Keeping Our Eyes on the Prize

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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 much 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

- 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

**48 isolated states**

**11 isolated inter-state zones**

**1 interconnected system**

**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
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 CO₂ 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.

**System peak and annual load**
- Northeast: 90 GW, 435 TWh
- Texas: 151 GW, 715 TWh

**CO₂ emissions for no emission limits**
- Northeast: 193 gCO₂/kWh
  - (2018: 249 gCO₂/kWh)
- Texas: 83 gCO₂/kWh
  - (2018: 481 gCO₂/kWh)

**Storage energy capacity by region, by scenario**

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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 CGGT fueled by natural gas. Transmission constraints in the Northeast.

Substantial Decarbonization Increases Average Cost Modestly (Texas Example)
Marginal CO₂ abatement cost (= required carbon price) with substantial emissions reductions is reasonable, but rise sharply very near zero, even with inexpensive long-duration storage.
Price Variability Today: Hourly Day-Ahead Prices in ERCOT in 2019

### Hourly ERCOT Day-Ahead Prices (System Lambda) 2019

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<th>Bin</th>
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Another Look: Average Hourly Real-Time Prices at the ERCOT Houston Hub, 2019

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<td>More</td>
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Average Hourly Real Time Prices Houston Hub 2019
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)
As the share of renewables increases, wholesale electricity prices will be very low for many hours, but sometimes very high – despite storage.
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!