



LCOE Perspective

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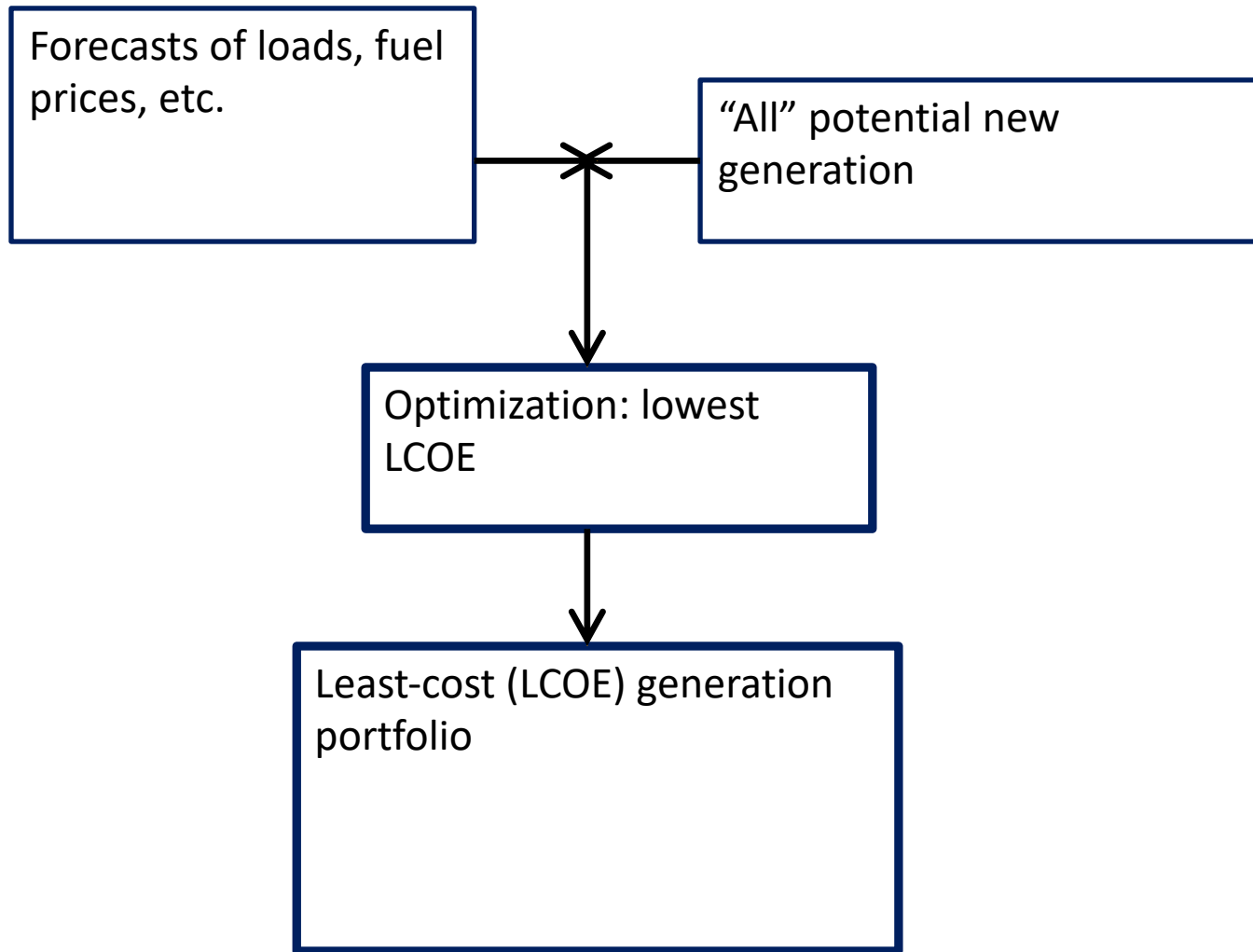
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Context

- **Traditional generation planning models; search for min LCOE of portfolio**
- **EGEAS, PowerSym, others...**
- **Only needed because selecting only the single source with min LCOE won't work**
- **What is included: carbon? What discount rate? What are key sensitivities**
- **Good for basic comparison but is only a single indicator**

Example of Uses of LCOE

- **Generation (resource) planning**



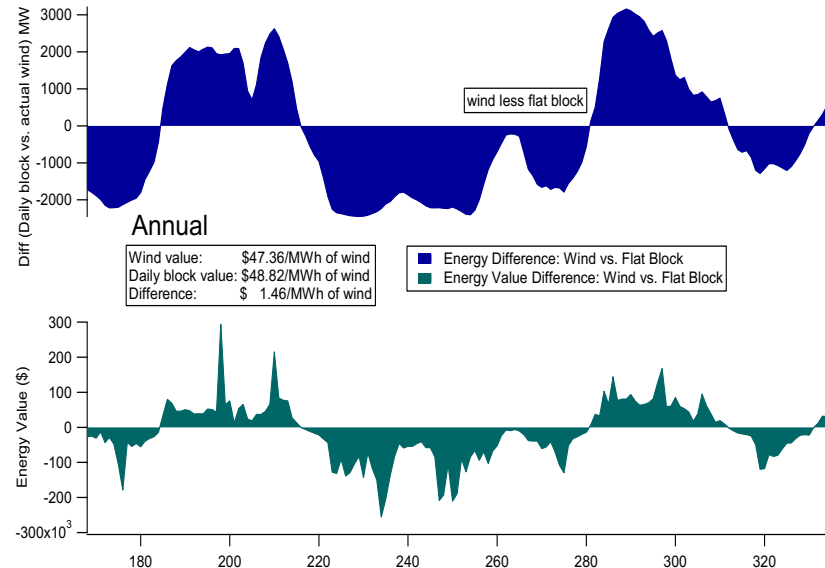
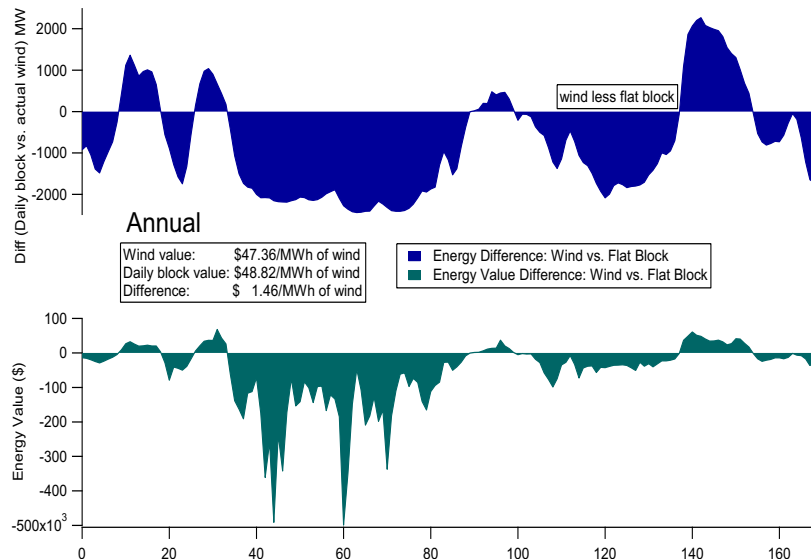
From LCOE to “Integration Cost”

- **In the early 2000’s, interest in “adjusting” the LCOE of wind to account for cost of variability+uncertainty**
 - In spite of methodological problems (more later) these were useful explorations
 - The short history: a simple question, but in the ~15 years since this began, there has been *no general agreement* on an acceptable method

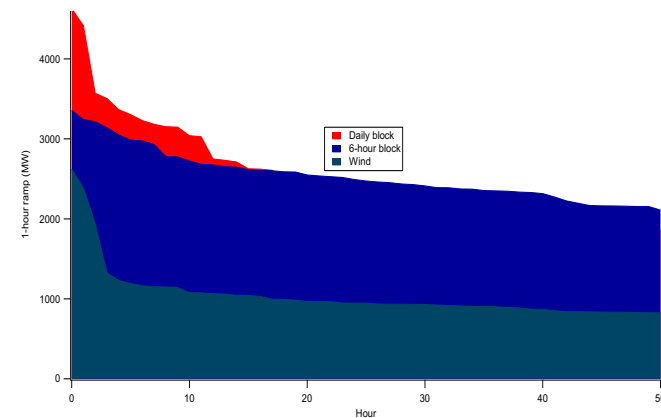
Integration Cost

- **Calculate incremental cost of wind by simulating system with/without wind**
- **What to compare wind to? A daily flat block of equivalent energy**
- **The approach was useful in the early days, showing how system can operate successfully with wind**
- **However:**
 - Multiple, non-linear interactions: "integration cost" of wind is heavily influenced by system flexibility and other factors
 - "Everything" has an integration cost; should we calculate them all?

Relative market values of the daily block and wind change from week to week



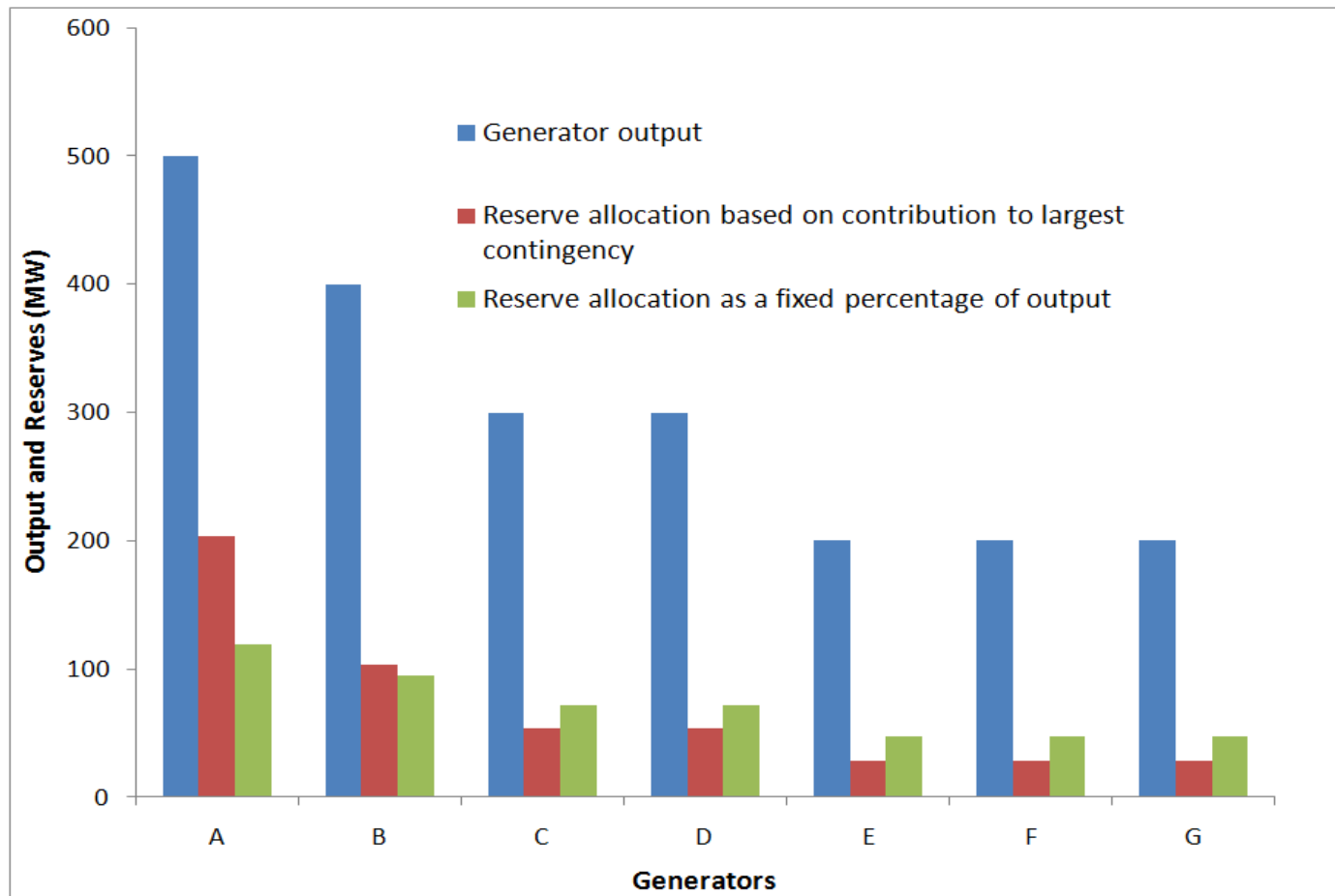
- ▶ Annual wind value \$47.36/MWh
- ▶ Annual daily block value \$48.82/MWh
- ▶ Difference \$1.46/MWh
- ▶ Ramping artifact



Graph from NREL – citation at end.

Large units can have an integration cost

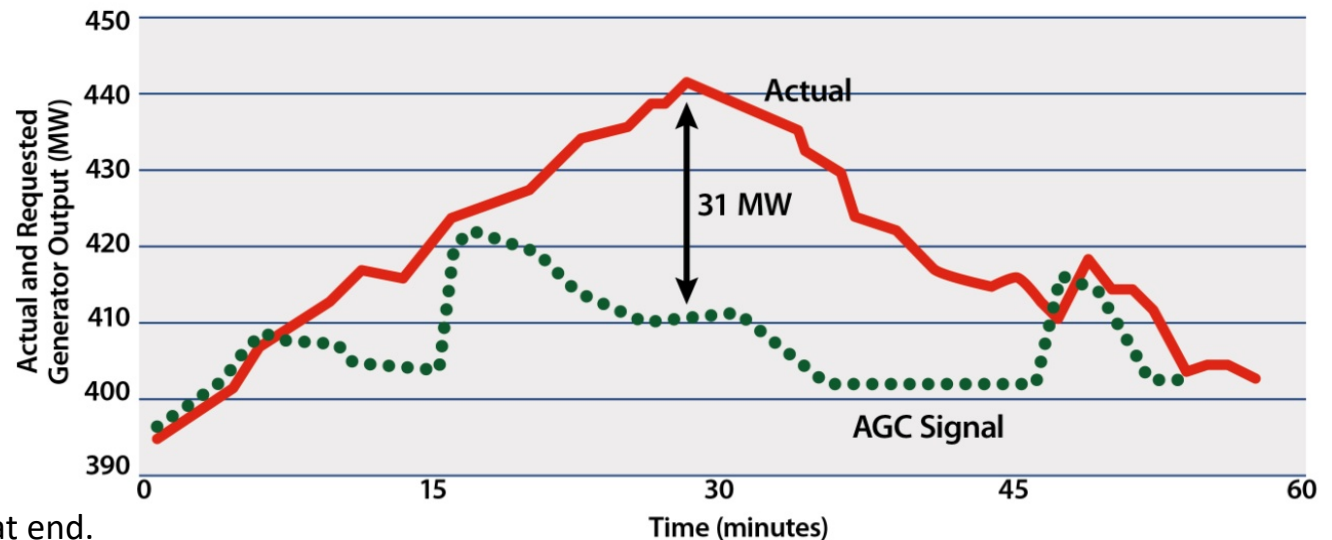
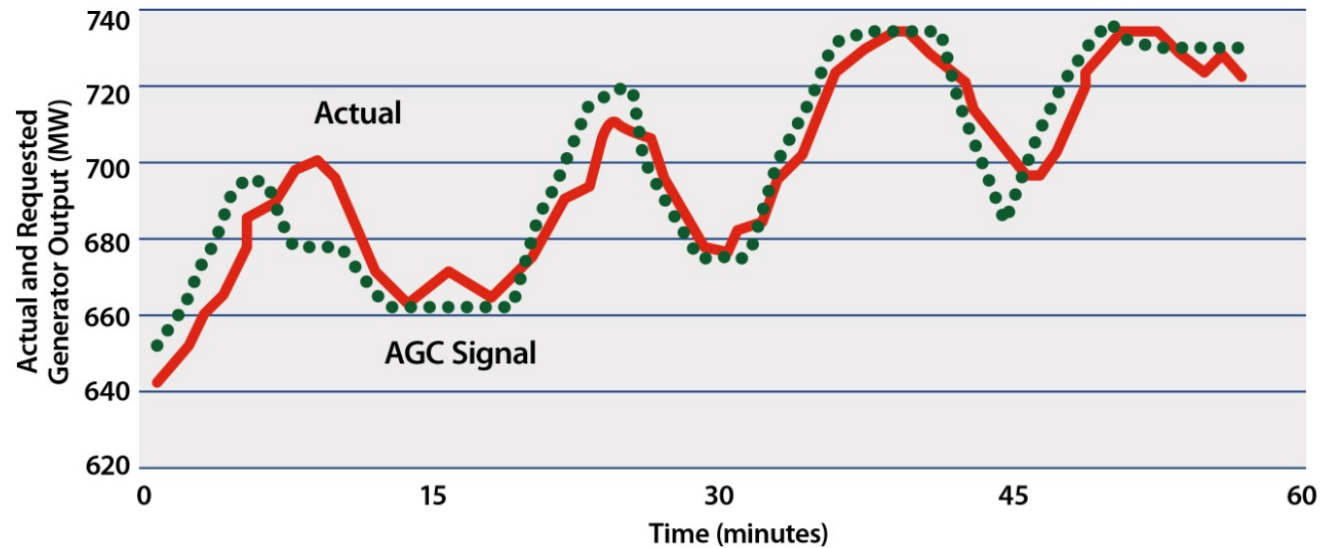
- Many costs are shifted from one resource to another: Example of contingency reserves



Graph from NREL – citation at end.

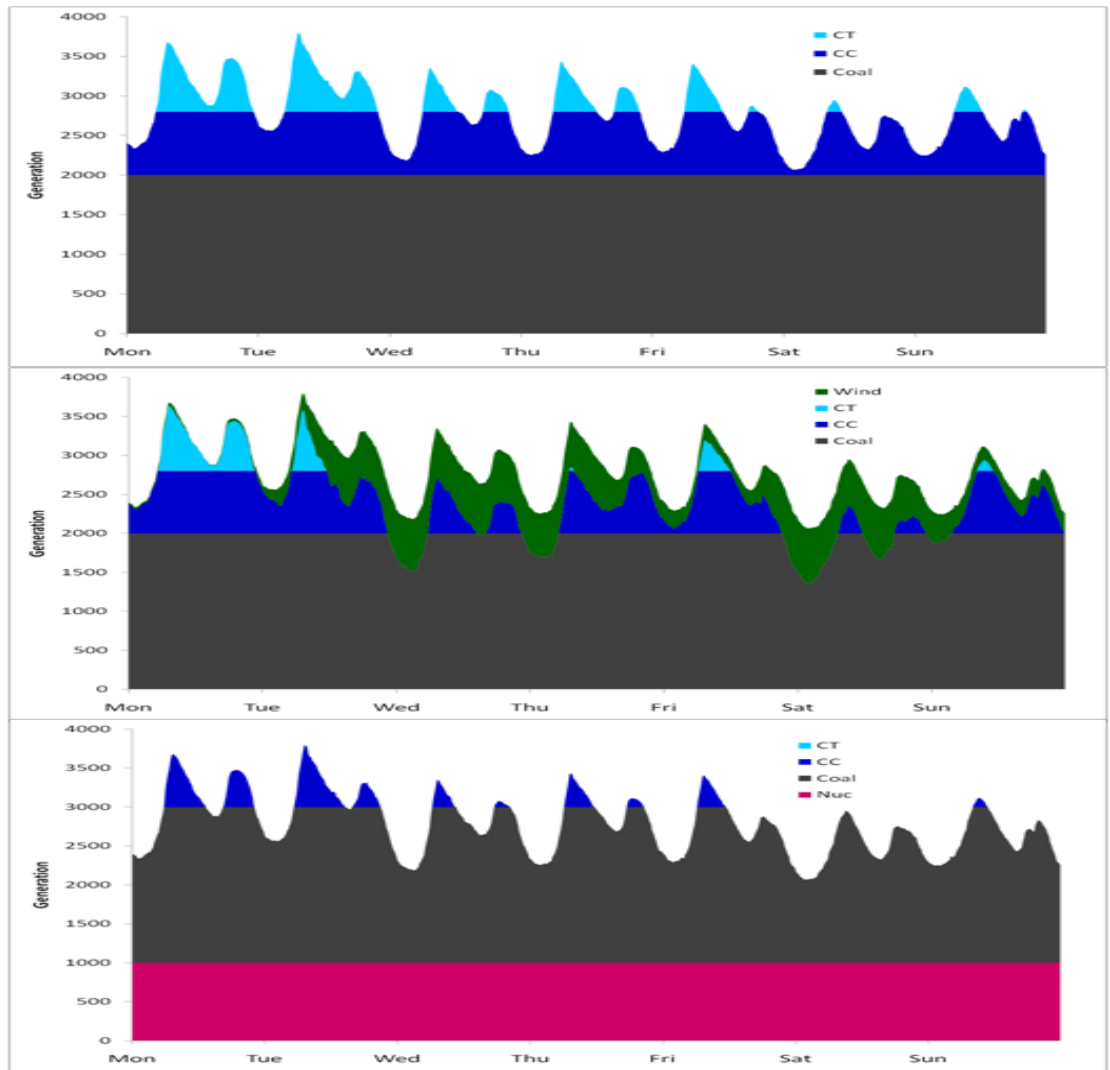
Other units impose a cost of variability

- Actual data from 2 thermal units which were selling regulation into MISO



Graph from NREL – citation at end.

- Even base-load generation has an integration cost



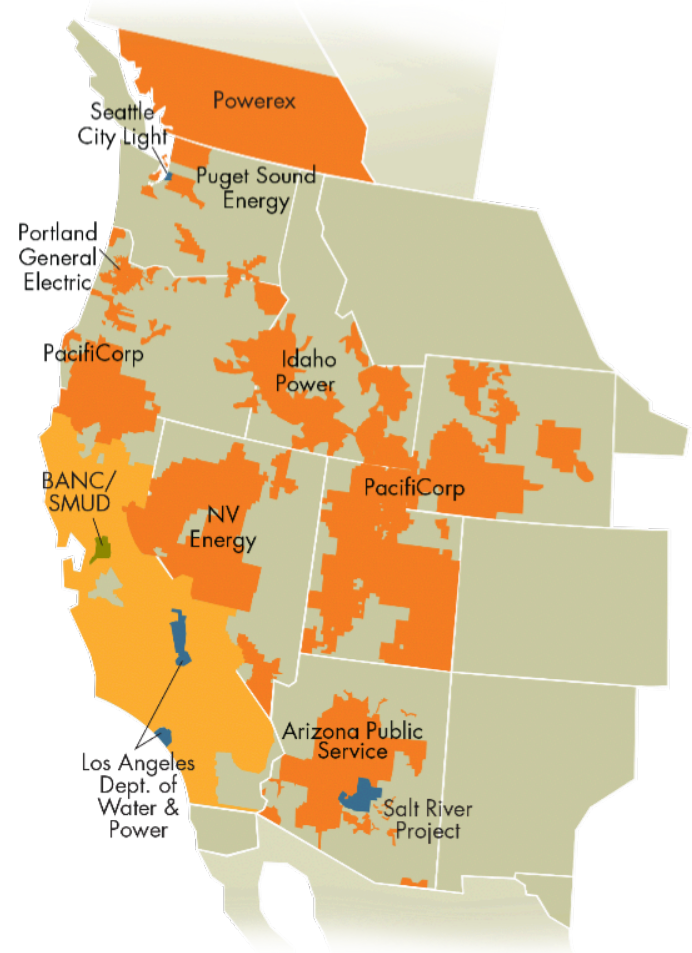
Graph from NREL – citation at end.

Anomalies were not uncommon

- **Example: PSCo Integration Study, circa 2005-6**
- **Interest in calculating impact of gas prices on wind integration cost**
- **As gas prices increased from ~\$3.00/MBTU to ~\$7.00, the integration cost increased**
- ***However*, no recognition of the increased benefit of wind in reducing expensive gas burn**

Inefficient Market Design/Flexibility has an Integration Cost

- Example Energy Imbalance Market (EIM) work found savings of ~\$300B/year of a full-fledged EIM in the West
- According to CAISO 10/1/2018 last quarter savings of the EIM were \$71M.
- The "integration cost" of small, slow dispatch in the West could be interpreted as the benefit of the EIM



Inflexible Generation has an Integration Cost

- **Min-gen constraints have an impact on system operation**
 - Increase VG curtailment
 - Increase costs by imposing a constraint on the economic dispatch

Why so many difficulties?

- **Sum of all parts may not equal the whole**
- **Focus on one component without taking big-picture into account**
- **“Benchmark” unit doesn’t exist, and other resources were not subject to these analyses**
- **No well-accepted method has emerged in the last ~15 years, which indicates significant methodological problems**

Moving beyond integration cost

- **UK ERC**

- <http://www.ukerc.ac.uk/publications/the-costs-and-impacts-of-intermittency-2016-update.html>

- **“Different categories of impact ...create(s) the risk of double-counting some elements of costs, and the possibility that the benefits offered by particular types of generator are not accurately represented in some cost estimates.”**
- **Most folks have moved on, in favor of more all-inclusive estimates of costs/benefits (IEA Task 25 paper Milligan, Kirby, Holttinen, et al (in references))**

Lessons Learned

- **Isolating “integration cost” is difficult, or (more likely) impossible.**
- **The sum or the parts vs. the whole → LCOE of a part may be hard to interpret**
- **Emerging best-practice: Comparison of all-in costs**

References

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- Also see Stark, (2015) A Systematic Approach to Better Understanding Integration cost. NREL Technical report <https://www.nrel.gov/docs/fy15osti/64502.pdf>

Questions?

