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WIRES UNIVERSITY

Graduate School

ELECTRIC TRANSMISSION INFRASTRUCTURE

May 25, 2017

NEMA National Electrical Manufacturers Association

EESI Environmental and Energy Study Institute

Grid Innovation Caucus

GRIDWISE ALLIANCE

James Hoecker
Counsel, WIRES
Husch Blackwell LLP
Former FERC Chairman

WIRES

Welcome to WIRES University

Jim Hoecker

WIRES (www.wiresgroup.com)

Former FERC Chairman, Husch Blackwell LLP

Today's friends & co-sponsors –

Environment & Energy Study Institute(www.eesi.org)
National Electrical Manufacturers Association(www.nema.org)
GridWise Alliance (www.gridwise.org)
The Grid Innovation Caucus of the House of Representatives

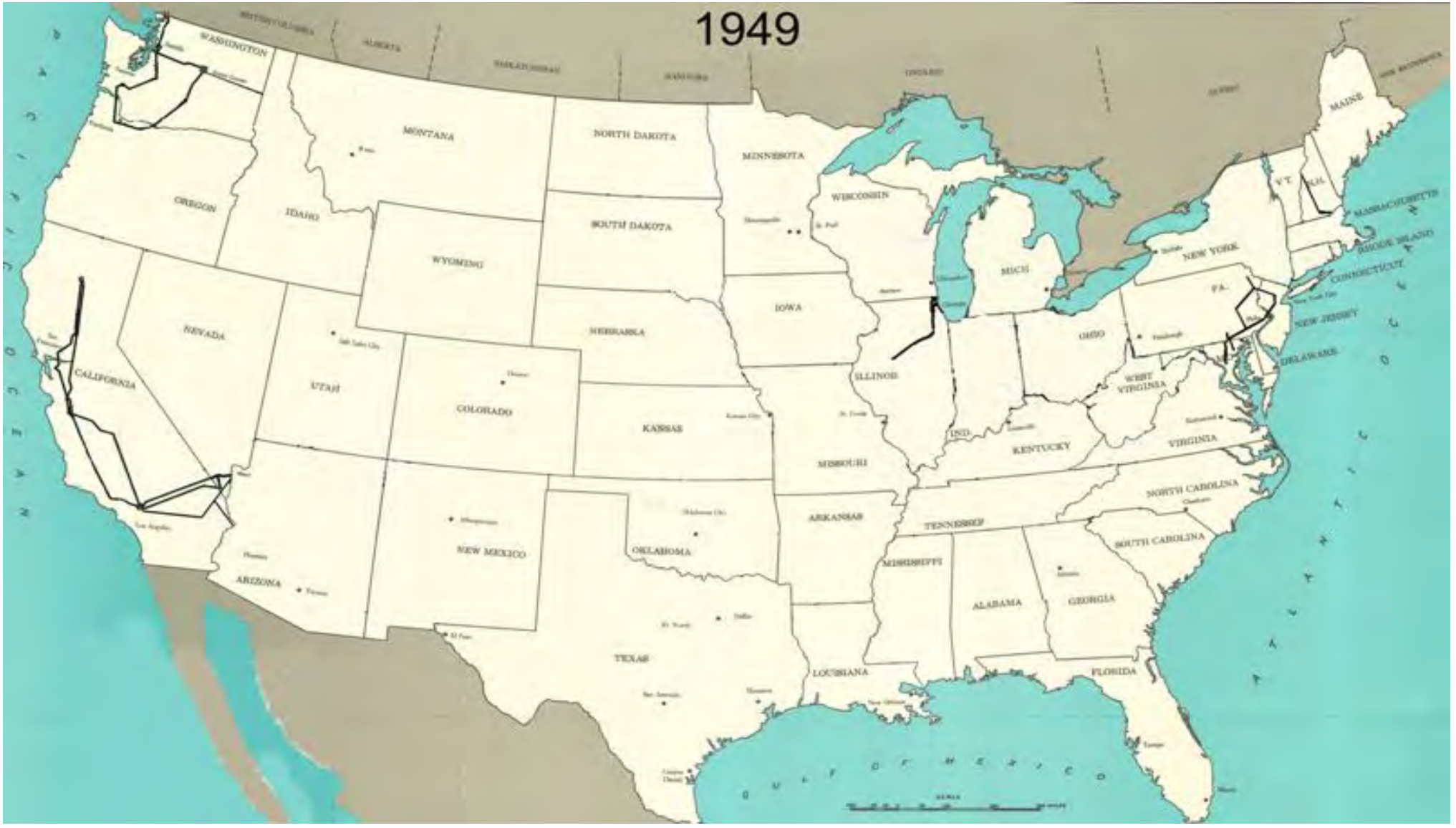
"The Nation's infrastructure crisis is no less serious for being silent. [Fixing it] will improve our quality of life, our standard of living and our competitiveness." *(Warren Rudman and Felix Rohatyn, 2005)*

Electric Transmission Infrastructure— Why Invest? Why Now?

The Purpose of Today's Session –

- **The Electron Superhighway is VITAL INFRASTRUCTURE**
- **Transmission is Strategic and An Enabler of Technology & Markets**
- **The Grid Faces Serious Challenges**
- **Planning for the Future Electrified Economy**
- **The Role of Public Policy**

EHV Transmission Growth (300 kV +)



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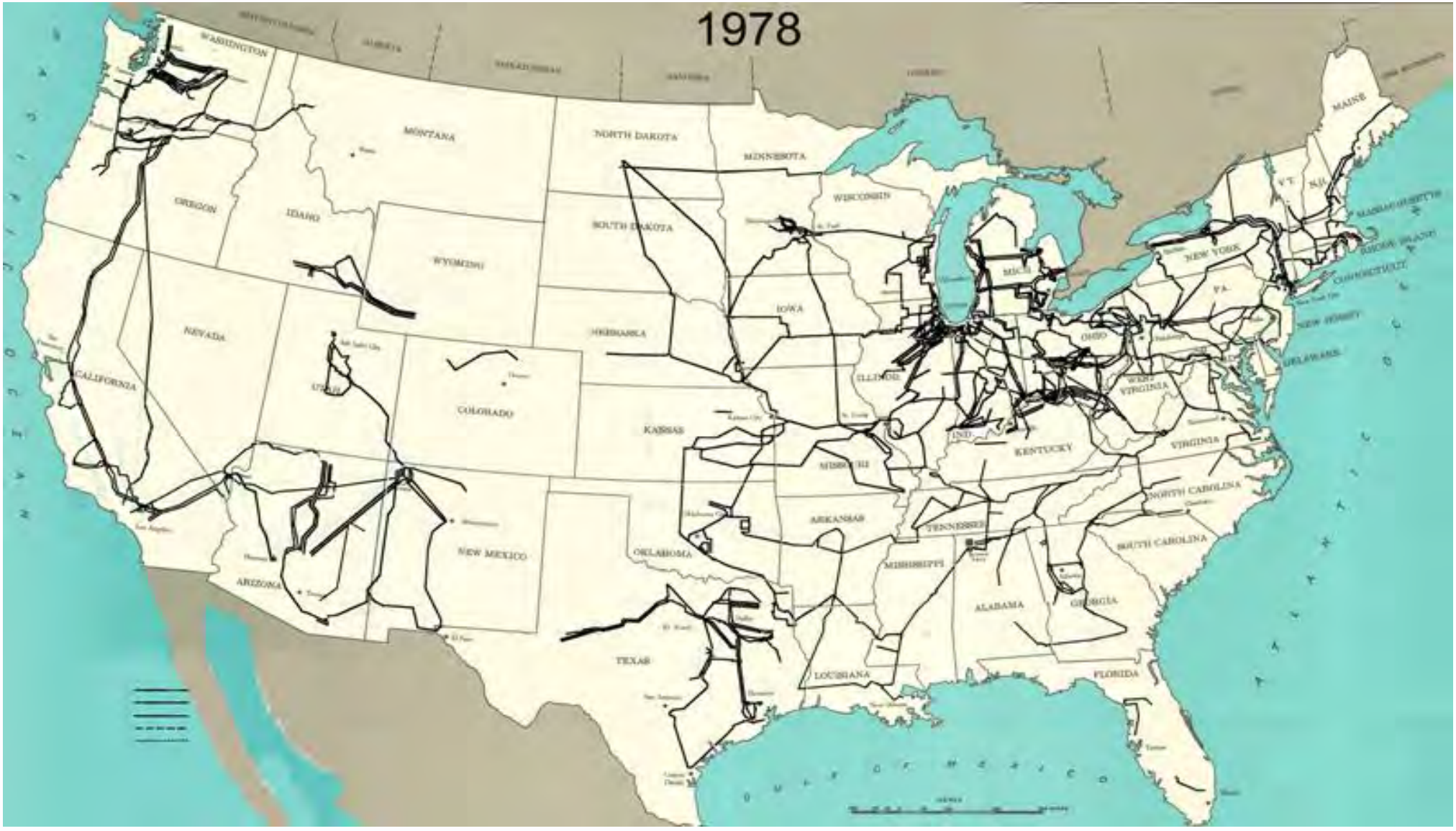

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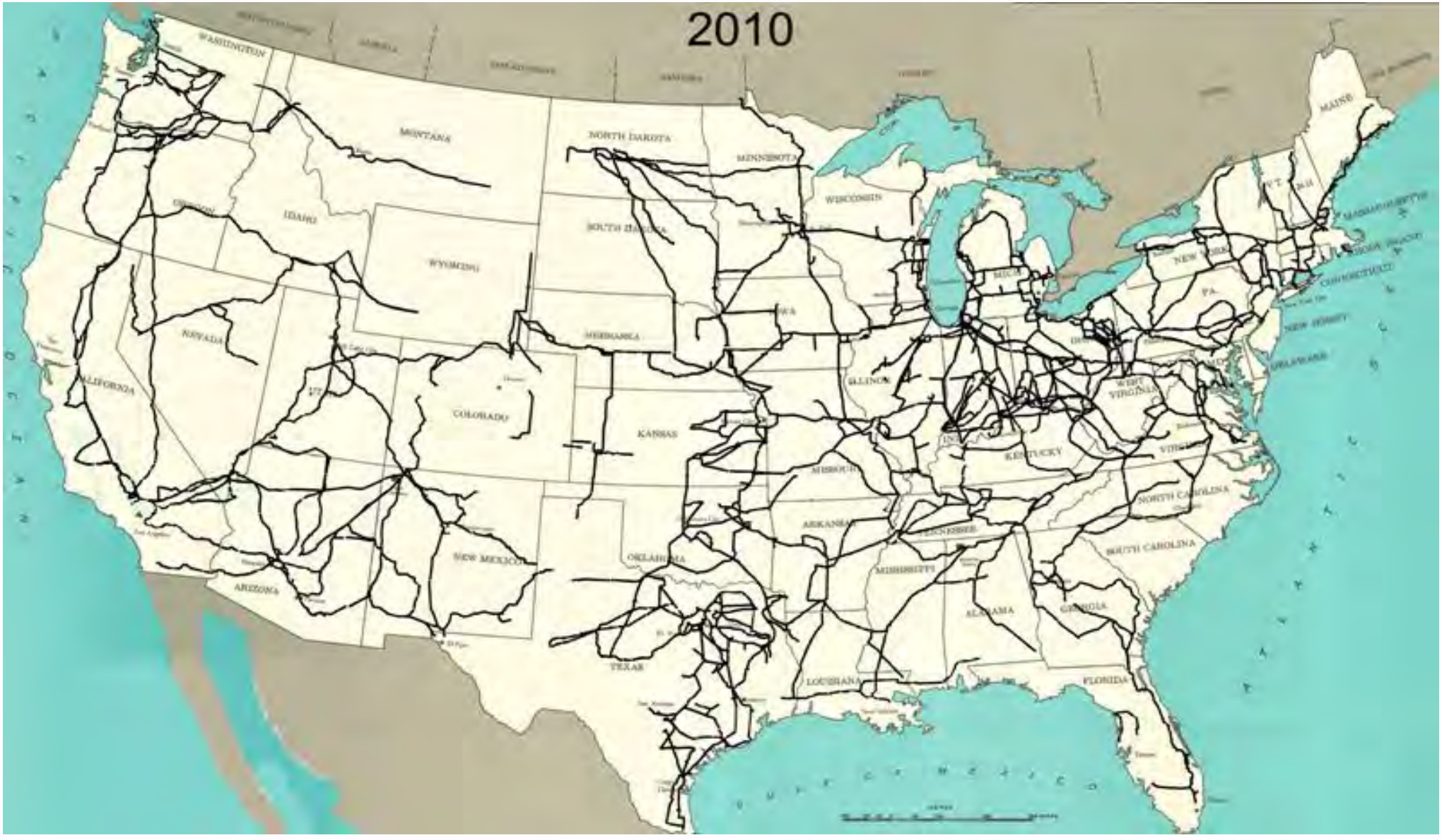


The Facts About the Electron Superhighway

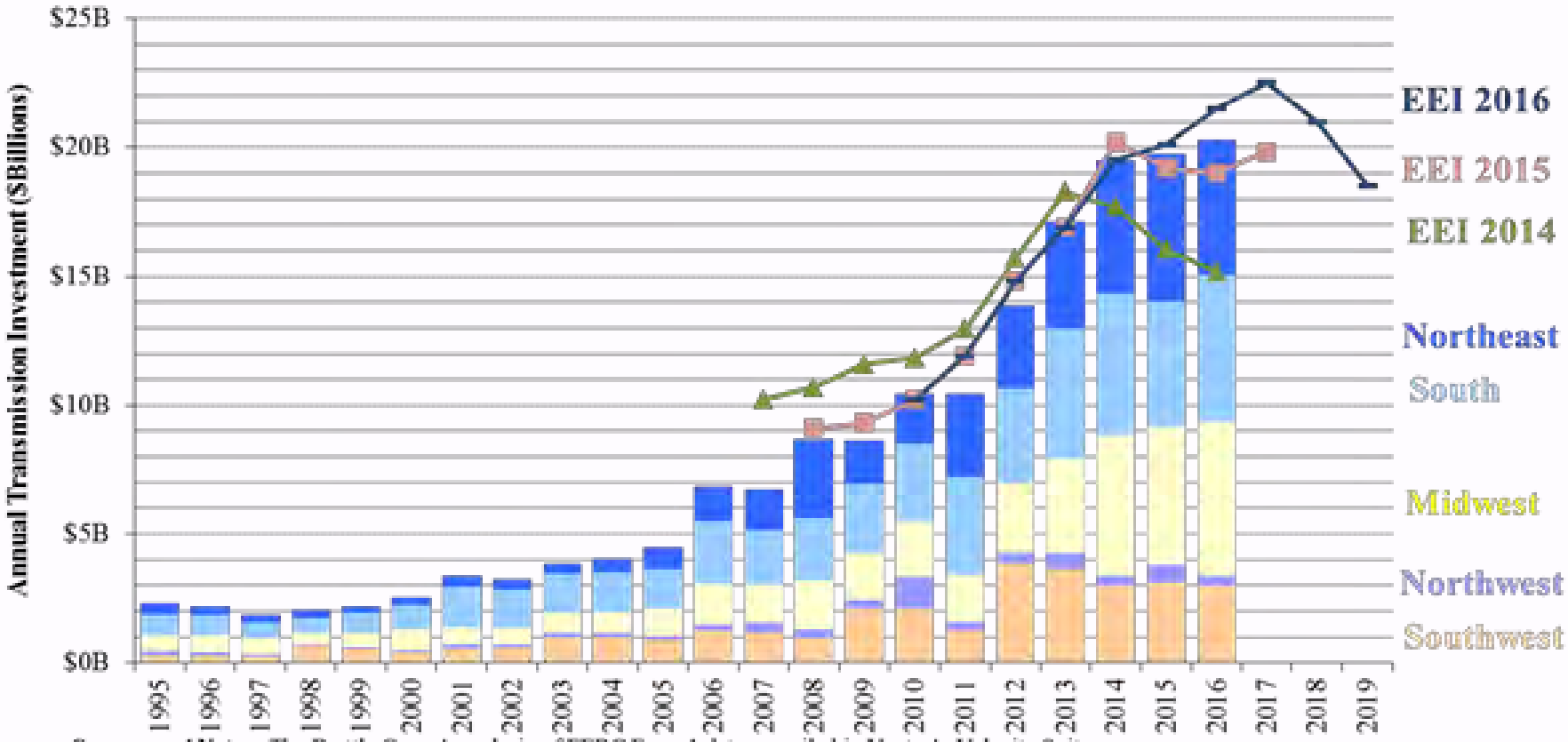
- **Over 500,000 miles of transmission wires and substations (200,000 circuit miles) connect 7,000 power plants of all types**
- **U.S., Canada and potentially Mexico are heavily interconnected and participate in major bulk power market**
- **The U.S. needs to spend $200B on transmission by 2040, compared to $1.5T on whole electric system**
- **The American Society of Civil Engineers rates the U.S. grid a D+ and predicts a $177B investment shortfall for the entire system within just a few years.**

The Urgency, By The Numbers

- As much as 40% of grid facilities are 35+ years old and beyond their useful life, in need of replacement
- Investment in transmission, vigorous for the past decade, is slowing, just as the U.S. was recovering from a quarter century of underinvestment
- The electrical system is changing, and will continue to change as the environment becomes more carbon-constrained and cleaner forms of electric generation become competitive
- Transmission is often the only way for high quality resources and new technologies to access electricity markets
- The North American economy will become increasingly electrified and animated by digital technologies, which will require expansion and upgrade of the transmission grid
- On average, it takes three times longer to permit, site, and construct a transmission line than a fossil energy pipeline

The Urgency, By The Numbers

1995-2019 Average Transmission Investment per MWh of US IOUs in RTO and Non-RTO Regions



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 October 2015 shown (2008-2018) based on prior year's actual investment through 2014 and planned investment thereafter.

Grid Modernization: Invest Now, Save For Years

Resilience, Innovation, and Economic Development

- Grid resilience in the face of extreme weather and cyber threats
- Enhanced reliability in the face of congestion, long term demand growth, and a more decentralized electric generation mix
- Connection of new, remote, and diverse resources to load centers
- Competitive bulk power markets
- Macro-efficiencies that translate into $50B in annual savings for future consumers of energy, from reduced generation and transmission costs
- Aggregation and delivery of the benefits of new smart technologies and distributed resources
- Robust infrastructure construction will generate over 100,000 jobs annually and indirectly help make U.S. energy independent, cleaner, economically efficient, and hospitable to digital innovation in transportation, manufacturing, education, health care and other sectors.

Today's Panels

I. A Glimpse Into the Future – what do we mean by "modernizing" the grid; if demand for power is flat, why would we ramp up investment? What does a more electrified economy tell us about what the grid will be supporting in 20-30 years?

II. What are the various roles and benefits of grid investment? Why is the grid of such central economic importance to the economy? Are there threats that we need to meet – now?

III. The perennial challenge is attracting capital. But regulated returns are declining; macro-economic factors are changing; industry is still learning how to plan. Will the transmission capacity be there?

IV. The high voltage network is already doing things for which it wasn't designed. Investors and policy makers will stretch to find strategies that can integrate digital technologies, advanced materials, and DERs, to meet market responses, operational challenges, shifts in consumption. A strong grid will be key!

The WIRES Library Is Your Best Resource

All titles available at www.wiresgroup.com Click "Resources"

"Well Planned Electric Transmission Saves Customer Costs," with The Brattle Group (2016)

The electric industry needs to develop improved regional and interregional transmission planning right away to fully realize the potential future savings ranging from $30-70 billion for at least three reasons:

- Transmission projects require at least 5–10 years to plan, develop, and construct; as a result, planning would have to start now to more cost-effectively meet the challenges of changing market fundamentals and the nation's public policy goals in the 2020–2030 timeframe;
- A continued reliance on traditional transmission planning that is primarily focused on reliability needs will lead to piecemeal projects instead of developing integrated and flexible transmission solutions that enable the system to meet public policy goals more cost effectively; and
- We are in the midst of an investment cycle to upgrade or replace the existing transmission infrastructure, mostly constructed in the 1960s and 70s; this provides unique opportunities to create a more modern and robust electricity grid at lower incremental costs and with more efficient use of existing rights-of-way for transmission.

"Toward More Effective Transmission Planning - Addressing the Costs and Risks of An Insufficiently Flexible Electricity Grid," with The Brattle Group (2015)

For a more robust, flexible transmission infrastructure that reduces the costs and risks of delivering power, grid planners should:

- Not assume that less transmission is always a lower-cost solution. Instead, policy makers should urge planners to move from "conservatively" estimating transmission-related benefits to recognizing the full spectrum of benefits that transmission infrastructure investments can provide.
- Urge planners to move from "least regrets" transmission planning that identifies only those projects that are beneficial under most circumstances to also considering the potential "regrettable circumstances" that could result in very high-cost outcomes because of inadequate infrastructure.
- Urge transmission planners to move from compartmentalizing projects into "reliability," "economic," and "public policy" projects to considering the multiple values provided by all transmission investments.
- Expand interregional planning processes to allow for the evaluation of projects that address different needs in different regions, recognizing that benefits can differ across inter-connecting regions.
- Refrain from resorting to "least common denominator" approaches to interregional planning that consider only a subset of the benefits recognized in the individual regions.
- Consider the combined set of benefit metrics from all interconnected regions, even if some of the benefit metrics from other regions are not yet used in some of the regions' planning processes.
- Consider the unique additional values offered by interregional transmission projects, such as increased wheeling revenues or reserve sharing benefits that interregional transmission investments can provide.
- Apply benefit-to-cost thresholds to interregional projects that are no more stringent than those applied within each region.

"Market Resource Alternatives: An Examination of New Technologies in the Electric Transmission Planning Process," with London Economics (2014)

The report explains MRAs, analyzes the capabilities of each technology, and examines how supply-side and demand-side options (distributed generation, demand response, storage, smart grid technology, microgrids) can "serve as complements to transmission and vice versa."

> "MRAs [microgrids, distributed generation, demand response, energy storage, smart grid, and energy efficiency] can be broadly considered as programs or technologies that complement the transmission system and provide benefits similar to those provided by the transmission system. But some MRAs may face limitations that prevent them from providing the full suite of services and benefits that are created as a result of transmission investment. . . . The challenge for the regulators and planners is striking the right balance, not simply picking the "best" technology."

"The Benefits of Electric Transmission: Identifying and Analyzing the Value of Investments," with The Brattle Group (2013)

This is the first and best study to document the broad range of potential transmission-related benefits, metrics, and estimation practices which should be taken into account when planning any transmission investment.

> "Transmission planning has gradually expanded beyond addressing reliability and load serving concerns to include economics and public Policy drivers. In that context, planners and regulators increasingly recognize that planning for economic- and public policy-driven transmission projects require consideration of a range of benefits and costs associated with these investments."
>
> Transmission "tends to provide a broad array of benefits that accrue to a wide variety of parties over a large geographic dimension. That is, the benefits accrue at a micro and local level but transmission also directly benefits a broader set of customers in the electricity sector and indirectly creates benefits for society as a whole . . ." - London Economics

"Employment and Economic Benefits of Transmission Infrastructure Investment in the U.S. and Canada," with The Brattle Group (2011)

Transmission investment has risen in the 21st century as reliability needs are addressed and aging facilities are upgraded or replaced. However, certain economic and public policy goals, in particular congestion relief and renewable energy standards, necessitate more transmission investment, underscoring the multi-faceted benefits of a robust transmission network, including hundreds of thousands of jobs.

"Smart Transmission: Modernizing the Nation's High Voltage Transmission System" (2011)

This report focuses on transmission-level technologies and the new investments being made to enhance the transmission system with those technologies. It seeks to place in perspective investment in smart technologies and in the physical transmission capacity that will be more fully utilized as part of the Smart Grid.

"Integrating Locationally-Constrained Resources Into Transmission Systems: A Survey of U.S. Practices," with CRA International (2008)

This paper reviews effective practices to integrate locationally-constrained generation into the existing transmission network. Locationally-constrained generation refers to power production that faces limitations on geographical placement due to i) inputs, ii) technology, or iii) outputs.

"A National Perspective on Allocating Cost of New Transmission Investment: Practice and Principles," with a Blue Ribbon Panel of Experts (2007)

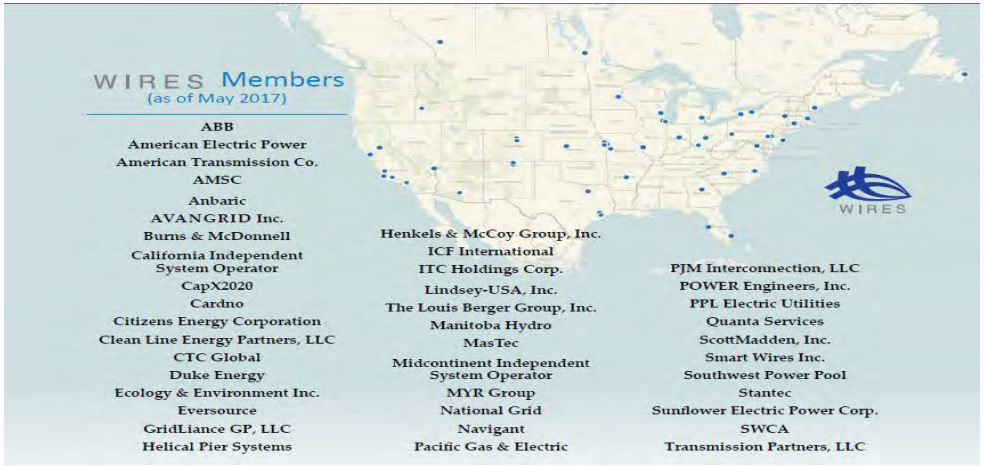
This white paper focuses on the principles for determining the benefits of new transmission investments, and for allocating the costs efficiently and equitably among those who benefit from the enhancement.

WHAT IS WIRES ?

WIRES is the principal international industry coalition dedicated solely to promoting investment in North America's most critical energy infrastructure network to ensure the grid's reliability and resilience, promote resource (fuel) diversity, alleviate congestion and replace outdated technologies, support competitive bulk power markets, and save consumers costs.

WIRES members are:

- Investor-owned utilities
- Member-owned cooperatives (G&Ts)
- Independent transmission providers
- Renewable energy developers
- Technology & service companies
- Environmental & engineering firms



Our Goals

- **A robust electric transmission grid to serve the growing electrification needs of the changing 21st Century North American economy**

- **Increased private capital grid investment through regulatory certainty and reduced barriers to development**

Honorable Jerry McNerney (D-CA)
U. S. Representative and Member, House Committee on Energy and Commerce
Co-Chair, Grid Innovation Caucus

WIRES

Panel 1

GRID MODERNIZATION FOR THE ELECTRIFIED ECONOMY

WIRES

WIRES – a international association of entities dedicated to investment in a strong, well-planned and environmentally beneficial electricity high-voltage transmission system in the US

Barbara Tyran

Executive Director
Government & External Relations

Electric Power Research Institute

WIRES

WIRES – a international association of entities dedicated to investment in a strong, well-planned and environmentally beneficial electricity high-voltage transmission system in the US

EPRI ELECTRIC POWER RESEARCH INSTITUTE

Our Energy Future

Integrated Energy Network

Barbara Tyran

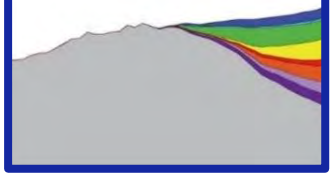
Executive Director

Government & External Relations

May 2017

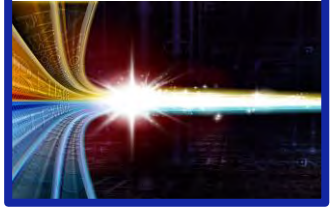
The Integrated Energy Network Builds upon Decades of EPRI Thought Leadership

PRISM: Portfolio for Clean Generation



Energy Efficiency

Flexible, Resilient, and Connected Power System



Connected Customers

Integrated Grid

EPRI ELECTRIC POWER RESEARCH INSTITUTE

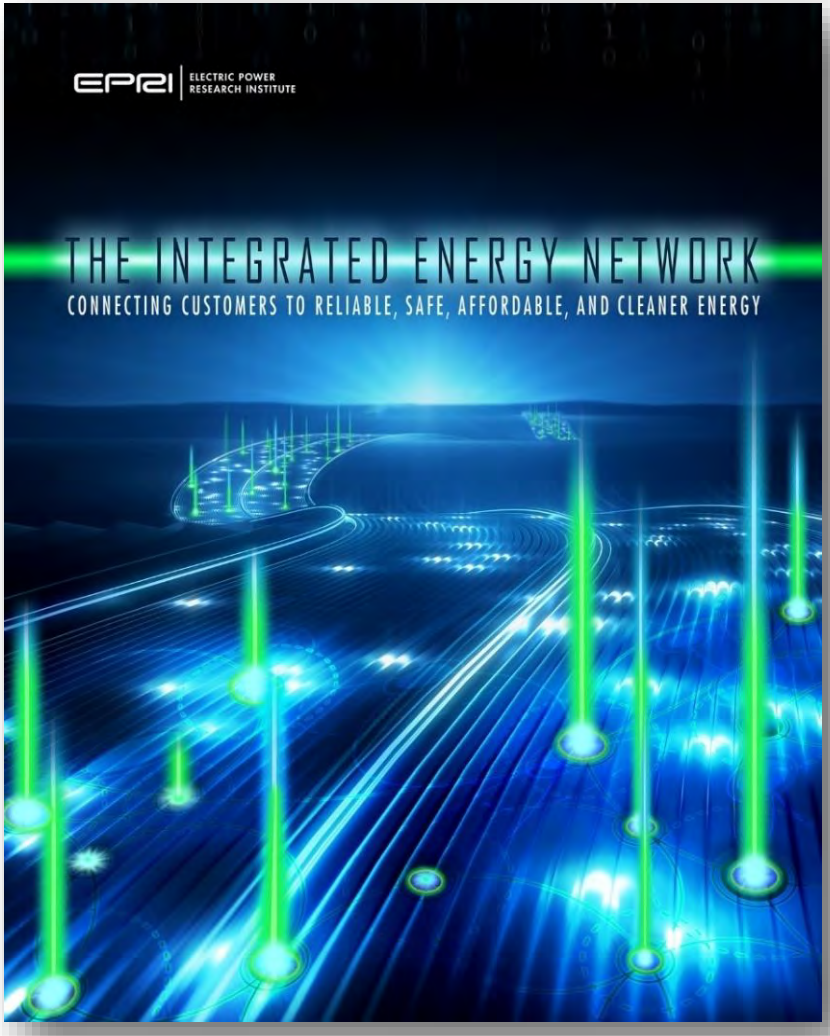
Energy Sources

The systems and infrastructure for supplying electricity, gas, and water are minimally integrated across these energy sectors

Integrated Energy Network

Imagine an energy future where all forms of energy can be optimally integrated to connect customers with safe, reliable, affordable and clean energy resources

Integrated Energy Network



Website: http://ien.epri.com

We welcome your engagement as we continue to discuss *The Integrated Energy Network*

Cristin Lyons

Partner & Practice Lead-
Grid Transformation

ScottMadden

WIRES

WIRES – a international association of entities dedicated to investment in a strong, well-planned and environmentally beneficial electricity high-voltage transmission system in the US

Smart. Focused. Done Right.®

Distributed Energy Resources and Transmission

WIRES University

June 2017

Energy is Who We Are

ScottMadden is a management consulting firm with more than 30 years of deep, hands-on experience.

We deliver a broad array of consulting services—from strategic planning through implementation—across the energy utility ecosystem.

WE DO

WHAT IT TAKES TO GET IT DONE

RIGHT

ENERGY

Our Energy practice has been serving the industry since 1983 by solving the right problem, the right way, and delivering real results.

We provide guidance on how to solve the right problem with industry-leading practices and management insights.

GRID TRANSFORMATION

Our Grid Transformation practice helps clients transform the way they operate, plan, and maintain the grid and interact with their customers.

We provide guidance on how to proactively engage with regulators through this transformation.

CLEAN TECH & SUSTAINABILITY

Our Clean Tech & Sustainability practice helps clients develop innovative solutions based on a unique understanding of what works in the energy through a perspective built from 30 years of energy experience.

We provide guidance on navigating clean and renewable sources of energy, smart energy management, and sustainability.

REGULATORY, RATES, & ECONOMICS

We assist our clients with regulatory strategy and litigation services, ranging from strategy development to expert witness testimony.

We provide data-driven analysis of market trends and future scenarios and offer economic and financial advisory services to help you structure, negotiate, and finalize transactions.

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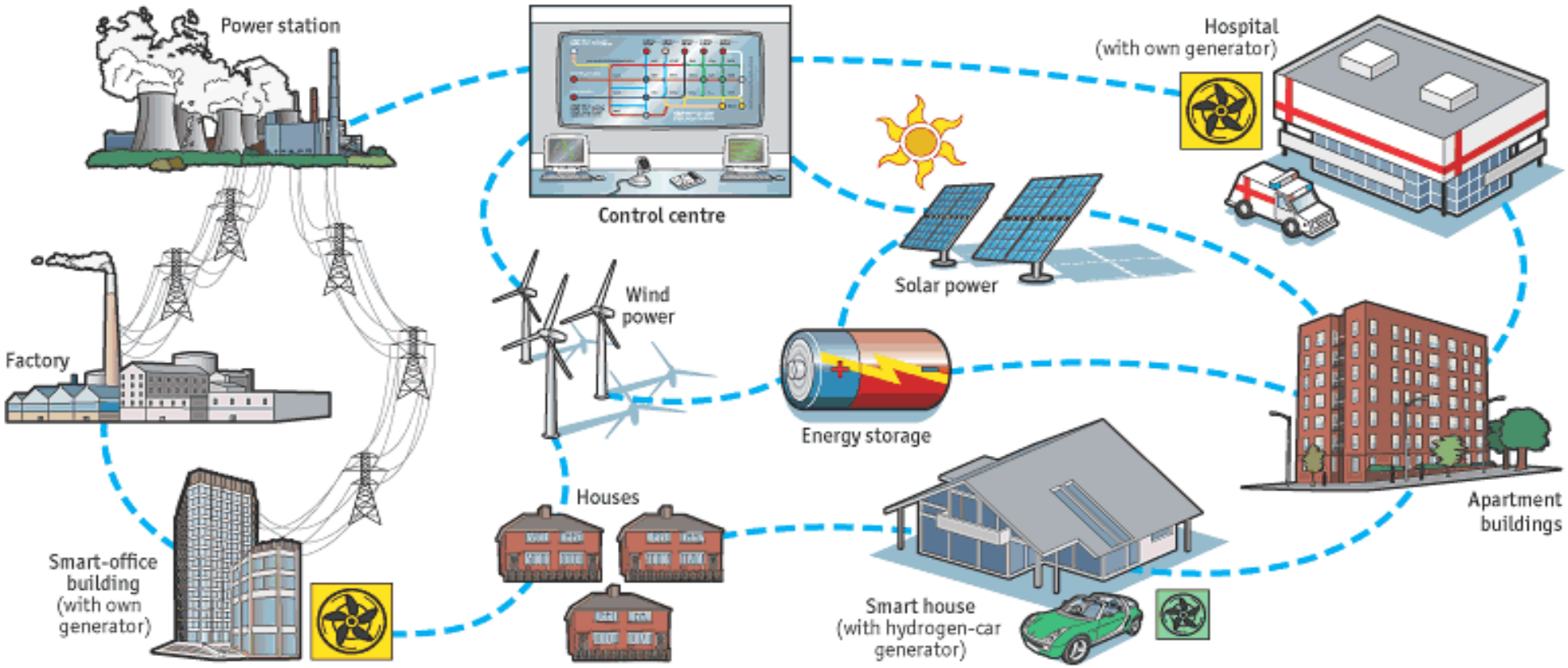
Distributed Energy Resources (DERs)

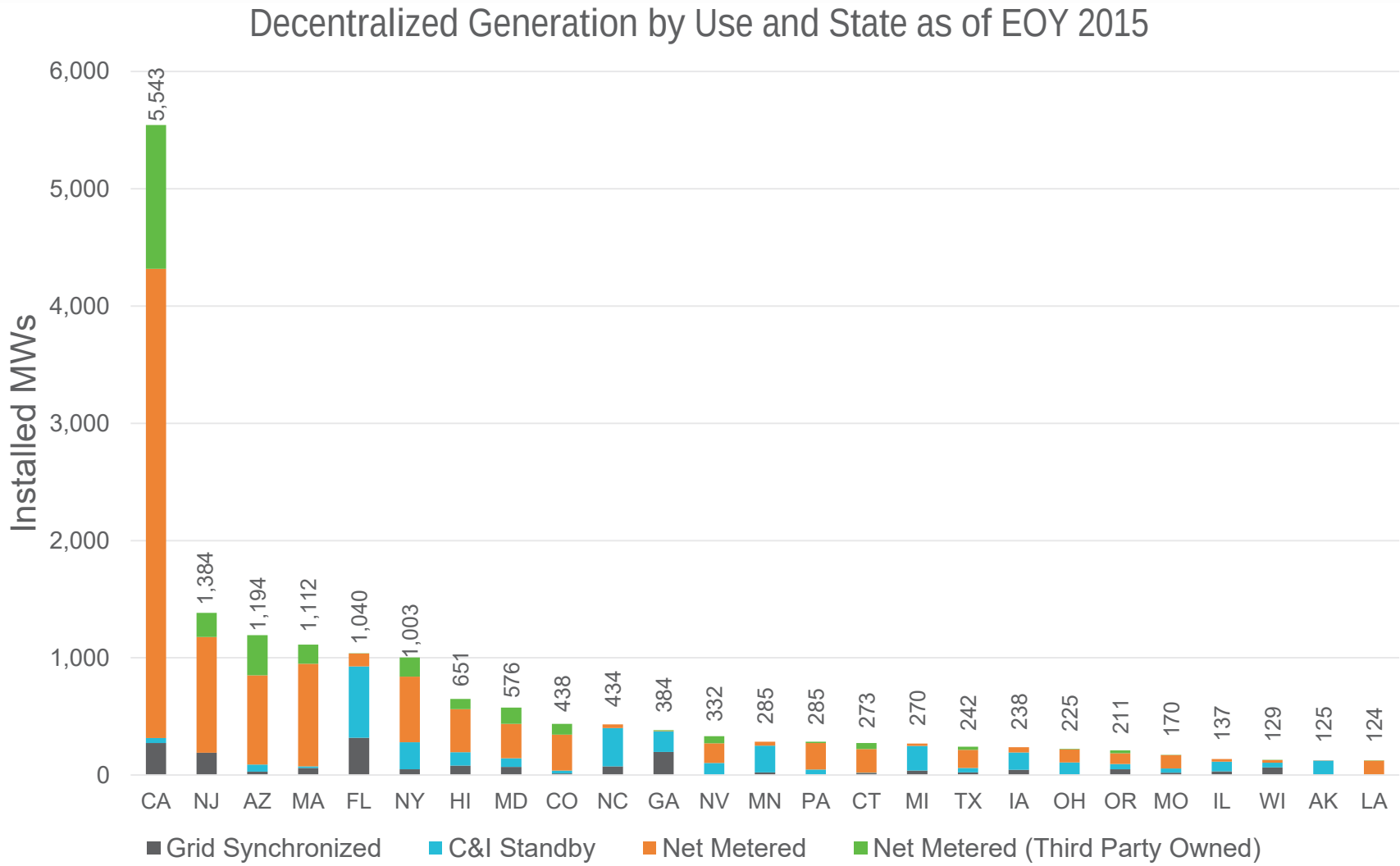
DERs include energy efficiency, demand response, distributed generation, electric vehicles, battery storage, and microgrids



Sources: *The Economist*; ABB

DERs

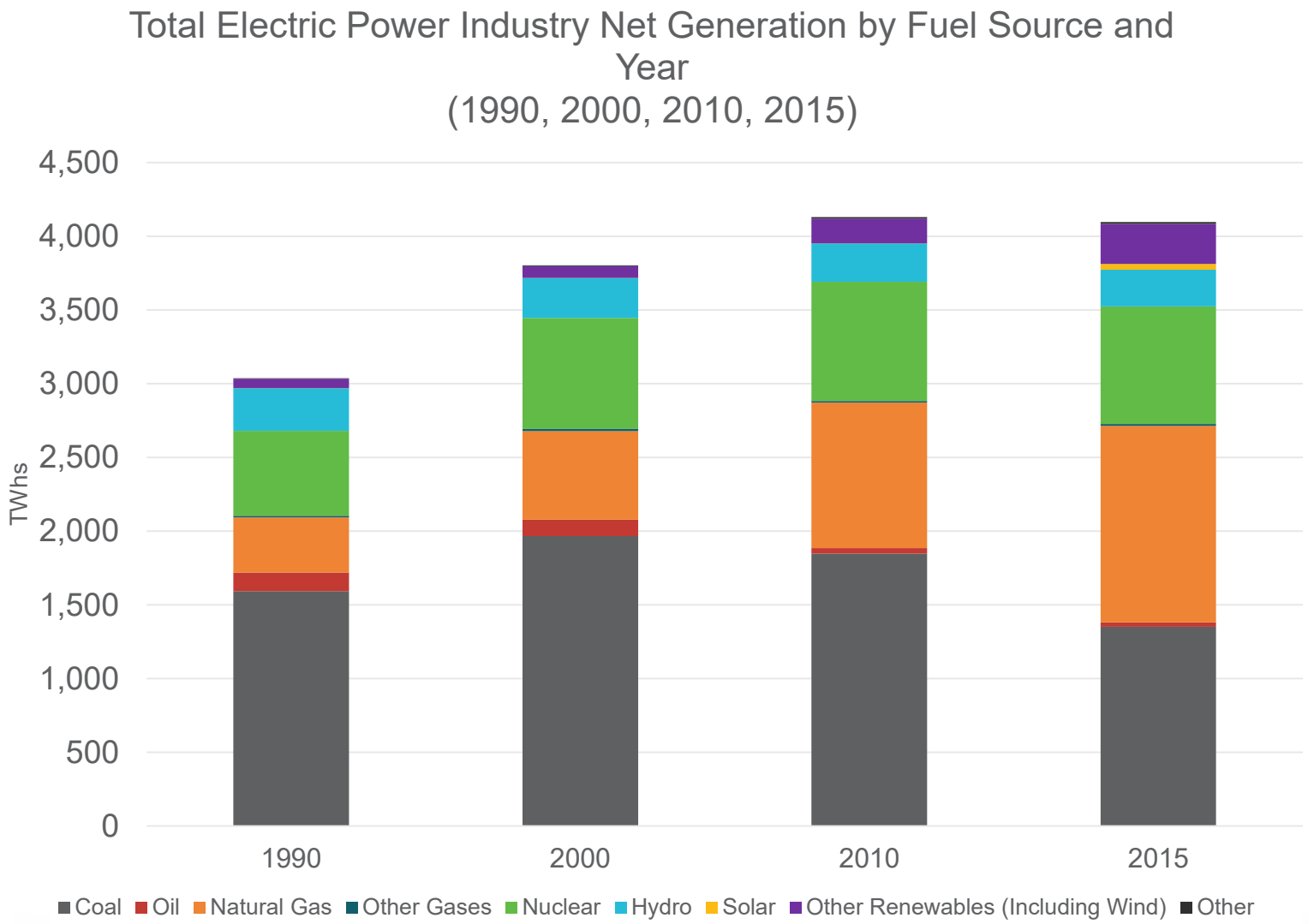
Decentralized Generation



NOTES:
The grid-synchronized category includes commercial and industrial generators less than 1 MW in capacity that are grid connected and grid synchronized. The C&I standby category includes commercial and industrial generators less than 1 MW in capacity that are not connected nor synchronized to the grid. The net metered category refers to residential, commercial, and industrial generators that are less than 2 MWs in capacity and maintain a net-metering agreement with the local utility. Due to the nature of the data, it is possible some systems may be double counted. Figures are from 2015, the most recent data available.
SOURCE: EIA Form 861

Historical Energy Data

Net Generation by Fuel Source



Notes:
- Figures as of January 2017
- SOURCE: EIA Electric Power Annual

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Transmission Owners and Operators Will Have To:

- Manage an increasingly intermittent system (utility scale renewables, DERs)
- 'See' into the distribution system
- Enable the aggregation of DERs and manage them in wholesale markets
- Plan the transmission system differently

A robust transmission system is critical to managing increasing amounts of intermittent resources

Cristin Lyons

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Judy Chang

Principal/Director

The Brattle Group

WIRES

WIRES – a international association of entities dedicated to investment in a strong, well-planned and environmentally beneficial electricity high-voltage transmission system in the US

Well-Planned Transmission System **To Integrate Customers' Needs** and Resources

New System for the New Era

PRESENTED AT:

WIRES University
"ELECTRIC TRANSMISSION INFRASTRUCTURE:
Economic, Policy, & Technology Benefits of Investment"

PREPARED BY:

Judy Chang
Johannes Pfeifenberger

May 25, 2017

THE Brattle GROUP

Agenda

Electricity Industry Trends

- Customers' Preferred Resources
- Electrification and Future Power Grid

Drivers of Transmission Investments

Transmission and the New Era

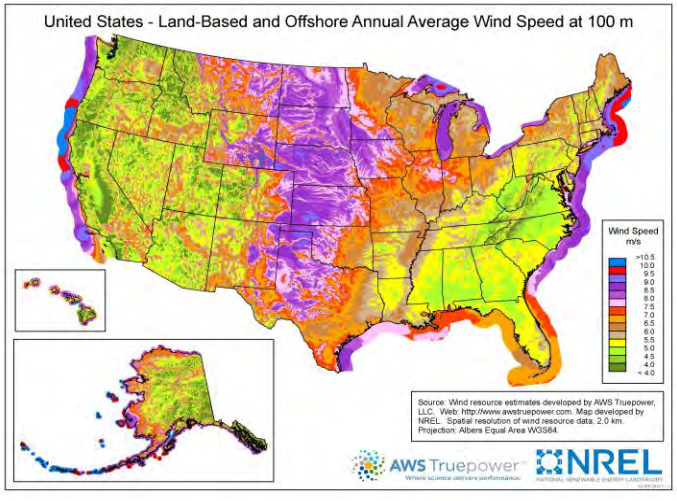
Electricity Industry Trends

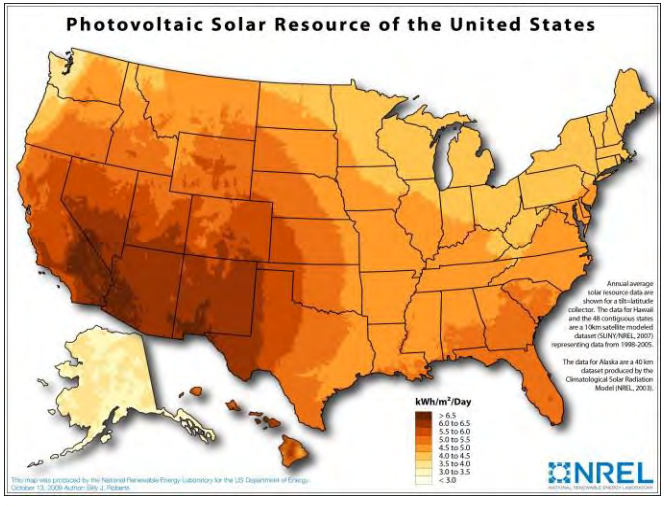
- **Reduced growth in traditional electricity consumption**, even in the age of internet of things
- **Increased customer preferences for conservation and clean energy**
- **Technological advances** that allow customers and electric utilities to better monitor and control electricity usage
- Significant **cost reduction in solar and wind generation** and innovative project financing, yielding low cost clean resources
- **Low natural gas prices** place significant downward pressure on coal and nuclear plants
- **Increased stringency in other environmental regulations** of air emissions, water usage, waste disposal, and land use for all power plants
- **Increasing electrification** of transportation and heating

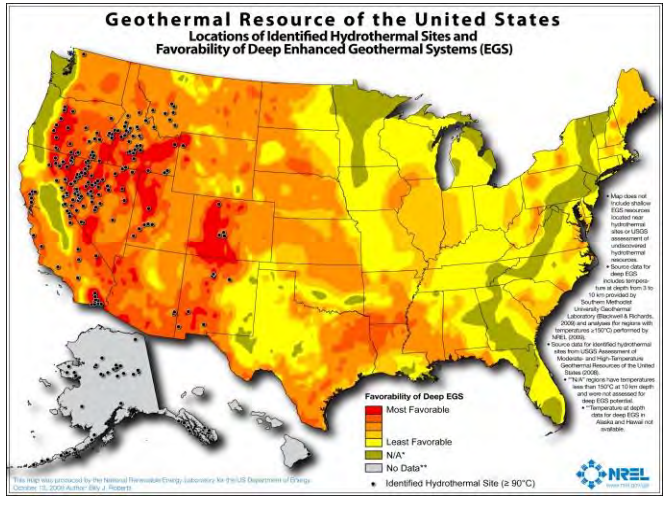
These are significant changes that utilities, grid operators and regulators are trying to manage.

Clean Energy to Meet Customers' Needs

- Potential for and quality of renewable energy resources vary by region
- Lowest-cost onshore wind resources are on the edges of Eastern and Western Interconnection and Texas.
- The Southwest has some of the best solar resources
- Some western states have high potential for geothermal
- Significant opportunity to increase import from Canadian hydropower across U.S. states





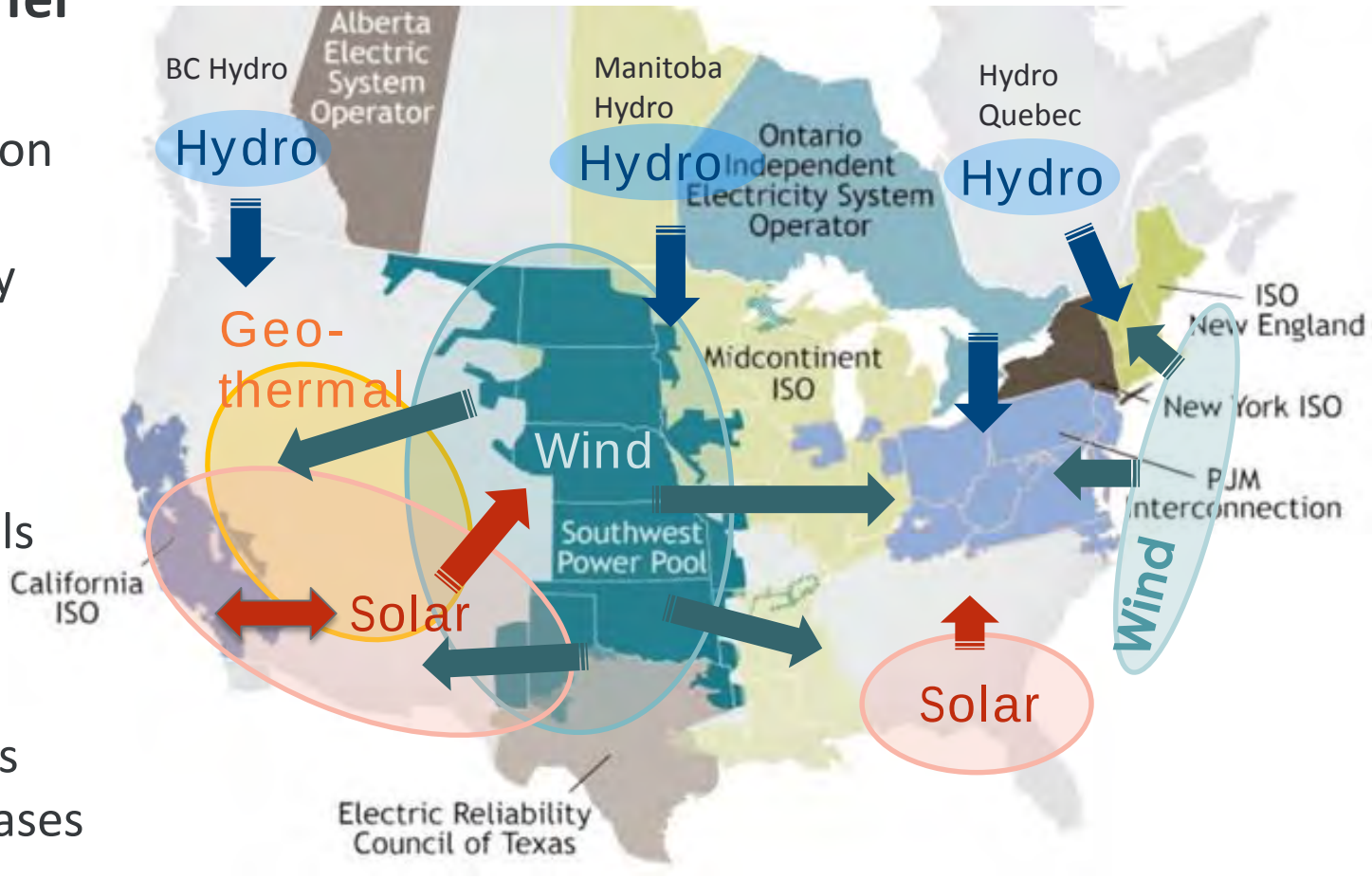


Source: NREL

Diversifying Use of Low-Cost Clean Energy

Focusing on resource diversification can offer significant benefits:

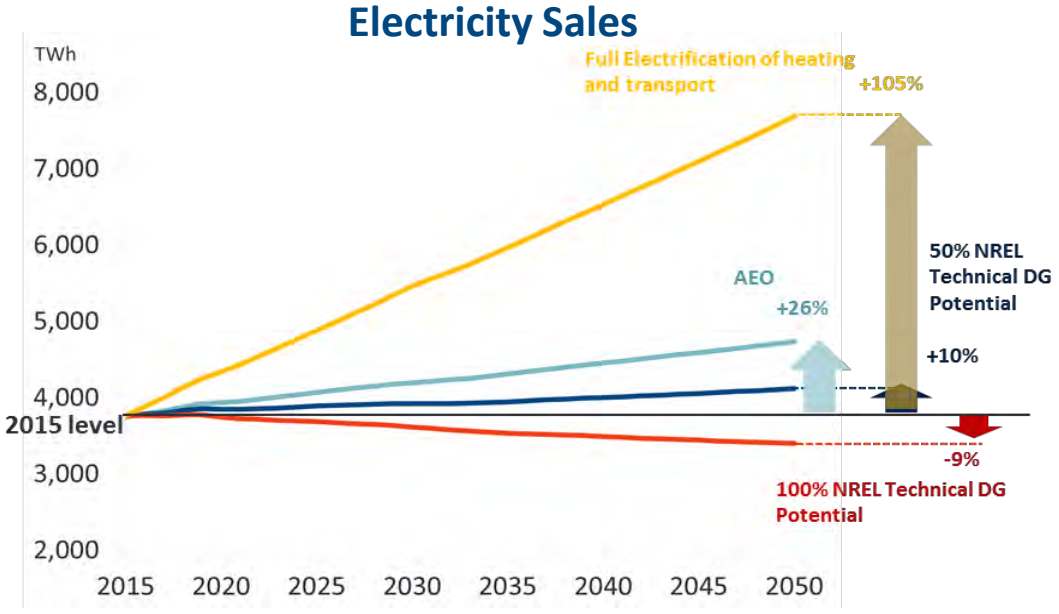
- Regional diversification of resources (and customers' electricity usage) reduces the investment and balancing cost in a future with high levels of intermittent resources
- Diversity of resources (and load) also increases the value of transmission that interconnects them

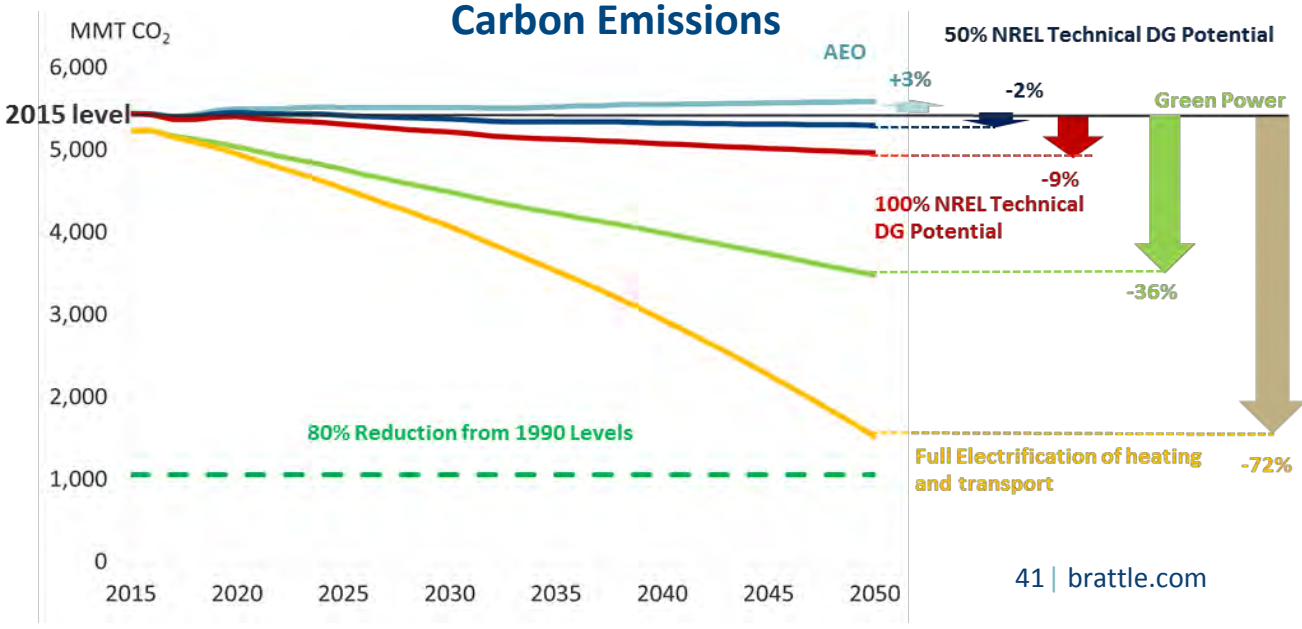


Electrification of Transportation

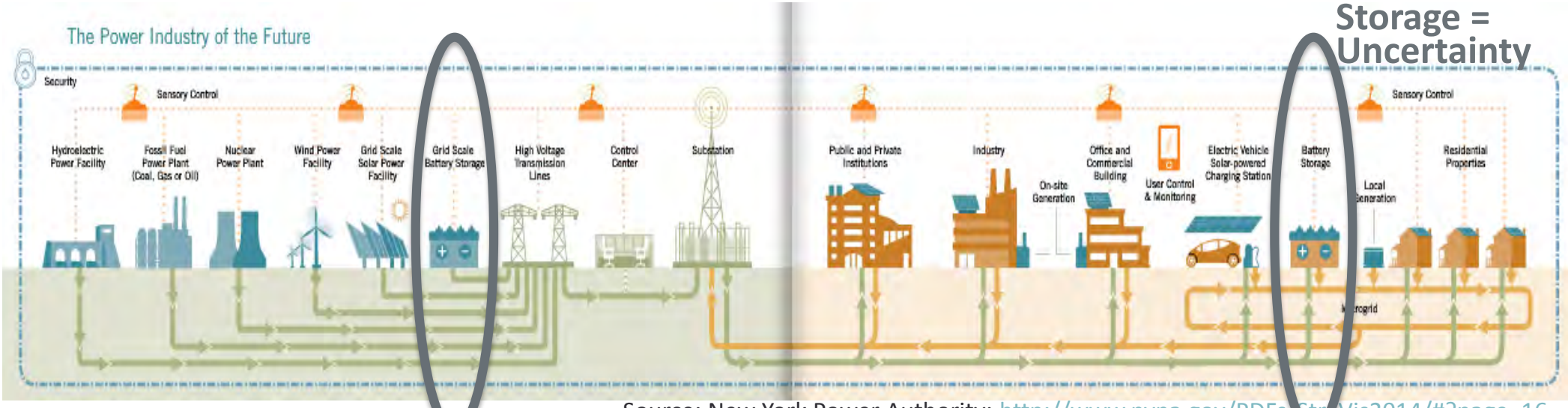
With full electrification:

- Electrification could double electricity sales and (mostly) achieve long-term emissions reduction goals
- 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**





The Future Power Grid



Source: New York Power Authority: http://www.nypa.gov/PDFs/StraVis2014/#?page=16

- Customers becoming "Prosumers": simultaneously producers and consumers
- This creates tremendous opportunities for:
  - Customers to control electricity usage
  - Customers to engage with other customers and new service providers

The "new" transmission system needs to interface with the "new" distribution systems to ensure efficient operations and investment on both systems

Main Drivers of Transmission Needs

- **Serve growing load**
- **Capture diversity of customers' needs**
- **Relief system congestion**

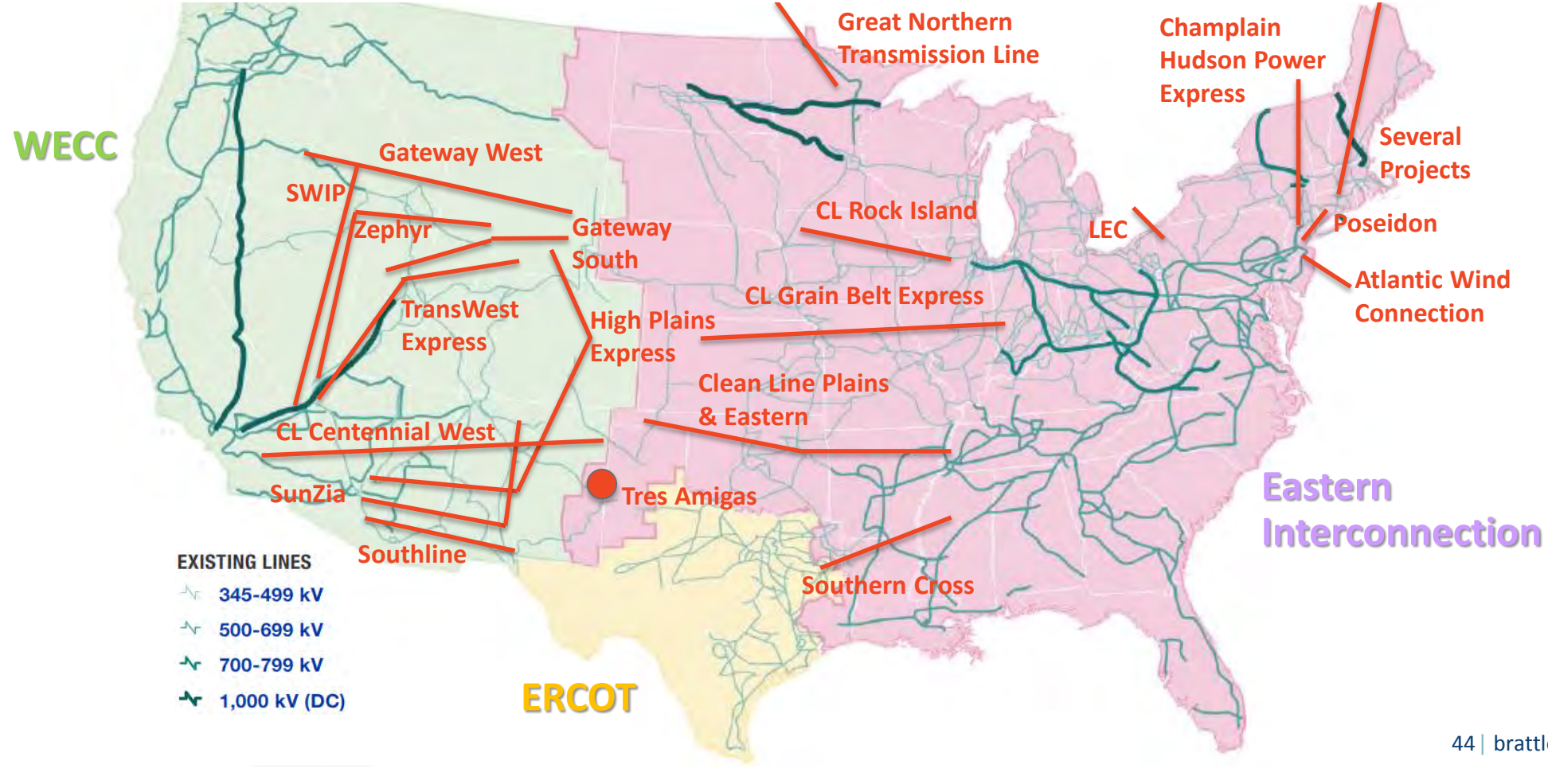
Traditional Drivers

- **Access to low-cost renewable and clean energy**
- **Capture renewable energy and fuel diversity**
- **Help meet regional needs**

New Drivers

Already-Proposed Interregional Projects

Numerous developers have already proposed participant-funded or merchant transmission projects, most of which are driven by plans to deliver low-cost wind, solar, or hydro resources to regions with desired clean energy needs. Their location choices are right on!



Industry Studies Show Well-Planned Transmission Investments Reduce Total Costs

European studies come to the same conclusions:

- **Integration of Distributed Generation in Europe:**
  - Choice between centralized, utility-scale generation and distributed generation does not have a direct impact on transmission needs
  - **Germany:** three new north-south transmission lines needed to reduce the cost of a clean energy future despite substantial reliance on distributed generation
- **European E-Highway 2050 Study:** Interregional transmission investments significantly reduce the cost of a low-carbon electricity sector by facilitating the integration and diversification of lower-cost renewable resources region-wide
- **Transformation of Europe's Power System Until 2050:**
  - McKinsey study found that the most cost-effective way to reach 40–45% renewables by 2050 would require a doubling of existing region-wide transmission capabilities by 2020 and an almost fourfold increase in transmission capabilities by 2050.
  - Local approach would be 30–35% more expensive Europe-wide interregional coordination.
- **Integration of Renewable Energy in Europe:**
  - Most cost-effective path to achieving Europe's overall renewable energy policy objectives requires a substantial expansion of its transmission networks; delay in investments increases the overall system-wide costs and price volatility.

Well-Planned Transmission Investments Can Reduce Electricity Costs for Customers

U.S. industry studies consistently show that well-planned transmission investment can significantly reduce overall 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.

Bio and Contact Information

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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.*

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.

Speaker Bio and Contact Information

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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.

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

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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.

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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

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

Panel 2

THINKING ABOUT THE GRID AS A STRATEGIC ASSET, AN ENABLER, AND PROBLEM SOLVER

WIRES

WIRES – a international association of entities dedicated to investment in a strong, well-planned and environmentally beneficial electricity high-voltage transmission system in the US

Rob Gramlich

Founder

Grid Strategies LLC

WIRES

WIRES – a international association of entities dedicated to investment in a strong, well-planned and environmentally beneficial electricity high-voltage transmission system in the US

Grid Expansion as Enabler

Rob Gramlich, Grid Strategies LLC

WIRES University 5/25/17

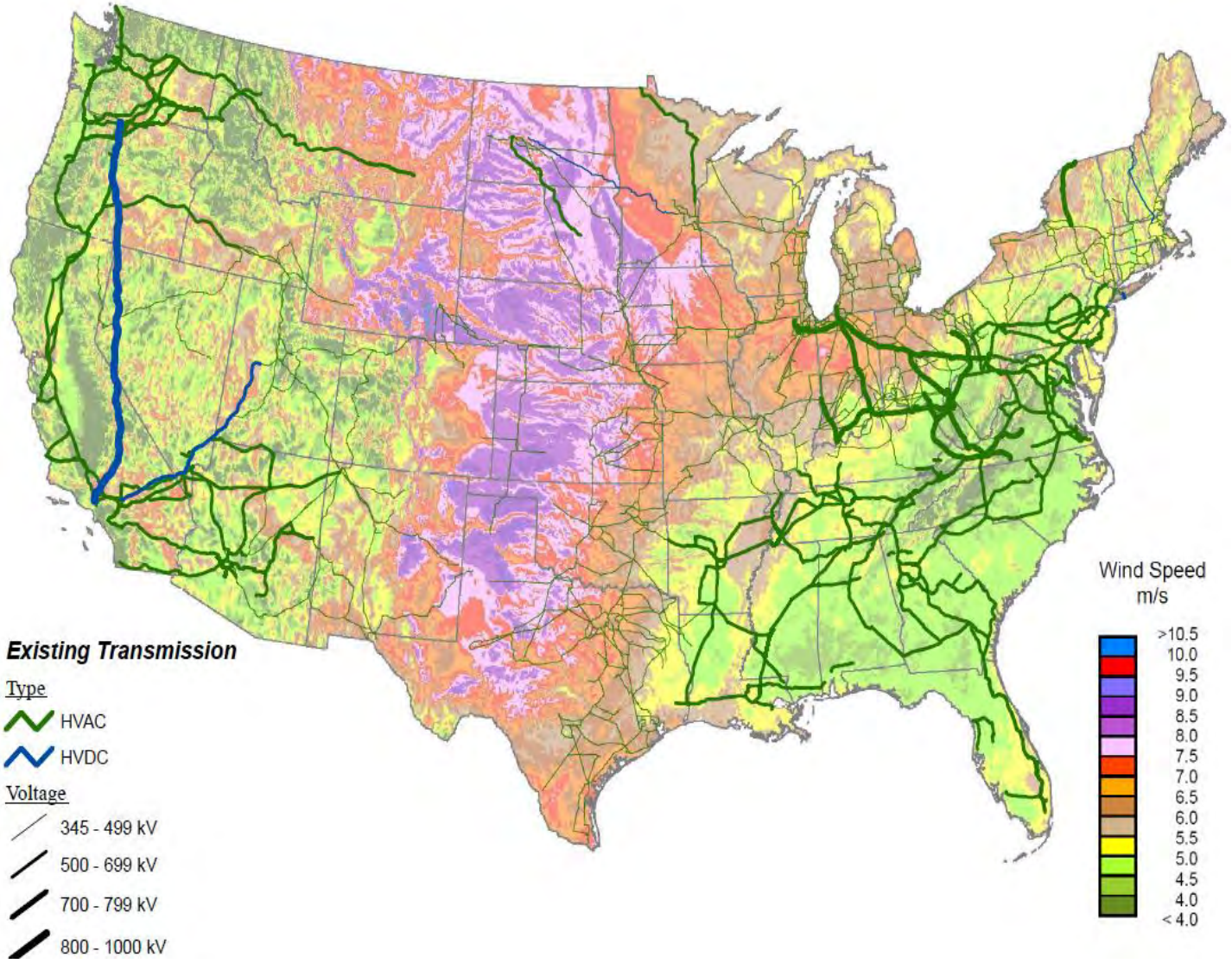
What is Grid Strategies LLC

- Strategy and policy for clean energy delivery
- Started February 2017
- Washington, DC area
- FERC, DOE, RTOs, states, utilities
- www.gridstrategiesllc.com

GRID STRATEGIES

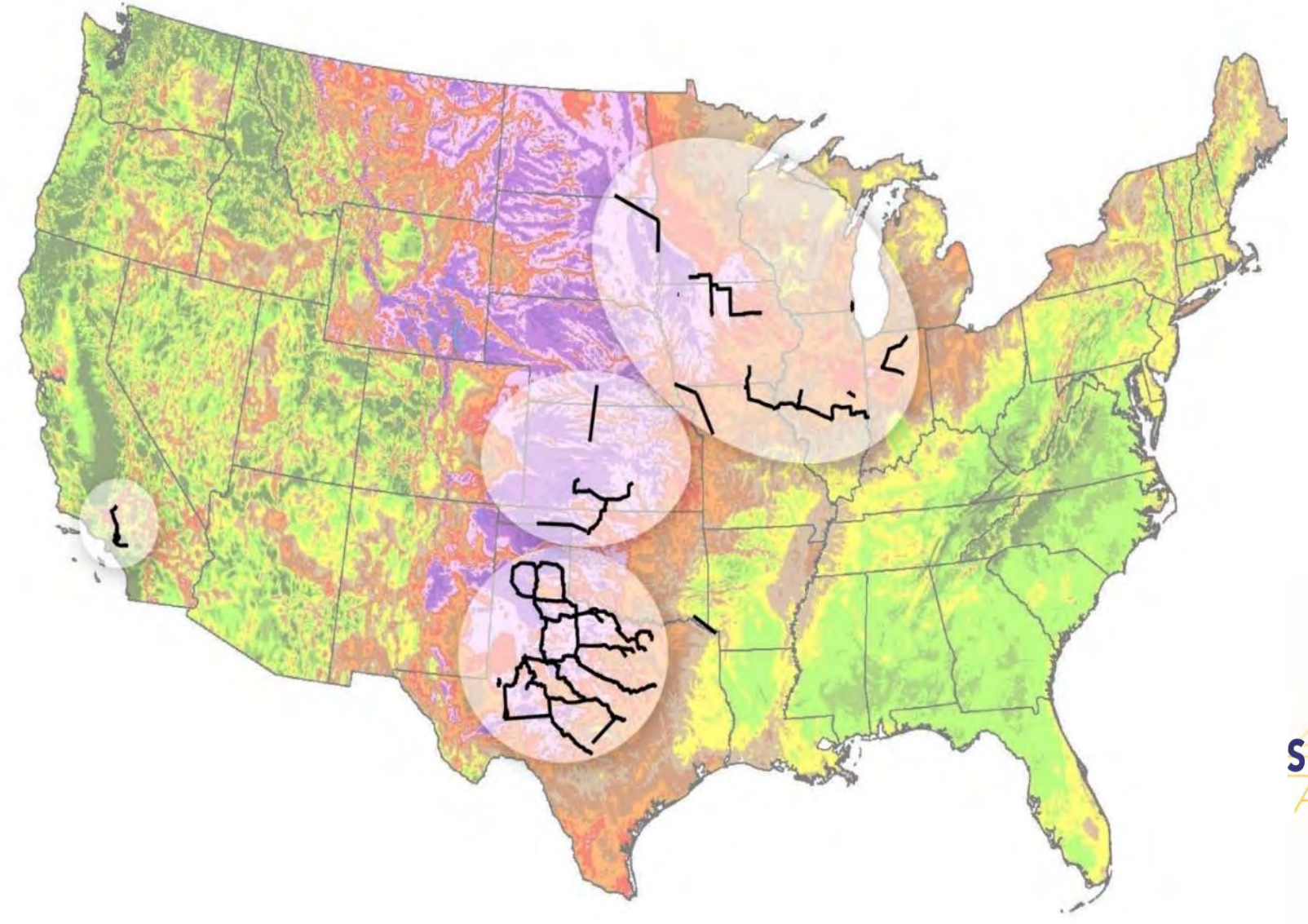
The Grid We Have Connected Remote Resources

but the best resources are untapped



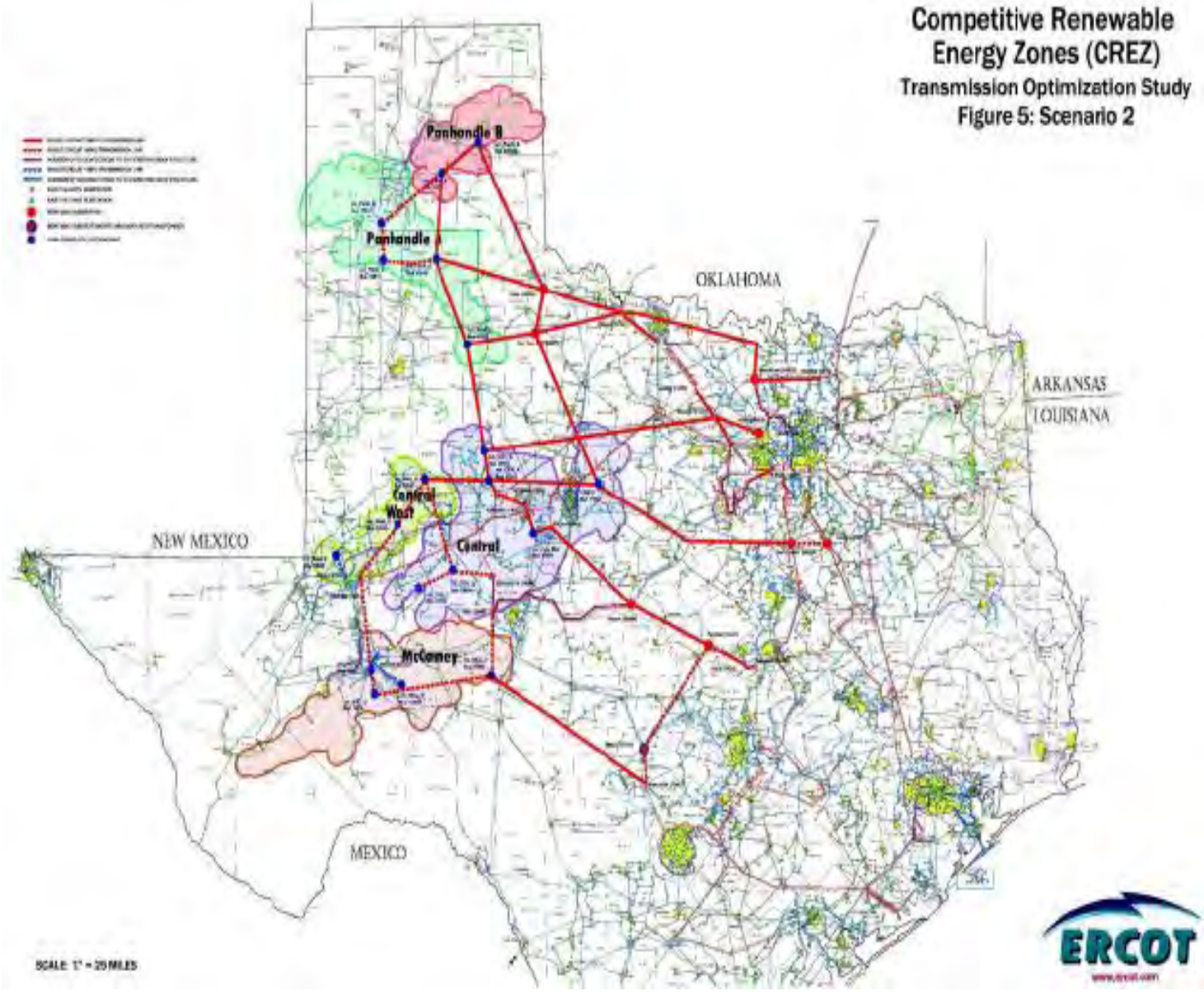
GRID STRATEGIES

Recent Successful Grid Expansion



GRID STRATEGIES

Texas Competitive Renewable Energy Zones

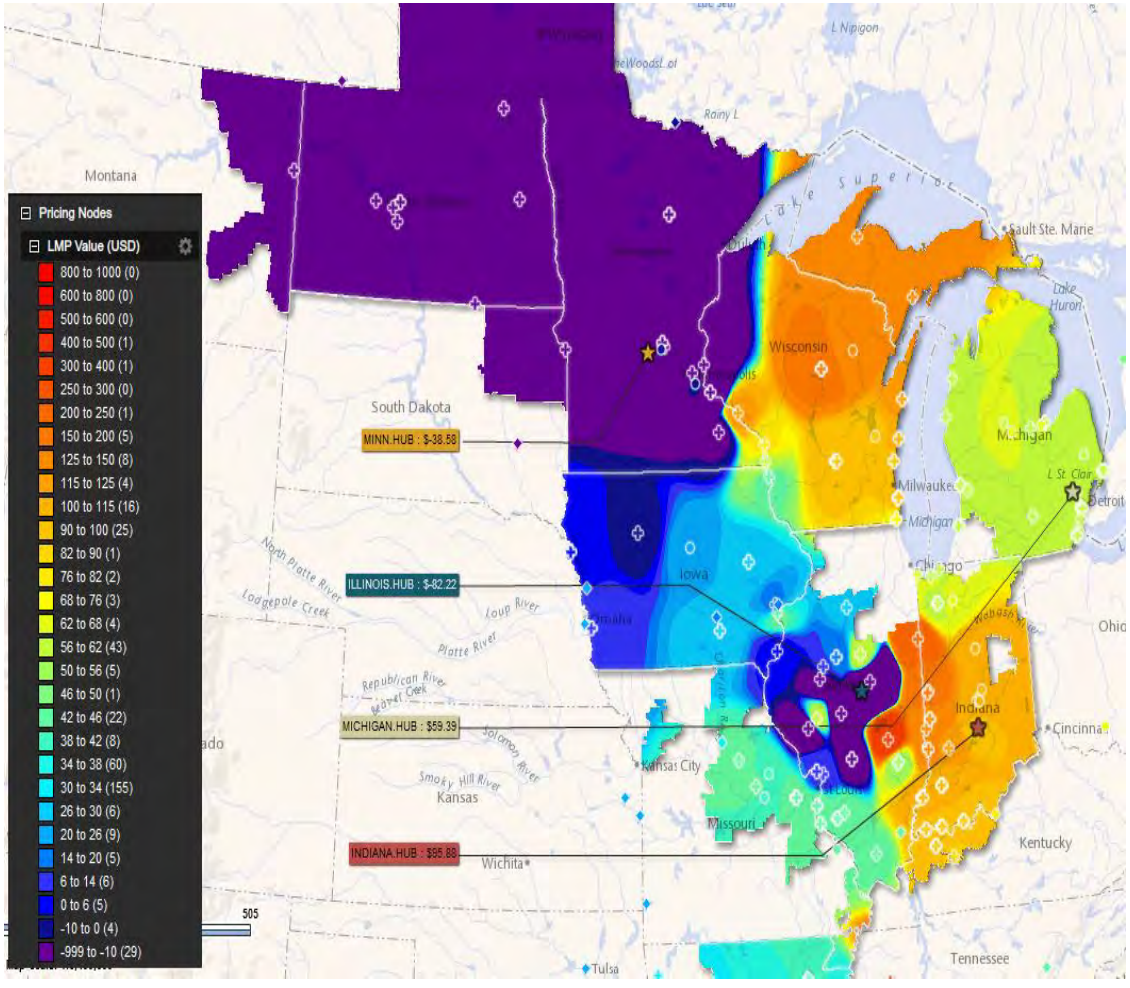


How We Did It

- From $4b/year to nearly $20b/year nationally
- Broad regional pro-active planning
  - Compare all benefits to all costs
    - Benefits 2 to 3x the cost
- Cost allocation to all beneficiaries
  - Accounting for a range of benefits
    - (eg, MISO “Multi-Value Projects”)
- Easier in Texas with one state
- FERC and RTO challenges in multi-state regions

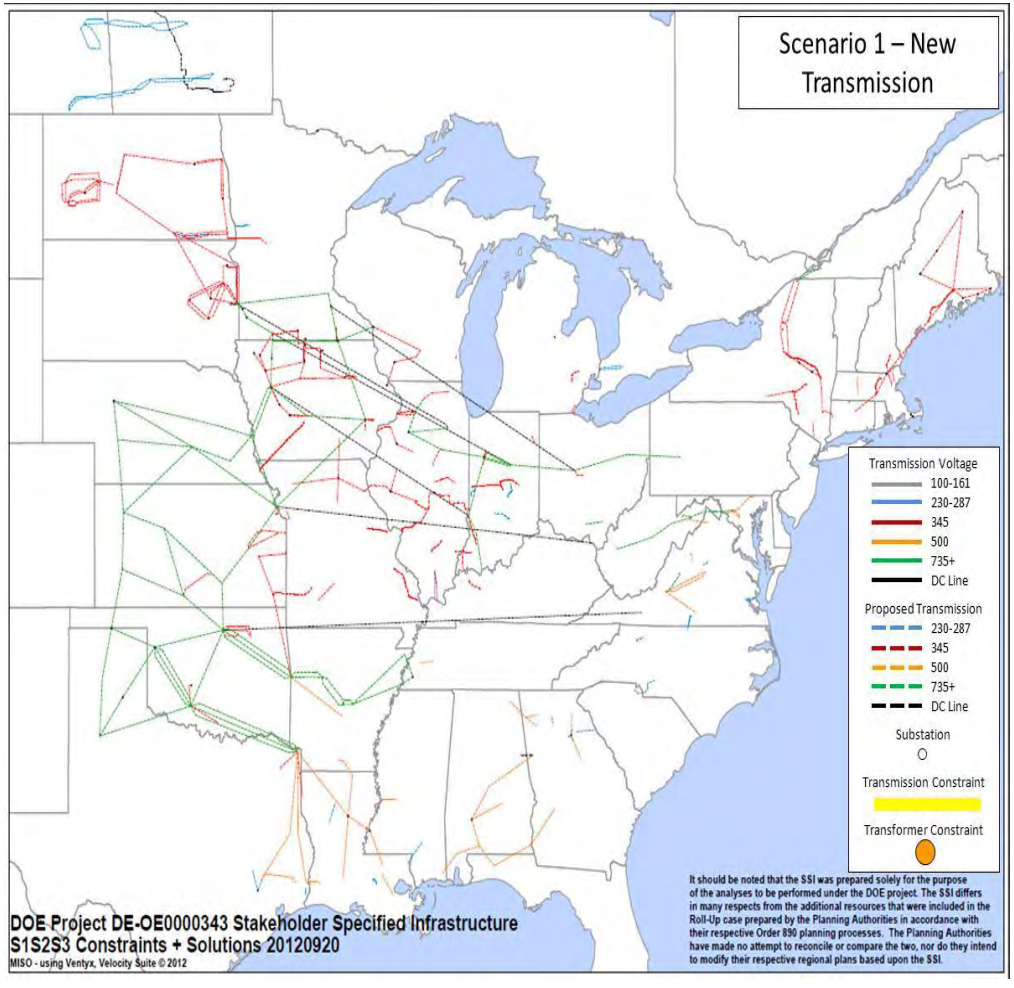
GRID STRATEGIES

We Need More Grid to Reduce Congestion



GRID STRATEGIES

Modeling Shows Beneficial Lines and Paths



GRID STRATEGIES

Two Business Models for Grid Expansion

- Integrated AC network lines
  - Regionally planned
  - Regionally cost-allocated by planner, overseen by FERC
  - Permitted by counties, states, federal land agencies

- Merchant DC lines
  - Paid through voluntary capacity reservations
  - Also permitted by counties, states, federal land agencies

GRID STRATEGIES

Grid Expansion Policy Framework

- Improve permitting
  - Recognize national role when states disagree
  - Use limited authorities that exist
  - FAST-41, inter-agency coordination

- FERC support for:
  - Pro-Active Economic Planning
    - Regional + Inter-regional
    - Resilience related
  - Cost allocation to beneficiaries

- Incentives to Right-Size Lines

GRID STRATEGIES

J. Arnold Quinn

Director – Office of Energy Policy & Innovation

Federal Energy Regulatory Commission

WIRES

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Caitlin Durkovich

Leadership Team

Toffler Associates

WIRES

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Dan Prowse

Transmission & Special Projects Officer

Manitoba Hydro

WIRES – a international association of entities dedicated to investment in a strong, well-planned and environmentally beneficial electricity high-voltage transmission system in the US



Thinking About the Grid as a Strategic Asset, An Enabler, and Problem Solver: Cross Border Trade

WIRES UNIVERSITY Graduate School
"ELECTRIC TRANSMISSION INFRASTRUCTURE:
Economic, Policy, & Technology Benefits of Investment"

May 25, 2017
One Constitution Avenue, N.E.
Washington, DC

Dan Prowse, P. Eng, FEC
Transmission Systems Operations
Manitoba Hydro

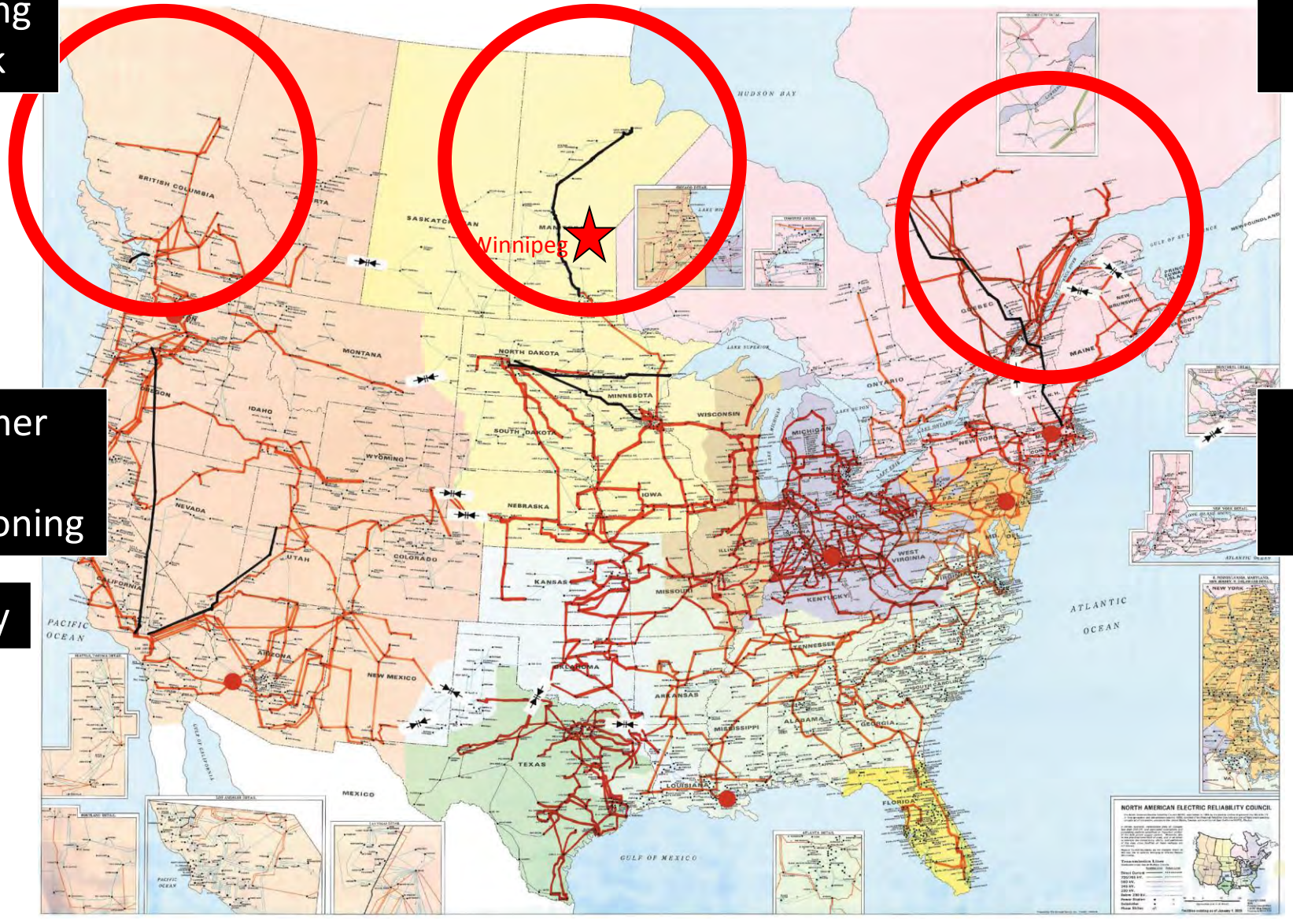
Manitoba Hydro

Cross-Border Trade Shares
Canadian **Hydro** with US Markets

Winter Heating Peak

Summer Air Conditioning

Monthly



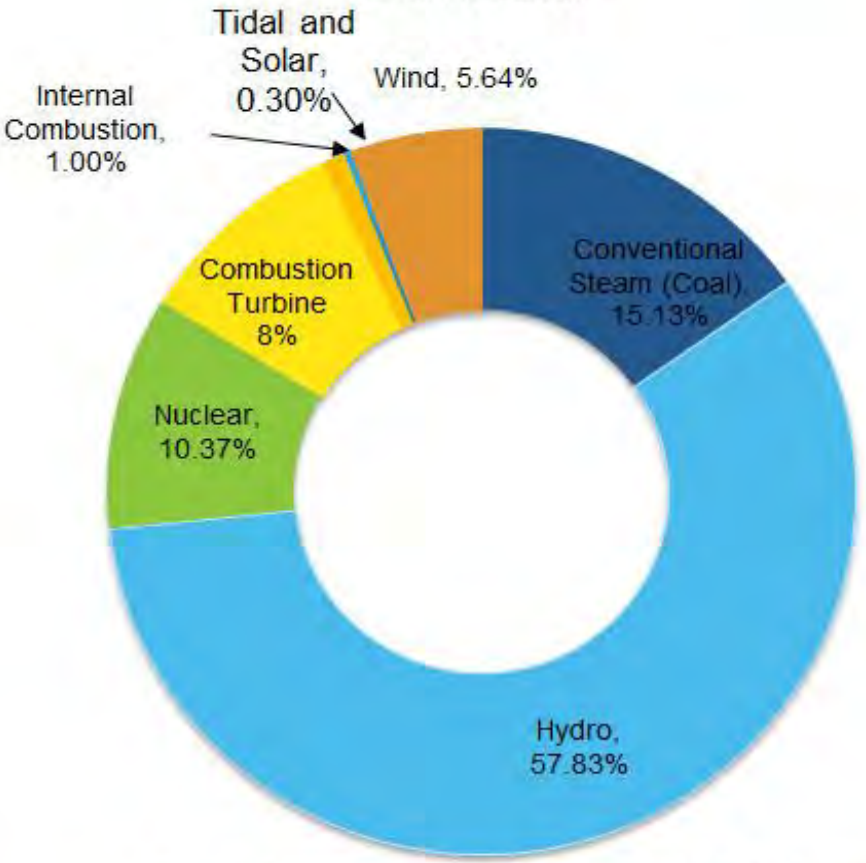
Hydro Energy Storage

Variable Wind Power

5 Minutes

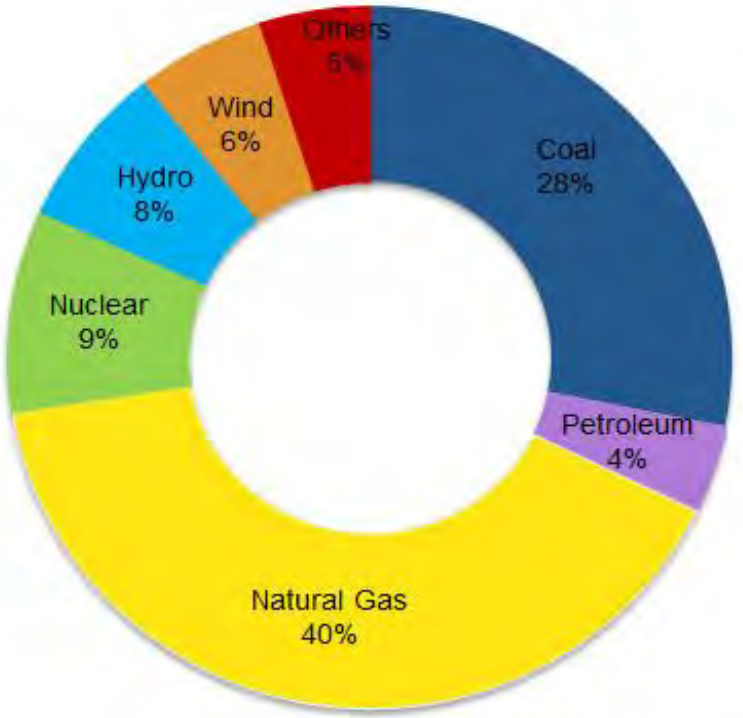
Electricity Generating Capacity in the US and Canada by Fuel Type,[1] 2015

Canada



Total Generating Capacity = 135.3 GW

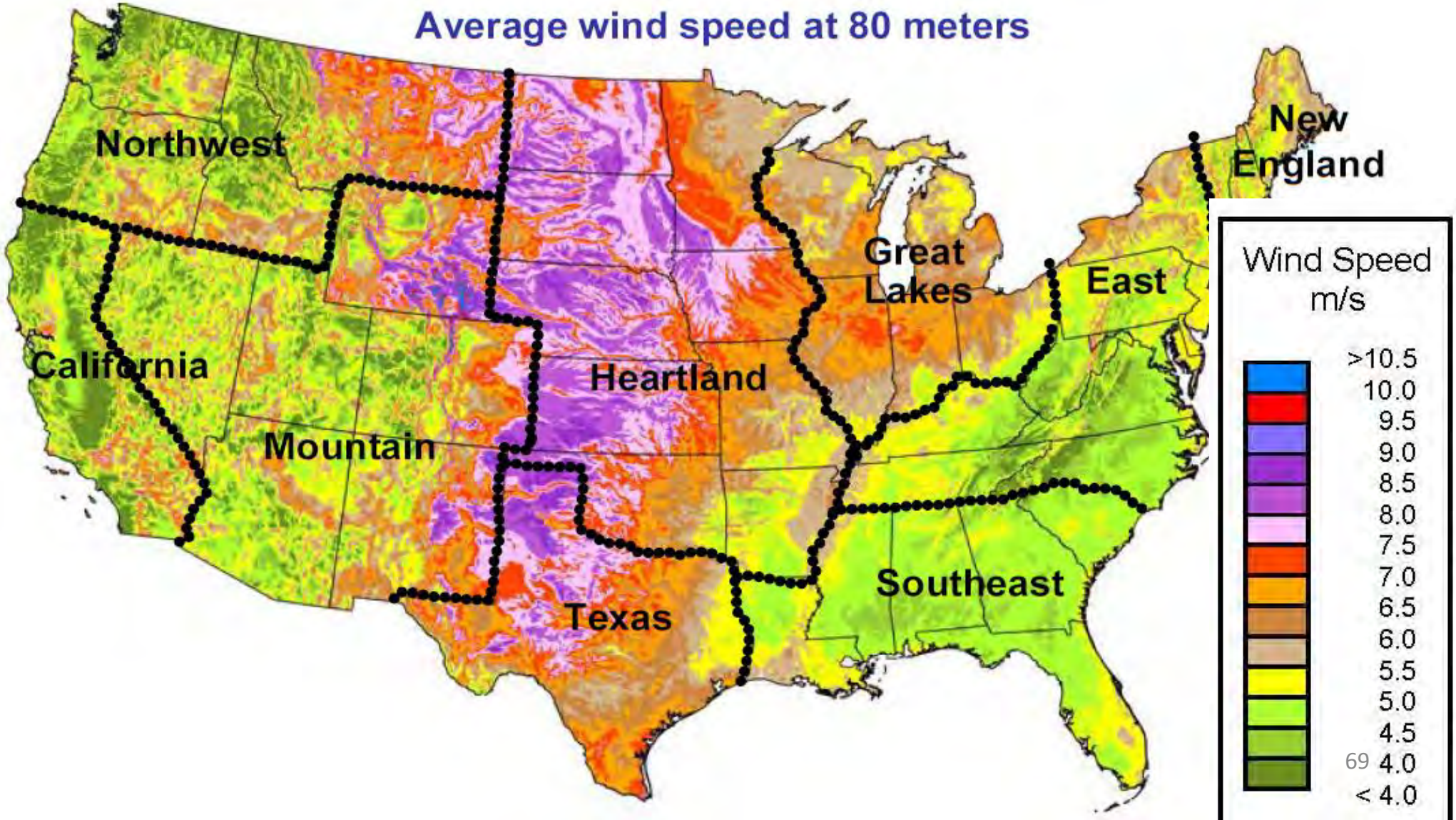
United States



Total Generating Capacity = 1,066.5 GW

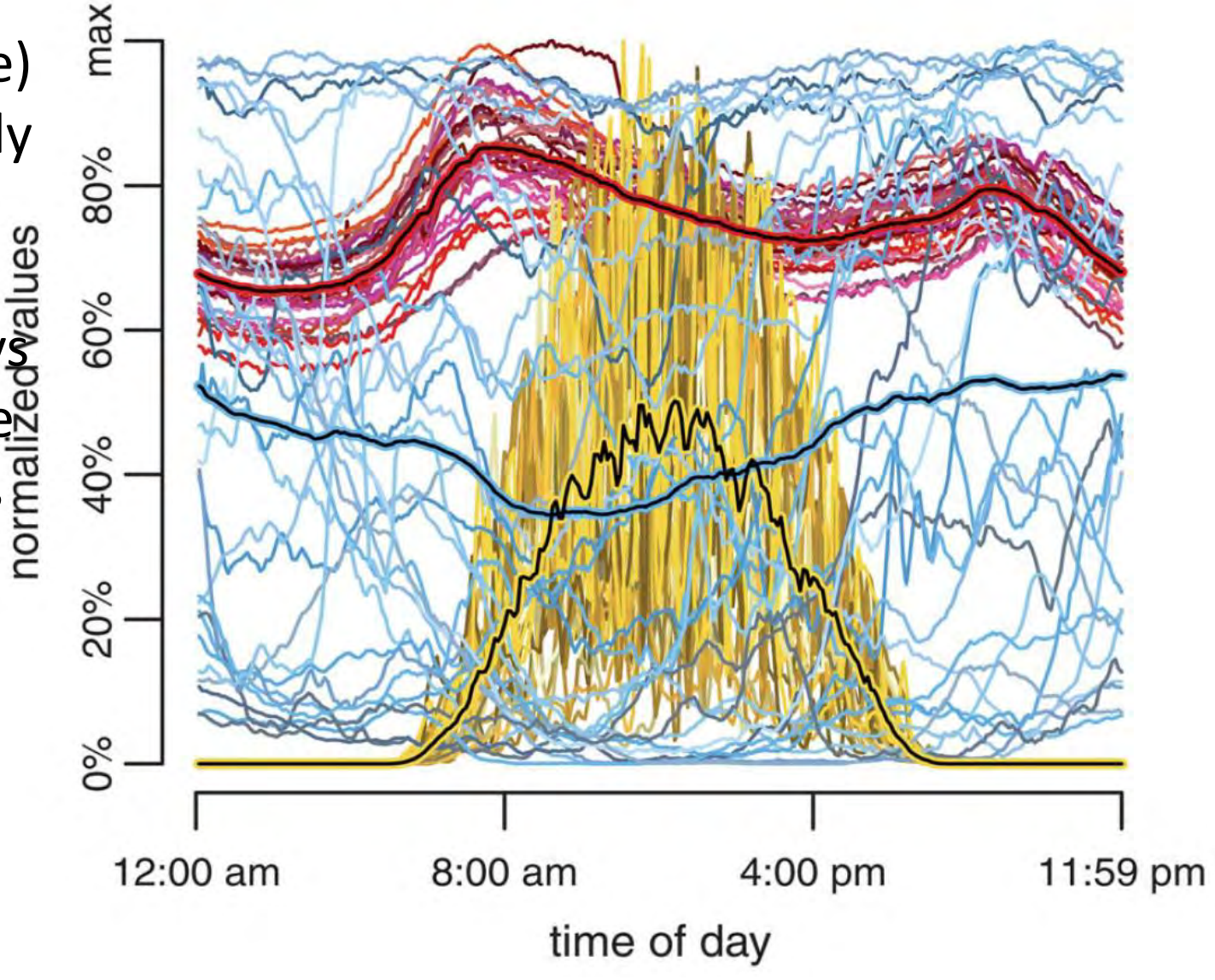
[1]Numbers may not sum to 100 percent due to rounding.
Source: US Energy Information Administration, *Electric Power Monthly, November 2015* and Statistics Canada, *CANSIM Table 127-0009*, 2015

A Great Plains Natural Advantage: Wind



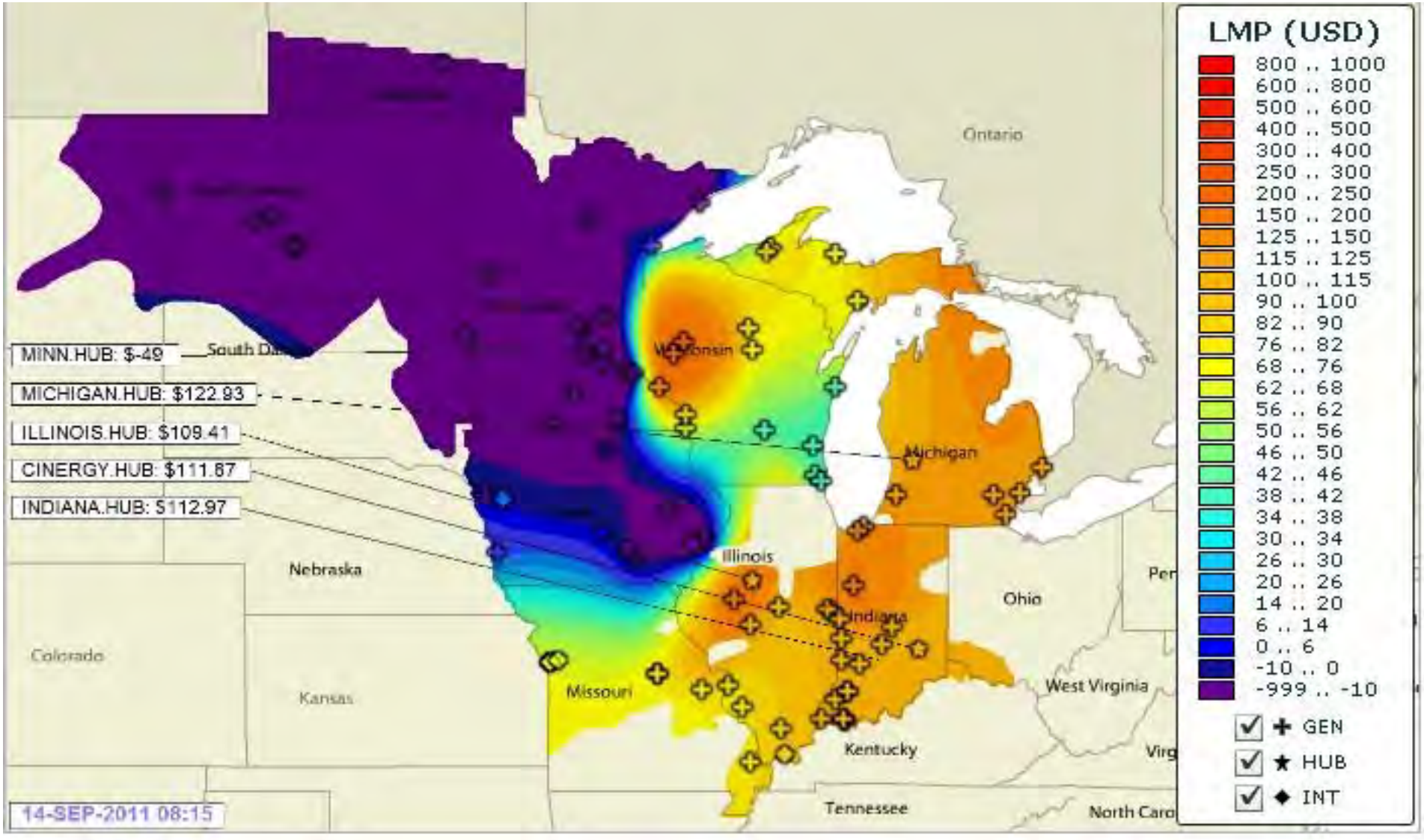
Challenge: Need for Flexibility

Load (red), wind (blue) & solar (yellow) supply variations at Bonneville Power Authority over 30 days in April 2010 illustrate grids with large levels of variable generation require other very flexible supply options



"The energetic implications of curtailing versus storing solar- and wind-generated electricity", Charles J. Barnhart, Michael Dale, Adam R. Brandt and Sally M. Benson; Energy & Environmental Science, 2013, 6, 2804–2810 "

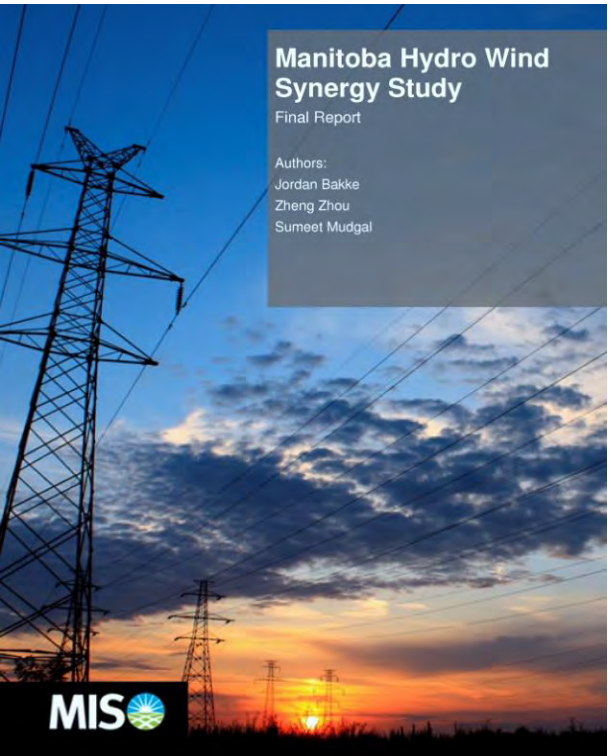
Challenge: Eliminate Barriers



Economic Benefits of Trade:

MISO modelled wind power, the MISO energy market, production from new Canadian hydropower in a landmark study and observed:

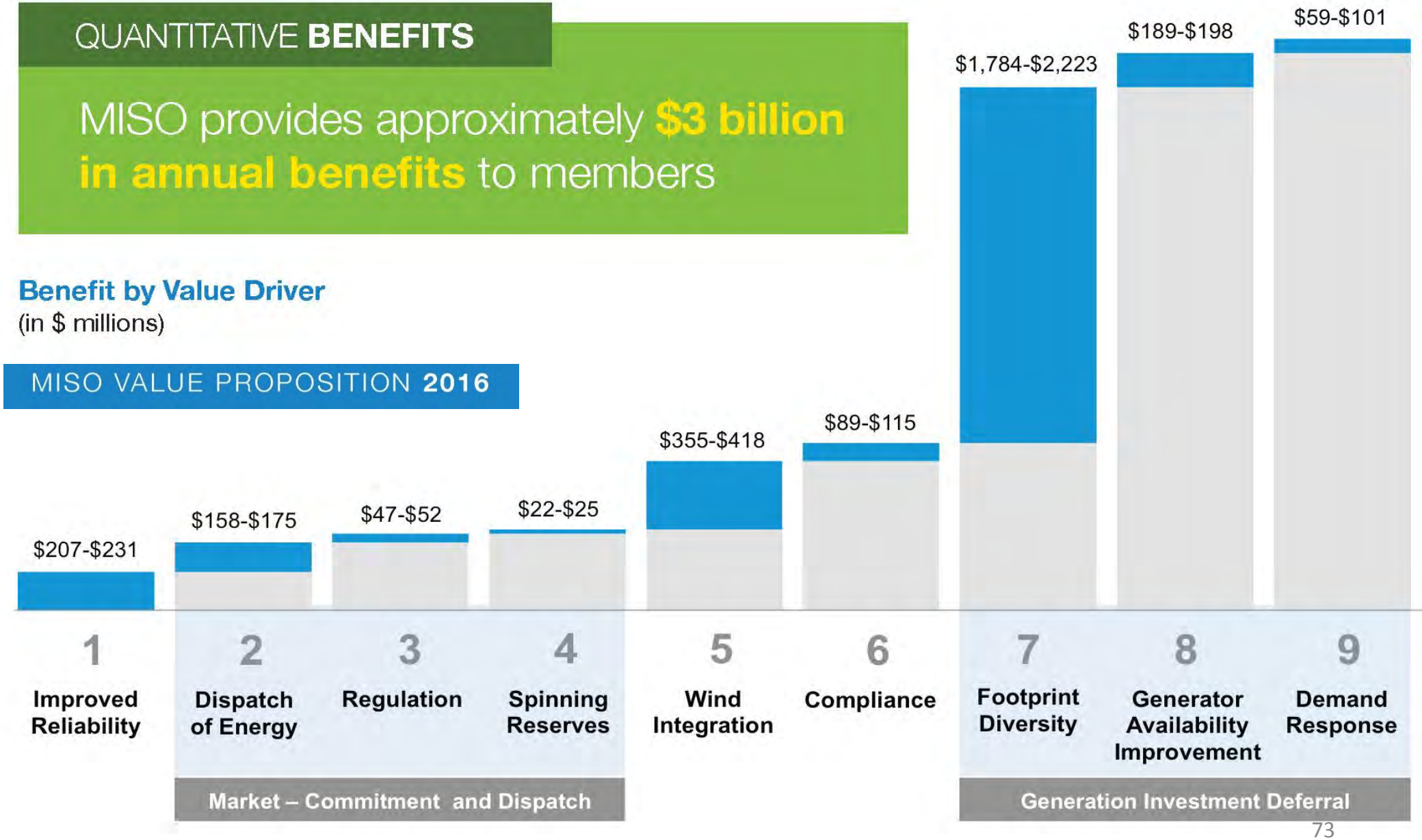
- Desirable interaction between MH generation and wind power in northern MISO (hydro smoothes out wind power variations)
- Additional low-variable cost energy from Manitoba reduces market price for energy: Load Cost Savings(2027): $183-$1302 Million/yr



- High cost generators in MISO run less often and use less fuel: Production Cost Savings(2027): $227-$455 Million/yr

This is an example of how an effective grid and an innovative grid operator can permit low cost Canadian hydro power to deliver energy, provide energy storage and fast acting response when needed by a RTO/ISO

Economics of Barrier Reductions



Benefits of Cross-Border Electricity Trade

- Over a few decades the North American electricity grid has grown from bulk commodity exchange to a highly integrated operation achieving new levels of efficiency and reliability
- Canada and U.S. bring different energy sources (hydro vs. gas & wind) and products (ramping & storage vs. drought protection and low cost surplus) to cross-border trade
- Canada and U.S. have shared interests: energy security; rational investment; reliability; jobs

Benefits of Cross-Border Electricity Trade

- In electricity trade, Canada and U.S. are each other's customers and suppliers with Canada being an important regional supplier of low-cost electricity (12%-16% of retail sales in NY & New England; 12% of supply in MN & ND)
- Canadian and U.S. experts work together to develop best practices and institutions (NERC, common electrical trade frameworks) and share information (Carbon Capture & Storage in Saskatchewan, cyber security)

Benefits of Cross-Border Electricity Trade

- Cross-border electricity trade is a mutually beneficial exchange between reliable and trusted partners which fosters infrastructure investments, policy and process developments that help make our grid affordable, reliable, safe, secure and clean
- Experience has shown that eliminating administrative and physical barriers on the electrical grid (including those at borders) reduces cost to consumers, improves reliability and improves price certainty



Thinking About the Grid as a Strategic Asset, An Enabler, and Problem Solver: Cross Border Trade

WIRES UNIVERSITY Graduate School
"ELECTRIC TRANSMISSION INFRASTRUCTURE:
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May 25, 2017
One Constitution Avenue, N.E.
Washington, DC

Dan Prowse, P. Eng, FEC
Transmission Systems Operations
Manitoba Hydro
Contact: dcprowse@hydro.mb.ca

Manitoba Hydro

Tiler Eaton

International Representative

International Brotherhood of Electrical Workers (IBEW)

(Video)

WIRES

WIRES – a international association of entities dedicated to investment in a strong, well-planned and environmentally beneficial electricity high-voltage transmission system in the US

Honorable Tim Walberg (R-MI)
U. S. Representative and Member, House Committee on Energy and Commerce

WIRES

Panel 3

WHY INVEST IN TRANSMISSION INFRASTRUCTURE?
WHY NOW?
ECONOMIC & FINANCIAL DRIVERS

WIRES

WIRES – a international association of entities dedicated to investment in a strong, well-planned and environmentally beneficial electricity high-voltage transmission system in the US

Dr. Sugandha Tuladhar

Associate Director

NERA Economic Consulting

WIRES

WIRES – a international association of entities dedicated to investment in a strong, well-planned and environmentally beneficial electricity high-voltage transmission system in the US

NERA
ECONOMIC CONSULTING

Economic Consequences of Transmission Infrastructure In A Changing Environment

Sugandha D. Tuladhar, Ph.D.
Associate Director
NERA Economic Consulting
Washington DC

WIRES University Graduate School – Electricity Transmission Infrastructure

Thursday, 25 May 2017
Reserve Officers Association
Washington, DC

Insight in Economics™

Infrastructure Investment Examples and Economic Benefits

NERA ECONOMIC CONSULTING

Example-1:
AKLNG Project

- $45 billion investment with 800 miles of pipeline
- Effects on energy markets, environmental effects, energy security, economic impacts on Alaska and the U.S. as a whole.

Economic Benefits

- Increase in production of natural gas
- More supply to the constrained domestic market resulting in lower natural gas price to Alaskan
- More industrial output and higher economic activity
- Improvement in consumer wellbeing

Example-2:
Hydro Plant Investment in Eastern Europe

- Small developing East European country with limited domestic resources

$280 MW project in Eastern Europe

- Country relies on imported natural gas

Economic Benefits

- Reduction in natural gas subsidies
- Stability to the grid and higher reliability
- Lower electricity prices
- Improvement in gross domestic product
- Higher wage income and consumption
- More jobs

Transmission Requirements will Depend upon Regulations, Market Conditions, Technologies

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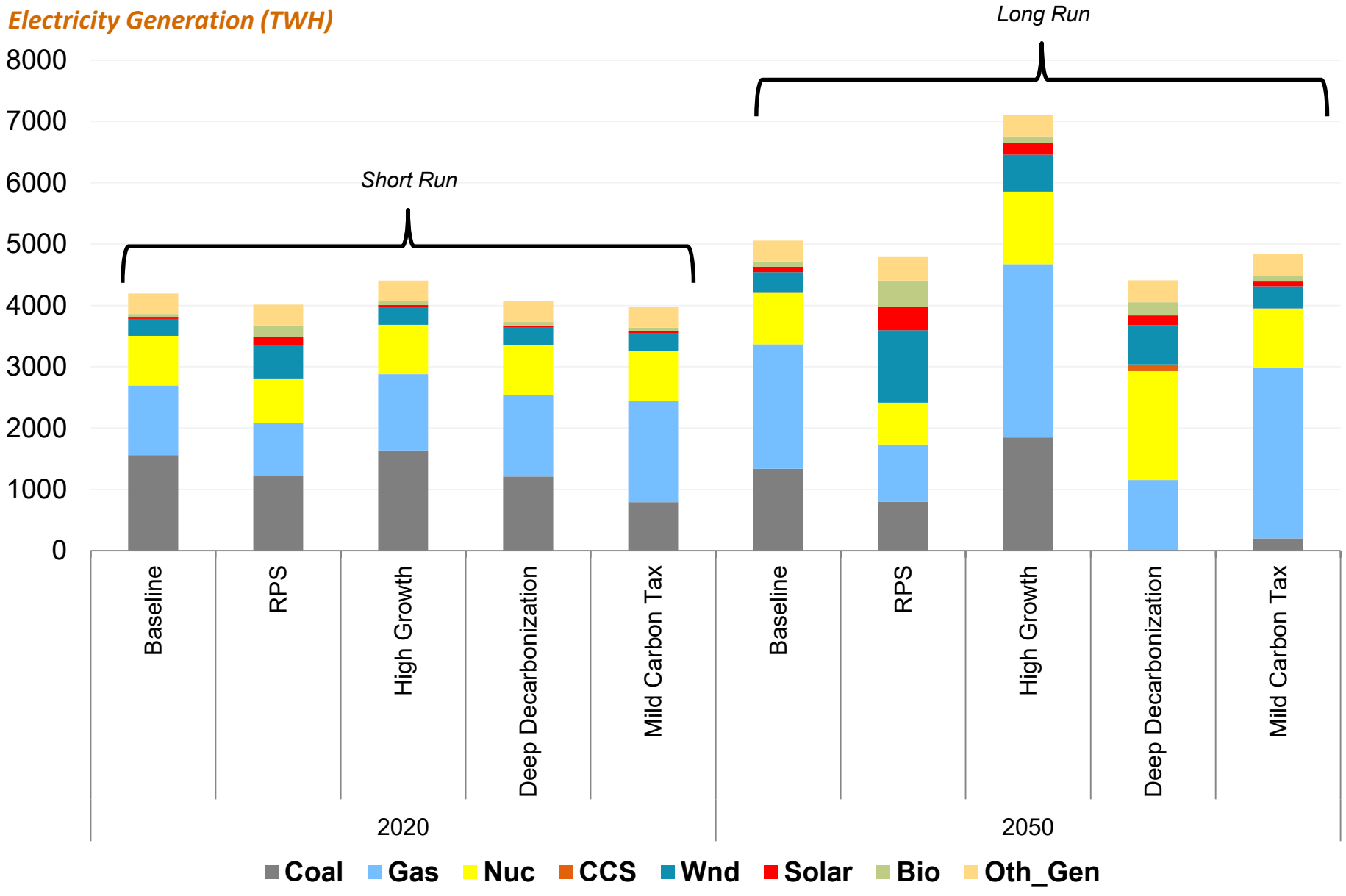
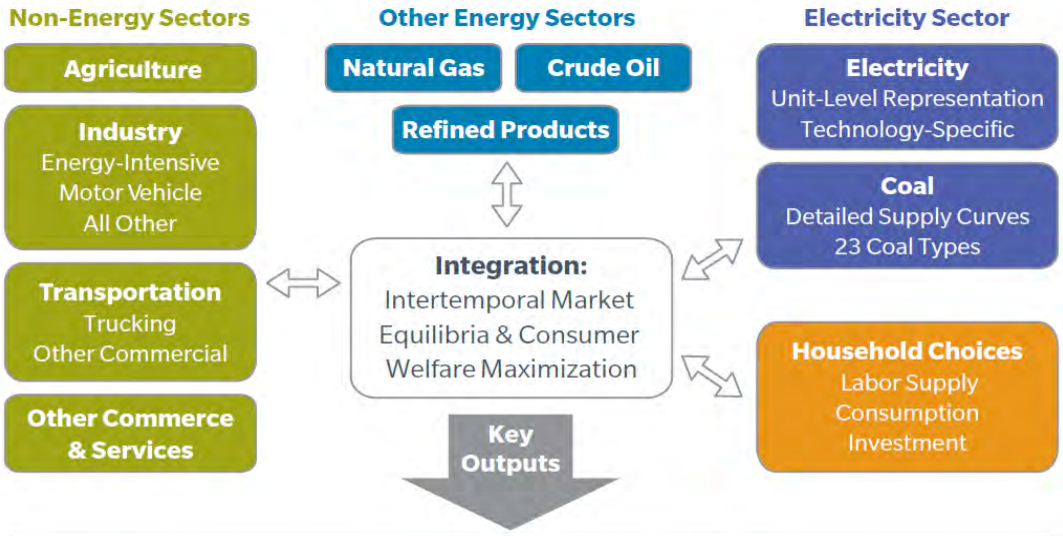


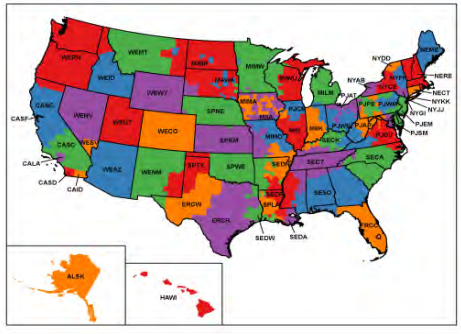
Economist's Tool for Quantifying Costs and Benefits of Infrastructure

NERA ECONOMIC CONSULTING

N_{ew}ERA Modeling Framework



Macroeconomic (National/Regional)	Primary Energy (National/Regional)	Electricity (National/Regional/Generating Unit)
Welfare	Demand	Prices
GDP, consumption, investment	Prices	Builds, retrofits, retirements
Output by sector	Production	Load and Dispatch



- Representation of regions at sufficient granularity – *Regional representation*.
- Investment needs to capture impacts at the micro and macro level – *detailed electricity sector and other sectors of the economy*.
- *Transmission* planning and investment is based on long run outlook – *dynamic model with anticipation*.
- Representation of financing and factor market – *Capital and labor market*
- Model flexible to perform range of scenarios to capture uncertainties around market conditions, technology costs, and policies – *Broad range of model instruments*.
- Model able to analyze measures of public interest – *Wellbeing of consumers or economic activity measured by GDP*.
- Dynamic Computable General Equilibrium model with a detailed electricity model captures costs and benefits of infrastructure investment at the micro and macro level.

NERA
ECONOMIC CONSULTING

Thank you!

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Christi Tezak

Managing Director – Research

Clear View Energy

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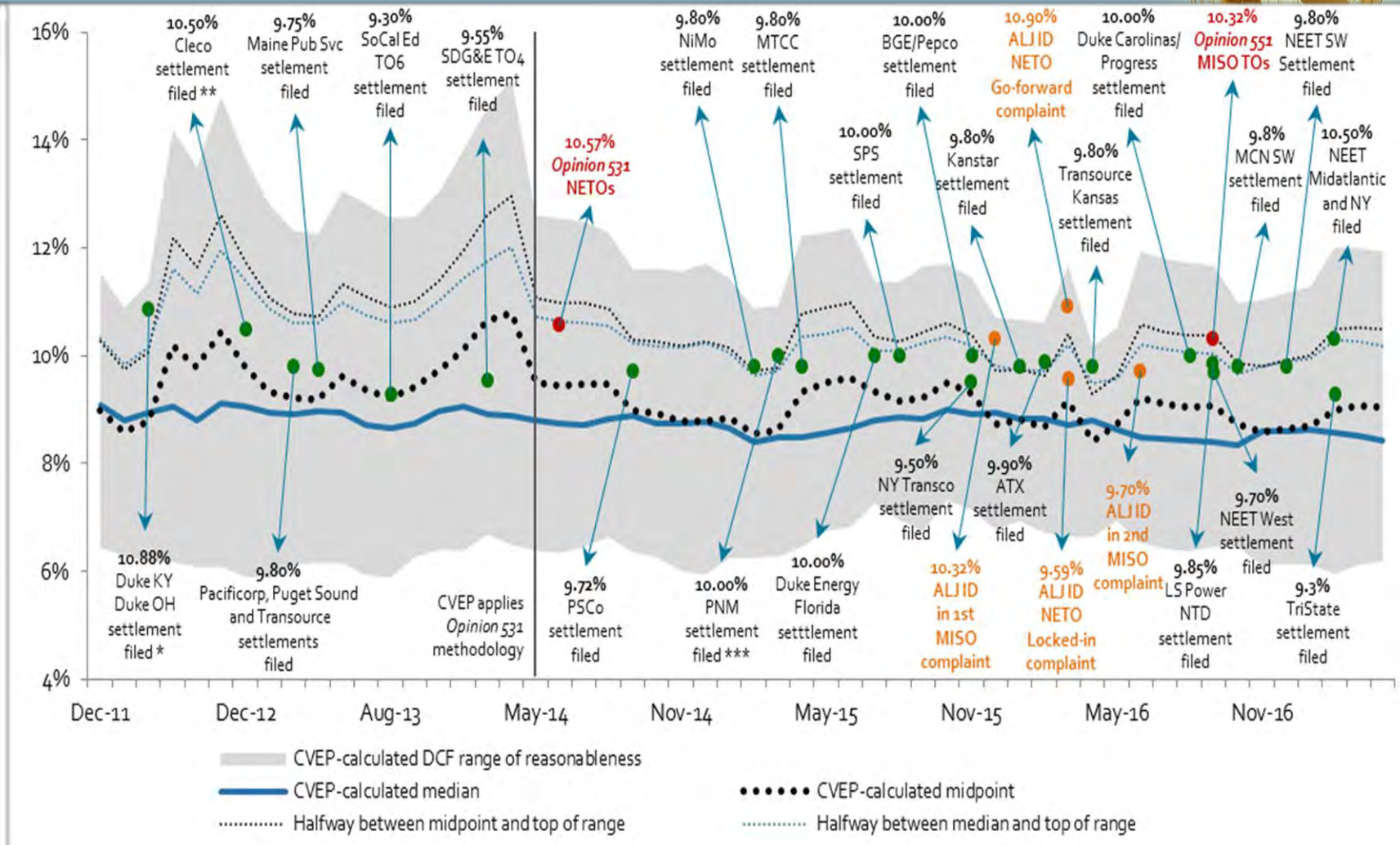
FERC-Jurisdictional Transmission Returns

NOTES:

* The ROE settlement by Duke Energy KY and Duke Energy OH was negotiated in April 2012.
** Cleco's settlement included a 10% reduction applied to the total rate. This rate was superseded when Cleco joined MISO.
*** PNM does not belong to an RTO and therefore is not eligible for that 50-bp adder. The other companies with settlements shown are eligible for at least a 50-bp RTO adder and may own assets eligible for other incentive adders.

FERC changed its DCF methodology when it issued *Opinion 531* in June 2014. Our DCF analysis under the new methodology begins with data from the six-month period ending May 2014.
The settlements are shown based on the dates they were filed at the Commission. The proxy groups used in the particular cases may differ from the CVEP-modeled DCF results presented here. Single-company rate cases reference the median as the measure of central tendency. Regional rate cases reference the midpoint.



Source: ClearView Energy Partners, LLC based on FERC data through April 29, 2017

CLEARVIEW ENERGY PARTNERS LLC

James Lucier

Managing Director

Capital Alpha Partners

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Todd Ryan

Director of Regulatory Affairs

Smart Wires, Inc.

WIRES

WIRES – a international association of entities dedicated to investment in a strong, well-planned and environmentally beneficial electricity high-voltage transmission system in the US

SMART WIRES
REIMAGINE THE GRID

Advantages of Advanced Transmission

May 2017

Navigating a Challenging Storm

SMART WIRES
REIMAGINE THE GRID

1 **Rapidly changing generation**

2 **Unpredictable future load**

3 **Challenge building new lines and stranded asset risk**

4 **Global, energy-driven economy**

Flexible technologies for an uncertain future

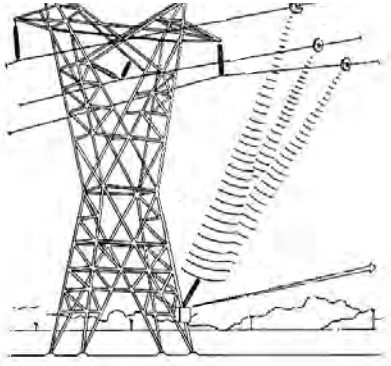
Valuable alternatives to traditional transmission investments

SMART WIRES
REIMAGINE THE GRID

Advanced Power Flow Control

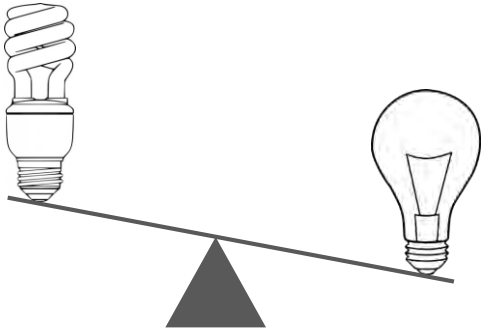
SMART WIRES

Dynamic Line Rating

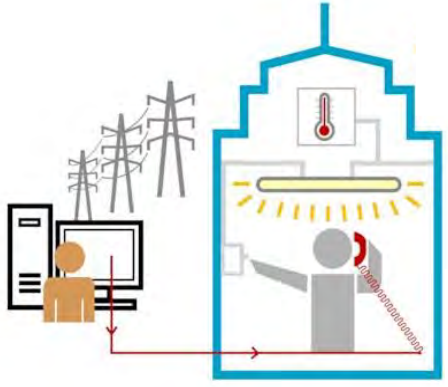


Advanced EMS Data Analytics

Energy Efficiency



Demand Response

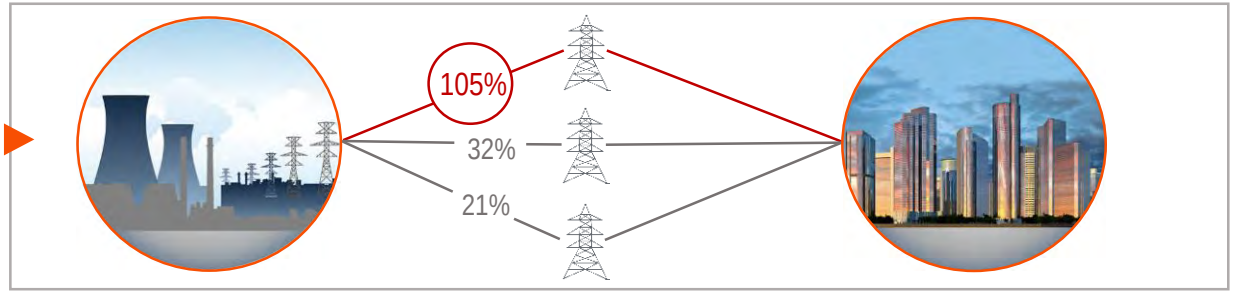


Energy Storage

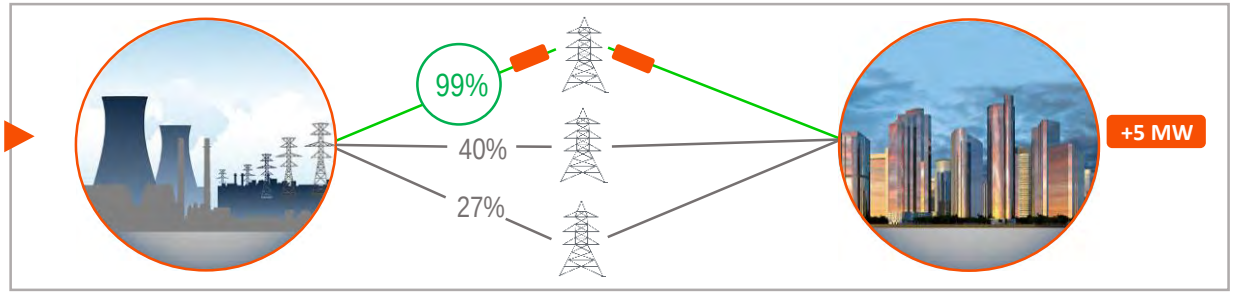
The Smart Wires Advantage

SMART WIRES
REIMAGINE THE GRID

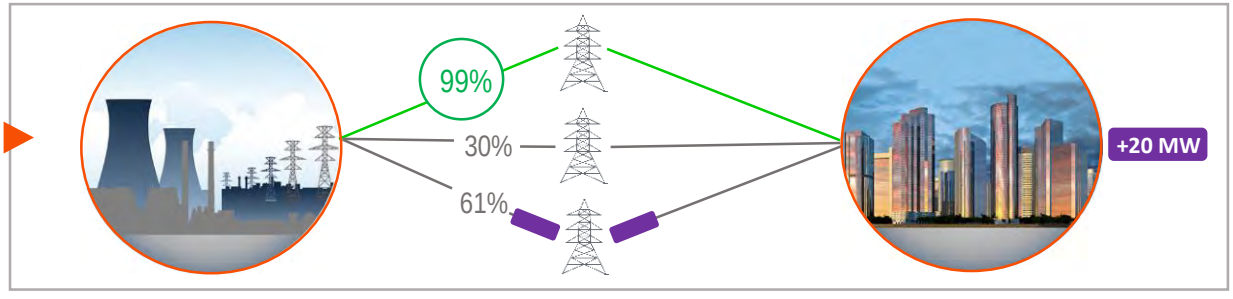
Before Smart Wires
Simplified planning scenario predicts future overload



With Smart Wires Guardian
Power is pushed to alternate lines with spare capacity, resolving overload



With Smart Wires Router
Power is pulled onto lines with spare capacity, resolving overload



Smart Wires Power Flow Control Solutions

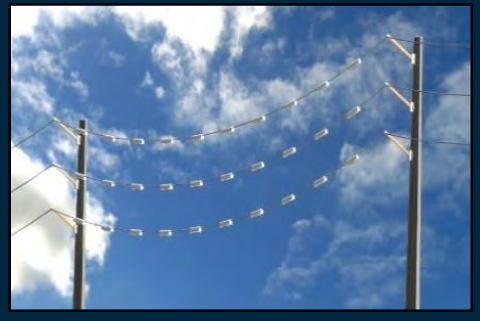
SMART WIRES
REIMAGINE THE GRID

Power Line Guardian®

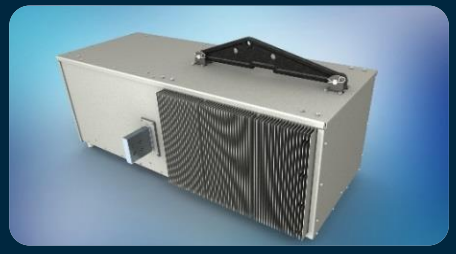
Push

Mount on Conductor

Compact Deployment



Power Guardian™



Push

Smart Tower™

Smart Bank™

Power Router™

Push + Pull

Smart Wires Impact

1 **Build a Better Grid**	Smart Wires, in conjunction with traditional investments, can provide **more transfer capability and more transmission flexibility for a given capital budget**.
2 **Rapid Solution**	Deployable in weeks, Smart Wires **can be deployed quickly for economic development (*e.g.,* data centers)** or to solve other near term transmission challenges.
3 **Better Integrate Renewables**	DNV GL Study: Deploying Smart Wires **cut transmission investment costs** by $1.8B (out of $4B) and lowered consumer energy bills by more than $850M per year
4 **Capital Optimization**	Smart Wires solutions **typically cost 20% of reconductoring** and have demonstrated **$200M in savings** on a typical $500M portfolio for one large West Coast utility**.**

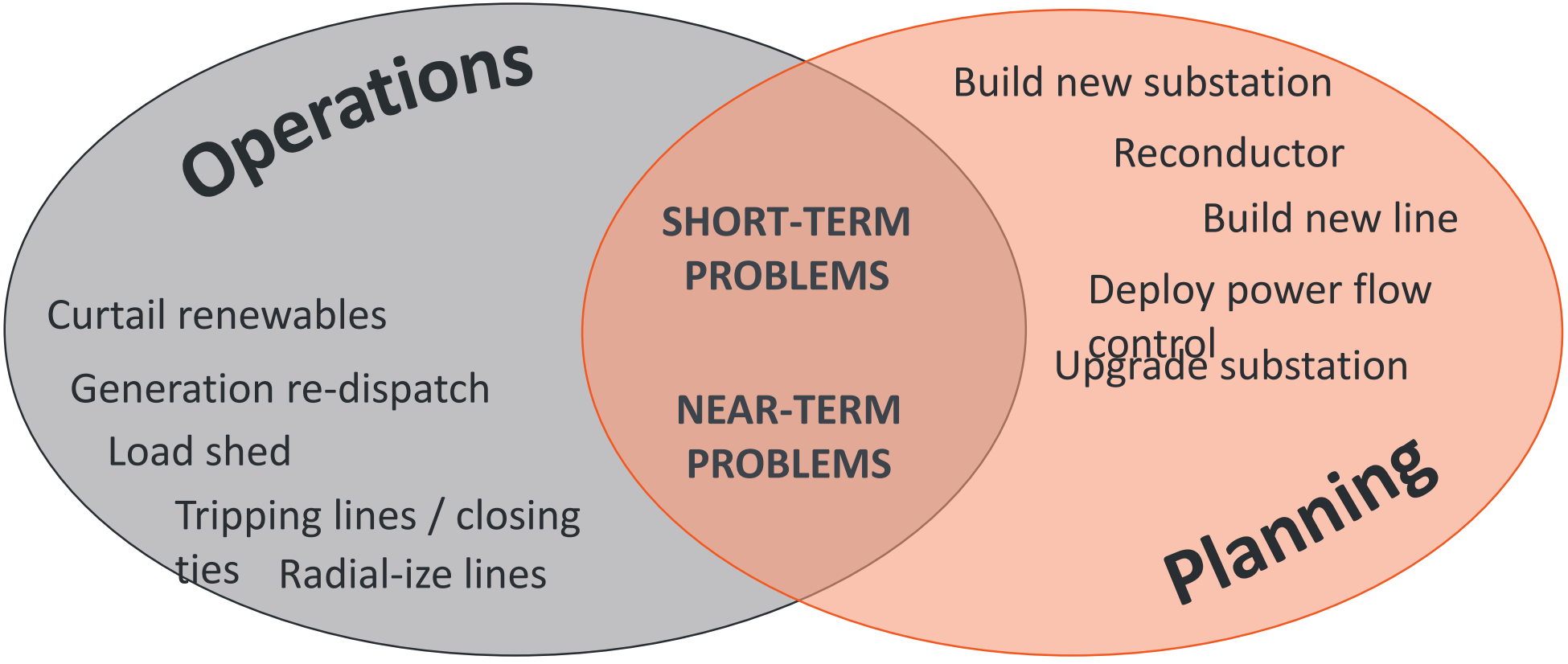
Introduction to Short-Term/ Near-Term Problems

What are Short-Term/Near-Term Problems?

Short-Term Problem: A problem identified over the planning horizon that also disappears over the planning horizon for one or more credible scenarios.

Near-Term Problem: A problem that currently exists or is projected to appear within the next 1 to 2 years and is currently not resolved by any transmission or operations solution.`

What are Short-Term/Near-Term Problems?



Technology Incubated by Utilities for Utilities

SMART WIRES
REIMAGINE THE GRID

Leadership

Gregg Rotenberg
Acting CEO and President
Former GM of Renewable Power Group at Chevron Energy Solutions

Tom Voss
Smart Wires Executive Chairman
Former CEO, Ameren

Advisory Board

David Ratcliffe
Former Chairman & CEO, Southern Co.

David Whiteley
Executive Director Eastern Interconnection Planning Collaborative

Elisabeth Brinton
Executive General Manager, New Energy for AGL Energy Limited

Anjan Bose
Regents Professor, WSU
IEEE Fellow

Ian McLeod
Former CEO, Ergon Energy

Daniel Dobbeni
President, GO–15
Former President, ENTSO–E

Awards

2016 PLATTS GLOBAL ENERGY AWARDS FINALIST

GCCA LATER STAGE AWARD 2016

CIO Review 20 MOST PROMISING UTILITIES TECHNOLOGY SOLUTION PROVIDERS - 2016

FROST & SULLIVAN

Customers

Southern Company

People. Power. Possibilities. Central Hudson A FORTIS COMPANY

PG&E

TransGrid

western power

minnesota power AN ALLETE COMPANY

Rte

TVA

EIRGRID

Partners

Georgia Tech NEETRAC National Electric Energy Testing, Research and Applications Center

BGE

NRECA A Touchstone Energy® Cooperative

U.S. DEPARTMENT OF ENERGY

Questions?

Todd Ryan, Ph.D.
Director of Regulatory Affairs
Todd.Ryan@smartwires.com
617.784.5342

Smart Wires, Inc.
201 Spear St, Suite 1350
San Francisco, CA 94105
smartwires.com

Panel 4

THE WIRES NETWORK IN THE DISTRIBUTED ENERGY & TECH INNOVATION ENVIRONMENT

WIRES

WIRES – a international association of entities dedicated to investment in a strong, well-planned and environmentally beneficial electricity high-voltage transmission system in the US

Laura Manz

Managing Director - Transmission

Navigant

WIRES

WIRES – a international association of entities dedicated to investment in a strong, well-planned and environmentally beneficial electricity high-voltage transmission system in the US

WIRES UNIVERSITY

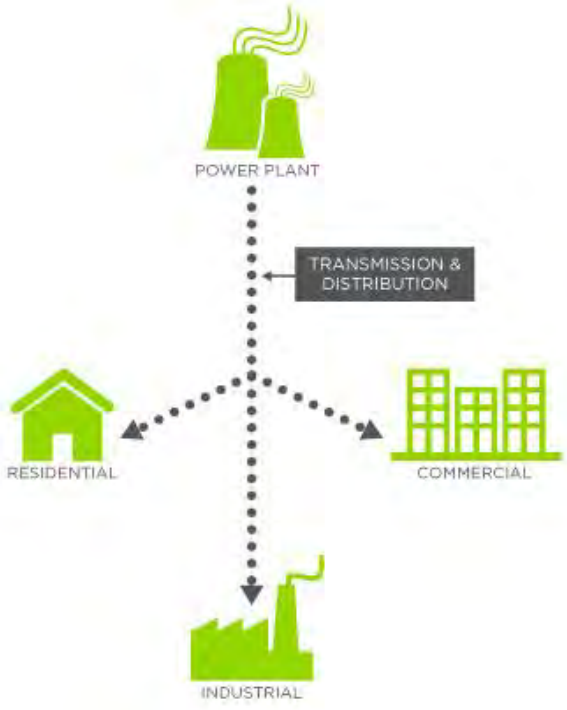
THE WIRES NETWORK IN THE DISTRIBUTED ENERGY & TECHNOLOGY INNOVATION ENVIRONMENT

MAY 25, 2017

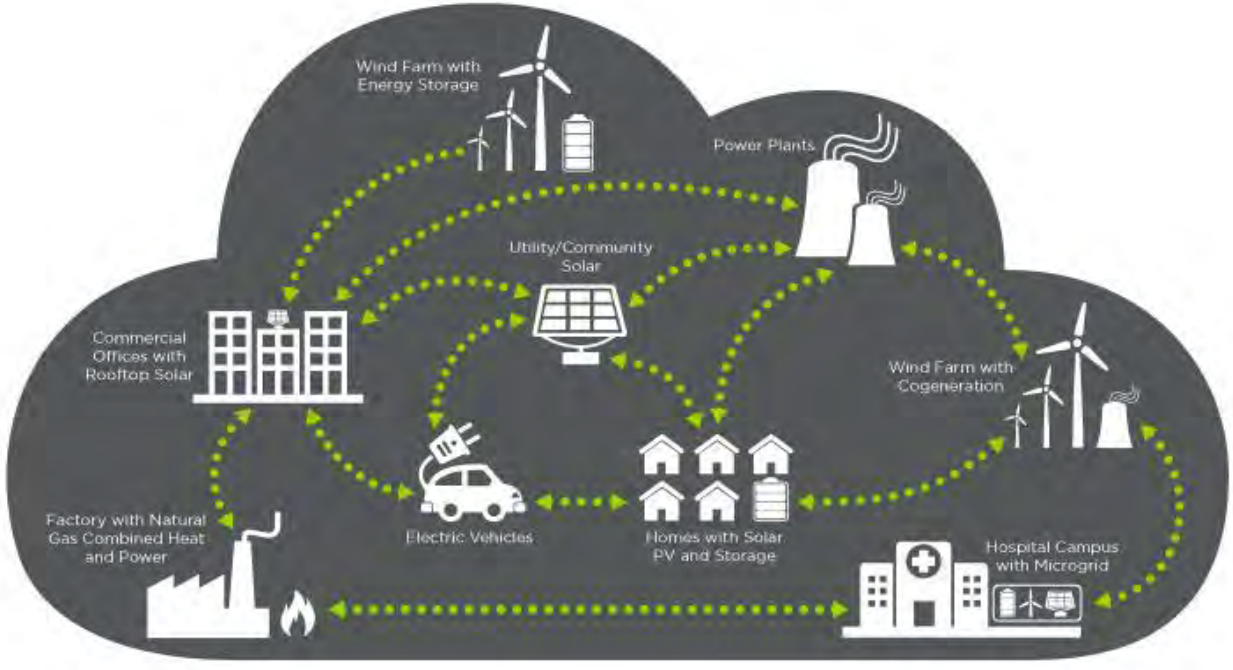
NAVIGANT

TRANSMISSION OPPORTUNITIES:
ENABLES THE ENERGY CLOUD

TODAY: TRADITIONAL POWER GRID
Central, One-Way Power System



EMERGING: THE ENERGY CLOUD
Distributed, Two-Way Power Flows



(Source: Navigant Consulting)

[1] The Energy Cloud: Emerging Opportunities on the Decentralized Grid (white paper)

NAVIGANT

TRANSMISSION OPPORTUNITIES:
ONGOING TRANSFORMATION ENABLED BY TRANSMISSION

Power Forward: 215 Fortune 500 companies investing in GHG reductions, sustainability, and renewable energy initiatives

DER growing 3 times faster than central station generation between 2015-2019 in the US (168 vs 57 GW)

In 2016, natural gas, solar, and wind expected to make up 93% of U.S. generation additions

Paris Climate Agreement signed by 175 countries limiting global warming to <2° C by 2100

AEP decommissions 11 coal plants (6,500 MW) and builds renewables (4,000 MW)

Value of utility M&A deals quadrupled in 2014-15 (compared to 2012)

CAISO saving $18.9M in first quarter of 2016 by using 113 GWH of surplus renewable energy across participants

2018 - Tesla producing 500,000 cars per year (range > 200 miles, 30-40K)

NAVIGANT

TRANSMISSION DRIVERS:
NEED FOR CONSISTENT ENERGY CLOUD MESSAGING

Customers will want to **utilize transmission** infrastructure to **enable** their choices securely and reliably

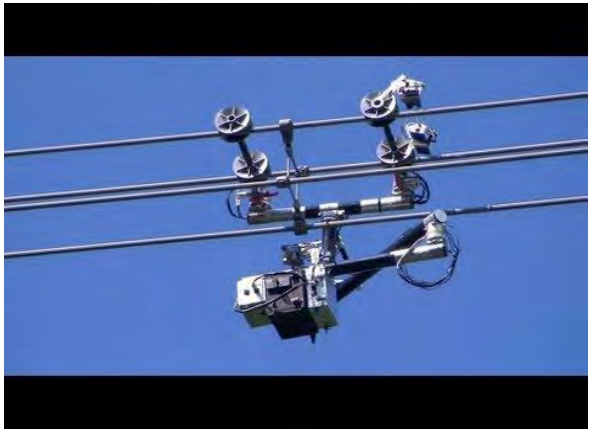
Enhanced operations tools and controls **utilizing** emerging **smart grid enhancements** are required to ensure reliability while maintaining physical and cyber security

Incumbent utilities need to **adapt to DER trends** and incorporate them into integrated resource planning and operations **without disrupting current model** (safe, reliable, affordable power)

Justification for transmission will need to shift toward supporting customer choice, enhancing public policy (climate, security), enabling markets and renewal of critical assets

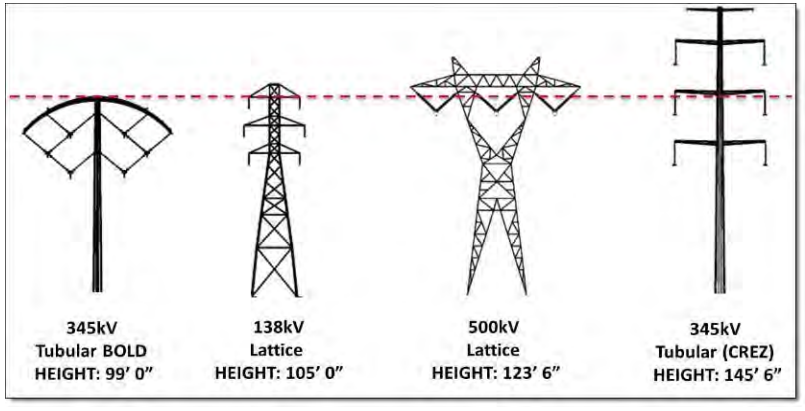
TRANSMISSION OPPORTUNITIES:
NEW TECHNOLOGY IMPLEMENTATION

Smartwire Guardian

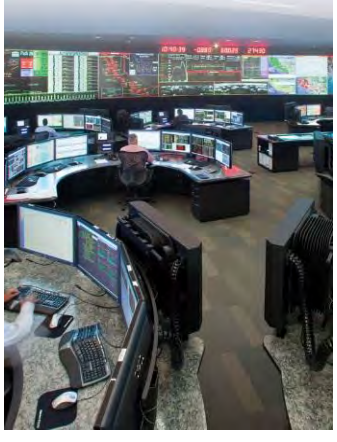


Robotic Maintenance

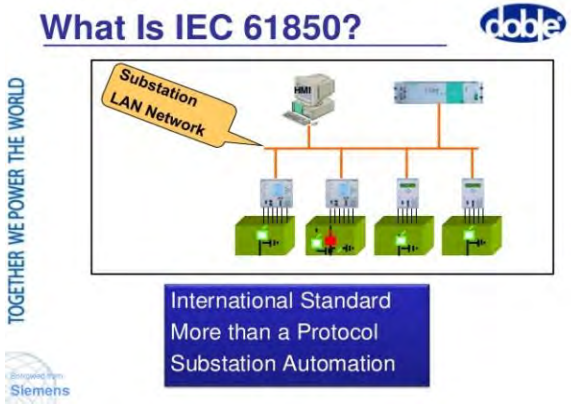
Better Data



AEP BOLD Tower Design



Enhanced Visualization



Expanded Automation

NAVIGANT

THANK YOU

NAVIGANT

Stephen Harper

Global Director - Transmission

Intel

WIRES

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Tim Ash

Market Director

AES Energy Storage

WIRES

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Unlocking the Potential:

Energy storage in the Transmission network

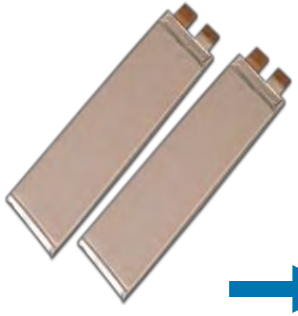
Tim Ash, Market Director
AES Energy Storage

AES Energy Storage

Advancion Energy Storage

Batteries on the grid

Advancion®
Energy Storage



Battery cells

Battery packs

Battery modules

Advancion® Nodes

Advancion® Array

AES
Energy Storage

Unlocking the full potential of the electric system.

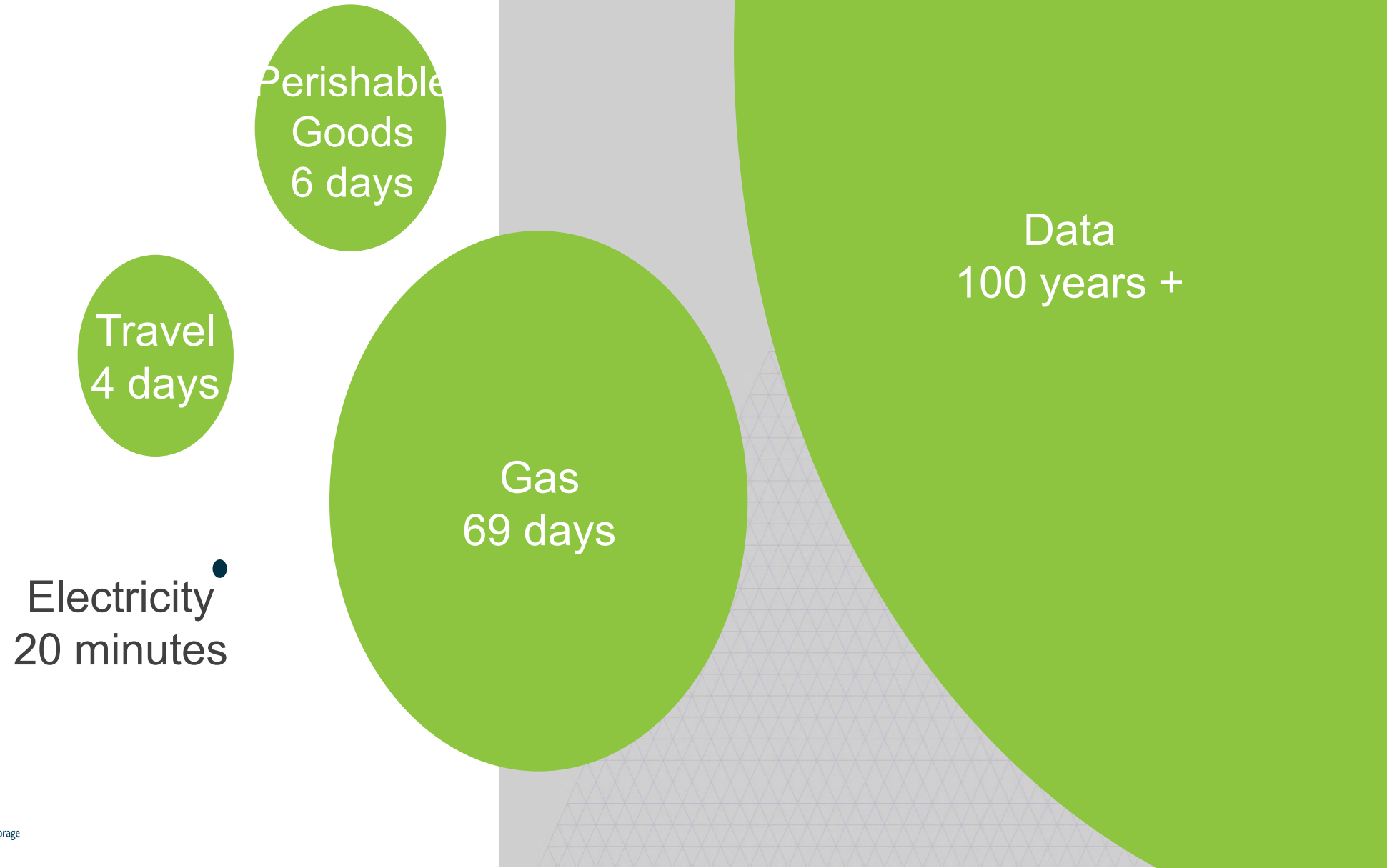
The new energy network is emerging.

Electrify everything.

Accelerate renewables.

Transform the grid with energy storage.

Storage makes networks more reliable, more resilient, and more efficient



AES Energy Storage

Thank you!

Tim Ash

Market Director

AES Energy Storage

WRAP-UP

- Concluding Remarks
- WIRES thanks you for attending

Contact us at www.wiresgroup.com

Jim Hoecker

202-378-2316

WIRES

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