Hidden Values, Missing Markets, and Electricity Policy:

The Experience with Storage and Transmission

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THE Brattle GROUP

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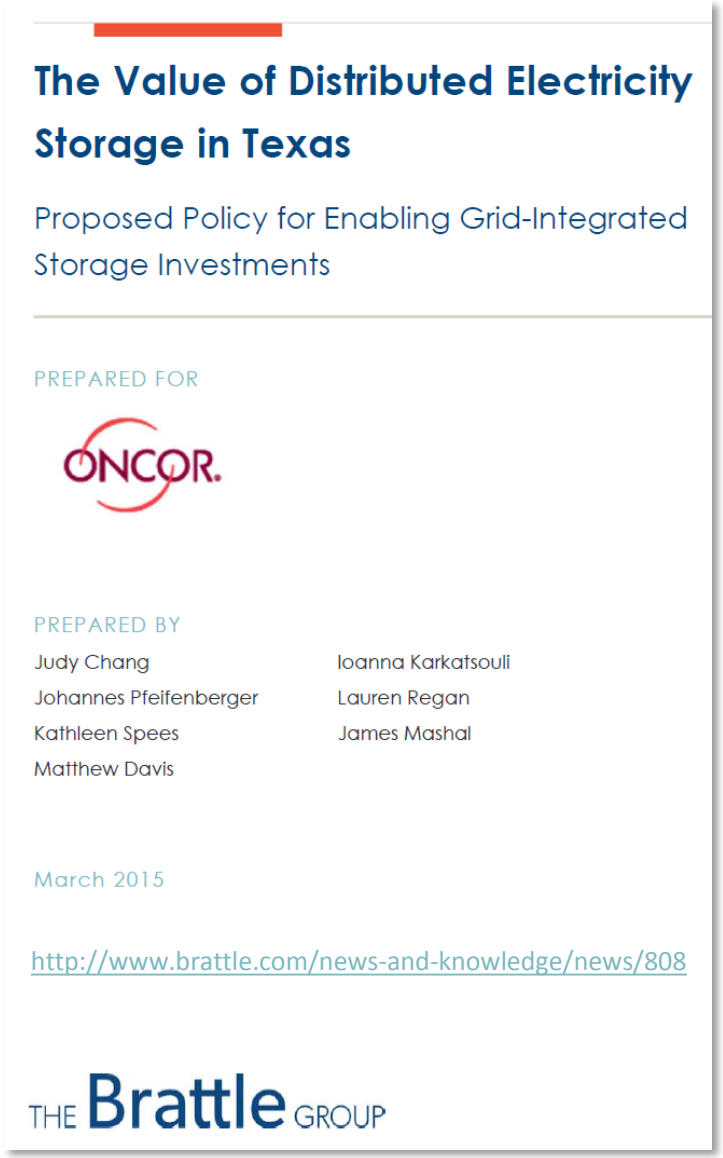
Background: ERCOT Storage Study



Analyzed grid-integrated storage on distribution systems across Texas

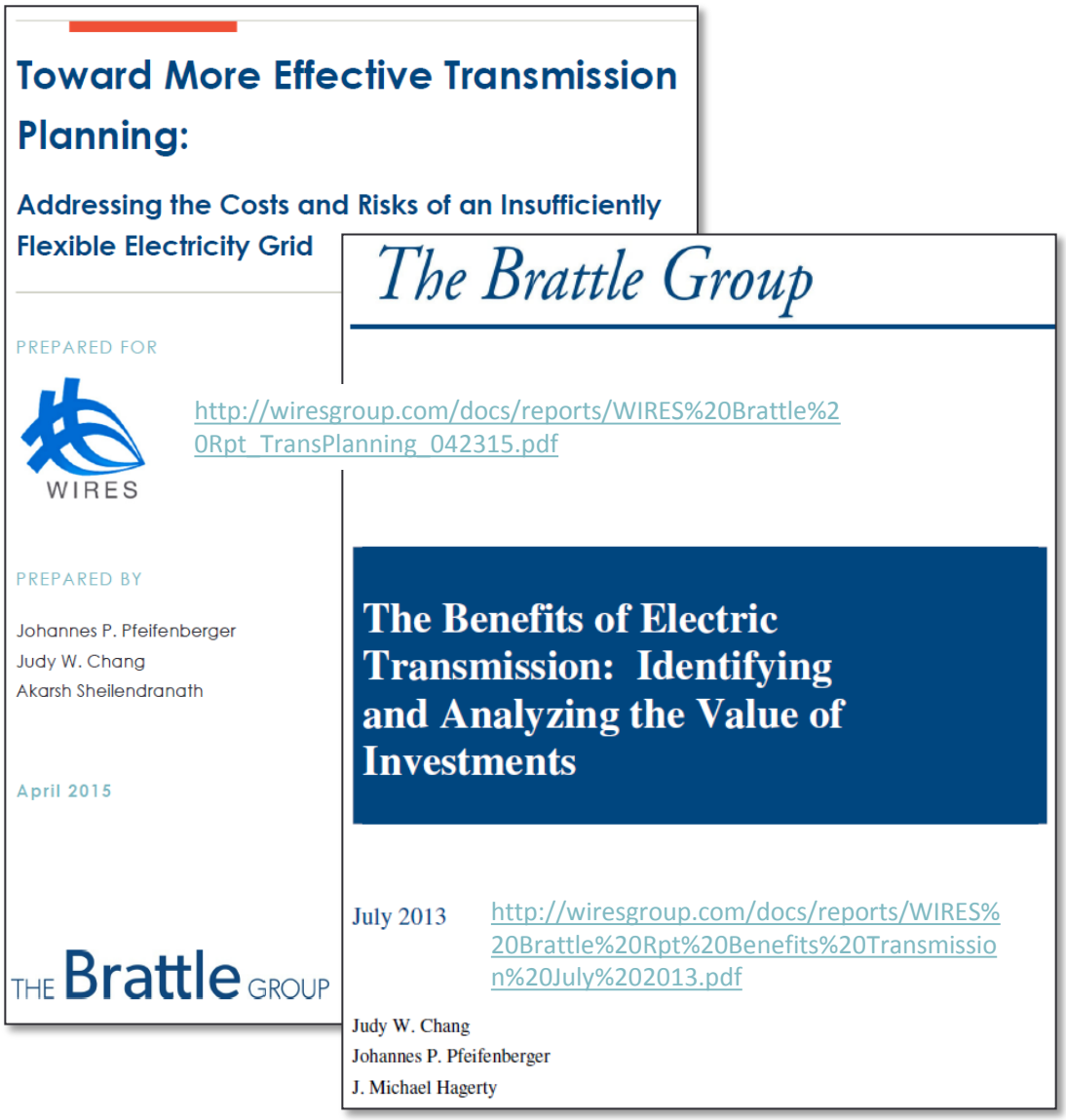
- 5,000 MW cost effective from a system-wide perspective at cost of $350/kWh
- Total customer benefits (lower bills and improved reliability) would exceed costs
- This level of storage deployment reduces but does not eliminate need for new generation

Found that current market and regulatory mechanisms do not enable cost-effective deployment

- Neither wholesale market participants nor T&D companies can capture all value streams offered by distributed storage

Requires new business models and policy frameworks

Background: Transmission Benefits and Planning



Reviewed effectiveness of transmission planning processes and extent to which economic benefits are considered

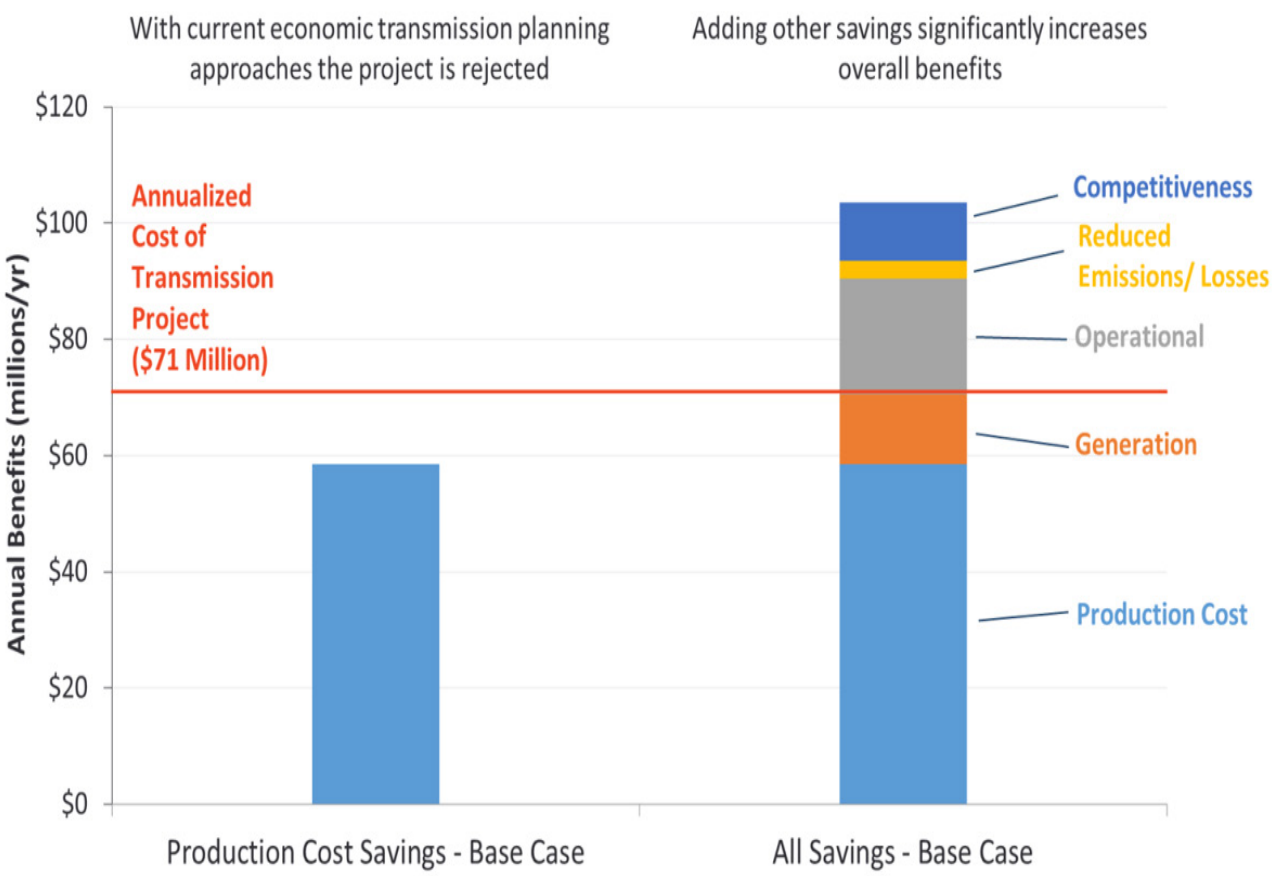
- Many economic benefits are ignored or understated in traditional planning approaches
- Planners and policy makers do not account for the potentially very high costs and risks of an insufficiently robust/flexible transmission grid
- Interregional planning processes are largely ineffective and unable to identify valuable projects

Our Encounters with "Hidden" Values

Market participants often cannot capture a sufficiently large share of the total value provided by certain investments and new technologies. These economic barriers to beneficial investments are associated with:

1. Externalities
   - Lack of markets for the greenhouse gas emissions and other environmental costs/benefits (such as reduced mercury and particulate pollution)
   - Transmission investments that provide system-wide benefits but very limited merchant value
2. No markets to price distribution-level benefits and costs, such as reliability, power quality, or avoided/deferred/induced investments
3. No liquid market for some wholesale-level benefits, such as reactive power, inertia, black-start capability, risk mitigation, transmission reliability
4. Incomplete or distorted wholesale markets (e.g., lack of scarcity pricing; reliability standards and regulated contracts that distort pricing)
5. Regulatory barriers that prevent capturing all value streams (e.g., wires companies that cannot own competitive assets in some jurisdictions)
6. Regulated planning process that do not consider the full range of benefits or costs

Example: Economic Benefits of Transmission



Understating benefits means:

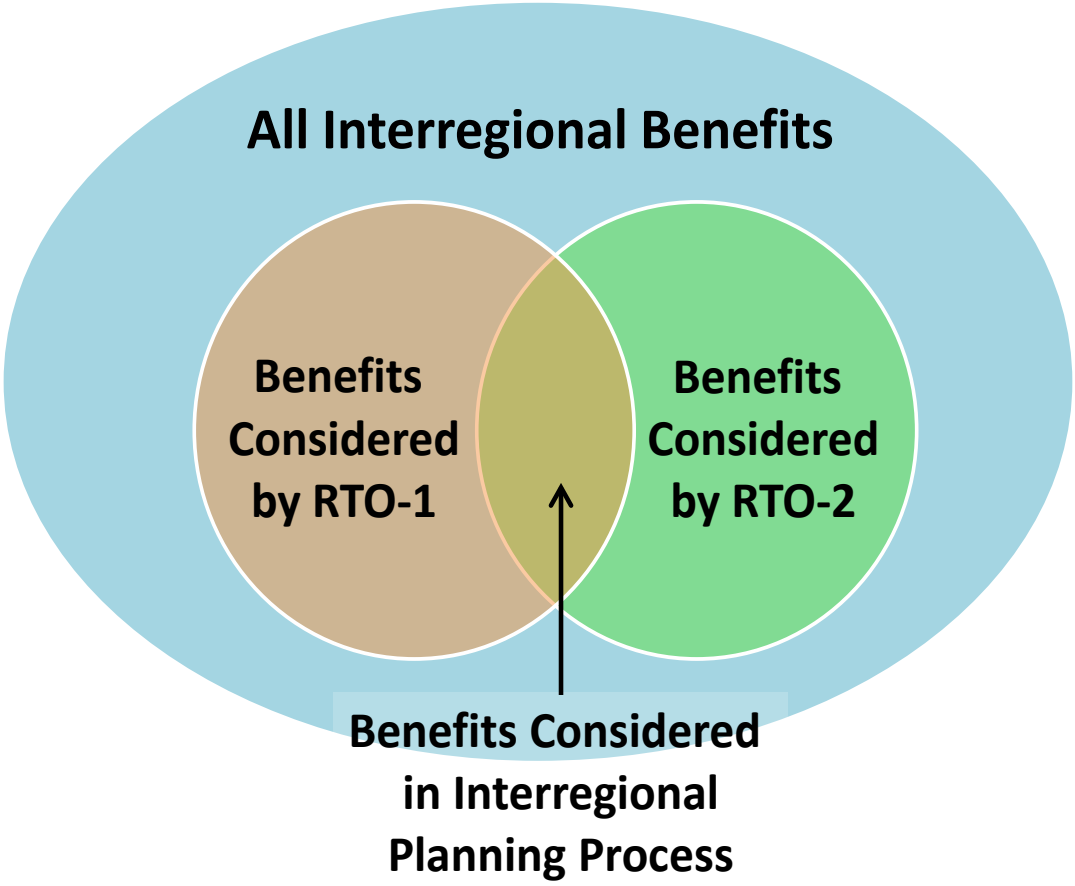
- Underinvestment in transmission with higher overall system-wide costs
  - Lost opportunities to identify lower-cost or higher-value projects
- An insufficiently robust/flexible grid that exposes customers and other market participants to higher risks

Example: Economic Benefits of Transmission

Benefit Category	**Transmission Benefit** (see 2013 WIRES paper)
Traditional Production Cost Savings	Production cost savings as currently estimated in most planning processes
1. Additional Production Cost Savings	a. Impact of generation outages and A/S unit designations
	b. Reduced transmission energy losses
	c. Reduced congestion due to transmission outages
	d. Mitigation of extreme events and system contingencies
	e. Mitigation of weather and load uncertainty
	f. Reduced cost due to imperfect foresight of real-time system conditions
	g. Reduced cost of cycling power plants
	h. Reduced amounts and costs of operating reserves and other ancillary services
	i. Mitigation of reliability-must-run (RMR) conditions
	j. More realistic "Day 1" market representation
2. Reliability and Resource Adequacy Benefits	a. Avoided/deferred reliability projects
	b. Reduced loss of load probability or c. reduced planning reserve margin
3. Generation Capacity Cost Savings	a. Capacity cost benefits from reduced peak energy losses
	b. Deferred generation capacity investments
	d. Access to lower-cost generation resources
4. Market Benefits	a. Increased competition
	b. Increased market liquidity
5. Environmental Benefits	a. Reduced emissions of air pollutants
	b. Improved utilization of transmission corridors
6. Public Policy Benefits	Reduced cost of meeting public policy goals
7. Employment and Economic Stimulus Benefits	Increased employment and economic activity; Increased tax revenues
8. Other Project-Specific Benefits	Examples: storm hardening, fuel diversity, flexibility, reducing the cost of future transmission needs, wheeling revenues, HVDC operational benefits

Example: Economic Benefits of Transmission

Divergent criteria in neighboring regions result in "least-common-denominator" planning approaches that significantly undervalues transmission between regions



- Experience already shows that few (if any) interregional projects are found to be cost effective under existing planning approaches
- Multiple threshold tests create additional hurdles
- Means that planning processes are unable to identify valuable projects transmission or reject them even if identified

Understating and Overstating Value

Developers and regulators proposing or opposing projects often either:

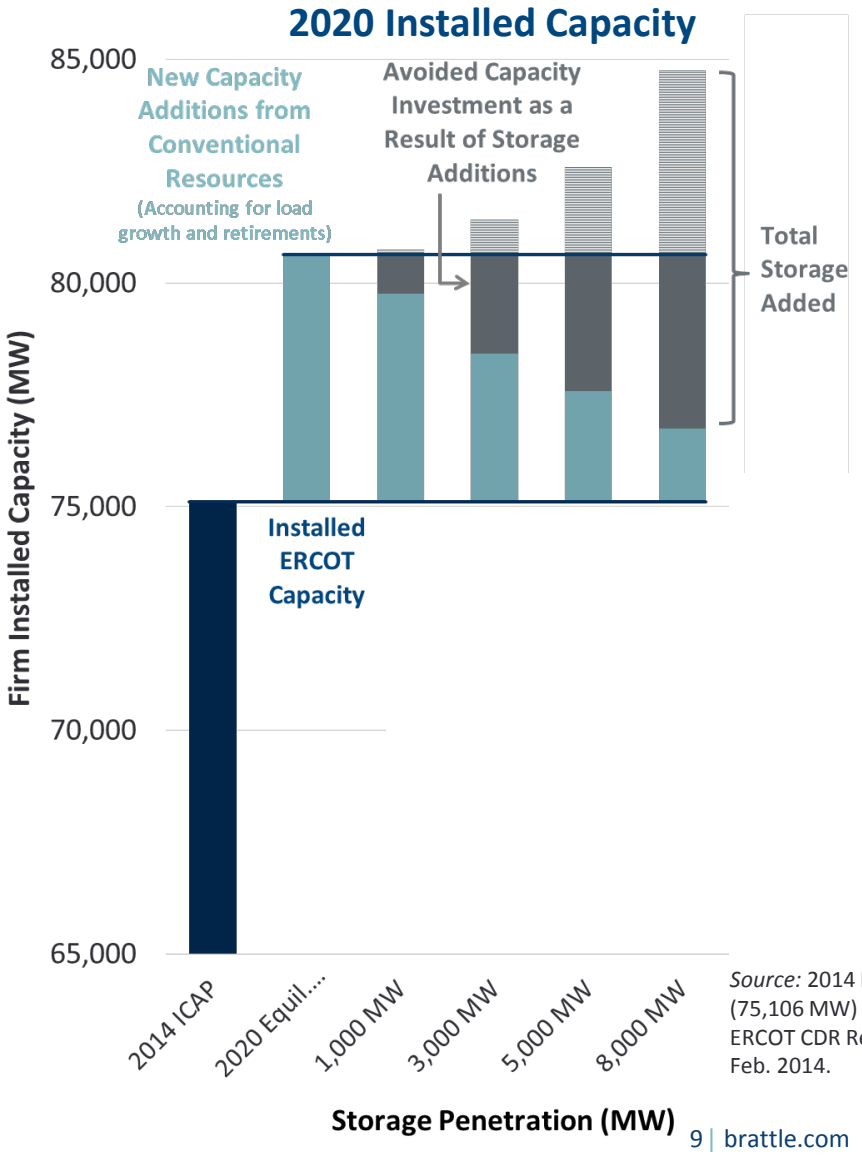
- **Understating value**: by not considering or not capturing some of the available (and sometimes "hidden") benefits
- **Overstating value**: by ignoring market responses, summing up benefits that are not additive, considering benefits that are overlapping (leading to double counting) or mutually exclusive

Example: List of (partially overlapping) storage-related benefits

1. Energy Market Arbitrage
2. Providing Ancillary Services
3. Reducing Ancillary Services Needs
4. Reducing Production Costs
5. Avoiding Generation Investments
6. Deferring of T&D Investments
7. Increasing Customer Reliability
7. Increasing Power Quality
8. Integrating Intermittent Renewable Resources
9. Reducing Cycling of Conventional Generation
10. Reducing Emissions
11. Reducing Line Losses

Example: Generation Investment Response

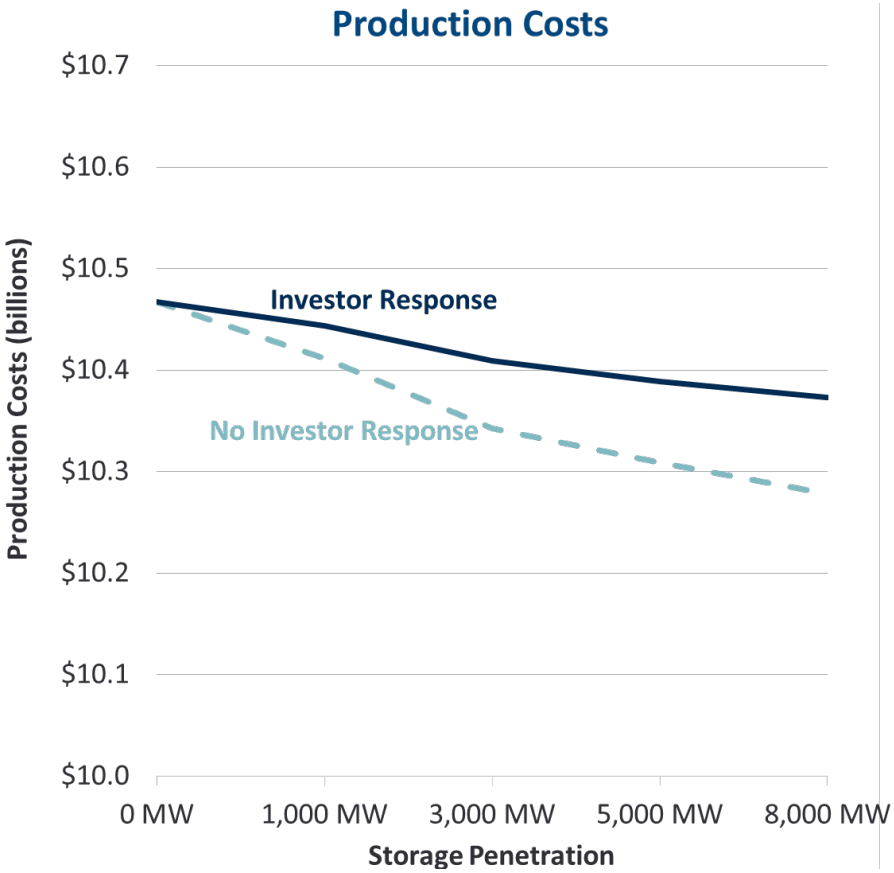
- Evaluated the likely generation investment (or retirement) **response to storage** added to the ERCOT system
- Simulated ERCOT's energy-only market in 2020 with and without storage:
  - With full "Operating Reserve Demand Curve"
  - With normal and extreme weather years to arrive at realistic distribution of generator margins
- Yields sustainable reserve margin consistent with a market outcome
  - 5,000 MW of storage results in 3,100 MW of reduced generation investment (or increased retirements)

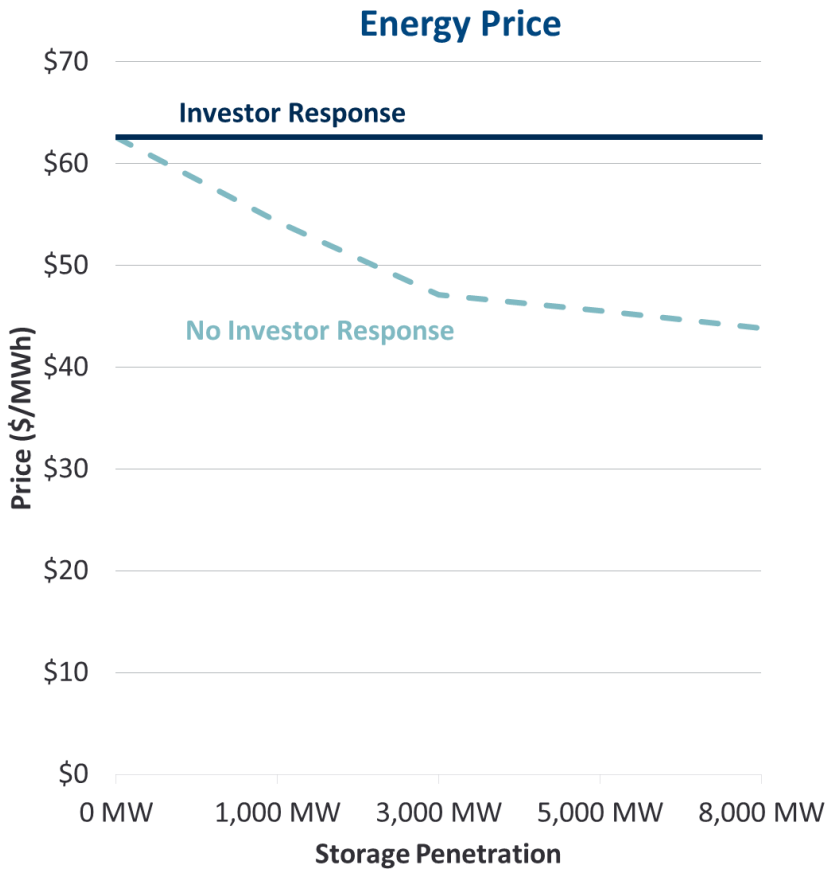


Source: 2014 ICAP (75,106 MW) From ERCOT CDR Report, Feb. 2014.

Example: Generation Investment Response

Generation investment (or retirement) response often will substantially reduces static estimates of price impacts and customers supply cost benefits





Example: Employment Benefits

Employment and economic stimulus benefits are routinely estimated for public policy-driven investments to justify financial support, but careful and proper interpretation of these values is extremely important

- Investments (e.g., in transmission) stimulate the local economy, produce additional tax revenues, support industrial growth, or allow the development of renewable power projects
  - These benefits are incremental to a region only if alternative activities do not and would not offer similar benefits
  - If employment rate is high, building more may not offer additional employment benefits to the region
  - Job creation alone does not ensure that an investment is a productive use of capital
  - The economic stimulus impact associated with a certain investment needs to be weighed against the implications of any increases in electricity costs

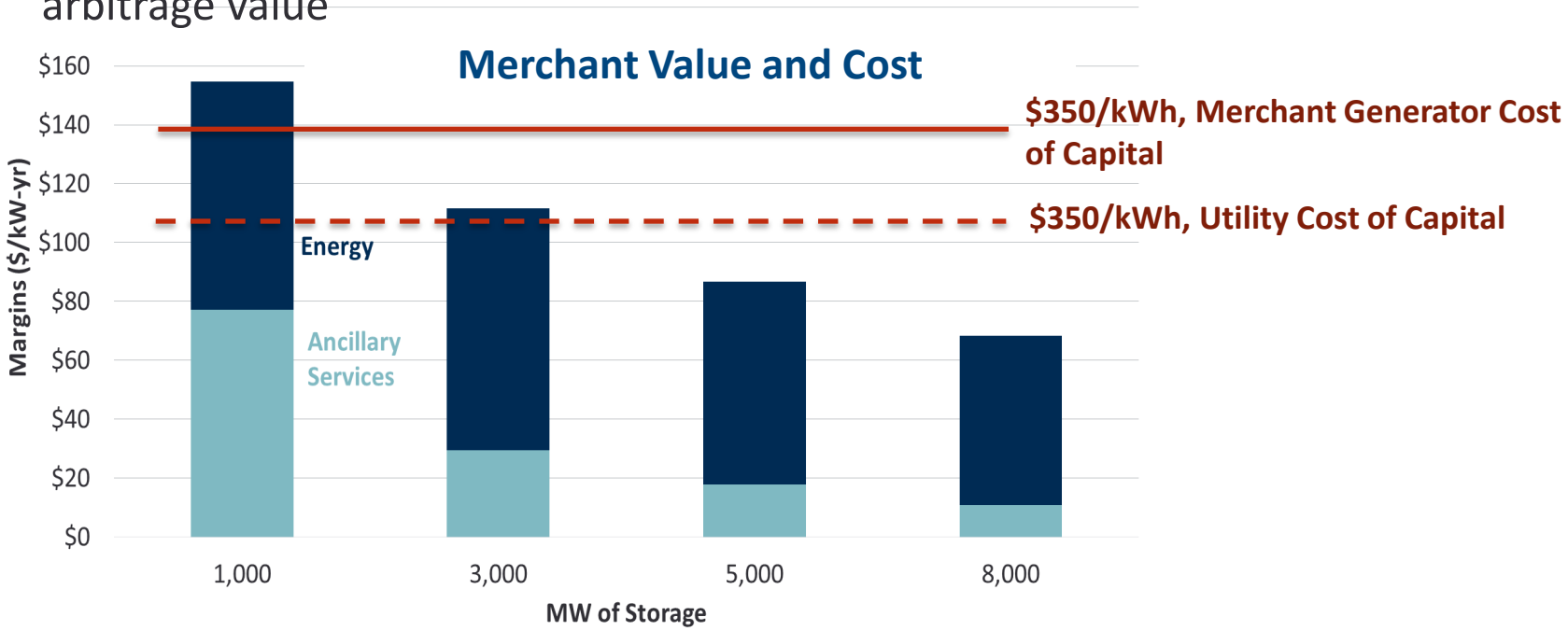
While useful information to policy makers, these benefits cannot simply be added to other project benefits for the purpose of benefit-cost analyses

Benefit to Whom? The Perspective Matters

Merchant Value	• Profits that a private investor could capture from the wholesale market • Driven mostly by energy arbitrage value and ancillary service prices • **Importance:** Determines whether wholesale market incentives by themselves are sufficient to attract investment
"Societal" or "System-Wide" Benefits	• System-wide benefits, including reduction in production, investment, and outage costs (regardless of whether suppliers or customers benefit) • Also known as “total resource cost” benefits • **Importance:** Sound policy for "economic" projects should require analysis of net “societal” or “system-wide” benefits
Customer Benefits	• Customer bill savings from reduced wholesale prices, deferred transmission and distribution costs, and revenue offsets • Increase in realized distribution system reliability (reduced outages) • **Importance:** Customer impact will always be a key metric for policy makers

Example: Merchant Value of Storage in ERCOT

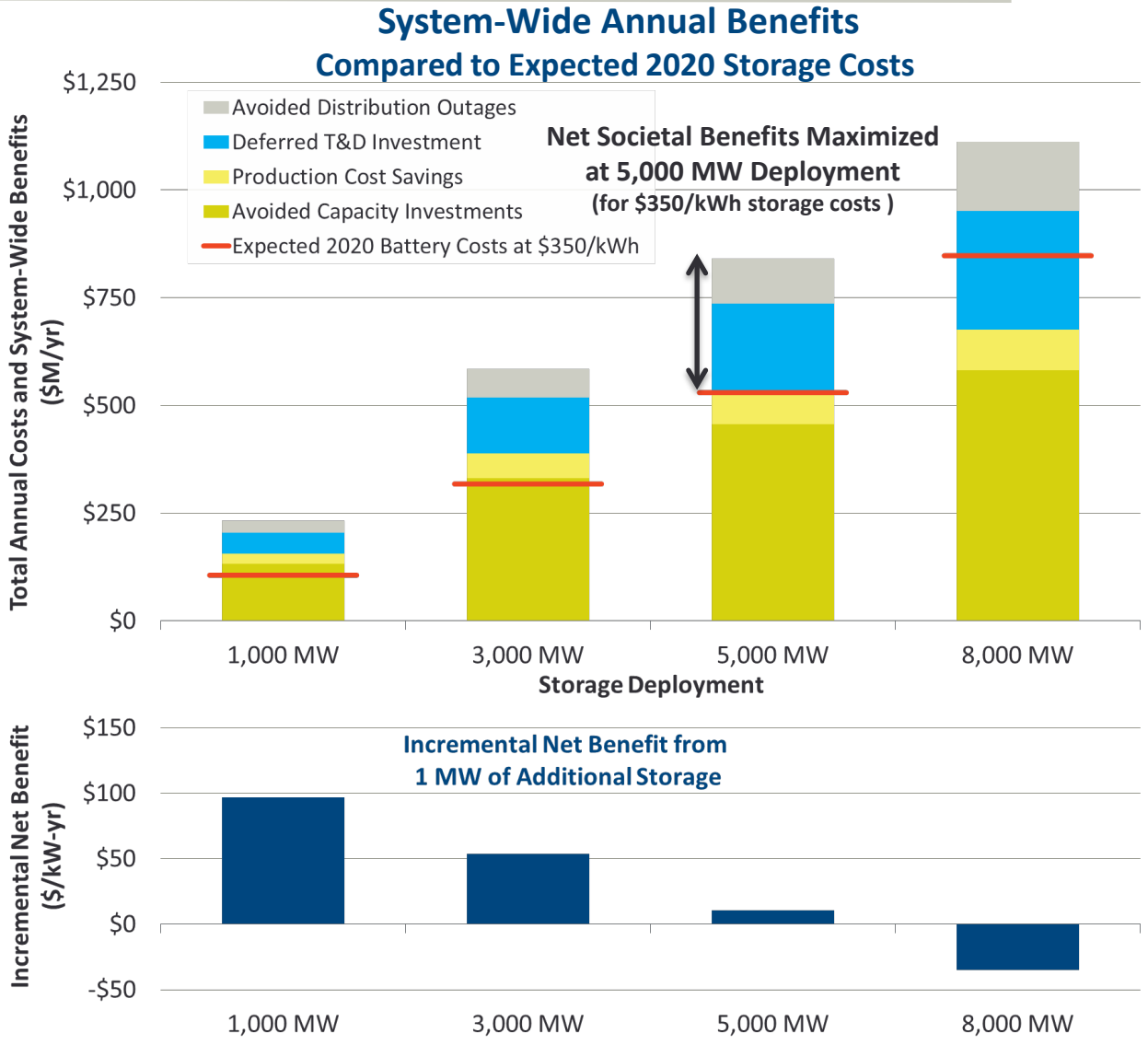
- Even at the low projected battery costs, the wholesale market value of storage (without capturing T&D and reliability benefits) is too limited to support merchant investments at significant scale
- Particularly true if cost remain above $350/kWh, if investment risks were to exceed merchant generators' cost of capital, or if technology limitation (e.g., on charging and discharging frequency) does not allow to capture the full energy arbitrage value



Notes: Merchant value represents the margins that a merchant investor would receive by participating in ERCOT's energy and ancillary services markets; assuming storage with a 3-hour discharge capability, 85% round-trip efficiency, and no other variable operations and maintenance (VOM) costs. Storage costs of $350/kW-y are based on battery vendors' estimates of $200/kWh as quoted to Oncor, plus an Oncor-estimated installation cost of $150/kWh, plus fixed operations and maintenance costs equal to 1% and 2% of investment costs for the "expected" and "high" cost levels.

Example: Societal Benefits of Storage in ERCOT

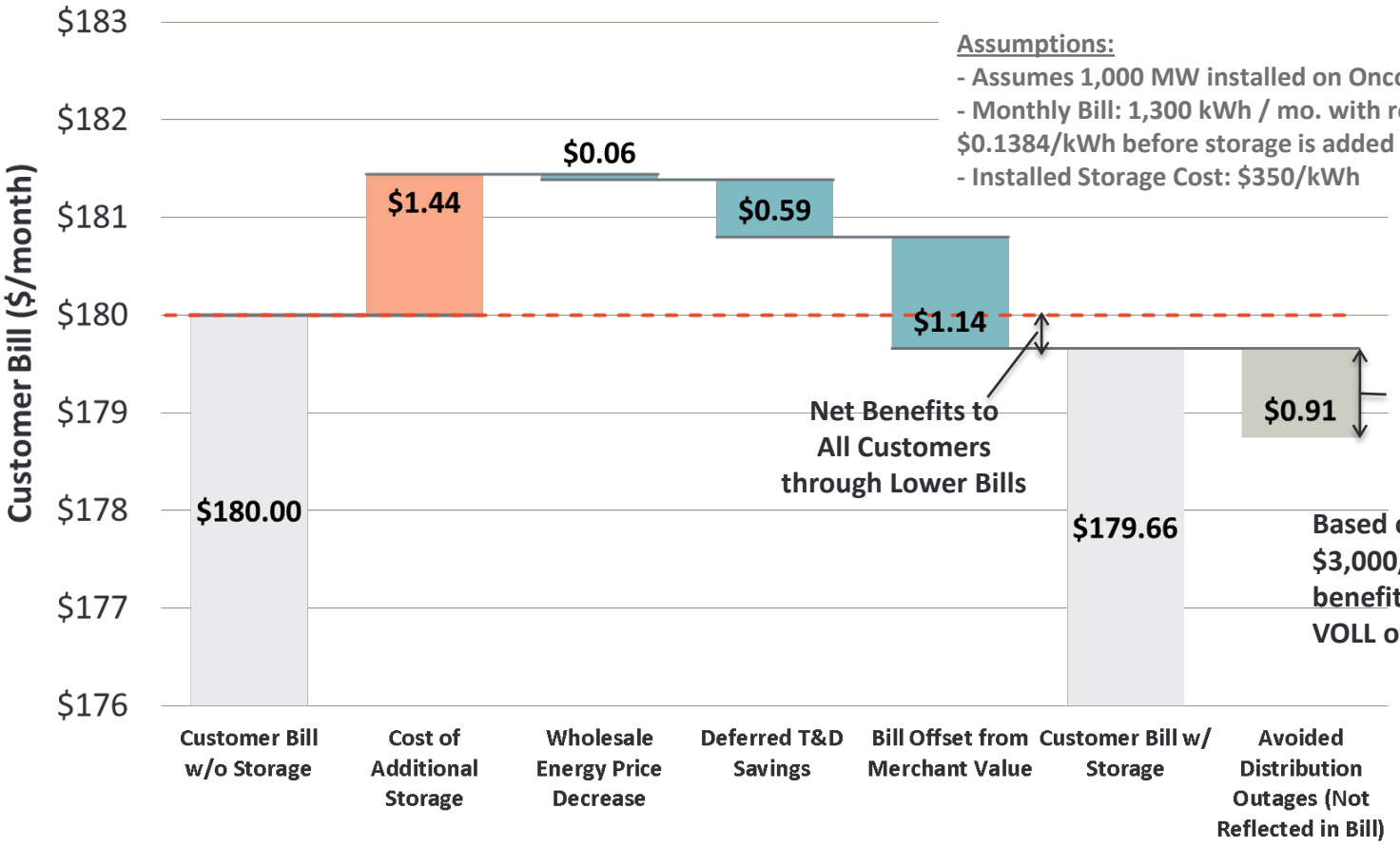
- From a system-wide societal perspective, distributed storage offers significant value streams:
  1. Avoided generation investments and production costs
  2. Deferred T&D investments
  3. Reduced outages
- At $350/kWh, the total value is maximized for **5,000 MW** of storage on an ERCOT-wide basis



Notes: The expected 2020 battery costs are annualized based on Oncor's 6.3% ATWACC, with 15- and 30-year assumed lifetime for the battery and balance of plant respectively.

Example: Consumer Benefits of Storage in ERCOT

Impact on Typical Residential Bill in 2020 for 3,000 MW of Storage ERCOT-wide



Assumptions:
- Assumes 1,000 MW installed on Oncor's System
- Monthly Bill: 1,300 kWh / mo. with retail rate $0.1384/kWh before storage is added
- Installed Storage Cost: $350/kWh

Net Benefits to All Customers through Lower Bills

Additional Reliability Benefits to the Subset of Residential Customers on Feeders with Storage

Based on residential VOLL of $3,000/MWh. C/I reliability benefit is much higher with VOLL of $20,000/MWh

Notes: We assume that Oncor installs 1,000 MW out of 3,000 MW of storage deployed on an ERCOT-wide basis, with storage costs and wholesale-market proceeds reflecting the same proportion of installations. Oncor customers realize deferred transmission and distribution investment benefits based on the 1,000 MW installed on Oncor's system. The avoided distribution outage value shown is for a typical residential customer on a feeder with storage. Customers not located on a feeder with storage would not realize these reliability benefits.

Conclusions and Recommendations

- Hidden values (externalities) reduce market payments that investors receive
  - Expand markets to capture the hidden values (e.g., internalize the cost of emissions) or allow for separate payments (e.g., customers to who value greater power quality to partially pay for storage investments)
- Regulated planning (e.g., integrated resource or economic transmission planning) is prone to either understating or overstating benefits
  - Understating value can leads to under-investment that increases costs and risks
  - Overstating value (e.g., price suppression) can lead to wasteful investments, higher costs, and potentially stranded assets in the future
  - Ensure that regulated investments are planned in an integrated manner
- Policies should focus on removing barriers to capturing all value streams and avoid under-investment
  - Investments with value streams in both competitive and regulated segments of the industry will require innovative policies that allow the full value to be captured without distorting competition
- Focus on societal benefit perspective, but do not ignore merchant value and customer benefits

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