Electricity Market Trends and Implications for Public Power

System needs to support renewables and engaged consumers

Presented to
AMP/OMEA Conference

Presented by
Judy Chang

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Agenda

What are the major changes in the wholesale electricity markets?

How are systems responding to flexibility and resiliency needs?

What are some of the proposed market design changes that are being considered in the regional energy markets?

What is the latest in the transmission business?

- Transformative changes of the electricity industry
- Shift toward more clean energy
- Increasing need for and value of flexibility
- Value of hydropower and storage
- Competition in Transmission
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 continual downward pressure on coal and nuclear plants.
- Reduced growth in traditional electricity consumption, even in the age of “internet of things”.
- Increasing electrification of transportation and heating.
- Increased customer preferences for clean energy.
- Technological advances that allow customers and electric utilities to better monitor and control electricity usage.
- Restrictions on environmental impact related to air emissions, water usage, waste disposal, and land use for all power plants and transmission.

These are significant changes that utilities, grid operators, generators, and regulators have to manage.
Customers & Utilities: Green Tariff

Customers
(1) Price Stability / Hedge
(2) Corporate Sustainability Goals

Utilities
(1) Revenue Certainty
(2) New Market Opportunities and Corporate Partnerships

Green Tariff Adoption

Source: “Utility Green Tariff Programs: Considerations for Federal Agencies,” NREL, NREL/PR-6A20-68179
**Example: Sleeved PPA or Subscriber Program**

**NV Energy’s “Green Energy Rider”**

<table>
<thead>
<tr>
<th>Eligibility</th>
<th>Structure</th>
<th>Cost Breakdown</th>
<th>Contract Length</th>
<th>Value of Contract</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Commercial customers</td>
<td>- Customer negotiates with utility to dedicate new or existing renewable energy facilities; or</td>
<td>- Full cost of renewable energy facility on a kWh basis; or</td>
<td>Minimum of two years</td>
<td>- Protection from fuel cost adjustments</td>
</tr>
<tr>
<td>- Industrial customers</td>
<td>- Customer contracts with utility for 50% or 100% of their consumption</td>
<td>- 12-month average cost of procuring renewable energy</td>
<td></td>
<td>- Ability for customer to meet energy needs from renewable resources</td>
</tr>
<tr>
<td>- Demand between 50 and 500 kWs; or monthly usage greater than 10,000 kWhs</td>
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<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Global Growing Need for Data Storage and Cloud Computing

- With the Internet of Things, abundance of sensor-based automation, cloud computing needs growing, the demand for data center-based workloads is increasing rapidly.
- Consumer applications such as video streaming and social networks are the fastest growing applications of data center capacity.
- Annual growth rates for needed storage capacity and workloads are in the 20-30% range.

Types of Data Centers

- Data centers serve all segments of the economy, from healthcare, banking, manufacturing, agriculture, to calculating and storing information from sensor-based processes.
- Data centers can be located on premise of businesses or located (and shared) remotely.
- Data centers can be categorized as:
  - **Edge data centers**: small (shipping container size) and distributed (such as base of cell towers), at the edge of the IT network, close to where data originates (for example: collect and process data from power generators, medical devices and sensors, manufacturing, agriculture) – reduces the need to transfer data back and forth between centralized computing locations.
  - **Mega data centers**: in large centralized locations with at least 1 million square foot space – can be provided by third party for “co-located” data centers.
Data Center Owners and Users are Committed to Renewable Energy

Many major data center owners have pledged to achieve 100% renewable energy supply - driven by desire to use clean energy to “power our data”

— For economic and publicity purposes

Companies with 100% Renewable Energy Commitments

- 2011
  Facebook
- 2012
  Apple
  Google
- 2013
  Rackspace
  Salesforce
  Box
- 2014
  Amazon Web Services
  Microsoft
- 2015
  Equinix
- 2016
  Digital Realty
  Naver
  Switch
  Adobe
  HP
  Etsy
  Hewlett Packard Enterprise

Source: “Clicking Clean: Who is Winning the Race to Build a Green Internet,” 2017, Greenpeace
C&I Customers Increasingly Drive of Renewable Generation Investments
Electrification: Potential to **Double** Total Demand by 2050

Understanding pace, locations, and resulting infrastructure needs requires deeper understanding of customers, and more active engagement (including vehicle loads that can be controlled)

Shifts in the Resource Mix
Supply Resources Are Changing Rapidly

**Retirements**
Primarily from Traditional Supply

**New Builds**
Focused on New Technologies

*Data Source: ABB Velocity Suite (US and Canadian generation) and Brattle research (US-only distributed resource and storage).*
Changes in Energy Market Prices

- Energy prices fluctuate between greater price ranges as supply mix evolves
  - Variability of prices increase
  - Net load volatility increases: higher prices during net load peak, lower prices or negative during periods of high renewables generation
  - Flexible resources can effectively respond to the signals
  - Energy price fluctuations would likely be higher taking into account transmission constraints

Illustrative Day-ahead Price Duration Curves ($/MWh)

Source: The Brattle Group.
Energy Markets with Large 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!

Energy prices have fallen 79% with low gas prices and decarbonization

Source: ABB Velocity Suite, Brattle Group Analysis
Impact of Resource Mix Change on Flexibility Needs

Illustrative Example shows:

1. The growing level of renewables increases net load variability, uncertainty, and ramping, requiring more flexibility from the system.

2. The increase in renewables pushes down minimum net load levels, which puts pressure on dispatchable generators to operate at lower levels or go offline.

Example of Load Net of Wind and Solar Output

Average of All Hours in July (MW)

Day-ahead and Real-Time Load, Wind, and Solar
Illustrative three-day period (% of max day-ahead)

Wind and solar day-ahead forecast error (uncertainty) exceed load forecast error in percentage terms

Source: The Brattle Group.
Increasing Need for and Value of Flexibility
Implications for Planning

Several areas that will require significant focus in planning:

- Reliability of the System
- Efficient Operations of the System
- Ensure Competitive Pricing

- Redefine Reliability Metrics
- New Markets and Products

Support Customers’ Needs and Interests
Regional Markets’ 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 (work stream pursued alongside previously capacity market)
- **Market Renewal; enhancing operational flexibility**;
- **Increased regulation requirements; exploring new ramping product**
- **Price cap at $9,000/MWh, scarcity pricing, reforming AS products, improved storage integration**
- **5-min intertie scheduling, unbundled AS, new ramping product, scarcity pricing, footprint expansion of energy imbalance market (EIM)**
- **Capacity performance incentives, scarcity pricing, additional “replacement reserve” AS product, DR integration**
- **Updated scarcity pricing to align with neighboring systems, coordinated intertie scheduling with ISO-NE and PJM**
- **10-minute ramping product, scarcity pricing, dispatchable intermittent resources**
- **Capacity performance incentives, AS co-optimization, scarcity pricing, DR integration**

All North American markets are implementing broad flexibility enhancements, a subset of which is reported here.
Ramping capability procured in the current interval ensures the ability to meet expected plus unexpected ramping needs in future intervals. MISO and CAISO have both introduced a ramp product. SPP is in the process of proposing one.

• **Ramp up:** Holds back sufficient “headroom” to meet load in upcoming intervals & avoid scarcity events

• **Ramp down:** Mitigates the potential for minimum generation events (zero quantity procured in this example)

Value of Hydropower and Storage
Value of Pumped Storage in Providing Flexibility

Illustrative Storage Dispatch (MW)

- Pumped storage’s operations can shift considerably based on net load shapes, for example, in a solar-heavy region:
  - Storage shifts its charging from night to mid-day
  - Storage shifts discharging from late afternoon to evening peaks
- As renewable deployment increases, pumped storage tends to operate at higher charging and generating capabilities

Source: The Brattle Group.
Need for Clean-Energy Products in 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
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

<table>
<thead>
<tr>
<th>Products</th>
<th>Value</th>
<th>Market Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Energy</td>
<td>▼</td>
<td>▪ Lower energy prices during low-load and on average in most hours will most strongly affect baseload and dominant variable resources</td>
</tr>
<tr>
<td>Scarcity Pricing</td>
<td>▲</td>
<td>▪ But higher peak prices, driven by volatility, scarcity pricing, and demand response/storage; rewards fast-response resources</td>
</tr>
<tr>
<td>Flexibility &amp; Reserves</td>
<td>▲</td>
<td>▪ Need for greater quantities and new types of flexibility products ▪ Higher ramping needs reward flexibility</td>
</tr>
<tr>
<td>Capacity</td>
<td></td>
<td>▪ 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</td>
</tr>
<tr>
<td>Clean Attributes</td>
<td>▲</td>
<td>▪ Some form of CO₂ pricing and/or clean energy payments introduced to meet policy and/or customer demand ▪ Value must be large enough to attract new clean resources</td>
</tr>
<tr>
<td>Adjacent Customer &amp; Distribution Markets</td>
<td>▲</td>
<td>▪ Technology and consumer-driver demand for adjacent products and services (smart home, electric vehicles) ▪ Participation may overlap with wholesale, clean, and retail/distribution markets</td>
</tr>
<tr>
<td>Interties &amp; Geographic Diversification</td>
<td>▲</td>
<td>▪ Increasing value of larger, more diverse regional markets ▪ Greater value of trade/diversification across market seams through inter-regional grids</td>
</tr>
</tbody>
</table>
Hydro resources are well positioned to compete in the emerging products-based wholesale power markets

<table>
<thead>
<tr>
<th>Products</th>
<th>Resources/Technologies (Existing and New)</th>
<th>Number of Competing Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>DA Energy</td>
<td><strong>Nuclear</strong></td>
<td><strong>RoR</strong></td>
</tr>
<tr>
<td></td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
<td>10</td>
</tr>
<tr>
<td>RT Energy (5 min)</td>
<td>O ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓</td>
<td>9</td>
</tr>
<tr>
<td>Regulation</td>
<td>X ✓ ✓ ✓ ✓ O O O ✓ ✓ ✓ O X O</td>
<td>7.5</td>
</tr>
<tr>
<td>Spinning Reserves</td>
<td>X O ✓ ✓ ✓ ✓ X X ✓ ✓ ✓ O X O</td>
<td>6.5</td>
</tr>
<tr>
<td>Non-Spinning Reserves</td>
<td>X X ✓ ✓ X ✓ ✓ ✓ ✓ ✓ ✓ O X O</td>
<td>5</td>
</tr>
<tr>
<td>Load following / Flexibility</td>
<td>O O ✓ ✓ O ✓ ✓ ✓ ✓ ✓ ✓ O X O</td>
<td>7.5</td>
</tr>
<tr>
<td>Capacity / Res. Adequacy</td>
<td>✓ O ✓ ✓ ✓ ✓ O O O ✓ ✓ ✓ ✓ ✓ ✓</td>
<td>10</td>
</tr>
<tr>
<td>Clean Energy</td>
<td>✓ ✓ ✓ ✓ X O O ✓ ✓ ✓ O O ✓ ✓ ✓</td>
<td>9</td>
</tr>
<tr>
<td>Reactive / Voltage Support</td>
<td>✓ ✓ ✓ ✓ ✓ ✓ ✓ O O ✓ ✓ X X O</td>
<td>8.5</td>
</tr>
<tr>
<td>Black Start</td>
<td>X ✓ ✓ ✓ ✓ O ✓ ✓ ✓ X X O X X O</td>
<td>6</td>
</tr>
</tbody>
</table>

**Legend**
- ✓ Well Suited (1.0)
- O Neutral (0.5)
- X Not / Poorly Suited (0)
Example: Brattle Estimates 700-1,000 MW Nevada Storage Potential (50,000 MW US-Wide)

Achieving economic potential depends on “stacking” value streams: energy, ancillaries, capacity, T&D, environmental, and avoided outages.

**Nevada: Storage Benefits & Costs**

<table>
<thead>
<tr>
<th>Benefits &amp; Costs ($Million/year)</th>
<th>200</th>
<th>400</th>
<th>600</th>
<th>800</th>
<th>1,000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Avoided Distribution Outages</td>
<td>$200</td>
<td>$150</td>
<td>$100</td>
<td>$50</td>
<td>$0</td>
</tr>
<tr>
<td>High Battery Cost</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Deferred T&amp;D</td>
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<tr>
<td>Low Battery Cost</td>
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<tr>
<td>Production Cost Savings</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Avoided Capacity Investments</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

**Sources and Notes:**
Nominal dollars. Assumed energy storage configuration of 10 MW / 40 MWh. Brattle Storage potential studies for Nevada and US.
Competition in Transmission Development
Main Drivers of Transmission Needs

- Serve growing load
- Generation interconnections
- Local and regional reliability
- Congestion relief

Traditional Drivers

- Access to low-cost renewable and clean energy
- Capture renewable energy and fuel diversity
- Help meet regional economic and public policy needs
- Cost reductions offered by better interregional coordination
- Mitigate risks and create valuable options to address uncertainties proactively

New Drivers
Scope of ISO/RTO Oversight in US Transmission Investments

Of $75 billion in transmission investments by FERC-jurisdictional TOs in ISO/RTO regions between 2013 to 2017, ~47% was made without comprehensive ISO/RTO and stakeholder engagement through the regional planning process.

| Transmission Investments Subject to Full or Limited Review in ISO/RTO Regional Planning Processes |
|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|-------------------------------------------------|
| Years Reviewed                                  | FERC Jurisdictional Additions by Transmission Owners (nominal $million, based on FERC Form 1 Filings) | Investments Approved Through Full ISO/RTO Planning Process (nominal $million) | % of Total FERC Jurisdictional Investments Approved Through Full ISO/RTO Planning Process | % of Total FERC Jurisdictional Investments with Limited ISO/RTO Review |
| CAISO                                           | $7,528                                           | $4,043                                           | 54%                                             | 46%                                             |
| ISO-NE                                          | $7,488                                           | $5,300                                           | 71%                                             | 29%                                             |
| MISO                                            | $15,530                                          | $8,068                                           | 52%                                             | 48%                                             |
| NYISO                                           | $2,592                                           | n/a                                              | n/a                                             | n/a                                             |
| PJM                                             | $31,469                                          | $14,458                                          | 46%                                             | 54%                                             |
| SPP                                             | $6,202                                           | $4,226                                           | 68%                                             | 32%                                             |
| Total                                           | $70,810                                          | $36,095                                          | 53%                                             | 47%                                             |

Sources & Notes: Data based on FERC Form 1 and ISO/RTO Tracking Reports. CAISO data reflects only select transmission additions/approved investments of PG&E, SCE, and SDG&E for 2014-2016, based on available data. Aggregate investment for each ISO/RTO reflects total FERC Form 1 transmission additions over indicated time periods. Investments approved by ISO/RTO reflects total value of transmission additions placed in-service over indicated time periods, approved through ISO/RTO processes.
Across the US, **only 3% of FERC-jurisdictional transmission investments has been subject to full competitive processes** between 2013 through 2017.

On average, ~$540 million/year out of ~$20 billion/year of transmission investment has been subject to full competitive process in the US.

<table>
<thead>
<tr>
<th>Competitively-Developed Projects in FERC-Jurisdictional Regions In 2013-2017 (Project costs in nominal $million)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CAISO</strong></td>
</tr>
<tr>
<td>2013</td>
</tr>
<tr>
<td>2014</td>
</tr>
<tr>
<td>2015</td>
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<tr>
<td>2016</td>
</tr>
<tr>
<td>2017</td>
</tr>
<tr>
<td><strong>Total Estimated Competitive Project Costs Selected in 2013-2017</strong></td>
</tr>
<tr>
<td><strong>Total Reported FERC Form 1 Transmission Investment in 2013-2017</strong></td>
</tr>
<tr>
<td><strong>Total Estimated Competitive Project Costs Selected in 2013-2017 (of 2013-2017 Total Investment)</strong></td>
</tr>
</tbody>
</table>

*In estimating the total costs of competitive projects approved in PJM, we include 136 projects awarded under competitive windows to incumbent transmission owner with total costs of $952 million, of which 132 projects are upgrades to existing facilities that were not open to competitors.*
The experience in US indicates a significant potential for customer savings:

- If competitive projects can be developed as bid (without further cost escalations), savings would be 28%-50% relative to the costs had this projects been traditionally-developed.
- If costs of competitive projects escalate like traditionally-developed projects, the savings would still be between 15%-30%.

**Potential Cost Savings from Competition**

Source: “Cost Savings Offered by Competition in Electric Transmission,” The Brattle Group, 2019
Implications for Customers and Electric Industry

As documented in many other studies, making valuable transmission investments provide significant overall cost savings through a wide range of benefits.

Increasing the scope of competition would provide additional benefits:

- **Customer Benefits**: With average savings of 25%-30%, expanding the scope of competition from 3% to 33% of total transmission investments would yield customer benefits of $6-$9 billion over five years.

- **Innovation brings long-term advances** to the electric industry, which will further benefit customers and transmission providers.

### Estimated Savings from Competitive Processes

<table>
<thead>
<tr>
<th>(%) of Transmission Costs</th>
<th>20%</th>
<th>30%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimated 5-year US-wide Transmission Investment</td>
<td>$100 billion</td>
<td>$100 billion</td>
</tr>
<tr>
<td>Current Share of Competitive Projects (% of Total Investment)</td>
<td>3%</td>
<td>3%</td>
</tr>
<tr>
<td>Estimated Cost Savings over 5 years</td>
<td></td>
<td></td>
</tr>
<tr>
<td>25% of Transmission Investment Subject to Competition</td>
<td>$4.4 billion</td>
<td>$6.6 billion</td>
</tr>
<tr>
<td>33% of Transmission Investment Subject to Competition</td>
<td>$6.0 billion</td>
<td>$9.0 billion</td>
</tr>
</tbody>
</table>
Key Takeaways

- The power systems are changing, driven by customers’ demand and economics of resources
- Wholesale power market regulations and designs will need to evolve with changing system needs – particularly to compensate resources that provide the needed flexibility
- New hydro and storage resources will need to articulate their value proposition in a low-marginal cost wholesale market
- Additional product markets will be needed to compensate existing and new resources:
  - Clean energy resources
  - Flexibility products
- Competition in transmission can help save customers money in the long-term; thus worth exploring and encouraging
Ms. Judy Chang is an energy economist and policy expert with a background in electrical engineering, and has over 20 years of experience in advising energy companies on regulatory and financial issues, with a focus on power sector investment decisions in clean energy, electric transmission, and energy storage. Ms. Chang has submitted expert testimonies to the US Federal Energy Regulatory Commission, and US state and Canadian provincial regulatory authorities on topics related to resource planning, power purchase and sale agreements, and transmission planning, access, and pricing. She has authored numerous reports and articles on the economic issues associated with generation and transmission investments, clean energy development, energy storage investments, and systems planning. In addition, she has led teams of energy company executives and board members in comprehensive organizational strategic and business planning.

Ms. Chang holds a Bachelor of Science in Electrical Engineering and Computer Science from University of California, Davis and a Master of Public Policy from Harvard Kennedy School. She co-leads the power sector practice at Brattle and is the founding board member of the New England Women in Energy and the Environment.
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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:

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- 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

**SYSTEM**
- **MARKET IMPACT**
- **CAPACITY EXPANSION**
- **OPTIMAL BIDDING AND DISPATCH**
- **T&D SYSTEM BENEFITS**
- **CUSTOMER RELIABILITY BENEFITS**
- **CUSTOMER RETAIL COST**

**MARKET FORCES**
- End Users’ Objectives
- Policies and Regulations
- Market Rules and Operations
- Storage Capabilities and Costs
- Energy Company Strategic Issues

**POWERFUL INSIGHTS**
- Storage Valuation
- Investment Strategies
- Operational Approaches
- Design of Regulation and Market Rules

**ASSET OWNERS**

**CUSTOMERS**
bSTORE Application for Hydro E&AS Market Optimization

Optimal Bidding and Dispatch
- Markets Sequence: Co-optimize Day-Ahead and Real-Time participation
- Market Uncertainty: Imperfect foresight, develop strategies with recourse
- Market Constraints: Account for RTO Rules and Software limitations
- Transmission: Full network model supports nodal simulations

Product Selection
- Co-optimize revenues from Energy and Ancillary Services

Price Impacts
- Locational market response to change in plant operations

Resource Constraints
- Quantify impacts of Plant & Environmental constraints

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)
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