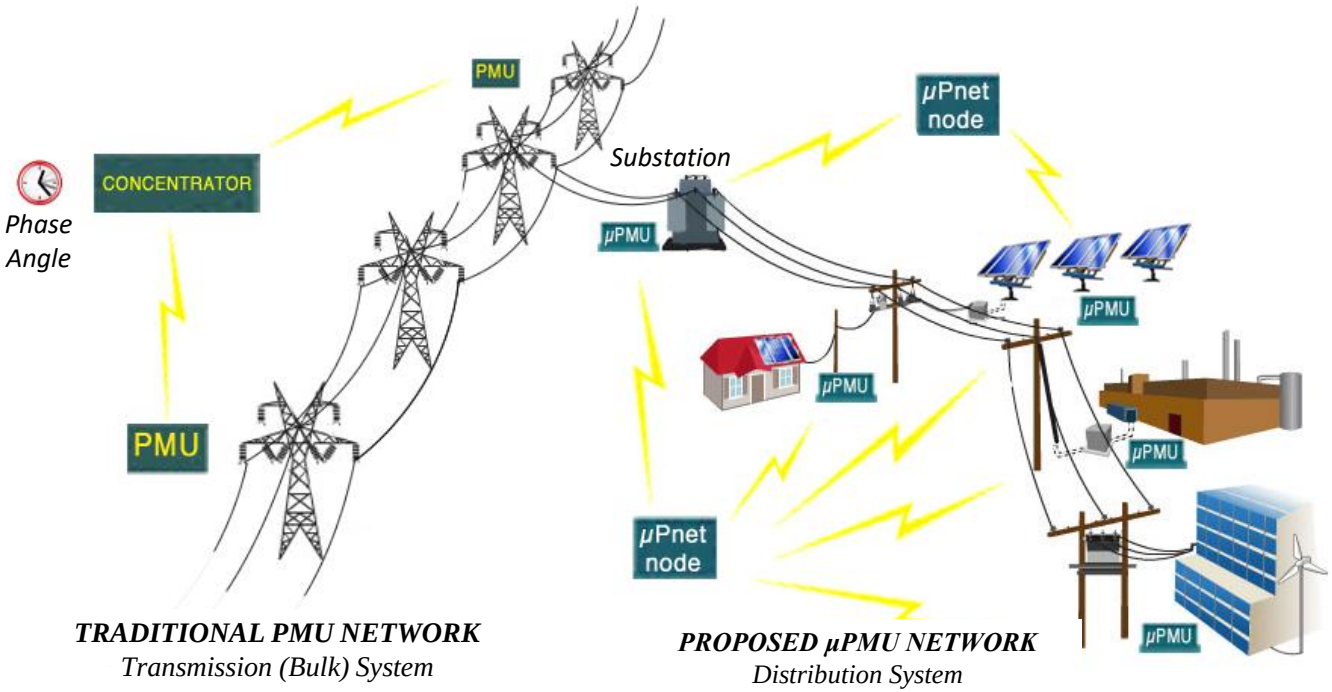
Need for Telecommunications – How Do Utilities Plan for and Manage Tsunami of Data Coming?



Smart Electricity Grid Communications



Another Source of Data: Emergence of µPMUs for Distribution Applications for Providing Information to System Operators



ciee California Institute for Energy and Environment

A Suite of Solutions Will Be Necessary – There Is No "Magic Bullet"

Storage – increase the effective participation by energy storage resources.

Western EIM expansion – expand the western Energy Imbalance Market.

Demand response – enhance DR initiatives to enable adjustments in consumer demand, both up and down, when warranted by grid conditions.

Regional coordination – offers more diversified set of clean energy resources through a cost effective and reliable regional market.

Time-of-use rates – implement time-of-use rates that match consumption with efficient use of clean energy supplies.

Electric vehicles – incorporate electric vehicle charging systems that are responsive to changing grid conditions.

Minimum generation – explore policies to reduce minimum operating levels for existing generators, thus making room for more renewable production.

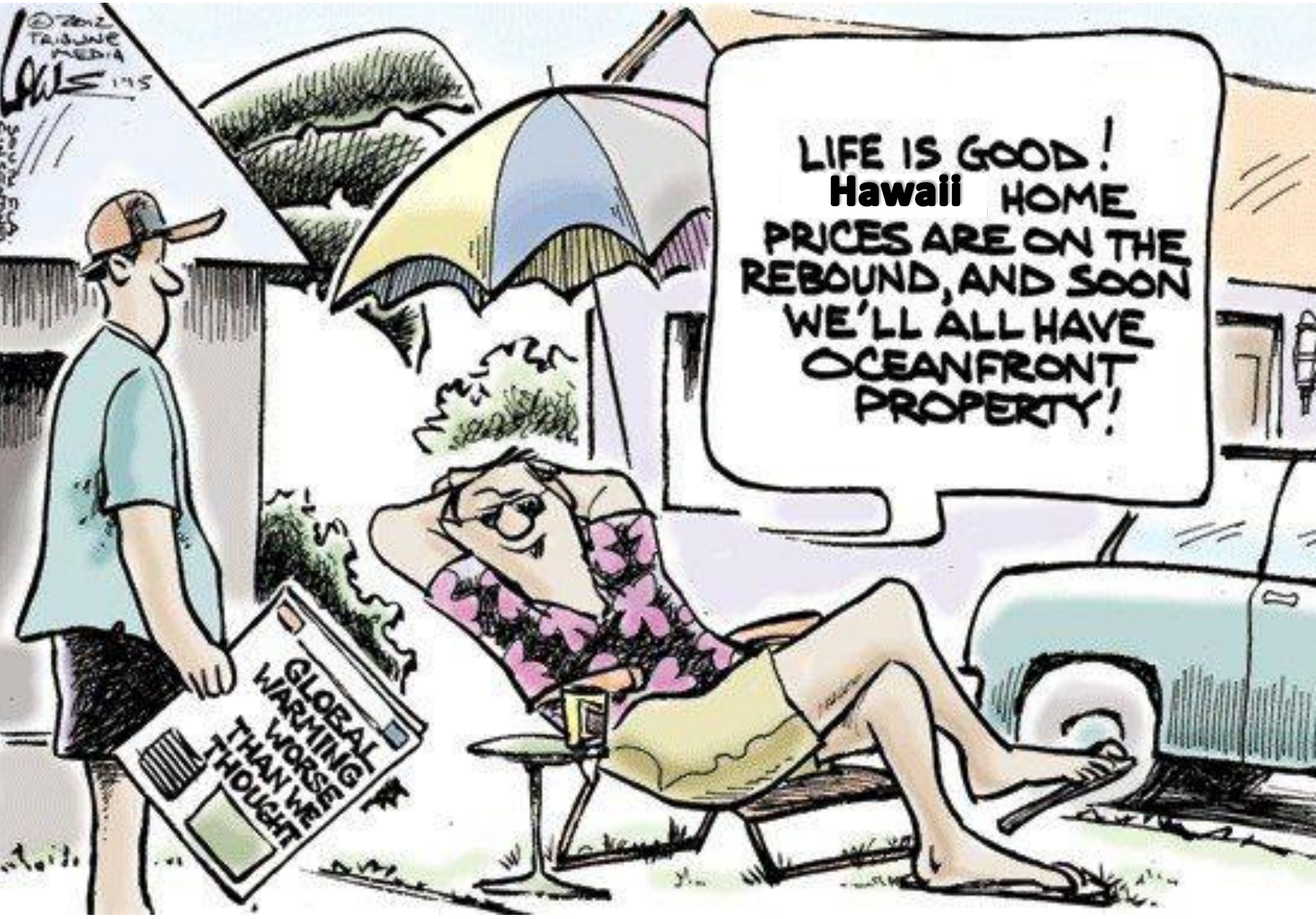
Flexible resources – invest in modern, fast-responding resources that can follow sudden increases and decreases in demand.

Changes Continue for US Grid – "stuff will move more quickly than we now anticipate."

- State Regulators – subject to legislative mandates
  - Evaluate societal/actual costs of various business models
  - Flexible regulations must adapt to technological advances
- Utility business models must change due to changes in technology and government policy
  - Insertion of new technologies must be considered from a systems perspective
  - Innovative, transformational, disruptive transitions will occur
  - Understanding and developing strategies and architectures for operating a much more information-rich distribution grid.
  - Bolting new things on legacy systems, while keeping lights on
- Everyone must work to ensure that

utilities are profitable and

electricity prices are reasonable


LIFE IS GOOD!
Hawaii HOME PRICES ARE ON THE REBOUND, AND SOON WE'LL ALL HAVE OCEANFRONT PROPERTY!
GLOBAL WARMING! WORSE THAN WE THOUGHT