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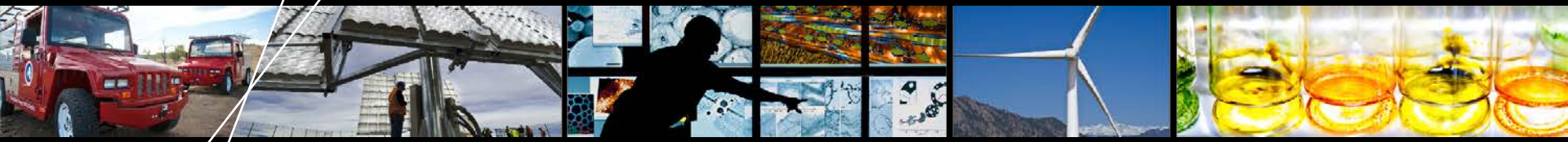
Flexible and Local Resources Needed for Reliability in the California Wholesale Electric Market



FERC Technical Conference

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Transmission and Grid Integration
National Renewable Energy Laboratory

July 31, 2013
Sacramento, CA

NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

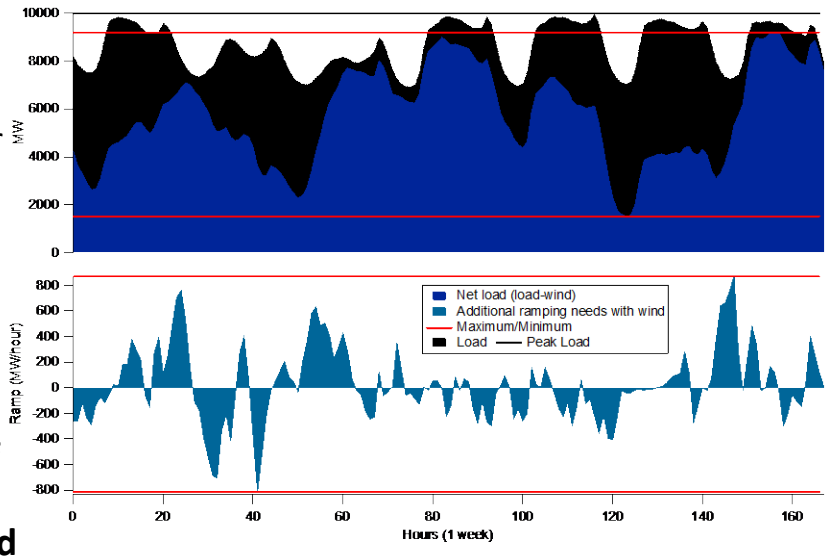
Why NREL's interest?

- **DOE funding to explore what is needed to efficiently integrate wind/solar *if* large amounts of renewable energy are deployed**
- **Specific funding to investigate bulk power markets – project underway with publication later this year**
- **This presentation addresses some market issues that policy-makers and market designers may wish to consider.**

Overview: Principles of Market Design

- **Market design should elicit economically efficient solution (least-cost way to fulfill objective)**
- **Need long-term and short-term consistency**
  - Long-run supply is necessary, but not sufficient, condition for efficient short-run deployment
  - Does short-run market/operating practice strand access to physically-capable flexibility?[1]
- **What is flexibility?**
  - Ramp as one of several flex features. Also turn down, min start etc.
  - Turndown hasn't received a lot of attention but is important
- **Does 0 (negative) LMP at night induce the "right" level of turndown in the long run?**
- **Demonstrate that the product paid for is actually received**
- **Principle: wind/solar or other technology should also be incentivized to participate. Market mechanisms should be performance-based**
- **Need a transition plan from today's relatively inflexible fleet to a more flexible fleet**

- **Most information from paper described below**



Black: load

Blue: load – wind = net load

Bottom panel: increased ramp requirements from wind

Wind (and solar) require

- Faster/steeper ramps
- Lower turndown
  - Wider operating range from conventional units

[1] Kirby, B.; Milligan, M. (2005). Method and Case Study for Estimating the Ramping Capability of a Control Area or Balancing Authority and Implications for Moderate or High Wind Penetration: Preprint. 19 pp.; NREL Report No. CP-500-38153.

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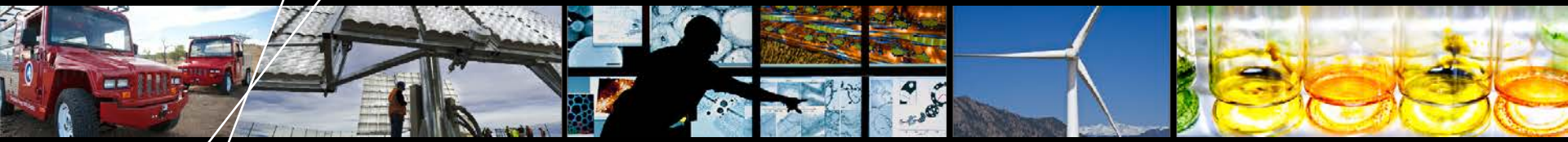
Markets to Facilitate Wind and Solar Energy Integration in the Bulk Power Supply: An IEA Task 25 Collaboration



International Workshop on Large-Scale Integration of Wind and Solar Power into Power Systems

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November, 2012
Lisbon, Portugal

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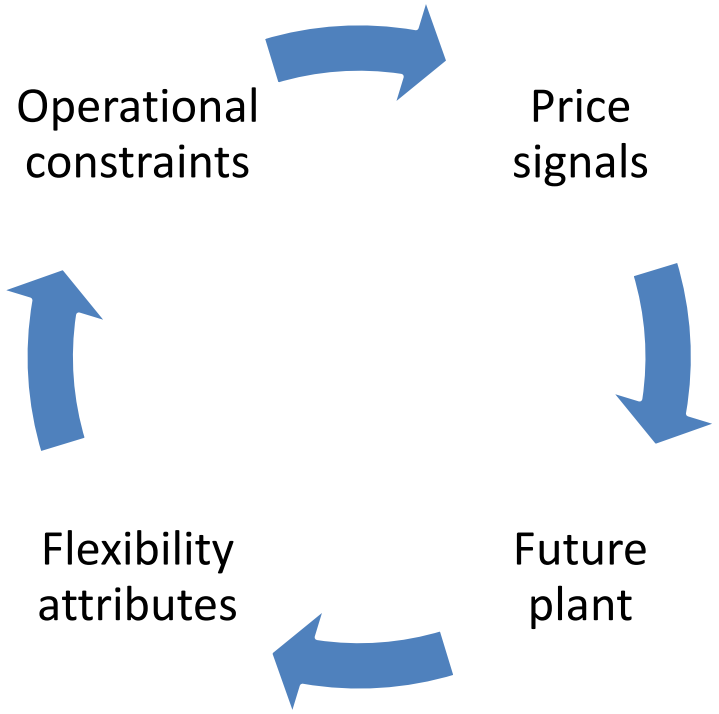
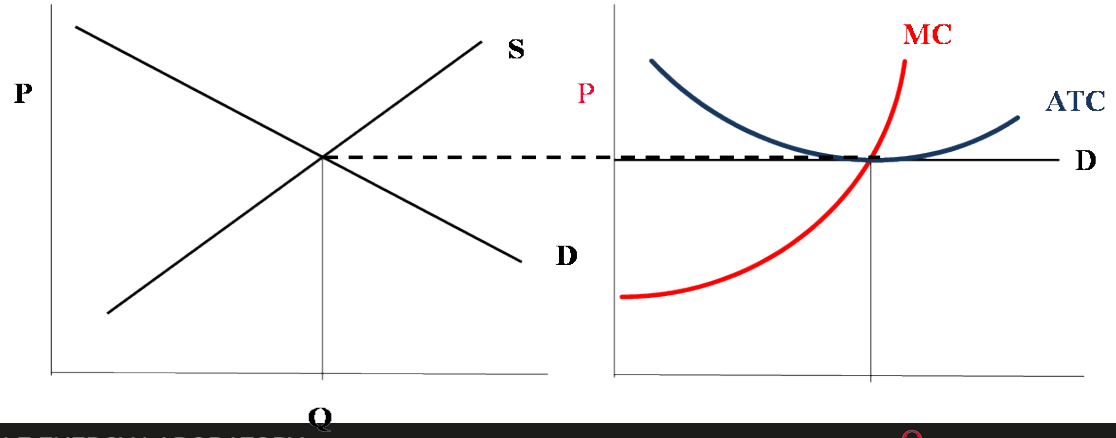
Long-term vs. short term

- **Long-term decisions (investments) are made based on price signals today, coupled with anticipated market position**
- **→ today's signals influence the future generation mix**
- **→ we need to carefully examine incentives**



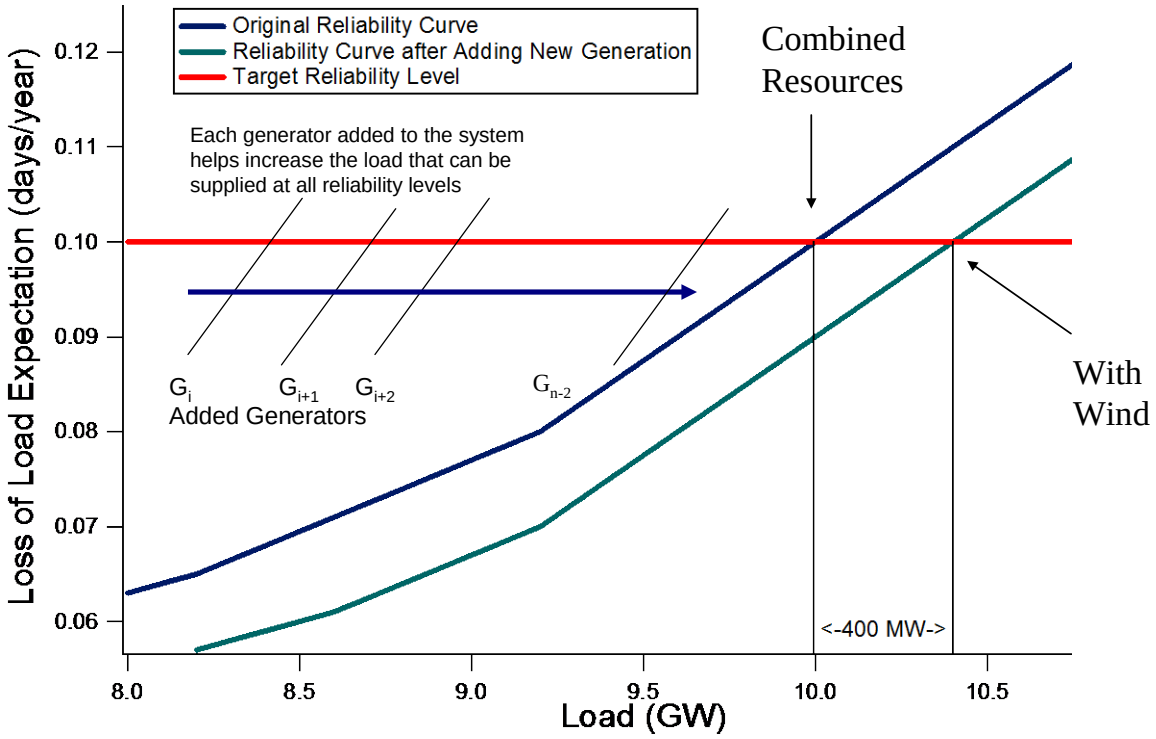
Impact of variable generation

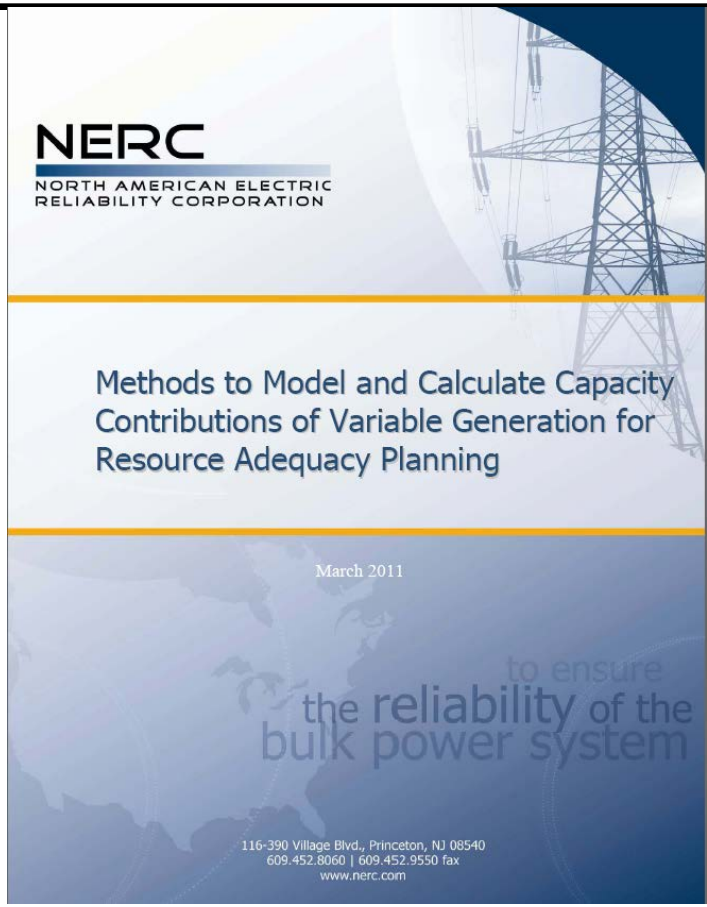
- Potentially depress prices; over-generation
- Potentially create more volatility in prices
- Lower capacity factors for other units → increasing risk of revenue insufficiency
- Market response is a function of the market classification: ~~perfectly competitive~~, monopolistically competitive, or oligopolistic



Capacity: How much…and what does it need to do?

How much: Effective load carrying capability

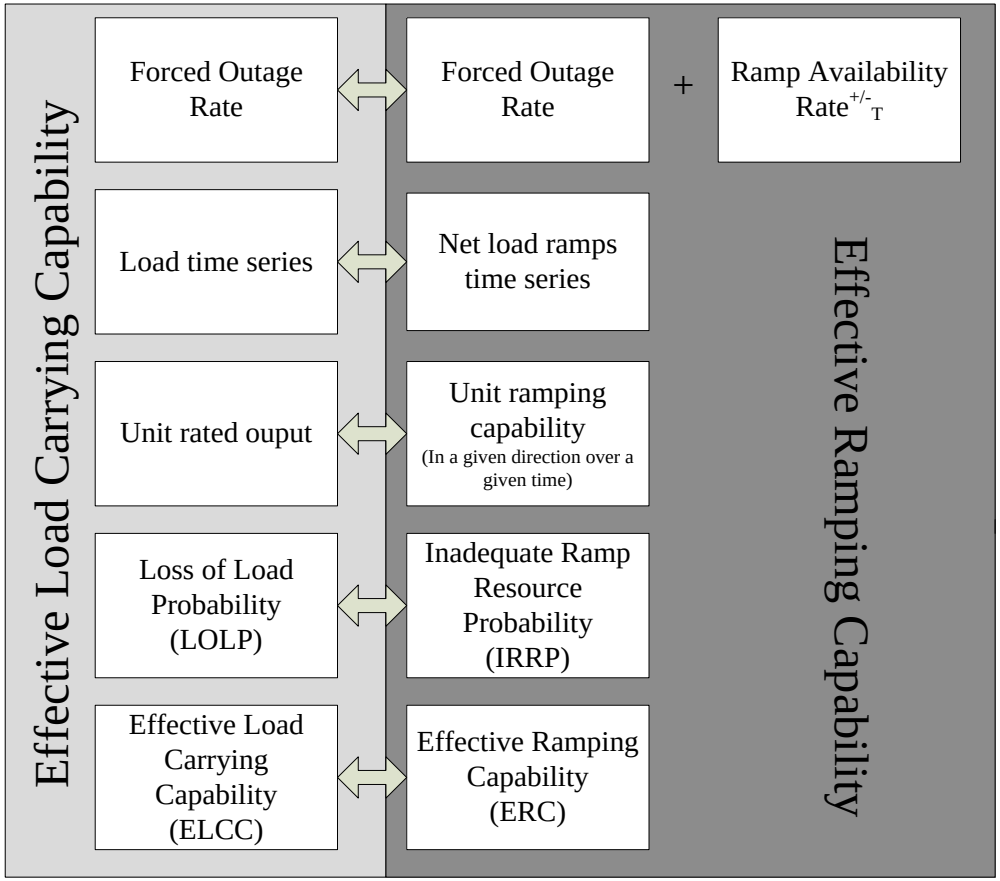




- NERC IVGTF 1.2 Report available at: http://www.nerc.com/docs/pc/ivgtf/IVGTF1-2.pdf
- IEEE Task Force paper: Capacity Value of Wind Power. IEEE Transactions on Power Systems, Vol. 26, No. 2, May 2011
- Milligan and Porter (2008): Determining the Capacity Value of Wind: An Updated Survey of Methods and Implementations. http://www.nrel.gov/docs/fy08osti/43433.pdf

How much capacity – *and what kind* – is needed?

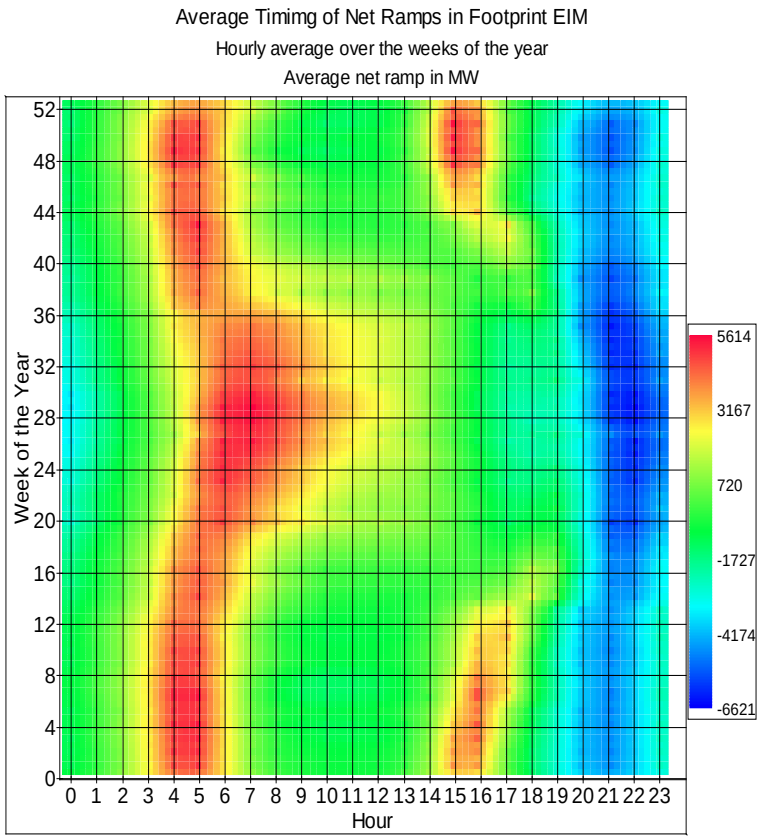
- **Effective load-carrying capability vs. ramping**
- **ELCC address the question "how much is contributed by this resource?"**
- **ERC is the ramping analogue**
- **LOLE for adequacy**
- **Ramping sufficiency**



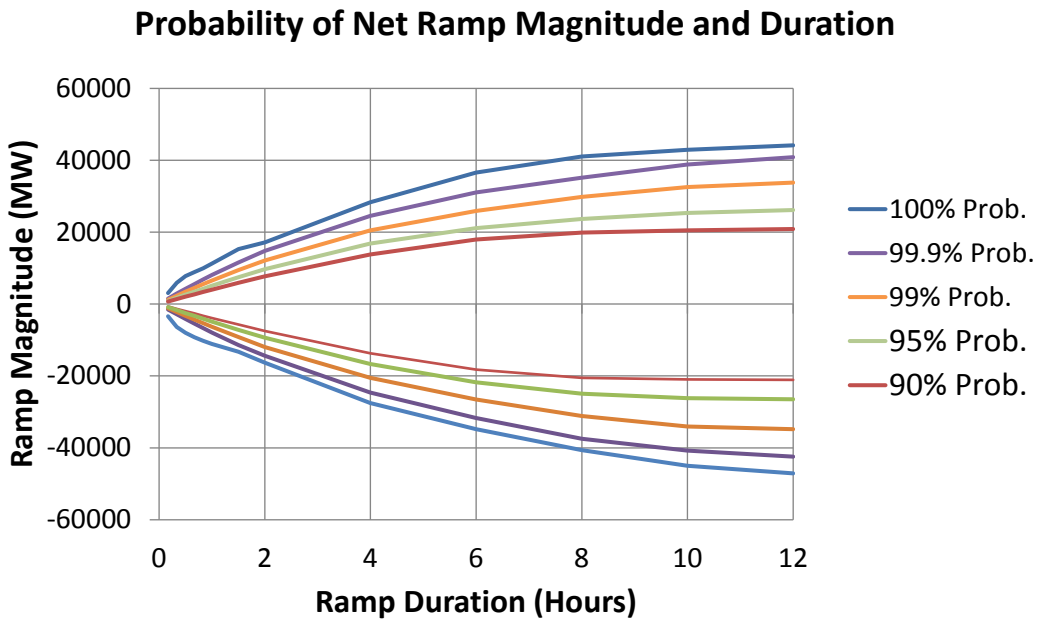
Lannoye, E.; Milligan, M.; Adams, J.; Tuohy, A.; Chandler, H.; Flynn, D.; O'Malley, M. (2010). Integration of Variable Generation: Capacity Value and Evaluation of Flexibility. IEEE PES GM, 2010.

Ramp timing and magnitude can be estimated

When do ramps occur?



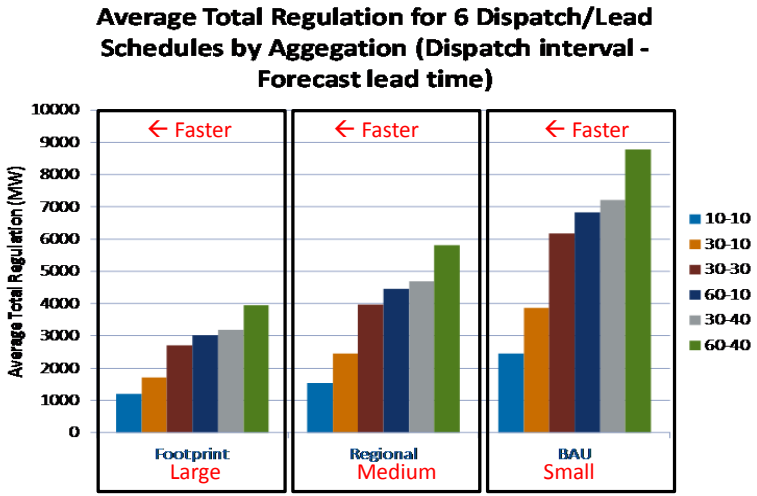
How long are the ramps?



M. Milligan, J. King, and B. Kirby (2011). Flexibility Reserve Reductions from an Energy Imbalance Market with High Levels of Wind Energy in the Western Interconnection. 100 pp.; NREL Report No. TP-5500-52330. http://www.nrel.gov/docs/fy12osti/52330.pdf.

Markets

- **How much flexibility can be extracted from large, fast energy markets?**



Milligan, Kirby, King, Beuning (2011), The Impact of Alternative Dispatch Intervals on Operating Reserve Requirements for Variable Generation. Presented at 10th International Workshop on Large-Scale Integration of Wind (and Solar) Power into Power Systems, Aarhus, Denmark. October

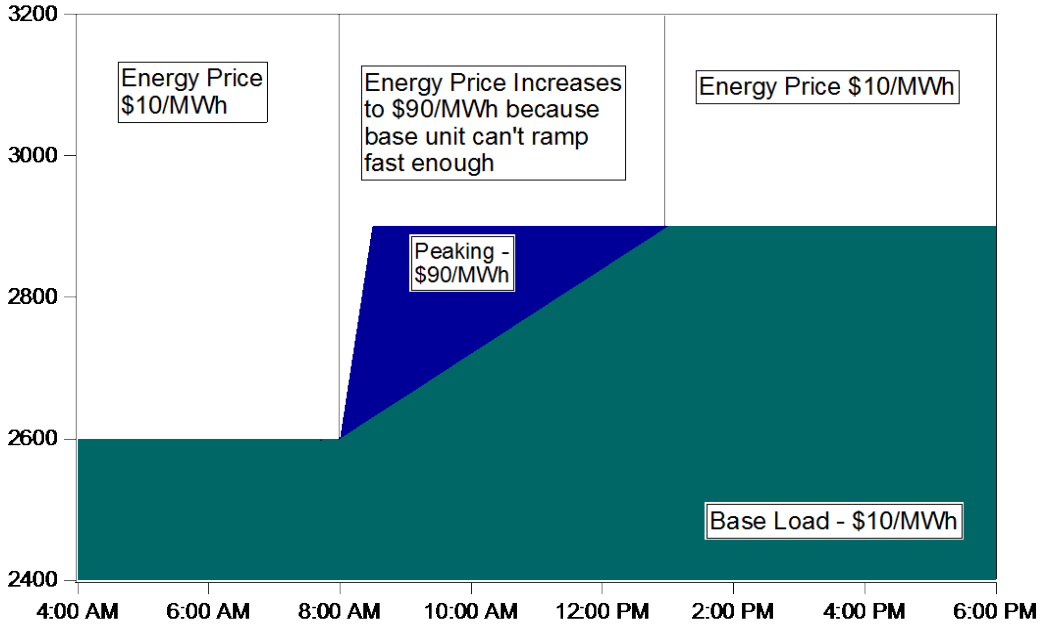
- **Are there unintended consequences of market design?**
  - Example: Energy and frequency response, Ela, E.; Milligan, M.; Kirby, B.; Tuohy, A.; Brooks, D. (2012). Alternative Approaches for Incentivizing the Frequency Responsive Reserve Ancillary Service. 21 pp.; NREL Report No. TP-5500-54393; another version in Electricity Journal, Vol 25, Issue 4, May 2012 pp 88-102.

- **Do operational markets (or other operating practices) inhibit access to the otherwise-available generation?** [1]
- **Must account for adequacy and flexibility Differentiate buckets of capacity types (fast ramp, slow ramp…)**
- **Auction or other mechanism**
- **Need to establish targets: how much is needed? What is VOLL? Can DR help? Selective wind/solar curtailment?**
- **Market monitor**

[1] Kirby, B.; Milligan, M. (2005). Method and Case Study for Estimating the Ramping Capability of a Control Area or Balancing Authority and Implications for Moderate or High Wind Penetration: Preprint. 19 pp.; NREL Report No. CP-500-38153.

Two views on flexibility

- **(1) The more volatile prices will encourage development of flexible resources**
  - a) High prices during ramps encourage ramp-resource investment
  - b) Low (negative) prices discourage base-load investment
  - c) Efficient level of flexibility is developed
  - d) Revenue sufficiency



- **(2) A ramp product is needed to supplement the energy market**
  - a) Price = 0 except when needed
  - b) Allows price discovery of energy lost opportunity cost
  - c) Does not reward inflexible generation
  - d) Can also allow for unexpected ramping needs
  - e) Question: does ramp pricing induce long-term investment and revenue sufficiency?

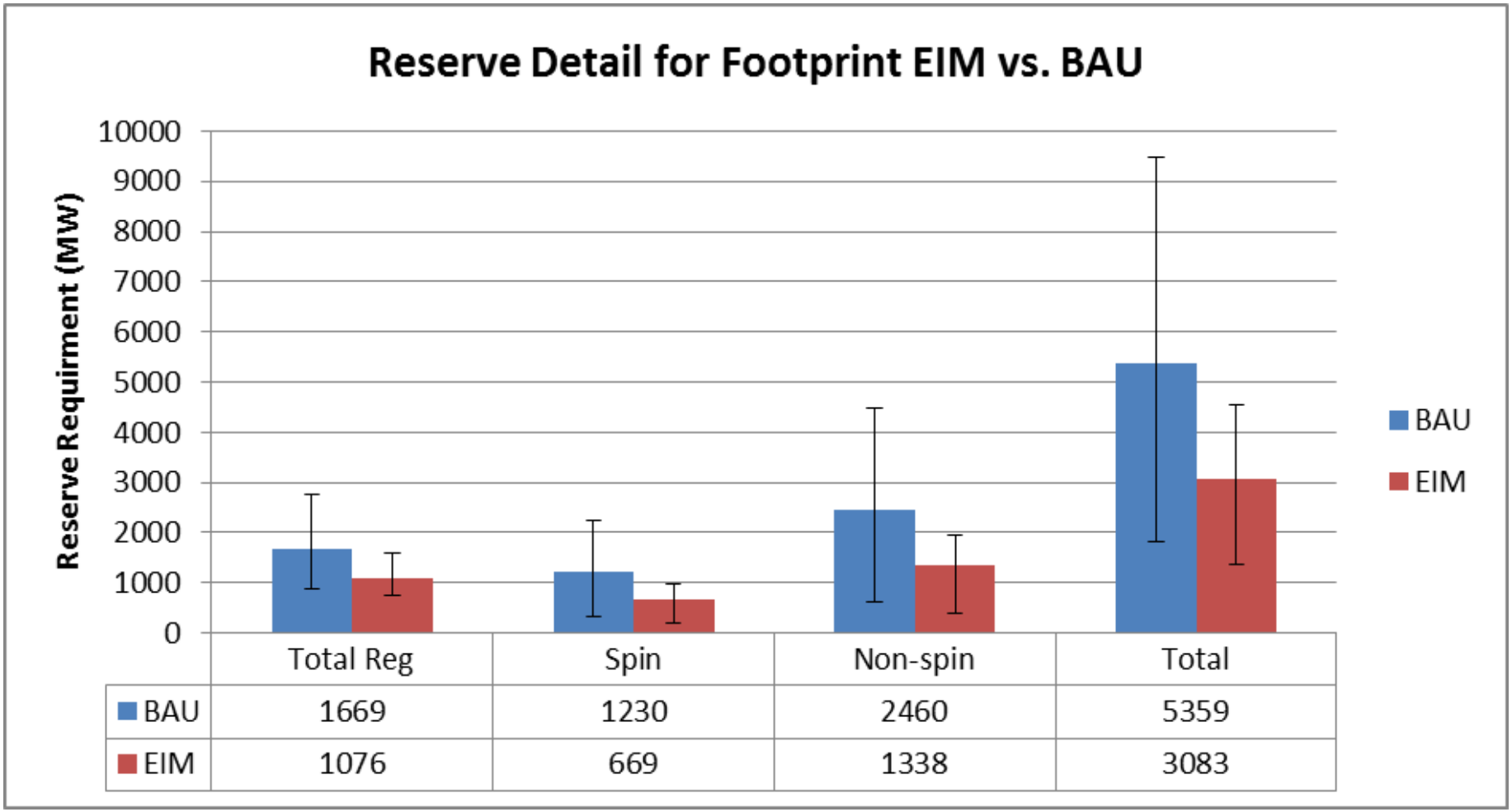
The simplistic example (note this is based on a single time period clearing for illustration):

Summary

- **Technology Neutral**
  - a reserve product could be defined by the required notification period, response speed, response depth, and length of performance. Thus the market design would consist of specifications that are technology-independent.
- **Pay for Performance**
  - Vertical Consistency
    - Two suppliers who provide different levels of service should be compensated accordingly. Thus if supplier A provides more of a product than B, A should receive a higher payment. This principle can also be applied to customers, demand, demand response.
  - Horizontal Consistency
    - Two suppliers of the same quantity of the same product should be compensated in the same way. A variation of this principle is that similar supply of a similar product should result in similar treatment or payment. This principle can also be applied to customers, demand, or demand-response.
- **Minimize unintended consequences**
  - Market testing (necessary, perhaps not sufficient)
  - Examine incentives and unintended consequences with other markets
  - Experimental economics
- **Transparent**

Supplemental Information on Flexibility

Response needs vary



King, J.; Kirby, B.; Milligan, M.; Beuning, S. (2012). Operating Reserve Reductions from a Proposed Energy Imbalance Market with Wind and Solar Generation in the Western Interconnection. 90 pp.; NREL Report No. TP-5500-54660

How do we know which type of market(s) will function efficiently and reliably?

- Modeling can help capture insights, but is not sufficient evidence
- Examination of incentives
- Account for uncertainties
- Experimental economics
- Trial and error

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- ~~Trial and error~~ Evolution

Example of “risk-based” pricing

- **Ela and O’Malley (2012) use a probability-weighted pricing scheme from a stochastic unit commitment and dispatch**
- **Probability-weighted LMPs**
  - Allow for “conversion” of stochastic methods into operable actions
  - Price responds to risk
  - Reduces negative profits, and thus uplift
- **Wang and Hobbs (2013) show that market design of a ramp market design may have unintended consequences**

✓ Ela, E.; O’Malley, M. (2012) Probability-Weighted LMP and RCP for Day-Ahead Energy Markets using Stochastic Security-Constrained Unit Commitment. PMAPS 2012

✓ Wang, B.; Hobbs, B. (2013) Flexiramp Market Design for Real-Time Operations: Can it Approach the Stochastic Optimization Ideal? IEEE Power and Energy General Meeting, Vancouver, BC, Canada.