Energy Markets and Water Power: Square Peg in a Round Hole?

PREPARED FOR

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PRESENTED BY

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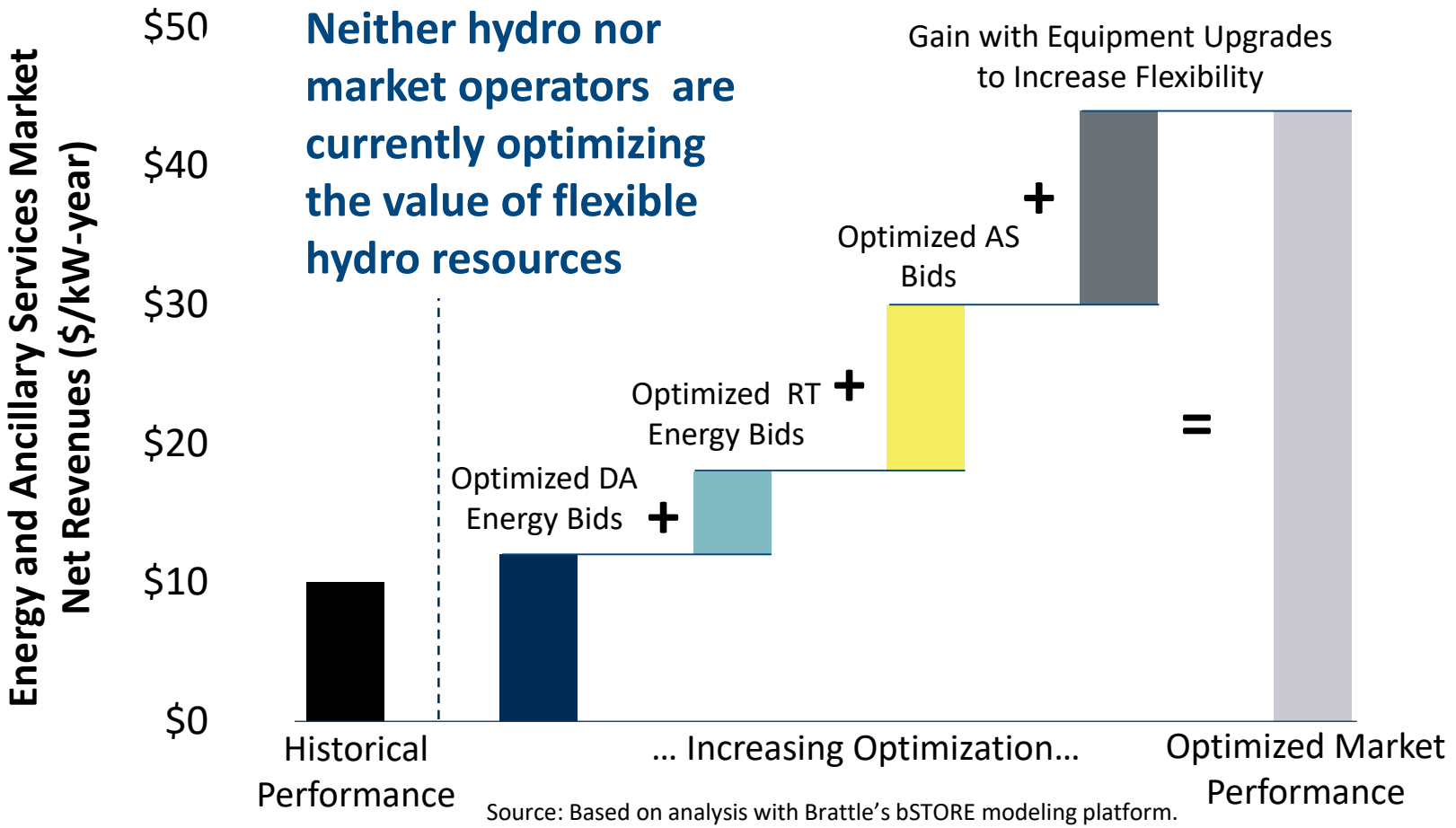
THE Brattle GROUP

U.S. Case Study: Flexible-Hydro is Currently Underutilized and Undervalued

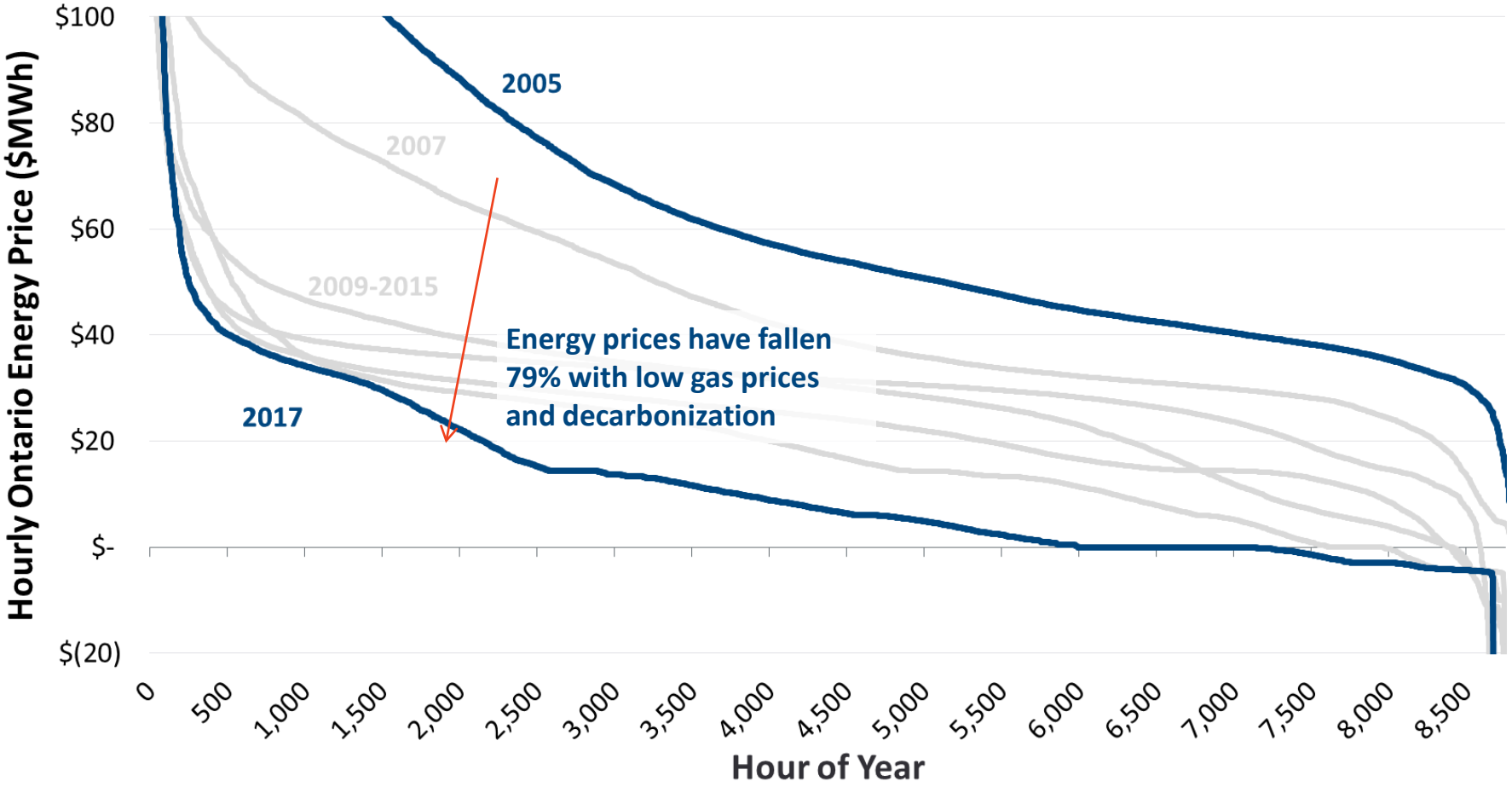


Source: Based on analysis with Brattle's bSTORE modeling platform.

Optimized operating strategies, accounting for existing market rules and DA/RT uncertainties, can increase storage revenues 2–5 times.

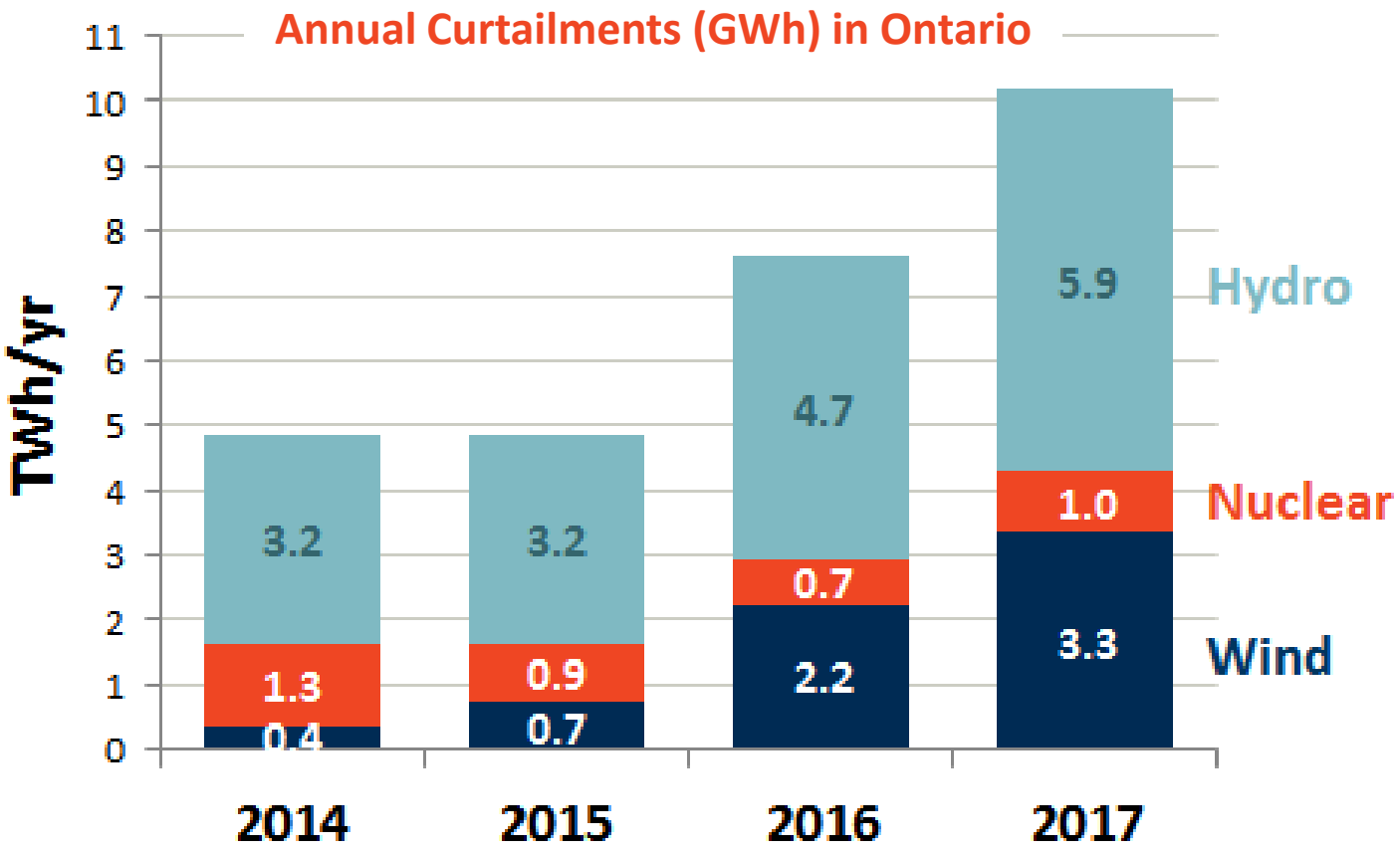
Energy Markets "Bottoms Out" with Clean, Low-Marginal-Cost Generation

Ontario experience: very low or negative prices with a 90% clean and low-marginal-cost fleet.



10 TWh Curtailments of Non-Emitting Ontario Resources in 2017!

High curtailments of hydro and other non-emitting Ontario resources point to insufficient hydro-system and market-operational flexibility

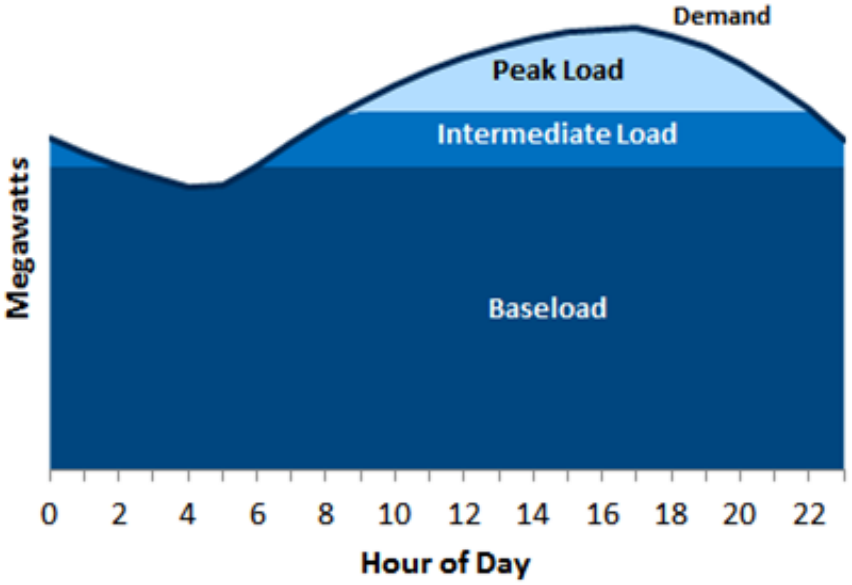


Source: IESO year-end data and OPG's annual & financial reports.

Changing Supply Mix = Need for More Flexibility

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

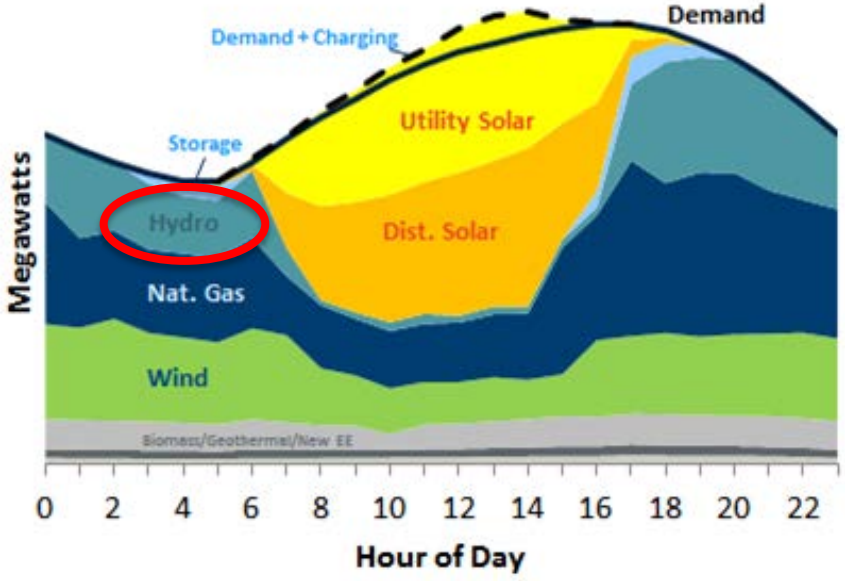
Electricity Demand and Traditional Supply Mix



Source: The Brattle Group.

Electricity Demand and Supply Mix with High Renewable Generation

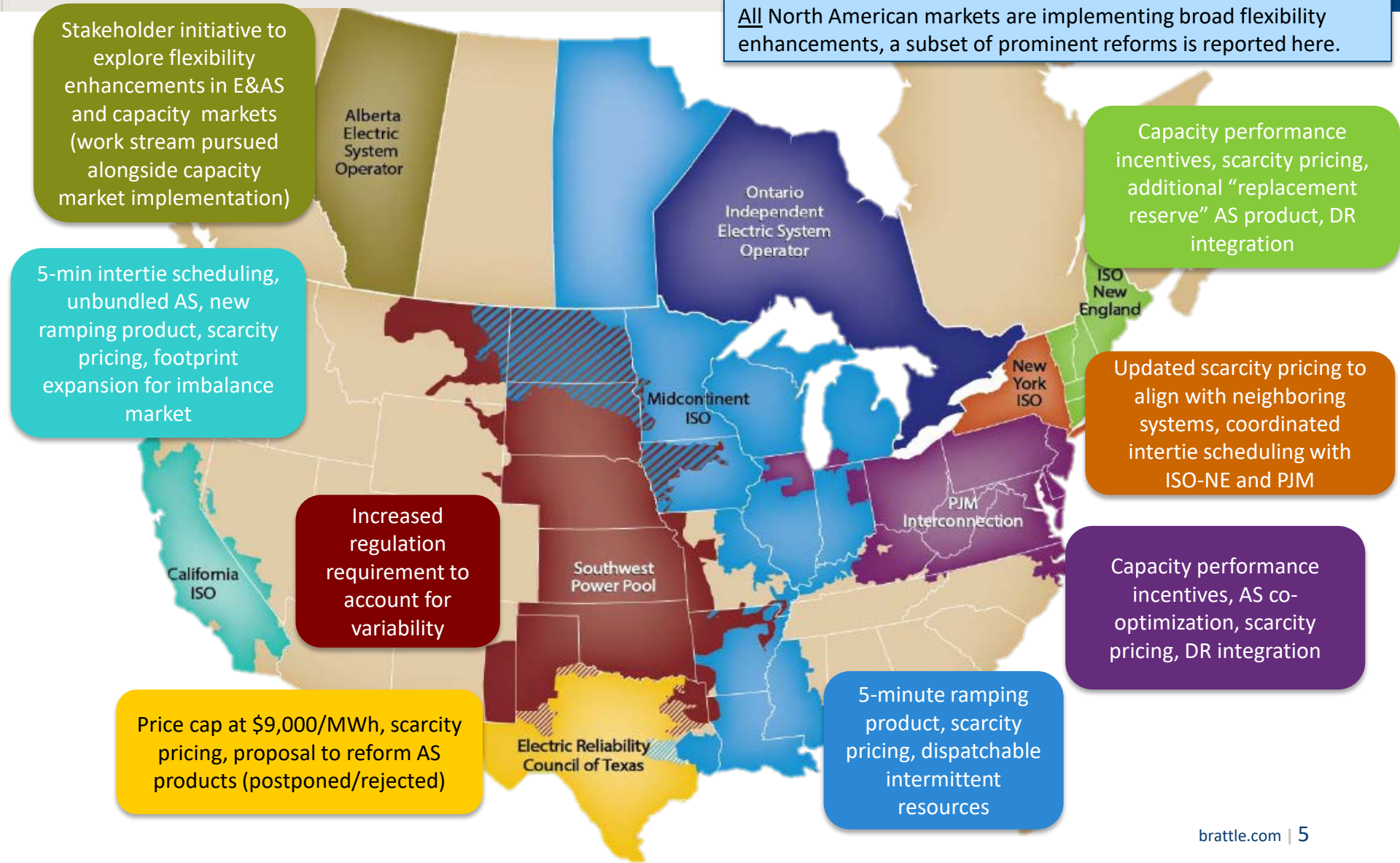
(High-Solar Example)



Source: The Brattle Group.

Regional Efforts to Incentivize Flexibility

All North American markets are implementing broad flexibility enhancements, a subset of prominent reforms is reported here.



Stakeholder initiative to explore flexibility enhancements in E&AS and capacity markets (work stream pursued alongside capacity market implementation)

Capacity performance incentives, scarcity pricing, additional "replacement reserve" AS product, DR integration

5-min intertie scheduling, unbundled AS, new ramping product, scarcity pricing, footprint expansion for imbalance market

Updated scarcity pricing to align with neighboring systems, coordinated intertie scheduling with ISO-NE and PJM

Increased regulation requirement to account for variability

Capacity performance incentives, AS co-optimization, scarcity pricing, DR integration

Price cap at $9,000/MWh, scarcity pricing, proposal to reform AS products (postponed/rejected)

5-minute ramping product, scarcity pricing, dispatchable intermittent resources

Revenue Sources will Shift from Energy to Other "Products"

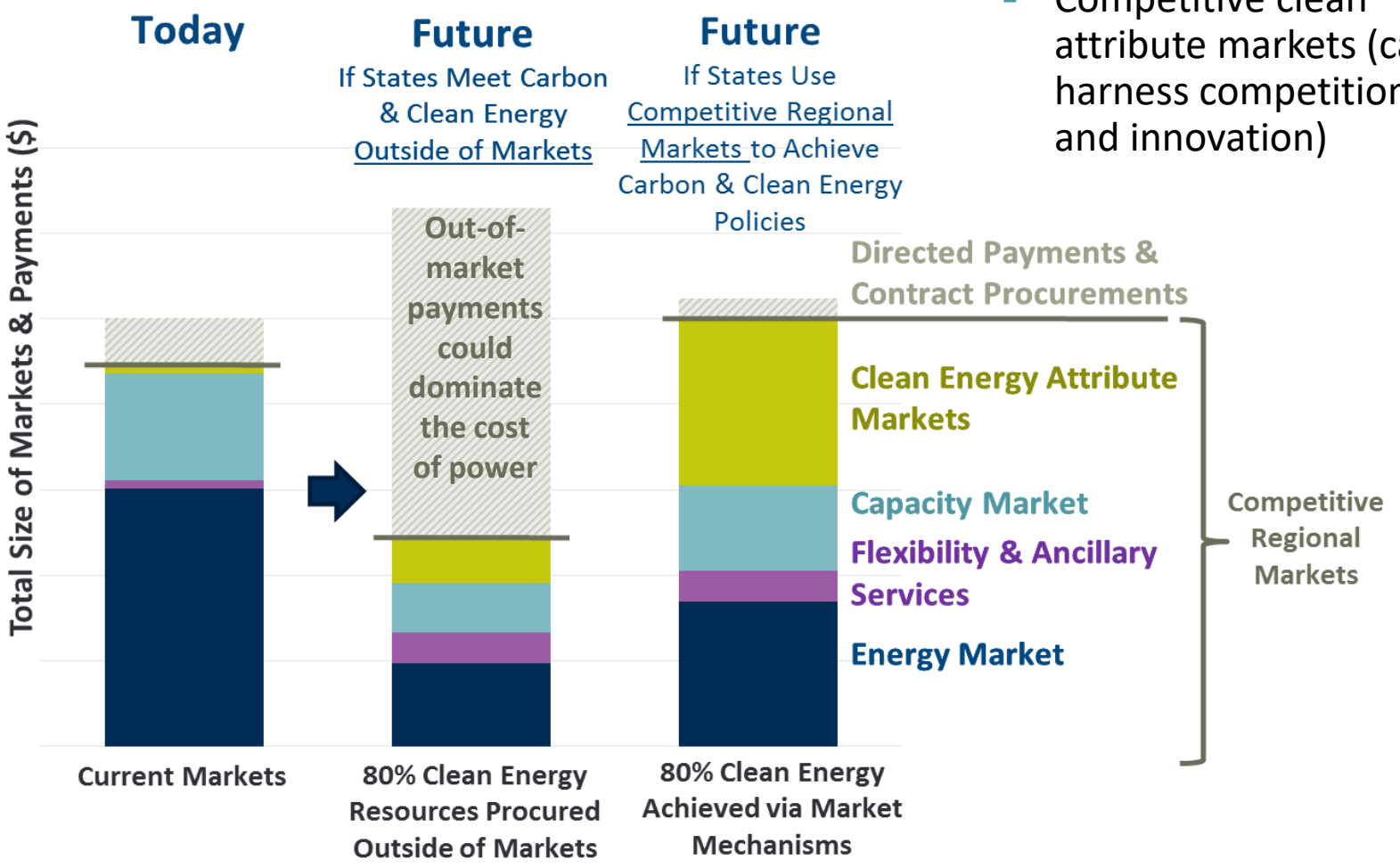
Markets designed for a clean, low-marginal-cost resource mix will need to focus more on flexibility and clean-energy products

Market	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 or down ▪ 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 fossil plants 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
Geographic Diversification		▪ Increasing value of larger markets and trade/diversification across market seams through inter-regional grids

How Will Clean Energy Products be Integrated into Regional Markets?

For wholesale markets to stay relevant, clean energy product markets are the "missing link" to align with customers and policy makers' preferences.

- Competitive clean attribute markets (can harness competition and innovation)



Product Markets Mobilize Competition from a Wider Range of Resources

Hydro resources are well positioned to compete in the products-based energy markets of the future

Products	Resources/Technologies (Existing and New)												Number of Competing Technologies
	Nuclear	RoR Hydro	Hydro w/ Storage	Coal	CC	CT	Wind	Solar	Battery Storage	DR	EE	Imports	
DA Energy	✓	✓	✓	✓	✓	○	✓	✓	○	○	○	✓	10
RT Energy (5 min)	○	✓	✓	✓	✓	○	✓	✓	○	○	○	○	9
Regulation	X	✓	✓	✓	✓	○	○	○	✓	○	X	○	7.5
Spinning Reserves	X	○	✓	✓	✓	✓	X	X	✓	○	X	○	6.5
Non-Spinning Reserves	X	X	✓	X	✓	✓	X	X	✓	○	X	○	5
Load following / Flexibility	○	○	✓	○	✓	✓	○	○	✓	○	X	○	7.5
Capacity / Res. Adequacy	✓	○	✓	✓	✓	✓	○	○	○	✓	✓	✓	10
Clean Energy	✓	✓	✓	X	○	○	✓	✓	○	○	✓	✓	9
Reactive / Voltage Support	✓	✓	✓	✓	✓	✓	○	○	✓	X	X	○	8.5
Black Start	X	✓	✓	○	✓	✓	X	X	○	X	X	○	6

Legend	Technical Capability to Provide Service
✓	Well Suited (1.0)
○	Neutral (0.5)
X	Not / Poorly Suited (0)

Takeaways

Existing hydro resources are well positioned to compete in a markets-based wholesale power industry

- Wholesale power market regulations and designs will need to be evolve with evolving customer preferences, technological changes, and associated system needs
- Hydro resources will need to be better optimized into (DA+RT) energy, ancillary services, flexibility, and capacity markets
- Upgrades to existing resources may be warranted to increase operating flexibility and capture additional market revenues

Parting Thought: New hydro investments will be challenged

- Substantial lead-times, permitting challenges, scale, high costs, and capital-intensive nature are a significant handicap of new hydro resources
- Rapid technological change (e.g., low-cost wind, solar, and batteries) combined with general uncertainty about future industry direction will favor shorter-lead-time, less capital-intensive technologies
- Who really should or would want to take the substantial investment risk?

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Mr. Johannes (Hannes) Pfeifenberger is an economist with a background in power engineering and over 25 years of experience in the areas of public utility economics and finance. He has published widely, assisted clients and stakeholder groups in the formulation of business and regulatory strategy, and submitted expert testimony to the U.S. Congress, courts, state and federal regulatory agencies, and in arbitration proceedings.

Hannes has extensive experience in the economic analyses of wholesale power markets and transmission systems. 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.

Hannes received an M.A. in Economics and Finance from Brandeis University and an M.S. in Power Engineering and Energy Economics from the University of Technology in Vienna, Austria.

About The Brattle Group

The Brattle Group provides consulting and expert testimony in economics, finance, and regulation to corporations, law firms, and governmental agencies worldwide.

We combine in-depth industry experience and rigorous analyses to help clients answer complex economic and financial questions in litigation and regulation, develop strategies for changing markets, and make critical business decisions.

Our services to the electric power industry include:

- Climate Change Policy and Planning
- Cost of Capital
- Demand Forecasting Methodology
- Demand Response and Energy Efficiency
- Electricity Market Modeling
- Energy Asset Valuation
- Energy Contract Litigation
- Environmental Compliance
- Fuel and Power Procurement
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- Rate Design and Cost Allocation
- Regulatory Strategy and Litigation Support
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