Net Zero Market Challenges

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The Electricity Industry is Undergoing Fundamental Changes

As many have articulated, the industry faces fundamental changes along three important dimensions (the "3Ds"):

1. DECARBONIZATION

To meet state, federal, and corporate clean-energy policy objectives, output from "emitting" resources (such as coal plants) is quickly replaced by renewable resources, with rapidly falling capital costs and close-to-zero variable costs. This is fundamentally changing (a) wholesale power prices and market design requirements; (b) grid operations; and (c) grid planning and investments.

2. DECENTRALIZATION

Declining costs of solar generation and batteries causes a shift away from large, central-station power plants to resources that are located on local electricity networks or "behind the meter" at homes and businesses—changing the role (but not decreasing the value) of the transmission grid.

3. DIGITALIZATION

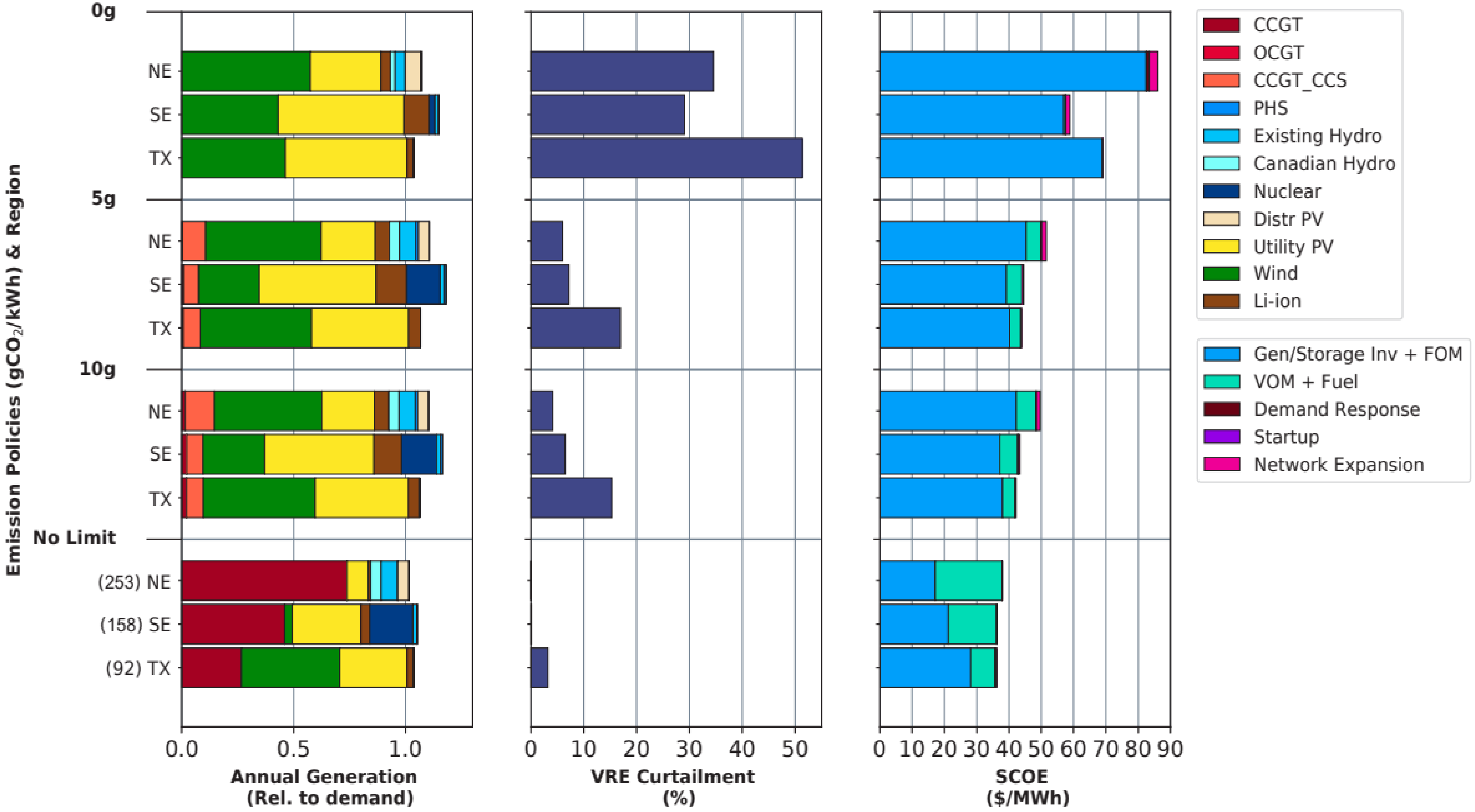
The revolution in information and communication technologies and platforms that will continue to change nearly everything in our economy, including energy services, grid operations, and grid planning.

Impact of Increasingly Cost-Effective Renewables, Storage, and Advanced Transmission Technologies

The declining costs and accelerating adoption of new energy technologies has profound implications on the grid of the future:

- **Declining costs of battery storage** (and exponentially-increasing deployment) will mean:
  - Grid reliability, resource adequacy, and resilience will increasingly shift from being provided by a centralized grid to rely more on distributed generation and storage resources
  - The role of the grid will increasingly shift from: (1) instantaneously delivering energy+capacity to (2) delivering sufficient energy on a daily basis from a geographically-diverse set of resources
- **Declining cost of solar** generation will mean increased utilization of the local T&D grid, but combined with need to diversify over geographic areas larger than typical weather systems
- **Declining cost of wind** generation will mean increased need for regional and interregional transmission to access (and diversify geographically) utility-scale wind plants in low-cost regions
- **Advanced transmission technologies** (dynamic line ratings, power flow and topology control) can help keep transmission to be cost-effective in light of declining renewables+storage costs
- New **reliability technologies** (long-duration storage, hydrogen, DER/DR) and market-based **reliability products** (forward clean energy markets) will be needed to decarbonize the grid

M.I.T.'s outlook for a decarbonized grid in 2050

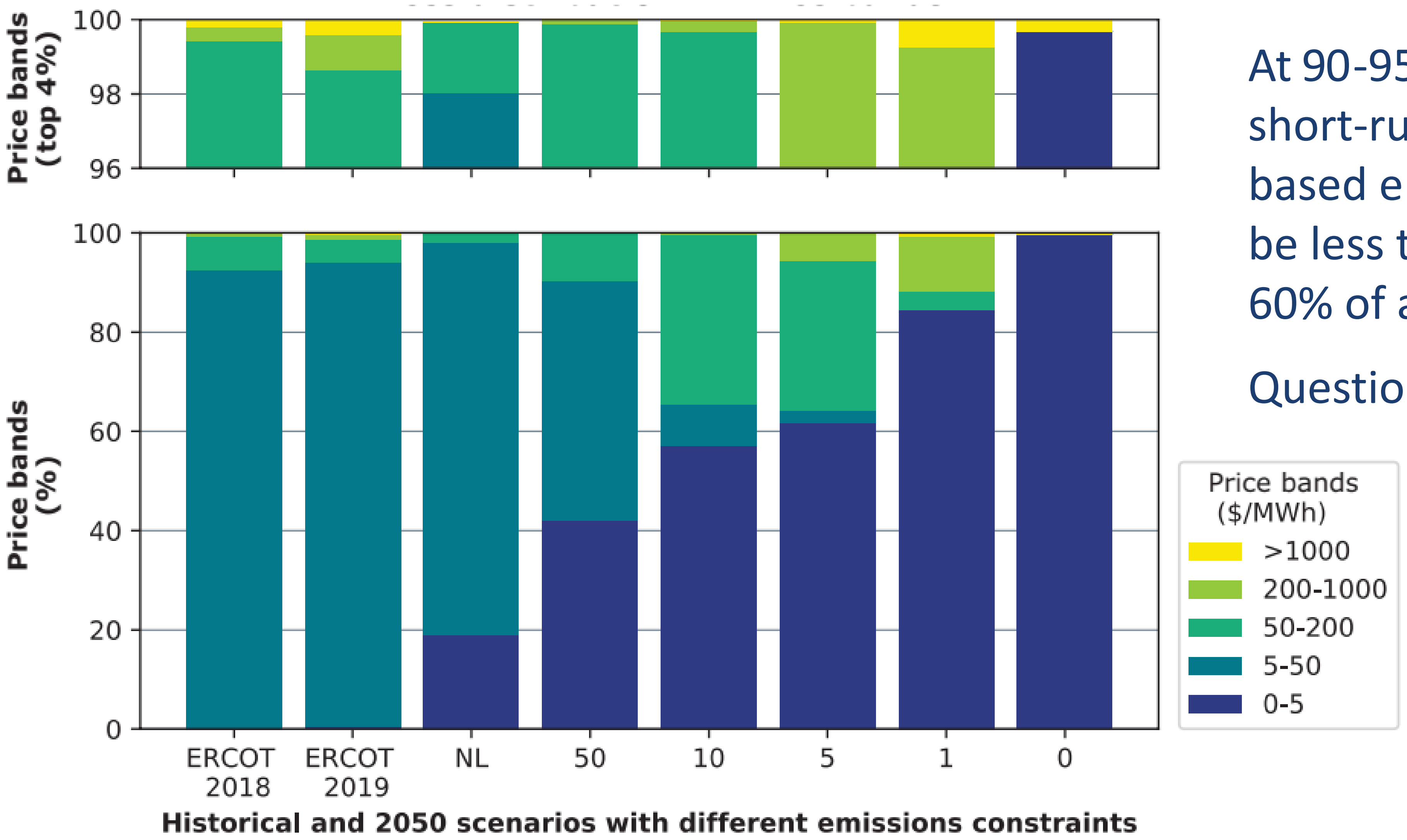


Alberta is often compared with Texas, but renewable resource quality and availability is closer to the Northeastern U.S.

Still, 90-95% decarbonization is feasible without substantially higher costs

Source: https://energy.mit.edu/wp-content/uploads/2022/05/The-Future-of-Energy-Storage.pdf

Outlook for wholesale energy market prices at different decarbonization levels (ERCOT 2050)



At 90-95% decarbonization, short-run marginal-cost-based energy prices would be less than $5/MWh during 60% of all hours.

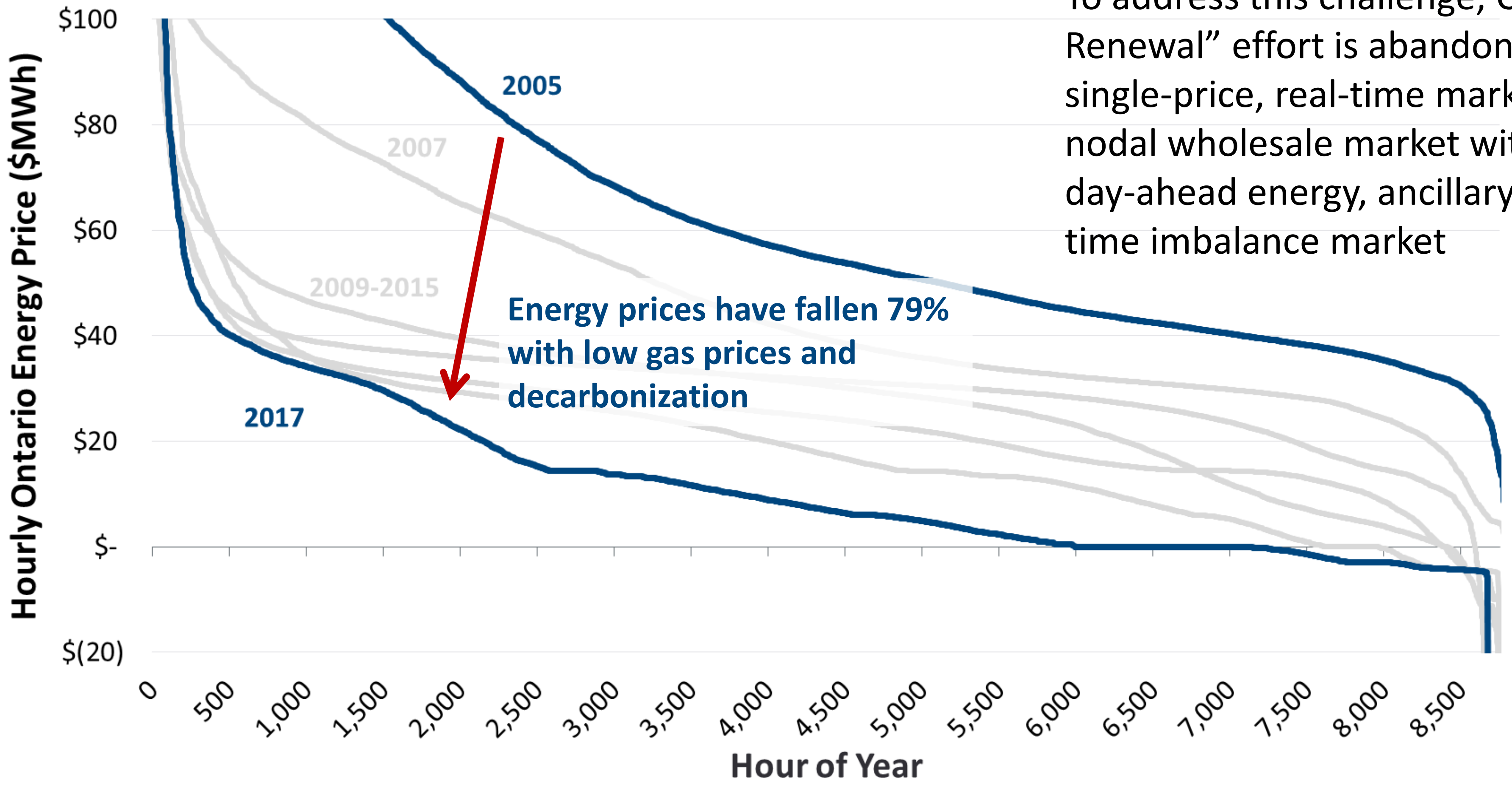
Question: Will energy market prices actually be based on short-run marginal costs?

Maybe not in Alberta?

Source: https://energy.mit.edu/wp-content/uploads/2022/05/The-Future-of-Energy-Storage.pdf

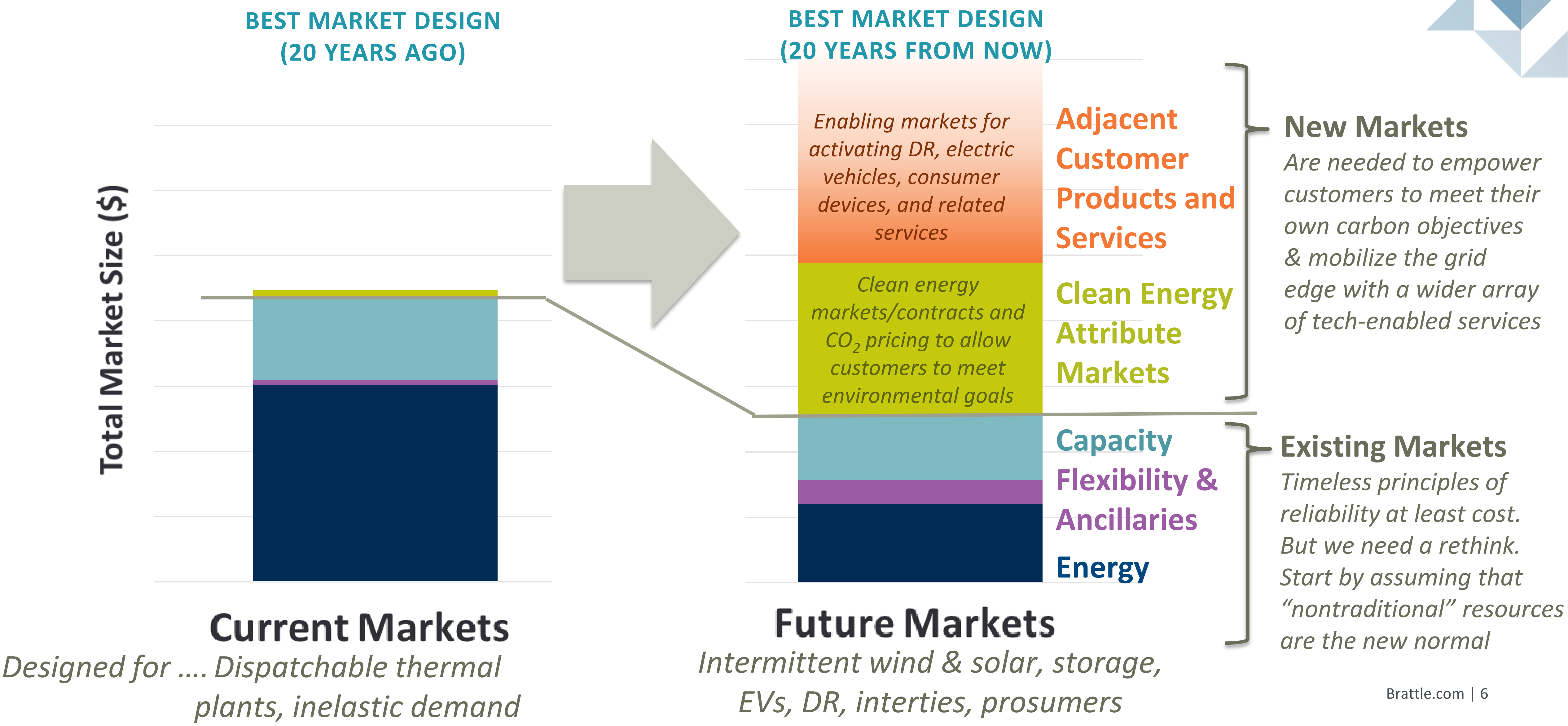
Ontario Example: by 2017 energy markets had already "bottomed out" with clean, low-marginal-cost generation

Very low or negative prices with a 90% clean and low-marginal-cost fleet; only 1/3 of all hours priced above $15/MWh!



To address this challenge, Ontario's "Market Renewal" effort is abandoning the existing single-price, real-time market to implement nodal wholesale market with co-optimized day-ahead energy, ancillary services, and real-time imbalance market

What might "future markets" have to look like?



More detail on how revenue sources will shift from energy to other “products”

Markets designed for a clean, low-marginal-cost resource mix will need to focus more on flexibility and clean-energy products

Products	Value	Market Implications
Average Energy	↓	▪ Lower energy prices during low-load and on average in most hours will most strongly affect baseload and dominant variable resources
Scarcity Pricing	↑	▪ But higher peak prices, driven by volatility, scarcity pricing, and demand response/storage; rewards fast-response resources
Flexibility & Reserves	↑	▪ Need for greater quantities and new types of flexibility products ▪ Higher ramping needs reward flexibility
Capacity	↓↑	▪ Value may go up (if redefined) or down (if left unchanged) ▪ Down if additional clean energy contributes to excess supply for a period, or if new capacity sellers are attracted by other value streams ▪ Up if new resources are needed for capacity, but only a small portion of their capital costs can be recovered from other markets
Clean Attributes	↑	▪ Some form of CO_2 pricing and/or clean energy payments introduced to meet policy and/or customer demand ▪ Value must be large enough to attract new clean resources
Adjacent Customer & Distribution Markets	↑	▪ Technology and consumer-driver demand for adjacent products and services (smart home, electric vehicles) ▪ Participation may overlap with wholesale, clean, and retail/distribution markets
Interties & Geographic Diversification	↑	▪ Increasing value of larger, more diverse regional markets ▪ Greater value of trade/diversification across market seams through inter-regional grids

Our simulations of deeply decarbonized power systems in North America generally show:

- market prices for traditional capacity and ancillary service products decline substantially
- market prices for new AS, clean-energy, and emission reduction products increase significantly

Competitive markets are pursuing a wide range of interlocking market reforms to support clean energy transition

Capacity Markets

- Enhanced reliability modeling
- Seasonal capacity markets
- Accurate capacity resource accreditation
- Robust obligation and penalties framework
- Strategic energy reserves (e.g. to manage wind drought or winter fuel supply risks)

Energy

- Granular dispatch, pricing, and settlements (nodal, 5-min)
- Storage optimization
- Enhanced scarcity pricing
- Full integration of DR, DER, EV and diverse resource aggregations into price formation

Ancillary Services

- Real-time co-optimization
- Large-scale ramping reserves (10/15-minute and 2/3-hour), aligned with net load uncertainty and procured via value-based operating reserve demand curve
- New services to address emerging system needs such as inertia and fast frequency response

Green Markets

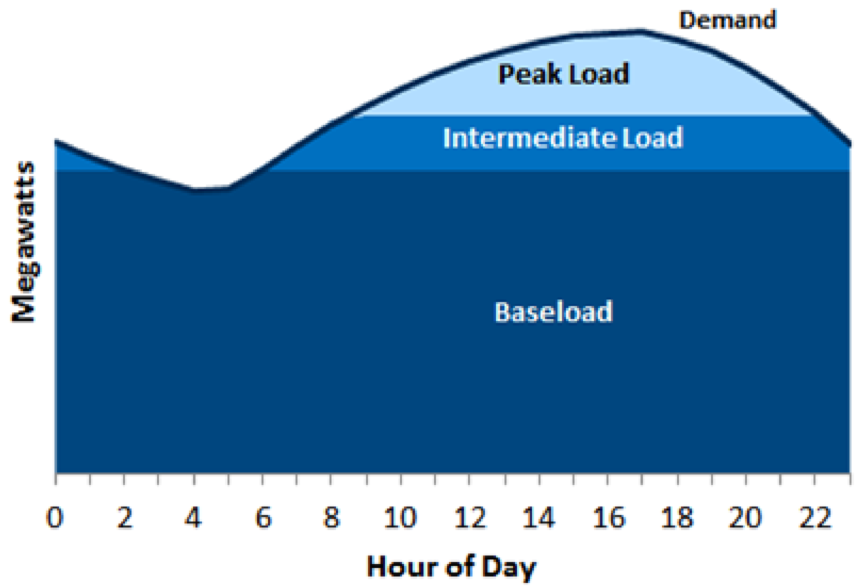
- Granular GHG Scope 2 emission accounting data for government and corporate goals
- Next generation of green attribute products (GHG abatement, clean capacity, 24x7 clean energy)
- RTO-operated forward clean attribute markets

Future markets need to more fully integrate a wider range of emerging technologies to unlock full potential

Changing supply mix = Need for more flexibility

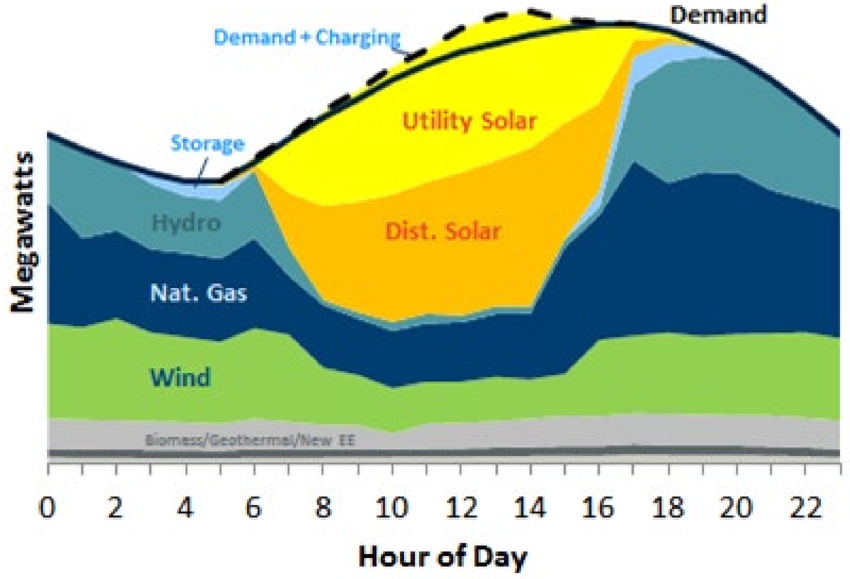
The resulting cleaner, more diverse supply mix **requires significantly more flexibility**, an attribute storage resources are especially able to supply

Electricity Demand and Traditional Supply Mix



Source: The Brattle Group.

Electricity Demand and Supply Mix with High (and Uncertain) Renewable Generation



Source: The Brattle Group.

Examples of how ancillary-services markets are evolving to meet increasing flexibility needs

Higher Quantities

- More ancillary services are required to manage variability and uncertainty
- Enhanced efficiency if procured quantity changes with price

New Products

- Nature of operational reliability challenges depends on fleet makeup
- Some grid services previously provided "for free" may become scarce if not defined and procured

Unbundled Products

- Traditional product definitions often "bundle" multiple services together
- Unbundling enables more resources (e.g. wind may supply regulation down, but not regulation up)

- **Ontario, New England:** Additional quantities of 30-minute reserves
- **ERCOT:** Higher regulation requirements to balance intermittency

- **MISO, CAISO:** Ramping products
- **Australia:** Considering inertia, fast frequency response, and voltage control
- **Ireland:** Inertial response, longer ramping products, and voltage response

- **Many US Markets:** Regulation and ramp defined as distinct up/down products
- **ERCOT:** Proposed unbundling contingency reserves based on response timeframe

Well-designed wholesale market products need to enable all types of resources to yield lower-costs procurement

Compared to traditional planning and long-term contracting, technology-neutral (capability-based) markets are more competitive

Technology Types

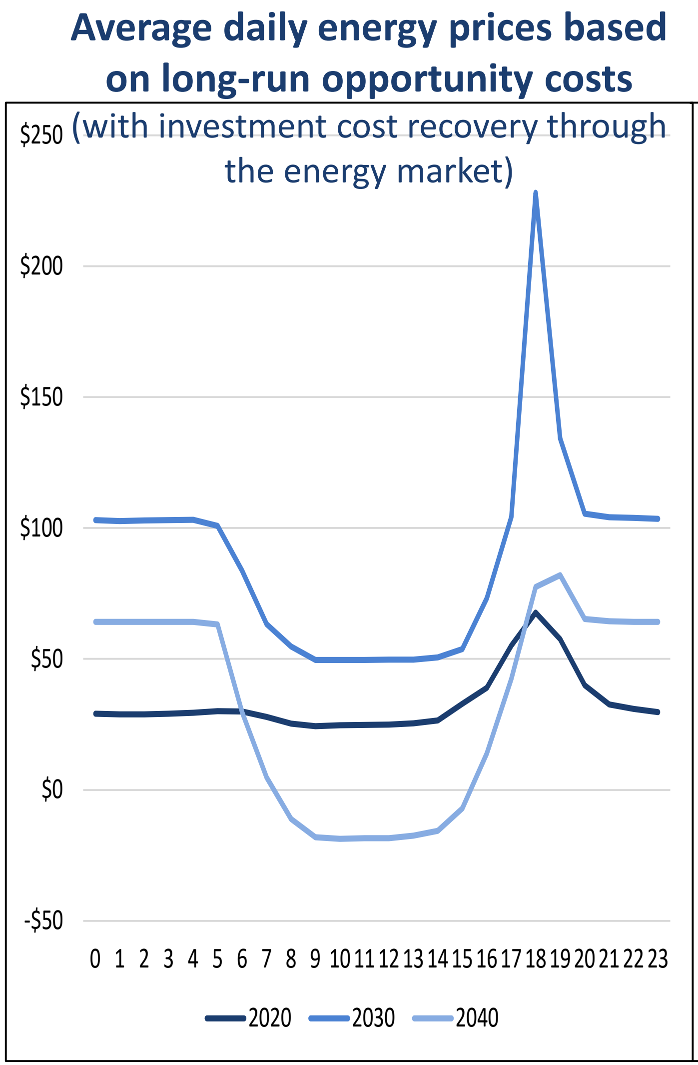
System Needs	Coal	CC	CT	Nuclear	RoR Hydro	Hydro w/ Storage	Wind	Solar	Battery Storage	DR	EE	Imports
Day-Ahead Energy	✓	✓	O	✓	✓	✓	✓	✓	O	O	O	✓
Real-Time Energy (5 Min)	✓	✓	O	O	✓	✓	✓	✓	O	O	O	O
Regulation	✓	✓	O	X	✓	✓	O	O	✓	O	X	O
Spinning Reserves	✓	✓	✓	X	O	✓	X	X	✓	O	X	O
Non-Spinning Reserves	X	✓	✓	X	X	✓	X	X	✓	O	X	O
Load following / Flexibility	O	✓	✓	O	O	✓	O	O	✓	O	X	O
Capacity	✓	✓	✓	✓	O	✓	O	O	O	✓	✓	✓
Clean Attributes (RECs)	X	O	O	✓	✓	✓	✓	✓	O	O	✓	✓
Reactive / Voltage Support	✓	✓	✓	✓	✓	✓	O	O	✓	X	X	O
Black Start	O	✓	✓	X	✓	✓	X	X	O	X	X	O

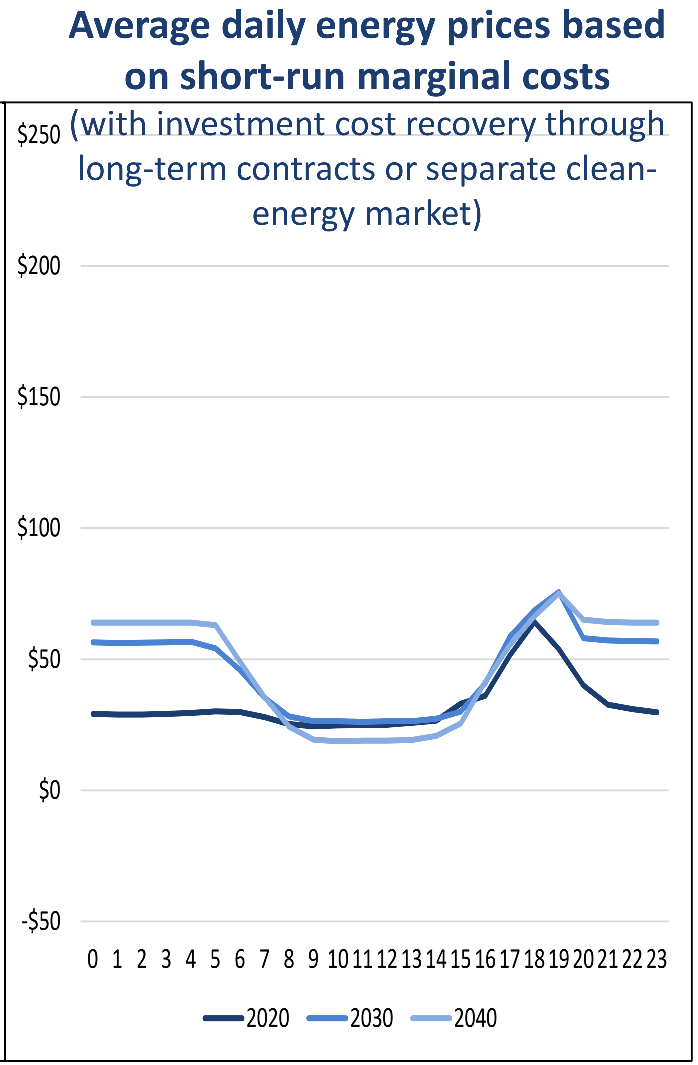
Technical Capability for Service

- ✓ Well Suited
- O Somewhat Capable
- X Not / Poorly Suited

Even non-traditional & carbon-free supply can provide essential grid services (<u>if</u> enabled to compete)

However: future energy prices greatly depend on market design





Market structure and market design will have significant impacts on the level of energy market prices

- Energy prices based on long-run opportunity costs that are sufficient to recover investments will tend to be much higher than energy price based on short-run marginal costs (with separate investment cost recovery)
- High scarcity prices and low constrained-off prices would make such energy prices much more volatile and less predictable
- Market designs likely necessary to address the "missing money"

What to do?

Some recommendations for addressing the market challenges of deep decarbonization efforts (from the recent MIT study):

- Responding to the challenges posed by a deeply decarbonized grid will require **market design** changes, especially in resource adequacy and ancillary service products.
- Regulators and ISOs should either (1) redesign existing market-based **resource-adequacy** mechanisms or (2) replace those resource-adequacy mechanisms with an increased reliance on **integrated resource planning**.
- Regulators and ISOs should **enable efficient participation**—in wholesale energy and ancillary service markets, as well as in capacity markets—of all grid-based and distributed resources (including from facilities located on behind customer meters). These rule reforms should accommodate the participation of aggregators in wholesale markets.
- **Price caps** need to be increased to reflect the value of lost load (VOLL).
- Regulators should (1) replace CP demand charges with rates that are less easily gamed; and (2) support independent research aimed at devising **efficient and equitable rate designs** for highly decarbonized (high renewables+storage) systems.

Source: Chapter 8 of https://energy.mit.edu/wp-content/uploads/2022/05/The-Future-of-Energy-Storage.pdf

About the Speaker

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Johannes (Hannes) Pfeifenberger, a Principal at The Brattle Group, is an economist with a background in electrical engineering and over twenty-five years of experience in wholesale power market design, renewable energy, electricity storage, and transmission. He also is a Visiting Scholar at MIT's Center for Energy and Environmental Policy Research (CEEPR), a Senior Fellow at Boston University's Institute of Sustainable Energy (BU-ISE), a IEEE Senior Member, and currently serves as an advisor to research initiatives by the U.S. Department of Energy, the National Labs, and the Energy Systems Integration Group (ESIG).

Hannes specializes in wholesale power markets and transmission. His recent experience includes the analysis of hydro and battery storage economics, transmission benefits, reviews of wholesale power market designs, testimony in contract disputes, cost allocation, and rate design. He has performed market assessments, market design reviews, asset valuations, and cost-benefit studies for investor-owned utilities, independent system operators, transmission companies, regulatory agencies, public power companies, and generators across North America. He has worked on wholesale power market matters in Alberta, Ontario, SPP, MISO, PJM, New York, New England, ERCOT, CAISO, and WECC.

He received an M.A. in Economics and Finance from Brandeis University's International Business School and an M.S. and B.S. ("Diplom Ingenieur") in Power Engineering and Energy Economics from the University of Technology in Vienna, Austria.

Understanding load flexibility: market potential and value

First, consider innovative new applications of DR: Load flexibility will do more than just shave the peak

1 Extend DR value streams →

	Generation capacity avoidance	Reduced peak energy costs	System peak related T&D deferral	Targeted T&D capacity deferral	Load shifting/ building	Ancillary services
Direct load control	X	X	X	X		
Interruptible tariff	X	X	X			
Demand bidding	X	X	X		X	
Time-of-use (TOU) rates	X	X	X			
Dynamic pricing	X	X	X			
Behavioral DR	X	X	X			
EV managed charging	X	X	X	X	X	X
Smart water heating	X	X	X		X	X
Timed water heating	X	X	X		X	
Smart thermostat	X	X	X	X		
Ice-based thermal storage	X	X	X	X	X	
C&I Auto-DR	X	X	X	X	X	X

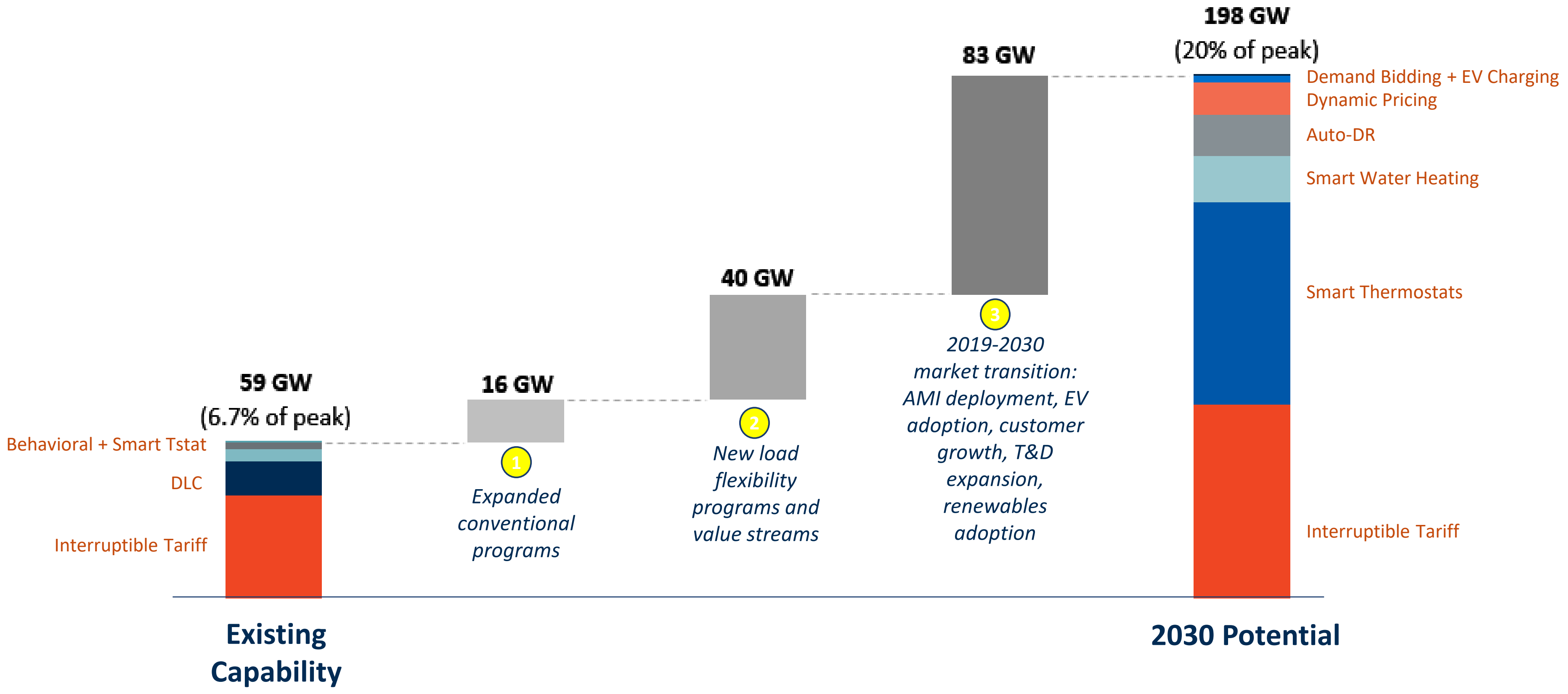
2 **Broaden definition of DR** ↓

Second, broaden the definition of DR: Load flexibility has the potential to provide higher value at a lower cost

Source: [Brattle Study: Cost-Effective Load Flexibility Can Reduce Costs by More Than $15 Billion Annually]

2030 load flexibility potential (DR 2.0) is 20% of peak load, triple today's 6.7% level of demand response (DR 1.0)

U.S. Cost-Effective Load Flexibility Potential

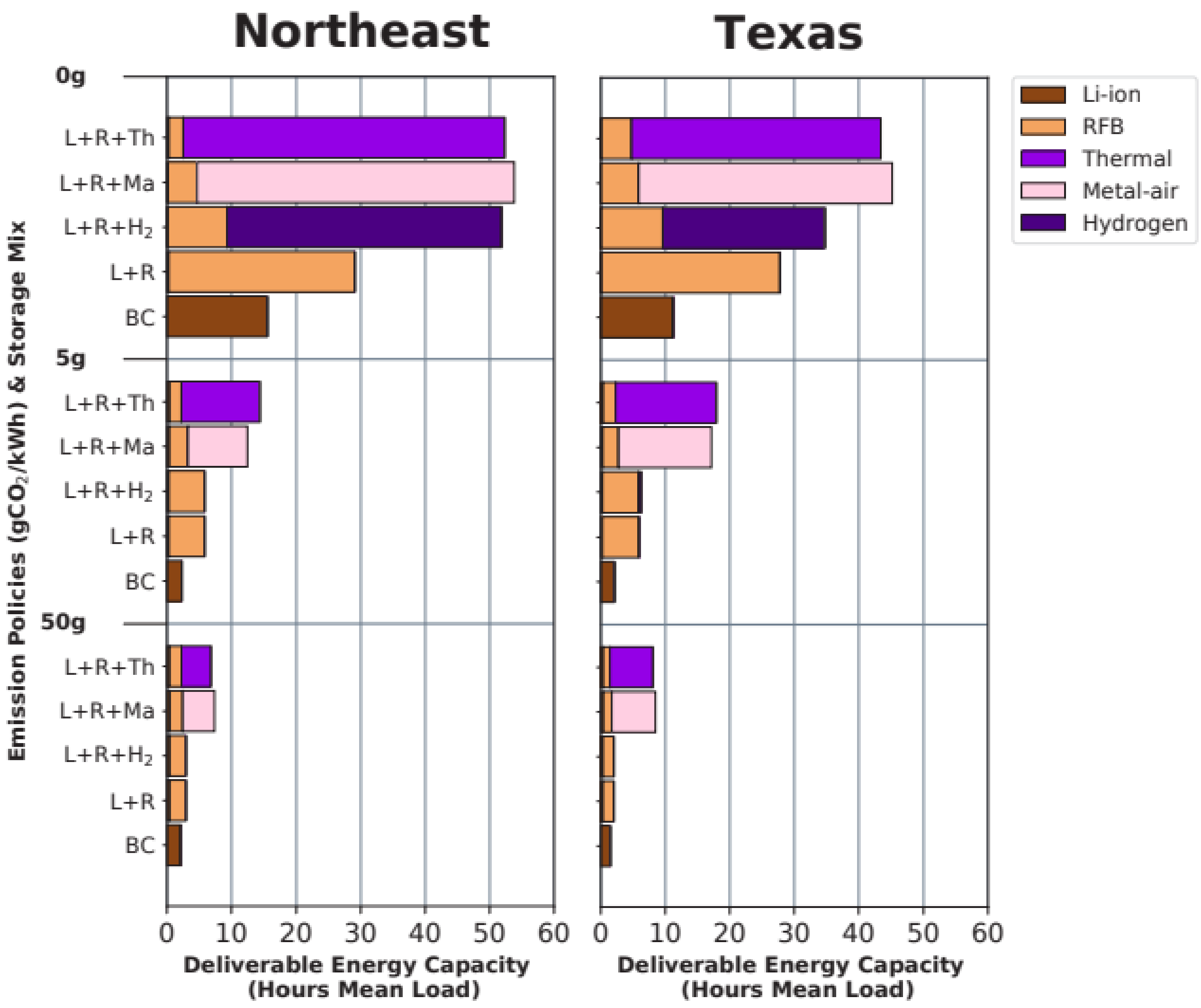


Alberta has significant opportunities to enable demand response and load flexibility as a key component of a cost effective future resource mix

Notes: Existing DR capability does not account for impacts of retail pricing programs, as fewer than 1% of customers are currently enrolled in dynamic pricing rates and the impacts of long-standing TOU rates are already embedded in utility load forecasts. See appendix for summary of key modeling assumptions.

Source: Brattle Study: Cost-Effective Load Flexibility Can Reduce Costs by More Than $15 Billion Annually

Side bar: the role of hydrogen and long-duration storage technologies vs. Lithium-Ion batteries



2050 simulations with different storage technology show:

- Give today's uncertainties about technology costs, any of the storage technologies may dominate all others
  - New storage technologies appear to outcompete Li-Ion, but projected cost savings are vary modest for anything but full decarbonization (absolute zero)
- Hydrogen is challenged:
  - Uneconomic unless full decarbonization?
  - Even in an absolute-zero carbon grid, significant competition from other long-duration technologies (redox-flow, metal-air, thermal)

Source: https://energy.mit.edu/wp-content/uploads/2022/05/The-Future-of-Energy-Storage.pdf

Brattle Group Practices and Industries

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- Competition & Market Manipulation
- Distributed Energy Resources
- Electric Transmission
- Electricity Market Modeling & Resource Planning
- Electrification & Growth Opportunities
- Energy Litigation
- Energy Storage
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- Finance and Ratemaking
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- Market Design
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