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Why Are We Talking About Capacity Markets?

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So, why ARE we talking about capacity markets?

Reliability

Goal of power system is to ensure reliable delivery of electricity at lowest cost to consumers

Market complexities → "Missing Money" → concerns over **resource adequacy**

Outline

- Market "Failure" and resource adequacy
- Capacity market design considerations for high variable generation (VG) systems
- Towards an optimum capacity market design

Electricity markets are uniquely complex

Fundamental Market Issues

- **Demand curve not visible to supplier**
- **Reliability is public good**
- **Missing markets**
- Uncertainty over future economic and policy factors
- Lumpiness (costs and time)
- Omission of externalities
- Market power

Amplifiers

- **Low- or zero-marginal cost generation**
- **Out-of-market subsidies**
- Lack of ample and cost-effective storage
- VG variability and uncertainty

Regulatory Response

- **Policy-based reliability requirements**
- **Administrative pricing rules**

Electricity markets are fundamentally different than any other market

United States observations reveal this complexity

- ISO/RTO market monitor reports noting low energy prices, driven by historically low natural gas prices and demand (and wind/solar to lesser degree)
- Nuclear premature proposed/planned shut downs due to insufficient revenues, resulting in subsidies

Are these symptoms of a deeper problem or an appropriate response to an evolving system?

Current market designs to ensure revenue sufficiency

1) Supplement energy-only market with A/S products and scarcity pricing

2) Forward capacity markets or capacity payments

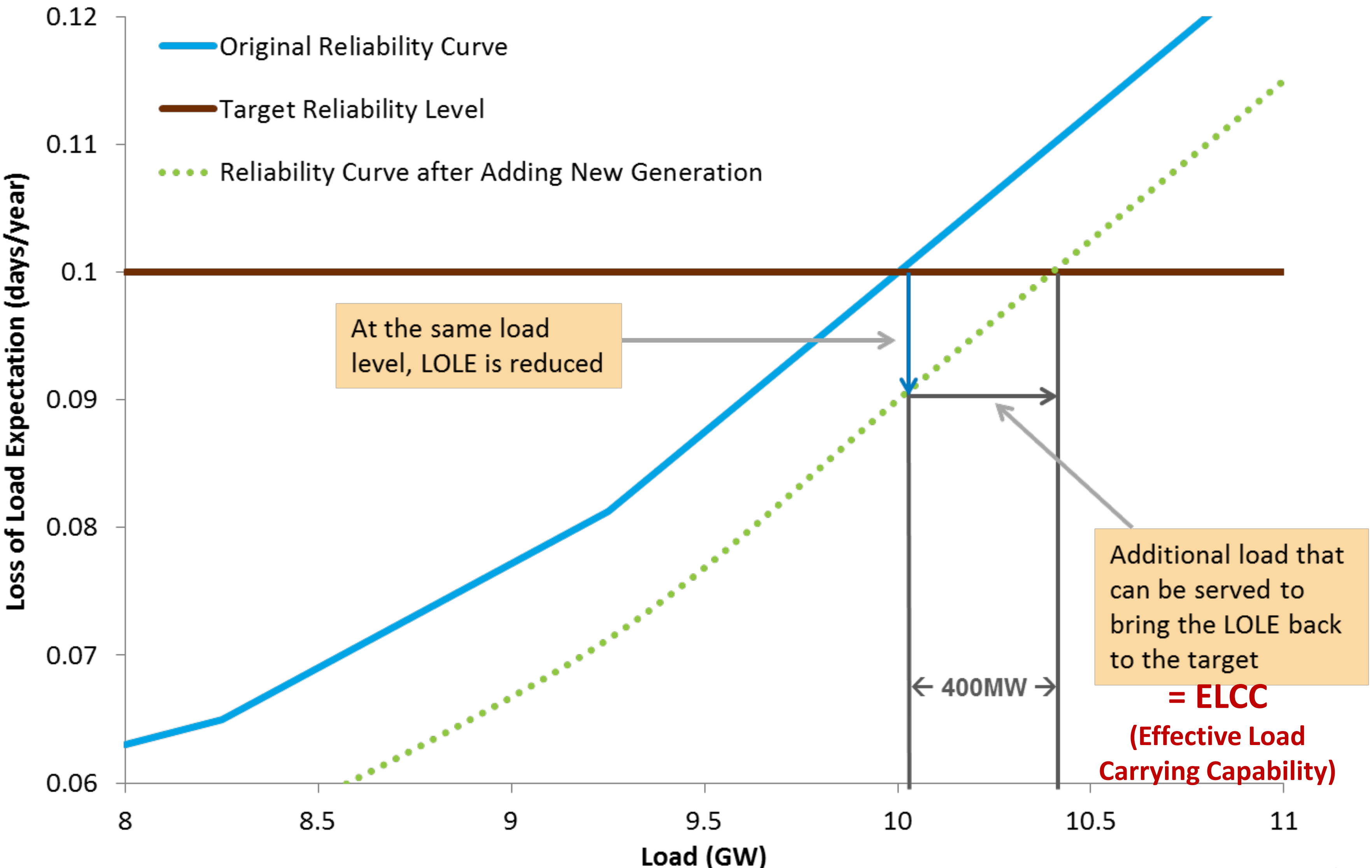
3) Power purchase agreements or other contracting approaches paid for with retail rates/cost recovery

Strategies to deal with this problem depend on existing market designs, and it remains unclear if/which of these can provide proper incentives to ensure longer-term reliability

What is Resource Adequacy (RA)?

- Having sufficient resources (generation, DR, storage) to supply all demand at a future date/time period/location
- Measured with reliability-based metric(s) that account for system performance
    - Set by policy: often 1 day/10 years loss of load, but any reliability target can be chosen (1d/y, 1d/20y, 4h/10y)

Preferred RA metric is based on LOLP



Milligan et al. 2016)

Recommended approaches for RA

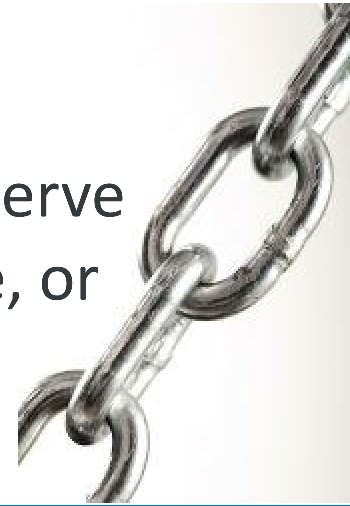
- Adopt a reliability target *such as* 1d/10y
- Derive the percentage reserve margin that corresponds to the reliability target
- Use ELCC to determine any generator's contribution
  - Wind and solar from net load time series
  - Conventionals with forced outage rates
- Use multiple years of data, and revisit as more data becomes available
- Interconnection or regional analysis

Linking RA with markets

- Ideally want to map LOLP-based methods to the markets to achieve
  - Optimal quantity of “sufficient” capacity
  - Revenue sufficiency

- US capacity markets have used various ‘true-ups’ with LOLP
  - E.g., NYISO – acquires installed capacity (ICAP) based on UCAP estimates (unforced capacity)

- ERCOT energy-only market includes LOLP in its reserve scarcity pricing (Operating Reserve Demand Curve, or ORDC)



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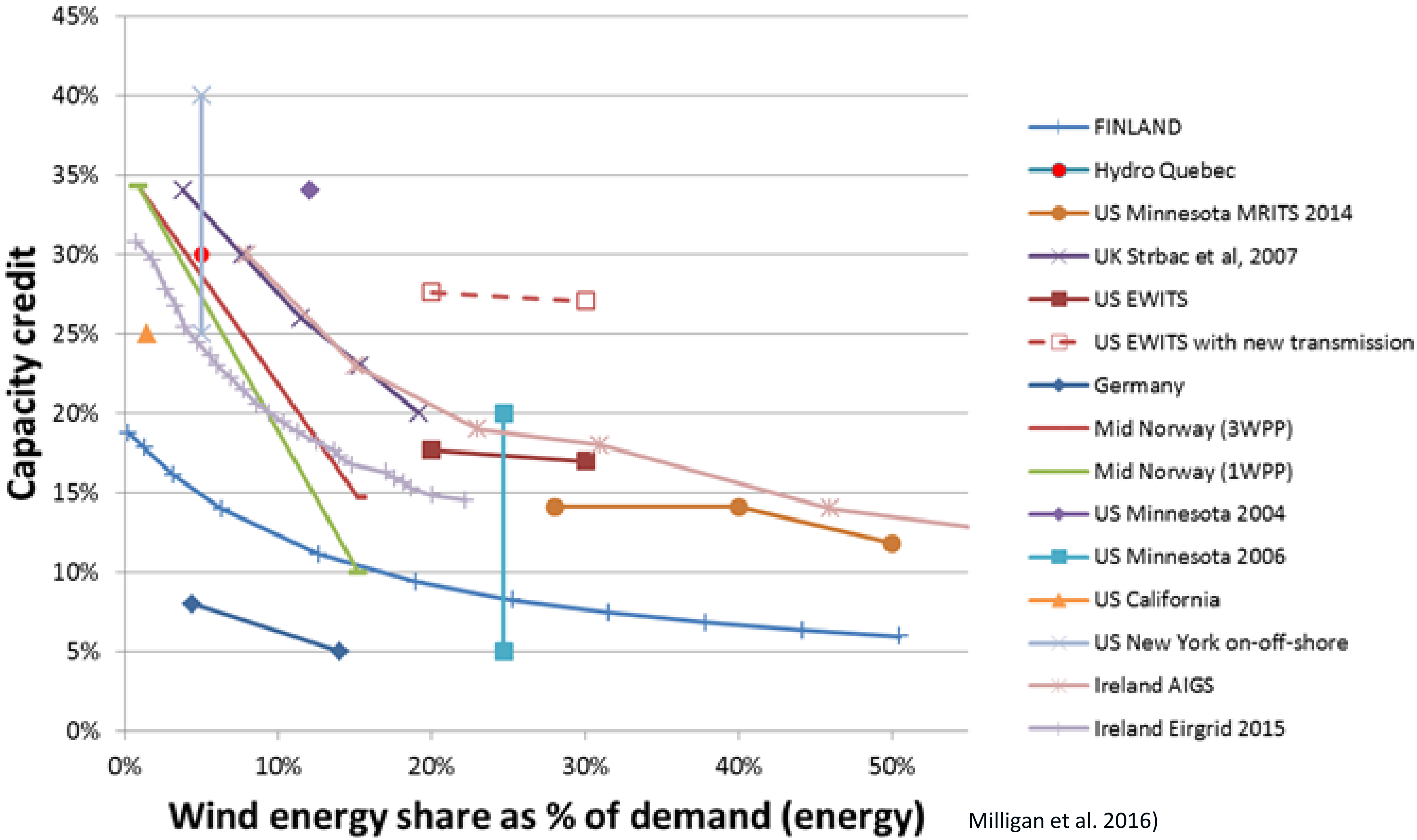
Declining CV with VG penetration level



Milligan et al. 2016)

Solar PV sees a similar decline, with marginal capacity values approaching 0 around 20% energy penetration (e.g., Munoz and Mills 2016)

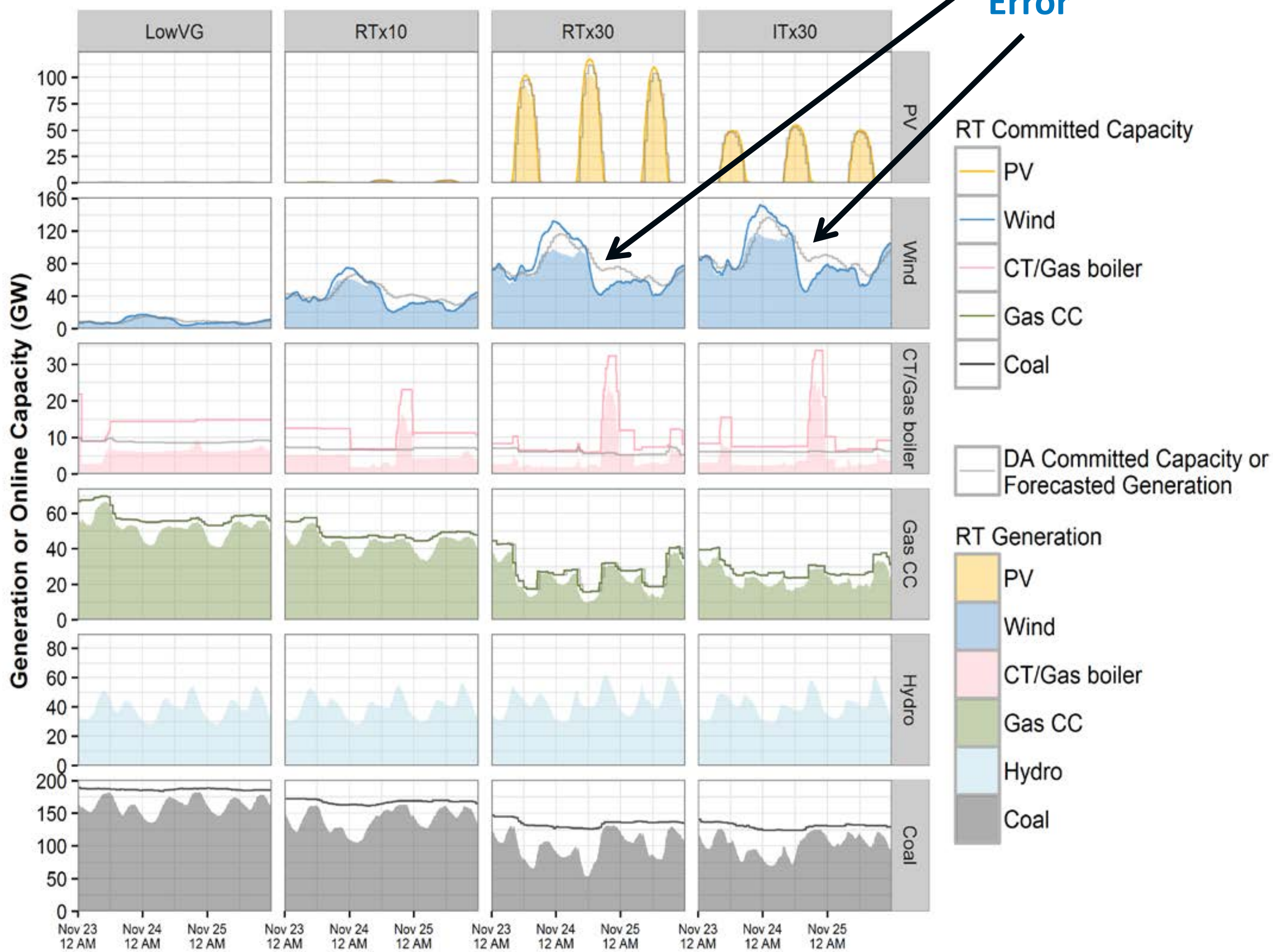
…And inconsistent methods for calculating CV

Operator	Geographic Resolution	Sampling Period	Intra-annual distinction	Historical Window
CAISO	Site-specific	Summer afternoons, Winter evenings	Monthly	3 years
ERCOT	System-wide (solar), Coastal vs non-coastal (wind)	Top 20 load hours	Summer, Winter	3 years (solar) 10 years (wind)
MISO	Nodal disaggregated from system-wide	Top 8 load hours	Annual	11 years (wind)
NE-ISO	Site-specific	Summer afternoons, winter evenings, shortage events	Summer, Winter	5 years
PJM	Site-specific	Summer afternoons	Summer only	3 years

Increased need for flexible capacity

NREL's Eastern Renewable Generation Integration Study (2016)

Wind Forecast Error

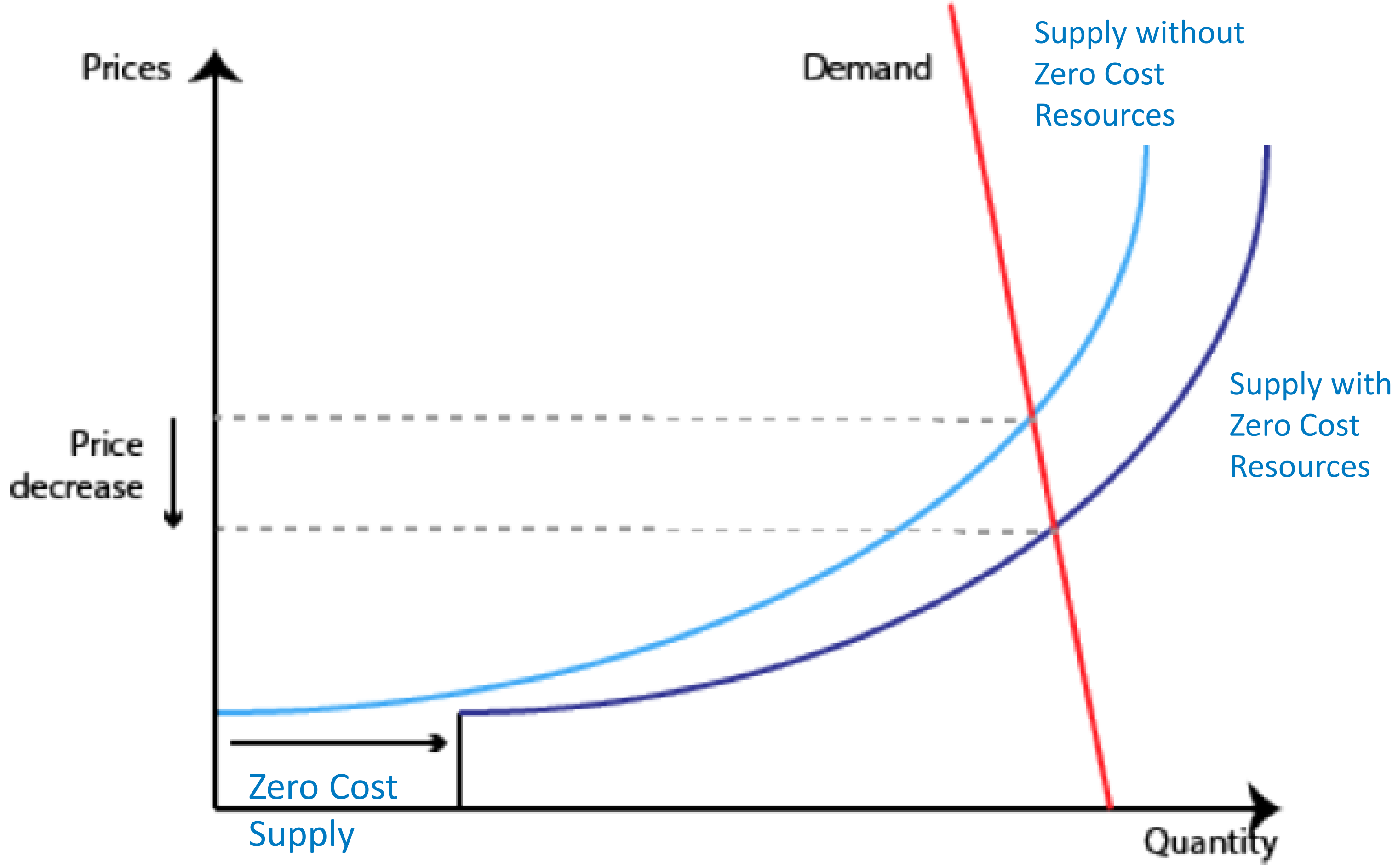


…which means increased need for flexible capacity via market signals

Market designs must incentivize the building of resources with the flexibility attributes for **long-term** needs so that flexibility is available for **short-term** operational needs

- e.g., CAISO flexible capacity requirement based on projected maximum 3-hour upward net load ramp by month

Merit Order Effect



modified from (Gallo, 2016)

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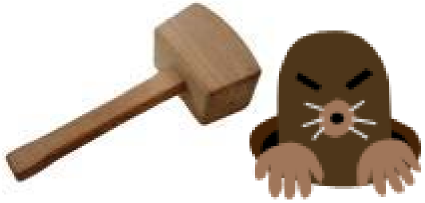
What is the objective of a capacity market?

Provide units *that are needed for reliability* sufficient opportunity to recover their fixed costs that cannot be recovered in energy and A/S markets

- Planning – will market encourage investors to build needed resources?
- Flexibility – will market ensure that future capacity is flexible enough for a high-VG world?
- How deal with unintended consequences?
- Is market design robust to resource mix? (eg. lots of recips or aeros or DR or ??)
- Is there an optimal mix of market pricing and administrative pricing/subsidies?

Need to consider expected revenues and capabilities (as incentivized) from energy and A/S markets…



Reliability and revenue sufficiency require full-market view

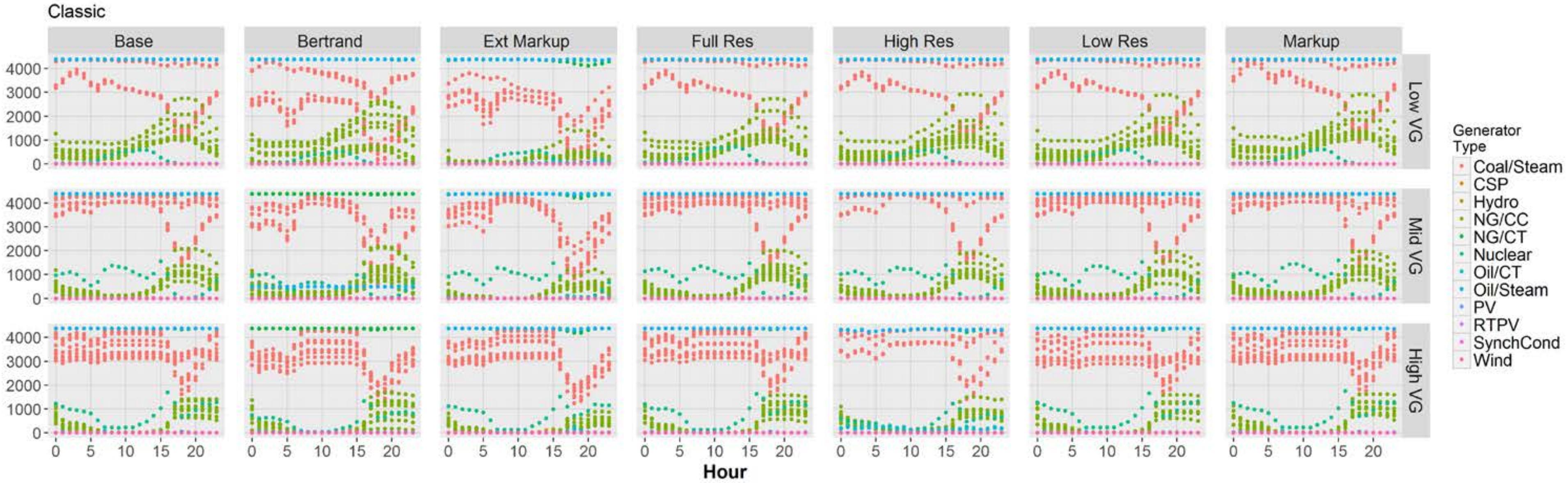
NREL collaborative work with ANL and EPRI

- Create a **multi-timescale market and reliability modeling framework**
- Quantify **reliability** and **revenue sufficiency** challenges and solutions under a wide range of market design options in an evolving power system

Revenue Sufficiency									
Reliability					**Market Efficiency**				
Resource Adequacy	*Flexibility Needs and Incentives*			*Essential Reliability Services Incentives*	*Price Impacts and Formation*			*Differing decision making criteria*	*Market Solver*
	Flexible Capacity	*Operational Flexibility*	*A/S*		*Self-Scheduling*	*Behavior*	*Rules*		
Capacity payments (link with ANL)	Add flexible capacity incentive	High Gen Outage	Spin, Reg, Flex Up	FESTIV PFR model rules	Self-Commit	Static Markups	Price caps	Different ownership structures (e.g., VI vs. IPP)	Market op. sequence
Premature retirement (nuclear)		Lower Ramp Rates	Up and Down	FESTIV SFR model rules (e.g., net provision vs. "mileage" payments)	Self-Dispatch	Dynamic Markups	LRMC		Storage dispatch methods (NOPR)
		High Trans. Outage	Vary reserve code uncertainty bands		Model bilateral contracts	Cournot	Lumpy costs		Complexity in solver vs. bids
		High Congestion	Multi-mode CC			Bertrand	Pay for Performance		
		High Forecast Errors	ERCOT Reserves				Uplift		
		Limited ngas fuel supply	ORDC						
		Low/High storage	Add nonspin						
		Low/High DR	Adjust reserve requirement during curtailment						

GridMod RTS parametric analysis

Frequency of unit-specific “uplift” across 5-min intervals



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