Regulatory and Policy Issues to Support Efficient Investment in and Utilization of Energy Storage:

INSIGHTS FROM MIT’S FUTURE OF ENERGY STORAGE STUDY

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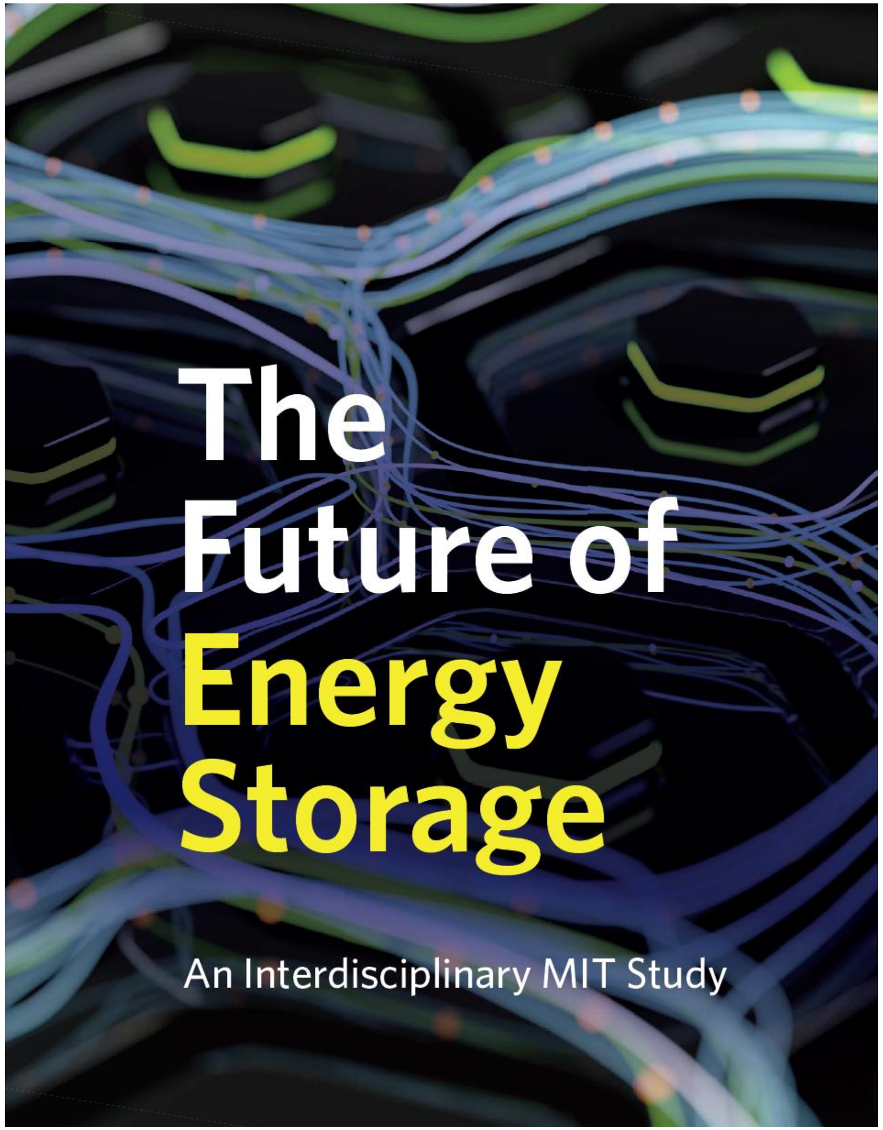
MITEI's *Future of Energy Storage* study explored the potential roles of various storage technologies in future decarbonized power systems. There are three main messages from the study:

1. Federal R&D policy should focus on long-duration storage technologies to support affordable, reliable future electricity systems.

2. Storage can make regionally-tailored, net-zero electricity systems affordable.

3. Market designs and regulatory policies need to be reformed to enable equitable & efficient decarbonization.

Today's webinar focuses on the third message



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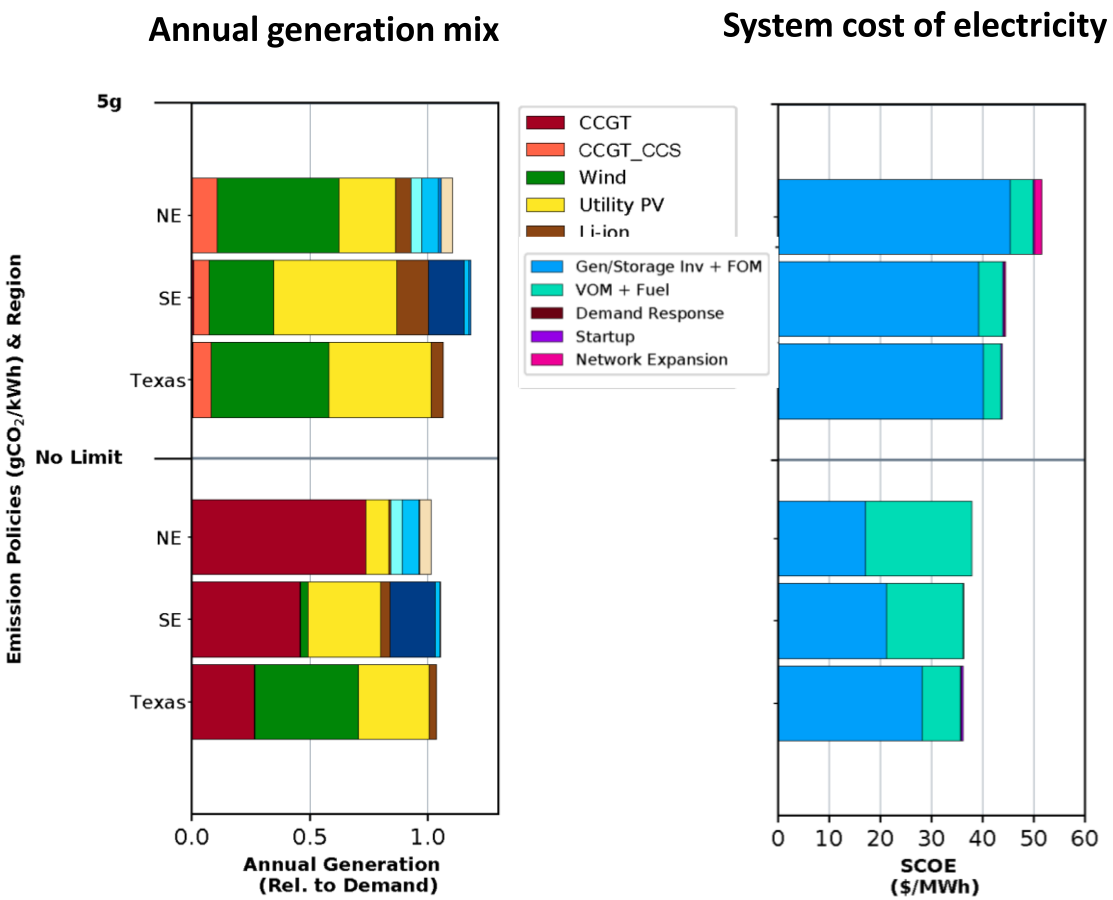
Optimization modeling for the study suggests near-complete decarbonization of major US regions by mid-century is feasible without sacrificing reliability or incurring significant cost penalty using VRE and Li-ion storage – *and a little gas*

2050 Scenarios



- Challenges of "getting to net-zero" vary across regions based on their resource endowments and demand patterns
    - Note high VRE penetration in Texas with no carbon limit: CO_2/kWh down 81%, all coal plants closed. NE up from nuke closing, SE down 57%
- Energy storage can substitute or complement all other elements of a power system (distribution, transmission, generation, demand management)
- Storage should earn revenues from providing a variety of products (energy arbitrage, ancillary services, transmission services, capacity/reliability)
- Transmission expansion can play an important role in reducing grid decarbonization costs and directly competes with storage
- Plausible demand shifting (hours) mainly substitutes for short-duration storage

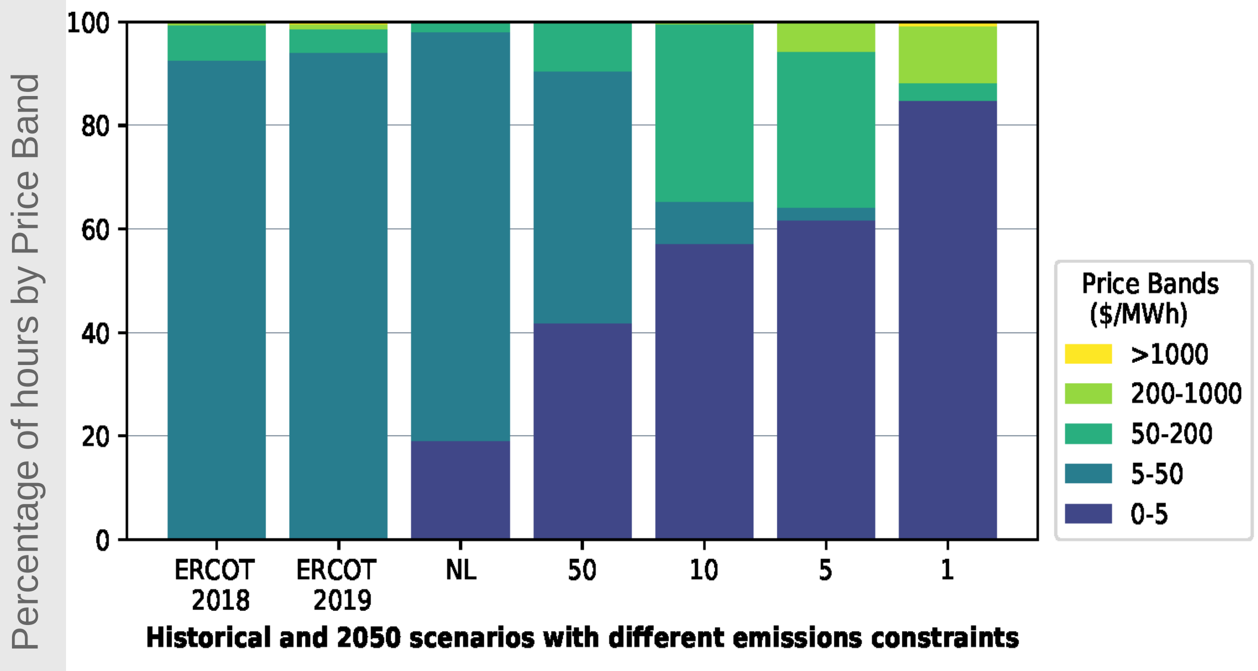
Two Important Features of Future Efficient Decarbonized Electric Power Systems that will Require Increasing Agencies' Analytic Capacity and Significant Reform:

Wholesale spot prices will be MUCH more volatile than spot prices in today's markets

- "Excess" VRE capacity substitutes for storage & transmission on the margin, and curtailment is common, which implies a zero marginal value of energy. More near-zeros as carbon constraint tightens.
- To cover higher investment costs despite more frequent low prices, need either more frequent high prices than today or (if price caps or other out-of-market actions), capacity payments of some kind, including long-term contract support via PPAs with credit-worthy counterparties.

Small-scale BTM generation & storage can have important grid-level effects – already a reality in some systems (e.g., CA, HI)

Frequency Distribution of Spot Prices

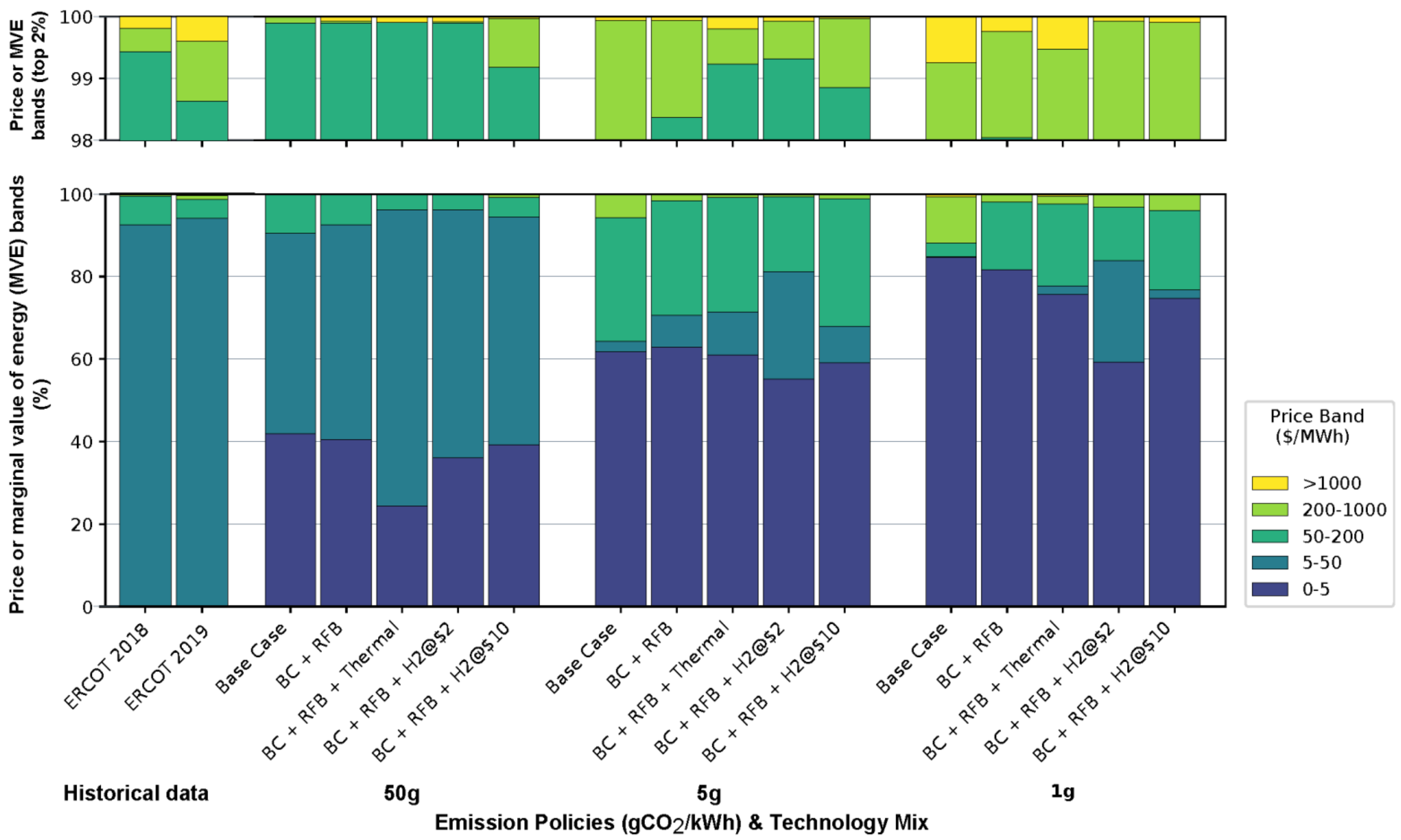


High Volatility Is Only Modestly Reduced by the Availability of Long-Duration Storage

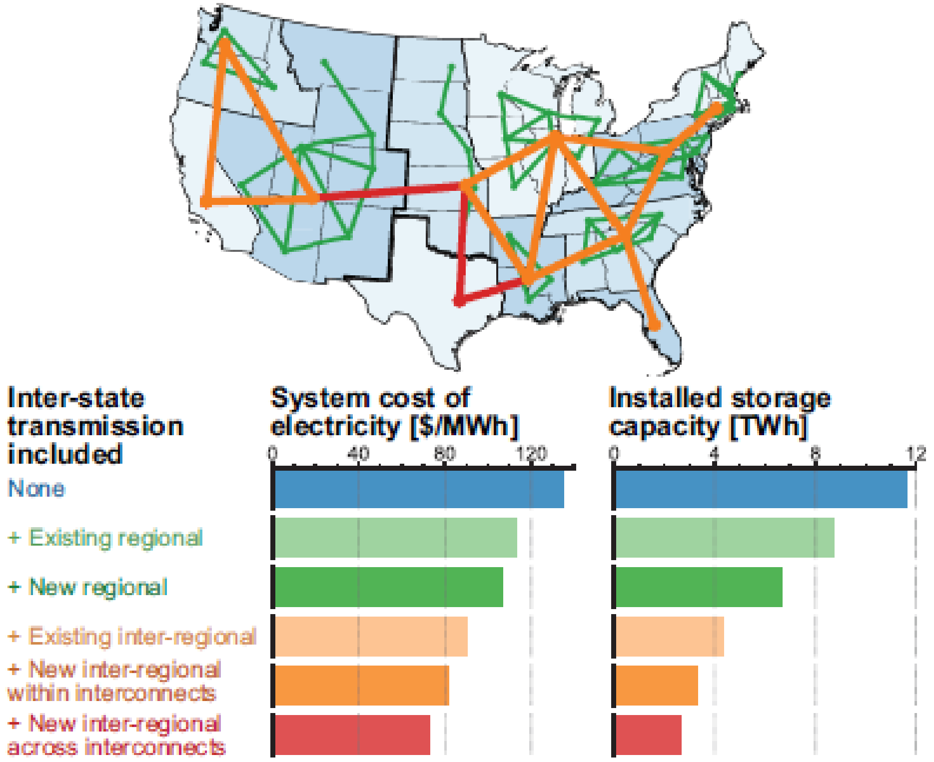
More results for Texas, now including mid- and long-duration storage technologies (MLDES) and additional detail for top 2% of Spot Price Frequency Distribution

- Availability of MLDES technologies significantly reduces likelihood of highest spot prices (yellow) in highly decarbonized (1 gram) case

- Still significant increase relative to history in very low (purple) spot prices



Modeling cited in the study suggests that transmission system expansion can greatly reduce cost of decarbonization and lower the optimal deployment of storage. Reducing regulatory barriers to new transmission is a high priority for decarbonization



Scenarios show the impacts on SCOE and optimal storage deployment if the country is modeled as isolated states (blue bars), isolated zones without and with new regional transmission (green bars), and a fully interconnected system with different levels of inter-regional transmission (orange and red bars) (Brown and Botterud 2021). The transmission assumptions in the regional case study discussed above are most similar to the "new regional" transmission scenario shown here.

- Transmission expansion can play an important role in reducing grid decarbonization costs and directly competes with storage
- Unlike natural gas transmission pipelines, which are primarily regulated at the federal level, states play a dominant role in the approval process for new electricity transmission
- Under the current regulatory structure it is both difficult and very time consuming to secure approvals for transmission lines that connect different regions of the country, particularly when those lines cross over states that do not receive significant benefits from the project
- Even lines within a region can be hard to build, as evidenced by the difficulties faced by Massachusetts in improving its access to generation in Quebec

Some Wholesale Market Design Challenges

Plausible givens: as now, wholesale prices will generally be capped below the value of lost load (VoLL) or system operators take out-of-market actions that affect wholesale market prices; capacity markets or related capacity remuneration mechanisms, including LT contract support, will be used to supplement energy market revenues (earned mainly in a few hours)

Reliability: Hard to measure contributions of VRE generators and storage to system reliability; measuring reliability contributions of storage facilities with time-varying energy in storage is *terra incognita*

- Unlike VRE generators, storage power is constant, but duration varies with technology and prior charge/discharge decisions
- Hard to design markets to yield "right" mix of technologies, expect continued major role for administratively-set requirements for specific technologies as in NY, CA – "hybrid systems," <u>aka Integrated Resource Planning</u>

VRE Generation: How to provide capacity revenue supplements for VRE generation if needed to support investment without distorting investment & operating decisions?

- Payment on a per-MWh basis distorts operating incentives: get generation when spot price is negative and/or uneconomic curtailment by ISO or utility to save money; <u>market participants must see spot price on the margin</u>
- Supplemental compensation for VRE generation should ideally be annual lump-sum – per-MW for capacity times a contracted capacity factor
- Any residual per-MWh subsidies (i.e., production tax credits) should fall toward to zero when there are curtailments & the spot energy price falls toward zero

Storage-Specific Wholesale Market Design Challenges

Energy Markets: For efficient operation, storage must pay spot energy prices (e.g. day-ahead or real time) for charging and be paid spot energy prices for discharging.

Capacity Markets: If supplemental capacity support payments are necessary, storage should be paid fixed annual technology specific- and system-dependent prices for capacity (MW) and duration (MWH/MW)

- Will need ELCC or ELCC-like measures of contributions to reliability, which will depend on stochastic demand and supply characteristics, charge/discharge profiles, interactions with system conditions, …
- Competitive procurement mechanisms should be used to determine market-clearing prices for supplemental capacity remuneration
- With competitive procurement, expected net energy market revenues will appropriately affect market-clearing prices for supplemental capacity remuneration
- Design of LT contracts is important to provide efficient charge and discharge incentives based on short-term market prices and operating conditions

Wires: When storage provides wires-related benefits (e.g., to defer transmission/distribution investment), it should be compensated for those benefits

- Treating storage as only "transmission" or as only "generation" is just wrong
- Storage should be permitted to participate in competitive procurements for transmission facilities or/or integrated into traditional transmission system planning in a way that reflects all expected revenue streams

Some (Harder!) Retail Rate Design Challenges

The efficiency costs of traditional, time-invariant rates for residential and small commercial customers will rise as wholesale prices become more variable; continuing to recover fixed costs via per-kWh charges will discourage efficient electrification

Integrating BTM PV and storage with wholesale markets (e.g. via aggregators) is important but will be challenging if retail rates do not reflect variations in wholesale market prices

Three important, competing principles for retail rate design:

- For efficient consumption/electrification/decarbonization incentives, consumers must see (loss-adjusted) wholesale spot energy prices *on the margin*, particularly when wholesale prices are low.
- But it will be politically infeasible to force consumers to pay spot prices for all their usage; the risks associated with potentially very high spot prices will be intolerable.
- Most of the costs in decarbonized systems will be fixed in the short run, and fixed costs should ideally be recovered by charges that are fixed in the short run, as in telecomm, but substantial uniform fixed charges are plainly inequitable and thus politically untenable.

The core challenge is to enable consumers to see *marginal energy* prices that vary with spot wholesale prices, while keeping variation in their *average* per-kwh cost at acceptable levels

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Some (Very Preliminary) Thoughts on Retail Rate Design

Easier to think about design for a monopoly LSE than requirements for competitive retailers, but retail competition might enable/encourage more movement from today's designs

Will need higher, *equitably differentiated* fixed charges to cover the system's higher fixed cost; these could be income-based, but more plausibly would be functions of consumers' past history and rate choice

Hedging: consumers purchase Q_0 kWh in advance at price P_0 as a hedge, then pay spot for any actual demand over Q_0

- Cost of hedges amounts to a customer-specific short-run fixed charge; gives strong incentives to reduce demand when wholesale price is unexpectedly high
- Consumption and spot wholesale prices vary systematically by time of day, day type, season, etc., and hedge prices and quantities would need to vary likewise – too complex?

Insurance: a simpler alternative, consumers buy insurance that lets them pay min of a specified ceiling price (P*) and spot price

- Cost of insurance, a short-run fixed charge depends (regulation or competition) on recent load profiles
- Pass-through of very low spot prices would encourage efficient electrification
- Would need automated load control to provide adequate response to high spot prices – incentives too weak?

Neither system is great; **we need much more research and outreach to policy markers in this area**.

Questions, Comments?