IES
Integrated Energy Systems

Introduction to Electricity Markets

Integrated Energy Systems (IES) Tools:
Capability Overview and Training
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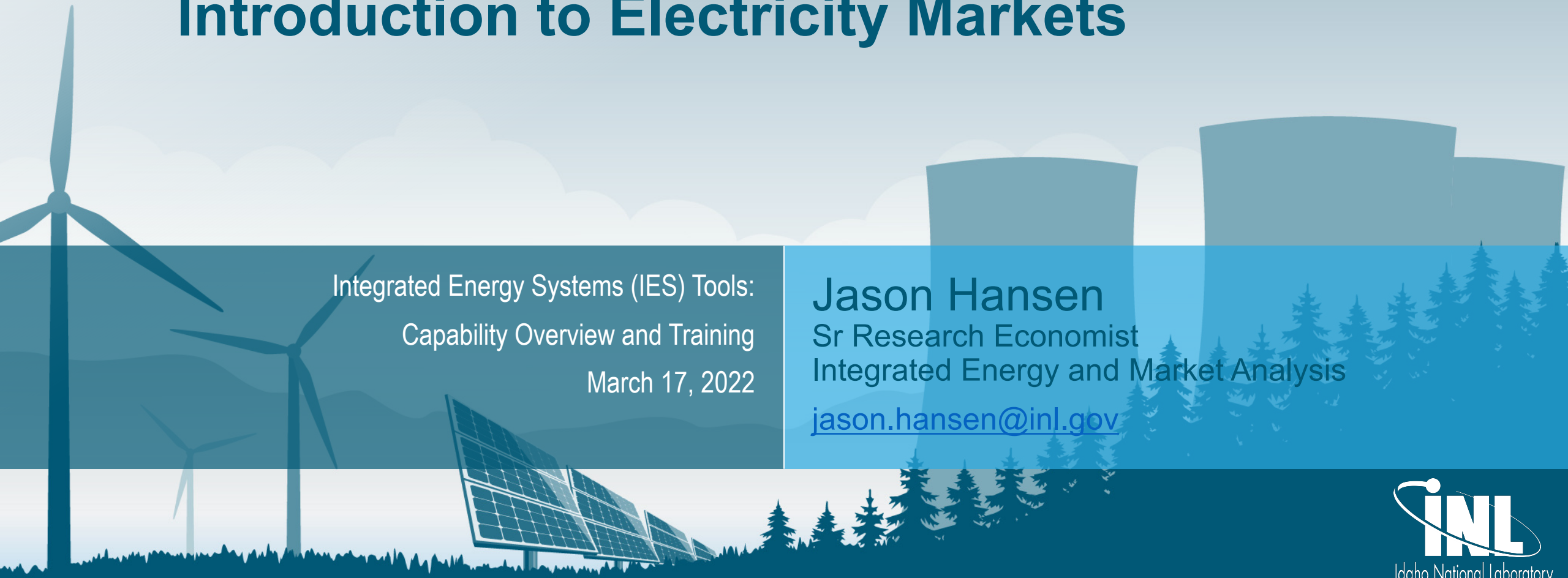
Jason Hansen
Sr Research Economist
Integrated Energy and Market Analysis
jason.hansen@inl.gov



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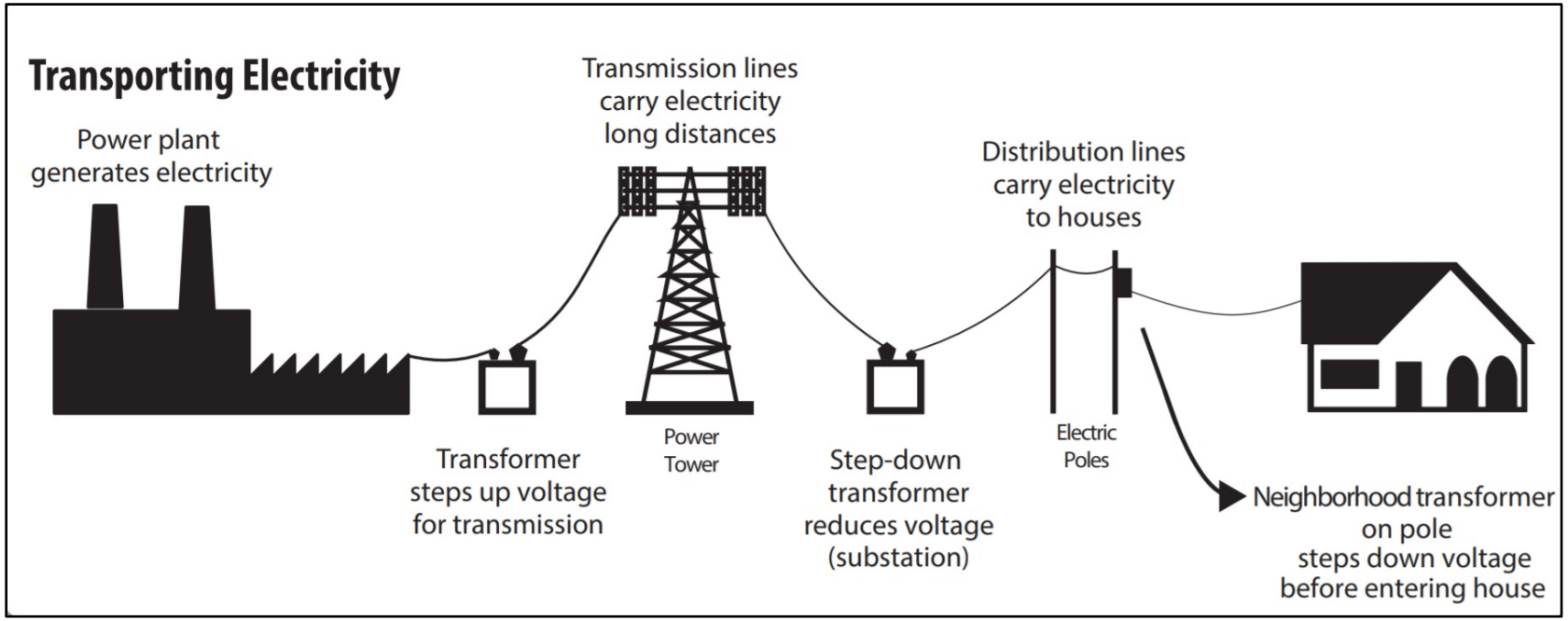
The Electricity System



Source: (NEED, 2020)

- Vertically integrated, regulated utility
- Restructured, deregulated, competitive model

- The **supply chain** of electricity
- **Technical** and **economic** considerations at each stage
- **Organizational** structure matters
  - Centralized
  - De-centralized

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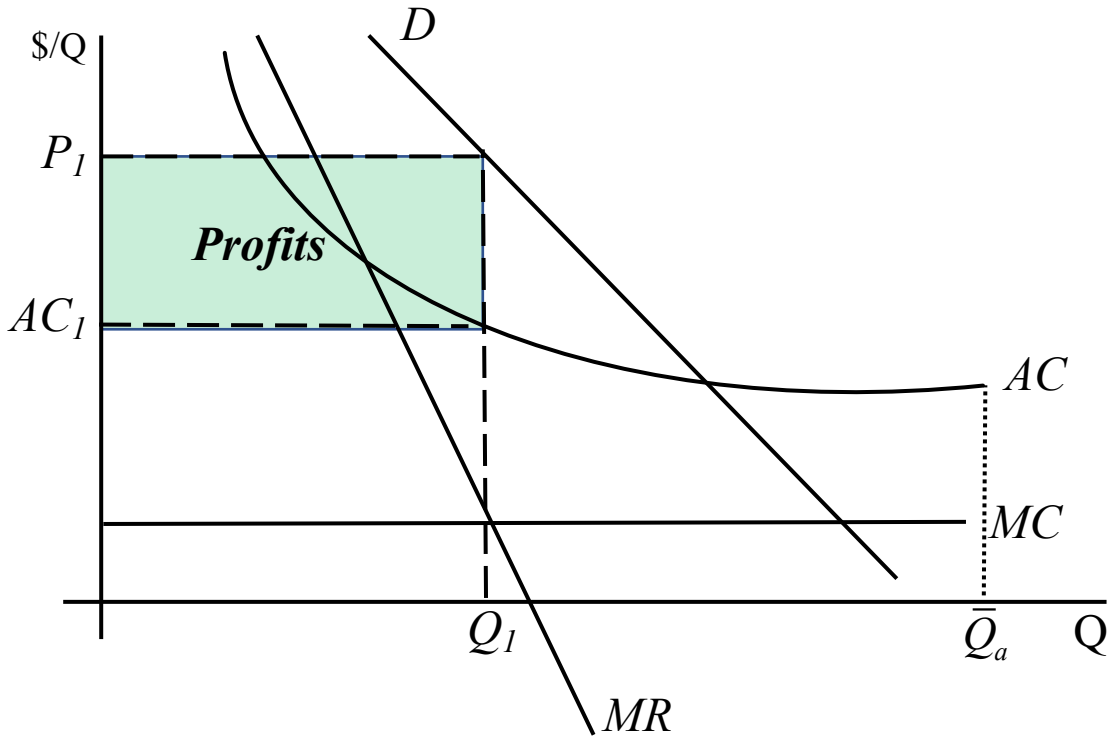
Outline

- Vertically Integrated Utilities
- Restructuring and Deregulation
- US Electricity Markets
  - Two-settlement System
  - Ancillary Services
  - Capacity Markets

The Vertically Integrated, Regulated Utility

- Single owner/operator structure of energy system means monopoly
  - one type of market failure
  - natural monopoly – large fixed costs
  - regulation to correct failure
- Rate of Return regulation
  - $\sum_{i=1}^{n} p_i q_i = \text{Expenses} + \text{sB}$
  - s = return on capital, B = investment expenses, rate base
- Subject to perverse incentives

Stylized Generator Cost Structure



Source:(Viscusi, Harrington Jr, & Vernon, 2005)

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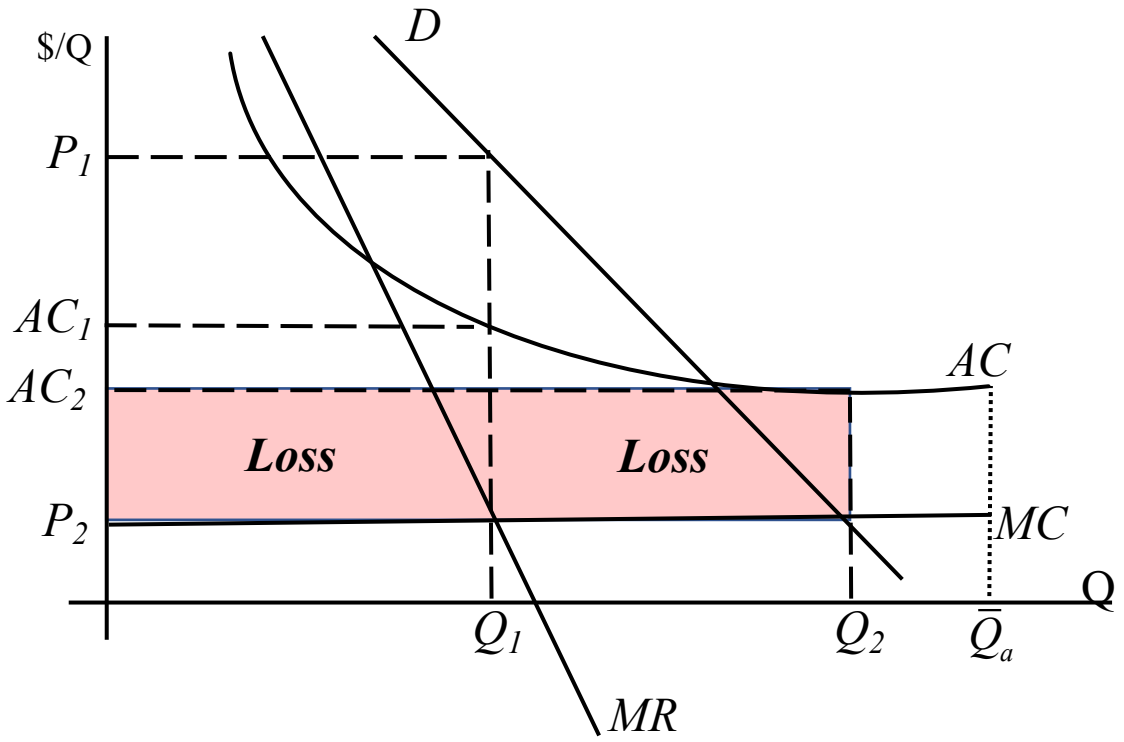
Restructuring and the Competitive Model (1)

- Generators bid their short run marginal cost
  - promise to provide Q capacity at P price at some time interval
- Bid covers variable costs but not fixed cost – "missing money problem"
- The scale of the missing money problem depends on the nature of generator cost structure (fixed costs)

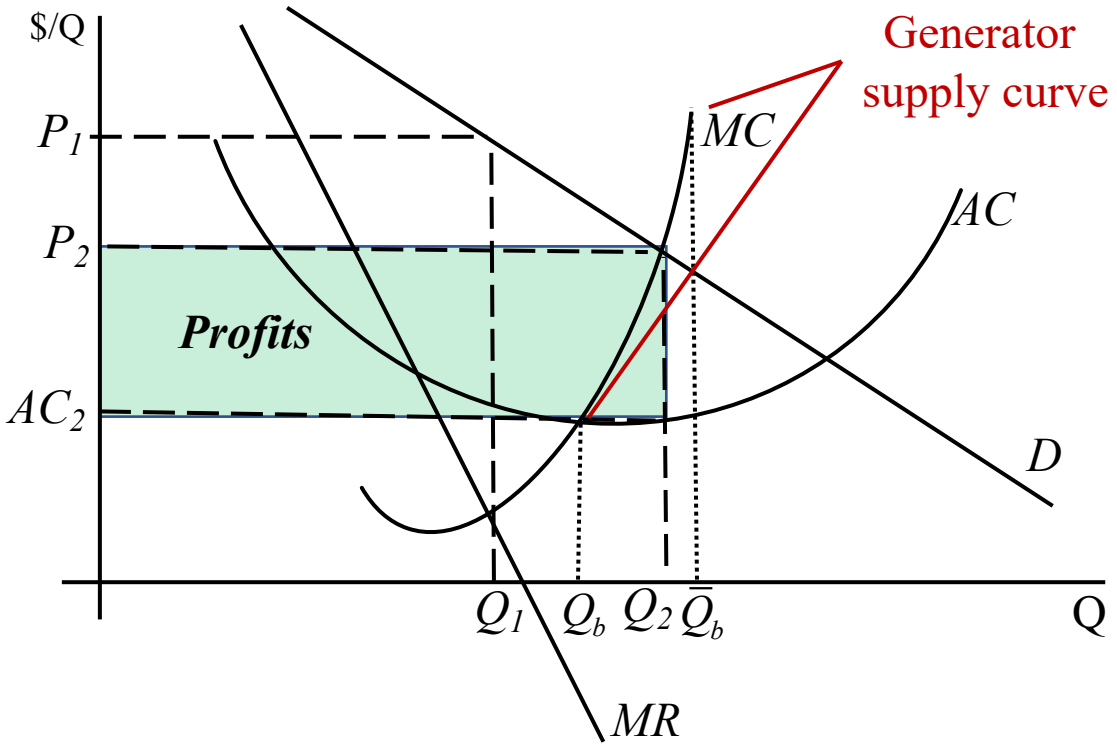
Stylized Generator Cost Structure



Restructuring and the Competitive Model (2)

- Bids for generators with increasing marginal costs cover variable and fixed costs
- Generator supply curve is the marginal cost curve above average ***variable*** cost
- If generators can't cover variable cost in short run then shut down

Stylized Generator Cost Structure



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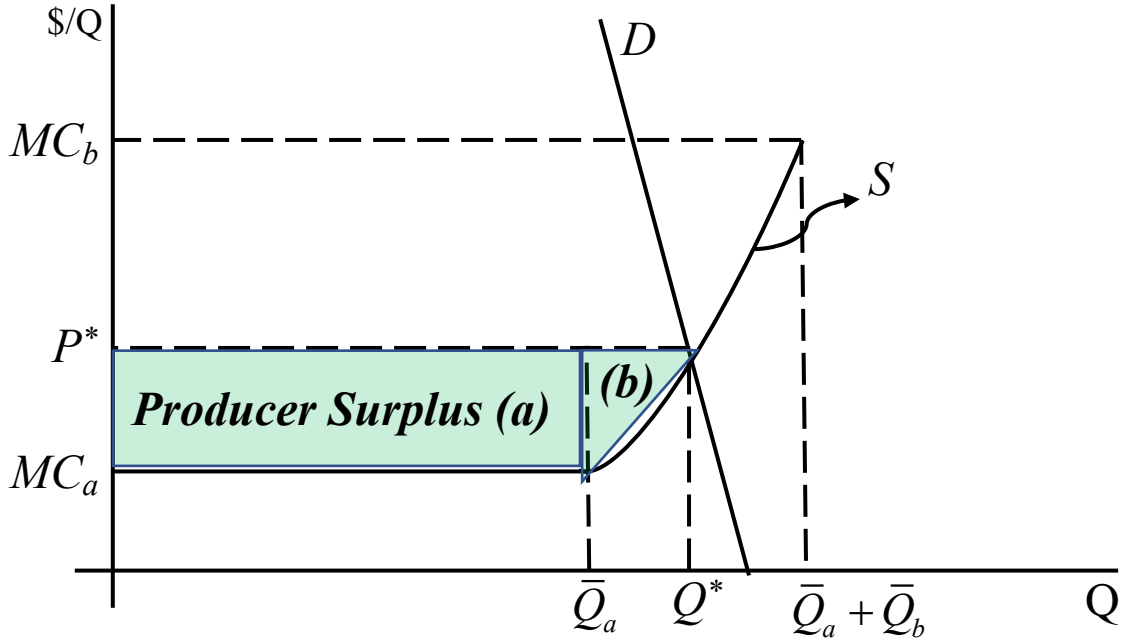
Restructuring and the Competitive Model (3)

- Market supply curve is the sum of the marginal cost curve across all generators in the market ("the stack")
- "marginal generator" is that for whom marginal cost intersects demand – "clearing price" P^*
- Dynamics of:
  - Production tax credit
  - Changing prices for natural gas
  - Carbon tax
- Note:

  Profits = Producer Surplus – Fixed Cost

Stylized Market Model



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Restructured US Wholesale Electricity Markets

Source: (FERC, 2020)

- In Northwest, Southwest, and Southeast, utilities operate in regulated markets
- In restructured markets, competitive market model used to allocate resources to:
  - Balance load
  - Regulation services
  - Expand capacity

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The Energy Markets in a Two-Settlement System

- (1) Day Ahead Market
  - Based on generator bids, DAM schedules generators to produce 24 hours out
  - Based on forecasted load (demand)
  - Generators can clear some capacity in DAM and hold out additional capacity in RTM
  - Prices called LMP (locational marginal price)
  - LMPs distributed across the grid
- (2) Real Time Market
  - Based on generator bids, RTM schedules generators to produce 1 hour out (or less)
  - Needed to settle the forecast imbalance from the DAM
  - LMPs
  - Grid distributed

Ancillary Services (1)

- Consider the fluctuations in the supply/demand balance in the DAM and the RTM. How does the grid operator adjust for these?
- Ancillary Services: tools of the grid operator to handle fluctuations in moments between clearing in the RTM
  - Regulation (frequency control) – adjustments within fractions of a second
  - Reserves (spinning and non-spinning) – adjustments within a few minutes

Ancillary Services (2): Regulation

- From physics, power = voltage * current
- Voltage and current are alternating sine waves
  - When waves are aligned then “in phase” power
  - Out of alignment then “out of phase” power
- Electricity demand can pull current and voltage out of phase
  - Then poor-quality performance in electric devices
  - Grid can “spin” out of control
- Reactive power is the additional voltage needed to bring voltage and current into alignment and return to in phase power
- Reactive power and real power compliments in consumption but substitutes in production

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Ancillary Services (3): Reserves

- Market for reserves (spinning and non-spinning) is a capability price
  - Generators commit to being willing and able to adjust by committed capacity amount
  - Paid capability price plus performance payment (electricity price from RTM)
- Grid operator uses reserves when regulation control is not enough to bring system back into alignment
  - Spinning reserves, generator spinning but not producing power
  - Non-spinning reserves, generator not spinning but can quickly go online
  - Must meet operator need within specific time frame

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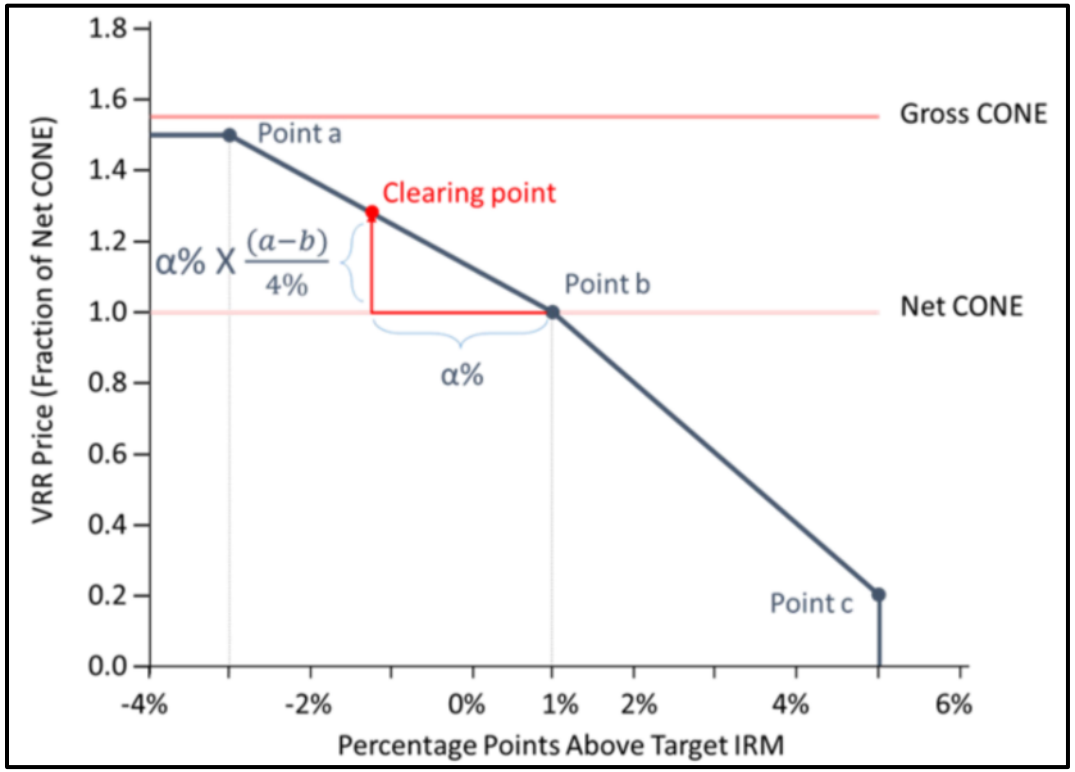
Capacity Market (1)

- In standard commodity pricing, per unit costs (variable and fixed) are covered by the price per unit.
- Electricity is not standard, de-regulated markets price electricity according to marginal cost (a function of variable cost) so how are power producers' fixed cost covered?
  - Policy constraints: NERC 1960s, FERC CA price caps
  - e.g., gas-peaker plant, LCOE > price cap in LMP
  - "the missing money problem"
- Capacity markets are a way for power producers to generate revenue for providing electricity capacity to the energy grid.
- Although it varies across ISOs, in general it is Load Serving Entities (LSEs), i.e., the entities providing electricity to end-use customers, who must secure reserve capacity. LSEs are the buyers.

Capacity Market (2)

- Capacity markets are a way for power producers to generate revenue for providing electricity capacity to the energy grid.
- ISOs set a price-cap called the CONE (cost of new entrant)
- Net CONE reflects generator revenue need to make up for shortfall from electricity revenue, estimate of missing money
- Cost of new generating capacity must fall below the CONE to bid in the capacity market
- The ISO sets a capacity target then generators bid based on their net CONE



Source: (Blumsack, 2020)

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Electricity Markets by Market Size

ISO/RTO	Energy ($B)	Capacity ($M)	Ancillary Services ($M)
CAISO	10.6	N/A	189
ERCOT	13.4	N/A	603.5
ISO-NE	6.0	3,600	130.9
MISO	21	431	70.5
NYISO	6.38	1,800	491
PJM	29.61	11,000	654
SPP	7.5	N/A	76

Source: (Hytowitz, Ela, Kerr, & Bernhoft, 2020)

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Summary

- Significant differences in modeling regulated utility versus restructured (“deregulated”) utility
- Shape of (or assumptions on) marginal cost curve impacts firm profitability – large fixed costs vs large variable costs
- In restructured markets a competitive market model is used to allocate resources formerly accomplished by a single entity
- Markets for ancillary services and capacity provide additional value for utilities, although not as strong as electricity market

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