Transmission Planning Strategies to Accommodate Renewables

PRESENTED AT:

EUCI Austin – Renewable Energy Grid Operations

PREPARED BY:

J. Michael Hagerty
Johannes Pfeifenberger
Judy Chang

September 11, 2017

THE Brattle GROUP

Agenda

Electricity Industry Trends Driving Transmission

Regional Approaches to Transmission Planning

Transmission Planning Improvements

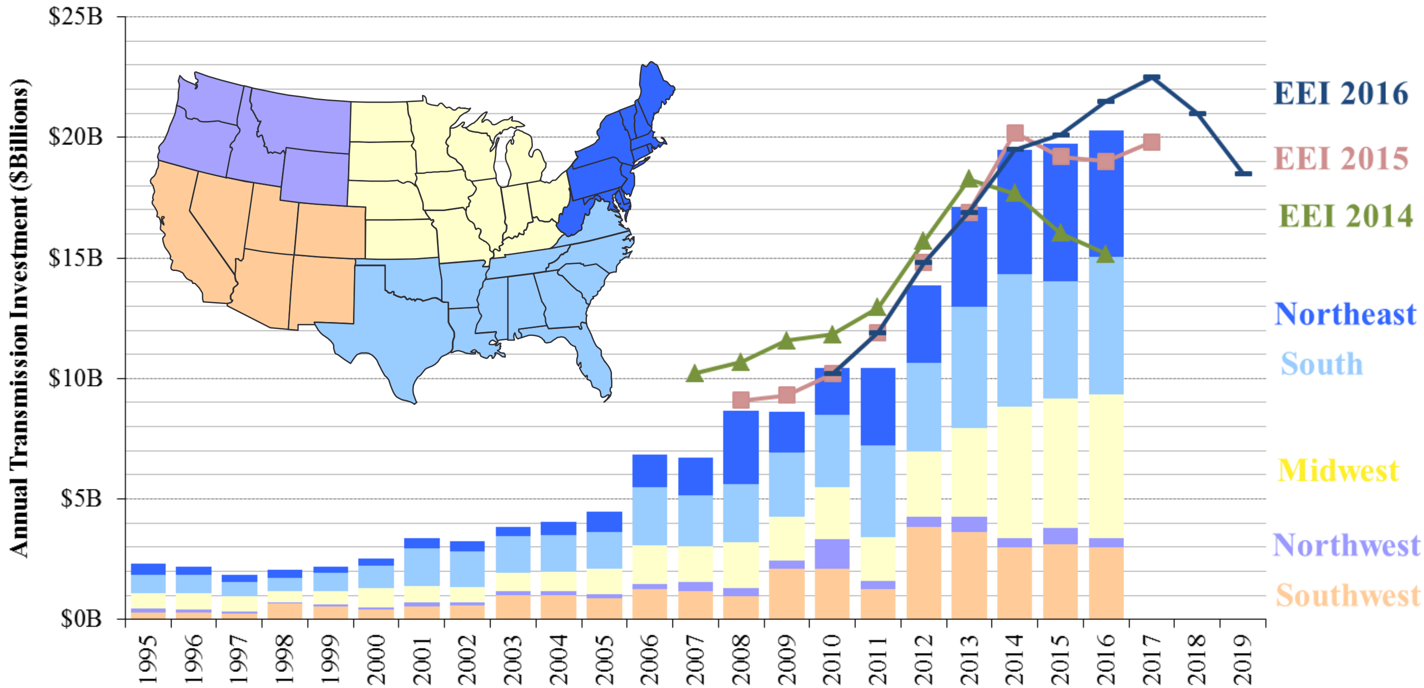
Note: The views expressed in this presentation are strictly those of the presenter and do not necessarily state or reflect the views of *The Brattle Group, Inc*.

Industry Trends Driving Transmission

Historical and Projected Transmission Investment

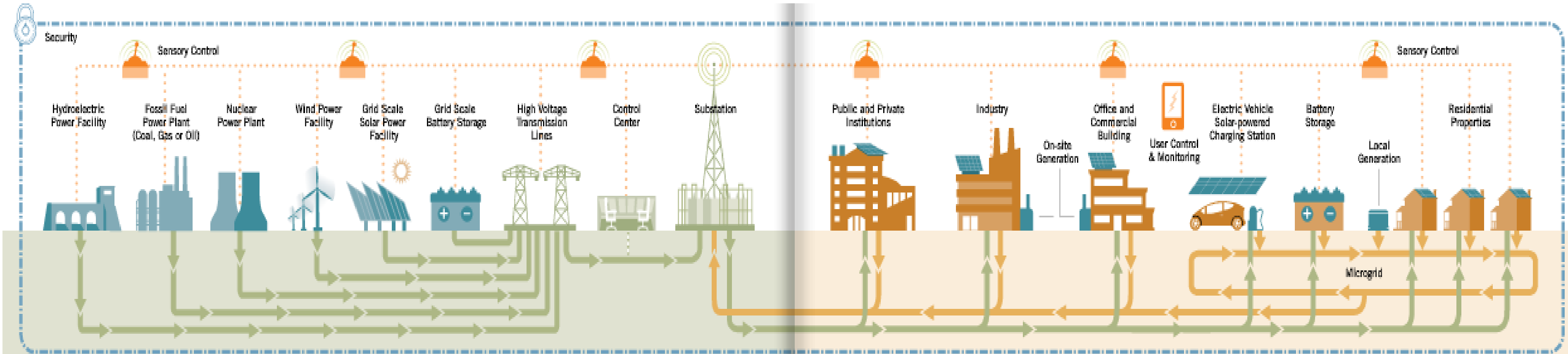
Transmission investment by FERC-jurisdictional providers has stabilized at nearly $20 billion/year in the past three years after steadily rising since 2000

Historical and Projected U.S. Transmission Investments
(FERC-jurisdictional entities only)



Sources and Notes: The Brattle Group's analysis of FERC Form 1 data compiled in Ventyx's Velocity Suite.
Based on EIA data available through 2003, FERC-jurisdictional transmission owners estimated to account for 80% of transmission assets in the Eastern Interconnection, and 60% in WECC and ERCOT. Facilities >300kV estimated to account for 60-80% of shown investments.
EEI annual transmission expenditures updated December 2016 shown (2010-2019) based on prior year's actual investment through 2015 and planned investment thereafter.

Industry Trends Creating New Challenges



Source: New York Power Authority.

Supply Side Trends:

1. **Cost reduction in solar and wind generation** and innovative project financing
2. **Low natural gas prices** place significant downward pressure on coal and nuclear plants, potentially triggering retirements
3. **Increased stringency in local environmental regulations** of air emissions, water usage, waste disposal, and land use

Demand Side Trends:

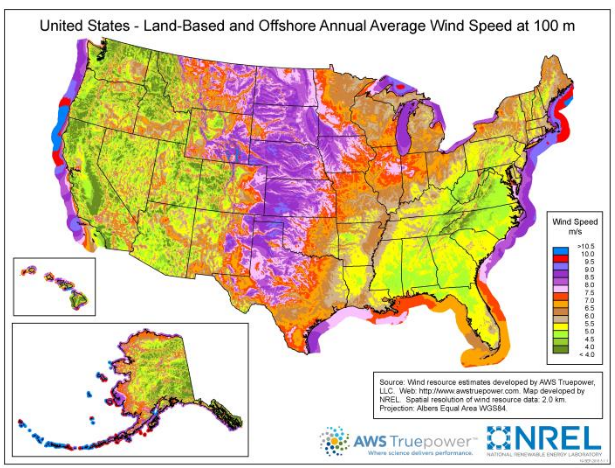
1. **Reduced growth** in traditional consumption
2. **Increasing electrification** of transportation
3. **Preferences for conservation and clean energy**
4. **Technological advances** that allow customers and electric utilities to better monitor and control electricity usage

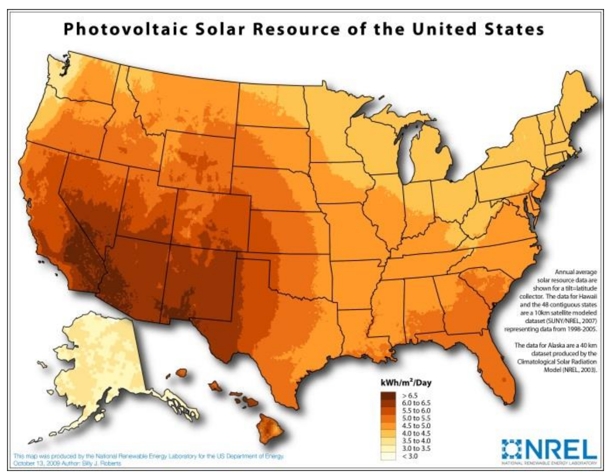
Transmission Drivers

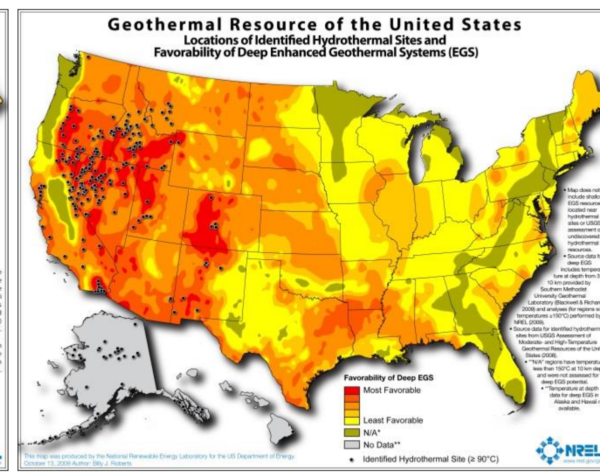
Clean Energy to Meet Customers' Needs

Potential for and quality of renewable energy resources vary by region

- *Wind*: Lowest-cost onshore wind resources are on the edges of Eastern and Western Interconnection and Texas; offshore developing on east coast
- *Solar*: The Southwest has some of the best solar resources
- *Geothermal*: Some western states have high potential for geothermal
- *Hydro*: Significant opportunity to increase Canadian hydropower imports





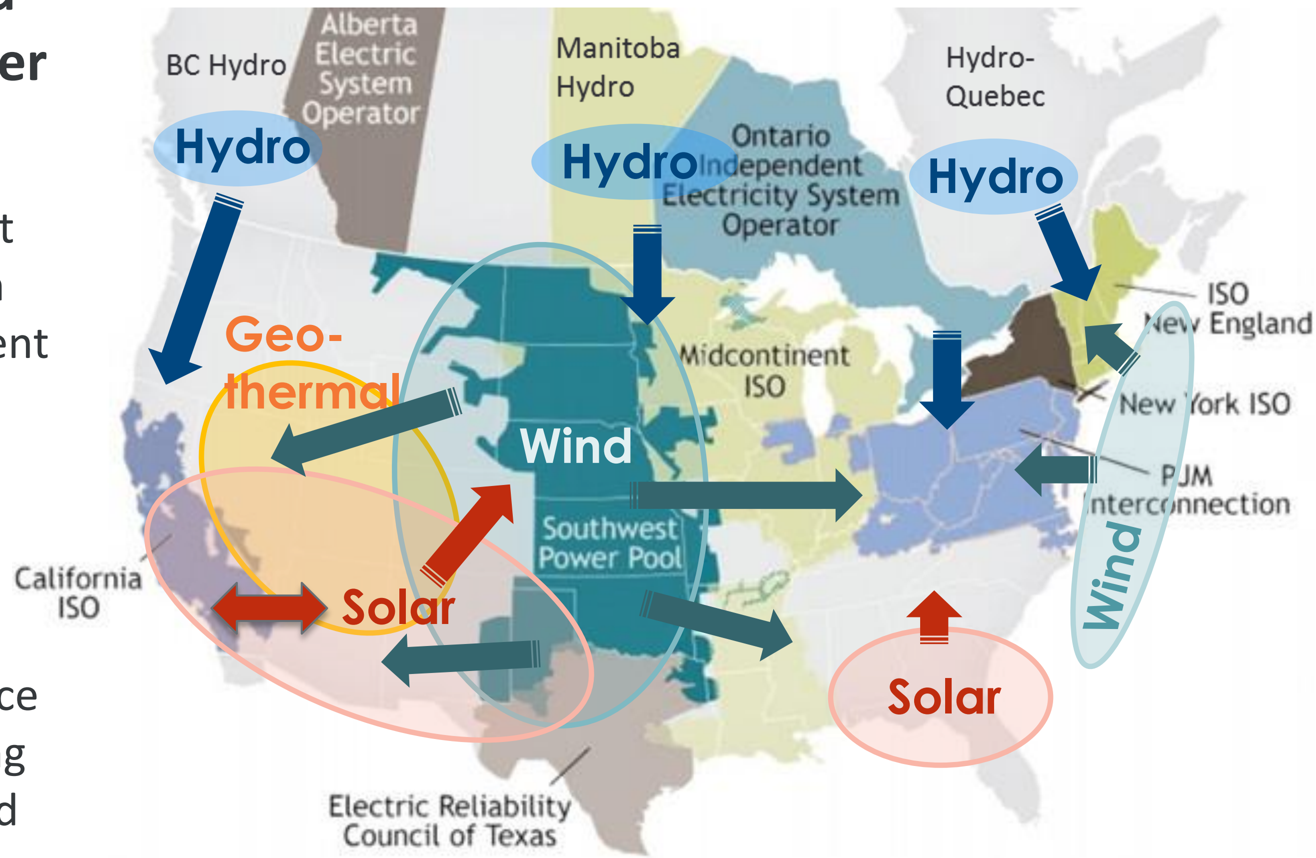


Source: NREL

Diversifying Low-Cost Clean Energy Resources

Resource and demand diversification can offer significant benefits:

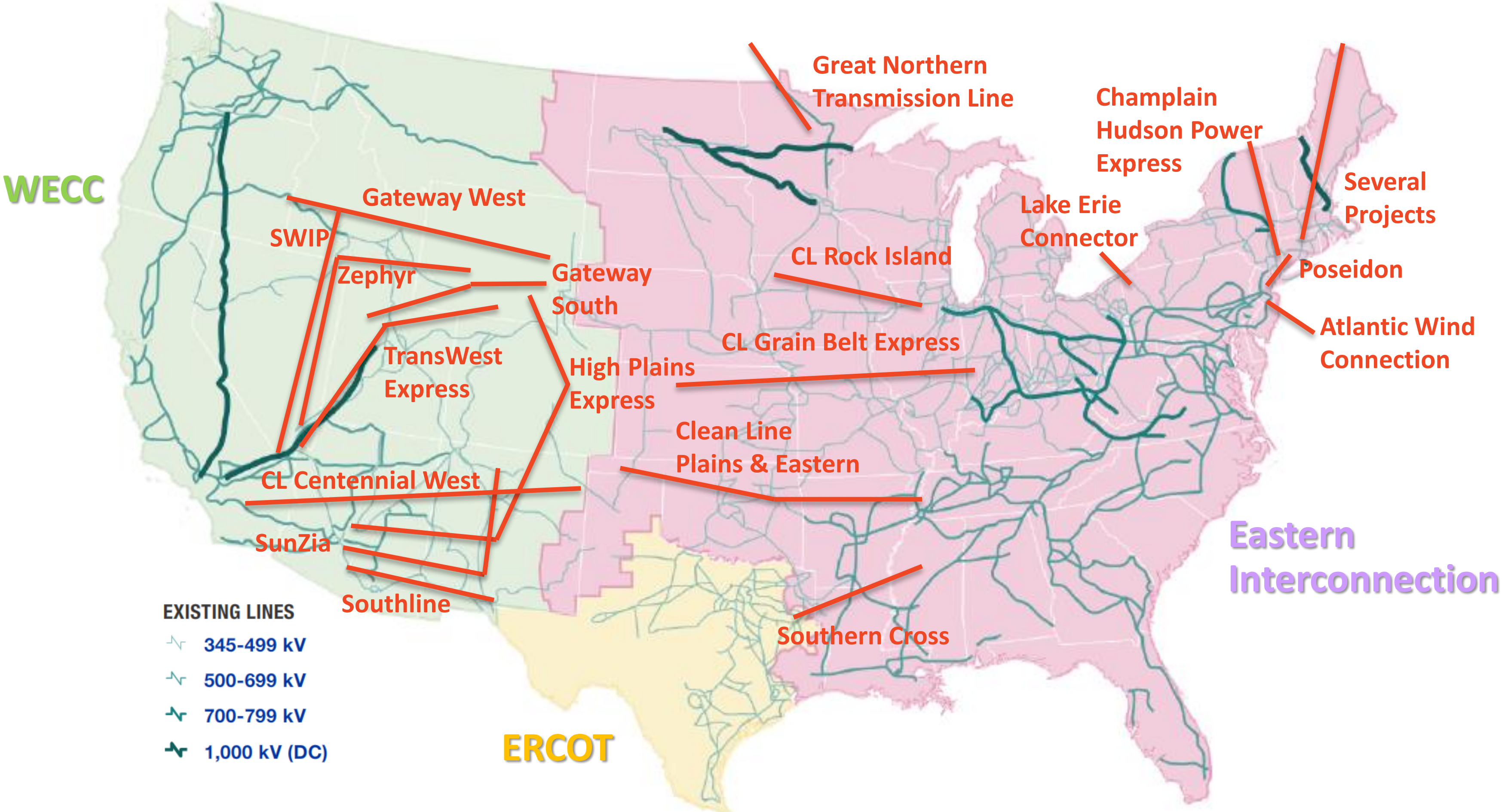
- Reduces the investment and balancing cost with high levels of intermittent resources
- Relies on build out of transmission to interconnect them
- Increases the importance of interregional planning processes going forward



Source: Underlying map is from ISO/RTO Council

Transmission Drivers
Proposed Interregional Projects

Developers have proposed participant-funded or merchant transmission projects intended to deliver low-cost wind, solar, or hydro to regions with clean energy needs



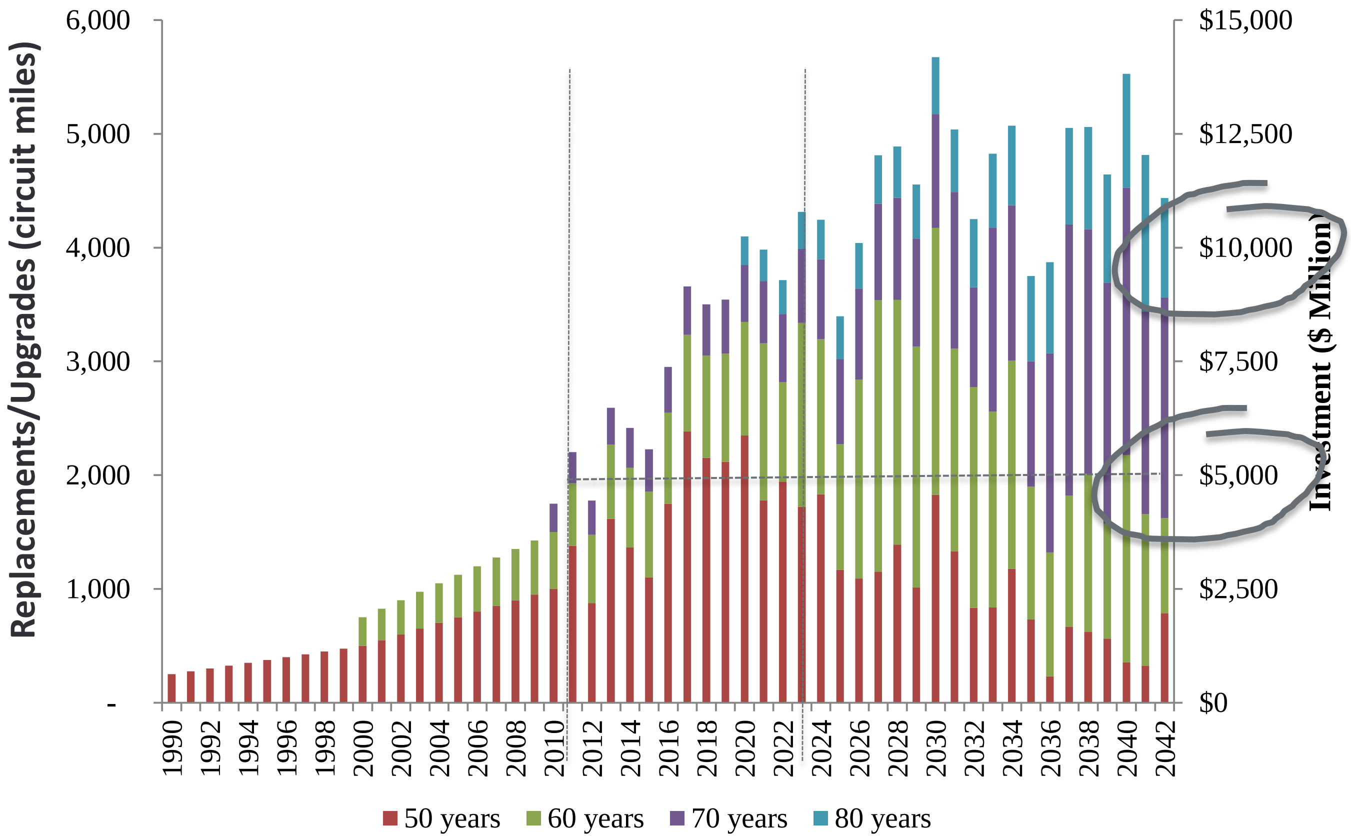
Their location choices are right on!

Transmission Drivers

Aging Transmission Will Require Significant Investments

- If all facilities were replaced after 50 to 80 years, investment could increase by $5 billion/yr over next decade
- The need for replacements may require:
  - Large upgrades, or
  - Provide opportunities for higher capacity lines in their place

Projected Circuit Miles Replaced/Upgraded and Total Projected Investment ($ million)

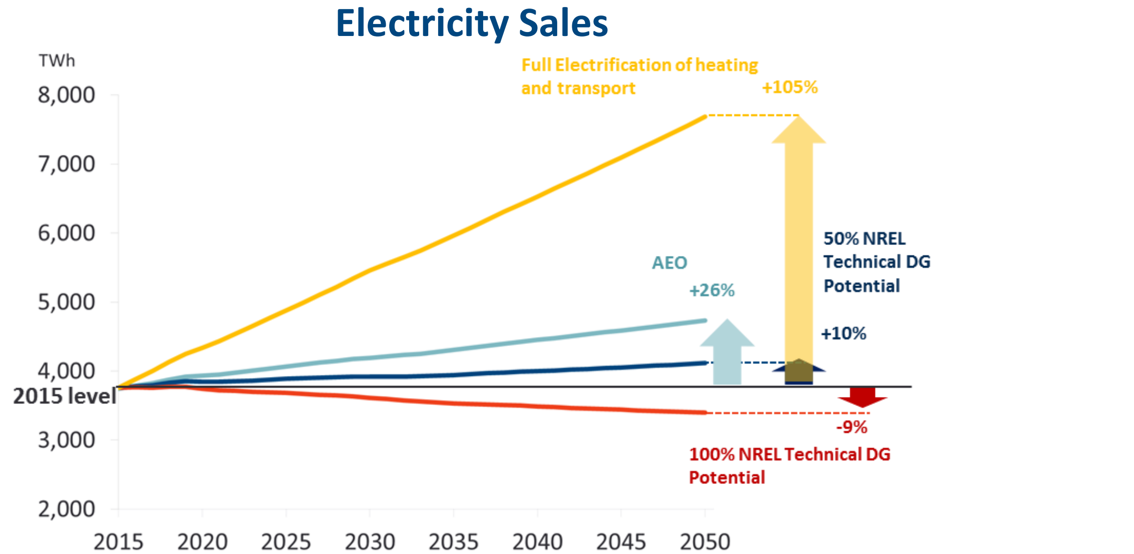


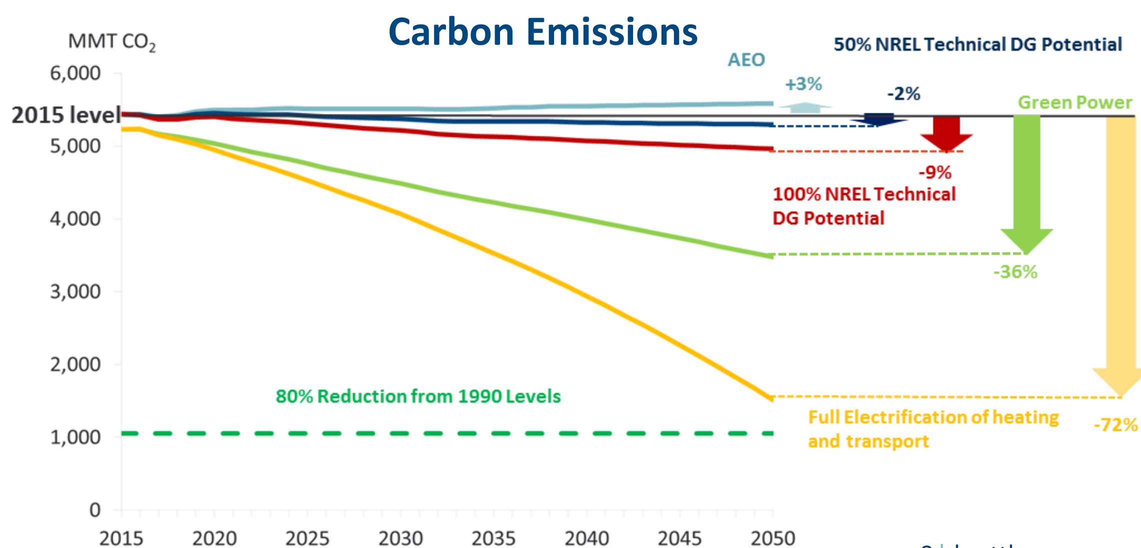
Notes: Assumes circuit mile costs equal to those of new lines

Electrification of Transportation and Heating

With full electrification:

- Utility sales could double by 2050, even with significant distributed PV penetration
- Economy-wide GHG emissions reductions could be achieved if coupled with clean generation
- **Utilities could grow in size and relevance, and help decarbonize the US economy**
- Adoption of highly utilized modes of transportation (such as Uber, autonomous technology) will accelerate adoption of EVs





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

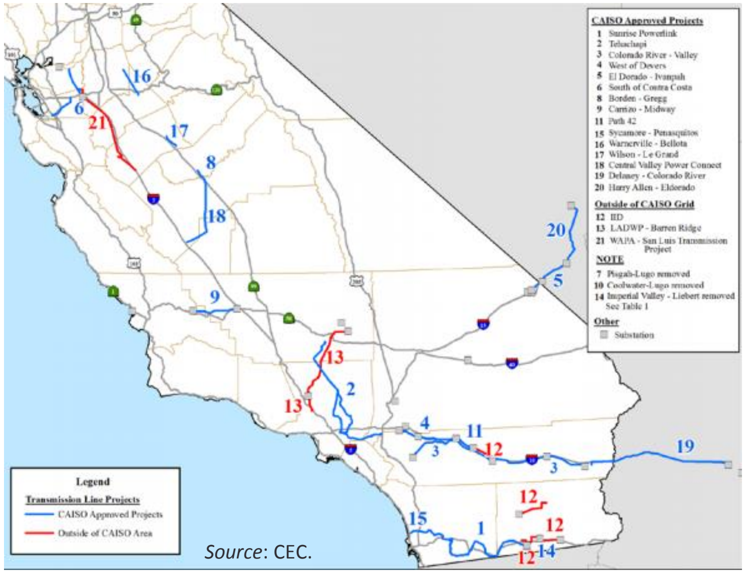
Regional Approaches to Transmission Planning

California and Western Interregional Planning

California (CPUC/CAISO)

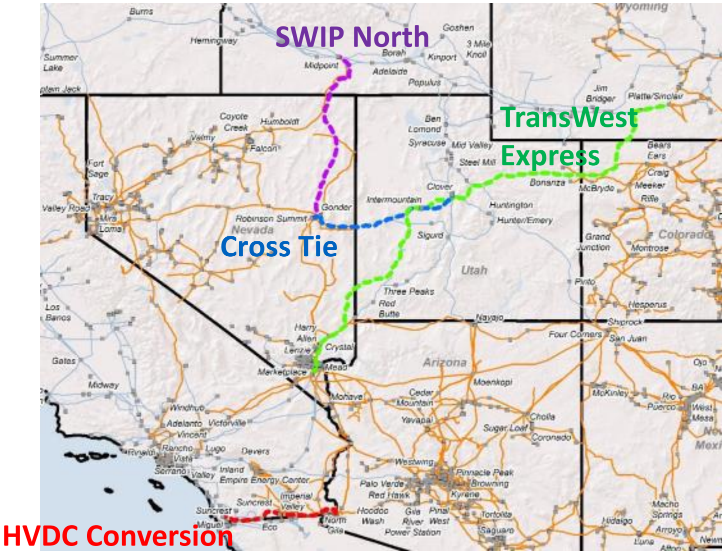
- CPUC approved Tehachapi ($2B) in 2009 in anticipation of interconnecting 4,500 MW of California wind
- CAISO approved 5 policy projects ($400M) in 2012-13 transmission plan and Delaney-Colorado River ($300M) in 2013-14 plan based on broad range of benefits
- CAISO still relies on 33% RPS case for post-2020 studies
- CPUC identified limited near-term need for transmission in 2016 RETI 2.0, but more significant long-term needs

CAISO Approved Transmission Projects



Source: CEC.

Western U.S. Interregional Planning Submissions



Western U.S. Interregional Planning

- Completing first planning cycle in 2016/17
- Four projects submitted that are primarily intended to deliver renewables to the California market
- SWIP North (purple), Cross Tie Project (blue), TransWest Express (green), HVDC Conversion Project (red)

Regional Planning
Interior RTOs Plan for Renewable Build Out

Midcontinent ISO (MISO)

- Approved 17 MVP projects ($6B) in 2011 with benefit-cost of 1.8 – 3.0 that will help access 12,000 MW of wind power; second MVP in the works?
- MTEP16 evaluated scenarios with 11–26% RE in 2031 and approved $108M line related to wind congestion in MN

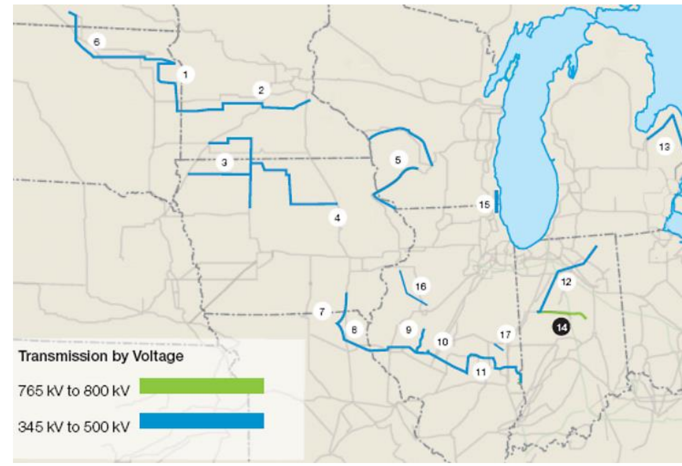
Southwest Power Pool (SPP)

- Started ITP in 2010 to identify projects based on multiple future scenarios and range of economic benefits
- Currently $5.5B in projects in the SPP pipeline
- 2017 ITP10 evaluated scenarios with 3–5 GW of additional wind, 2–3 GW solar; identified $200M in projects with benefits of 4.3 - 5.3x costs

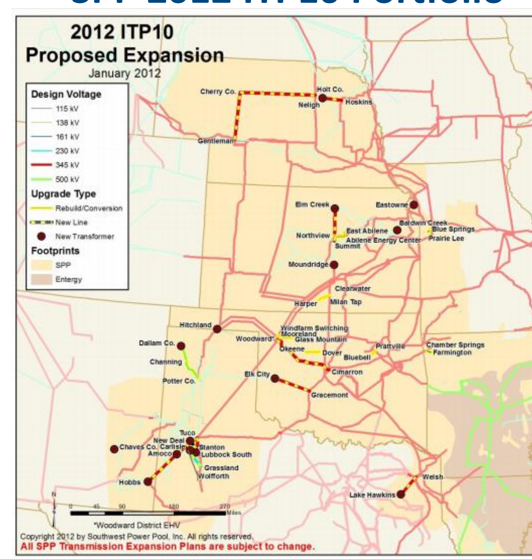
ERCOT

- CREZ projects ($7B) approved in anticipation of accessing 18,000 MW of wind capacity and completed in 2013
- LTSA uses scenario-based approach to identify long-term needs; 2016 study identified large increase in W-E flows

MISO 2011 Multi-Value Projects



SPP 2012 ITP10 Portfolio

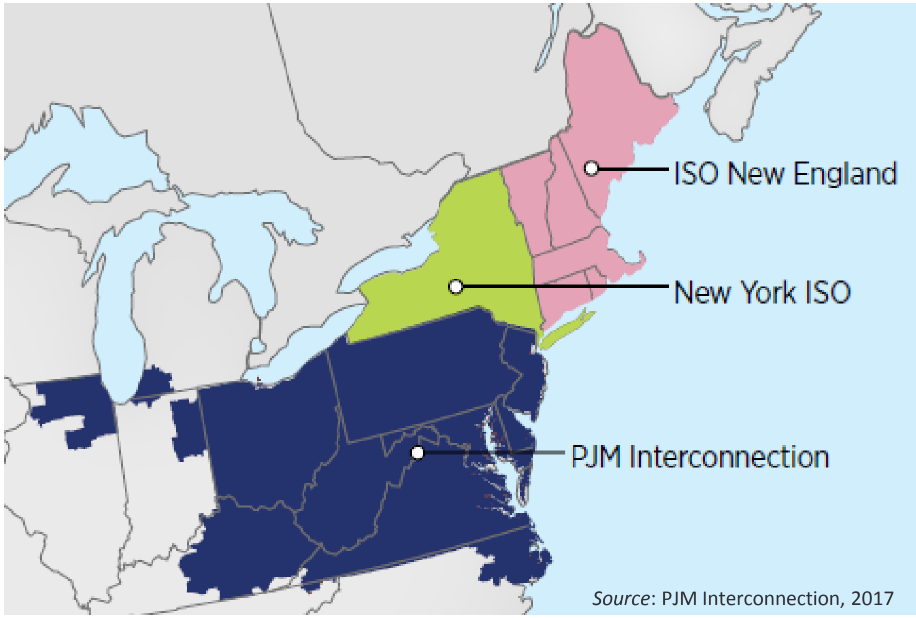


Regional Planning

Northeastern RTOs Developing New Approaches

ISO New England:

- Maine Renewable Integration Study identified two lines ($2B) for delivering 2,000 MW of wind
- Initiated its Public Policy Transmission Upgrade process in 2017, but no need identified
- MA RFP attracted HVDC, AC projects; parallel offshore wind RFP would reduce transmission need



Source: PJM Interconnection, 2017

New York ISO:

- DPS requested analysis of "public policy need" and identified need for $1.2B upgrade from Central NY to Hudson Valley
- Also identified need in Western NY for delivering additional hydro generation
- Approved $440M upgrade of aging line in Northern NY to provide capacity for incremental wind and hydro imports

PJM Interconnection:

- 2016 RTEP included 15,000 MW each of wind and solar based on interconnection queue
- Five projects ($17M) identified in PJM-MISO interregional planning

Improving Transmission Planning Processes

Key Shortfalls in Traditional Transmission Planning

Three key barriers to identifying and developing the most valuable transmission infrastructure investments:

1. Planners and policy makers **do not consider the full range of benefits** that transmission investments can provide and thus understate the expected value of such projects
2. Planners and policy makers **do not account for the high costs and risks** of an insufficiently robust and insufficiently flexible transmission infrastructure on electricity consumers and the risk-mitigation value of transmission investments to reduce costs under potential future stresses
3. **Interregional planning processes are ineffective** and are generally unable to identify valuable transmission investments that would benefit two or more regions

Additional challenges exist related to regional cost recovery and state-by-state permitting processes

Well-Planned Transmission Reduces Customer Costs

- **SPP:** $3.4 billion on transmission projects previously planned are expected to reduce customer costs by $12 billion at a benefit to cost ratio of 3.5-to-1 (retrospective evaluation)
- **MISO MVP:** Previously planned multi-value projects to integrate 40 million MWh of renewables and improve reliability provide benefits that exceed costs by factor of 2.6-3.1
- **Brattle:** Providing access to areas with lower-cost renewable generation that will meet RPS and clean energy needs through 2030 has the potential to reduce the combined generation and transmission investment needs by $30-70 billion
- **Eastern Interconnection States Planning Council:** Multi-stage anticipatory planning can reduce total generation costs by $150 billion, while increasing interregional transmission investments by $60 billion, with an overall savings of $90 billion system-wide
- **Eastern Interconnection Planning Collaborative:** Combination of interregional environmental policy compliance and interregional transmission may offer net savings of up to $100 billion in a future with stringent environmental policy goals
- **University of Colorado/National Oceanic and Atmospheric Administration:** Building more robust transmission grid would enable reducing U.S. carbon emissions from electricity sector by 80%, saving consumers $47 billion/year at benefit-to-cost ratio of almost 3-to-1.

Transmission Planning Improvements

"Checklist" of Transmission Benefits

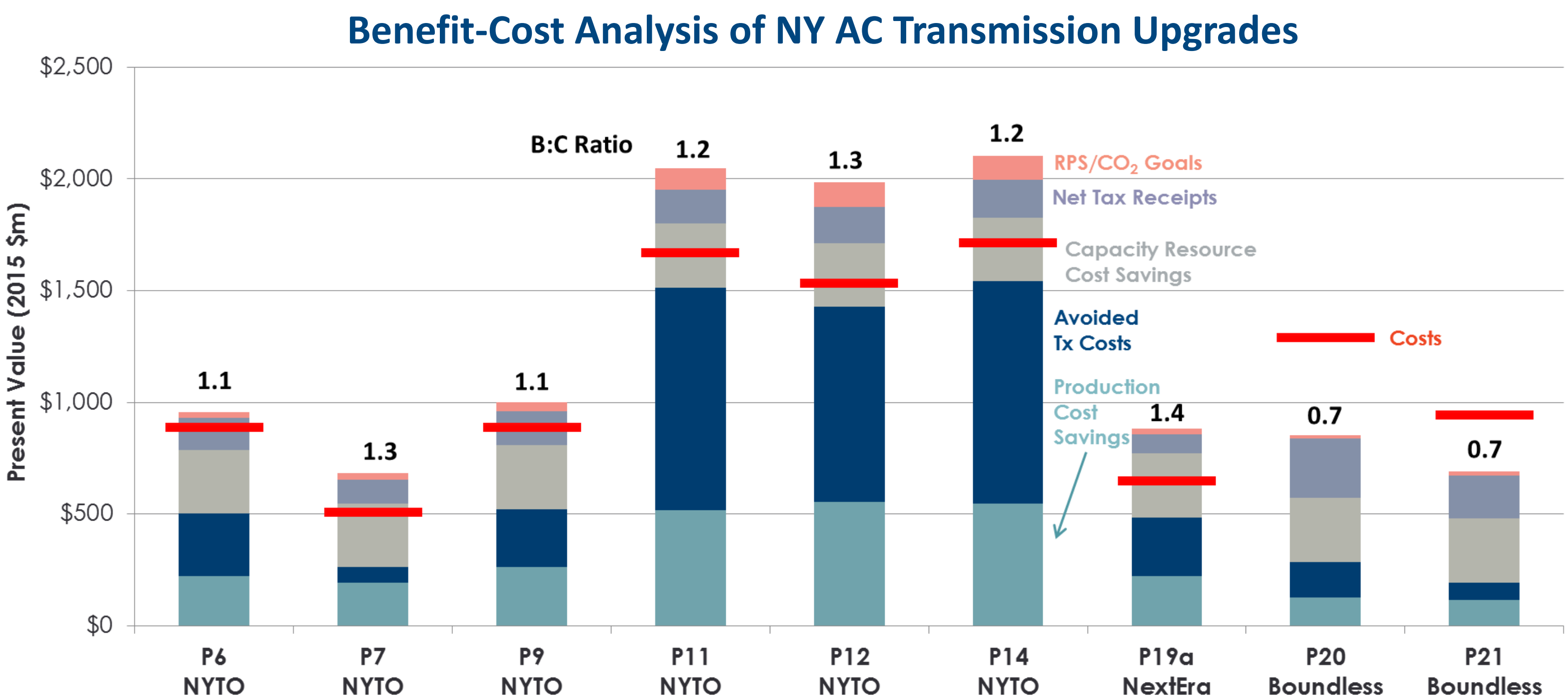
Benefit Category	**Transmission Benefit** (see 2013 WIRES paper)
Traditional Production Cost Savings	**Production cost savings as estimated in most planning processes**
1. Additional Production Cost Savings	a. Impact of generation outages and A/S unit designations
	b. Reduced transmission energy losses
	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

Note: Highlighted (red) benefit metrics quantified in NY transmission benefit study (next slide)

Important to Consider All Transmission Benefits

Considering only "traditional" production cost savings likely will miss the most significant source of benefits and result in under investment

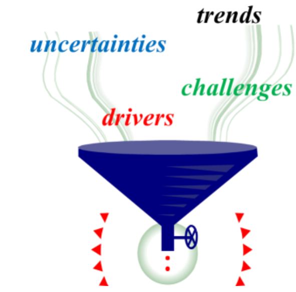
- Analysis of NYISO upgrades found 7 projects with net benefits (B:C ratio > 1.0)
- Production cost savings only accounted for about 25% of benefits
- Avoiding future upgrades of aging infrastructure played a significant role



Source: Newell, et al., Benefit-Cost Analysis of Proposed New York AC Transmission Upgrades, Sept. 15, 2015.

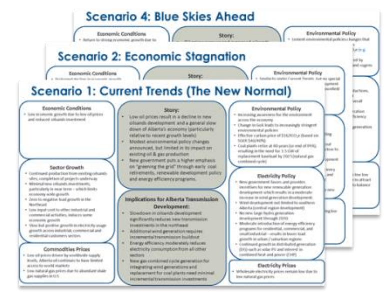
Effective Scenario-Based Transmission Planning

1. Identifying Future Trends, Drivers and Uncertainties



- Industry experts from within and outside of the power industry develop views on a range of future trends, drivers, and uncertainties

2. Developing Future Scenarios



- Develop but plausible set of future scenarios based on the trends, drivers and uncertainties identified
- Ensure that each scenario is internally consistent and captures a sufficiently wide range (but plausible)of future states of the world
- Distinguish clearly between scenarios and sensitivities

3. Transforming Future Scenarios into Planning Assumptions

- Translate the qualitative descriptions of the future scenarios to specific assumptions that are used in transmission planning

Key Driver	Current	Stagnation	Blue Skies
Economic Conditions	Base	Low	High
Sector Growth	Base	Low	High
Commodity Prices	Base	Low	High
Environmental Policy	Base	Low	Low
Electricity Policy	Base	Base	Low

4. Simulate the Grid under each Future Scenario

- Develop power flows for each future scenario
- Compare the size and timing transmission needs across scenarios

Line	Region	ISD	Cost
A	NE	2019	$X,XXX,XXX
B	Central	2025	$X,XXX,XXX
C	South	2027	$X,XXX,XXX

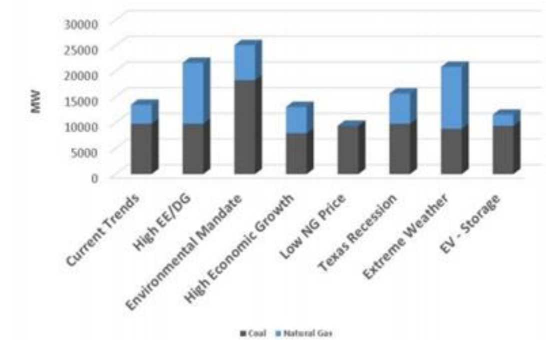
2016 ERCOT Long Term System Assessment

ERCOT 2016 LTSA Scenarios

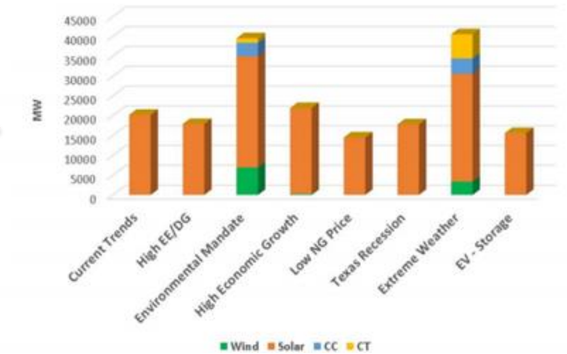
Scenario	Description
Current Trends	Trajectory of what we know and is knowable today (e.g., LNG export terminals, Texas growth, low natural gas and oil prices)
High Economic Growth	Significant population and economic growth from all sectors of the economy (affecting load from residential, commercial and industrial)
Texas Recession	Significant reduction in economic activity in Texas
Environmental Mandate	On top of current regulations, aggressive action on mitigating environmental impacts in the energy sector has occurred. Federal or higher Texas renewable standards
High Efficiency/High DG	Reduced *net* demand growth due to increase in distributed solar and higher building and efficiency standards
Extended Extreme Weather	Extreme weather conditions exist for an extended period impacting water-intensive generating resources.
Sustained Low Natural Gas Prices	Low domestic gas prices continue for the entire period.
Storage/Electric Vehicle Adoption	High penetration of electric vehicles and large amounts of residential and utility-scale storage

Source: ERCOT.

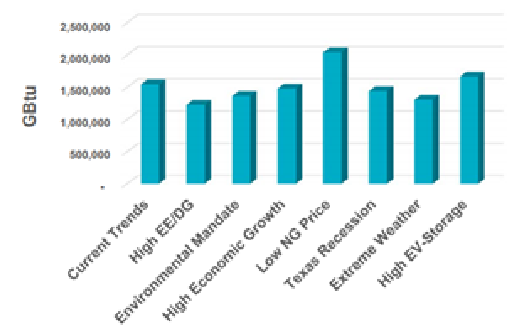
10,000 – 25,000 MW of retirements



15,000 – 40,000 MW of new additions



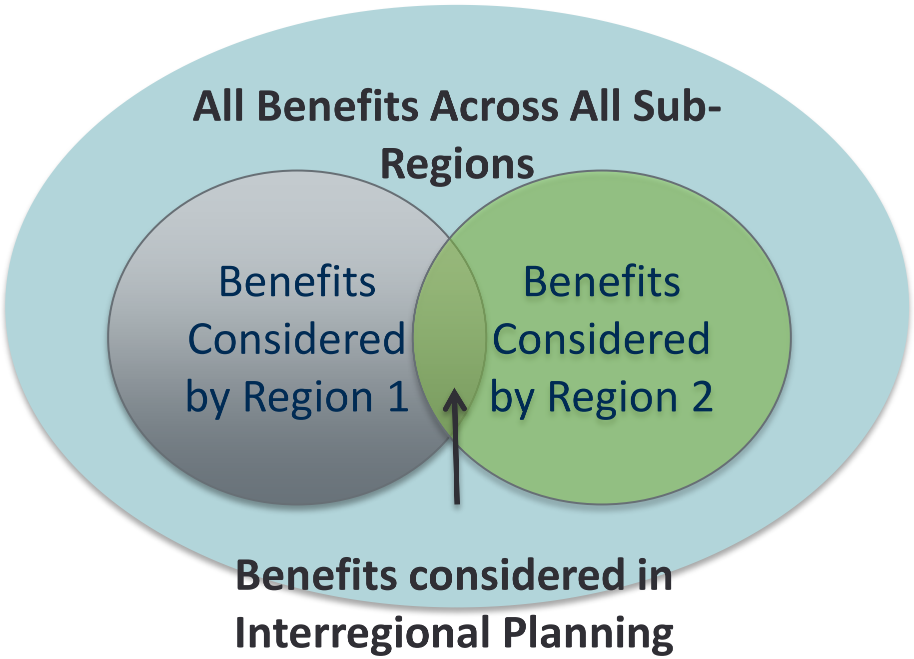
1 – 2 million Gbtu of natural gas burn



Ineffective Inter-Regional Transmission Planning

Divergent criteria result in "least-common-denominator" planning approaches create significant barriers for transmission between regions

- Experience in the East already shows that very few (if any) interregional projects will be found to be cost effective under this approach
- Multiple threshold tests create additional hurdles



Planning processes need to be improved to avoid this "least common denominator" outcome by evaluating interregional projects based on their combined benefits across all regions

Speaker Bio and Contact Information

Michael Hagerty
Associate, Washington, DC
Michael.Hagerty@brattle.com
202.955.5050 office
202.419.3323 direct

Michael Hagerty is an Associate at The Brattle Group with experience in transmission planning and development, strategic planning for utility companies electricity, renewable and climate policy analysis, and wholesale market design. Michael analyzed the value of new transmission in California, WECC, SPP, PJM, New England, and New York and worked with ERCOT to improve their long-term transmission planning process, including the development of scenario-based approaches. In addition, Michael has focused on analyzing opportunities and challenges of existing and proposed renewable energy and climate policies, including the EPA's Clean Power Plan (CPP), state-level Renewable Portfolio Standards (RPS), and California's GHG cap-and-trade market.

Michael holds a B.S in Chemical Engineering from the University of Notre Dame in South Bend, Indiana and an M.S. in Technology and Policy from the Massachusetts Institute of Technology in Cambridge, Massachusetts.

Bio and Contact Information

Johannes P. Pfeifenberger
Principal, Boston
Hannes.Pfeifenberger@brattle.com
617.864.7900 office
617.234.5624 direct

Johannes (Hannes) Pfeifenberger is an economist with a background in power engineering and over 20 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 reviews of RTO capacity market and resource adequacy designs, testimony in contract disputes, and the analysis of transmission benefits, 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.

Bio and Contact Information

Judy W. Chang
Principal, Boston
Judy.Chang@brattle.com
617.864.7900 office
617.234.5630 direct

Ms. Judy Chang is an energy economist and policy expert with a background in electrical engineering and 20 years of experience in advising energy companies and project developers with regulatory and financial issues. Ms. Chang has submitted expert testimonies to the U.S. Federal Energy Regulatory Commission, U.S. state and Canadian provincial regulatory authorities on topics related to power market designs, contract issues, and transmission rate design. She has authored numerous reports detailing the economic issues associated with system planning, including comparing the costs and benefits of transmission. In addition, she assists clients in comprehensive organizational strategic planning, asset valuation, finance, and regulatory policies.

Ms. Chang has presented at a variety of industry conferences and has advised international and multilateral agencies on the valuation of renewable energy investments. She holds a BSc. In Electrical Engineering from University of California, Davis, and Masters in Public Policy from Harvard Kennedy School, is a member of the Board of Directors of The Brattle Group, and the founding Director of New England Women in Energy and the Environment.

Additional Reading

Chang and Pfeifenberger, "Well-Planned Electric Transmission Saves Customer Costs: Improved Transmission Planning is Key to the Transition to a Carbon-Constrained Future," WIRES and The Brattle Group, June 2016, at http://wiresgroup.com/docs/reports/WIRES%20Brattle%20Report_TransmissionPlanning_June2016.pdf

Pfeifenberger, Chang, and Sheilendranath, "Toward More Effective Transmission Planning: Addressing the Costs and Risks of an Insufficiently Flexible Electricity Grid," WIRES and The Brattle Group, April 2015, at http://wiresgroup.com/docs/reports/WIRES%20Brattle%20Rpt_TransPlanning_042315.pdf

Chang, Pfeifenberger, and Hagerty, "The Benefits of Electric Transmission: Identifying and Analyzing the Value of Investments," WIRES and The Brattle Group, July 2013, online at: http://wiresgroup.com/docs/reports/WIRES%20Brattle%20Rpt%20Benefits%20Transmission%20July%202013.pdf

Pfeifenberger, Chang, and Tsoukalis, "Dynamics and Opportunities in Transmission Development, presented at TransForum East, December 2, 2014, at http://www.brattle.com/system/publications/pdfs/000/005/089/original/Dynamics_and_Opportunities_in_Transmission_Development.pdf?1417535596

Chang, Pfeifenberger, Newell, Tsuchida, Hagerty, "Recommendations for Enhancing ERCOT's Long-Term Transmission Planning Process," October 2013, at http://www.brattle.com/news-and-knowledge/news/brattle-consultants-assist-ercot-in-scenario-planning-and-improving-its-long-term-transmission-planning-process

Chang, "Implications of the Increase in Wind Generation for Alberta's Market: Challenges of Renewable Integration," presented at 13th Annual Alberta Power Summit, Calgary, Alberta, November 28, 2012.

Chang, "Challenges of Renewable Integration: Comparison of Experiences," presented at Transmission Executive Forum West 2012, Meeting Public Policy Objectives through Transmission Investment, October 22, 2012.

Pfeifenberger and Hou, "Seams Cost Allocation: A Flexible Framework to Support Interregional Transmission Planning," April 2012, online at: http://www.brattle.com/system/publications/pdfs/000/004/814/original/Seams_Cost_Allocation_Report_Pfeifenberger_Hou_Apr_2012.pdf?1378772132

Pfeifenberger, Johannes, "Transmission Investment Trends and Planning Challenges," presented at the EEI Transmission and Wholesale Markets School, Madison, WI, August 8, 2012, online at: http://www.brattle.com/system/publications/pdfs/000/004/432/original/Transmission_Investment_Trends_and_Planning_Challenges_Pfeifenberger_Aug_8_2012_EEI.pdf?1378772105

Pfeifenberger, Hou, Employment and Economic Benefits of Transmission Infrastructure Investment in the U.S. and Canada, on behalf of WIRES, May 2011, online at: http://www.brattle.com/system/publications/pdfs/000/004/501/original/Employment_and_Economic_Benefits_of_Transmission_Infrastructure_Investmt_Pfeifenberger_Hou_May_2011_WIRES.pdf?1378772110

Offices

CAMBRIDGE

NEW YORK

SAN FRANCISCO

WASHINGTON, DC

TORONTO

LONDON

MADRID

ROME

SYDNEY

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