

# The Future of Wholesale Electricity Market Design

With the Growth of Low-Carbon Generation

## PRESENTED TO

Energy Bar Association  
2016 Annual Meeting & Conference

## PRESENTED BY

Samuel Newell  
Roger Lueken

June 8, 2016



THE **Brattle** GROUP

# Agenda

---

## **I. Challenges to Electric Systems and Markets to Support Them**

- Operational Challenges
- Resource Adequacy Challenges

## **II. Market-Based Solutions**

- Energy Scarcity Pricing
- Ancillary Service Design
- Capacity Requirements
- Capacity Flexibility Requirements

## **III. Will Markets Support Adequate & Efficient Investment?**

# I. Challenges

## Introduction

---

### Problem Statement

- What is the future for market design to continue to reliably meet load at least cost, in a world with growing intermittent renewable generation and other low-carbon investment?

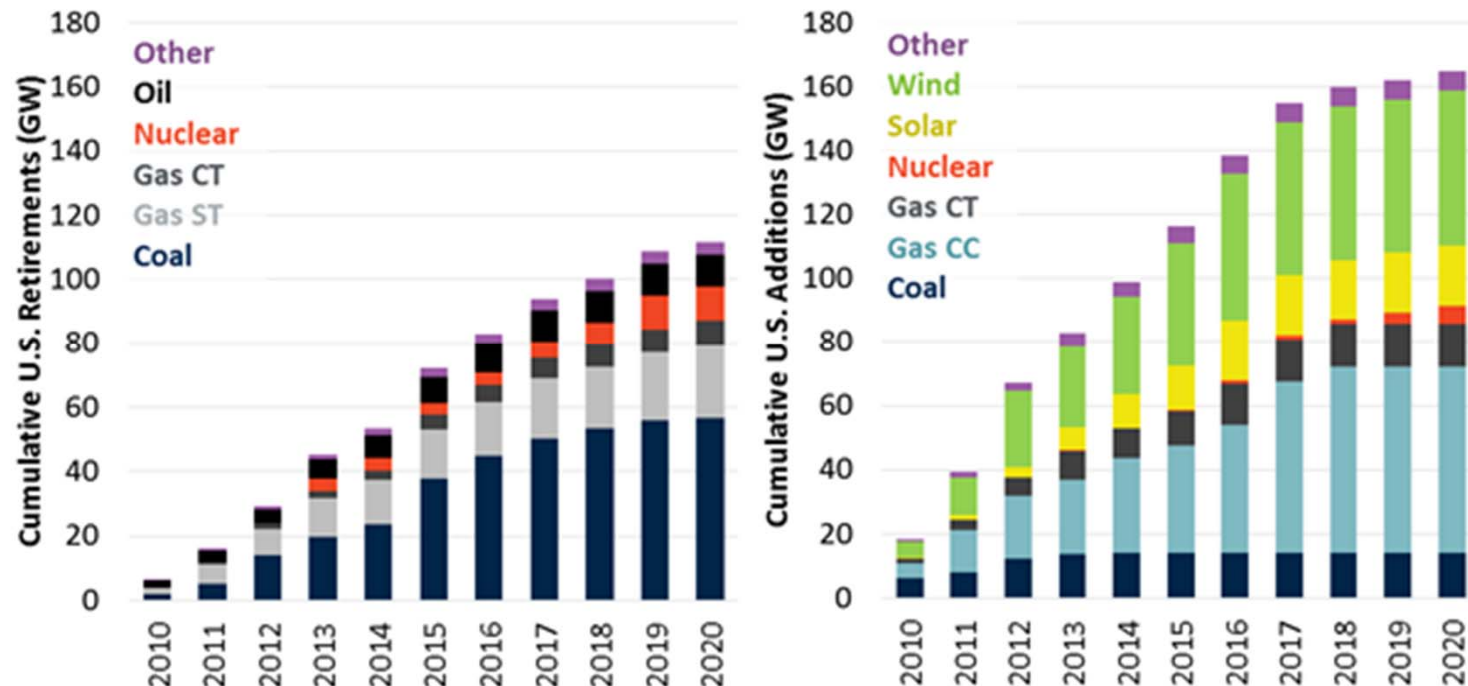
### Challenges

- The world is changing, with policy-driven renewables and clean power, low gas/electric prices, modest load growth, and baseload retirements.
- These trends may make economic and environmental sense, but they pose challenges for electric systems:
  - Operations: with highly variable generation from renewables, how to balance supply and demand in real time?
  - Resource adequacy: with zero-variable-cost generation depressing energy prices, how to ensure markets attract and retain enough capacity and flexibility?
- Note: this presentation does not evaluate the efficacy of different carbon policies; it takes decarbonization as given and explores the implications.

## I. Challenges

# Transition from Coal to Gas to Renewables

**Cumulative U.S. Retirements and Additions**  
(Net Summer Capacity)



Sources and Notes:

ABB Velocity Suite data. Wind and solar are nameplate capacity, not derated capacity value.

- 70 – 110 GW more nameplate renewable capacity expected by 2030, depending on whether CPP comes into effect (per AEO 2016 Early Release)

# I. Challenges

## Operational Challenges

Variable renewable energy resources (VER) provide clean energy, but with generation following the wind and sun patterns rather than patterns of need.

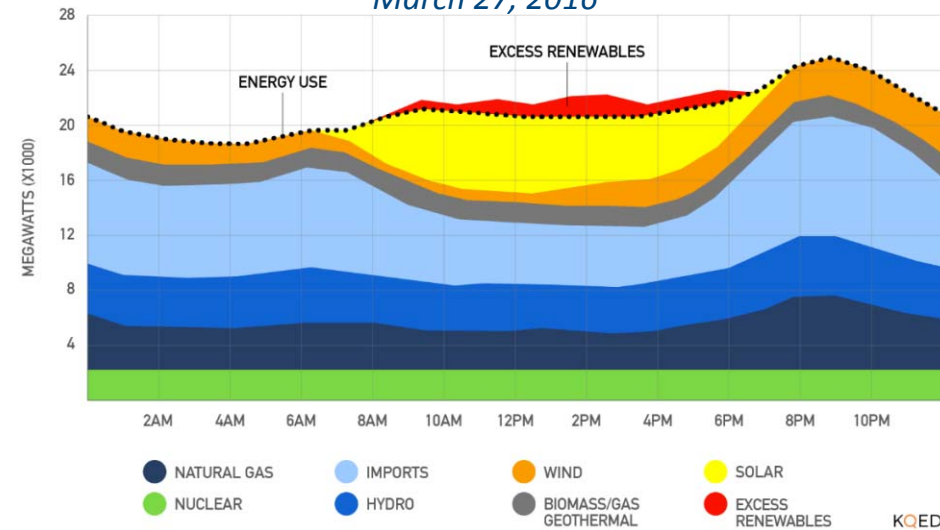
How to balance supply and demand in real-time? This is challenging because variable generation can:

- **Fluctuate up and down:** VER output can fluctuate substantially and unpredictably on short timescales (may need more regulation).
- **Over-generate:** At high penetration, net load can become negative, requiring curtailment of VERs absent load shifting, storage, or exports.
- **Sustain steep ramping down or up:** Sustained dramatic decreases or increases in VER output over longer timescales (>5 min) than dispatchable units online can ramp to (may need to commit more units that can ramp quickly).
- **Cause other generators to cycle excessively:** VER output patterns over the course of the day can force other units to cycle up/down, on/off more than they were designed to (may incur wear-and-tear and inefficient min-load generation, absent more flexible resources).

These challenges are generally small until VER penetration becomes high, e.g., NREL study begins to show over-generation and curtailment in CA w/ >50% renewables.

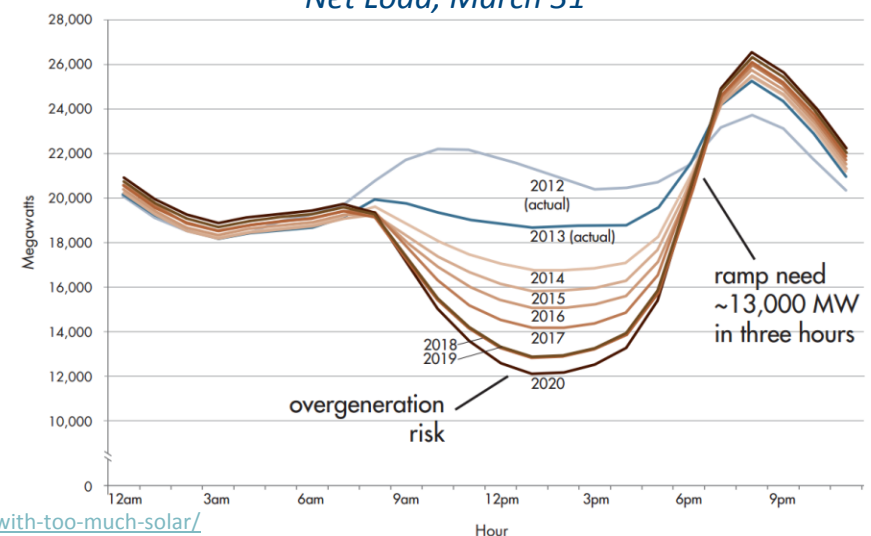
### California Solar and Wind Over-Generation

March 27, 2016



### California Ramping Needs

Net Load, March 31



Sources: Top chart: KQED, based on CAISO data. <http://ww2.kqed.org/science/2016/04/04/what-will-california-do-with-too-much-solar/>

Bottom chart: CAISO. [https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables\\_FastFacts.pdf](https://www.caiso.com/Documents/FlexibleResourcesHelpRenewables_FastFacts.pdf)

NREL Low Carbon Grid Study: <http://www.nrel.gov/docs/fy16osti/64884.pdf>

# I. Challenges

## Resource Adequacy Challenges

**How to attract and retain enough flexible capacity (and total capacity) to meet operational challenges at reasonable cost?**

**Variable energy resources themselves have limited capacity value.**

- Sun and wind may not be available when needed.
- The resource adequacy value of solar PV declines with increasing penetration as the net peak shifts into the late evening (see right).

**Gas-fired generation can balance VERs and provide resource adequacy, but faces depressed net energy revenues caused by VERs.**

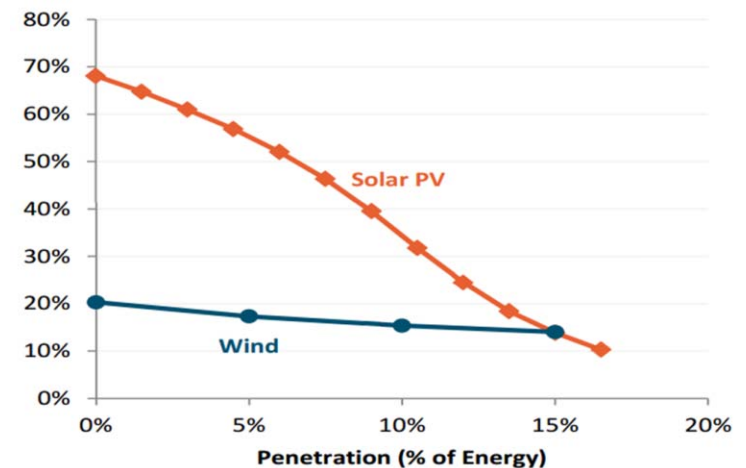
- Low gas prices have been the main factor depressing energy prices.
- But zero-variable-cost generation depresses energy prices too, especially when they become marginal.
- Negative prices are becoming more frequent in places with high penetration of renewables (see right).
- This especially reduces energy revenues of baseload generation; it can also reduce energy revenues for more flexible intermediate generation even for the most flexible, higher-variable-cost peaking generation.

**The rest of this presentation addresses how market design can address these challenges.**

**Note: a related concern is the effect on nuclear.**

- Existing nuclear is a carbon-free resource and should not be penalized by decarbonization policies.
- An appropriate price on carbon could solve this and get the right dispatch order among fossil units; this would avoid paying different prices to different resources per ton of CO<sub>2</sub> abated.
- Carbon policy questions are not addressed further in this presentation.

### Declining Marginal Capacity Value of VERs



Source: E3 Update on 2015 Special Study for CAISO and CPUC.  
[https://www.caiso.com/Documents/Updateon2015\\_50\\_SpecialStudy.pdf](https://www.caiso.com/Documents/Updateon2015_50_SpecialStudy.pdf)

### Number of Hours with Average Real-Time Energy Prices Less than \$5/MWh

Location	2013	2015
CAISO SP15	201	516
ERCOT Houston	22	127
MISO Minnesota	162	313
Germany	130	170
Denmark West	24	133

*Sources and Notes:*

ABB Velocity Suite, EXAA, Energinet.dk

Germany prices reported in EUR and Denmark prices reported in DKK then converted to USD using the exchange rate on July 1 of each year.



## II. Market-Based Solutions

---

**In a world that values energy that is low-carbon but still reliable, properly designed markets should signal the following:**

- Attract and retain zero- (or low-carbon) energy resources
- Retain, enhance, and attract flexible resources (supply & demand) that help balance the system
- Displace brown energy and retire when projected net energy revenues fail to justify ongoing fixed costs and CapEx

**As zero-variable-cost generation depresses energy prices some of the time, investment depends increasingly on scarcity value in other periods when supply is short relative to need, whether in the energy, ancillary services, or capacity markets.**

**The market design challenge is to define what the system needs, and how high prices can go when those needs are not fully met.² Four complementary solutions, approximately in descending order of priority:**

- A. Strengthening scarcity pricing in energy & ancillary services (E&AS) markets
- B. Getting the right ancillary services design
- C. Continuing capacity requirements
- D. Introducing capacity flexibility requirements

## II. Market-Based Solutions: Scarcity Pricing

# Strengthening E&AS Scarcity Pricing

---

**Principle: setting prices at the variable cost of the marginal resource does not express the value of lost load if the system runs out or threatens to run out.**

**Ideally, demand's willingness-to-pay would set the scarcity price for energy .**

- Little demand response (DR) is able to *set* prices currently. Like generation, DR needs the following to set prices: telemetry, RT-responsiveness, continuous adjustability (not block-loaded), and nodal settlement.
- Otherwise, DR can influence prices but not set them based on its own bids.
- With supply elasticity decreasing (renewable generation responds to wind and sun patterns as well as prices), it will become more important to increase demand elasticity (through demand response) to balance supply and demand and to foster efficient price formation.

**Until and unless more real-time price-setting DR develops, an administrative proxy must provide an efficient scarcity price.**

**Scarcity prices can signal the value of investment and operation of resources that can provide energy/flexibility when needed.**

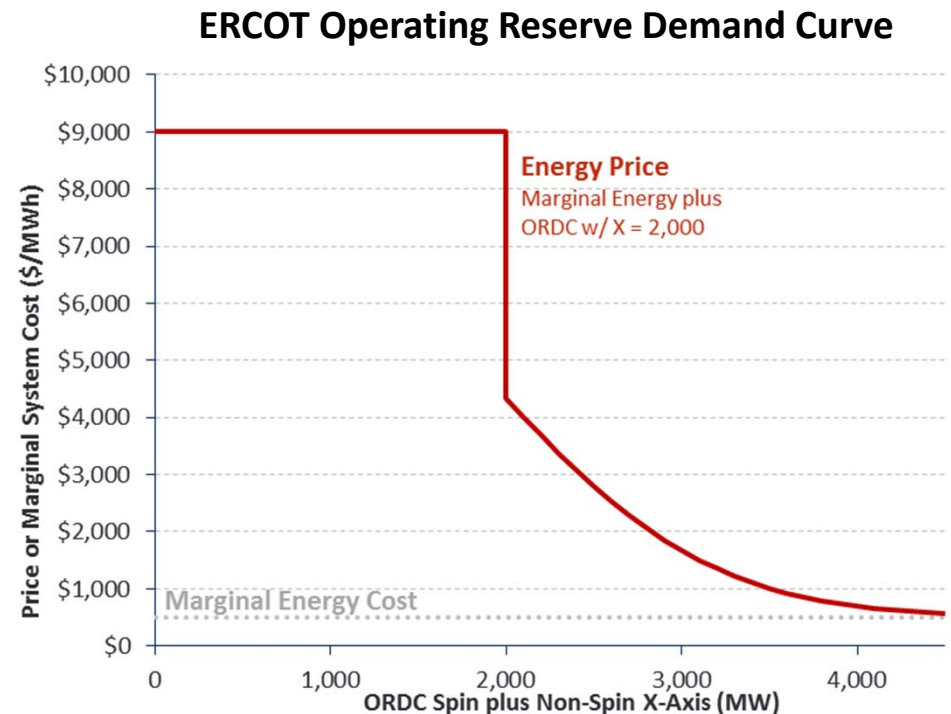
- For example, if VERs move the net peak load to evening or various random times, energy scarcity prices will reward whatever resources can generate at those times.
- Prices will spike when there's unexpected shortage of ramping capability; resources that can ramp up (or sustain their output) will benefit.
- ERCOT is the leader with high scarcity pricing (see next slide).
- All other U.S. ISOs have some form of scarcity pricing, generally implemented as operating reserve constraint penalty factors with real-time co-optimized energy and ancillary services.
- But, regulators, customers, and investors must be able to tolerate highly volatile, irregular pricing.



## II. Market-Based Solutions: Scarcity Pricing

### Example: ERCOT'S Scarcity Pricing

- In 2012, the Public Utility Commission of Texas (PUCT) initiated a proceeding to assess whether the energy-only market would provide enough investment incentive to maintain reliable supply.
- PUCT and ERCOT resolved to strengthen scarcity pricing to incentivize suppliers to invest and perform whenever needed to support operational reliability.
  - They implemented an Operating Reserve Demand Curve (ORDC), with administrative price adders rising as reserves become depleted.
  - ORDC prices are based on a loss-of-load-probability times an assumed value of lost load.
  - Prices can rise to \$9,000/MWh, higher than any other U.S. energy market.
- The ORDC and other market forces have attracted investment and propelled planning reserve margins to well above target.
- With high reserve margins, E&AS prices remain low, although prices exceeded \$1,000 during hot periods in summer 2015.



Source:

[http://ercot.com/content/wcm/key\\_documents\\_lists/72460/4.1\\_2015\\_Mid\\_Summer\\_Update.pdf](http://ercot.com/content/wcm/key_documents_lists/72460/4.1_2015_Mid_Summer_Update.pdf)

## II. Market-Based Solutions: Ancillary Services

# Refining Ancillary Services Designs

---

**The ultimate product is energy. But to balance the system's supply/demand fluctuations on various timescales (incl. contingencies), system operators procure ancillary services.\***

**With increasing VERs, system operators are asking whether different types or amounts of ancillary services are needed.**

- What capabilities are needed?
- How to design discrete products that accommodate resource capabilities?
- What quantities are needed as a function of system conditions?

**We have not yet seen substantial increases in requirements for existing AS products in the U.S.**

**But some systems with higher penetration rates are introducing new Ancillary Services.**

- MISO is introducing a 5-minute ramping ancillary service (see next slide).
- CAISO has proposed a 5-minute ramping ancillary service similar to MISO's. Relatedly, CAISO has a new planning requirement for flexible capacity, as discussed on slide 14.
- ERCOT proposed a redesign of its AS market to enable new technologies to help meet an anticipated growing need for frequency response in case inertia fell (see following slide).

*\* In a world with perfect information, energy prices alone could induce suppliers to hold operating reserves (although not necessarily enough to meet reliability criteria). Suppliers do not, however, have perfect information about system conditions or who else is providing reserves, so would not be able to coordinate an efficient level of real-time reserves. Thus the system operator needs to procure operating reserves.*

## II. Market-Based Solutions: Ancillary Services

# Example: MISO Ramping Product

---

**As part of its wind integration initiative, MISO became concerned about the system's capability to ramp in response to large amounts of wind.**

- Previously, MISO maintained ~750 MW of 'headroom' (*i.e.*, the difference between online and dispatched capacity) at all times. This was managed by manual commitment of resources. MISO did not directly consider the ramping capability of headroom resources.
- MISO developed the ramping product to support reliable operations and send price signals that would incentivize the development of more ramping capability when needed.

**MISO's 5-minute ramp product is designed to reserve rampable capacity to efficiently meet changes in net load.**

- MISO procures ramping in day-ahead (DA) and real-time (RT). DA procurements are based on a forecast of ramping needs. RT procurements are made every 5 minutes based on a 10-min and 20-min look-ahead.
- MISO procures separate products for ramp-up and ramp-down (up is the more critical one).
- Resources are paid a clearing price set by the marginal supplier's opportunity cost of not providing energy.

**This innovation should improve reliability, increase market efficiency and transparency, and send investment signals for more flexible resources if they were needed.**

**This new product went live May 1, 2016.**

- Prices not yet public (as of May 27).
- MISO may study and fine-tune the product in coming months.

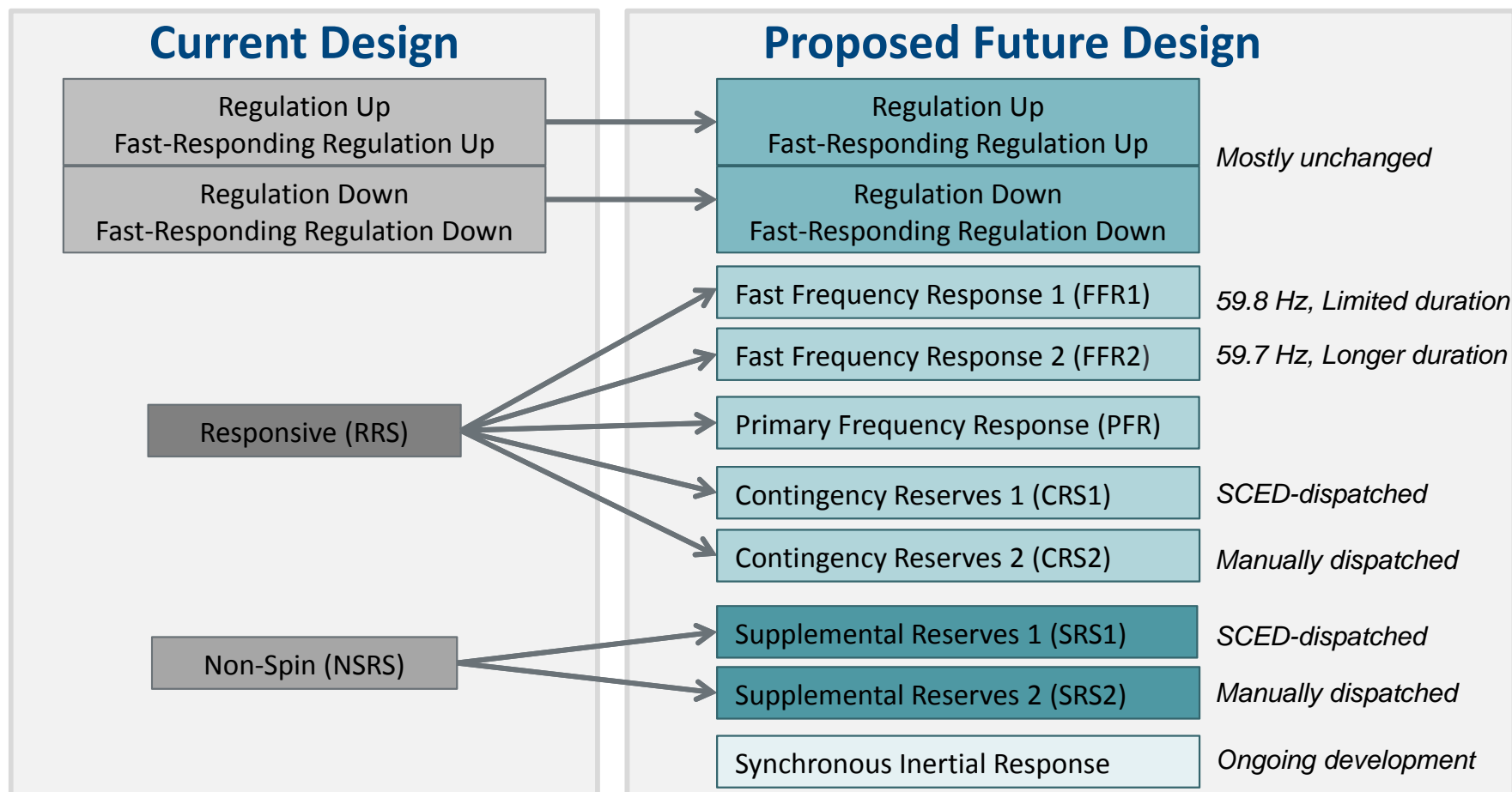
Sources and Notes:

<https://www.misoenergy.org/WhatWeDo/MarketEnhancements/Pages/RampManagement.aspx>

<https://www.misoenergy.org/Library/Repository/Communication%20Material/Strategic%20Initiatives/Ramp%20Product%20Questions%20and%20Answers.pdf>

## II. Market-Based Solutions: Ancillary Services

### Example: ERCOT's Proposal



- ERCOT's proposed Future Ancillary Services (FAS) design would unbundle responsive reserve services used for restoring frequency after a contingency; FAS would fine-tune service requirements to system conditions and resource capabilities.
- Brattle study found 10:1 benefit-cost ratio for FAS, reflecting production cost savings from a more efficient commitment and dispatch, with load resources and new technologies efficiently substituting for spinning reserves, and with less quick-start held in reserve. See [http://www.ercot.com/content/wcm/key\\_documents\\_lists/30517/667NPRR\\_12a\\_Cost\\_Benefit\\_Analysis\\_122115.pdf](http://www.ercot.com/content/wcm/key_documents_lists/30517/667NPRR_12a_Cost_Benefit_Analysis_122115.pdf).
- However, stakeholders did not support the change. See [http://www.adminmonitor.com/tx/ercot/technical\\_advisory/20160526/](http://www.adminmonitor.com/tx/ercot/technical_advisory/20160526/).

## II. Market-Based Solutions: Resource Adequacy Requirements

# Maintaining Resource Adequacy Requirements

---

**Most electric systems impose a resource adequacy (RA) requirement (defined as a reserve margin on top of peak load) on load-serving entities.**

- The requirement ensures having enough capacity to avoid shedding load more often than an administratively-determined reliability standard allows, *e.g.*, one event in ten years.

**The RA requirement creates a “demand” for capacity, which gives rise to a capacity market and determines capacity payments for suppliers. Several U.S. systems use centrally administered capacity auctions.**

- The premise for capacity payments is that E&AS markets alone would not attract enough capacity to meet traditional requirements, whether because E&AS prices are inefficiently low and/or the RA requirements themselves are inefficiently high.
- The system operator sets the requirement and rules for qualifying resources, then all resources compete to meet that requirement at least cost.

**Some market observers have criticized capacity markets for paying all resource types the same, rather than differentiating based on meeting policy objectives.**

- However, capacity markets were only ever about resource adequacy, for which all reliably available MW are in fact equally valuable over the delivery timeframes considered.
- Furthermore, capacity markets complement energy markets that recognize efficiency and fuel selection, and AS markets that reward flexibility.

## II. Market-Based Solutions: Resource Adequacy Requirements

# Capacity Market Accommodation of VERs

---

### Capacity markets can support resource adequacy even if VERs depress energy prices

- If resources' net energy revenues fall, they may increase their capacity offer prices, and this should raise capacity clearing prices enough to attract/retain sufficient MW.
- But the resulting mix of resources may tilt toward (more flexible) peaking/intermediate generation that suffers fewer hours of depressed energy prices than baseload while getting paid the same capacity price per MW.

### In some cases, VERs can depress capacity prices

- If enough VERs are added to overwhelm peak load growth, they could *reduce* capacity prices.
- However, that would signal suppliers to consider retiring existing capacity resources and reducing investment in new ones. (Retirements will put upward pressure on capacity prices. If a shortage arises, prices should signal when new, possibly more efficient and flexible, capacity should enter.)

### However, it is important for RTOs to discount VERs properly

- VERs are only partially counted as capacity, based on likely output during potential shortages.
- Many studies have looked at VER deratings. Need for probabilistic wind/solar analysis to assign correct capacity value (see example on slide 5).
- Note that the marginal value can be much lower than the average value, leading to questions about how much to compensate.



## II. Market-Based Solutions: Resource Adequacy Requirements

# Some Outstanding Questions

---

**With growing amounts of policy-driven entry, will the net demand for other new capacity become too thin, with too much regulatory risk to support investment?**

- The prospect of low energy + capacity prices in the future may deter entry...just enough to reflect the questionable value of fossil resources in a low-carbon future, or more so because investors heavily discount a future in which they cannot anticipate policymakers' actions to promote clean energy?
- Clean-energy entry has generally not been great enough to test U.S. capacity markets in this regard.

**Will markets attract enough flexible resources to support reliability operations with VERs? (see next slide)**

## II. Market-Based Solutions: Capacity Flexibility Requirements

# Introducing Capacity Flexibility Requirements

---

**Flexibility is needed to balance VERs, but what capabilities are likely to be scarce and warrant imposing a requirement on the planning timescale, *e.g.*, as a constraint in capacity markets?**

- It is unlikely that new requirements are needed for low-VER-penetration markets, where there is generally enough ramp capability available from online resources to get ramping for free.
- Even with higher penetration, the question is what flexibility capabilities are likely to be scarce and warrant imposing a requirement?
  - Simulation analyses can help determine whether existing resources can provide enough ramping in all timeframes (*e.g.*, 10-min ramping or 3-hr ramping), and how much more of each type would be needed to meet reliability criteria.
  - Introducing a planning requirement may be unnecessary if E&AS and capacity markets are sufficient.
  - The price premium for flexible MW over regular MW is likely to be nonzero only if, when there's no missing money for regular MW, the incremental cost of flexible MW is greater than the incremental revenue flexible resources can earn in the E&AS markets.

**Some systems with high renewable penetration are introducing flexible capacity requirements.**

- California has implemented a flexible resource adequacy procurement requirement on load serving entities, in order to support CAISO's ability to manage multi-hour ramps, *i.e.*, the “duck curve” as shown on the next slide.
- The Greek electric system regulator is proposing to implement a flexible capacity requirement similar to the one now imposed in California.

**Ideally, any flexible capacity requirement would correspond to an ancillary service in the day-ahead and real-time markets (with a uniform price rather than just unit-specific uplift), or else investment signals may not properly distinguish among resource types.**

# California Flexible Capacity Requirement

Increasing solar PV has led to extreme increases in net load in late afternoon, the so-called “duck curve.”

**“Flexible resource adequacy” was defined as a new capacity requirement for utilities to meet increasing ramping needs.**

- Each utility must procure sufficient resources to manage reliability during the greatest three-hour continuous ramp in each month.
- Flexible capacity needs range from 7,861 MW (August 2015) to 11,212 MW (December 2015).

**CAISO defined three categories of ramping to enable different types of resources to participate**

- Category 1 (Base Flexibility): Quantity set by the size of the largest 3-hour secondary ramp.
- Category 2 (Peak Flexibility): Quantity set by the difference between 95% of the maximum 3-hour net-load ramp and the largest 3-hour secondary net-load ramp.
- Category 3 (Super-Peak Flexibility): Quantity set by 5% of the maximum 3-hour net-load ramp of the month.

**This flexible capacity requirement will be complemented by a proposed new ramping ancillary service in the DA/RT markets.**

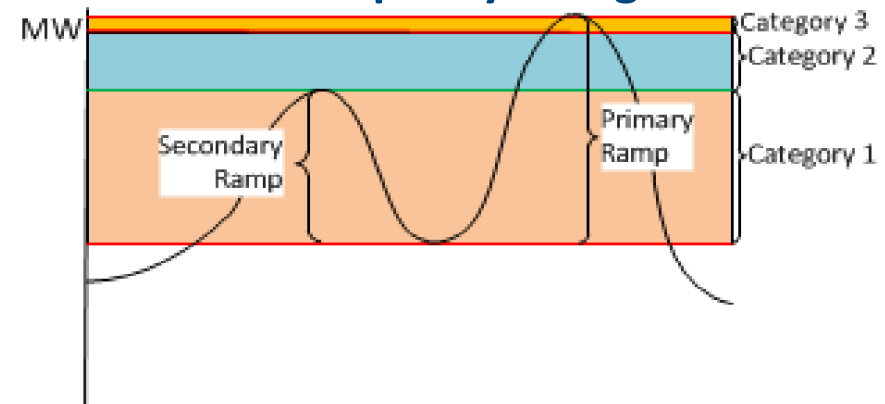
- The proposed ramping service would be similar to MISO’s.

## CAISO Hourly Net Load

March 28 – April 3, 2013 - 2016



## Flexible Capacity Categories



Sources and Notes:

<https://www.caiso.com/Documents/DecisionFRAC-MOO-Presentation-Mar2014.pdf>, <https://www.caiso.com/informed/Pages/StakeholderProcesses/FlexibleRampingProduct.aspx>,  
[http://docketpublic.energy.ca.gov/PublicDocuments/12-AFC-02/TN202691\\_20140713T202749\\_Ddecision\\_Adopting\\_Local\\_Procurement\\_and\\_Flexible\\_Capacity\\_Oblig.PDF](http://docketpublic.energy.ca.gov/PublicDocuments/12-AFC-02/TN202691_20140713T202749_Ddecision_Adopting_Local_Procurement_and_Flexible_Capacity_Oblig.PDF)

Source: Meredith Fowle, *The Duck has Landed*, <https://energyathaas.wordpress.com/2016/05/02/the-duck-has-landed/>

# III. Will Energy, Ancillary Services, and Capacity Markets Support Adequate and Efficient Investment?

---

**Some doubt these markets will encourage adequate investment in the right types of capacity to support reliability in a future with increasing policy-driven investment and with VERs displacing traditional dispatchable generation.**

- We face new challenges, as described on slides 4, 5, and 14.
- Most renewables that have been developed and are coming online in the next few years are supported by long-term contracts, limiting suppliers' market risks and moving away from a merchant investment model.

**I recommend not giving up too quickly on market approaches, considering historical successes and the breadth of approaches for continuing their success.**

- Markets have addressed other challenges (*e.g.*, recent coal retirements).
- Merchant investment in gas-fired generation and other resources has been robust.
- There are at least four complementary market design approaches, as outlined in this presentation.

**Moreover, market signals can be especially valuable in times of change.**

- Market prices signal when resources are or are not needed.
- Markets can achieve efficient tradeoffs among resources with different capital costs, fuel usage, and the ability to cycle and to capture energy price spikes or provide ancillary services.
- Market pricing can provide the right signals for demand response.

# Presenter Information

---



## **SAMUEL A. NEWELL**

Principal | The Brattle Group, Cambridge, MA

[Sam.Newell@brattle.com](mailto:Sam.Newell@brattle.com)

+1.617.864.7900

Dr. Samuel A. Newell, a Principal of The Brattle Group, is an economist and engineer with 18 years of experience in electricity wholesale markets, the transmission system, and RTO/ISO rules. He supports clients throughout the U.S. in regulatory, litigation, and business strategy matters involving wholesale market design, generation asset valuation, transmission development, integrated resource planning, demand response programs, and contract disputes. He has provided testimony before the FERC, state regulatory commissions, and the American Arbitration Association.

Dr. Newell earned a Ph.D. in Technology Management and Policy from MIT, and a M.S. in Materials Science and Engineering from Stanford University. Prior to joining Brattle, he was a Director at Cambridge Energy Research Associates.

The views expressed in this presentation are strictly those of the presenter(s) and do not necessarily state or reflect the views of The Brattle Group.

# About The Brattle Group

---

The Brattle Group provides consulting and expert testimony in economics, finance, and regulation to corporations, law firms, and governmental agencies worldwide.

We combine in-depth industry experience and rigorous analyses to help clients answer complex economic and financial questions in litigation and regulation, develop strategies for changing markets, and make critical business decisions.

Our services to the electric power industry include:

- Climate Change Policy and Planning
- Cost of Capital
- Demand Forecasting Methodology
- Demand Response and Energy Efficiency
- Electricity Market Modeling
- Energy Asset Valuation
- Energy Contract Litigation
- Environmental Compliance
- Fuel and Power Procurement
- Incentive Regulation
- Rate Design and Cost Allocation
- Regulatory Strategy and Litigation Support
- Renewables
- Resource Planning
- Retail Access and Restructuring
- Risk Management
- Market-Based Rates
- Market Design and Competitive Analysis
- Mergers and Acquisitions
- Transmission



# Offices



CAMBRIDGE



NEW YORK



SAN FRANCISCO



WASHINGTON, DC



TORONTO



LONDON



MADRID



ROME



SYDNEY