The Changing Role of Hydro Power in Transforming Wholesale Power Markets

PREPARED FOR

Canadian Hydro Power Association Conference

PREPARED BY

Johannes Pfeifenberger
Judy Chang
Pablo Ruiz

November 21, 2018

THE Brattle GROUP

Agenda

- Value of hydro assets not fully realized today
- Transformative changes of the electricity industry
- “De-marginalization” of wholesale power markets
- Increasing need for and value of flexibility and storage
- Shifting revenue mix in evolving wholesale power markets
- Benefits of (and the role of hydro) in more competitive, products-based wholesale-power markets
- Opportunities: dynamic clean-energy markets and improved grid operations
- Take aways

RTO Market Rules and Software Challenges

RTO rules and operational tools often limit hydro resources' market participation and ability to capture their full wholesale market value

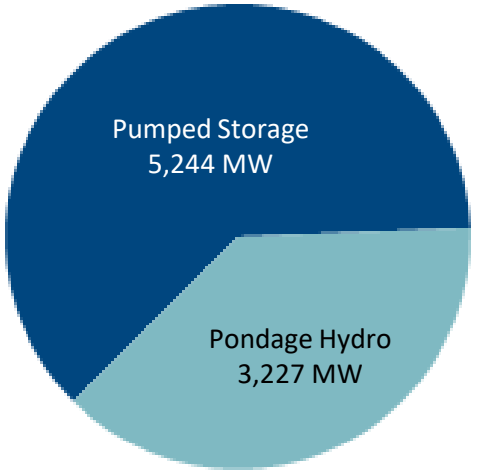
Example: PJM

- *Although opportunity costs are generally allowed, they are not well-defined or actively used for hydro units.*
- *Pumped-storage hydro can be scheduled by PJM, outside its market optimization engine.*
- *Hydro plants not scheduled by PJM (including all pondage plants) cannot submit price-based offers (they must self-schedule).*
- *Market enhancements have not yet focused on hydro plants.*

Potential Improvements

- ***Allow offering hydro energy at a price.***
- ***Optimize hydro scheduling as part of market clearing (pumped and pondage).***

Hydro Plants in the PJM footprint

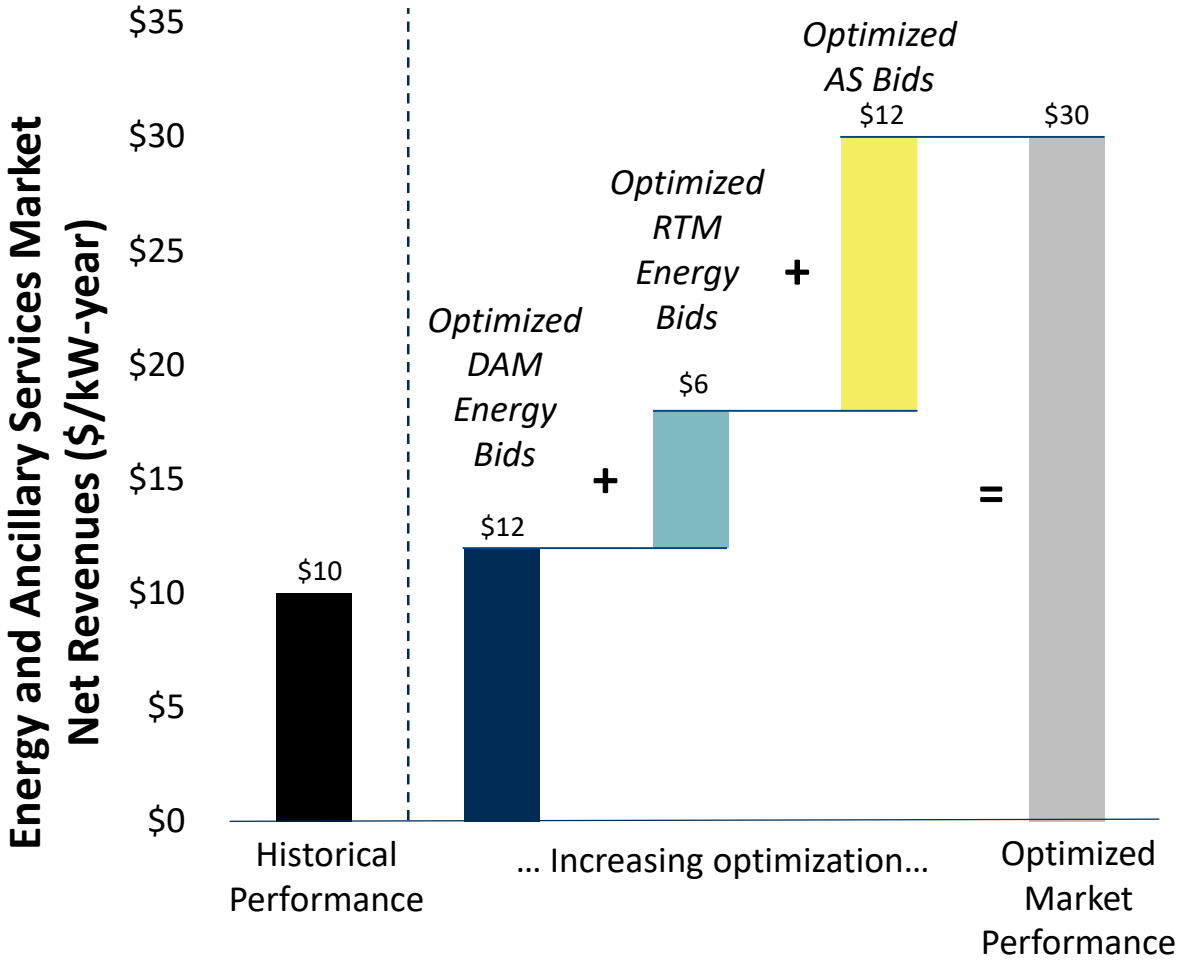


Sources:
PJM hydro rules: PJM Operating Agreement, Schedule 1, Section 1.10 Scheduling, http://www.pjm.com/directory/merged-tariffs/oa.pdf
Hydro plants: The Brattle Group analysis based on SNL and other data.

Notes:
** Other resources can submit price-based offers even if they do not have "fuel costs."*

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

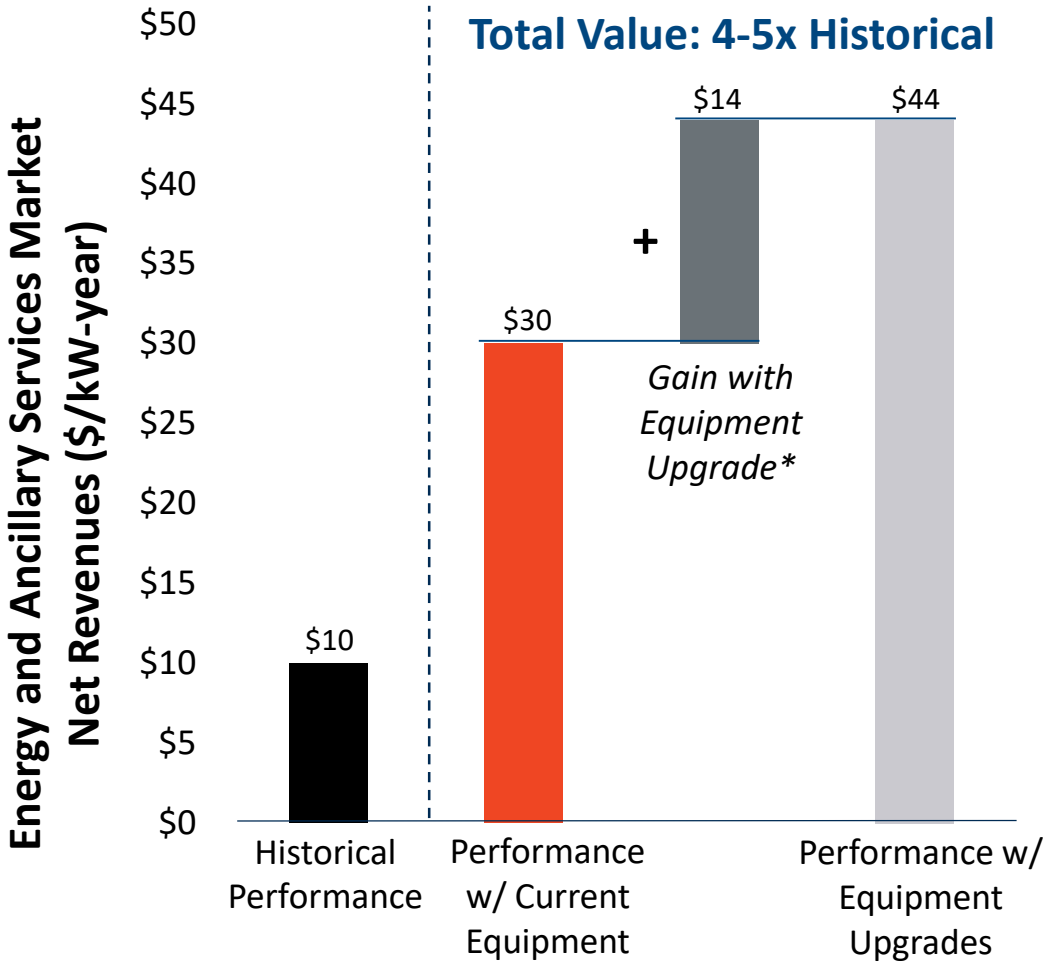
Example: Pumped Storage Hydro plant operating in U.S. RTO market



- Neither hydro nor market operators are currently optimizing the value of flexible hydro resources
- Hydro asset owners often have limited incentives to maximize market value
- **Optimized operating strategies can increase storage revenues 2–3 times!**
  - Accounting for: existing market rules considering DA/RT energy and AS markets, uncertainties, market impacts, and operational constraints

U.S. Case Study: The Value of Increasing the Flexibility of Existing Hydro Plants

Equipment upgrades can further increase the value of hydro plants



- Legacy plants may be subject to costly constraints:
  - Time to switch pump/generate modes can be too long
  - Limits AS and RT energy market opportunities
- Equipment upgrades to enable fast mode switching enables substantial AS and RT market gains
- **The value of enhancing flexibility of hydro plants will only increase by the transformation of wholesale power markets**

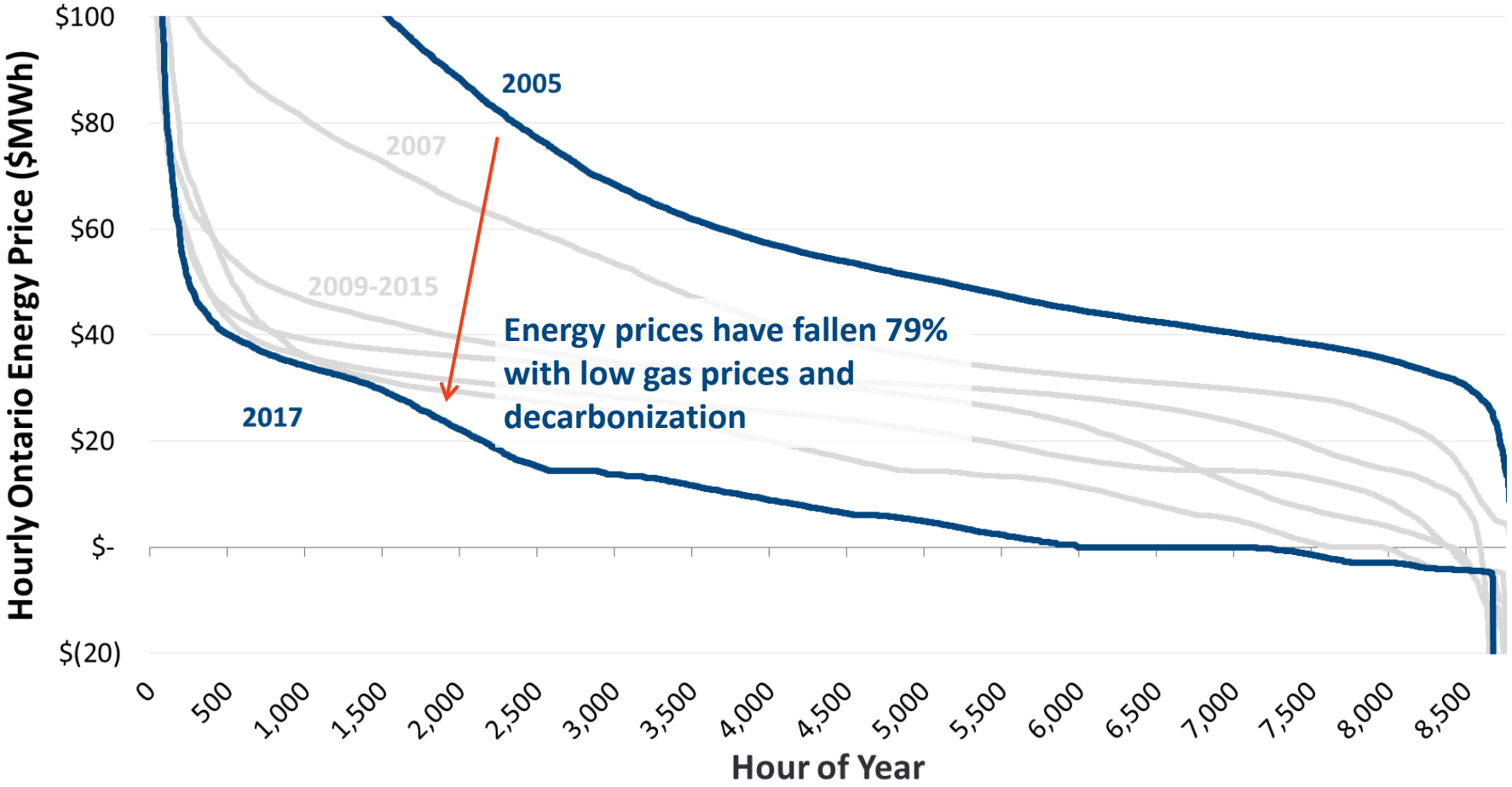
Transformative Changes of the Electricity Industry

- **Declining costs of solar and wind resources** will increasingly dominate the power grid with **low-marginal-cost** generation
- **Low natural gas prices** place significant downward pressure on coal and nuclear plants
- **Reduced growth in traditional electricity consumption**, even in the age of "internet of things"
- **Increased customer preferences for conservation and clean energy**
- **Increased desire for other environmental preferences** related to air emissions, water usage, waste disposal, and land use for all power plants
- **Technological advances** that allow customers and electric utilities to better monitor and control electricity usage
- **Increasing electrification** of transportation and heating

These are significant changes that utilities, grid operators, generators, and regulators have to manage

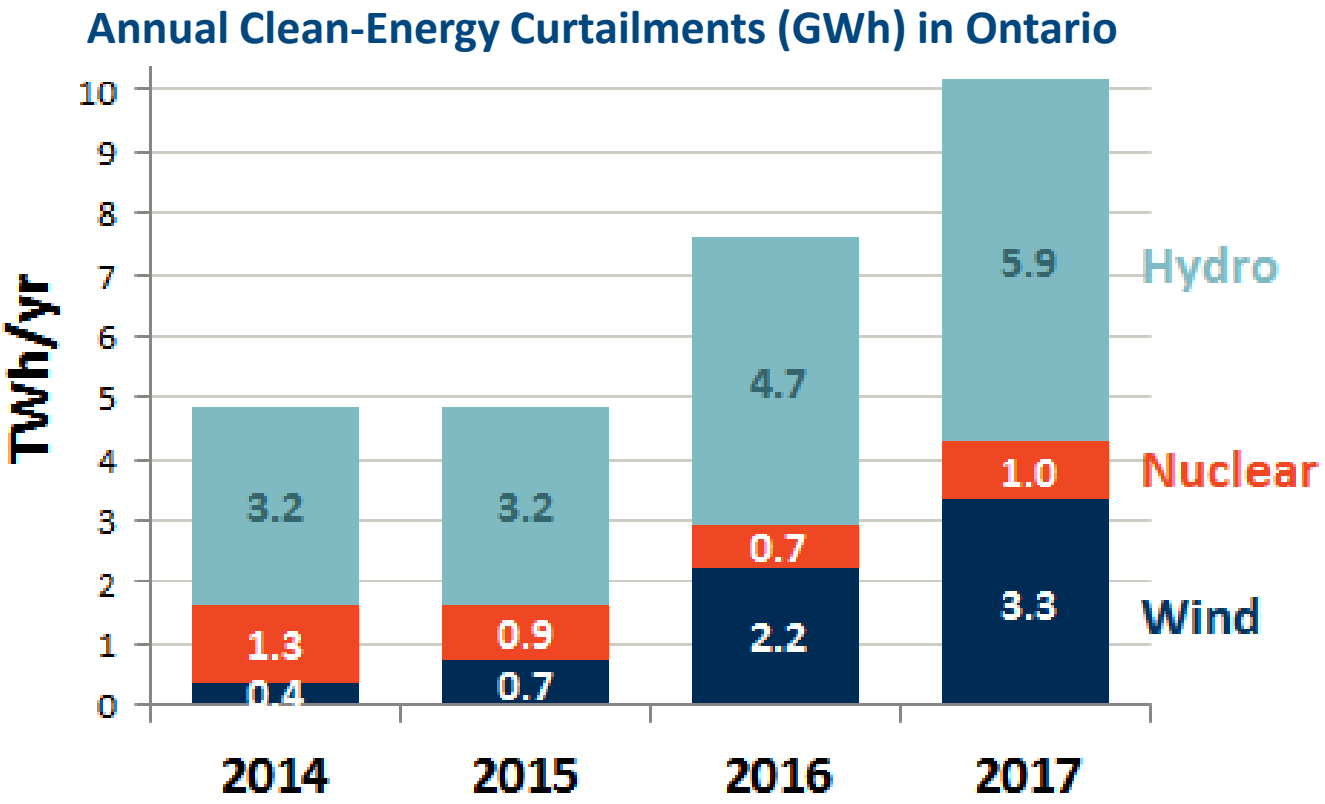
Energy Markets "Bottom Out" with Clean, Low-Marginal-Cost Generation

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



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

Spilling of hydro and curtailments of other non-emitting Ontario resources point to (1) inefficient royalty pricing and (2) insufficient hydro-system, market, and intertie flexibility



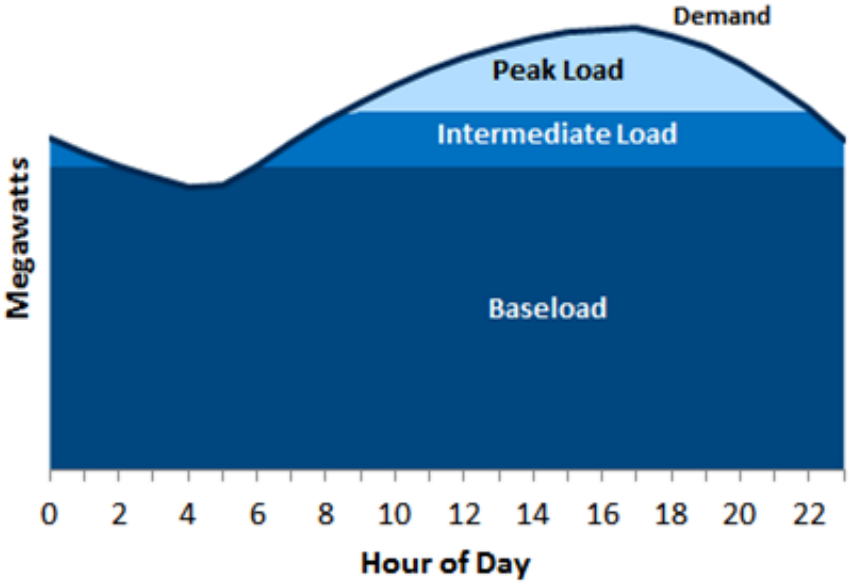
5.9 TWh of spilled hydro = approx. $80 million of lost hydro royalty revenues to the Province

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

Global Phenomenon: 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

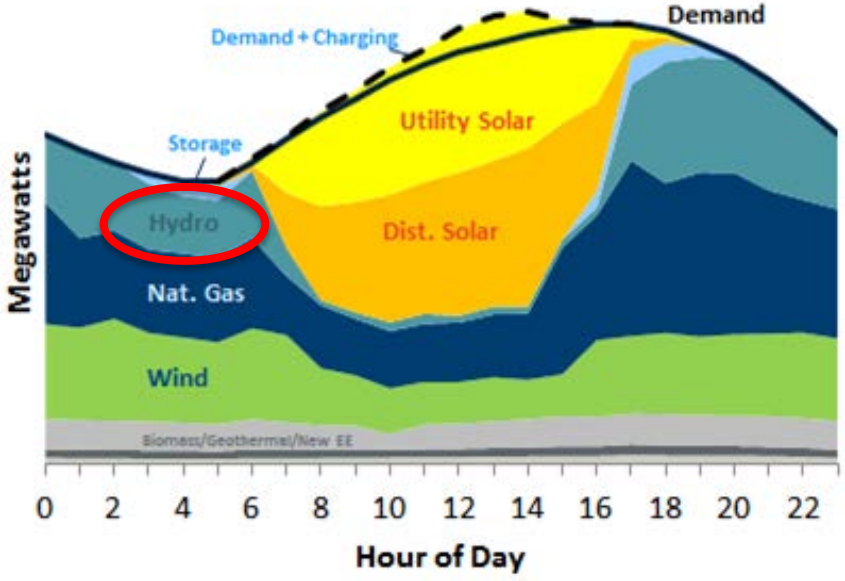
Electricity Demand and Traditional Supply Mix



Source: The Brattle Group.

Electricity Demand and Supply Mix with High Renewable Generation

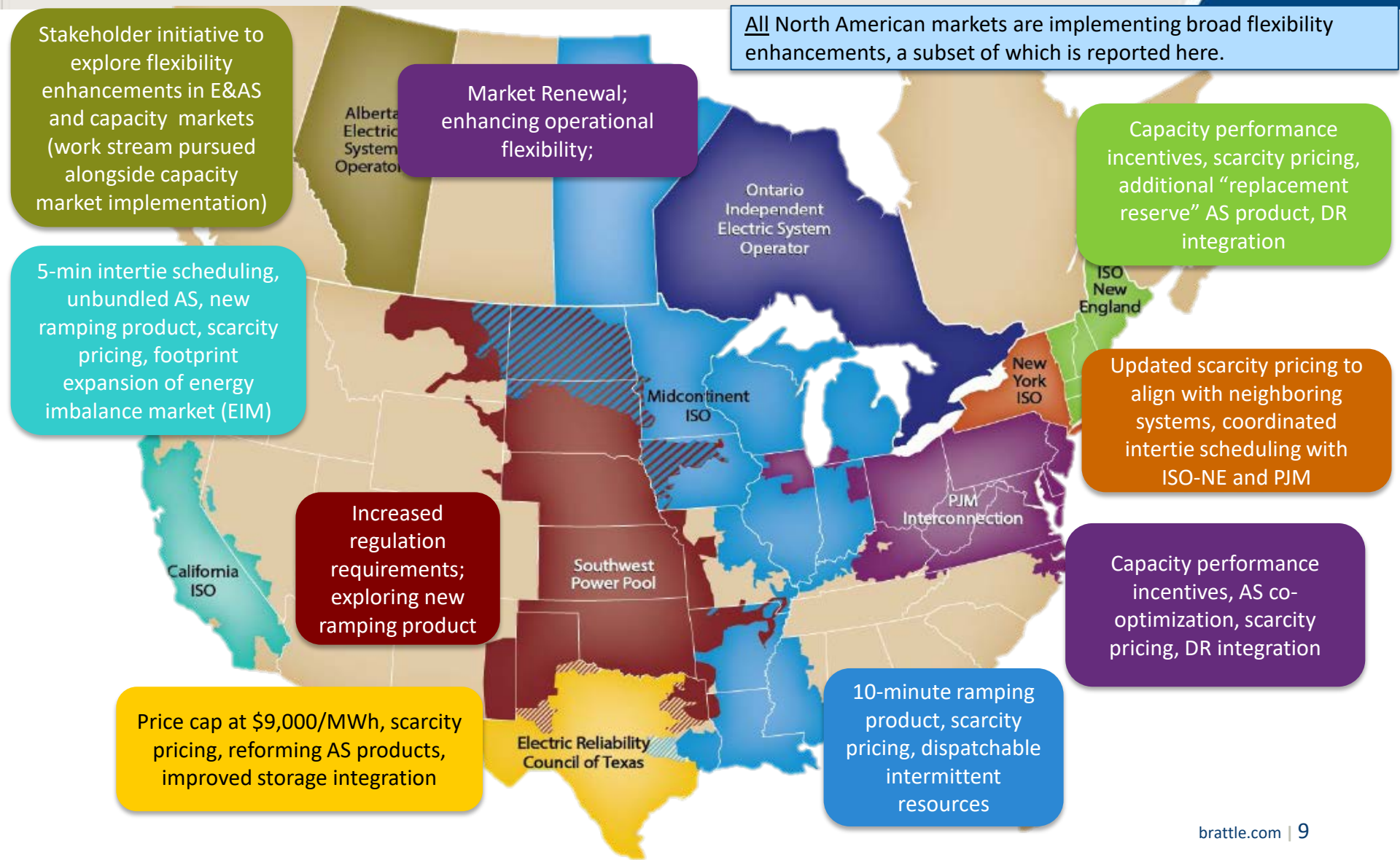
(High-Solar Example)



Source: The Brattle Group.

Examples: Efforts to Enhance Flexibility

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



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

Market Renewal; enhancing operational flexibility;

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 of energy imbalance market (EIM)

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

Increased regulation requirements; exploring new ramping product

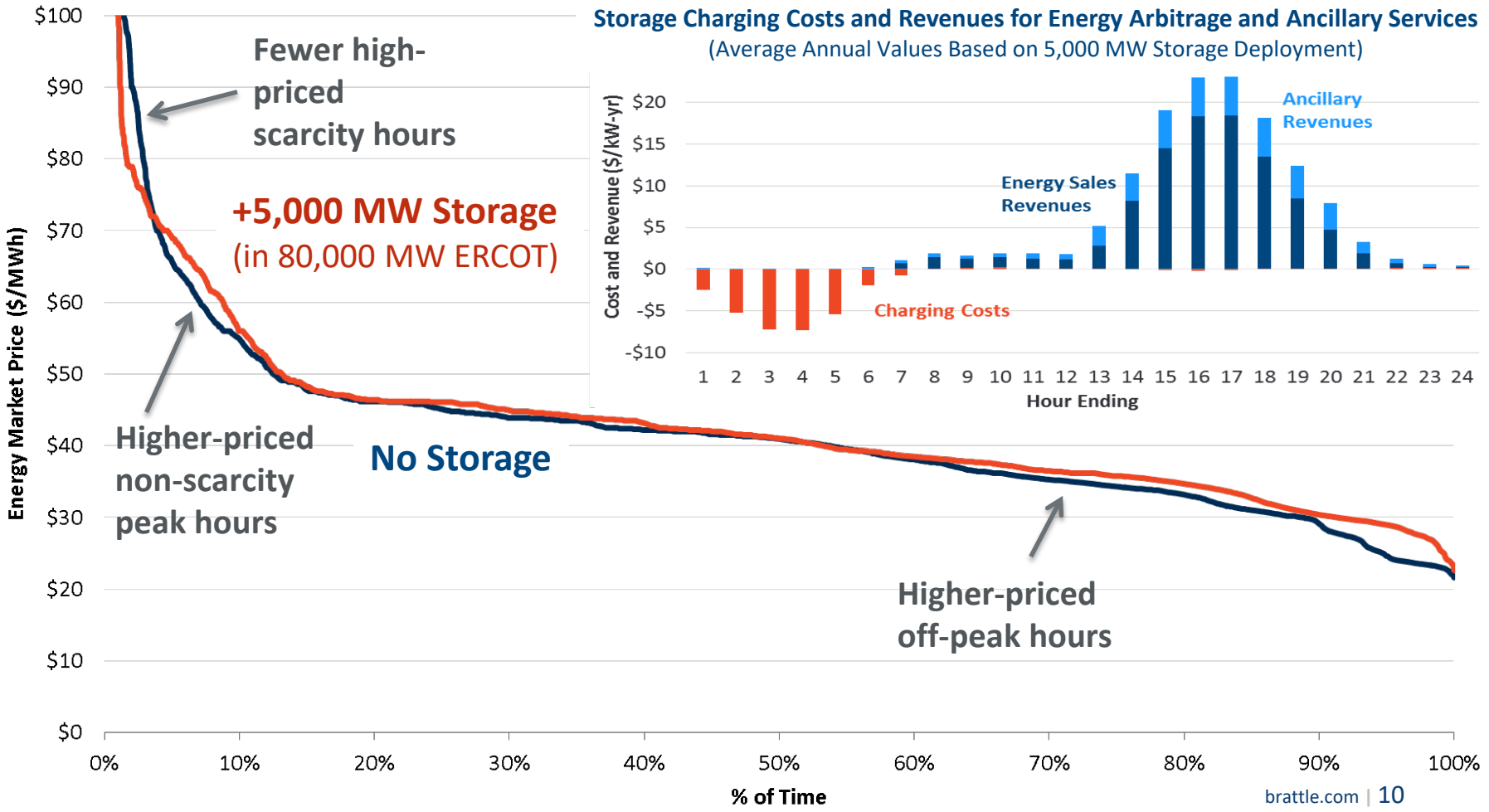
Capacity performance incentives, AS co-optimization, scarcity pricing, DR integration

Price cap at $9,000/MWh, scarcity pricing, reforming AS products, improved storage integration

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

Storage Can Address Many of the Emerging Industry Challenges

Storage will increasingly become the new marginal resource, reducing peak prices while supporting off-peak prices



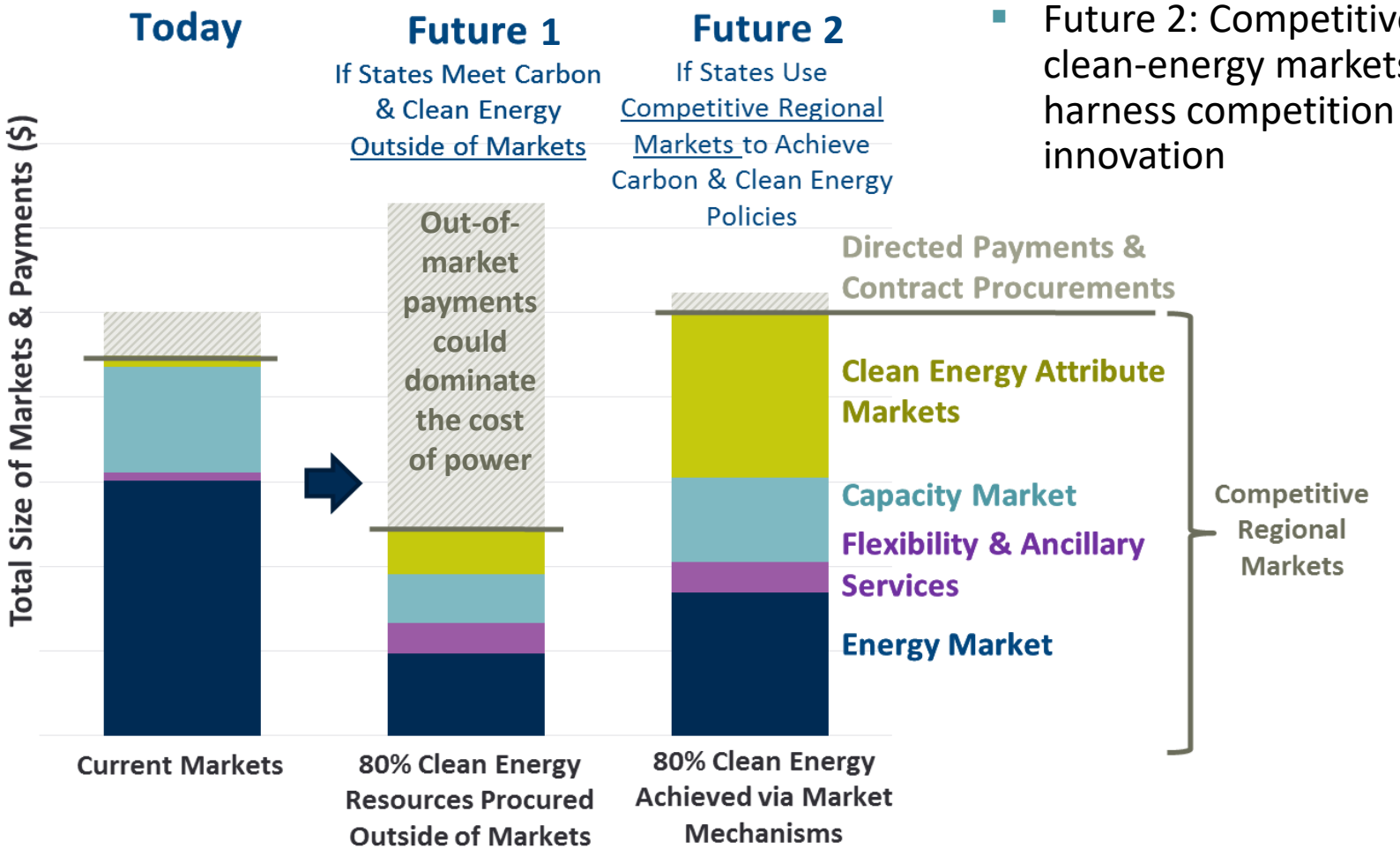
Revenue Sources will Shift from Energy to Other "Products"

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 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
Interties & Geographic Diversification		▪ Increasing value of larger, more diverse regional markets ▪ Greater value of 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.



- Future 2: Competitive clean-energy markets to harness competition and innovation

Product Markets Mobilize Competition from a Wider Range of Resources

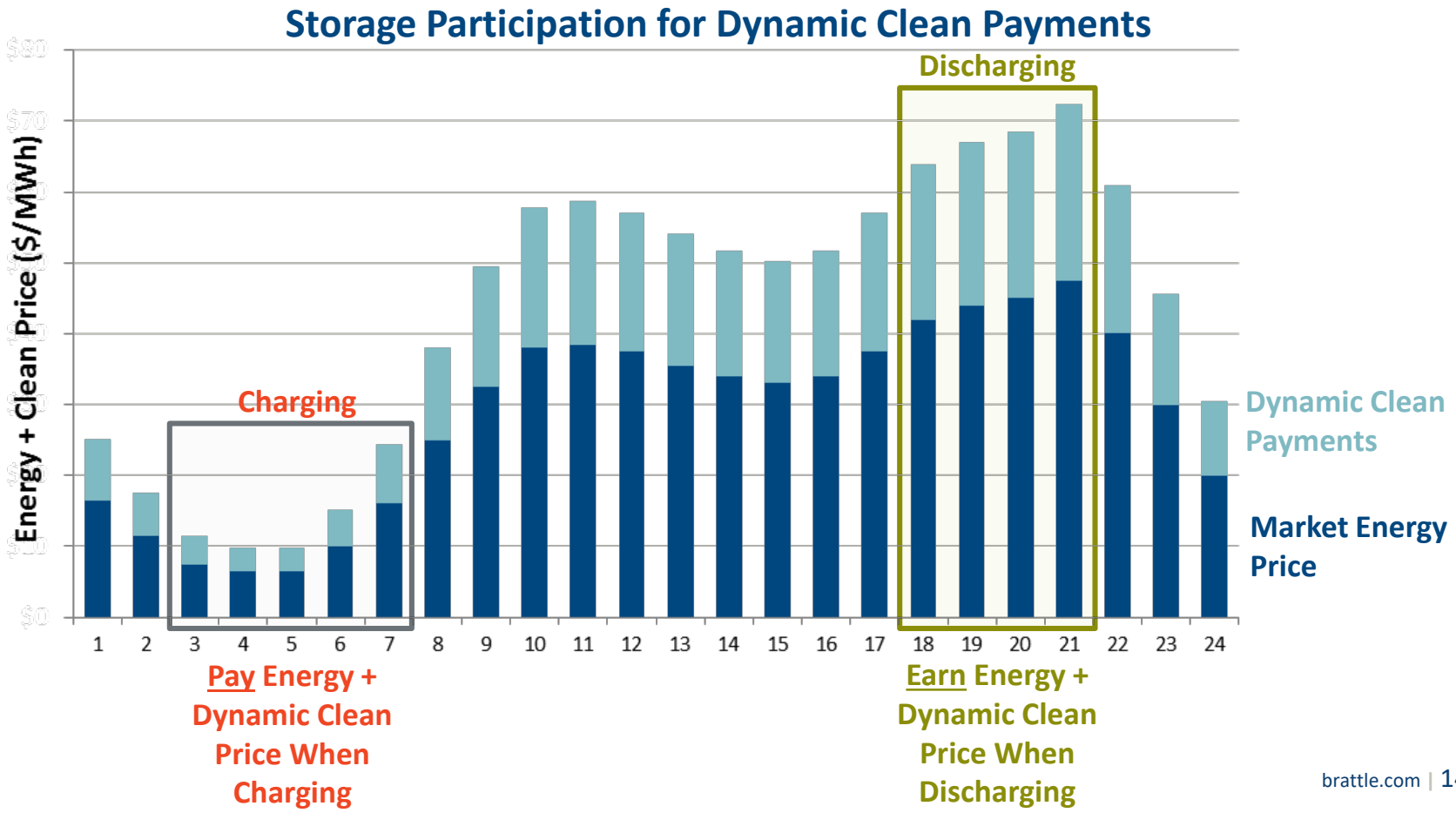
Hydro resources are well positioned to compete in the emerging products-based wholesale power markets

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)

Dynamic Pricing of Clean-Energy Further Enhances Storage Value

Dynamic payments for clean energy at the right times to displace emissions provide improved price signals and will further enable storage



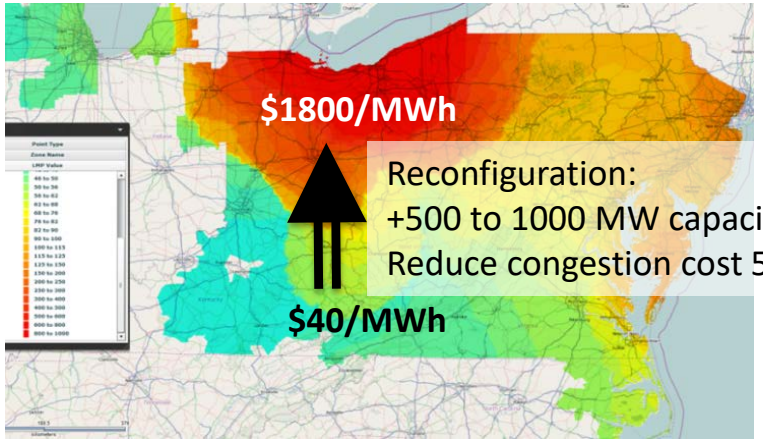
Transmission Congestion Relief Strategies Available to Enhance Asset Values

Congestion affecting hydro storage projects can usually be relieved cost-effectively by employing advanced transmission technologies

- Congestion is often seen by the plant owner as an erratic price signal
- Advanced transmission technologies provide cost effective and timely means to relieve plant congestion under these conditions
  - *Transmission reconfigurations (topology control/line switching)*
  - *Power flow control devices*
  - *Dynamic line ratings*

Case Study: PJM

- ✓ *Extreme peak conditions with outages*
- ✓ *Reconfiguration can increase transfer capacity by **5-10% (500-1000 MW)***
- ✓ ***50% reduction in congestion cost***
- ✓ *Similar relief of more localized congestion in PJM, SPP, MISO, ERCOT, UK*



PJM Real Time Prices, 18/7/2013, 15:30 (pjm.com)

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?

PRESENTER BIO & CONTACT INFORMATION

Johannes Pfeifenberger

Principal, Boston
+1.617.864.7900 (Main)
+1.617.234.5624 (Direct)
Hannes.Pfeifenberger@brattle.com

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. (Dipl. Ing.) in Power Engineering and Energy Economics from the University of Technology in Vienna, Austria.

About The Brattle Group

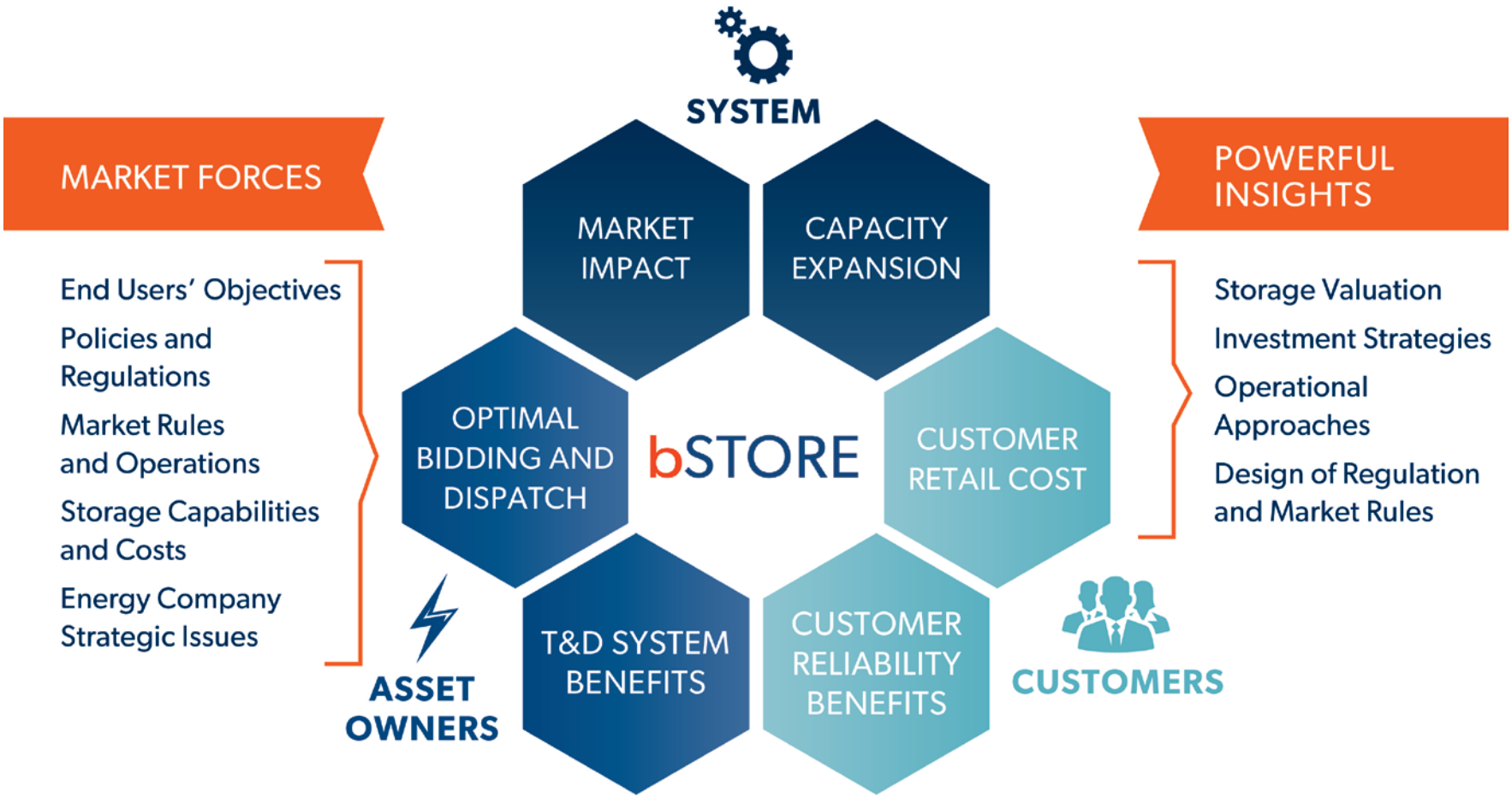
The Brattle Group provides consulting and expert testimony in economics, finance, and regulation to corporations, law firms, and governmental agencies worldwide.

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.

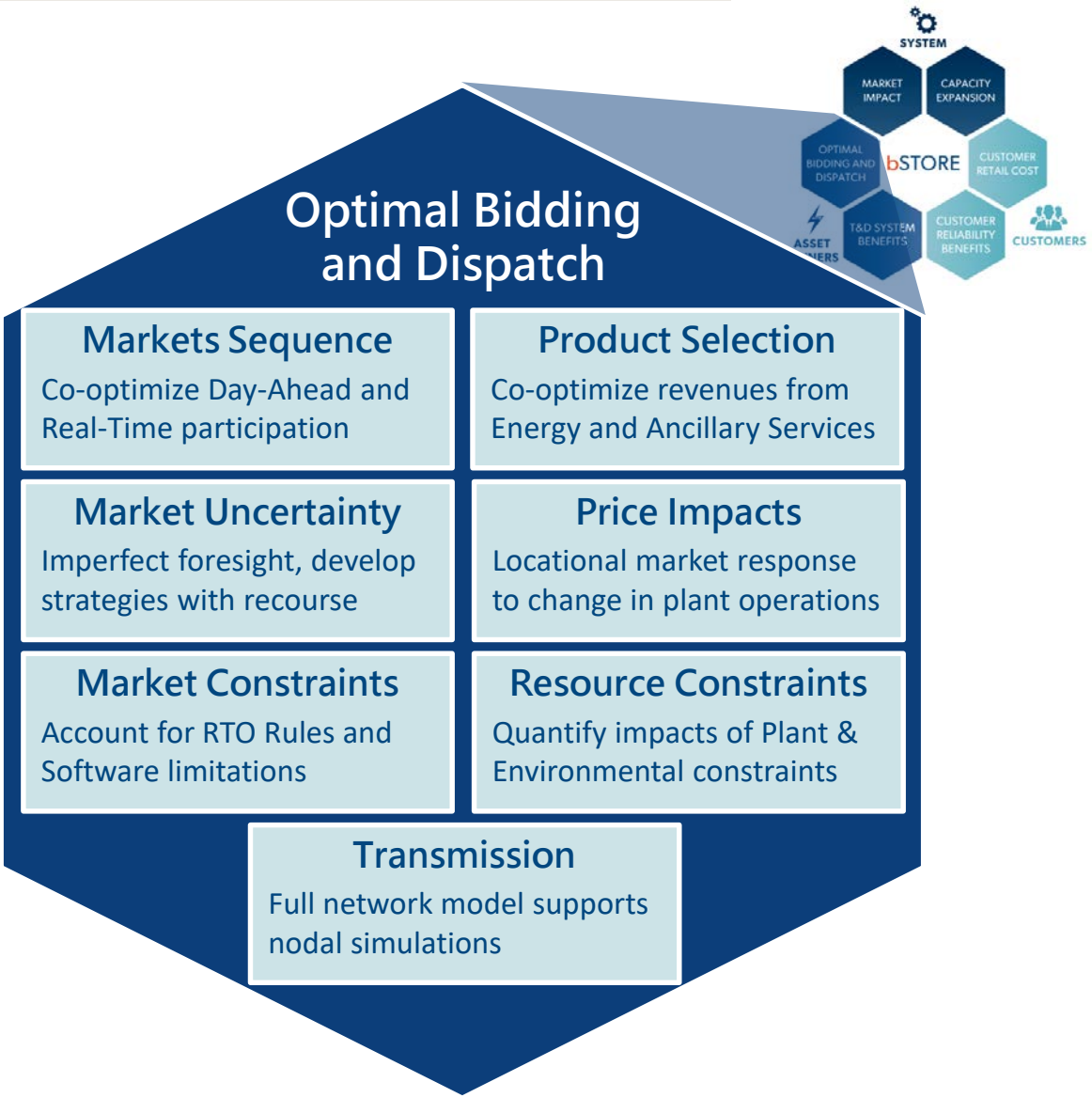
Our services to the electric power industry include:

- 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
- Incentive Regulation
- Rate Design and Cost Allocation
- Regulatory Strategy and Litigation Support
- Renewables
- Resource Planning
- Retail Access and Restructuring
- Risk Management
- Market-Based Rates
- Market Design and Competitive Analysis
- Mergers and Acquisitions
- Transmission

Brattle's bSTORE Storage Modeling Platform



bSTORE Application for Hydro E&AS Market Optimization



Module Features

- Mixed Integer Programming (MIP) solver as used by RTOs
- Rolling-horizon simulation with look-ahead optimization
- Sequential model of DA, RT and other decision cycles with feedback loops
- Scenario-based & heuristic-based uncertainty modeling
- Hydro modeling
  - Generation constraints
  - Reservoir constraints
  - Cascaded plants w/ delays
  - Value of water: calculate (long-horizon problems) or specify (short-horizon)

Our Offices

BOSTON

NEW YORK

SAN FRANCISCO

WASHINGTON

TORONTO

LONDON

MADRID

ROME

SYDNEY