Objectives, Constraints, and The Second Best

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Three Objectives for Electric Power Systems

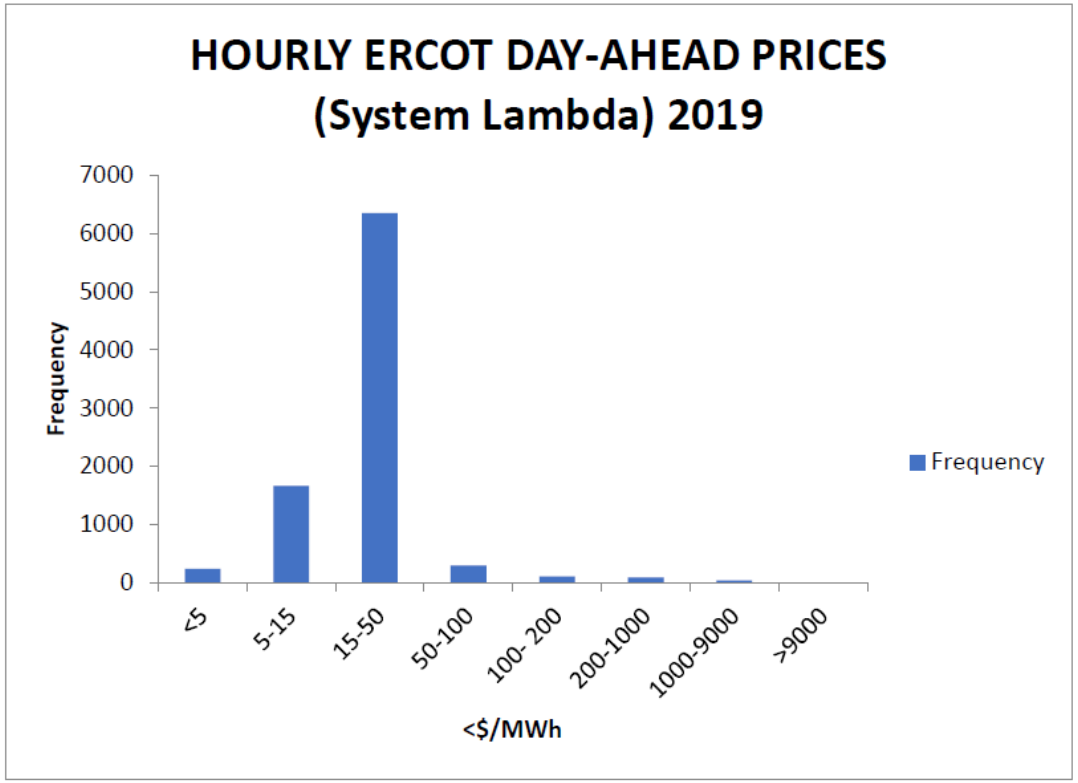
- In the short run, produce electricity & ancillary services efficiently, given available assets
- In the long run (*the focus of this project*), investment should produce asset fleets capable of reliable, low-cost production, taking into account all costs
- For the broader economy, retail prices should 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

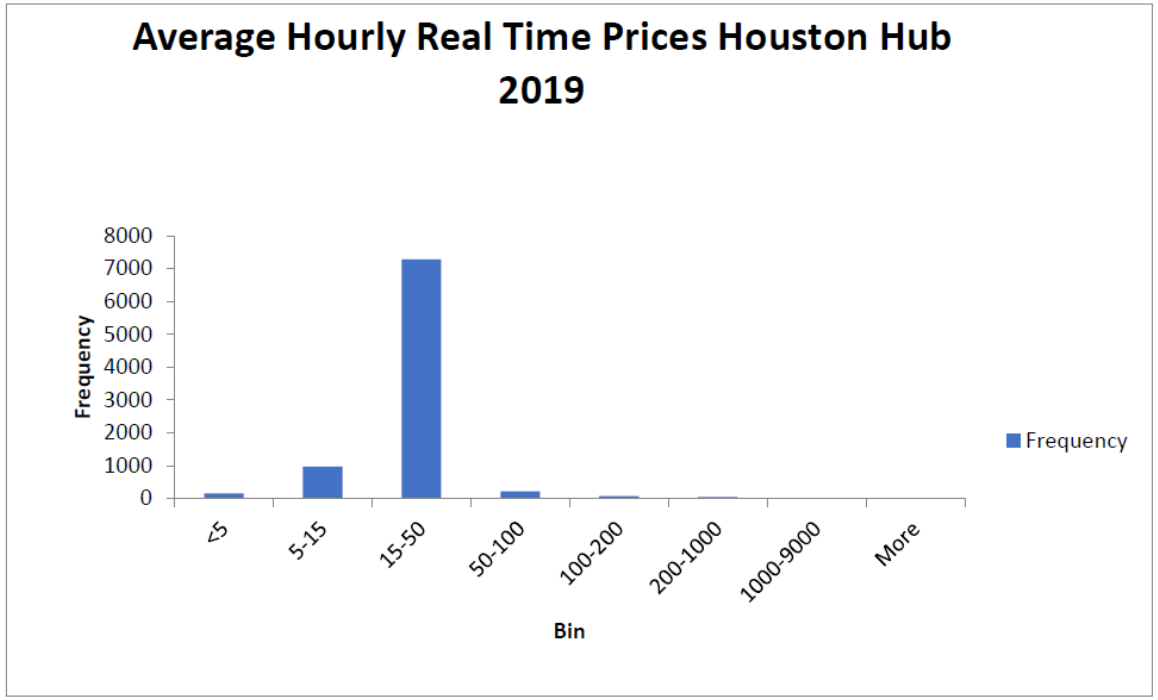
Bin	*Frequency*	
<5	232	2.6%
5-15	1661	19.0%
15-50	6354	72.5%
50-100	291	3.3%
100- 200	100	1.1%
200-1000	86	1.0%
1000-9000	35	0.4%
>9000	0	0.0%



From Paul Joskow

Average Hourly Real-Time Prices at the ERCOT Houston Hub, 2019

Bin	Frequency	
<5	150	1.71%
5-15	970	11.07%
15-50	7279	83.09%
50-100	224	2.56%
100-200	76	0.87%
200-1000	49	0.46%
1000-9000	11	0.13%
More	0	

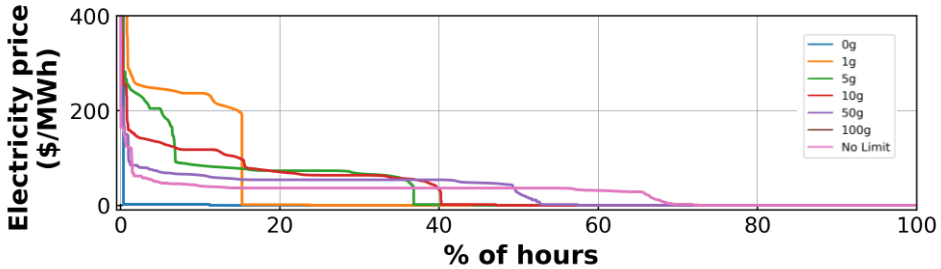


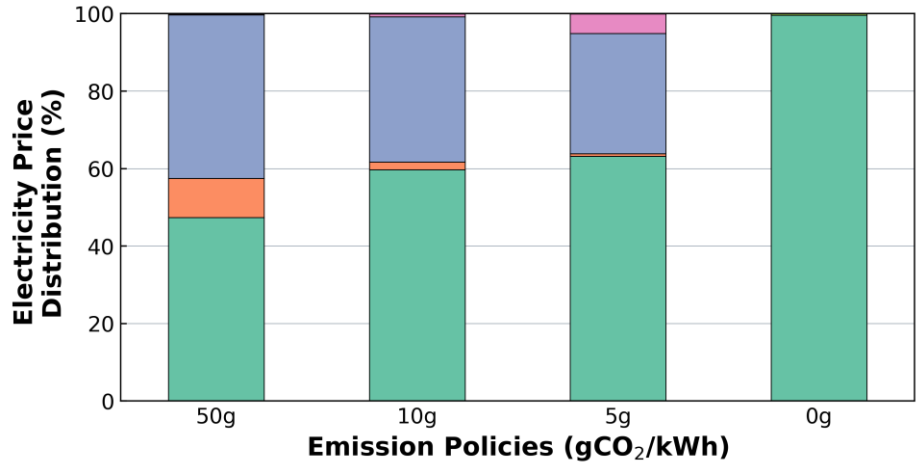
From Paul Joskow

Price Distributions In Optimized High-VRE Systems Are Highly Skewed

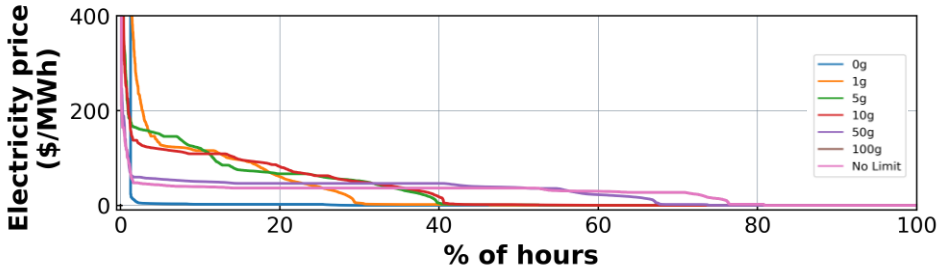
Distribution of wholesale electricity prices for various emissions and technology scenarios (Texas)

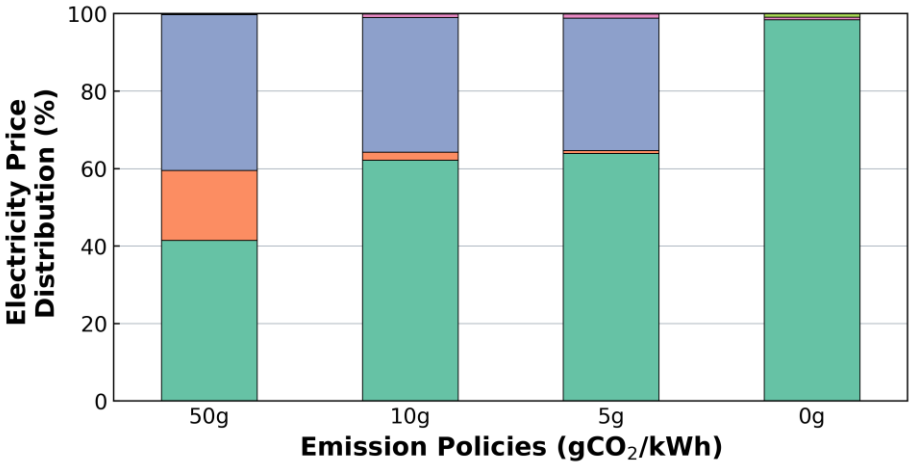
Li-ion





+ Flow + H_2

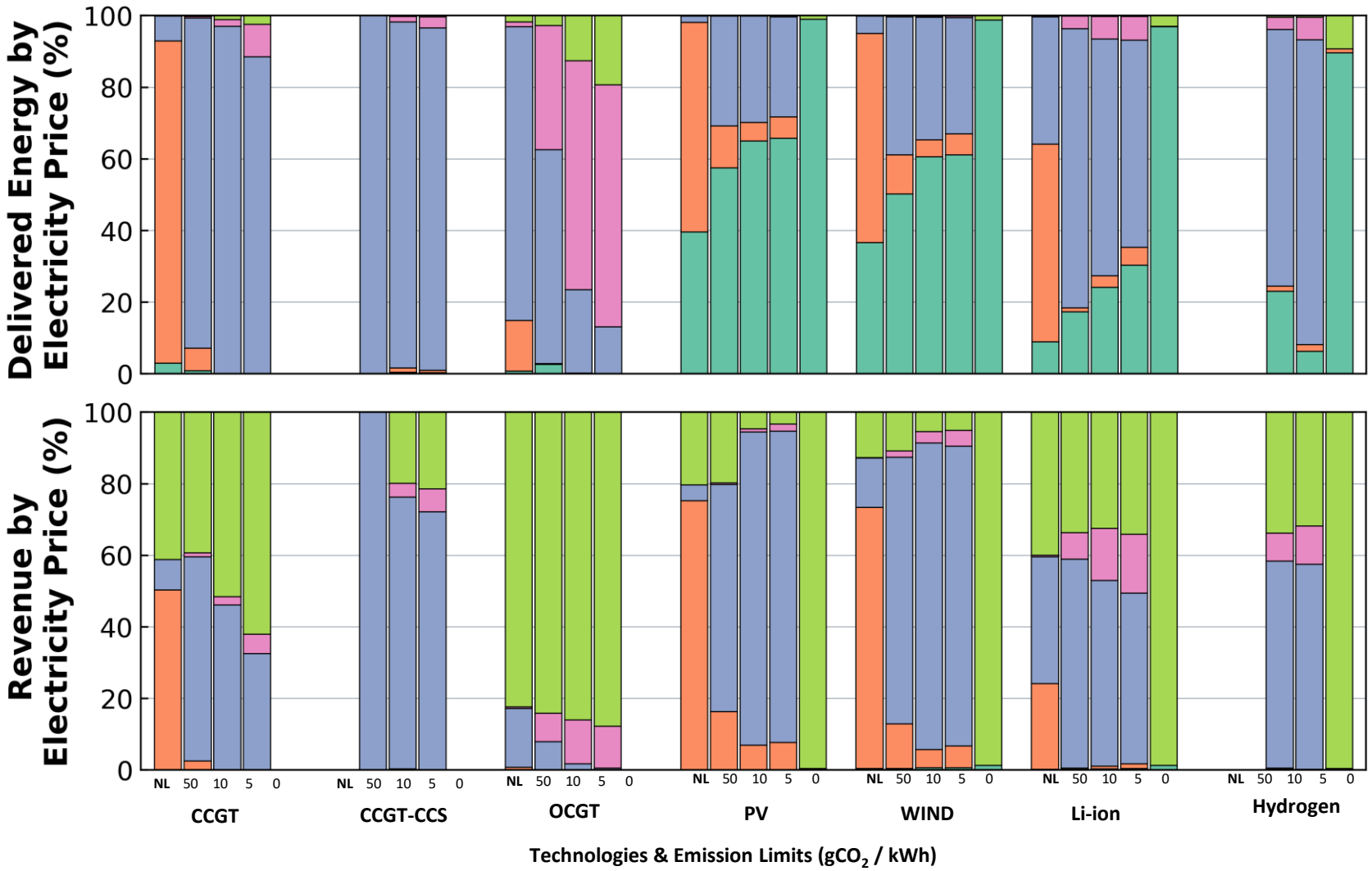




Price range ($/MWh)

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

Generators & Storage Earn Most of their Revenue in a Very Few Hours



Cases in Experiment A2

		VRE	Li-Ion	RFB	H_2	Metal-Air	Thermal
Base Case		M	M				
Exp. a2	A	M	M	M	M		
	B	M	M	M		M	
	C	M	M	M			M
	D	M	M		M		

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 qualitiative 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?

Thanks for your attention!

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Now, please solve these problems!