Keeping Our Eyes on the Prize

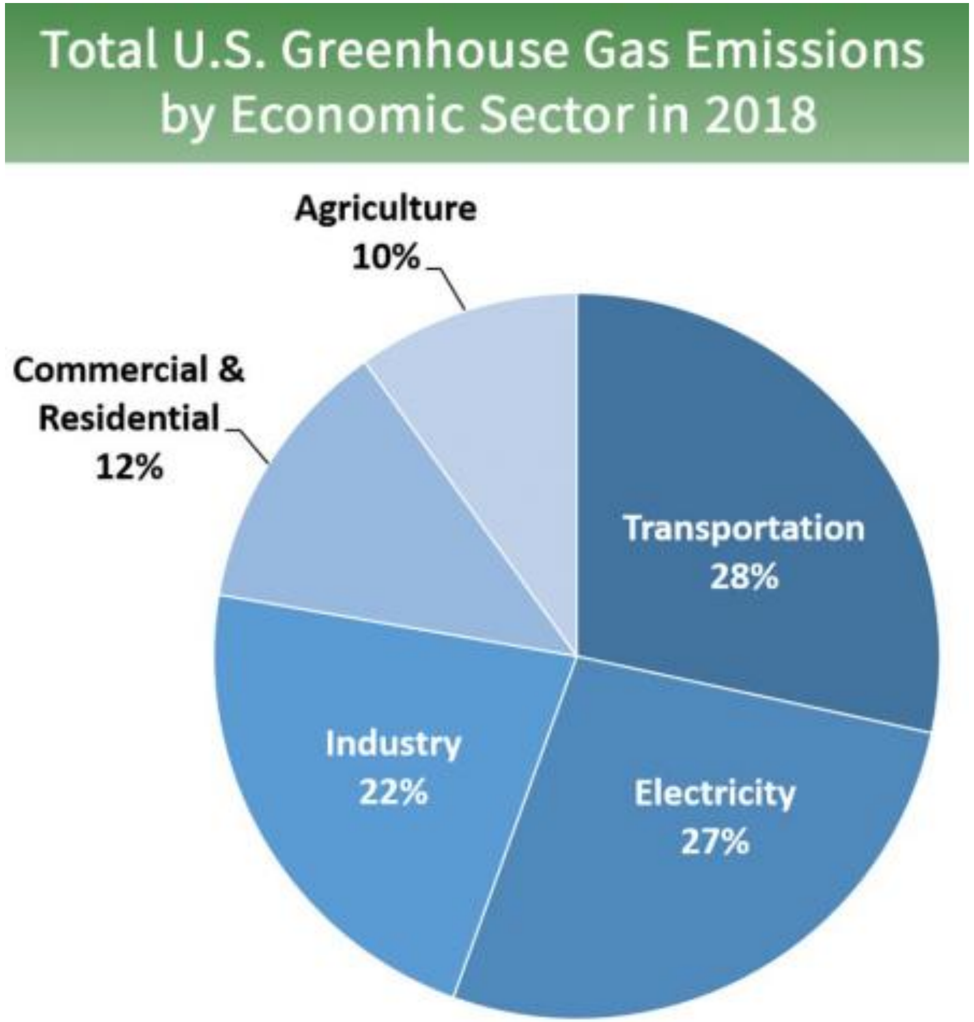
Richard Schmalensee

HEPG Workshop

February 3, 2021

The Prize: Economy-Wide Decarbonization

- The plan: decarbonize electricity, electrify everything else & greatly expand electricity
- If decarbonizing & expanding electricity is too expensive, political resistance may block it
- Average retail price will rise; if retail prices are not efficient, electrification may be too hard
- Because basic policy architectures are persistent, seemingly innocuous choices now (e.g., a Clean Energy Standard) may have undesirable effects for decades



Three Points, from Ongoing MITEI *Future of Storage* Study

- Study focuses on efficient systems circa 2050, but results have near-term implications
  - “If you don’t know where you are going, you might not get there”

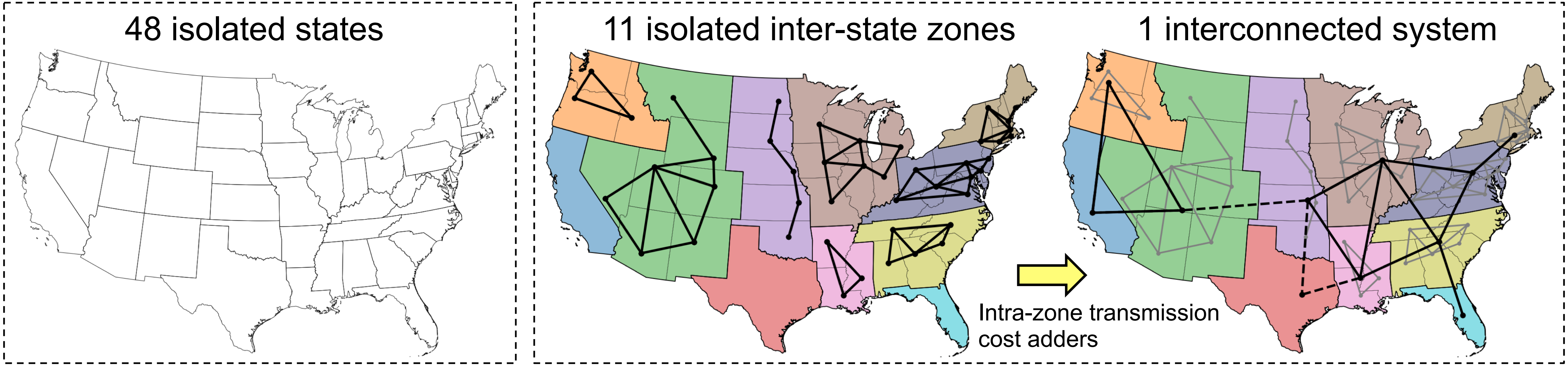
- Boundary-crossing (esp. inter-regional) transmission can slash electricity decarbonization costs
  - Electrification implies much more electricity, which implies much more transmission capacity
  - Regional differences in wind/solar resources implies great benefit from inter-regional transmission
  - State/federal barriers are complex & will take time to resolve; engagement delay may be costly

- Substantial power system decarbonization is cheap, but going to zero may require an absurd carbon price
  - Gas generation can get a system through long, low-wind periods; alternatives may be costly
  - Suggests research (e.g., direct air capture), not taking zero too seriously, importance of other sectors

- In efficient decarbonized wholesale markets, prices are <u>much</u> more variable than currently
  - Variable retail prices plus load-shifting can encourage innovation & electrification
  - MWH-focused policies (e.g., RPS, CES) discourage price variability & can raise electrification costs

Brown & Botterud, *Joule*, 12/11/2020: clean power system for lower-48 using onshore wind, PV, Li-ion & hydro

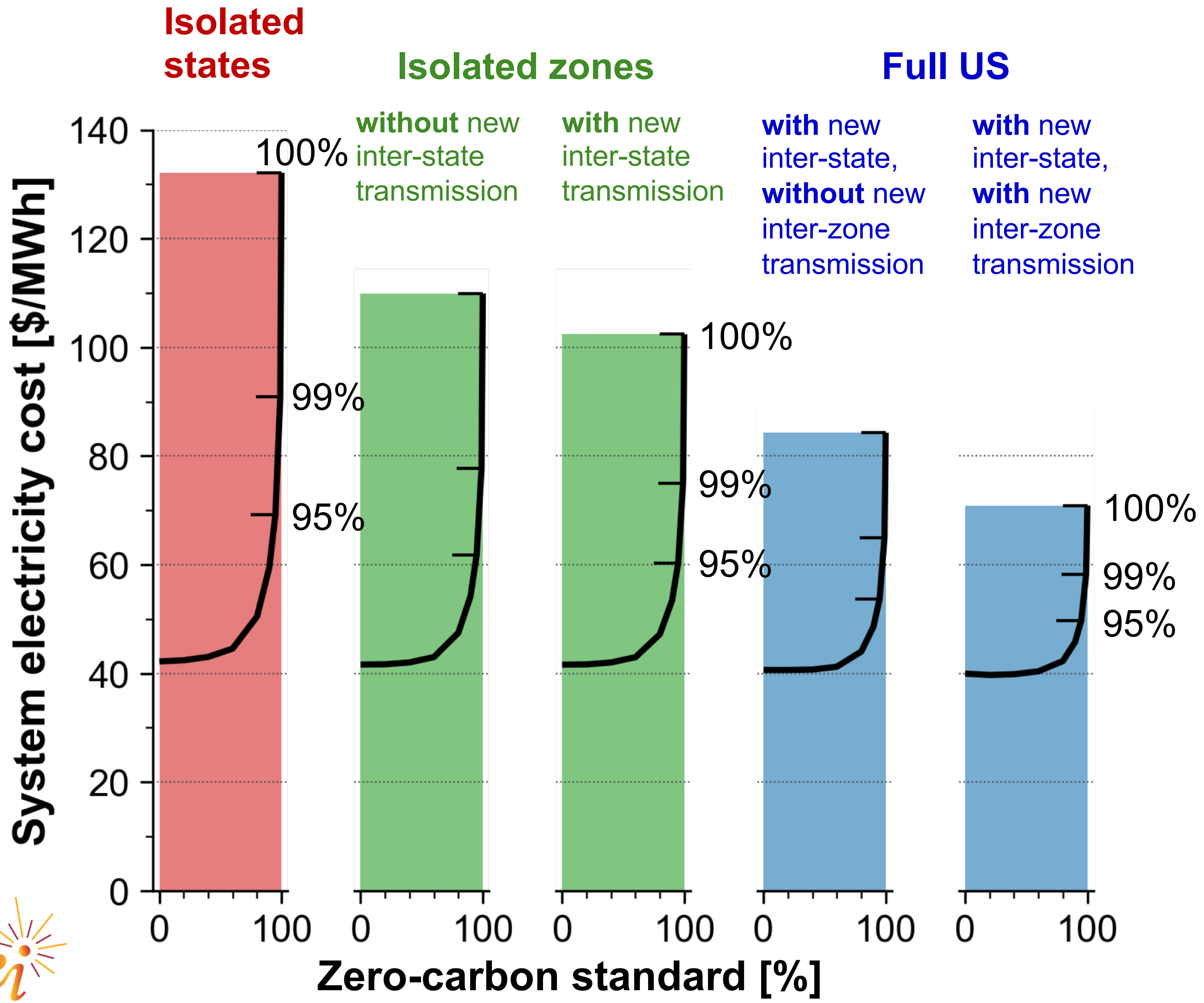
- Co-optimized capacity & operation of generation, storage, and transmission
- Linearized model, chronological hourly resolution over 7 years (2007-2013, 61296 hrs)
- Zero carbon as central case w/ sensitivities for nonzero carbon
- Three levels of geographic coverage: states, multi-state zones, continental US



Limitations:

- No sequential investment planning (single system snapshot)
- No treatment of sub-hourly availability or stability
- No OPF or security constraints; highly aggregated treatment of transmission
- Simplified treatment of dispatchable resources: Daily hydro balancing, no unit commitment
- Isolated US system; connections to Mexico and Canada not included

Lower Decarbonization Costs for an Interconnected System



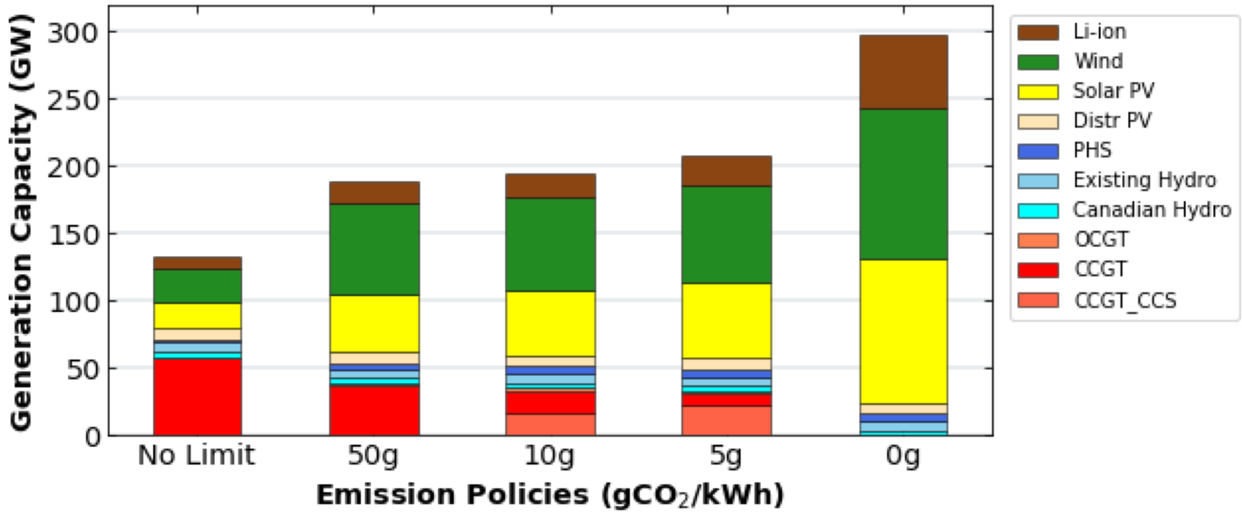
Electricity cost increases significantly on approach to zero carbon for isolated systems, but to a **much smaller extent for full-US system**

Regional Analysis in the MITEI *Future of Storage* Study

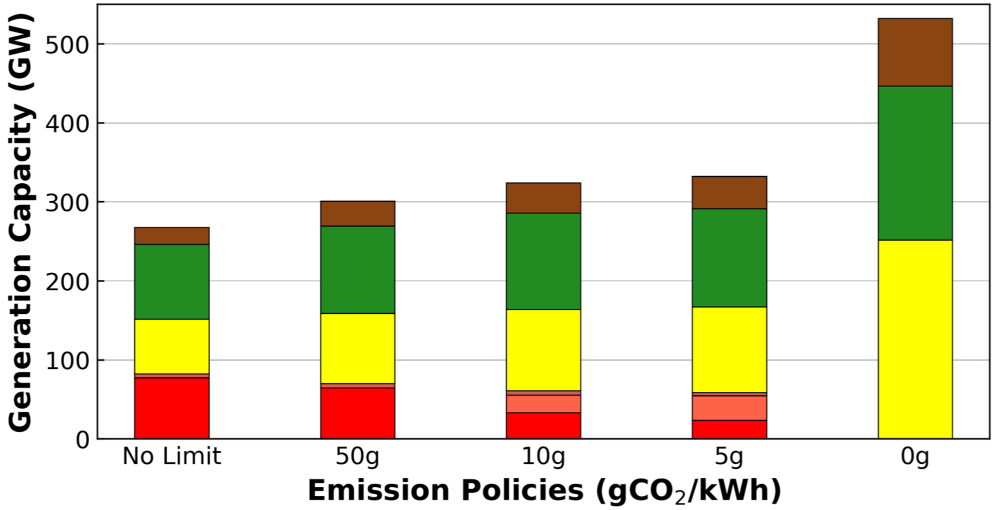
- **Regions:** Texas (ERCOT), Northeast (w/ existing hydro), Southeast (w/ some nukes)
- **Framework:** Constant returns, perfect foresight, 7 years of weather data
- **Base Case**: On- & Off-shore wind, PV, gas, CCS available; NREL high electrification, no demand flexibility, $50k VOLL, intra-region transmission expansion, *only Li-ion available (medium costs), no biomass at scale*
- **Variations:** Different CO_2 Constraints (carbon taxes), different assumptions about storage technologies & costs, demand flexibility, no nukes in SE...
- Not aiming to forecast or pick winners; "What if?" exercises for insights
- Many model runs; *work is still in progress, but patterns reported here seem to be robust*

With only Li-ion (& existing hydro in NE), substantial decarbonization requires only modest increases in generation capacity; going to zero eliminates natural gas & requires lots more generation

Northeast



Texas



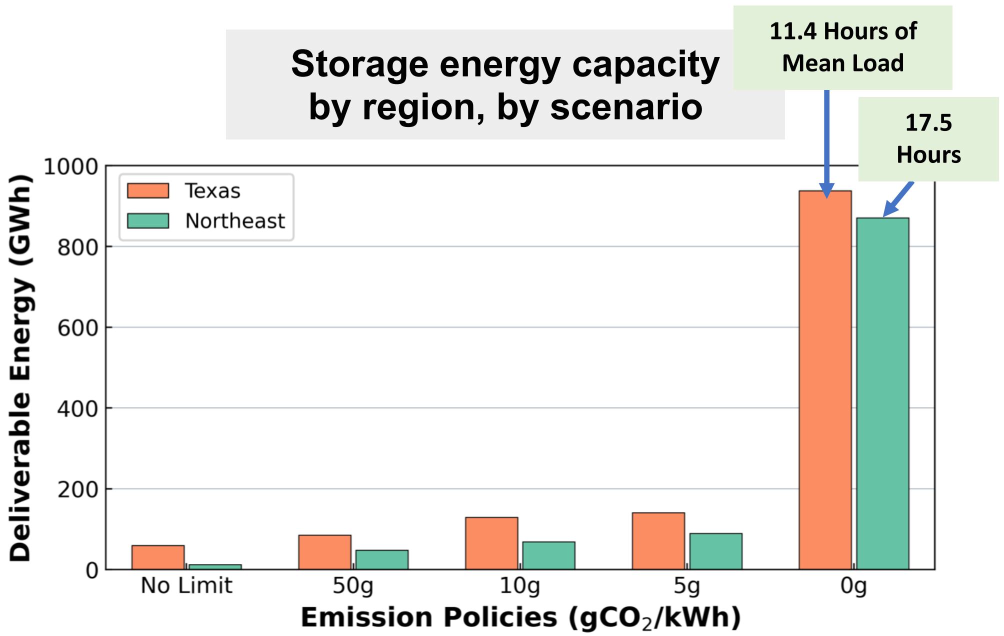
System peak and annual load[a]

- Northeast: 90 GW, 435 TWh
- Texas: 151 GW, 715 TWh

CO_2 emissions for no emission limits

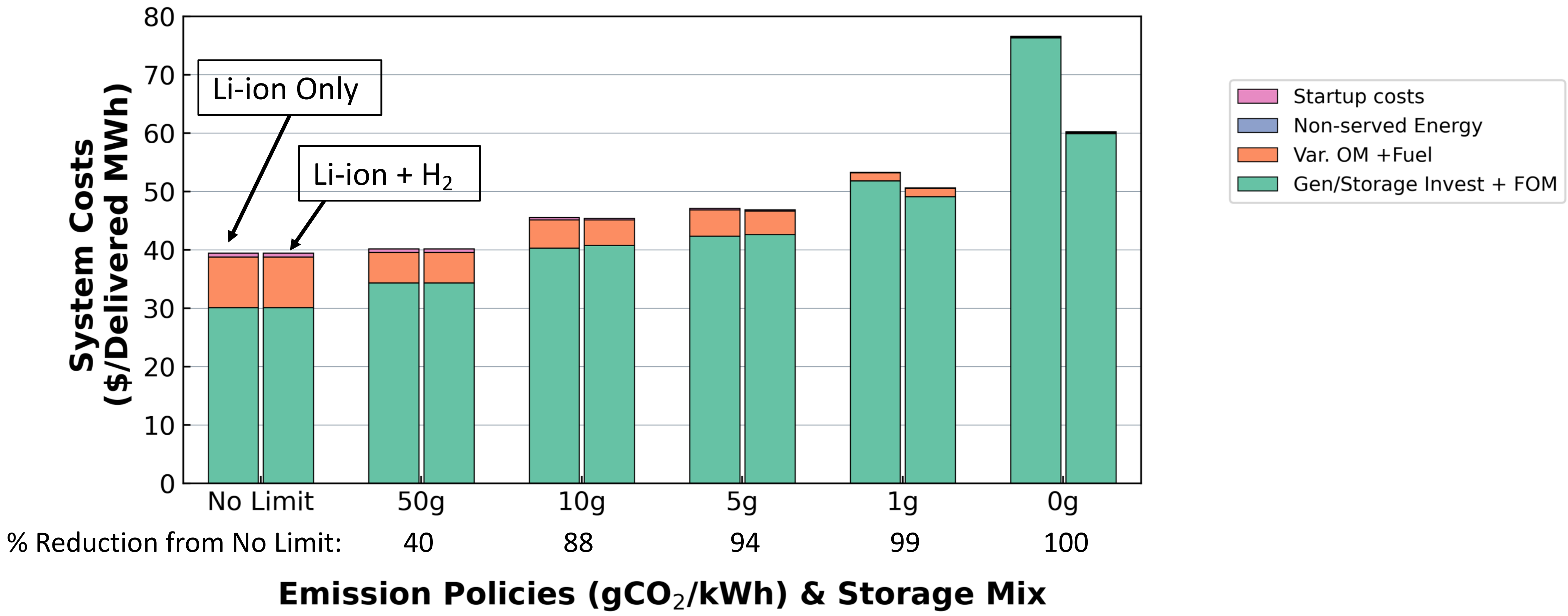
- Northeast: 193 gCO_2/kWh
  (**2018**: 249 gCO_2/kWh[1,2])
- Texas: 83 gCO_2/kWh
  (**2018**: 481 gCO_2/kWh[2])

Storage energy capacity by region, by scenario

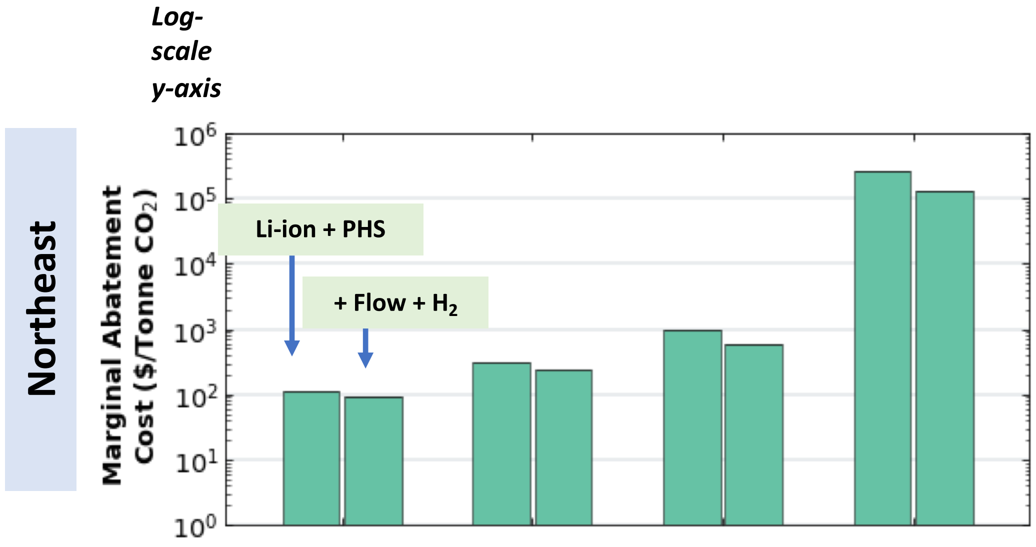


Main assumptions: Load per Reference scenario with moderate technology improvement from NREL electrification study. Allowed storage: Li-ion ($244/kW, $125/kWh, 85% RTE), pumped hydro (Northeast only with 12-hour duration, $1,966/kW with 80% RTE), OCGT and CCGT fueled by natural gas. Transmission constraints in the Northeast.
Sources: 1. 2018 ISO-New England Electric Generator Air Emissions report. 2. https://www.eia.gov/electricity/state/.

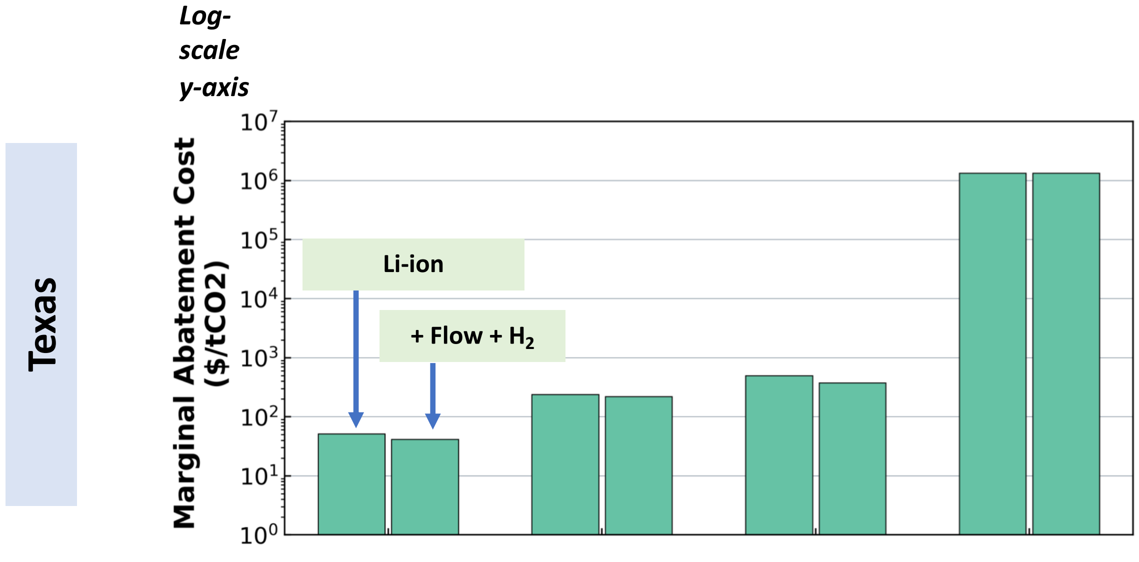
Substantial Decarbonization Increases Average Cost Modestly (Texas Example)



Marginal CO_2 abatement cost (= required carbon price) with substantial emissions reductions is reasonable, but rise sharply very near zero, even with inexpensive long-duration storage



Decarbonization reference	50 gCO_2/kWh	10 gCO_2/kWh	5 gCO_2/kWh	0 gCO_2/kWh
2018 Levels (249 gCO_2/kWh)	80%	96%	98%	100%
No limits scenario (193 gCO_2/kWh)	74%	95%	97%	100%

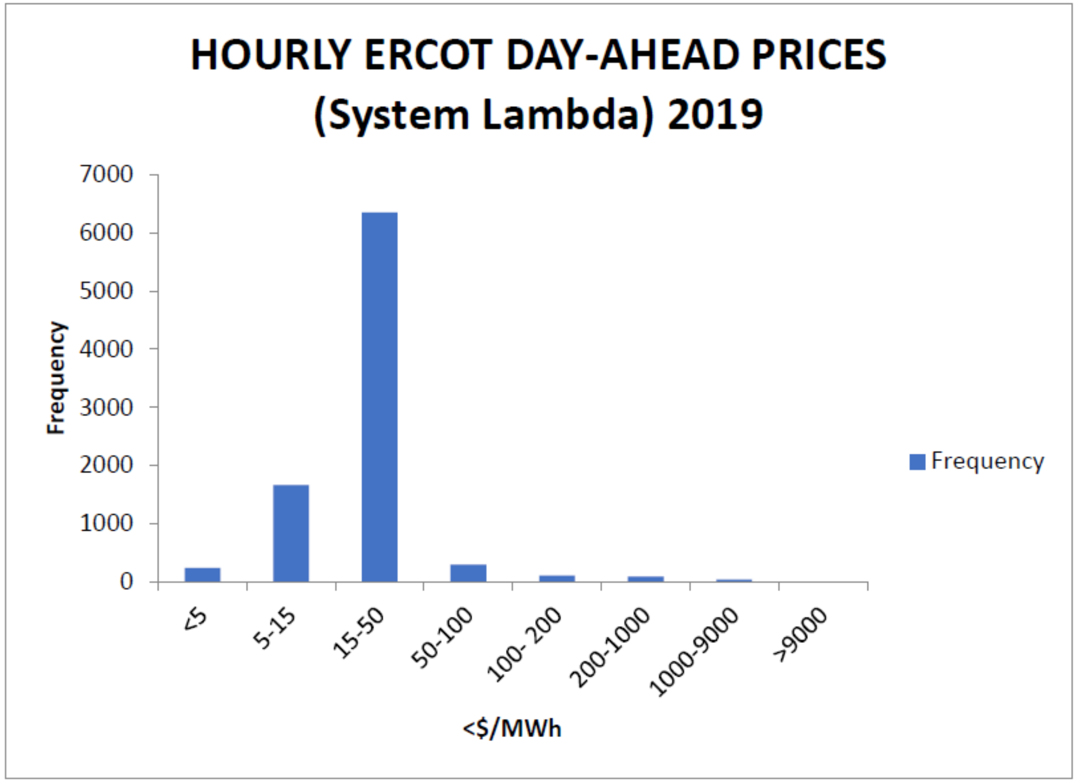


Decarbonization reference	50 gCO_2/kWh	10 gCO_2/kWh	5 gCO_2/kWh	0 gCO_2/kWh
2018 Levels (481 gCO_2/kWh)	90%	98%	99%	100%
No limits scenario (83 gCO_2/kWh)	40%	88%	94%	100%

Marginal carbon abatement costs at 50 gCO_2/kWh with only Li-ion (and PHS in the Northeast) is $115/tonne CO_2 in the Northeast and $52/tonne CO_2 in Texas.

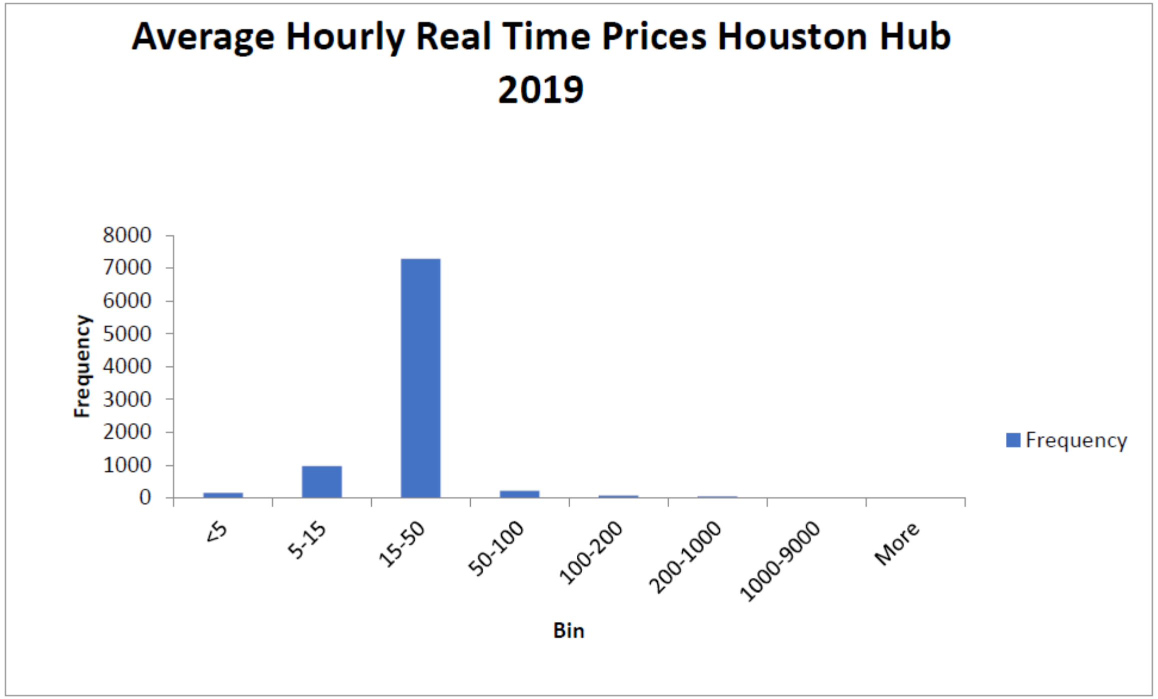
Price Variability Today: Hourly Day-Ahead Prices in ERCOT in 2019

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%



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

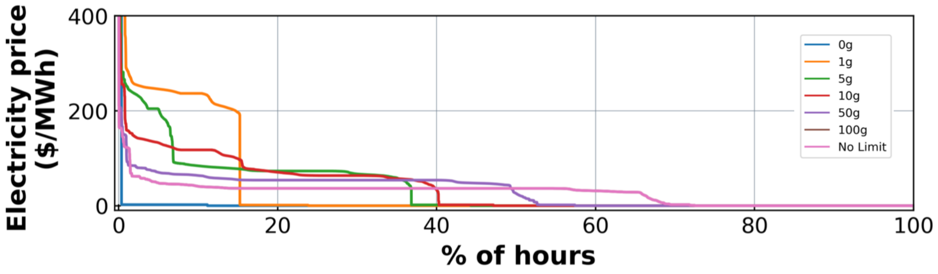
Bin	*Frequency*	
<5	150	1.71%
5-15	970	11.07%
15-50	7279	83.09%
50-100	224	2.56%
100-200	76	0.87%
200-1000	49	0.46%
1000-9000	11	0.13%
More	0	

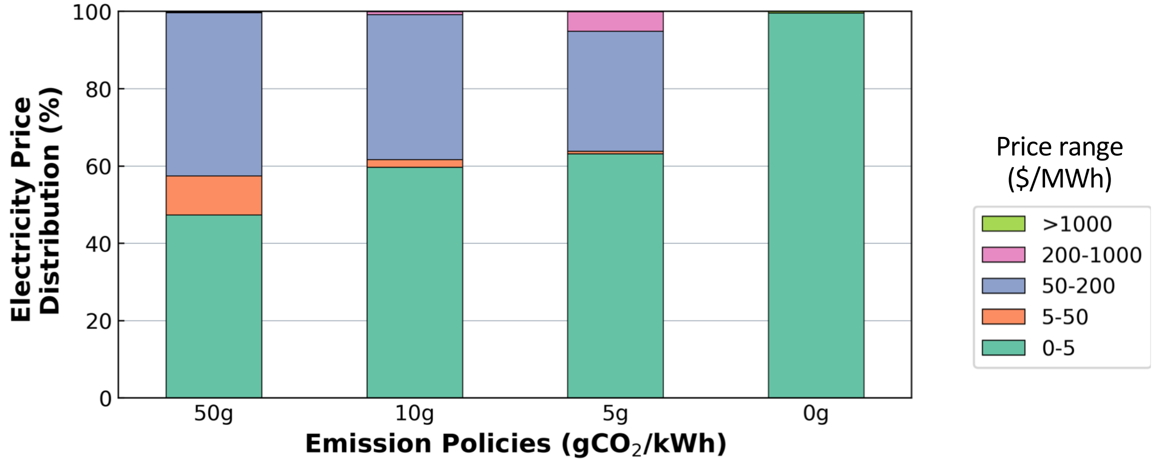


As the share of renewables increases, wholesale electricity prices will be very low for many hours, but sometimes very high – despite storage

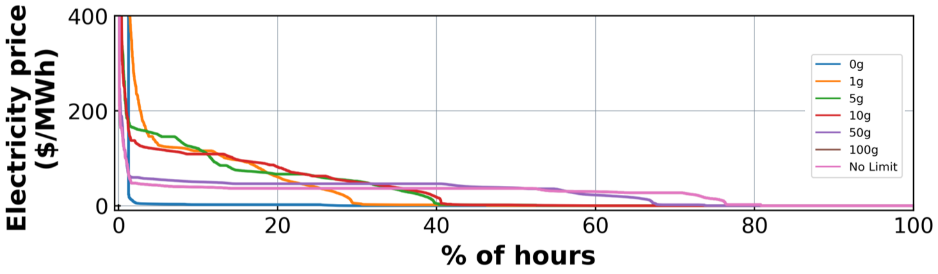
Distribution of wholesale electricity prices for various emissions and technology scenarios (Texas)

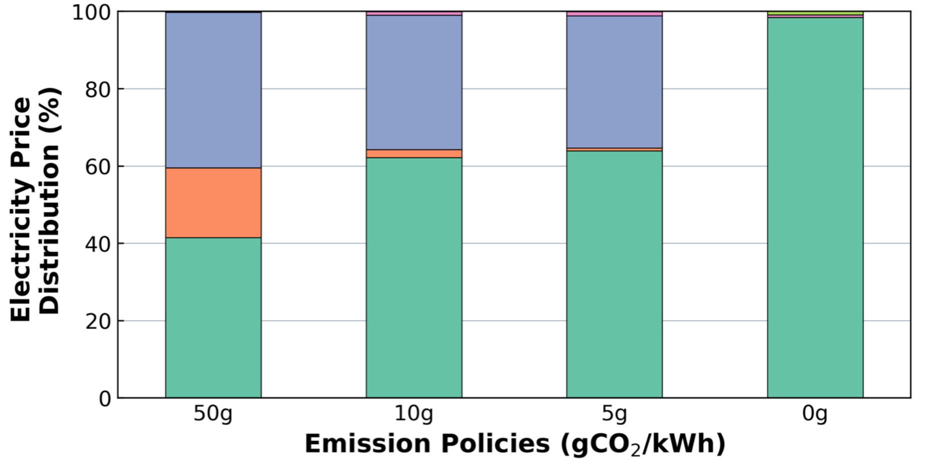
Li-ion





+ Flow + H_2



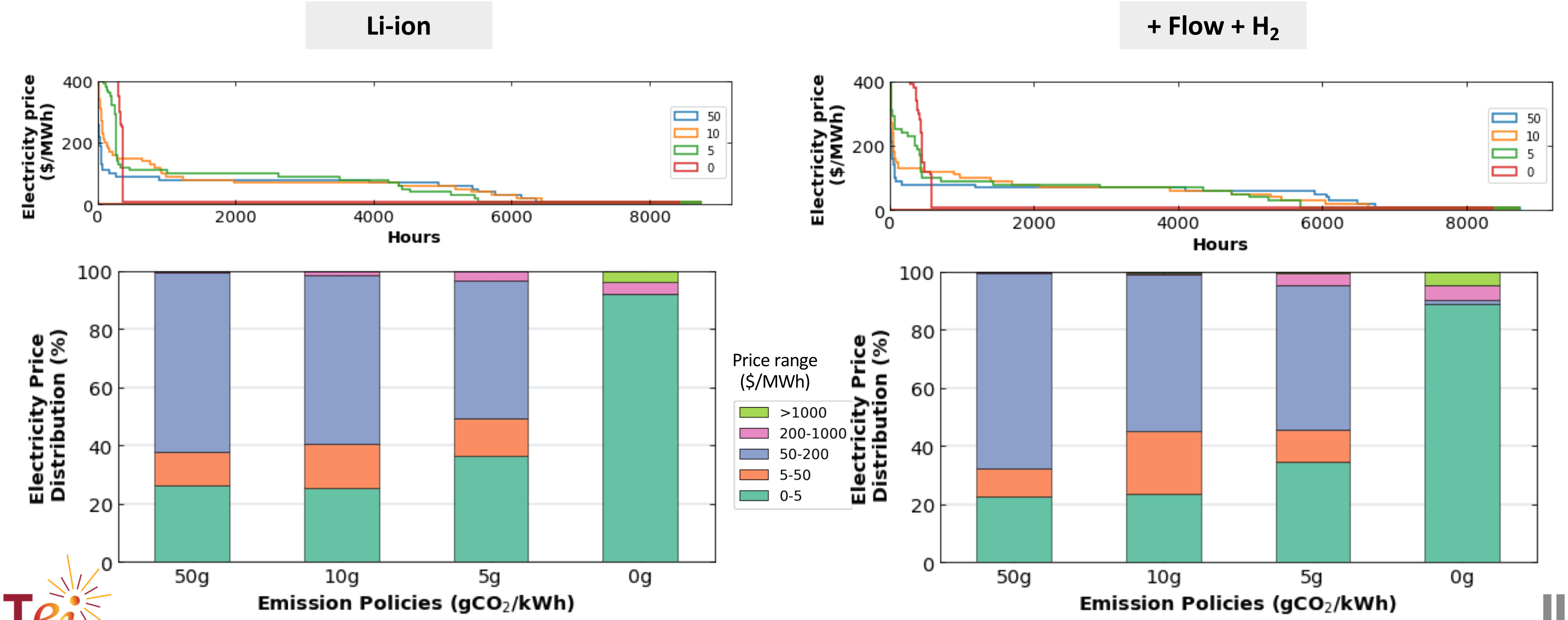


MITei

MIT

As the share of renewables increases, wholesale electricity prices will be very low for many hours, but sometimes very high – despite storage

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



Some Implications of Efficient Variability

- MWh-based decarbonization policies (e.g., RPSs) distort wholesale prices and support flat retail rates
  - A carbon tax does not have these problems
  - My son in Hawaii pays $0.30/kWh to charge his EV when the utility is curtailing solar
  - Retail prices that reflect efficient wholesale prices will encourage innovation, efficient electrification
- A pure energy-only market design + dynamic retail rates would solve this but seems unlikely
  - Investors will protest against making no money except in a few random hours
  - ISOs, regulators intervene to limit volatility now; this + missing money will surely get worse
- Inevitable market interventions need to be disciplined – IRP updated v. CA storage mandates
  - Fixed capacity subsidies should be recovered through (equitable) fixed charges at retail
  - Need to move retail rate-making closer to mobile phone pricing – subscription plus marginal rates
  - Marginal retail rates should be T&D-adjusted wholesale prices; low-price periods will drive electrification
- If we don't get the basic policy architecture right now, electrification will only become harder

I look Forward to the Discussion!