Objectives, Constraints, and The Second Best

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Three Objectives for Electric Power Systems

- In the **short run**, produce electricity & ancillary services efficiently, given available assets.

- In the **long run** (*the focus of this project*), investment should produce asset fleets capable of reliable, low-cost production, taking into account all costs.

- For the **broader economy**, retail prices should reflect SRMC (+losses, congestion) and so induce efficient consumption of electricity.
  - Efficient retail pricing should facilitate economy-wide electrification, which seems to be essential for **economy-wide** decarbonization to address the climate problem.
In Theory, Energy Markets Can Achieve the First-Best in High-VRE Systems

• The MITEI *Future of Storage* Project has been modeling welfare-optimal decarbonized regional systems (Northeast, ERCOT, Southeast) circa 2050 – some key robust results
  • Assuming constant returns to scale, perfect foresight, and an explicit VOLL

• Welfare optima correspond to long-run competitive equilibria, with all generation & storage investments just breaking even – a theorem

• System stress often arises from low supply, with demand well below peak (CA outages just a taste); nameplate-based capacity mechanisms would be off-target

• Wholesale prices are **much** more variable than today
  • The implied retail price variability encourages decarbonization despite **higher mean prices** (decarbonization is not free!) through many hours of very low prices
For Comparison, Hourly Day-Ahead Prices in ERCOT in 2019

<table>
<thead>
<tr>
<th>Bin</th>
<th>Frequency</th>
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<tr>
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### Hourly ERCOT Day-Ahead Prices
(System Lambda) 2019
Average Hourly Real-Time Prices at the ERCOT Houston Hub, 2019

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![Average Hourly Real Time Prices Houston Hub 2019](chart.png)
Price Distributions In Optimized High-VRE Systems Are Highly Skewed

Distribution of wholesale electricity prices for various emissions and technology scenarios (Texas)

- **Li-ion**
- **+ Flow + H₂**

![Price Distribution Graphs](Image)

- Price range ($/MWh)
  - >1000
  - 200-1000
  - 50-200
  - 5-50
  - 0-5

- Emission Policies (gCO₂/kWh)
  - 50g
  - 10g
  - 5g
  - 0g
Generators & Storage Earn Most of their Revenue in a Very Few Hours

![Bar chart showing delivered energy and revenue by electricity price for different technologies and emission limits.](image)

### Cases in Experiment A2

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<th>RFB</th>
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### Price range

- **>1000**
- **200-1000**
- **50-200**
- **5-50**
- **0-5**

**Technologies & Emission Limits (gCO₂ / kWh):**

- CCGT
- CCGT-CCS
- OCGT
- PV
- WIND
- Li-ion
- Hydrogen
Is this pure energy-only model a feasible alternative for decarbonized systems?

• Investors will be reluctant to make investments that depend for viability on very few hours of very high prices & will want long-term contracts – not the key problem

• Most system operators find today’s variability problematic and intervene to avoid high prices; this resistance will only increase as VRE penetration rises

• Operators’ price caps < VOLL + competition → reliability as if cap = VOLL; i.e., too low → A need for capacity mechanisms to supplement energy market revenues
  • Need a second instrument for a second (reliability) target

• More broadly (per Paul Joskow), regulators & other policy makers have regularly second-guessed markets; rapid qualitative change will only strengthen that impulse

• If the pure model is not feasible, what is?
A Feasible **Non-Market** Design for Decarbonized Systems

- Hawaii: 100% renewables by 2045, a vertically integrated utility, investment decisions via integrated resource planning for reliability (i.e., negotiation), **muddling**

- Regulator pushes competitive procurement of grid-level generation & storage (mainly flat, per-MW contracts); utility wants wires, with ROR regulation

- May have productive efficiency + reliability (given rooftop solar), but has **flat retail rates**

- $0.30/kWh to charge my son’s EV when solar is curtailed will discourage electrification

- Keeping the lights on with low-carbon generation is not good enough!
Thoughts on Designing Second-Best Market Rules

• One view of this project: looking for good second-best market designs, subject to the constraint that regulators won’t tolerate very high prices & rapid unmanaged change

• Having market rules disciplines market participants and regulators (vs. Hawaii) but can limit flexibility or require frequent revisions (e.g., California)

• Price constraint → need a supplement to energy market revenues to increase reliability; capacity markets focused on dispatchable capacity & peak demand won’t work

• Want good performance on all three objectives: short-run efficiency, long-run efficiency, and, to decarbonize the economy, retail rates that vary with marginal cost
Elements of a Good Solution (without the details, where the devil lives)

• Evaluating alternative generation+storage+wires portfolios in high-VRE systems is complex: need something like IRP, not CA-like from-the-hip mandates
  • Of course, need to specify counterparties, timing/frequency, bidding rules...

• For energy + ancillary services competition to yield SR efficiency, LT contracts must not distort operating incentives – RPS per-MWh vs. fixed price plus performance minima

• Fixed costs of capacity subsidies should be recovered through (equitable) fixed charges at retail; loading them on per-kWh charges will impede electrification
  • Need to move retail rate-making closer to mobile phone pricing

• Marginal retail rates should be T&D-adjusted wholesale energy prices, with smart meters this will encourage electrification
  • Can retail competition (ultimately) deliver this?
Now, please solve these problems!

Thanks for your attention!