Transmission – The Great Enabler: Recognizing Multiple Benefits in Transmission Planning

PRESENTED BY

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PRESENTED TO

ESIG Fall Workshop: Closing Plenary Session

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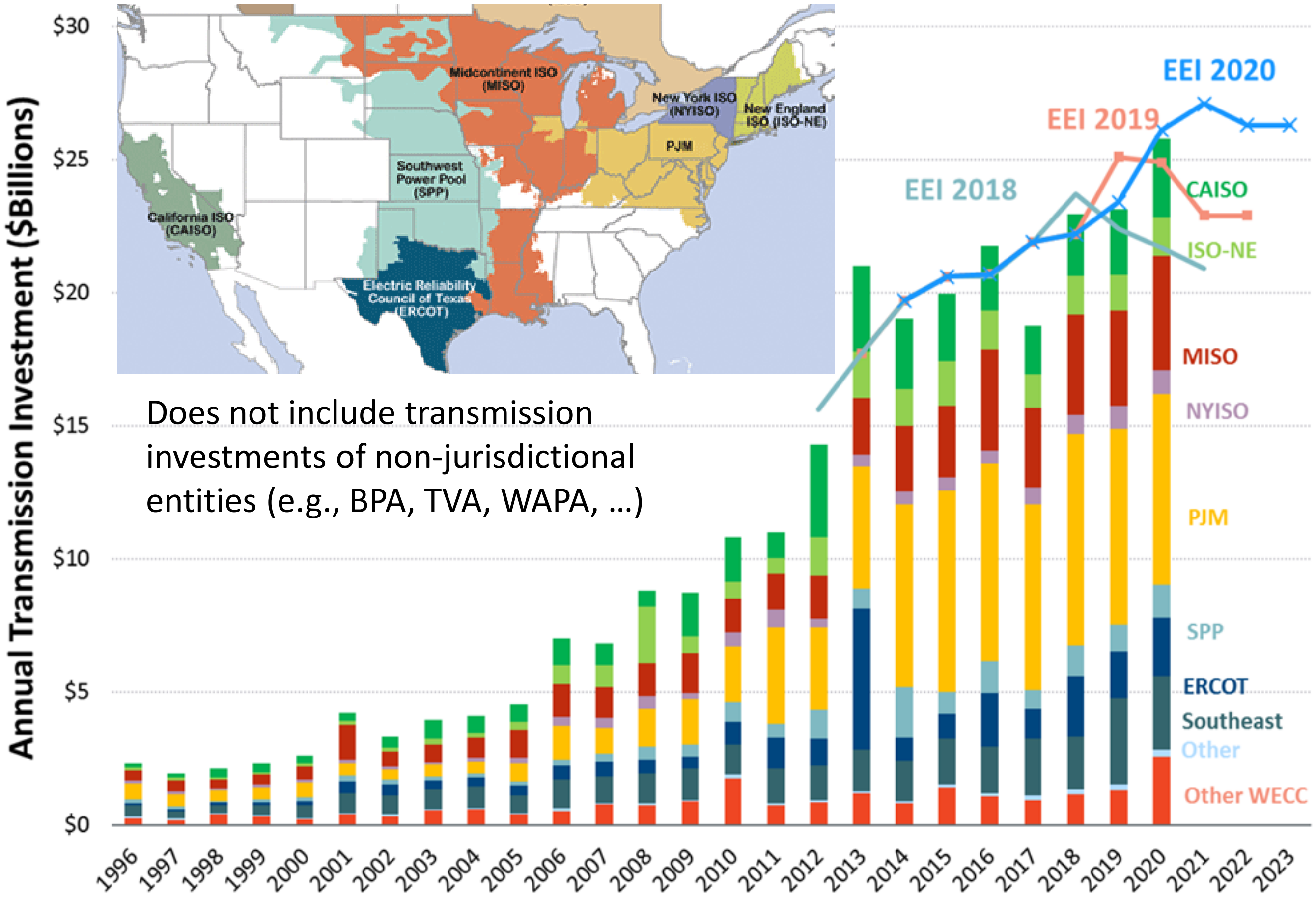
Brattle

Transmission Investment is at Historically High Levels

Annual Transmission Investment
As reported to FERC by Region (1996 – 2020)



Source: FERC Form 1 Data, EEI "Historical and Projected Transmission Investment" most recent accessed here: https://www.eei.org/resourcesandmedia/Documents/Historical%20and%20Projected%20Transmission%20Investment.pdf

$20-25 billion in annual U.S. transmission investment, but:

- More than 90% of it justified solely based on reliability needs without benefit-cost analysis
  - About 50% solely based on "local" utility criteria (without going through regional planning processes)
  - The rest justified by regional reliability and generation interconnection needs
- While significant experience with transmission benefit-cost analyses exists, very few projects are justified based on economics and overall cost savings

Current U.S. Transmission Planning = Higher Total Costs

Current planning processes do not yield the most valuable transmission infrastructure and result in higher overall costs:

- Reactive, reliability-driven planning results in piecemeal, higher-cost transmission solutions
  - For example: PJM generation interconnection studies for 15.5 GW of individual offshore wind plants identified $6.4 billion in onshore transmission upgrades
  - In contrast: A recent PJM study that proactive evaluated onshore upgrade needs for 17 GW of offshore wind (along with 14.5 GW of onshore wind and 45.6 GW of solar) identified only $3.2 billion in onshore upgrades
  - Result: **at least 50% lower costs** if renewable interconnection is planned proactively for the entire region's public policy needs (rather than one project at the time)
- Failure to evaluate multiple benefits of transmission projects does not result in the selection of the highest-value projects that reduce system-wide costs
- Failure to evaluate the full range of plausible futures (to explicitly account for long-term uncertainties), results in higher-cost outcomes when the future deviates from base case planning assumptions, which usually are based on "business-as-usual" or "current-trends" forecast
- Failure to consider interregional transmission solutions result in higher-cost regional and local transmission investments

The Electricity Industry is Undergoing Fundamental Changes, Which Will Require Improved Planning Processes

As many have articulated, the industry faces fundamental changes along three important dimensions (the "3Ds"), which will fundamentally change grid planning and operations

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; (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 <u>not</u> 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.

Needed: Transmission Planning for the 21st Century

Available experience already points to <u>proven planning practices</u> that reduce total system costs and risks:

1. **<u>Proactively plan</u> for future generation and load** by incorporating realistic projections of the anticipated generation mix, public policy mandates, load levels, and load profiles over the lifespan of the transmission investment.
2. **Account for the <u>full range of transmission projects' benefits</u>** and **<u>use multi-value planning</u>** to comprehensively identify investments that cost-effectively address all categories of needs and benefits.
3. **Address uncertainties and high-stress grid conditions explicitly through <u>scenario-based planning</u>** that takes into account a broad range of plausible long-term futures as well as real-world system conditions, including challenging and extreme events.
4. **Use comprehensive transmission <u>network portfolios</u>** to address system needs and cost allocation more efficiently and less contentiously than a project-by-project approach.
5. **Jointly <u>plan inter-regionally</u> across neighboring systems** to recognize regional interdependence, increase system resilience, and take full advantage of interregional scale economics and geographic diversification benefits.

Experience with Proactive & Comprehensive Planning Processes

Although still rarely used, significant experience exists with successful proactive, multi-benefit, portfolio-based transmission planning efforts:

	Proactive Planning	Multi-Benefit	Scenario-Based	Portfolio-Based	Interregional Transmission
CAISO TEAM (2004)[146]	✓	✓	✓		
ATC Paddock-Rockdale (2007)[147]	✓	✓	✓		
ERCOT CREZ (2008)[148]	✓			✓	
MISO RGOS (2010)[149]	✓	✓		✓	
EIPC (2010-2013)[150]	✓		✓	✓	✓
PJM renewable integration study (2014)[151]	✓		✓	✓	
NYISO PPTPP (2019)[152]	✓	✓	✓	✓	
ERCOT LTSA (2020)[153]	✓		✓		
SPP ITP Process (2020)[154]		✓		✓	
PJM Offshore Tx Study (2021)[155]	✓		✓	✓	
MISO RIIA (2021)[156]	✓	✓	✓	✓	
Australian Examples:					
- AEMO ISP (2020)[157]	✓	✓	✓	✓	✓
- Transgrid Energy Vision (2021)[158]	✓	✓	✓	✓	✓

Source: Transmission Planning for the 21st Century: Proven Practices that Increase Value and Reduce Costs (brattle.com)

Understanding Transmission-Related Benefits

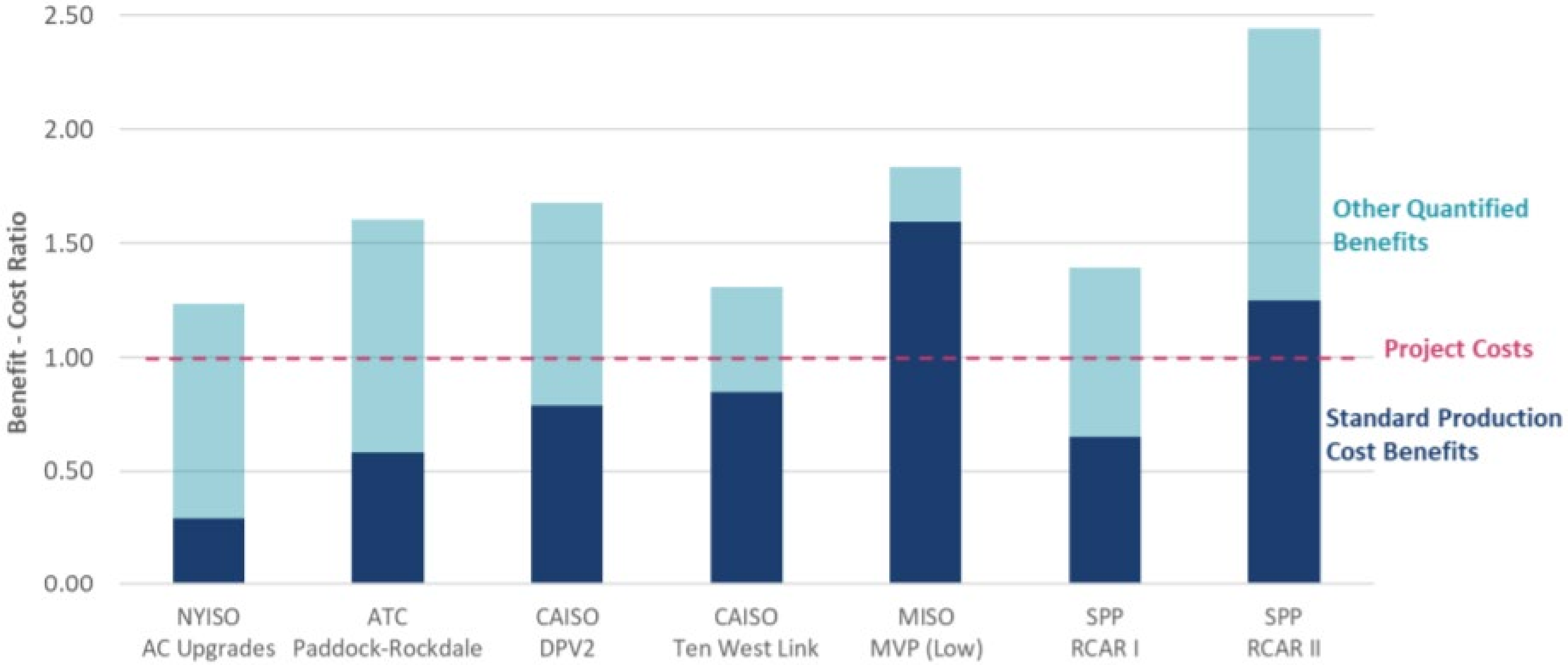
The wide-spread nature of transmission benefits creates challenges in estimating benefits and how they accrue to different users

▪ **Broad in scope, providing many <u>different types</u> of benefits**	• Increased reliability and operational flexibility • Reduced congestion, dispatch costs, and losses • Lower capacity needs and generation costs • Increased competition and market liquidity • Renewables integration and environmental benefits • Insurance and risk mitigation benefits • Diversification benefits (e.g., reduced uncertainty and variability) • Economic development from G&T investments
▪ **<u>Wide-spread</u> geographically**	• Multiple transmissions service areas • **<u>Multiple states</u>** or regions
▪ **<u>Diverse</u> in their effects on market participants**	• **<u>Customers</u>**, **<u>generators</u>**, **<u>transmission owners</u>** in regulated and/or deregulated markets • Individual market participants may capture one set of benefits but not others
▪ **Occur and <u>change</u> over long periods of time**	• Several decades (50+ years), typically increasing over time • Changing with system conditions and future generation and transmission additions • Individual market participants may capture different types of benefits at different times

Quantifying Benefits Beyond Production Cost Savings

Relying on solely on traditionally-quantified Adjusted Production Cost (APC) Savings results in the rejection of beneficial transmission projects:

FIGURE 5. BENEFIT-COST RATIOS OF TRANSMISSION PROJECTS WITH AND WITHOUT A BROAD SCOPE OF BENEFITS



Source: Transmission Planning for the 21st Century: Proven Practices that Increase Value and Reduce Costs (brattle.com)

The standard “Production Cost Savings” Metric Misses Many Important Transmission Benefits

Adjusted Production Costs (APC) is the most widely-used transmission benefit metric. It is a standard model output (e.g., from PROMOD, GRIDVIEW, etc) that is meant to capture the cost of generating power within an area, net of purchases and sales (imports and exports):

Adjusted Production Costs (APC) =

+ Production costs (fuel, variable O&M, startup, emission costs of generation within area)

+ Cost of hourly net purchases (valued at the area-internal load LMP)

– Revenues from hourly net sales (valued at the area-internal generation LMP)

Limitations:

- Assumes no losses; no unhedged congestion costs for delivering generation to load within each area
- Does not capture “gains of trade” – the extent that a utility can buy or sell at a better “outside” price
  - Assumes import-related congestion cannot at all be hedged with allocated FTRs
  - Assumes there here are no marginal loss refunds with imports or exports
- For simplicity, APC are typically only quantified for “normal” base-case conditions with perfect foresight
  - No transmission outages (every transmission element is assumed 100% available all the time)
  - Only “normal” conditions (weather-normalized loads, only “normal” generation outages)
  - No consideration of renewable generation uncertainty, change in A/S needs, reduction in transmission losses, fixed O&M cost of increased generation cycling, etc.
- Does not capture any investment-related (capacity cost) and risk-mitigation (insurance value) benefits

We have a Decade of Experience with Identifying and Quantifying a Broad Range of Transmission Benefits

SPP 2016 RCAR, 2013 MTF

Quantified

1. **production cost savings***
   - value of reduced emissions
   - reduced ancillary service costs
2. avoided transmission project costs
3. reduced transmission losses*
   - capacity benefit
   - energy cost benefit
4. lower transmission outage costs
5. value of reliability projects
6. value of mtg public policy goals
7. Increased wheeling revenues

Not quantified

8. reduced cost of extreme events
9. reduced reserve margin
10. reduced loss of load probability
11. increased competition/liquidity
12. improved congestion hedging
13. mitigation of uncertainty
14. reduced plant cycling costs
15. societal economic benefits

(SPP Regional Cost Allocation Review Report for RCAR II, July 11, 2016. SPP Metrics Task Force, *Benefits for the 2013 Regional Cost Allocation Review*, July, 5 2012.)

MISO MVP Analysis

Quantified

1. **production cost savings** *
2. reduced operating reserves
3. reduced planning reserves
4. reduced transmission losses*
5. reduced renewable generation investment costs
6. reduced future transmission investment costs

Not quantified

7. enhanced generation policy flexibility
8. increased system robustness
9. decreased natural gas price risk
10. decreased CO_2 emissions output
11. decreased wind generation volatility
12. increased local investment and job creation

(Proposed Multi Value Project Portfolio, Technical Study Task Force and Business Case Workshop August 22, 2011)

CAISO TEAM Analysis

(DPV2 example)

Quantified

1. **production cost savings*** and reduced energy prices from both a societal and customer perspective
2. mitigation of market power
3. insurance value for high-impact low-probability events
4. capacity benefits due to reduced generation investment costs
5. operational benefits (RMR)
6. reduced transmission losses*
7. emissions benefit

Not quantified

8. facilitation of the retirement of aging power plants
9. encouraging fuel diversity
10. improved reserve sharing
11. increased voltage support

(CPUC Decision 07-01-040, January 25, 2007, Opinion Granting a Certificate of Public Convenience and Necessity)

NYISO PPTN Analysis

(AC Upgrades)

Quantified

1. **production cost savings*** (includes savings not captured by normalized simulations)
2. capacity resource cost savings
3. reduced refurbishment costs for aging transmission
4. reduced costs of achieving renewable and climate policy goals

Not quantified

5. protection against extreme market conditions
6. increased competition and liquidity
7. storm hardening and resilience
8. expandability benefits

(Newell, et al., Benefit-Cost Analysis of Proposed New York AC Transmission Upgrades, September 15, 2015)

* Fairly consistent across RTOs

Brattle Group Reports on Transmission Benefit-Cost Analyses Summarize Much of the Available Experience

Well-Planned Electric Transmission Saves Customer Costs:
Improved Transmission Planning is Key to the Transition to a Carbon-Constrained Future

Link: https://bit.ly/3dnKrxe

PREPARED FOR

WIRES

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May 2016

THE Brattle GROUP

Toward More Effective Transmission Planning:
Addressing the Costs and Risks of an Insufficiently Flexible Electricity Grid

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Akarsh Sheilendranath

April 2015

Link: https://bit.ly/2GU4h7w

The Brattle Group

Link: https://bit.ly/3jS0PsB

The Benefits of Electric Transmission: Identifying and Analyzing the Value of Investments

July 2013

Judy W. Chang
Johannes P. Pfeifenberger
J. Michael Hagerty

Link: https://bit.ly/2KaFLAk

BU
Boston University Institute for Sustainable Energy

The Value of Diversifying Uncertain Renewable Generation through the Transmission System

September • 2020

Transmission Planning for the 21st Century: Proven Practices that Increase Value and Reduce Costs

Link: Brattle Grid Strategies

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GRID STRATEGIES LLC

Documents proven approaches to quantifying various benefits

"Checklist" of Transmission Benefits With Proven Practices for Quantifying Them

We have documented in our recent report (filed with ANOPR comments), available proven practices:

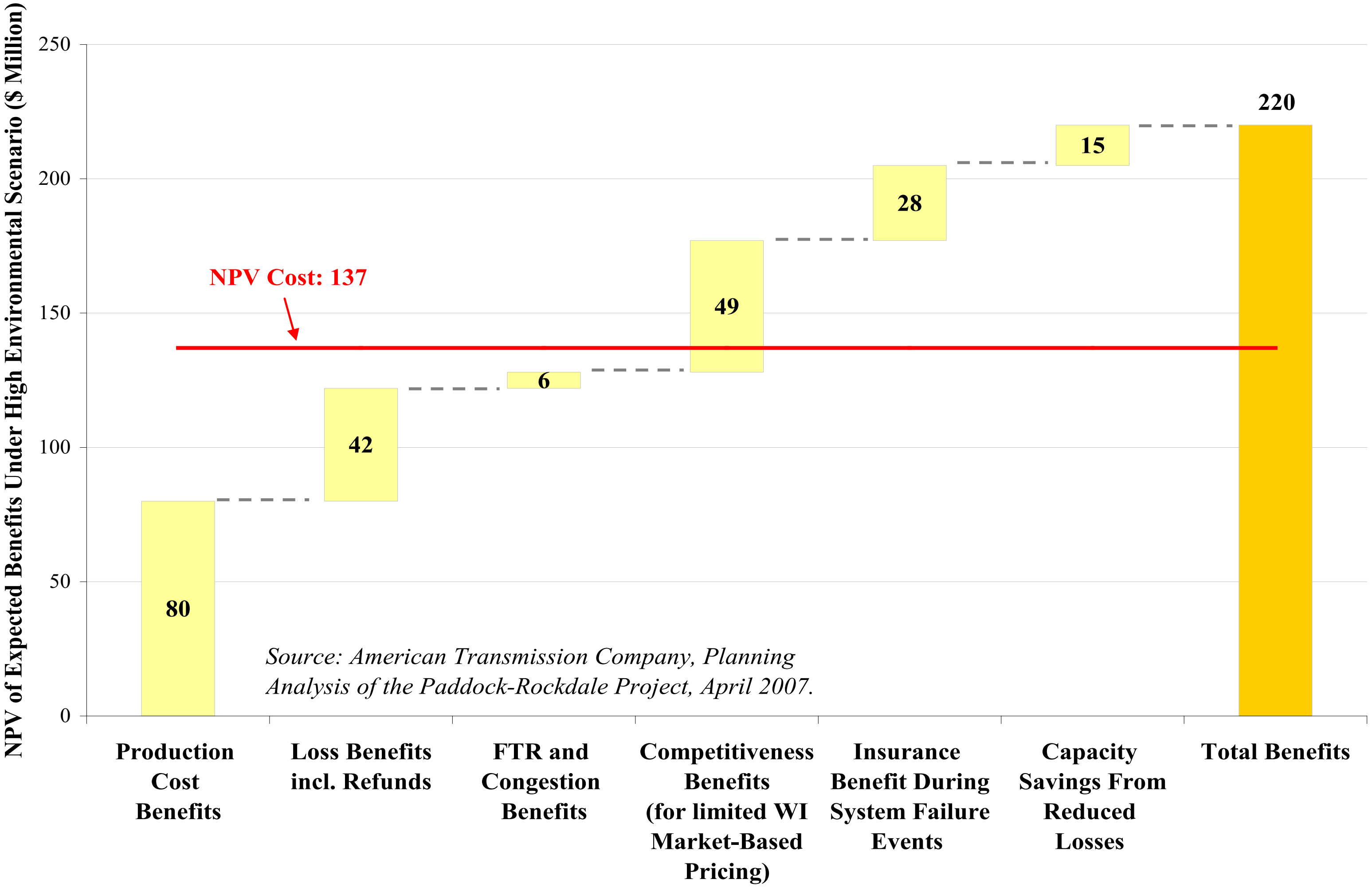
1. Consider for each project (or synergistic portfolio of projects) the full set of benefits transmission can provide (*see* table)
2. Identify the benefits that plausibly exist and may be significant for that particular project or portfolio; then
3. Focus on quantifying those benefits

(See our recent report with Grid Strategies for a summary of quantification practices)

Benefit Category	Transmission Benefit
1. Traditional Production Cost Savings	Adjusted Production Cost (APC) savings as currently estimated in most planning processes
2. Additional Production Cost Savings	i. Impact of generation outages and A/S unit designations
	ii. Reduced transmission energy losses
	iii. Reduced congestion due to transmission outages
	iv. Reduced production cost during extreme events and system contingencies
	v. Mitigation of typical weather and load uncertainty, including the geographic diversification of uncertain renewable generation variability
	vi. Reduced cost due to imperfect foresight of real-time system conditions, including renewable forecasting errors and intra-hour variability
	vii. Reduced cost of cycling power plants
	viii. Reduced amounts and costs of operating reserves and other ancillary services
	ix. Mitigation of reliability-must-run (RMR) conditions
	x. More realistic "Day 1" market representation
3. Reliability and Resource Adequacy Benefits	i. Avoided/deferred cost of reliability projects (including aging infrastructure replacements) otherwise necessary
	ii. (a) Reduced loss of load probability or (b) reduced planning reserve margin
4. Generation Capacity Cost Savings	i. Capacity cost benefits from reduced peak energy losses
	ii. Deferred generation capacity investments
	iii. Access to lower-cost generation resources
5. Market Facilitation Benefits	i. Increased competition
	ii. Increased market liquidity
6. Environmental Benefits	i. Reduced expected cost of potential future emissions regulations
	ii. Improved utilization of transmission corridors
7. Public Policy Benefits	Reduced cost of meeting public policy goals
8. Other Project-Specific Benefits	Examples: increased storm hardening and wild-fire resilience, increased fuel diversity and system flexibility, reduced cost of future transmission needs, increased wheeling revenues, HVDC operational benefits

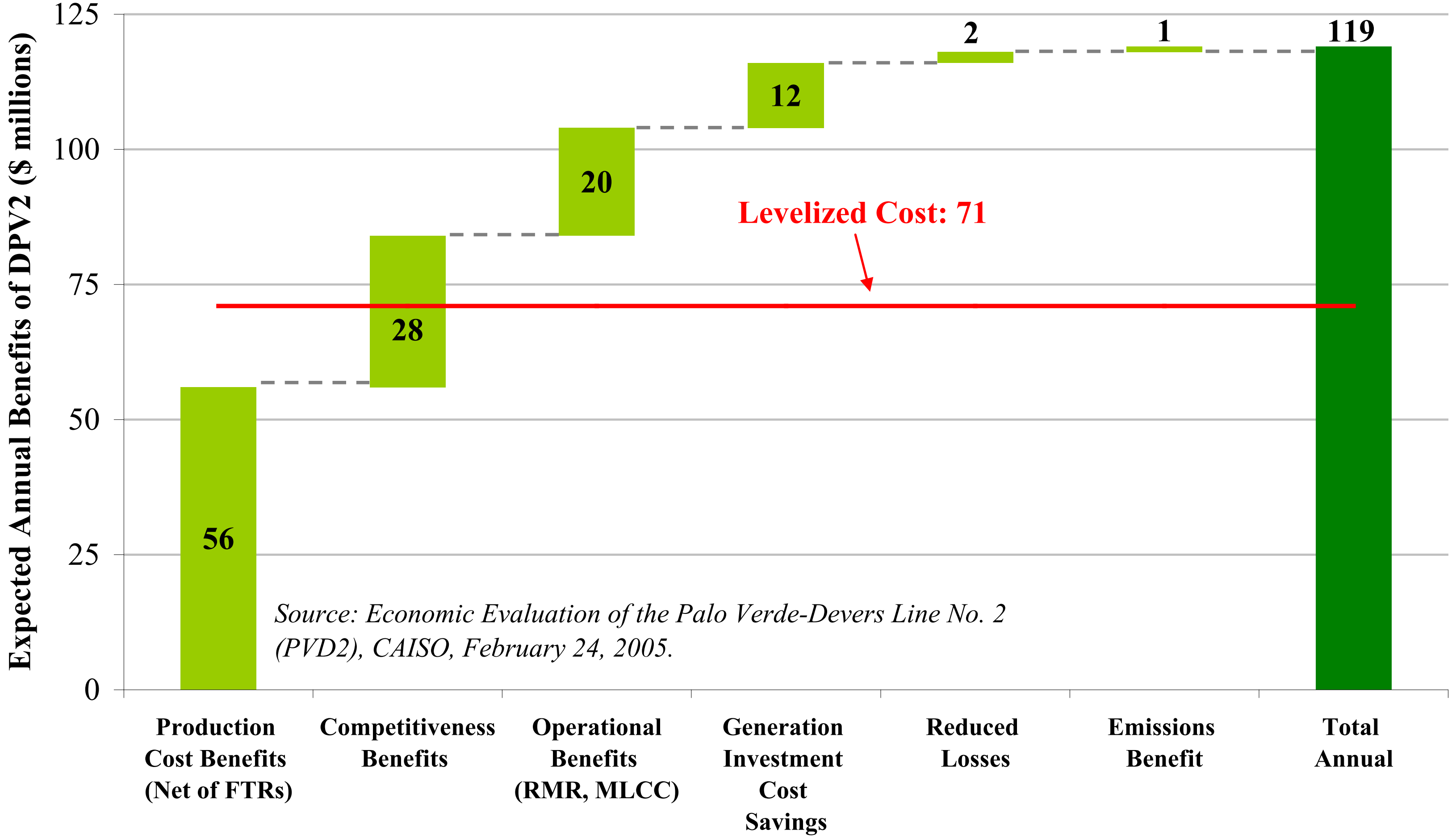
Example: Transmission Benefits and Costs in Wisconsin

ATC's Paddock-Rockdale Project study: Total benefits significantly exceed production cost savings



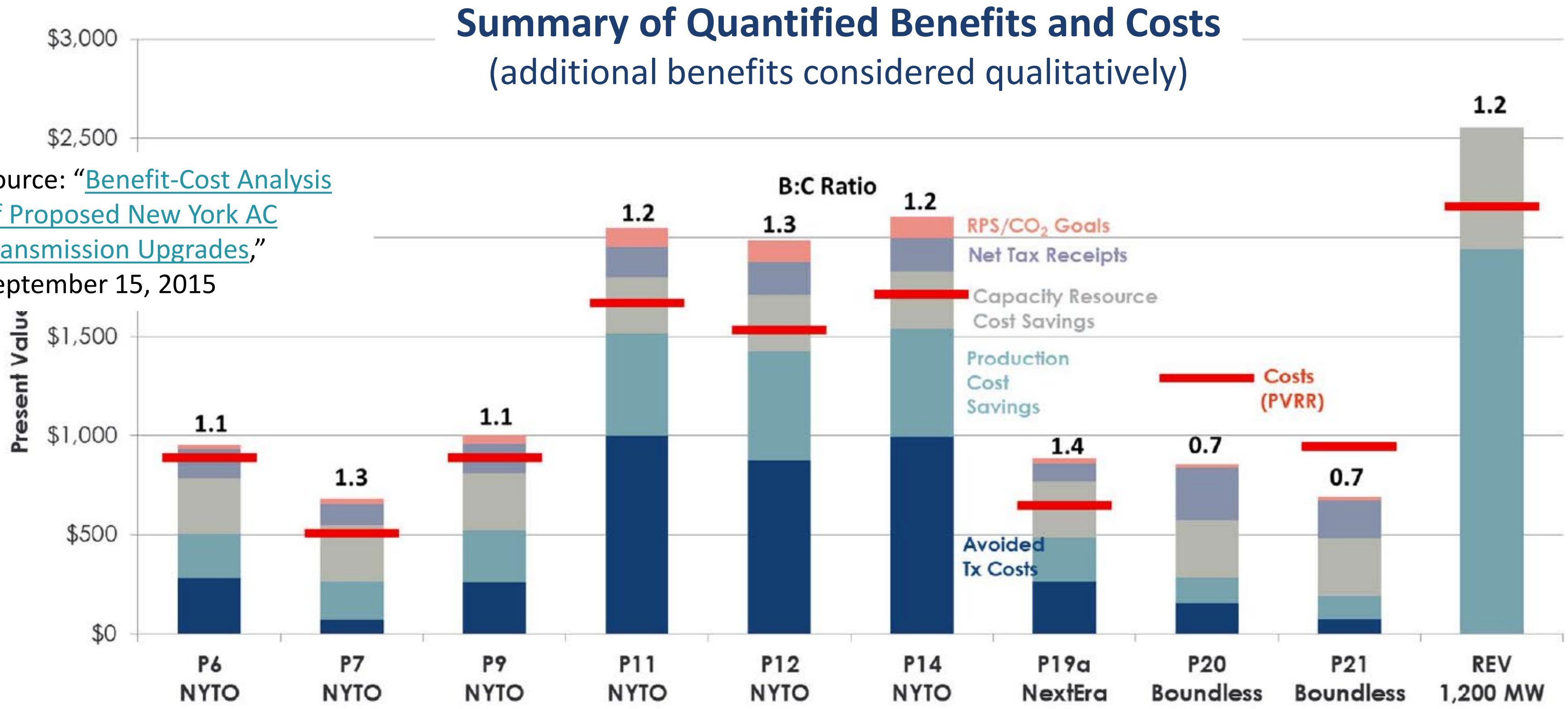
Example: CAISO Transmission Project Benefits vs. Costs

Total benefits of CAISO's DPV2 project exceeded project costs by more than 50%, but only if multiple benefits are quantified



Example: New York's (Multi-Value) "Public Policy" Transmission Planning Process

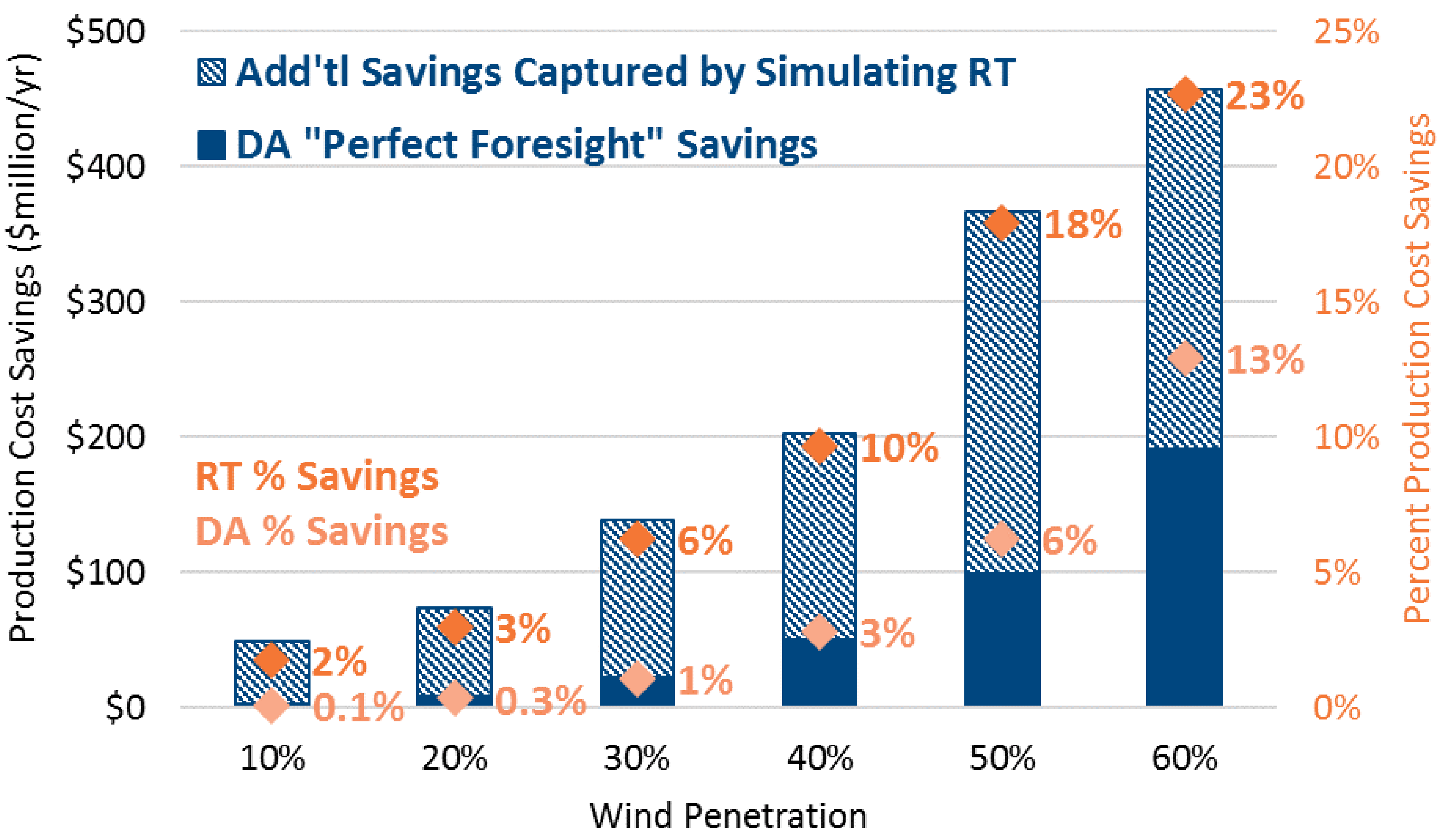
New York DPS recently modified its "public policy" transmission planning process by mandating that a full set of benefits be considered. Resulted in approval and competitive solicitation of two major upgrades to the New York transmission infrastructure



Source: "Benefit-Cost Analysis of Proposed New York AC Transmission Upgrades," September 15, 2015

Simulating Forecast Uncertainty → Higher, More Accurate Benefits

Annual Production Cost Savings, RT vs DA-only "Perfect Foresight" Simulation



Key takeaways

- Quantified transmission benefits can be significantly understated using the prevailing "Perfect Foresight" simulation approach:
  - **RT = 10x DA at 20% renewables**
  - **RT = 3x DA at 50% renewables**
- The higher benefit means optimal tradeoff shifts more from building local renewables to building more regional and interregional transmission to cost-effectively meet policy goals

Inadequate Transmission Creates High Risks of Costly Outcomes in Both Short- and Long-term

Most transmission planning efforts do not adequately account for short- and long-term risks and uncertainties affecting power markets

- **Short-Term Risks:** transmission planning generally evaluates only "normal" system conditions
  - Planning process typically ignores the high cost of **short-term challenges and extreme market conditions** triggered by high-impact-low-probability ("HILP") events due to weather, transmission outages, fuel supply disruption, or unexpected load changes associated with economic booms/busts
  - Can be addressed through modeling assumptions and **sensitivities** that capture these short-term challenges
- **Long-Term Risks:** Planning does not adequately consider the full range of long-term scenarios
  - Does not capture the extent to which a less robust and flexible transmission infrastructure will help reduce the **risk of high-costs incurred under different (long-term) future market fundamentals**
  - Can be addressed through improved **scenario planning** that covers the full range of plausible futures

A more flexible and robust grid provides "insurance value" by reducing the risk of high-cost (short- and long-term) outcomes due to inadequate transmission

- Costs of inadequate infrastructure (typically are not quantified) can be much greater than the costs of the transmission investment
- Project may not quite be cost effective in "base case" future but be highly beneficial in 3 out of 5 futures

Risk Mitigation Through Transmission Investments

Additional considerations regarding the risk mitigation and insurance value of transmission infrastructure:

- Given that it can take a decade to develop new transmission, delaying investment can easily **limit future options** and result in a **higher-cost, higher-risk** overall outcomes
  - “Wait and see” approaches limit options, so can be costly in the long term
  - The industry needs to plan for both short- and long-term uncertainties more proactively – and develop "anticipatory planning" processes
- **“Least regrets” planning** too often only focuses on identifying those projects that are <u>beneficial under most circumstances</u>
  - Does not consider the many potentially “regrettable circumstances” that could result in very high-cost outcomes
  - Focuses too much on the cost of insurance without considering the cost of not having insurance when it is needed
- **Probabilistic weighting assumes risk neutrality** and does not distinguish between investment options with very different risk distributions

Example: Better "Least-Regrets" Planning

"Least Regrets" analysis can help planners avoid decisions that reduce flexibility to respond to uncertain future market conditions

- The "least-regrets" option may not be **"least cost"** in any future (nor have the lowest cost on a probability-weighted average basis)

Total Cost to Customers of 3 Options in 4 Futures (Option 1 can be not building)

	Future 1	Future 2	Future 3	Future 4	Average
Option 1	$100m	$120m	$125m	$144m	**$122m**
Option 2	$105m	$121m	$128m	$134m	**$122m**
Option 3	$110m	$121m	$128m	$130m	**$122m**

Option 1 is **least cost** in Futures 1-3

Option 3 is **least cost** in Future 4

Difference Between Lowest-Cost Option and Maximum Regret of Each Option

	Future 1	Future 2	Future 3	Future 4	Max Regret
Option 1	--	--	--	$14m	$14m
Option 2	$5m	$1m	$3m	$4m	$5m
Option 3	$10m	$1m	$3m	--	$10m

Option 2 is **least regret** across all Futures

https://nicholasinstitute.duke.edu/sites/default/files/publications/ni_wp_13-05.pdf

Scenario Analysis Example: ATC's Paddock-Rockdale Project

In evaluating the Paddock-Rockdale Project, ATC evaluated <u>seven</u> plausible futures, spanning the range of long-term uncertainties.

- The 40-year PV of customer benefits fell short of the $136 million PV of the project's revenue requirement in the "Slow Growth" future, but exceeded the costs in all other futures
- The <u>net</u> benefits in the other six futures ranged from:
  - $100 million (above cost) under the "High Environmental" future
  - to approx. $400 million under the "Robust Economy" and "High Wisconsin Growth" futures
  - reaching up to approx. $700 million under the "Fuel Supply Disruption" and "High Plant Retirements" futures

The analyses of multiple scenarios of plausible futures show:

- The estimated benefits can range widely across sets of plausible futures
- The project is beneficial in most (but not all) futures
- Not investing in the $136 million project can leave customers up to $700 million worse off in two of seven plausible futures

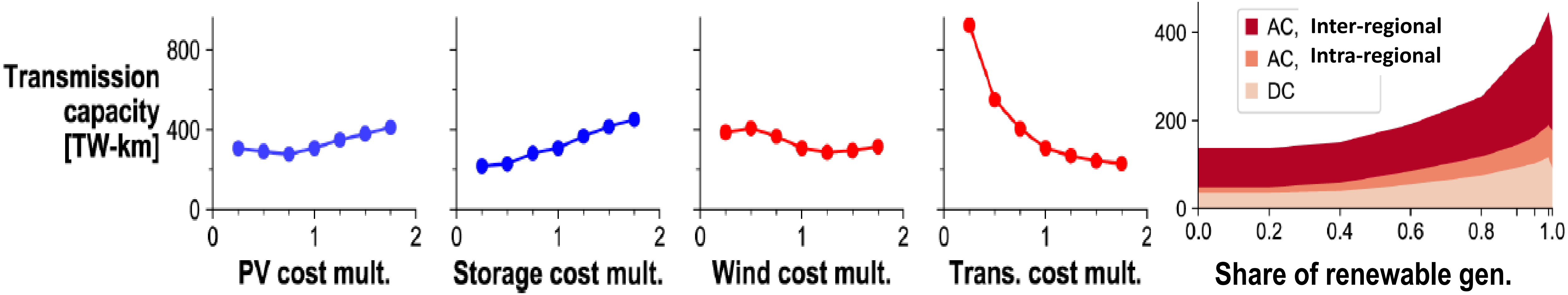
Implications of Increasingly Cost-Effective Renewables, Storage, and Advanced Transmission Technologies

The declining costs and accelerating adoption of new energy technologies has profound implications on how the grid will have to be planned and operated in 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 regional and interregional grid will increasingly shift from instantaneously delivering energy+capacity to 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, flow and topology control) can help keep transmission to be a cost-effective, competitive solution in light of declining renewables+storage costs
  - But near-term fears of "lower ratebase" would need to yield to a longer-term strategic goal maximizing the value of transmission in face of declining costs of complementary technologies (renewables, storage)

Transmission Benefits Depend on the Cost and Mix of Resources

MIT's simulations show that the most beneficial level of transmission investment…



…increases 25% if solar costs are higher than projected

…declines 25% at lower storage costs; increases 25% at higher storage costs

…almost doubles at lower cost of wind generation

…increases exponentially with declining transmission costs

… (a) is about double today's transfer capability at low shares and (b) increases exponentially with growing shares of renewables

Source: Brown, P. R., and A. Botterud. 2020. "The Value of Inter-Regional Coordination and Transmission in Decarbonizing the U.S. Electricity System." Joule 5(1): 115-134. https://doi.org/10.1016/j.joule.2020.11.013.

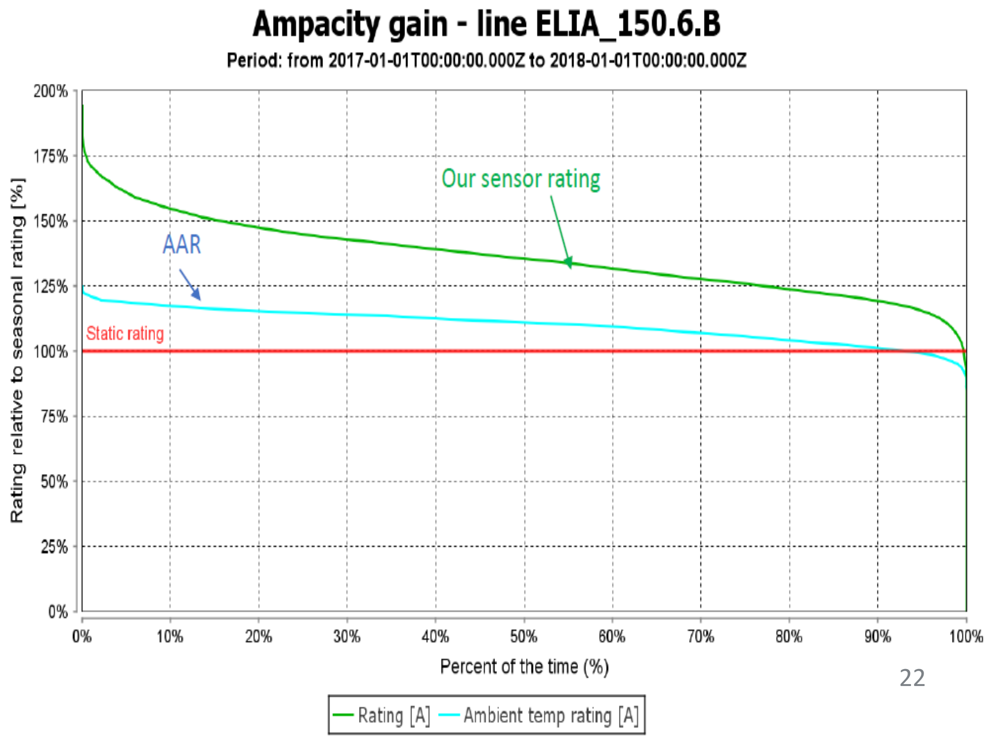
Advanced Grid Technologies: Making Transmission More Valuable

Advanced transmission technologies can significantly increase the capability of the existing grid and make new transmission projects more cost-effective and valuable, reducing syste-wide costs

- Increasingly well-tested and commercially-applied technologies include: dynamic line rating, smart wires and flow control devices, grid-optimized storage, and topology optimization.
- Can be deployed quickly to integrate renewable on existing grid (see Chapter III of NY Power Grid Study)
- Brattle case study in SPP: DLR, topology optimization, and advanced power-flow controls can integrate 2,670 MW of renewable generation for $90 million

Example: Dynamic Line Ratings (DLR)

- DLR can increase transmission ratings above static ratings by 25-30% on average over a year at 5% of the cost of a new line
  - **Increase > 10% during 90% of the year, > 25% during 75% of the year, and > 50% during 15% of the year**
  - During 2% of the year dynamic line ratings are below static ratings, increasing reliability and system awareness
- Particularly effective in reducing (on-ramp-related) curtailments of wind energy (particularly in markets, like EIM)
- Elia, the grid operator in Belgium, has successfully applied DLR since 2008; now used on 35 major transmission lines; U.S. experience too



Summary and Recommendations

Benefit-cost analyses and cost allocations can be improved to offer more cost-effective and less controversial outcomes:

- More fully consider broad range of reliability, economic, and public-policy benefits, including experience gained though:
  - SPP value of transmission and RCAR benefits metrics
  - NYISO broad set of benefits quantified for public policy projects
  - MISO MVP benefits; CAISO economic and public policy projects
- Reduce divisiveness of cost allocation through broad set of portfolio-based benefits
  - Recognize broad range of benefits → more likely to be evenly distributed and exceed costs
  - Focus on larger portfolios of transmission projects → more uniform distribution of benefits
  - Broad range of benefits for a portfolio will also be more stable over time

In addition: Focus less on addressing near-term reliability and local needs, but proactively on infrastructure that provides greater flexibility and higher long-term value at lower system-wide cost

- Recognize that every transmission project offers multiple values
- Lowest-cost transmission is not "least cost" from an overall customer-cost perspective

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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 Senior Fellow at Boston University's Institute of Sustainable Energy (BU-ISE), a Visiting Scholar at MIT's Center for Energy and Environmental Policy Research (CEEPR), and serves as an advisor to research initiatives by the Lawrence Berkeley National Laboratory's (LBNL's) Energy Analysis and Environmental Impacts Division and the US Department of Energy's (DOE's) Grid Modernization Lab Consortium.

Hannes specializes in transmission and wholesale power markets. He has recent studied New York power grid needs, evaluated offshore wind transmission options in New York State and New England, analyzed the role of renewable generation and transmission in economy-wide decarbonization, and presented renewable integration challenges at a number of industry meetings, including the Atlantic Council and the Harvard Electricity Policy Group.

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.

Additional Reading on Transmission

Pfeifenberger et al, Transmission Planning for the 21st Century: Proven Practices that Increase Value and Reduce Costs, Brattle-Grid Strategies, October 2021.

Pfeifenberger, Transmission Options for Offshore Wind Generation, NYSERDA webinar, May 12, 2021.

Pfeifenberger, Transmission Planning and Benefit-Cost Analyses, presentation to FERC Staff, April 29, 2021.

Pfeifenberger et al, Initial Report on the New York Power Grid Study, prepared for NYPSC, January 19, 2021.

Pfeifenberger, "Transmission Cost Allocation: Principles, Methodologies, and Recommendations," prepared for OMS, Nov 16, 2020.

Pfeifenberger, Ruiz, Van Horn, "The Value of Diversifying Uncertain Renewable Generation through the Transmission System," BU-ISE, October 14, 2020.

Pfeifenberger, Newell, Graf and Spokas, "Offshore Wind Transmission: An Analysis of Options for New York", prepared for Anbaric, August 2020.

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Ruiz, "Transmission Topology Optimization: Application in Operations, Markets, and Planning Decision Making," May 2019.

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Brattle Group Practices and Industries

ENERGY & UTILITIES

- Competition & Market Manipulation
- Distributed Energy Resources
- Electric Transmission
- Electricity Market Modeling & Resource Planning
- Electrification & Growth Opportunities
- Energy Litigation
- Energy Storage
- Environmental Policy, Planning and Compliance
- Finance and Ratemaking
- Gas/Electric Coordination
- Market Design
- Natural Gas & Petroleum
- Nuclear
- Renewable & Alternative Energy

LITIGATION

- Accounting
- Analysis of Market Manipulation
- Antitrust/Competition
- Bankruptcy & Restructuring
- Big Data & Document Analytics
- Commercial Damages
- Environmental Litigation & Regulation
- Intellectual Property
- International Arbitration
- International Trade
- Labor & Employment
- Mergers & Acquisitions Litigation
- Product Liability
- Securities & Finance
- Tax Controversy & Transfer Pricing
- Valuation
- White Collar Investigations & Litigation

INDUSTRIES

- Electric Power
- Financial Institutions
- Infrastructure
- Natural Gas & Petroleum
- Pharmaceuticals & Medical Devices
- Telecommunications, Internet, and Media
- Transportation
- Water

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