Electricity Markets for Process Engineers: Why can’t you just give us a mass flow?

7/30/2019
Agenda

- Fundamentals of Electricity Economics
- Economic Decision Making for Generation Assets
  - Operational Decisions
  - Investment Decisions
- Implications for CCS Systems
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The electricity “supply stack” is built up from the marginal production cost for each generator in the system
- Marginal cost consists of fuel cost plus any variable O&M costs

The clearing price of electricity is set by the price where demand intersects supply
Applying a Carbon Price Increases the Marginal Cost of Emitting Resources

- A carbon price would manifest itself as a marginal cost for carbon emitting generators
- When a fossil generator is the price setting unit, this increases the market electricity price
Continuous Balancing of Supply and Demand Results in Changing Price

- Both the supply and demand characteristics of the market are continuously changing.
- Output from variable resources shift the supply stack, while changes in electricity consumption move the demand curve.
Electricity Value Represented by a Locational Marginal Price

- The continuous balancing of supply and demand leads to a shifting system price
- Physical system constraints (transmission) drive additional differences in price at each node within an electricity network
- The resulting price for electricity is the Locational Marginal Price (LMP)

2030 estimates from LBNL 50% RPS study (Balanced Portfolio scenario): Seel, Joachim, Andrew D. Mills, and Ryan H. Wiser. "Impacts of high variable renewable energy futures on wholesale electricity prices, and on electric-sector decision making." (2018).
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Marginal Cost of a CCS Enabled Plant Will Dictate Its Order in the Supply Stack

- Depending on the operational economics of a CCS enabled plant, its marginal costs may be higher or lower than a non-CCS unit subject to the carbon cost.
High Marginal Cost CCS Unit

- If the marginal cost of the CCS enabled unit falls above other dispatchable resources on the grid, the price of electricity will rarely rise to a level that enables profitable operations.
- In this scenario, the optimal economic decision is to not run the plant at all.

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Low Marginal Cost CCS Unit

- When a CCS enabled unit represents a lower marginal cost option than other dispatchable generators, then the electricity price is likely to regularly exceed the level required for the plant to generate operational profits.
- The plants operations will be optimized to maximize earnings and minimize losses.

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Idealized Unit Dispatch

- Plant ramps up to capture periods of profitability
- For extended periods of where prices fall below costs, plant is shut down
- For shorter loss-making periods, plant is ramped down, but not turned off
  - Avoids costs associated with startup
  - Enables faster ramp up
  - Reduces total losses

- Physical constraints imposed by the CCS process will impact the economics of operation

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Price swings due to fluctuations in both wind output and demand, including unexpected RT price swings

Sustained periods of pricing below variable cost with short irregular profitable periods
A (CCS equipped) plant’s operating profile is linked to its design

1. The design of a plant determines how costs vary with respect to output

2. Under an economic dispatch framework, plants are scheduled for operation in accordance with their marginal costs

3. A plant’s dispatch schedule dictates its capacity factor and the energy-based revenues that it earns

4. The anticipated earnings of a plant drive design and deployment decisions
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And Now, The Rest of the Story Money

- An existing plant continues to operate if its gross profit exceeds its ongoing fixed costs
  - Gross profit = \[\text{electricity revenues} - \text{variable costs}\]
- A new plant, however, will only be constructed if justified by a sufficient rate of return
- The gap between these values is often referred to as the “missing money problem”
Finding the Missing Money

- In many markets, the “missing money” gap is filled by capacity payments
  - Texas’ ERCOT market does not use this mechanism, instead has high scarcity pricing in its energy market
- 1st and Nth plants likely to have different capacity payment requirements
- Designs that require lower capacity compensation can be more successfully deployed

![Plant P&L Graph](chart.png)

**Source:** NRDC

![Diagram](diagram.png)

- Generators A and B will clear the market because their bids are equal to or less than the clearing price.
- Generators C and D will not clear the market because their bids are higher than the clearing price. These plants may choose to retire because they may lose money through operating.
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Market Implications for CCS Systems

- Marginal costs of operating a CCS equipped power plant dictate its opportunities for generating operational profits
  - Maintaining a marginal cost lower than conventional generators exposed to a given carbon price likely critical for maintaining a sufficient capacity factor

- Physical constraints imposed on the power plant by the CCS unit can hamper the plants economic performance
  - Maintaining power plant flexibility (ramping rate and turndown) likely to be important

- Capacity payments likely to be a key source of revenue for CCS enabled plants – minimizing the capacity payments required will be important to drive initial investments
  - In the long-term, deployment of CCS enabled plants will impact energy revenues, shrinking any gains from the marginal cost advantage against a carbon price
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Why can’t you just give us a mass flow?

A deterministic CO$_2$ flow profile cannot be provided because the ultimate power plant generation profile will be a function of the design properties of the CCS unit.
Market Conditions Are Not Static

- For a first of a kind plant, economics can be optimized for one or more assumed LMP profiles
- As a technology becomes a meaningful component of the supply stack, it impacts market prices
- Capacity expansion models that analyze this feedback loop are used to evaluate capital expenditure decisions
Investment Planning Requires Long Time Horizon System Modeling

- The inner iterative loop, driven by a dispatch model, evaluates the ongoing operational performance of a plant
  - Optimizes for dispatch given physical characteristics and market signals
  - Evaluates design tradeoffs under given market characteristics

- The outer loop, capacity expansion, evaluates the scale of deployment for all available technologies and how that deployment impacts the market