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INCENTIVIZING FLEXIBILITY IN SYSTEM OPERATIONS AND RECOVERING THE COST OF FLEXIBILITY

Large-Scale Grid Integration of Renewable Energy in India

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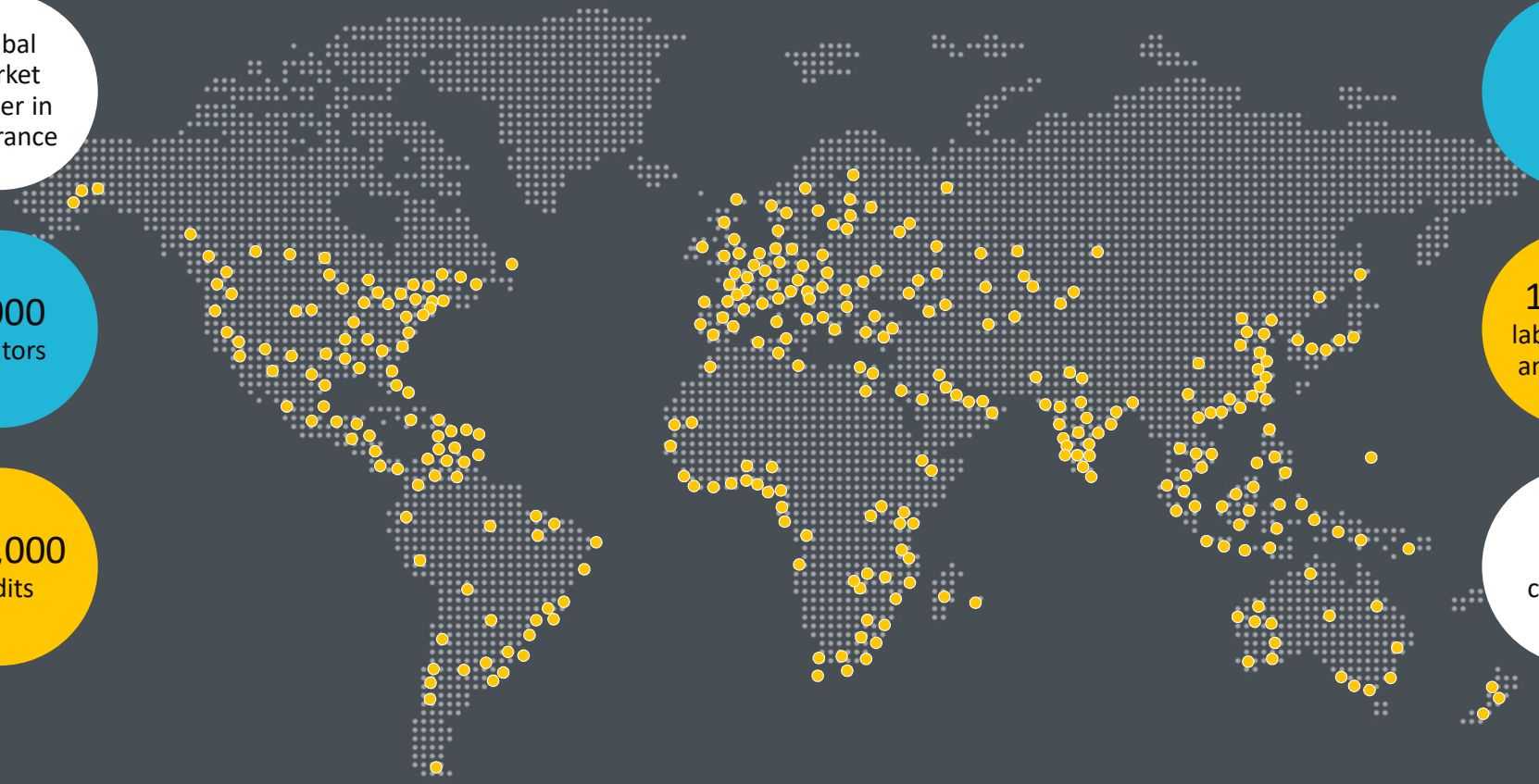
OUR GLOBAL NETWORK AND CAPABILITIES

Global ATIC Business with over **42,000 Employees**

Global Market Leader in Assurance

3,000 auditors

100,000 audits



Global Market Leader in TIC

1,000+ laboratories and offices

100+ countries

OUR HERITAGE

1885

Caleb Brett founds a marine surveying and cargo certification business in the UK

1886

Thomas Edison sets up the Lamp Testing Bureau in the US (this later becomes the Electrical Testing Laboratories or ETL – a mark that Intertek still applies today)

1911

Virginius Daniel Moody establishes Moody Engineering for construction and engineering projects in the US, later moving into oil and gas testing and certification

2009

Intertek acquires APTECH Engineering to expand its Industrial Services offering, with focus on Engineering and Failure Analysis.

2012

ATI (AWARE) joins Intertek Industry Service. Intertek adds Asset Integrity Management Software to its portfolio.

2017

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Video: Looking Back at our History

OUR GOAL

Grid Flexibility

Incentive

+

Generator Flexibility

Cost Recovery

=

Increased RE

Goal

IMPACT OF FLEXIBLE GENERATION ON THE CONVENTIONAL FLEET

↑Maintenance/Overhaul Costs

↑Forced Outage Rates

↑Emissions Per MWh Generated

↑Long Term Production Cost

↑Long-Term Capacity Costs

↓Revenue

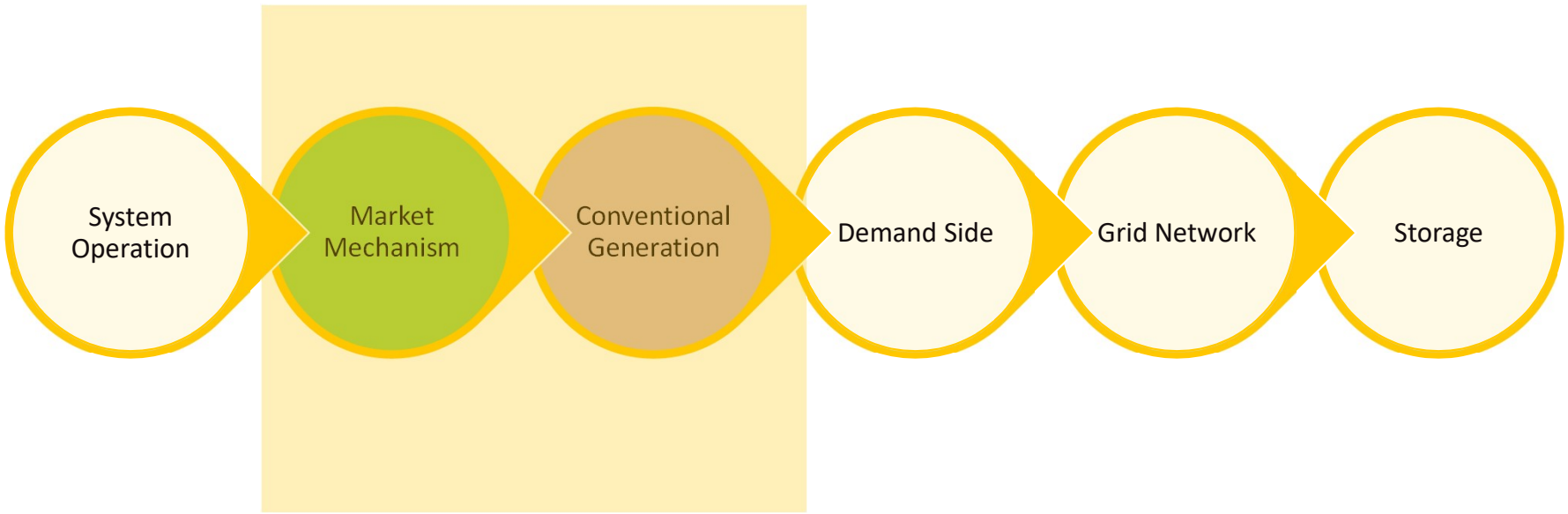
↓Plant Performance (efficiency)

↓Capacity Factors

↓Short Term – Production Cost

↓Unit Life Expectancies

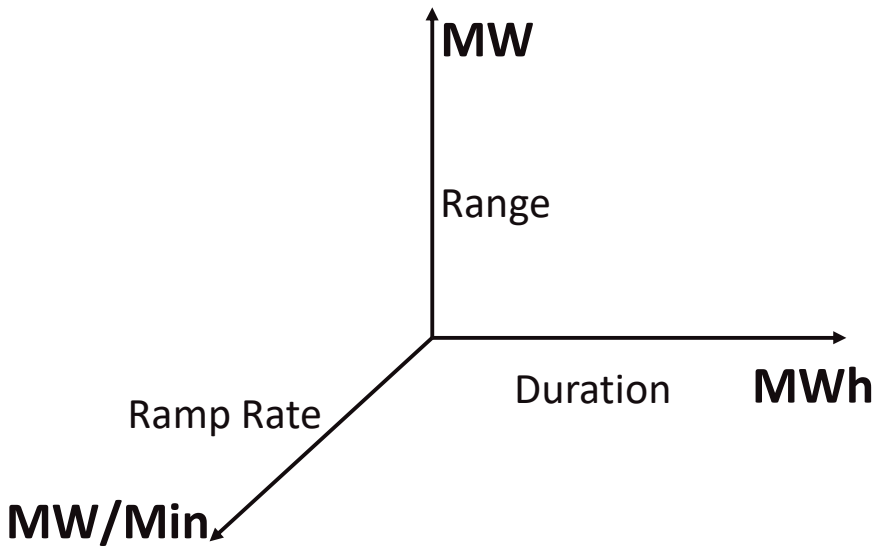
MECHANISM FOR INCREASED FLEXIBILITY



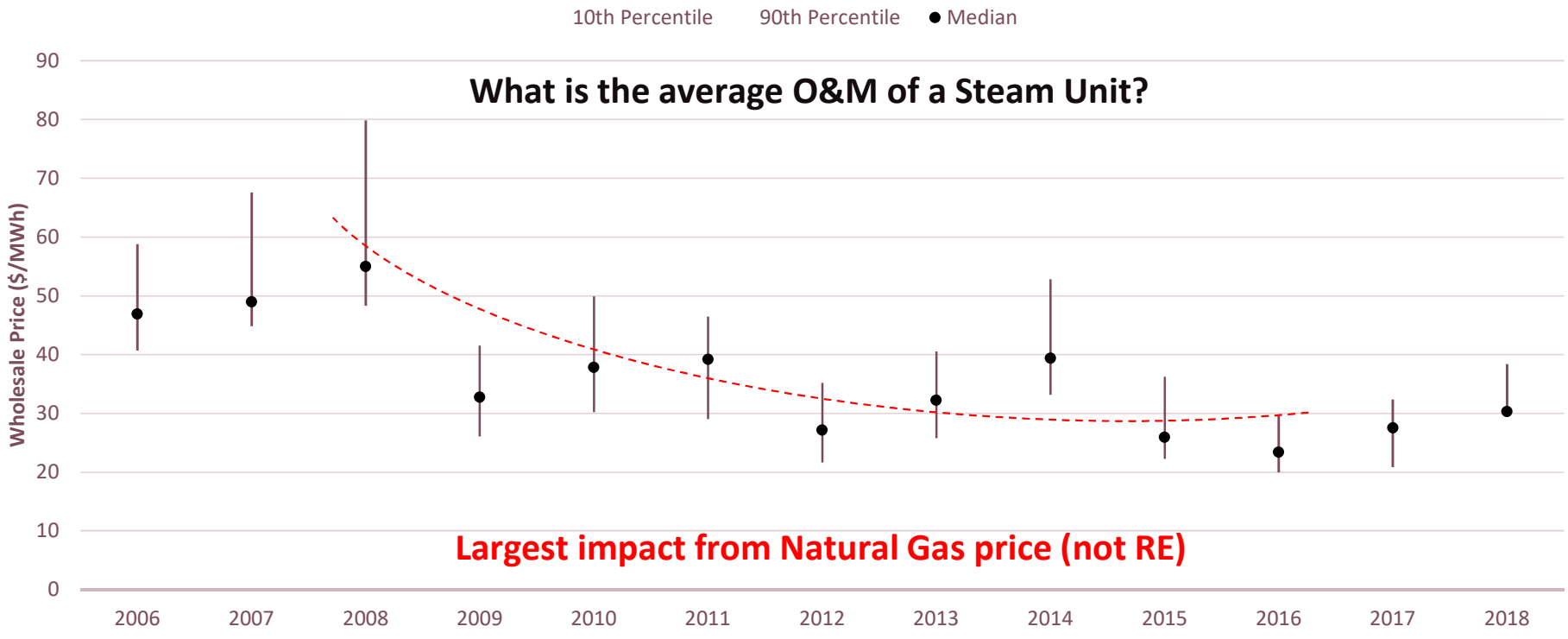
GRID FLEXIBILITY

Frequency Response	Frequency Regulation	Spinning Reserves	Non-Spinning Reserves	Ramping
Immediate Response	0-10 Seconds	10 Minutes	10-30 Minutes	5 Min
Frequency	Power imbalance	Sub-optimal dispatch	Sub-optimal dispatch	RE
Auto Control	AGC	Market Signal	Market Signal	AGC or Market Signal
No market	Auction	Auction	Auction	*CAISO

POWER PLANT FLEXIBILITY



WHOLESALE PRICES HAVE DECLINES IN THE U.S.



Source: *Impacts of Variable Renewable Energy on Bulk Power System Assets, Pricing, and Costs; Ryan H Wiser, Andrew D Mills, Joachim Seel, Todd Levin, Audun Botterud LBNL Report Number: LBNL-2001082*

POWER PLANT FLEXIBILITY THEMES

- Startup time
- Minimum Load (Turndown)
- Emissions Compliance
- Ramp Rates

What's Important?

- Safety
- Equipment Life
- Reliability
- Costs
- Revenue

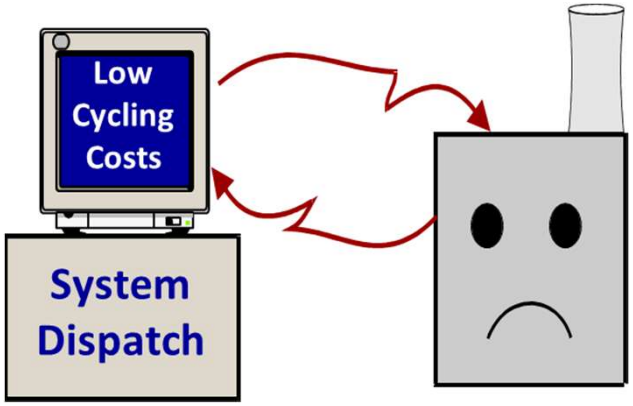
Impact

- Operational adjustment
- Capital Improvements
- Assess which flexibility attributes are the most valuable

Mitigation

PROBLEM STATEMENT

- Why do we need to incentivize power plant flexibility?
  - A major root cause of increase in Capital and Operations & Maintenance (O&M) cost for many fossil units is unit cycling.
  - Utilities have been forced to cycle aging fossil units that were originally designed for base load operation.
  - Market signals are resulting in lower revenue.
- What can and should we do once we understand the impacts and costs?



Generation Units Originally Designed for Baseload Operations Running in Cycling Modes

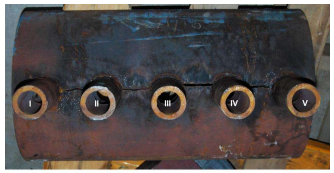
OUR VIEWPOINT

- Almost any unit can be cycled.
  - This can be done with minimal capital investment.
- However, we have to account for:
  - Long term penalty of **increased wear & tear damage** and reduced reliability.
  - Short term penalty of **higher heat rate, increased O&M, training requirements, and equipment efficiency**.
- Component Damage can be determined
  - Understand amount of damage present
  - Rate of accumulation
  - Total damage before failure
- Cycling a power plant is more difficult operating mode than baseload operation.

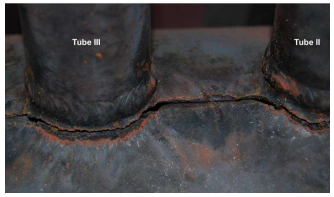
FACTORS AFFECTING POWER PLANT FLEXIBILITY COSTS

Maintenance-related activities	Equipment design and manufacturer	Vintage of technology	Turbine design and pressure and MW capacity
Fuel type, quality and deviation from design fuel specifications	Environmental equipment (including retrofits)	Time between planned outages (boiler overhauls)	Timing of turbine/generator overhauls,
Plant configuration, size, economies of scale and scope	Controls and instrumentation	Retrofit of equipment, especially, for greater flexibility in moving among duty cycles, and	Modes of cycling operation over time

SOME RECENT EXAMPLES

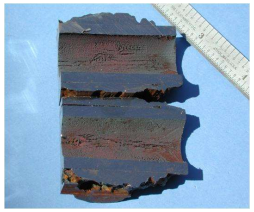


Section A-B Outside

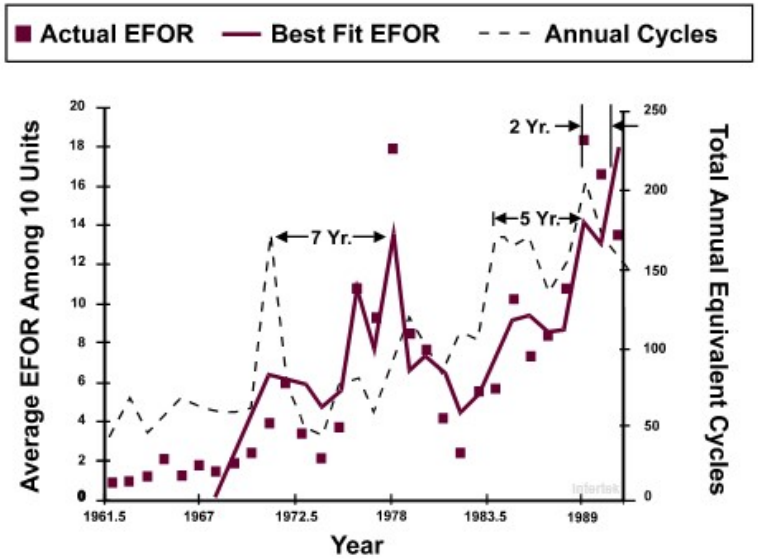


Q. Please describe the outage at Boardman.

A. Boardman went offline on July 1, 2013. During a restart, the cold reheat line (CRH line) sustained damage due to a water hammer event. The CRH line directs steam from the High Pressure (HP) turbine back to the boiler reheater for further heat addition in order to improve efficiency. The source of the water was the reheat steam line attemperator, the device that cools superheated steam, when required, with cooler main feedwater to protect from overheating. After the plant inadvertently shutdown, the attemperator either continued or began leaking feedwater. As part of the standard plant restart procedure, steam was admitted to the HP turbine and the cold reheat non-return check valve opened. As the check valve opened, superheated steam mixed with saturated steam (a steam water mix) created by the attemperator leak, causing the water hammer event. This mixing resulted in a traveling pressure wave that lifted the CRH line and caused the hangers and restraints to break loose resulting in the damage discussed above.



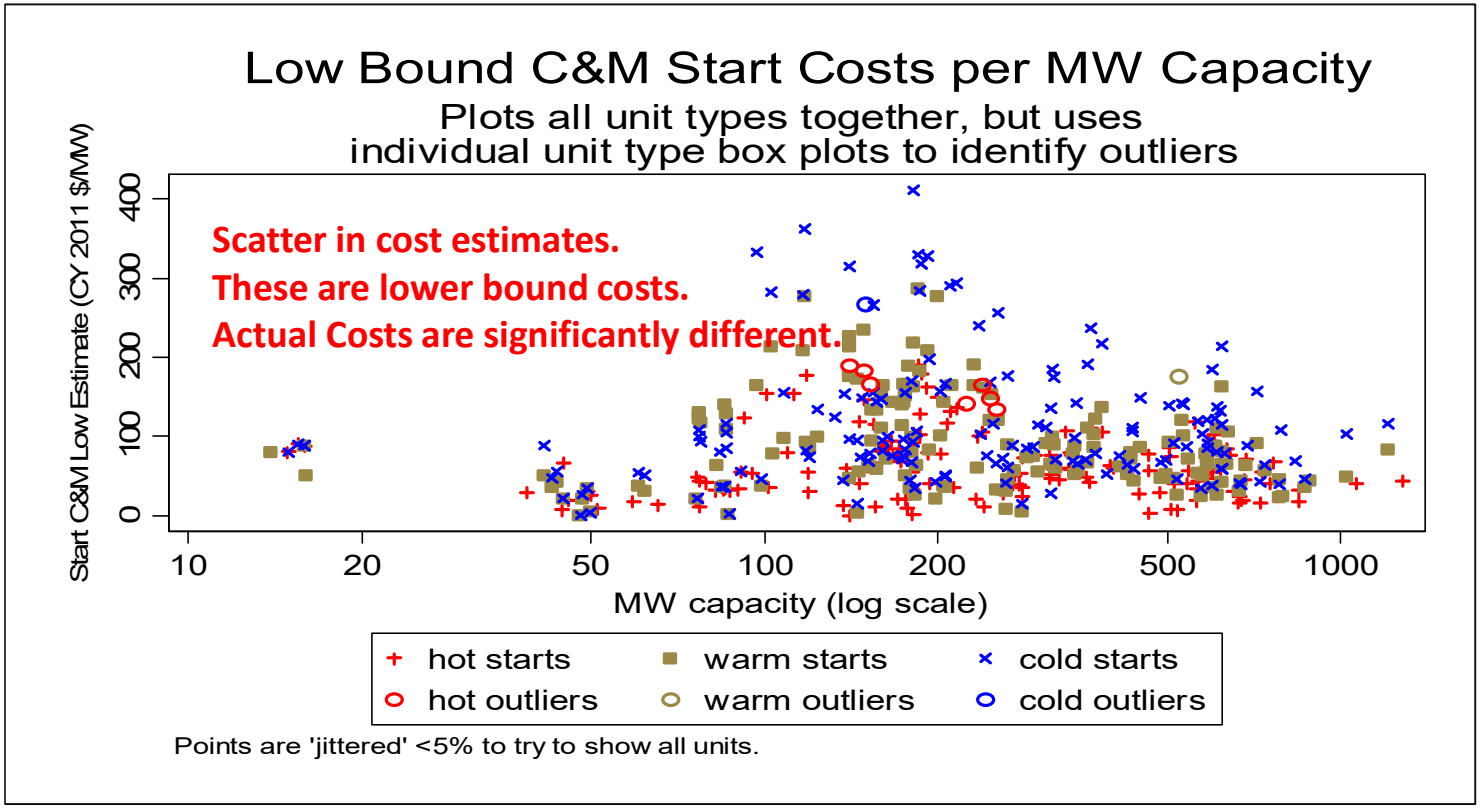
EFFECTS OF CYCLING – RELIABILITY



Actual Plant Data Reflects Creep Fatigue Interaction Design Curve

Source: *Power Plant Cycling Costs*, N. Kumar et al., Intertek (April 2012). http://www.nrel.gov/docs/fy12osti/55433.pdf

THERE IS A COST TO CYCLING POWER PLANTS



Power Plant Cycling Costs, N. Kumar et al., Intertek (April 2012). http://www.nrel.gov/docs/fy12osti/55433.pdf

CHALLENGE & OPPORTUNITY

RE will increase demand for flexibility.

RE will replace conventional generation, i.e. lower capacity factors.

Flexible power plants are less exposed to revenue loss and reliability impacts.

Change in peak load timing

Lower Average Prices ($/MWh)

More hours at prices below $5/MWh.

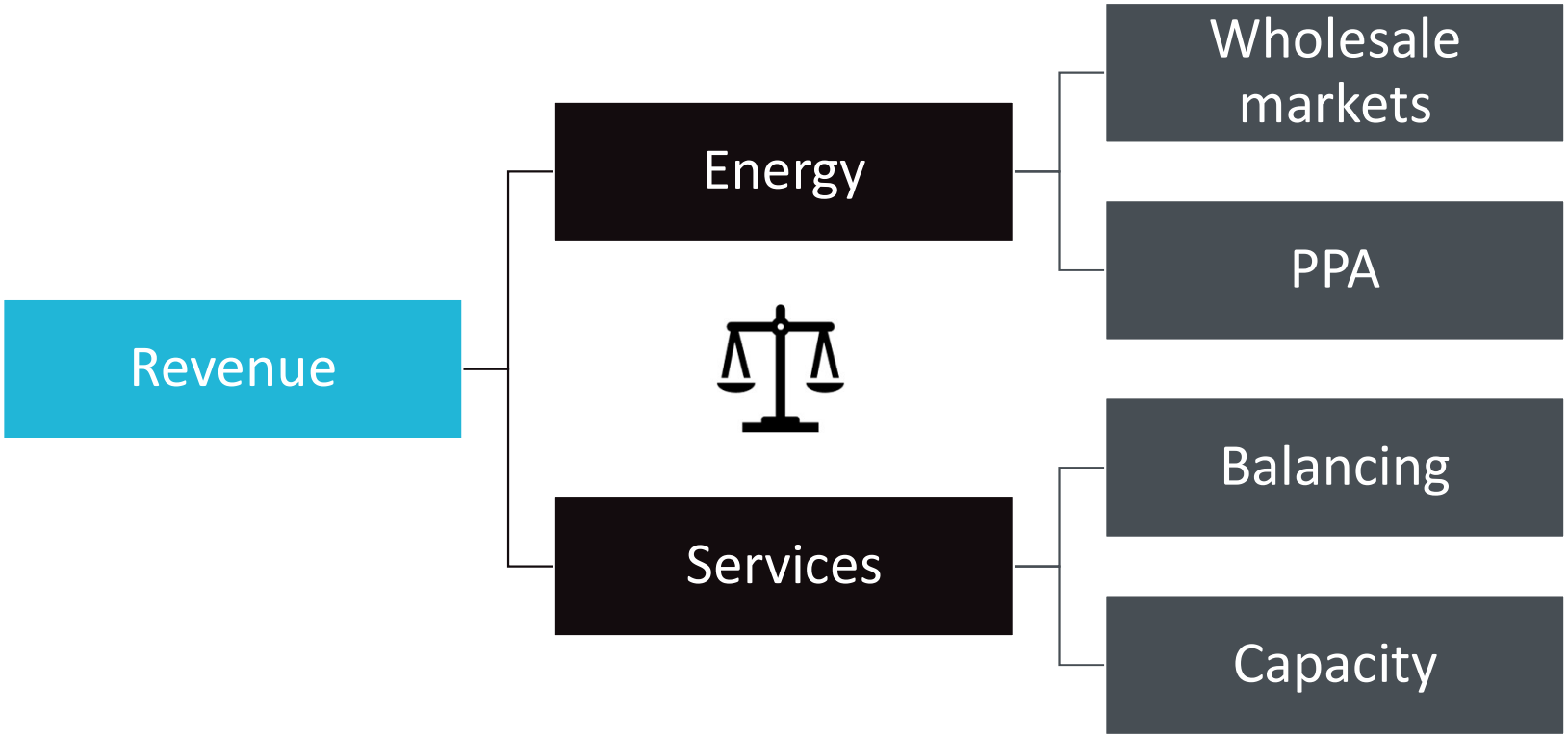
Increased Price Volatility

Higher AS Price

If we don't build flexible resources, the incentives are moot!
The system operator cannot dispatch what it doesn't have.

Source: *Impacts of High Variable Renewable Energy Futures on Electric-Sector Decision Making, J. Seel, A. Mills, R. Wiser (LBNL)*

REVENUE – EVOLVING OPPORTUNITIES



INCENTIVE – MAYBE?

Energy based (Past)

- Waning PPAs and Bilateral Transactions, particularly on aging units.
- Revenue from Energy is insufficient – no incentive to build flexible generation

What's Needed?

- Pricing Signal – capacity
- Pricing Transparency & Signal – flexibility
- New Services

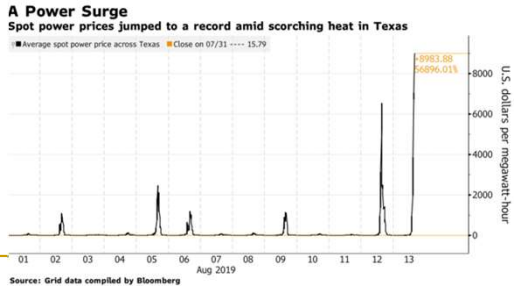
Where is the incentive? Dispatch @ 5 Minute, but Pay @ 60 Minute

INCENTIVES EVOLUTION

Shorter Pricing Intervals	FERC issued Order 825, requires prices and settlements on 5 minute intervals, rather than hourly.
Pay for performance	FERC Order 755 required all system operators to incorporate a resource's speed and accuracy into a performance-based payment
Flexible Ramping	Upward and downward ramping capability. Reduce energy to provide ramp in 5-minute.

INCENTIVES EVOLUTION

Real-time Price Adder	Incentivize units with high flexibility, but low capacity factor with higher real-time energy prices during periods of scarcity
Resource Adequacy	Procurement of fast-ramping capacity – minimize ramping uncertainty, and incentivize generators.
Capacity Markets	ERCOT's target reserve margin is lower than PJM's. Prices in ERCOT surged past $9,000/MWh

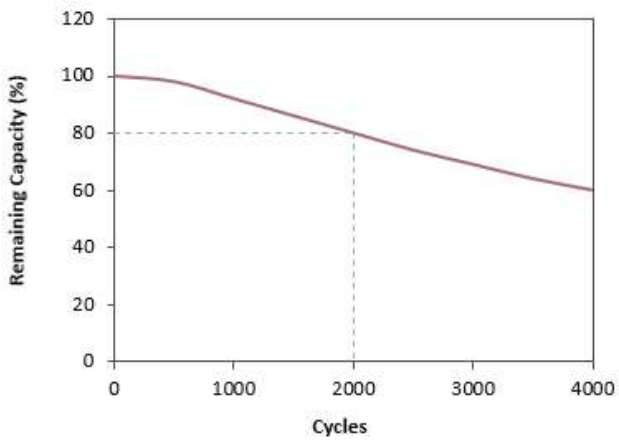


POSSIBLE BRIDGE IN THE INDIAN CASE?

- Province of Alberta: Power Purchase Arrangement Regulation
- Alberta's electricity system transitioned from regulated to a competitive deregulated market. PPA Buyers would bear the risk of buying and selling electricity in Alberta, but with possible profits.
- The PPAs took into account the operating and maintenance costs along with projections for capital upgrades over the period of 2001 – 2020 (20 years)
- PPA implicitly included flexible operation limits and cost recovery mechanisms: "Equivalent Hot Starts" and Limits on EHSs.
- PPAs were terminated.

UNINTENDED CONSEQUENCES – ENERGY STORAGE CASE

- RegD is the frequency regulation signal for fast-response resources (storage) in PJM
- Originally designed for energy neutrality within 15 min
- PJM found that quick response resources would sometimes worsen the frequency regulation problem
  - Fast response resources are energy-limited
  - If a battery is depleted while responding to the RegD signal, then it would start charging
  - More RegA resources (slow-response, not time-limited) are needed to correct the signal
- PJM reengineered the RegD signal in Jan. 2017 such that RegD resources are conditionally neutral within 30 min
  - No longer guarantees energy neutrality for RegD resources
  - Energy neutrality supported when extra capacity from RegA resources are freely available
- Batteries are operating longer and subject to higher energy exchanges



- More frequent high energy/power exchanges
- More cycling
- Higher average temperature
- **Concern: changed operation; irreversible reaction; accelerated degradation**

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