WIRES UNIVERSITY

“ELECTRIC TRANSMISSION–The Survey Course”

Sponsored by WIRES
In conjunction with the House Grid Innovation Caucus, the Midwest Governors Association, the National Electric Manufacturers Association, and the Environmental & Energy Study Institute

Moderated by:

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Federal Energy Regulatory Commission

WIRES - a national coalition of entities dedicated to investment in a strong, well-planned and environmentally beneficial electricity high voltage transmission system in the US.

www.wiresgroup.com

HOW THE GRID WORKS:
TECHNOLOGY & OPERATIONS

Presented by:

Don Morrow
Senior Vice President Corporate Technology
Quanta Technology

Adriann McCoy
T&D Market Strategy Manager
Burns & McDonnell

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Transmission 101: The Fundamentals Of High Voltage Transmission

How the Grid Works: Technology & Operations

April 21, 2015

- **Donald Morrow**, Sr. V. P. Corporate Strategy, Quanta Technology
- **Adriann McCoy**, T&D Market Strategy Manager, Burns & McDonnell

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Agenda

- Basic Definitions & Components of the Grid
- Grid Operations & Markets
- Grid Planning & Development
- Emerging Technologies
- Summary
- Q&A

Objectives

- Understand the Power System in 60 minutes or less
  - Understand elements of the Power System
  - Understand its basic physics
  - Understand how the Power System is controlled
  - Develop a basic understanding of energy markets
  - Understand some of the challenges in planning the Power System

Basic Definitions & Components of the Grid

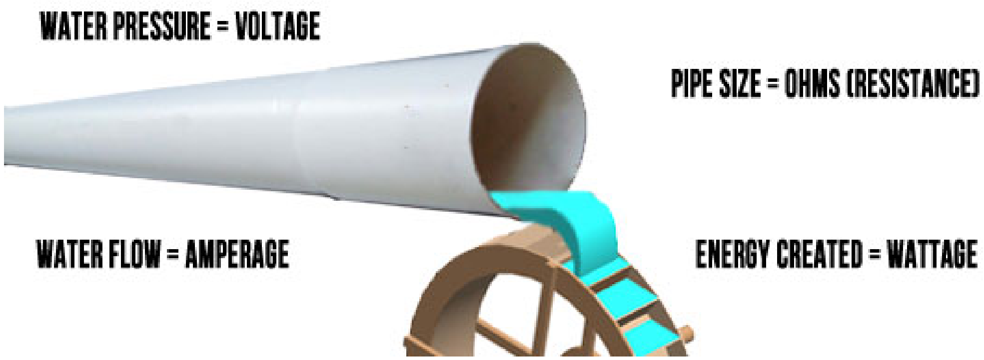
Industry Overview – Basic Definitions

“THE GRID”

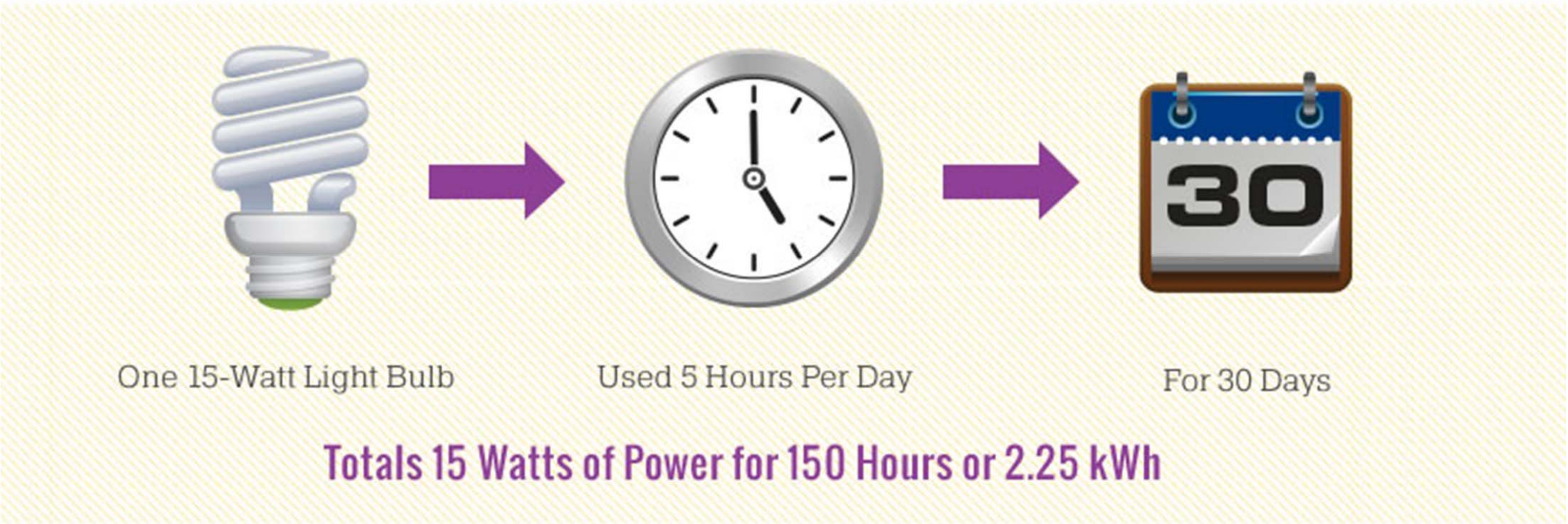
The networks that carry electricity from the plants where it is generated to consumers. This includes wires, substations, transformers, switches and more.

Industry Overview – Basic Definitions

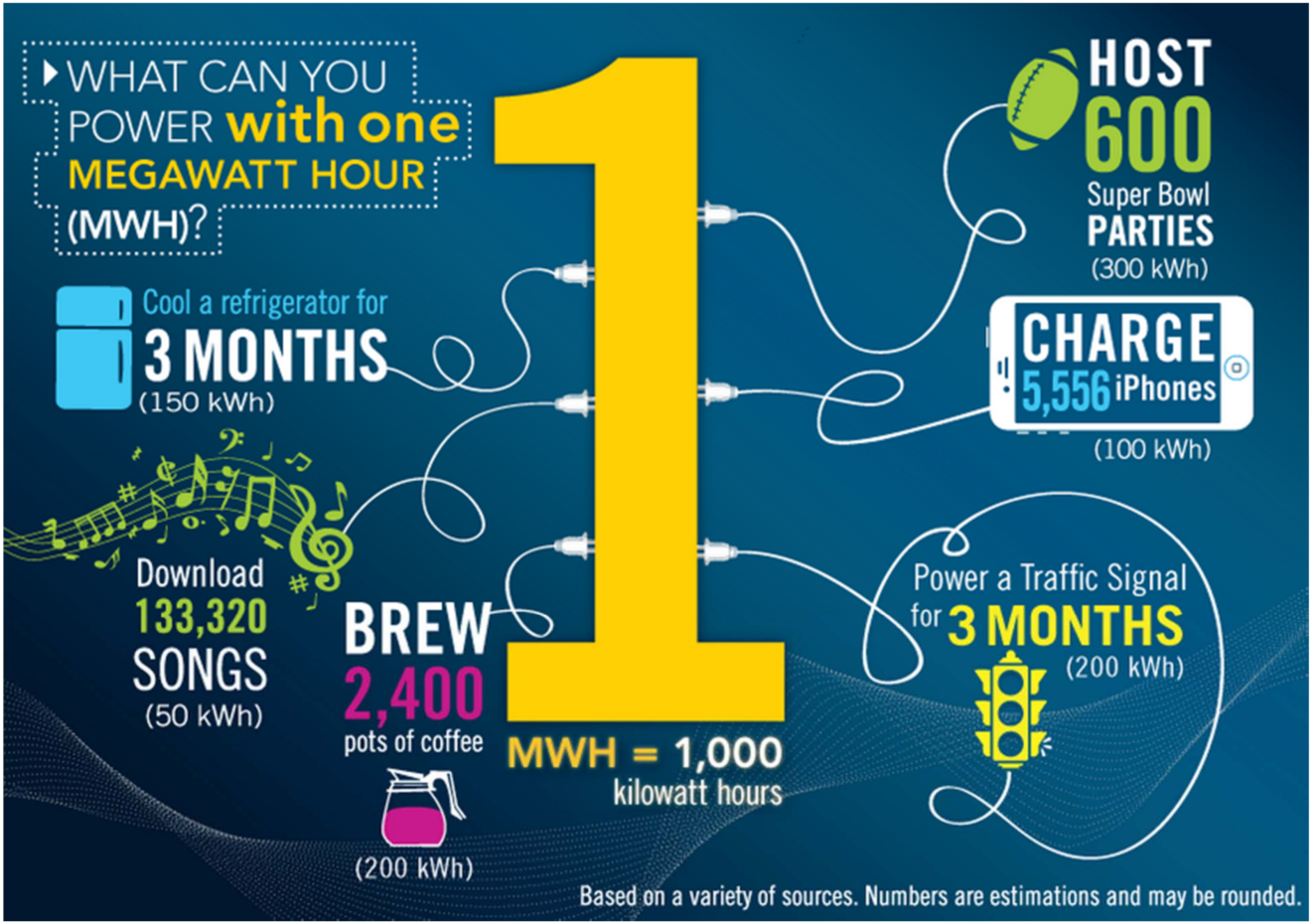
- **Voltage** – electrical "pressure" measured in volts. For power systems we typically measure in 1000's of volts or kilovolts (kv)
- **Current** – the movement of charge (electrons) through a conductor. Measured in Amperes (A)
- **Power** – Rate at which electricity is transferred. Measured in Watts or more typically kilowatts (kW) or megawatts (MW)
- **Energy** – The amount of work that can be done by electricity. Measured in Watt-hours or more typically kilowatt-hours (kWh) or megawatt-hours (MWh).



Industry Overview – Basic Definitions



Source: www.eei.org


WHAT CAN YOU POWER with one MEGAWATT HOUR (MWH)?
1
MWH = 1,000 kilowatt hours
Cool a refrigerator for 3 MONTHS (150 kWh)
Download 133,320 SONGS (50 kWh)
BREW 2,400 pots of coffee (200 kWh)
HOST 600 Super Bowl PARTIES (300 kWh)
CHARGE 5,556 iPhones (100 kWh)
Power a Traffic Signal for 3 MONTHS (200 kWh)
Based on a variety of sources. Numbers are estimations and may be rounded.

Industry Overview - Utility Ownership

Private – Investor-Owned (IOUs)

- Supported via private funds of shareholders
- Prevailing form of ownership – Nearly 75% of utility customers
- 190+ investor-owned utilities
- Holding Companies

Pacific Gas and Electric Company

Public – Government-Owned

- Funded by taxes from those directly served
- 2,000+ government-owned utilities
- Mostly communities with populations <10,000

Los Angeles Department of Water & Power

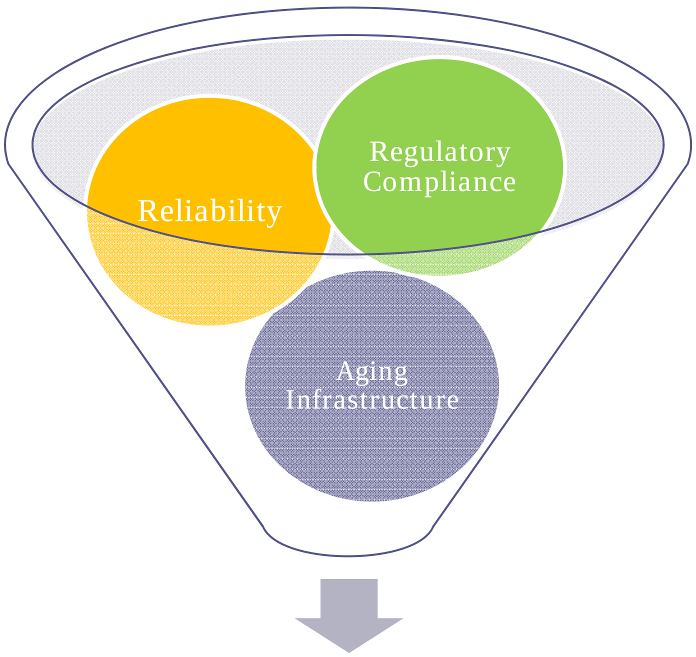
Cooperative – Member-Owned

- Owned by their members/ consumers
- 800+ in 47 states
- Mostly distribution only
- Provide "at-cost" service
- Every member's share is equal

PLUMAS-SIERRA RURAL ELECTRIC CO-OP PSREC

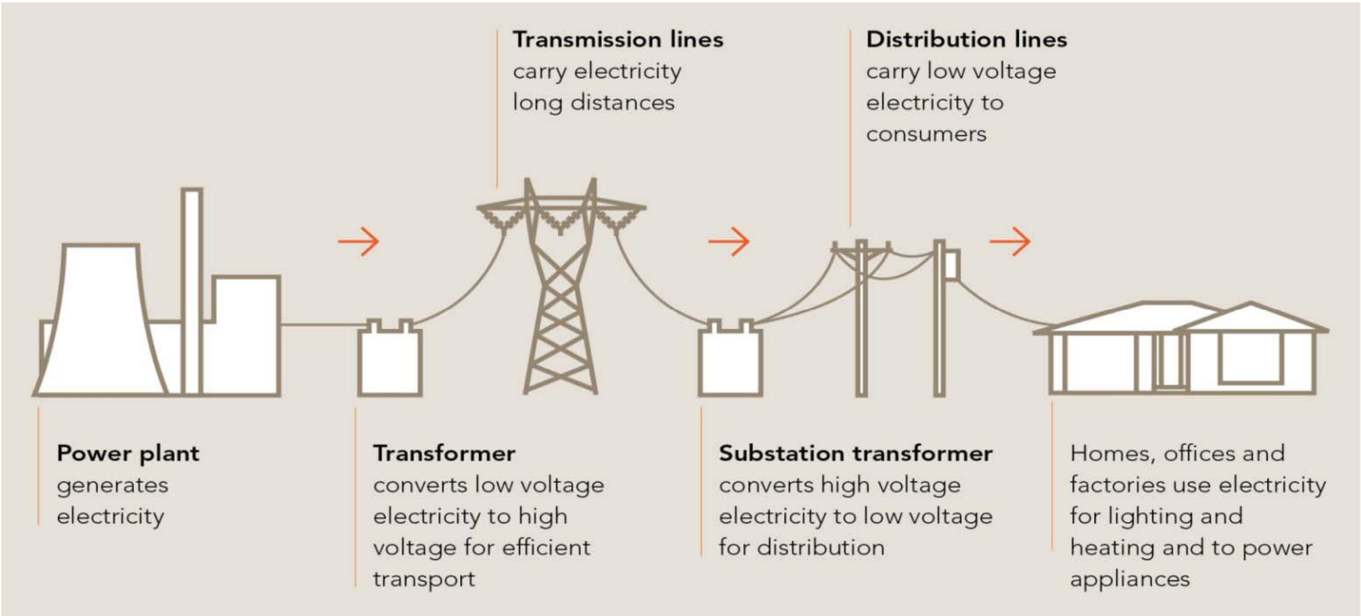
Industry Overview – Special Nature of Utilities

- “Public Utility” ≠ Publicly Owned
- Capital Intensive
  - Efficiencies
  - Economies of Scale
  - Depreciation over 30-40 yrs
- Regulated Market
- Obligation to Serve
  - “Quid Pro Quo”



Balancing Act

Components of the Grid



Generation
- Fuel Source
- Energy Conversion
- Non-regulated/ Competitive in most of the country

Transmission
- Power Transformation (Step Up)
- Demand/ Supply
- 115 kV – 765 kV

Distribution
- Power Transformation (Step Down)
- 4 kV – 34.5 kV

Load (Delivery)
- Metering
- Billing
- 120 V – 240 V

Components of the Grid – Generation

- “Creates” electric energy using a variety of fuel sources including coal, nuclear, wind, gas, biomass, solar, and hydro

Components of the Grid – Load

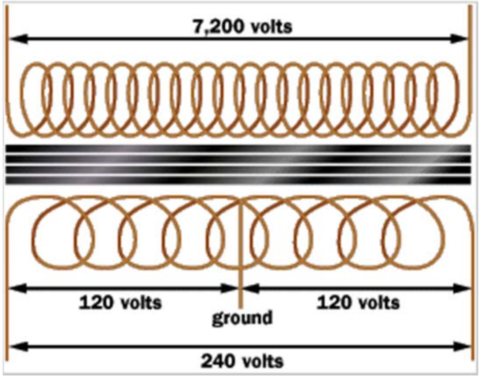
- "Consumer" of electric energy
- Loads can be smaller than your cell phone hooked to its wall charger (say 1 watt) or as large as an industrial facility (in the 10's of millions of watts)

Components of the Grid – Distribution

- Primary purpose is to serve loads (your house is connected to a distribution system)

- Generally radial (non-networked) in nature

- Not used for interstate commerce



Components of the Grid – Transmission

- Used to move power relatively long distances from generators to load with lower losses
- Highly interconnected for enhanced reliability
- The "interstate system" for electricity



Components of the Grid – Transmission Enables Us To...

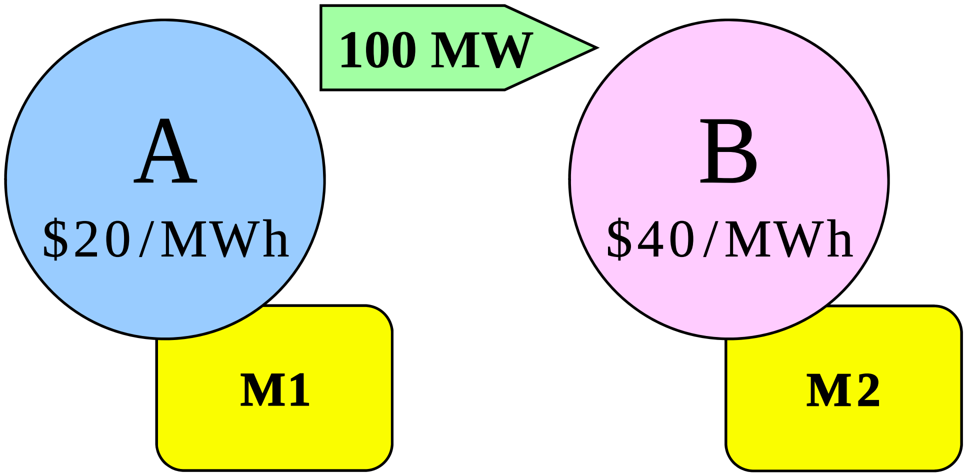
- ...build generation in areas removed from the loads
  - More desirable environmental and fuel factors
- ...build larger, more efficient generators
  - Economies of scale
- ...get power to remote areas with lower losses
  - Rural electrification
- ...create robust interconnected networks
  - Increased reliability
  - Decreased costs
  - Makes possible power pools, markets, bulk power transactions

Power Flow Across the Grid

Simple Bi-Lateral Transaction – Contract View

Sale from A to B at 4-5 pm of 100 MW

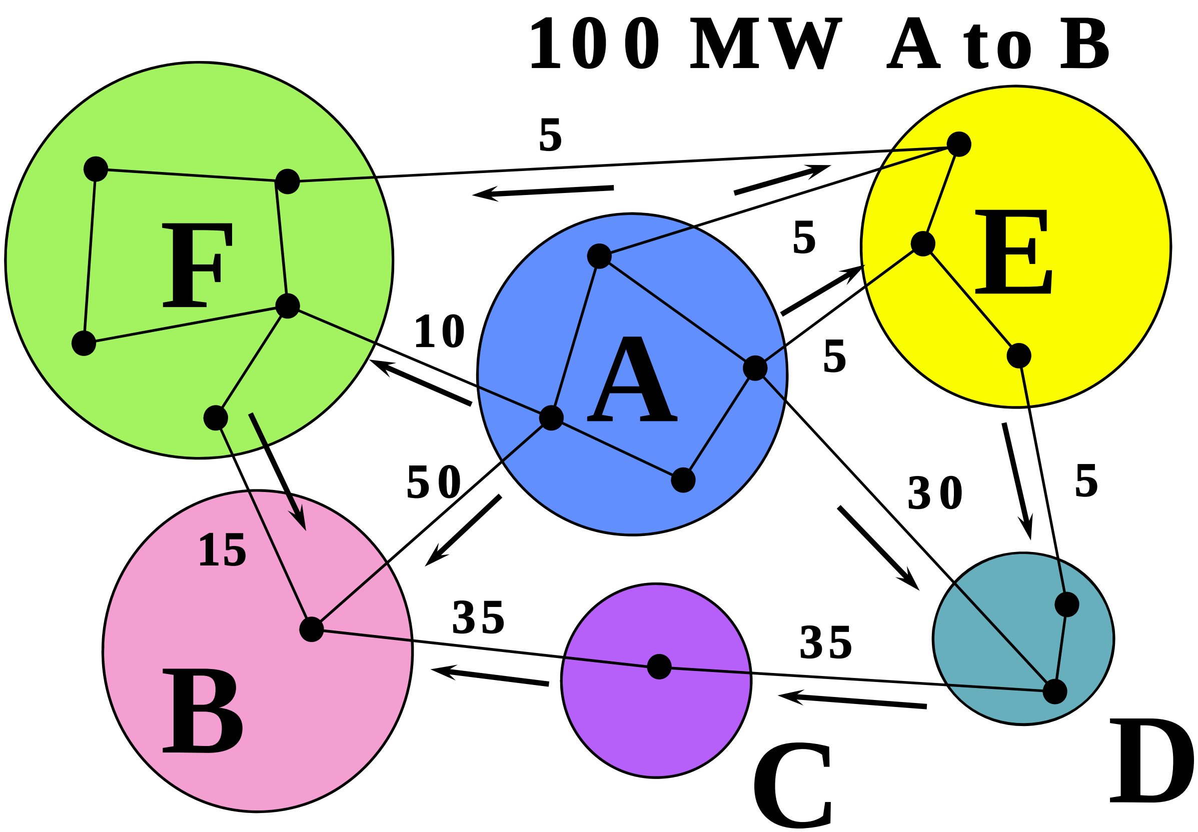
- 3:40 pm Schedule
- 3:55 pm Confirm
  - Seller increases generation
  - Buyer decreases generation
- 5:00 pm End
  - Seller decreases generation
  - Buyer increases generation



Areas A & B may be separated by thousands of miles. Price may be affected by various factors including transmission congestion

Simple Bi-Lateral Transaction – Physics View

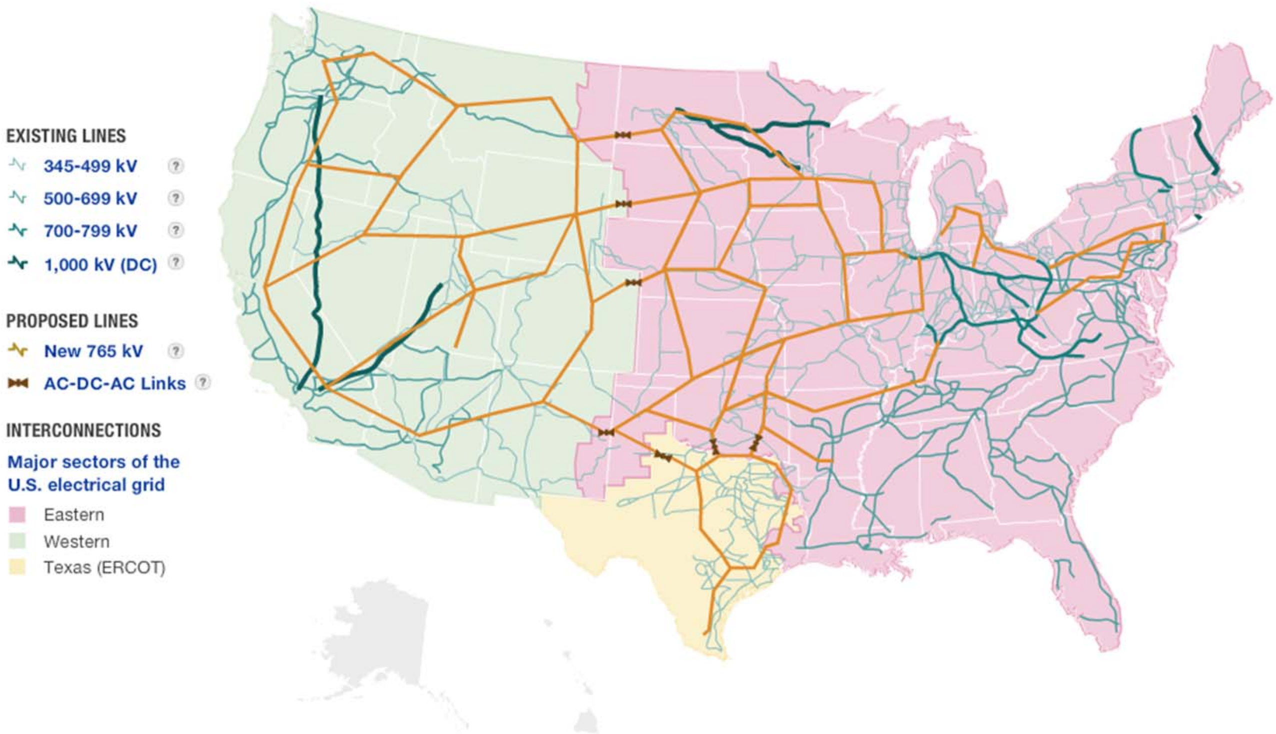
Contrary to popular belief, the power from A does NOT flow directly to B despite my best contract negotiating skills.



Grid Operations and Markets

Grid Operation

- Unlike highways, pipelines, and telecom, the flow of electricity on the AC grid can not be easily routed or controlled. Power flows via the path of least resistance. This is a critical difference in how the grid differs from other transportation mechanisms



Source: American Electric Power, American Wind Energy Association, Center for American Progress, Department of Energy, Edison Electric Institute, Energy Information Administration, Electric Power Research Institute, Federal Energy Regulatory Commission, National Renewable Energy Laboratory, U.S. Environmental Protection Agency, Western Resource Advocates

Credit: Producer: Andrew Prince; Designer: Alyson Hurt; Editors: Avie Schneider and Vikki Valentine; Supervising Editors: Anne Gudenkauf and Quinn O'Toole; Additional Research: Jenny Gold; Database and GIS Analysis: Robert Benincasa

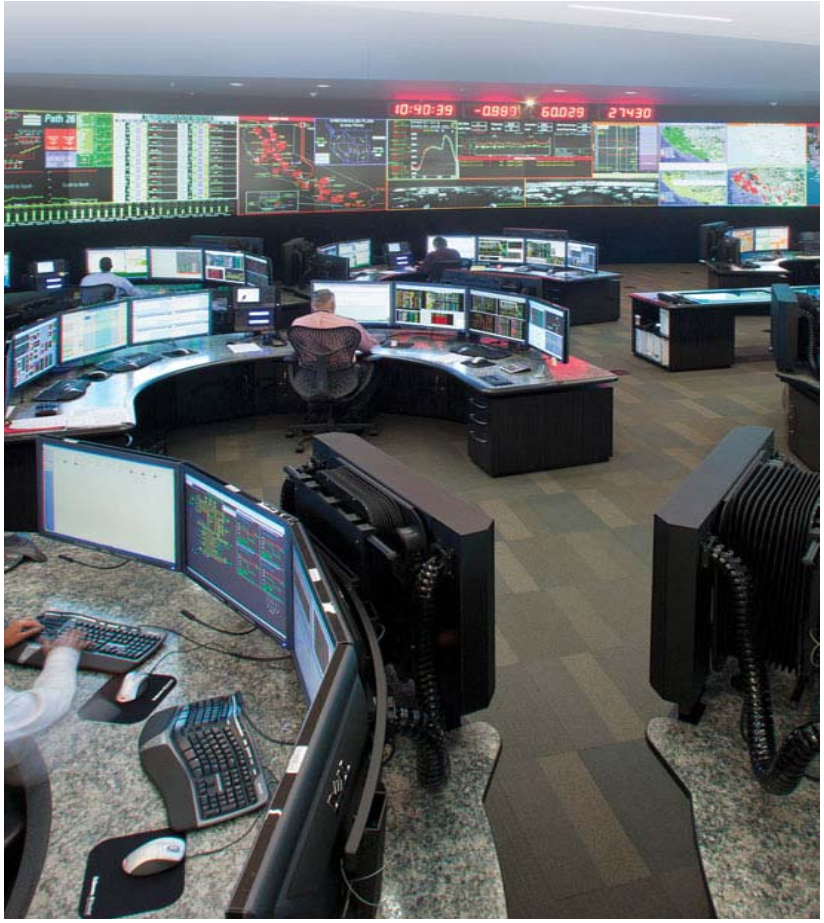
Grid Operation

- Control centers are staffed 24 hours a day, 365 days a year to ensure the safety, reliability and availability of the system for electric customers
- The primary task of a Grid Operator is to make sure that as much power is being generated as is being used – if not, the grid's voltage could drop, causing the grid to become unstable

Example: California ISO Control Center

Positions Include:

- Transmission Operators
- Market Operators
- Balancing Authority Operators
- Operational Assessment Engineers
- Maintenance Schedulers
- Supervision



Source: www.caiso.org

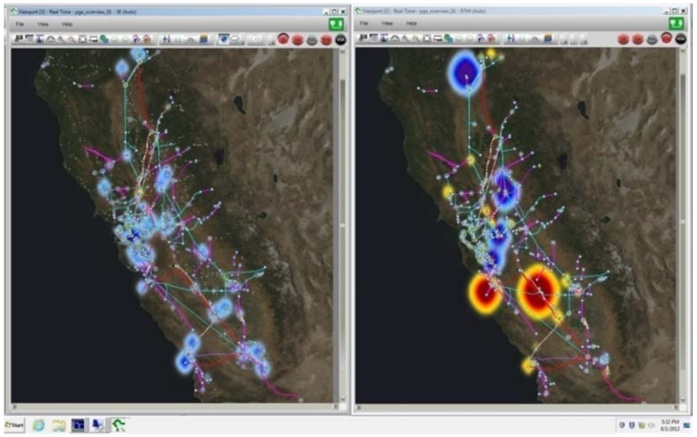
Grid Operation – Smart Grid

- Operators take immediate actions to isolate and mitigate issues that arise on to minimize any interruption of power
- “Smart Grid” refers to an upgraded system which would offer Grid Operators more visibility and control over the system.

Grid Operation – Smart Grid

- Computer Control
  - Two-way digital communication between the device in the field and the utility's network operations center
  - Automated technology to allow remote control of devices from a central location

- Current Smart Grid Enhancements
  - Enhanced measurement devices and sensors to collect data
  - Improved interfaces to improve Situational Awareness



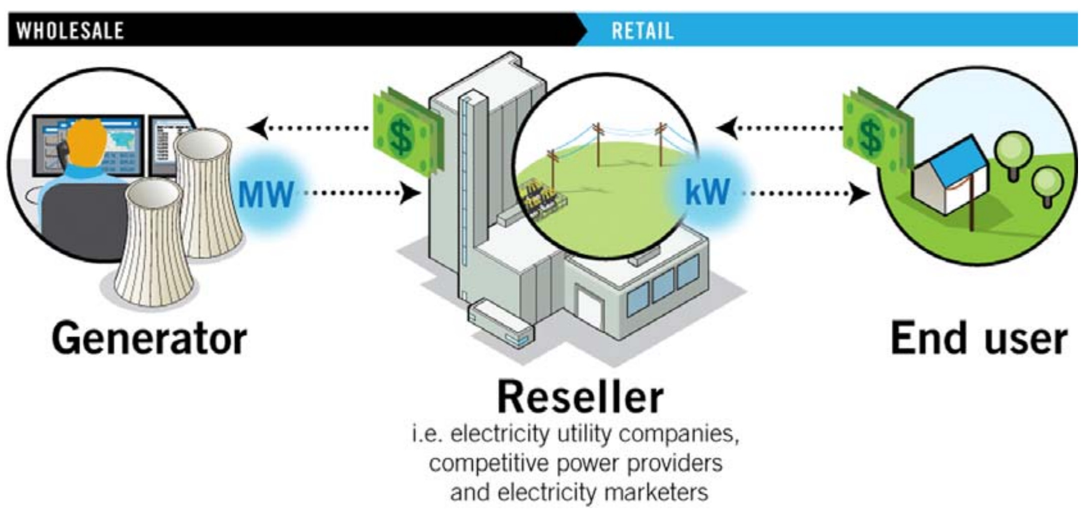
Grid Operation – Emerging Smart Grid Developments

1. **Distributed Generation** – Can sell energy surplus back to the utility and get paid as microgenerators
2. **Smart Appliances** – Can monitor cost of electricity and shut down when power is too expensive
3. **Remote Control Applications** – Utilities can control consumers' non-essential appliances remotely
4. **Plug-in Hybrid Cars** – Can refuel using clean electricity generated locally
5. **Locally Generated Power** – Avoids the long-distance power losses
6. **Wireless Chips** – Communication between houses and utilities to swap price and usage information
7. **Web and Mobile Phone Interfaces** – Allow consumers to monitor and control appliances when away from home
8. **Energy Storage** – Can store clean solar energy for use at night when the sun isn't shining

Source: The New York Times

Electricity Markets

- A megawatt of electricity, like any other commodity, is frequently bought and re-sold many times before finally being consumed. These transactions make up the wholesale and retail electricity markets
- Market participants include competitive marketers and suppliers, independent power producers (IPPs), and traditional vertically integrated utilities

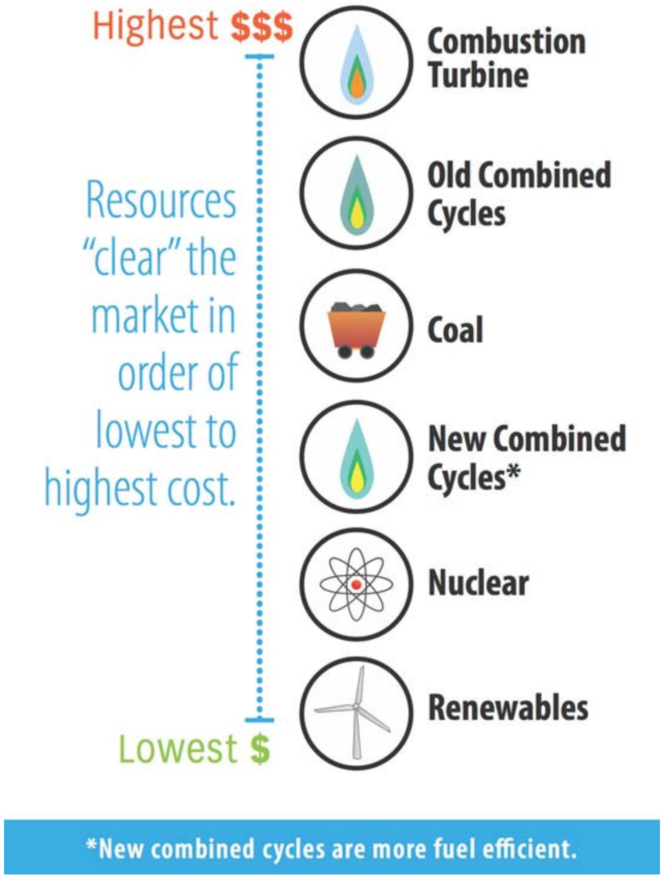


Source: www.learn.pjm.com

Wholesale Electricity Markets

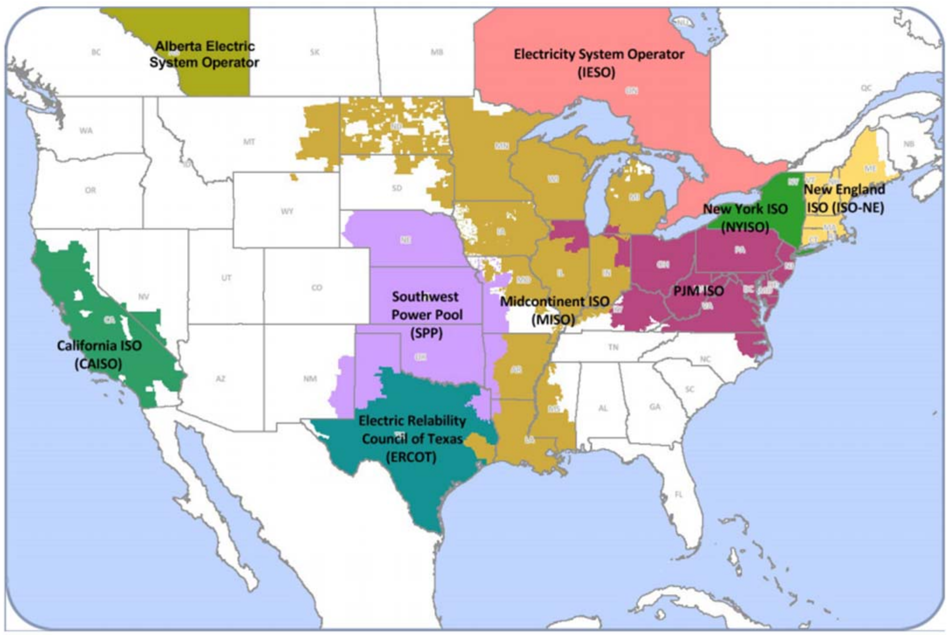
- The price for wholesale electricity can be pre-determined by a buyer and seller through a bilateral contract or by organized wholesale markets

- The clearing price for electricity in these wholesale markets is determined by an auction in which generation resources offer in a price at which they can supply a specific number of megawatt-hours of power



Source: www.learn.pjm.com

Wholesale Electricity Markets



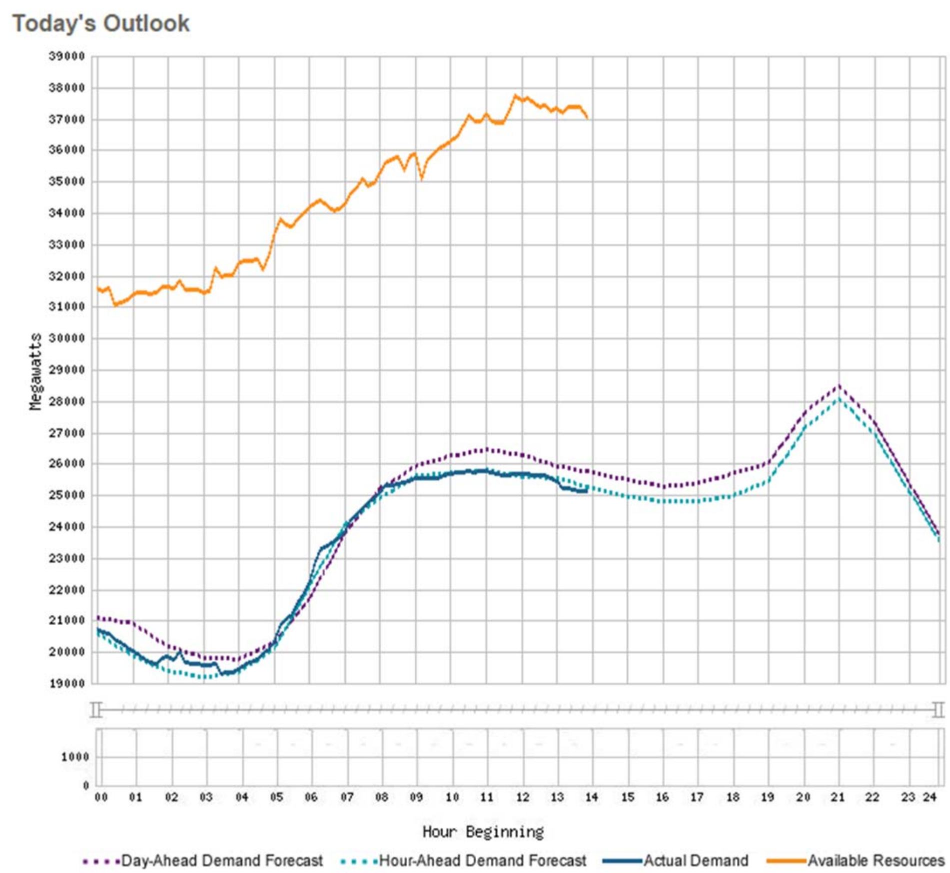
Many regions organize their markets under an ISO/ RTO as a result of FERC Orders 888-889 which aimed to ensure non-discriminatory open access to the transmission system

Regional Transmission Organizations Independent System Operators

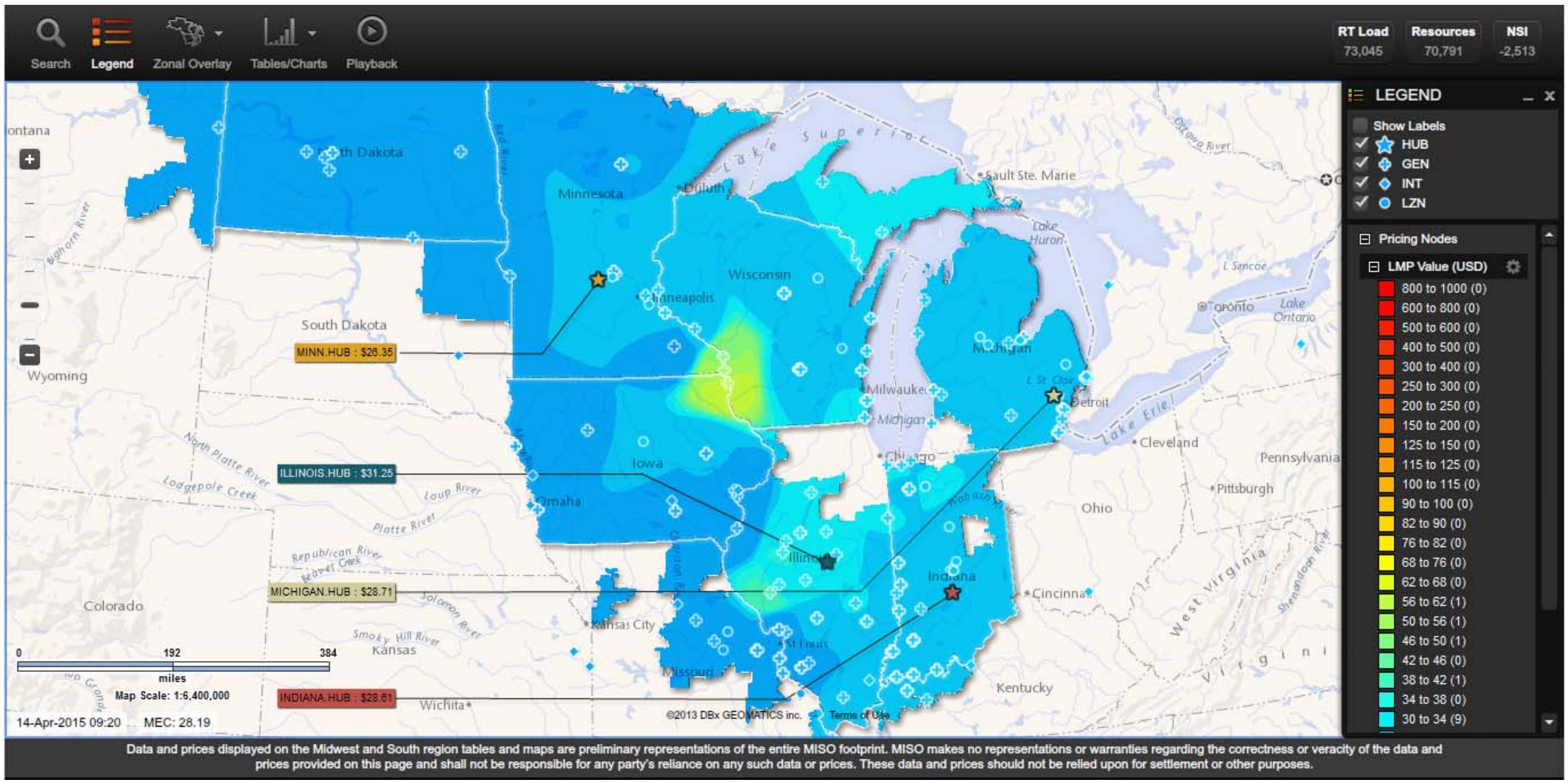
- No standard market design for every ISO/RTO
- Manage and provide a central clearing house for transactions (transmission and generation) versus bilateral markets with parties working directly to establish terms and conditions
- Participants still negotiate bilateral arrangements as appropriate for business needs
- Provides more efficient grid management
- Participation is officially voluntary though FERC provides incentives to encourage membership

Wholesale Electricity Markets

- Spot Markets (aka Day 1 or real-time)
- Day Ahead Markets (aka Day 2)



Example: MISO Real-time LMPs 4/14/15 @ 10:15am



Grid Planning and Development

Regional Grid Enlargement

- FERC regulates only wholesale transmission by “public utilities.”
  - One-third of U.S. transmission is not owned by public utilities nor subject to full FERC wholesale regulation.
  - Transmission not fully regulated by FERC includes transmission owned by public power (governments), by most cooperatives, and by most of the utilities in Texas.
- Outside RTOs and ISOs, FERC’s ability to promote coordinated enlargement of the interconnected grid is weaker than in RTOs and ISOs because its policies to do not apply to all the owners of the interconnected system

How is The Grid Planned?

A well planned system considers…

- Adequacy – Normal and Contingency
- Balance – Size and Strength
- Maintenance – Effective, Efficient, Suitable & Flexible
- Safety & Protection
- Recovery - Restoration

Primary Purpose of Transmission Planning

- To determine the transmission and substation additions which render the transmission network to be able to supply the loads and facilitate wholesale power marketing with a given criteria at the lowest possible cost and risk to the system

Issues and Factors in a Transmission Planning Study

- Planning Period
- Load Forecast and transmission usage projection
- Generation Resources (Location, Type, etc.)
- Discrete Transmission Capacities
- Alternative Solutions
- Economy of Scale
- Economic and Financial Constraints
- R-O-W Limitations
- New and Emerging Technology
- Various Uncertainties and Risks
- Service Reliability and Cost Considerations
- Institutional & Government Regulations

Regional Planning

- Per FERC O. 1000 (in conjunction with O. 890), all public utility transmission providers must participate in a regional transmission planning process

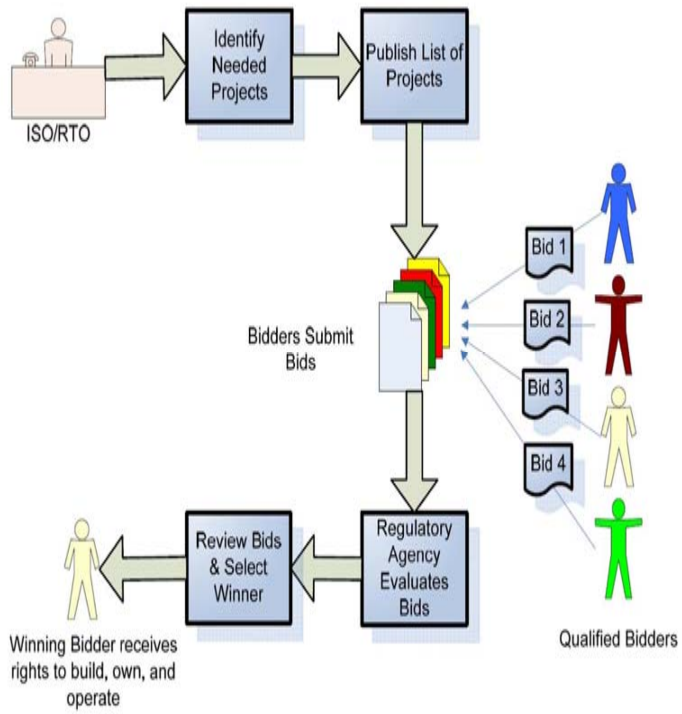
- Public utility transmission providers in neighboring transmission planning regions must coordinate to determine if there are more efficient or cost-effective solutions to their mutual transmission needs

- Stakeholders can provide input and advocate positions throughout the process

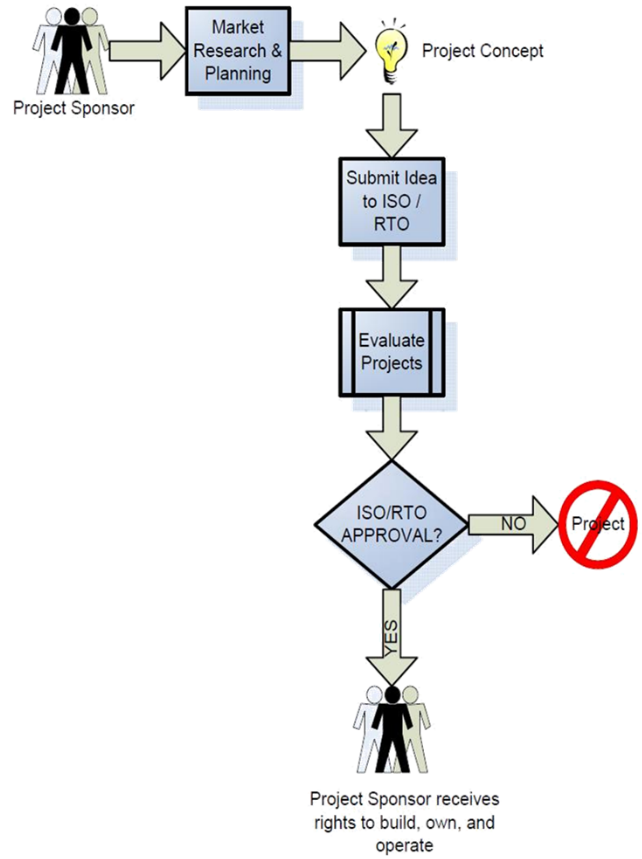
- Processes vary by region as dictated by individual transmission planning tariffs

Regional Planning - FERC Order 1000

Competitive Bid Model



Sponsorship Model



Regional Planning – Cost Allocation

- As a result of FERC Order 1000, regional planning and related cost allocation is expanding beyond ISO/RTOs to include other regions
- Cost allocation is very challenging given complex and highly interconnected nature of the bulk power system and existing regulatory frameworks, not considering merchant transmission developments and opportunities which can transcend regions
- Certainty regarding cost allocation and cost recovery of transmission investments are critical for grid expansion

Transmission Project Development

- Rate Based Projects
  - Submit project and justification to ISO/ RTO
  - ISO/ RTO studies the project
  - If ISO approves, project is funded by rate payers and receives FERC-approved rate of return
- Participant Funded Projects
  - Transmission developer has a participant willing to pay to use transmission line
  - Execute contract with stated terms, payment amounts, etc.
  - Transmission developer uses contract to attract third party financing
  - Rate payers are not affected
- Merchant Projects
  - Similar to participant funded, except no contract from participant
  - Goal is to capitalize on arbitrage opportunities resulting from inefficient markets

Emerging Grid Technologies

Storage

5 MW Energy Storage System at the Salem Smart Power Center in Salem, OR

Source: www.energy.gov

Synchrophasors/ Phasor Measurement Units (PMUs)

- A synchrophasor is a sophisticated monitoring device that can measure the instantaneous voltage, current and frequency at specific locations on the grid.
- They give operators a near-real-time picture of what is happening on the system, and allows them to make decisions to prevent power outages.

Synchrophasors/ Phasor Measurement Units (PMUs)

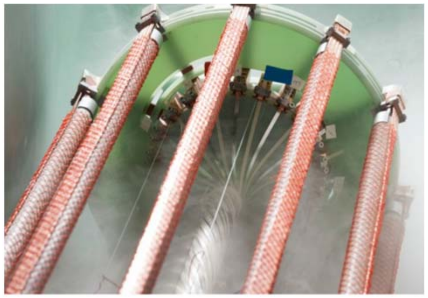
- Synchrophasors are measured by high-speed monitors called PMUs that are 100 times faster than existing SCADA technology

- PMU measurements record grid conditions with great accuracy and offer insight into grid stability or stress

- Overall = Improved grid reliability, efficiency and lower operating costs

Superconductors

- Superconductors are made of alloys or compounds that will conduct electricity without resistance below a certain temperature, thus eliminating inefficiencies
  - National electricity transmission and distribution losses average about 6% of the electricity that is transmitted and distributed in the United States each year
- Could enable the transfer of power over long distances at residential voltages
- Huge cost impacts!



Smart Wires Technology

- Smart Wires react in real time to grid needs, adjusting the impedance of each line to optimize the flow of power on the grid
- Can limit the number of customers affected by the outage by re-directing power around the outage using alternative routes.
- Has ability to transform the way power systems are planned and operated

SMART WIRES
REIMAGINE THE GRID

Summary

- The power system is:
  - Composed of generation, distribution and transmission
  - Relies on transmission to deliver cost effective generation to load centers
  - Uses the transmission backbone to support energy markets
  - Is complicated to operate and requires constant monitoring and control
  - Regional in operation
- Today's challenges to investment:
  - Planning to meet stakeholder needs
  - Integration of competitive transmission development
  - Getting agreement on cost allocation
  - Emerging technologies

Questions?

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Sources:

- www.eei.org
- www.ferc.gov
- www.epsa.org
- www.learn.pjm.com
- www.energy.gov
- www.misoenergy.org
- www.caiso.com

WHO PLANS & REGULATES THE GRID – LAW, POLICY MAKING, AND PROCEDURE

Presented by:

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WIRES University
Transmission 101:
Who Plans & Regulates the Grid

April 21, 2015

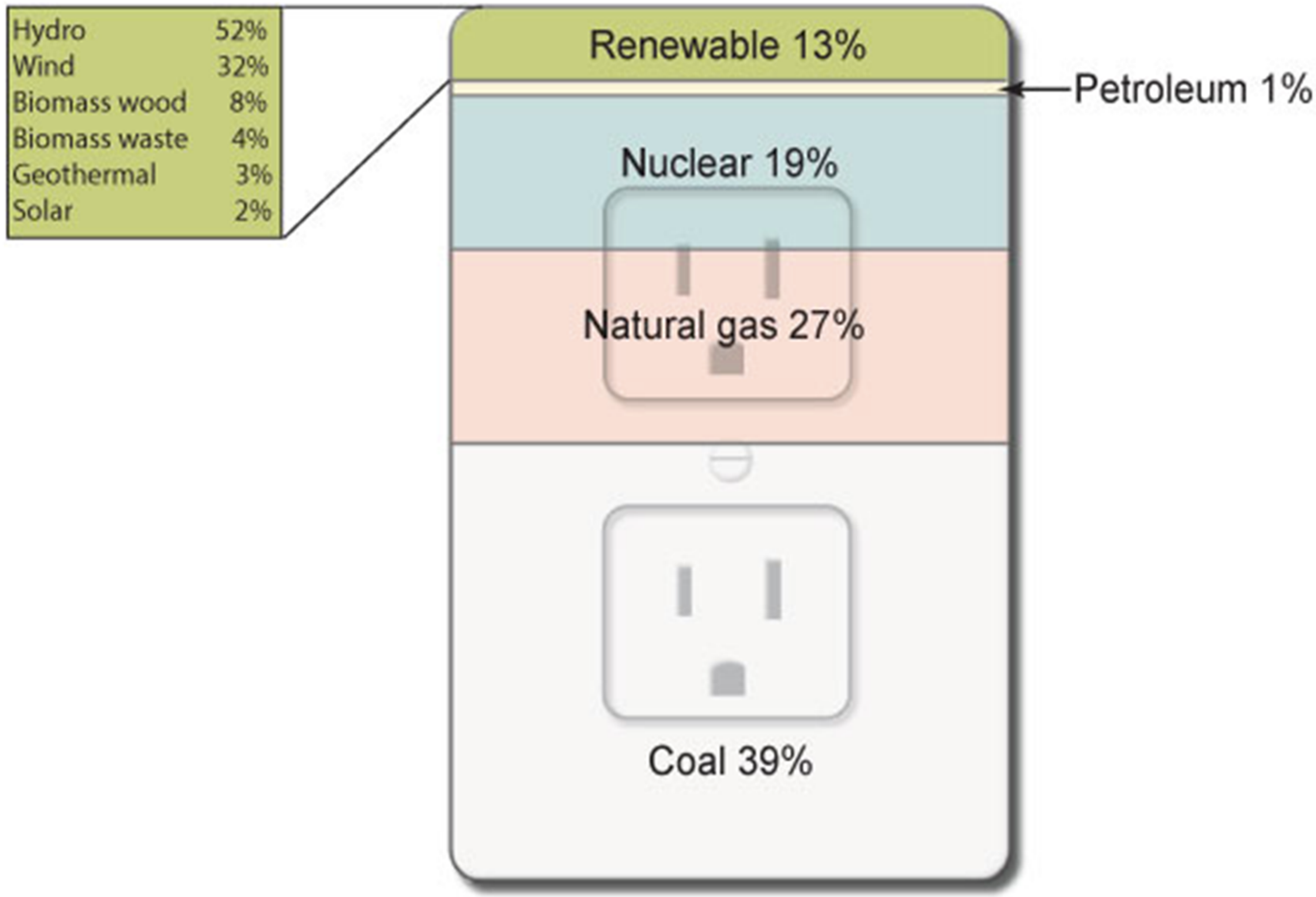
Professor Amy L. Stein
University of Florida Levin College of Law

Overview

- Transmission Basics
- Transmission Jurisdiction
- Transmission Management

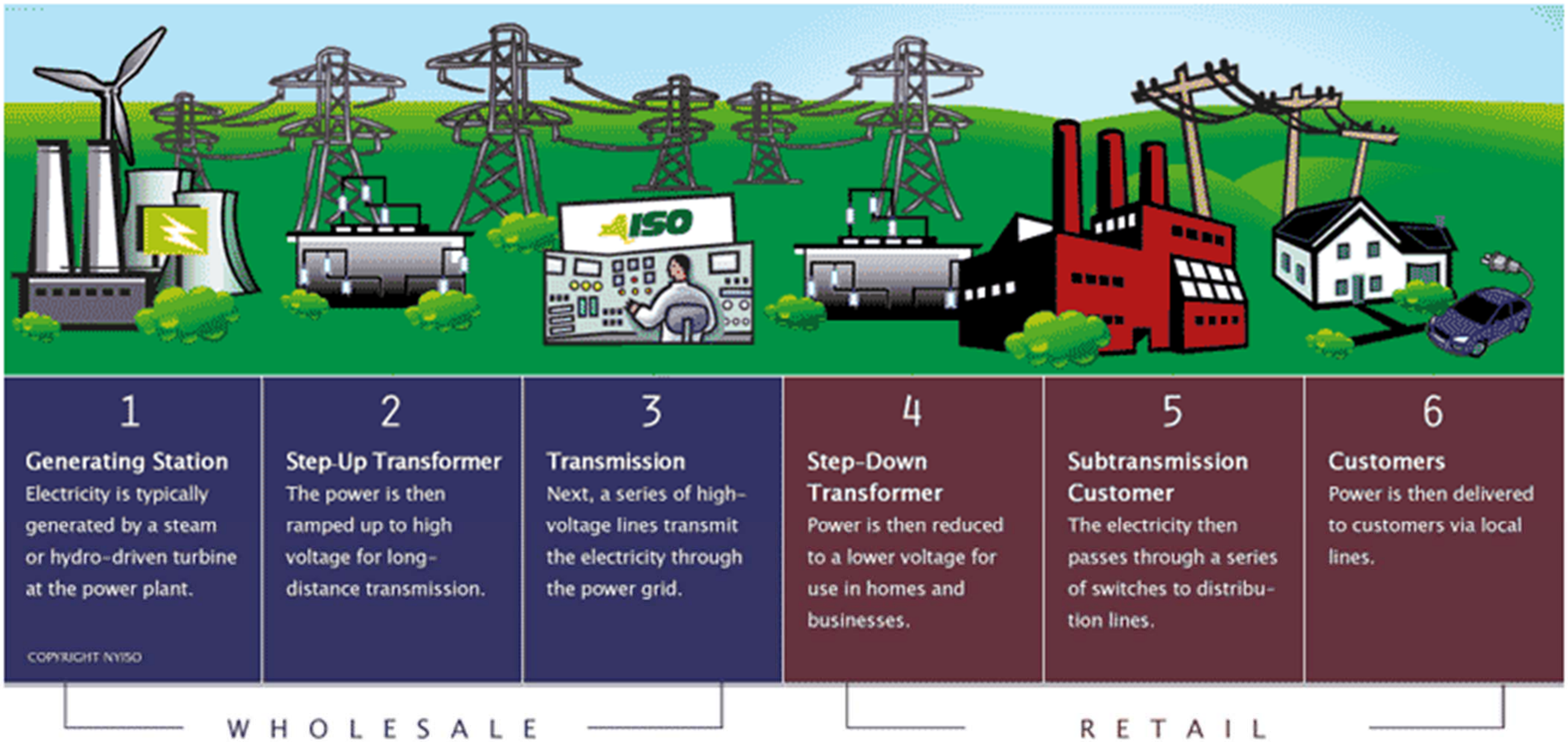
Transmission Basics

Sources of U.S. electricity generation, 2013



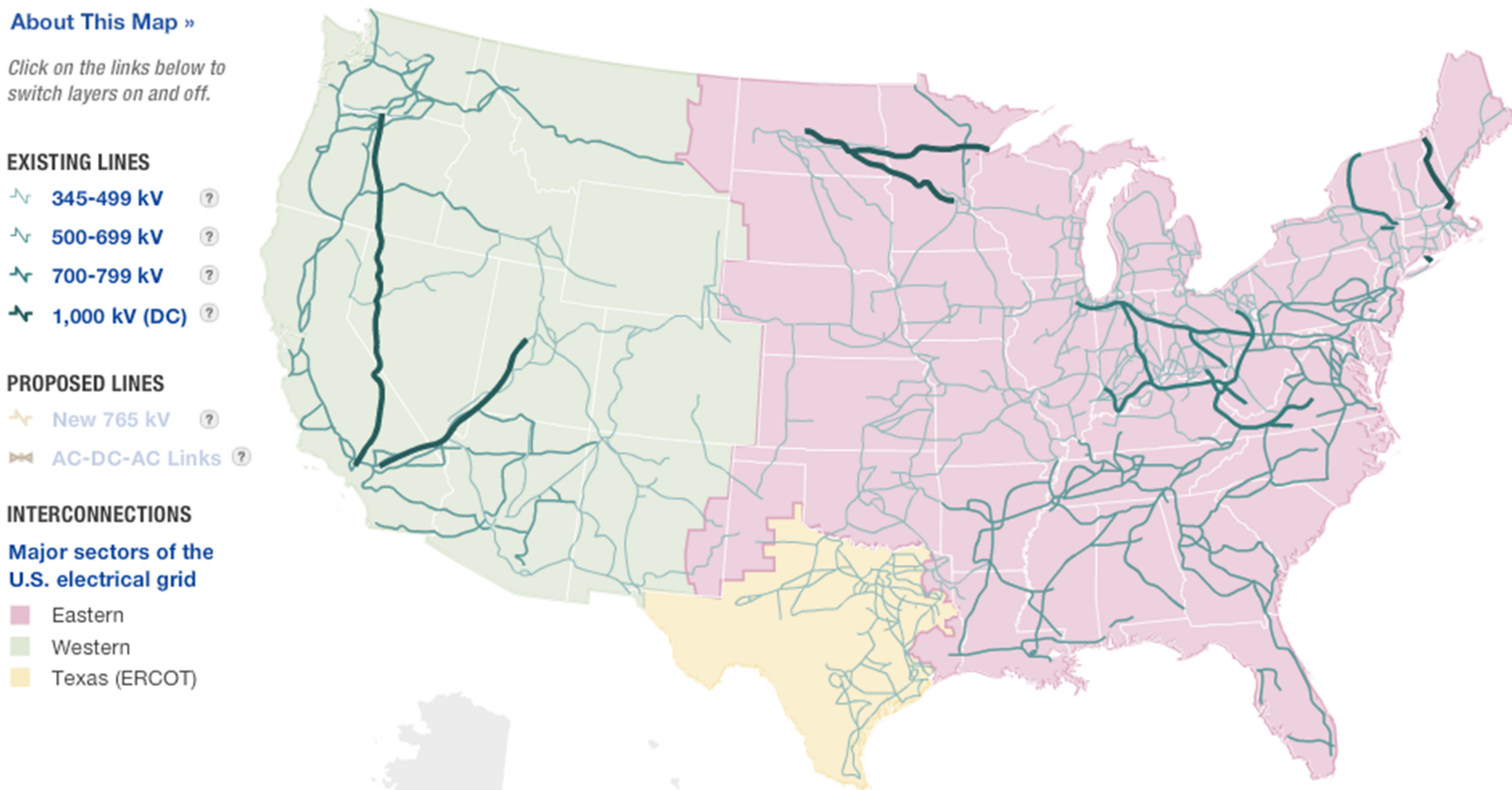
Source: U.S. Energy Information Administration, *Electricity Power Monthly* (February 2014). Percentages based on Table 1.1 and 1.1a; preliminary data for 2013.

Note: Sum of components may not equal 100% due to independent rounding.



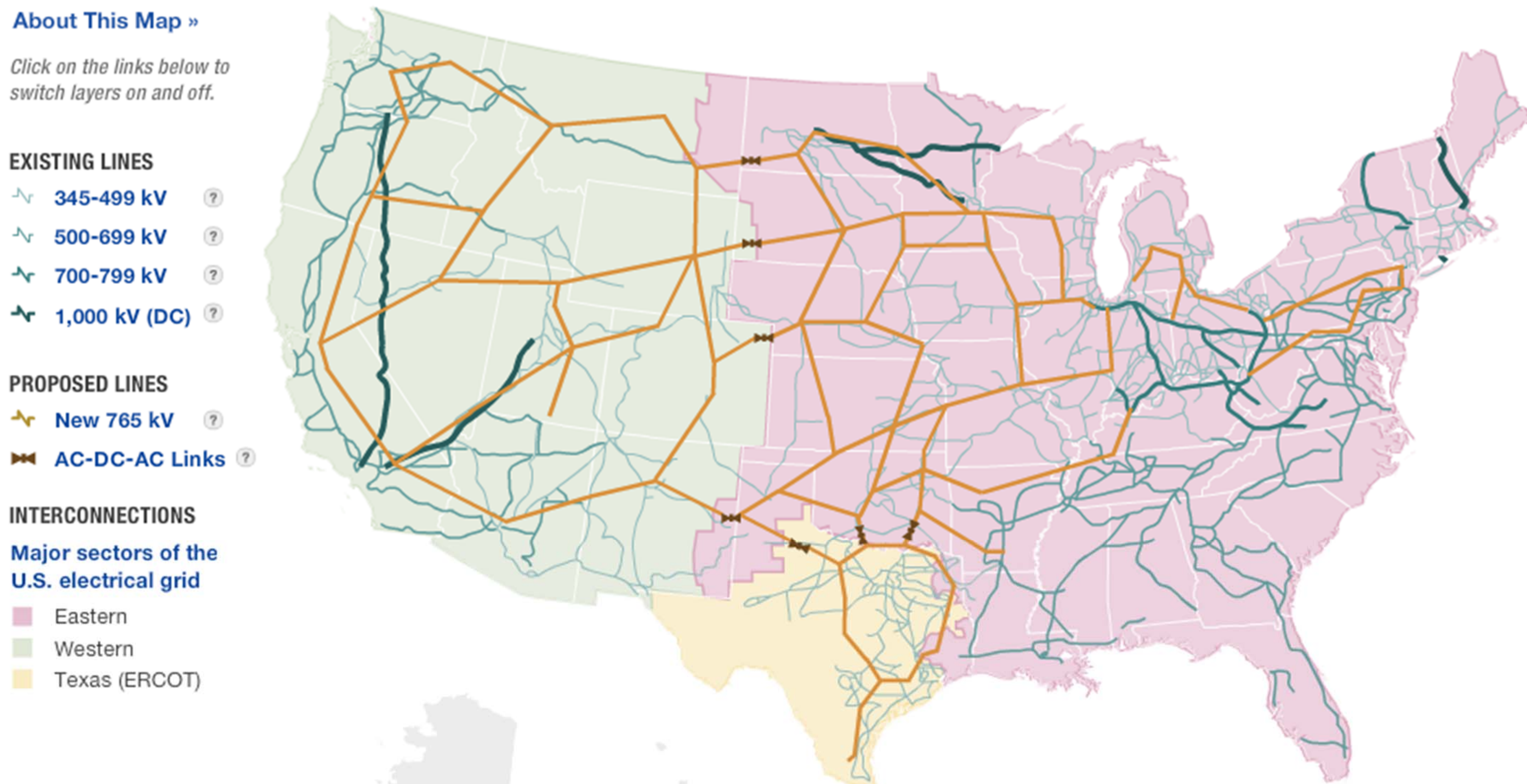
Source:
http://www.nyiso.com/public/about_nyiso/understanding_the_markets/wholesale_retail/index.jsp

Existing Transmission Lines



Source: http://www.npr.org/2009/04/24/110997398/visualizing-the-u-s-electric-grid

Proposed Transmission Lines



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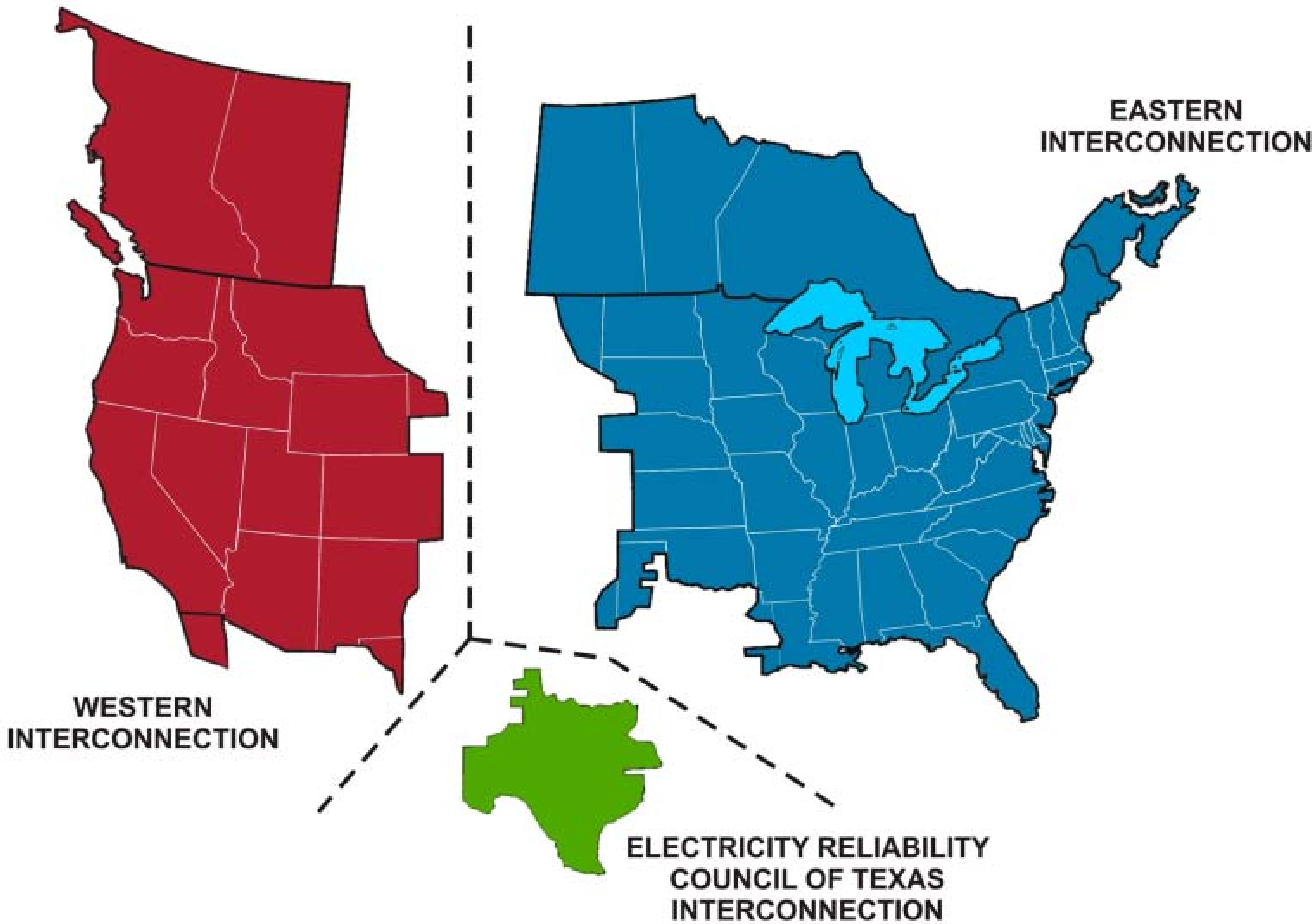
North American Electric Reliability Corporation Interconnections



Source: http://energy.gov/oe/downloads/north-american-electric-reliability-corporation-interconnections

Drivers of New Transmission

- Enhance reliability of grid
- Relieve congestion
- Facilitate wholesale market competition
- Support a diverse and changing generation portfolio
- Ensure a more flexible and resilient grid

Transmission Jurisdiction

The Federal Power Act: Rates and Terms For Transmission

- Provides Federal Energy Regulatory Commission (FERC) with exclusive jurisdiction over "transmission of electric energy in interstate commerce"
  - 16 U.S.C. § 824(b); FPA Section 201(b))
- Requires FERC to ensure that all rates, charges, terms, and conditions of transmission service are
  - "Just and reasonable"
  - "Not unduly discriminatory or preferential"
    - 16 U.S.C. § 824d and 824e; FPA Section 205 and 206

The Federal Power Act: Jurisdictional Entities

- FERC has jurisdiction over "public utilities" ("any person who owns or operates facilities subject to the jurisdiction of the Commission under this subchapter ….") 16 U.S.C. § 824(e); FPA § 201(e).
  - Most investor-owned electric utilities
  - A few electric cooperatives

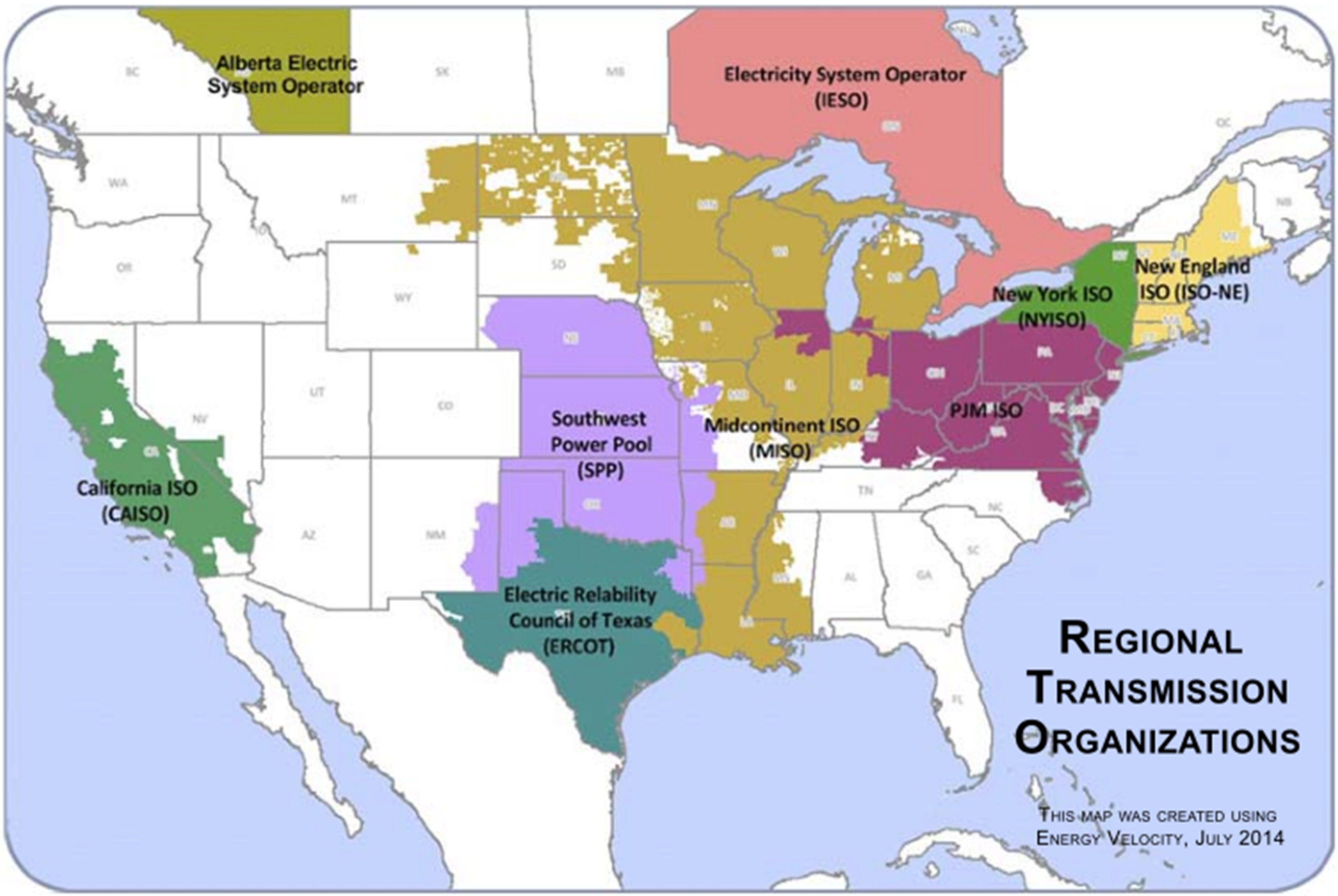
- FERC does not have jurisdiction over the following "non-jurisdictional entities" 16 U.S.C. § 824(f); FPA § 201(f).
  - State and municipal utilities
  - Most electric cooperatives
  - Federal utilities

The Federal Power Act: Siting of Transmission Lines

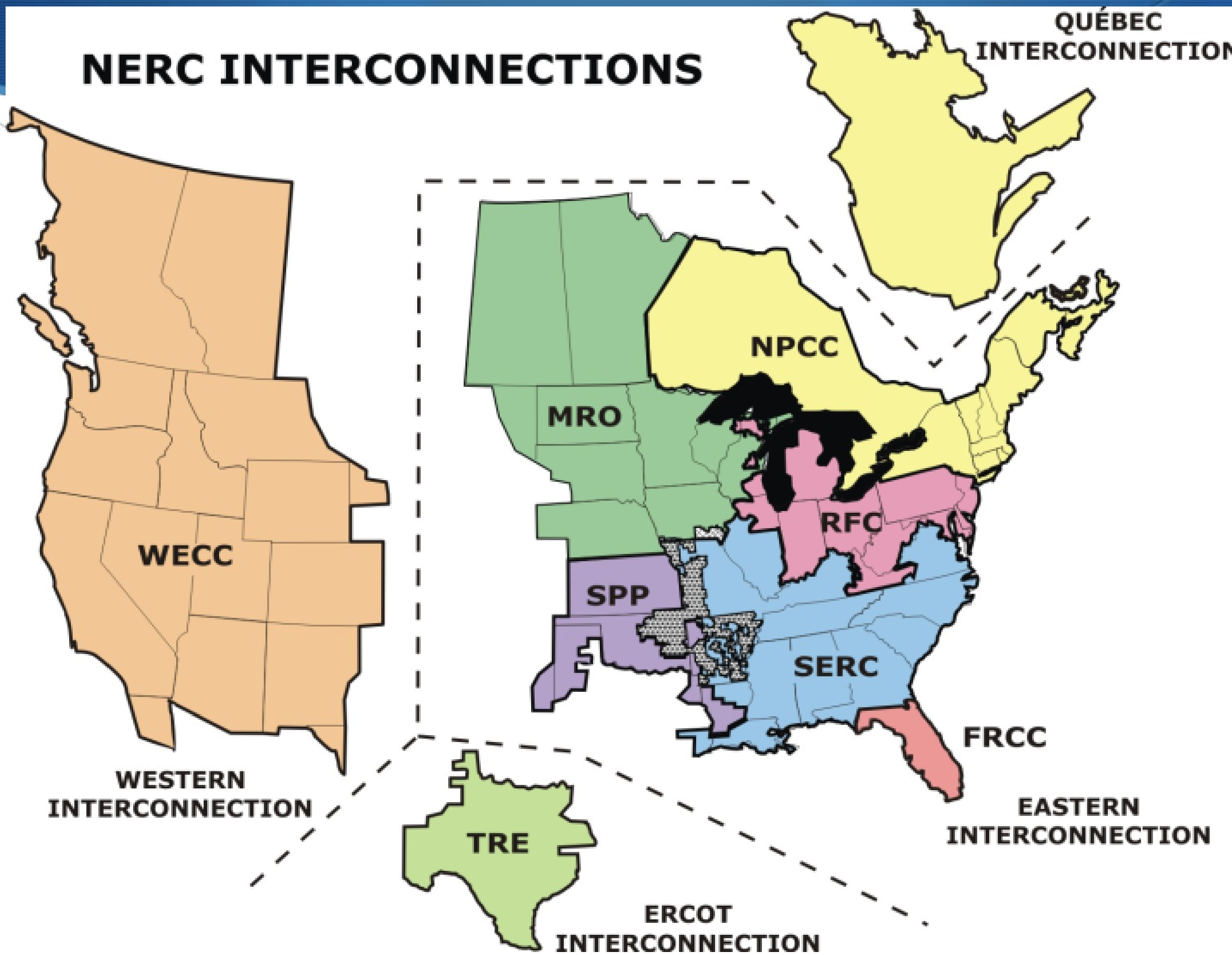
- Reserves power to the states over transmission siting
  - 16 U.S.C. § 824(b); Section 201(b))
- Except in very limited circumstances where FERC "backstop" siting authority applies.
  - 16 U.S.C. § 824p; Section 216

Managing the Grid

RTOs/ISOs


Alberta Electric System Operator
Electricity System Operator (IESO)
New York ISO (NYISO)
New England ISO (ISO-NE)
Southwest Power Pool (SPP)
Midcontinent ISO (MISO)
PJM ISO
California ISO (CAISO)
Electric Reliability Council of Texas (ERCOT)
Regional Transmission Organizations
This map was created using Energy Velocity, July 2014

Managing Reliability in Three Interconnections



Thank You

Questions or Comments?

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WHO PLANS & REGULATES THE GRID – LAW, POLICY MAKING, AND PROCEDURE

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Who Plans & Regulates the Grid-Law, Policy Making, and Procedure

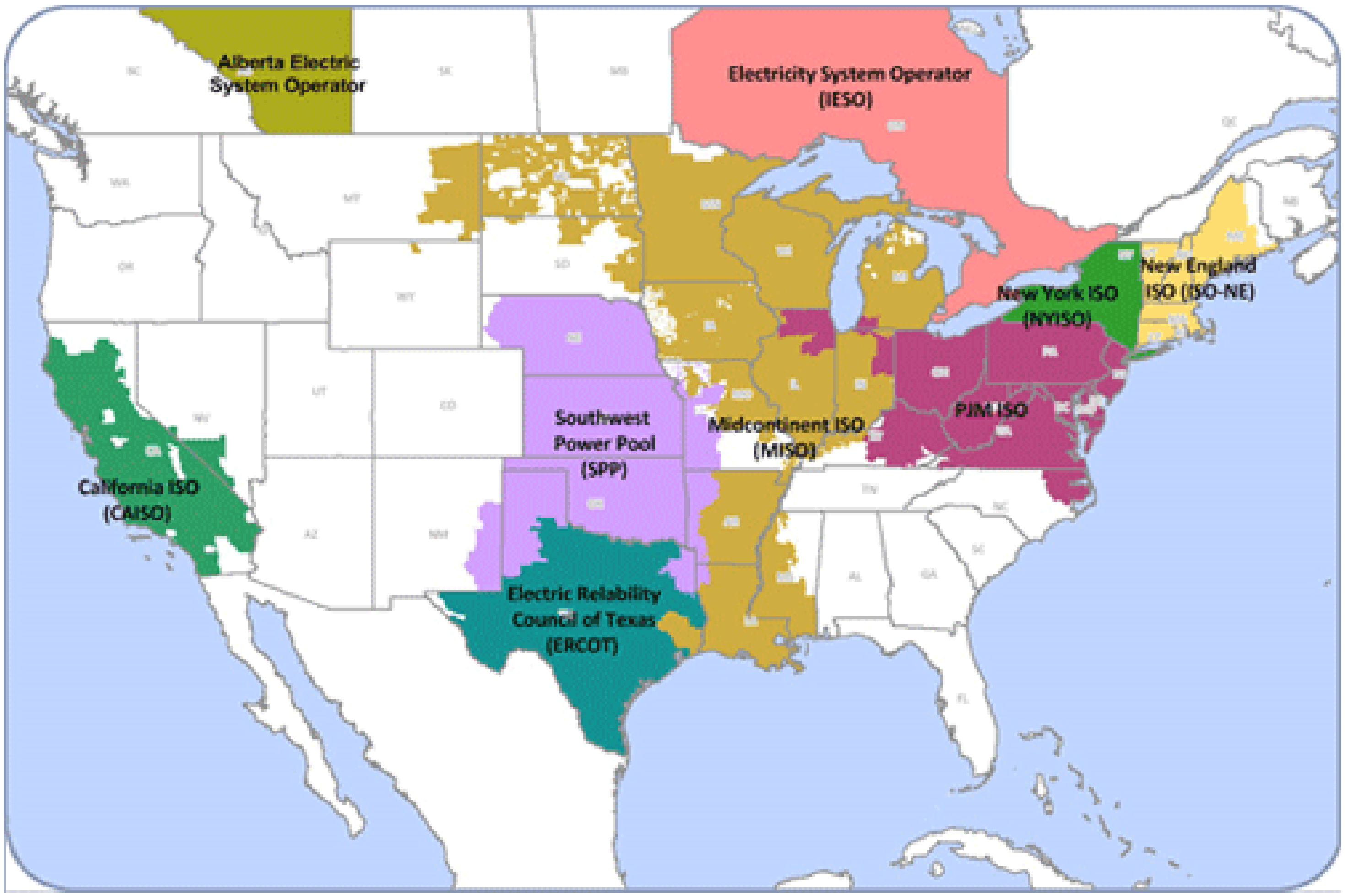
David L. Morenoff, General Counsel
Federal Energy Regulatory Commission

April 21, 2015

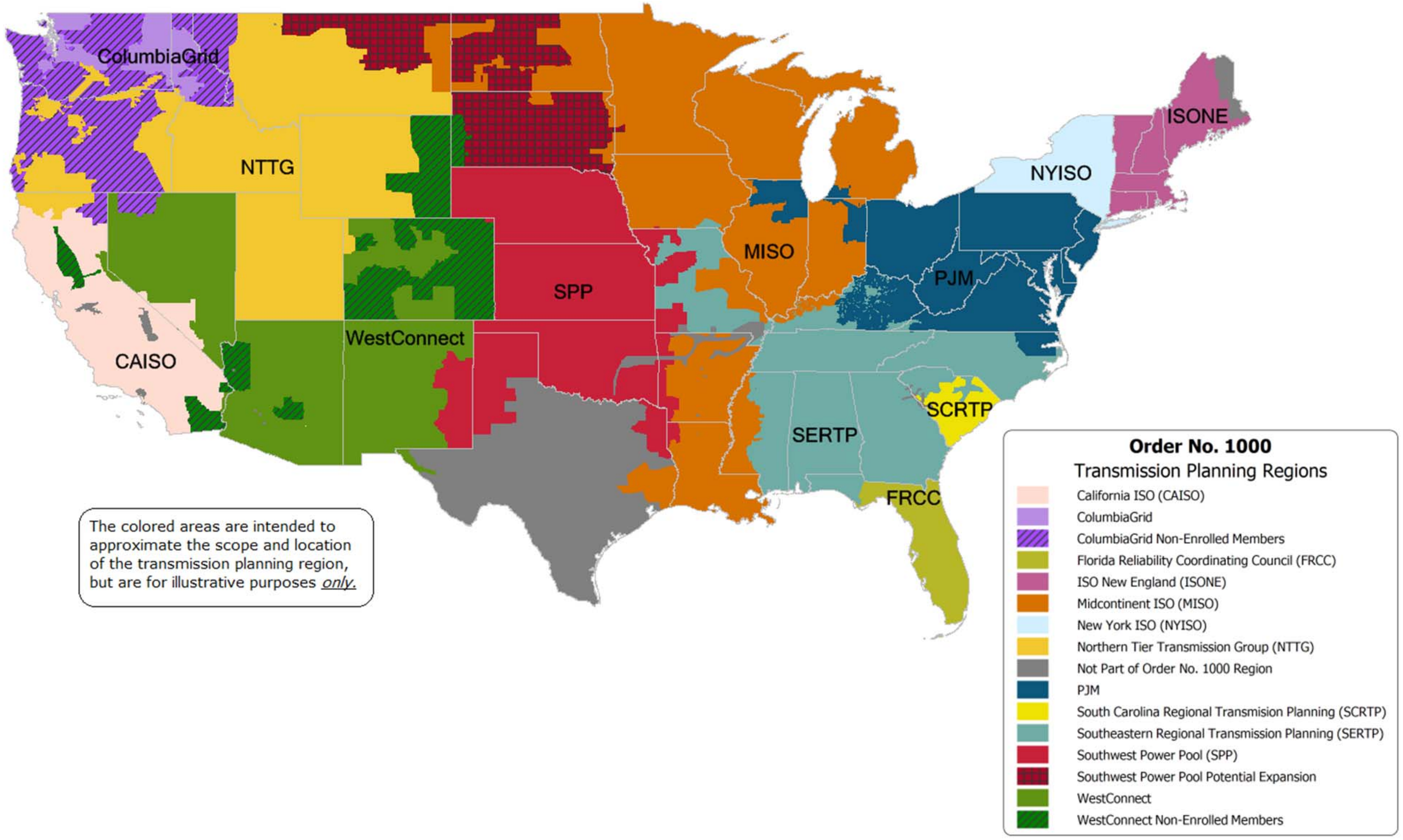
Notable FERC Rules Shaping Grid Operation and Development

- Order No. 888 (1996):
  Open Access Transmission
- Order No. 2000 (1999):
  Encouraging RTO Formation
- Order No. 1000 (2011):
  Transmission Planning and Cost Allocation

Regional Transmission Organizations & Independent System Operators



Order No. 1000 Transmission Planning Regions



Order No. 1000 Key Requirements

- Regional Transmission Planning
- Account for 3 Types of Transmission Needs
- Cost Allocation Requirements
- Nonincumbent Transmission Developer Requirements
- Interregional Transmission Coordination

WHO PLANS & REGULATES THE GRID - LAW, POLICY MAKING, AND PROCEDURE

Presented by:

Randall Satterfield
Executive Vice President
Strategic Planning & Project Development
American Transmission Co.

WIRES - a national coalition of entities dedicated to investment in a strong, well-planned and environmentally beneficial electricity high voltage transmission system in the US.

Siting Transmission

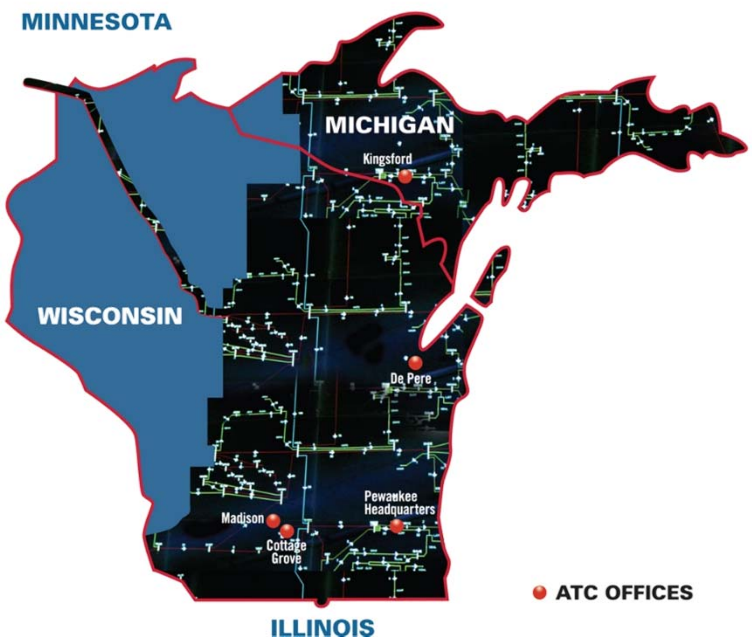
Randy Satterfield

Executive Vice President

American Transmission Company

ATC at a Glance

- Began operations in 2001 as first multi-state, transmission-only utility in U.S.
- Headquartered in Pewaukee, Wis.
- Grew from $550 million in assets in 2001 to $3.8 billion today
- Operating 9,530 miles of lines and 530 substations in Wisconsin, Michigan, Minnesota, Illinois



National Leader in Building Transmission

- Our track record: expert builder providing high quality
  - 2009 EEI Edison Award for 220-mile project
- $3.5 billion in investment
- More than 2,400 miles of line upgraded or built
- More than 176 substations built or improved
- Successful regulatory record
- Best-value projects resolve multiple system issues; designed to standards; built efficiently
- Alliance partnerships make efficient use of human and material resources

Transmission can be sited and built,

it requires time and effort.

Siting Process

- Phase 1: Study Area Analysis
  - A large, inclusive area
- Phase 2: Preliminary Corridors
  - Corridors are not routes
- Phase 3: Proposed Routes Identified
- Phase 4: Final Route(s)

For large projects this can be a 24- to 36-month public process.

Challenges to Interstate Projects

- State siting laws vary
  - Existing corridors, section lines
  - Number of route options
- Regulatory timelines do not align
  - State
  - Federal
  - Environmental permitting
  - Other agencies
- Stakeholder engagement
  - Complicated, lengthy process
  - Easement negotiations

What is Public Involvement?

Public involvement is a collection of processes that involve stakeholders (the public, elected officials, regulators, community representatives and other interested parties) in project development and decision making.

Public Involvement Philosophy

- A project is acceptable to the public only if people believe:
  - It is **needed**
  - It will provide **benefits**
  - Their input and concerns have been **heard**
- There will always be opponents
  - Counter their claims
  - Focus on everybody else

Public Involvement Outreach

- **Founding Principle:** Given enough information on a consistent basis, most people will come to accept the necessity of a project.
- **Goal:** Provide support for regulatory consideration on merits
- **Challenges**
  - Siting is a long process
  - NIMBY
  - Myths vs. facts
  - Media needs controversy
  - Opponents very vocal

Goals of Public Involvement

- Build and strengthen relationships with stakeholders
- Achieve public understanding
- Demonstrate legitimacy of process to regulators, media and public
- Get your project approved/permitted – on time and within cost

WIRES

Siting Transmission

AMERICAN TRANSMISSION COMPANY®

For additional information,
please visit:

American Transmission Company
Projects Learning Center

http://www.atc-projects.com/learning-center/

WIRES

WHO PLANS & REGULATES THE GRID – LAW, POLICY MAKING, AND PROCEDURE

Presented by:

Pauline Foley
Assistant General Counsel
PJM Interconnection, L.L.C.

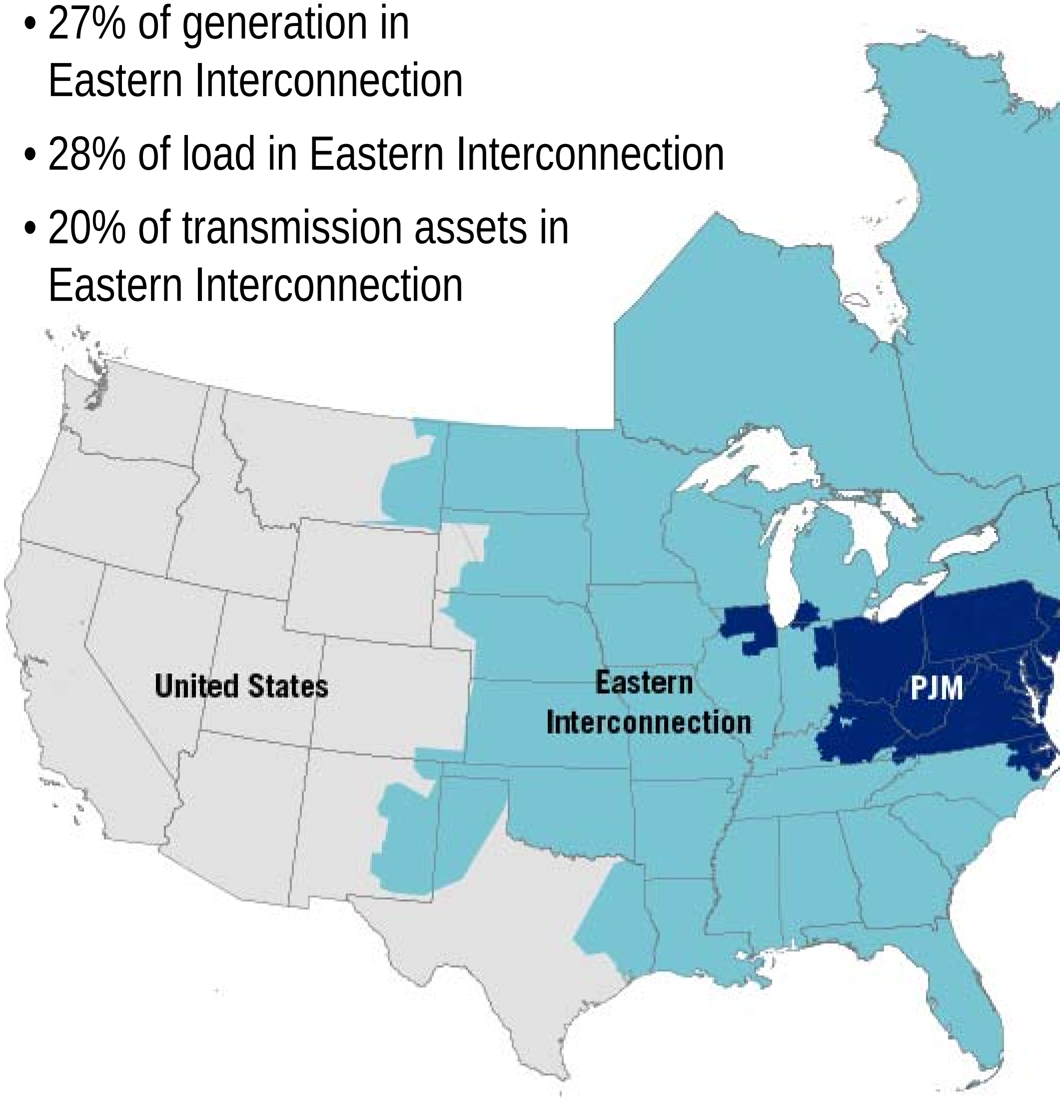
WIRES - a national coalition of entities dedicated to investment in a strong, well-planned and environmentally beneficial electricity high voltage transmission system in the US.

WIRES UNIVERSITY
ELECTRIC TRANSMISSION 101
OVERVIEW OF PJM

Pauline Foley
Assistant General Counsel
PJM Interconnection, L.L.C.
April 21, 2015

PJM as Part of the Eastern Interconnection

- 27% of generation in Eastern Interconnection
- 28% of load in Eastern Interconnection
- 20% of transmission assets in Eastern Interconnection

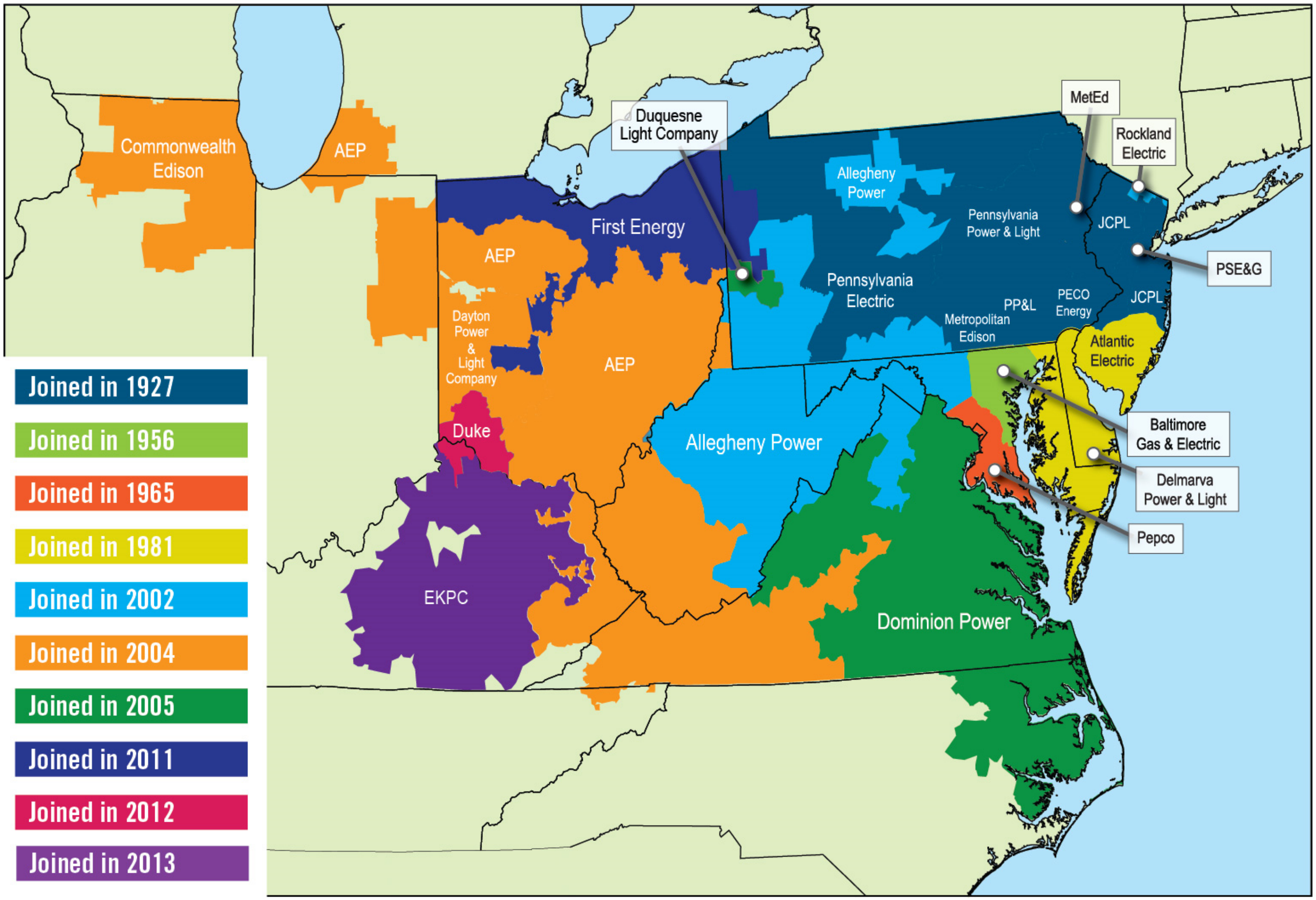


KEY STATISTICS	
PJM member companies	900+
millions of people served	61
peak load in megawatts	165,492
MWs of generating capacity	183,604
miles of transmission lines	62,556
2013 GWh of annual energy	791,089
generation sources	1,376
square miles of territory	243,417
area served	13 states + DC
externally facing tie lines	191

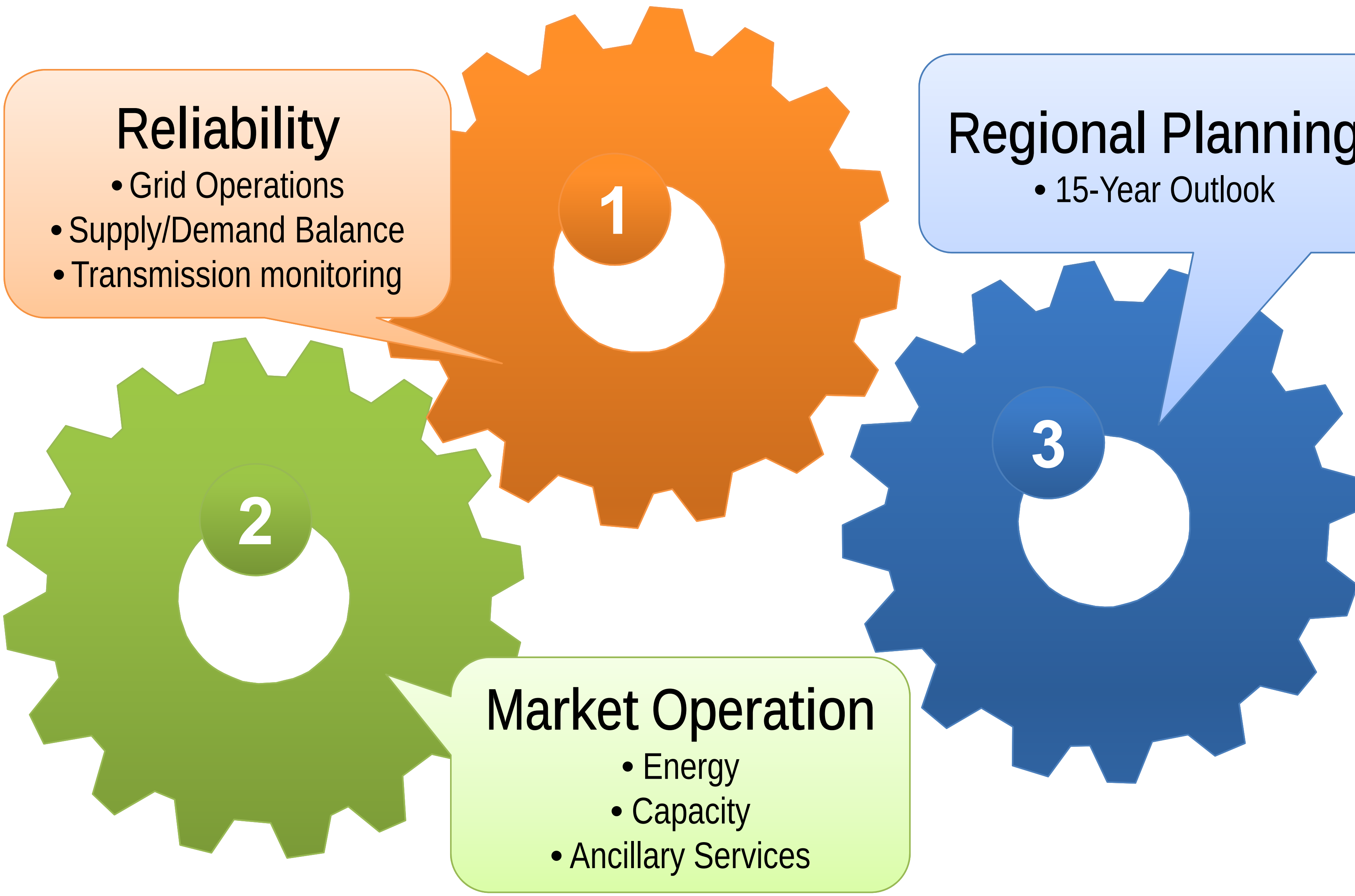
21% of U.S. GDP produced in PJM

As of 4/1/2014

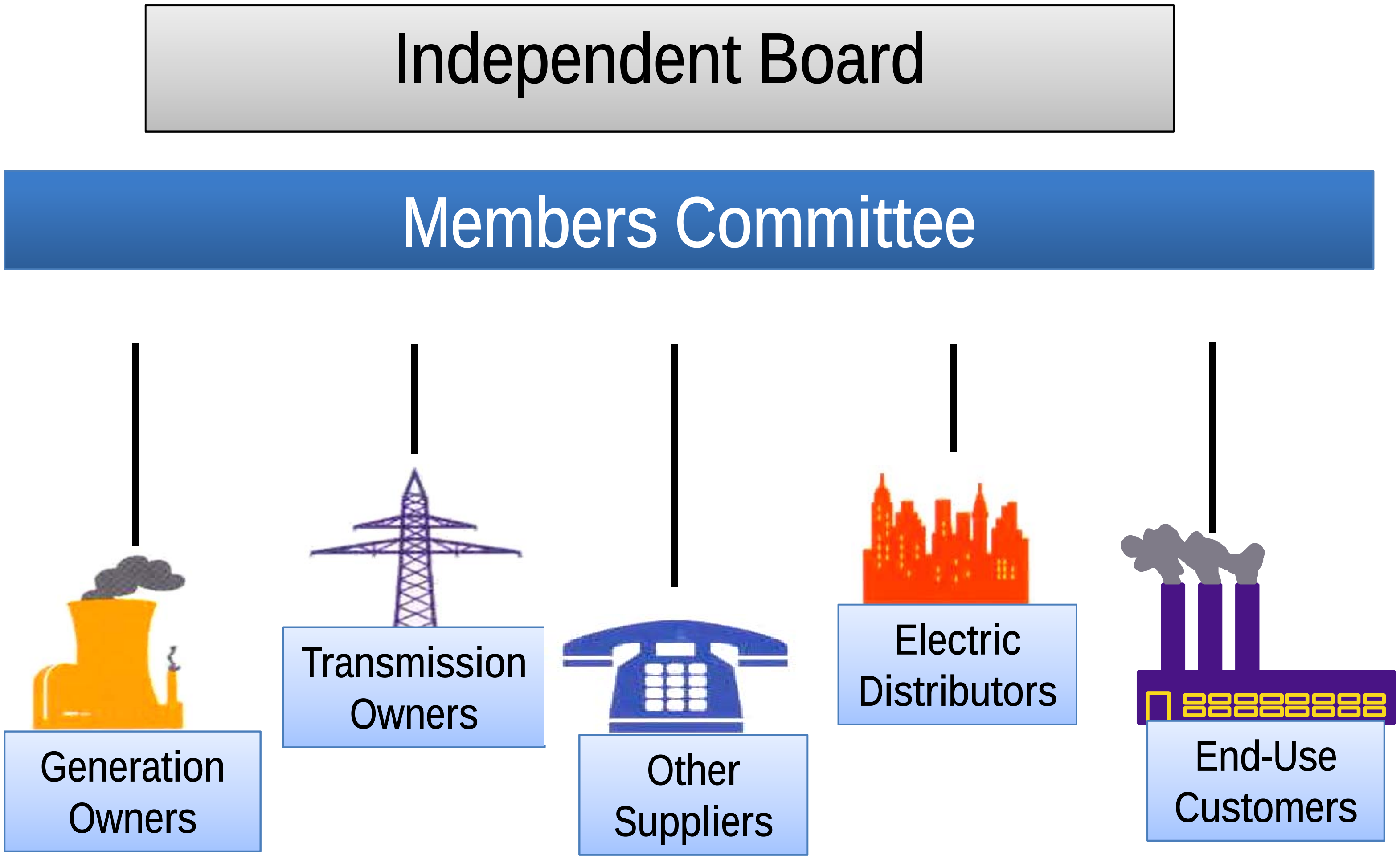
PJM Evolution



PJM – Focus on Just 3 Things



PJM Governance



Market Benefits

- Information and price transparency
- Seams elimination
  - Elimination of pancaking
- Reduced prices
- Operational efficiency
- Market liquidity
- Increased system reliability
- Regional transmission planning
  - Transmission investment
  - Generation investment
- Increased demand response
- Support innovation and renewable energy development

Regional Market Benefits

Reliability –

resolving transmission constraints, gains in economic efficiency from regional reliability planning – from $470 million to $490 million in annual savings

Generation investment –

reduced reserve requirements and increased demand response result in decreased need for infrastructure investment – from $640 million to $1.2 billion in annual savings

Regional Market Benefits

Energy production cost –

efficiency of centralized dispatch over a large region – from \$340 million to \$445 million in annual savings

Grid services –

cost-effective procurement of synchronized reserve, regulation – from \$134 million to \$194 million in annual savings

RTO Challenges Going Forward

- **Planning**: Order No. 1000 required
  - new competitive solicitation process for planning transmission included in the regional plan for cost allocation purposes; and
  - Consideration of Public Policy
  - Regional Cost Allocation
- **Markets**: *EPSA* ruling by the D.C. Circuit challenging FERC's jurisdiction over demand response.
- **EPA Clean Power Plan (CPP)**: PJM tasked with assessing potential impacts of the CPP proposal on PJM states.

WIRES

LET'S TALK…

pjm

Pauline Foley
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TRANSMISSION INVESTMENT AS MARKET ENABLER

Presented by:

Hannes Pfeifenberger
Judy Chang
The Brattle Group – On Transmission Benefits

WIRES - a national coalition of entities dedicated to investment in a strong, well-planned and environmentally beneficial electricity high voltage transmission system in the US.

Transmission As a Market Enabler: The Costs and Risks of an Insufficiently Flexible Electricity Grid

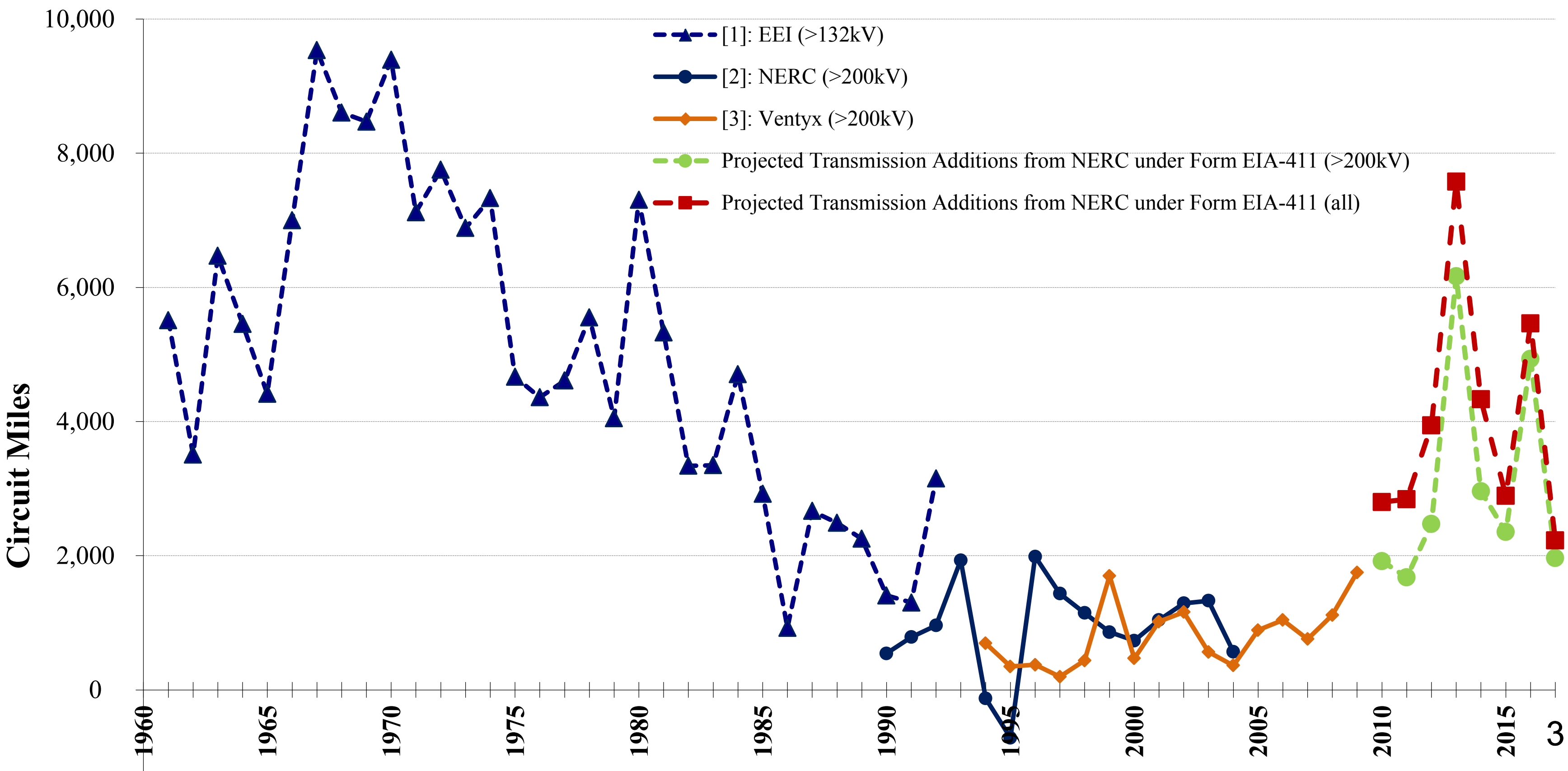
Johannes Pfeifenberger
The Brattle Group

Agenda

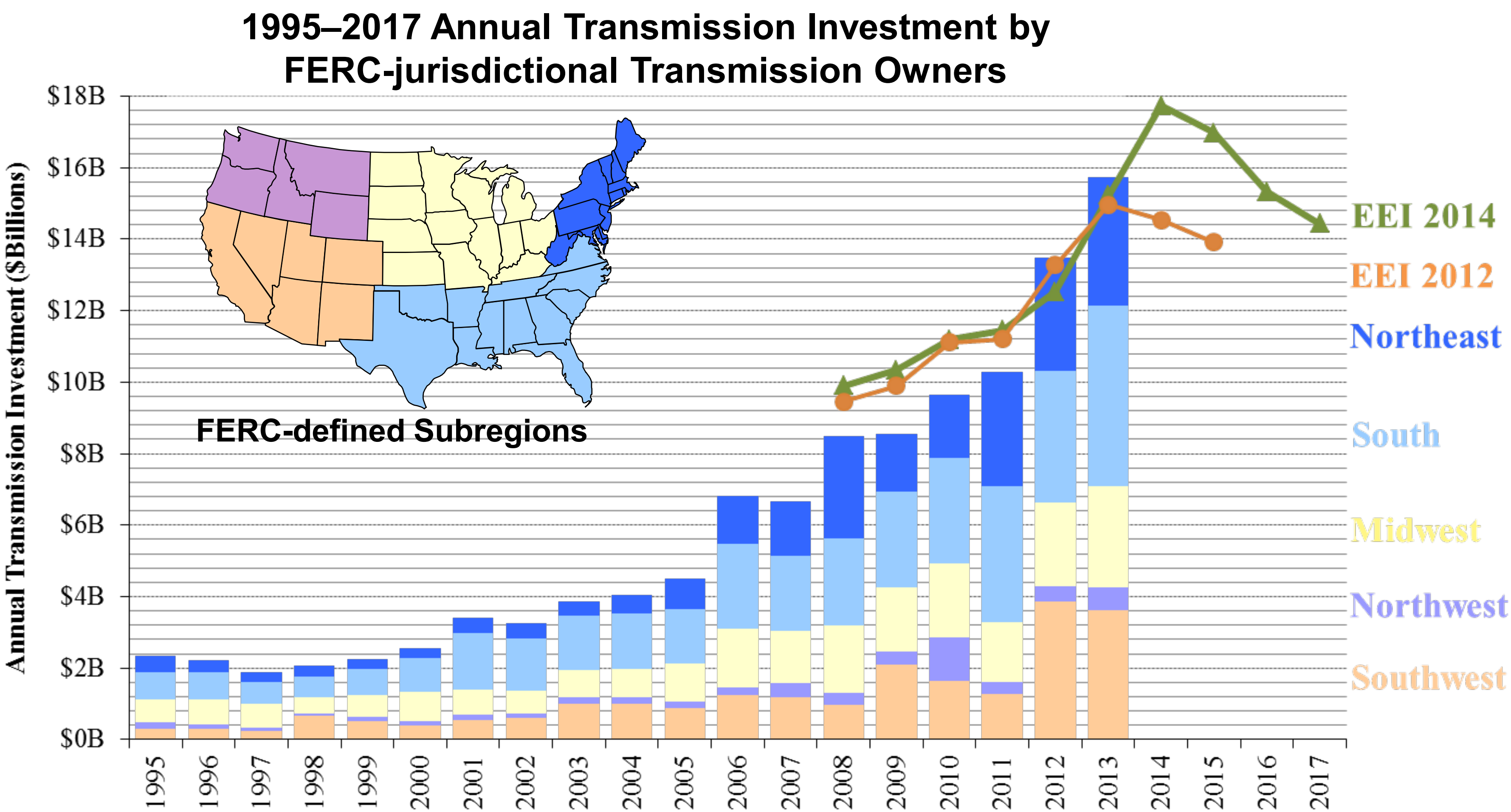
1. Historical Transmission Investment and Projected Needs
2. Key Barriers to Planning a More Robust Transmission Grid
3. Often Overlooked Benefits of a Flexible and Robust Transmission Grid
   - Numerous benefits that increase reliability and lower the cost of generating and delivering power to consumers
4. The High Costs and Risks of Inadequate Transmission Infrastructure
5. The Need for More Effective Interregional Transmission Planning
6. Recommendations for Policy Makers

Historical Circuit-Mile Additions Document Aging Grid

- Most of the existing grid was built 30-50+ years ago
- Even relatively high recent and projected circuit miles additions are below levels of additions in 1960s and 1970s



Growing Transmission Investments



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 May 2014 shown (2008-2017) based on prior year's actual investment through 2012 and planned investment thereafter.

Transmission Investment Drivers Looking Forward

Renewable Generation Additions

Coal Plant Retirement and Clean Power Plan

Aging Facilities

Nationwide Transmission Investments: $120-160 billion/decade

Reliability Upgrades, Gen Interconnection, Load Serving

Interregional Buildout

Pockets of High Load Growth (e.g., Oil & Gas Development)

Key Barriers to More Effective Grid Planning

We identified 3 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.

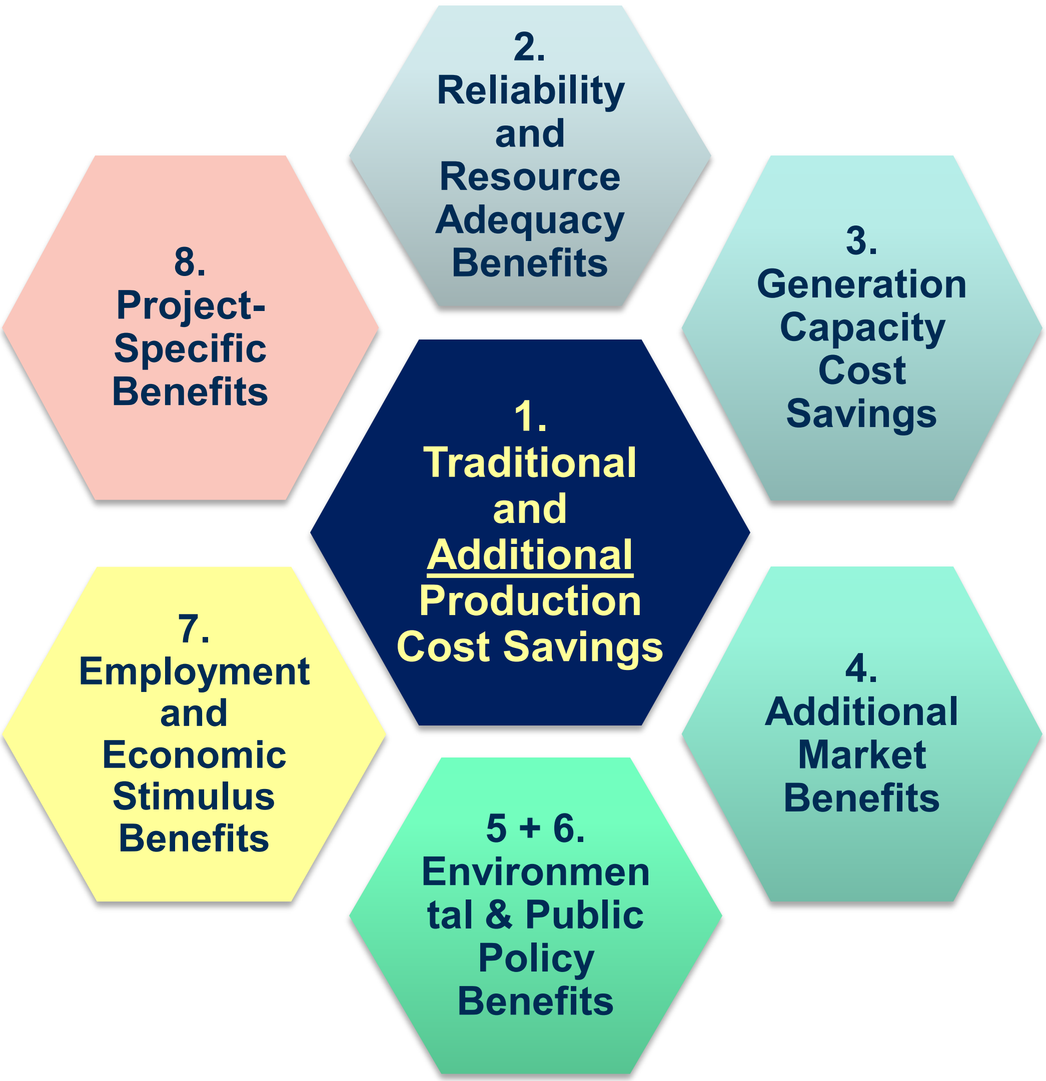
Additional challenges related to regional cost recovery and state-by-state permitting processes

The Need for More Effective Grid Planning

If not addressed, the identified barriers to more effective regional and interregional transmission planning will lead to:

- Underinvestment in transmission, which results in higher overall costs of delivered electricity
- Lost opportunities to identify and select alternative infrastructure solutions that are lower-cost or higher-value in the long term than the (mostly reliability-driven) projects proposed by planners
- An insufficiently robust and flexible grid that exposes customers and other market participants to higher costs and higher risk of price spikes

The Full Range of Transmission-Related Benefits

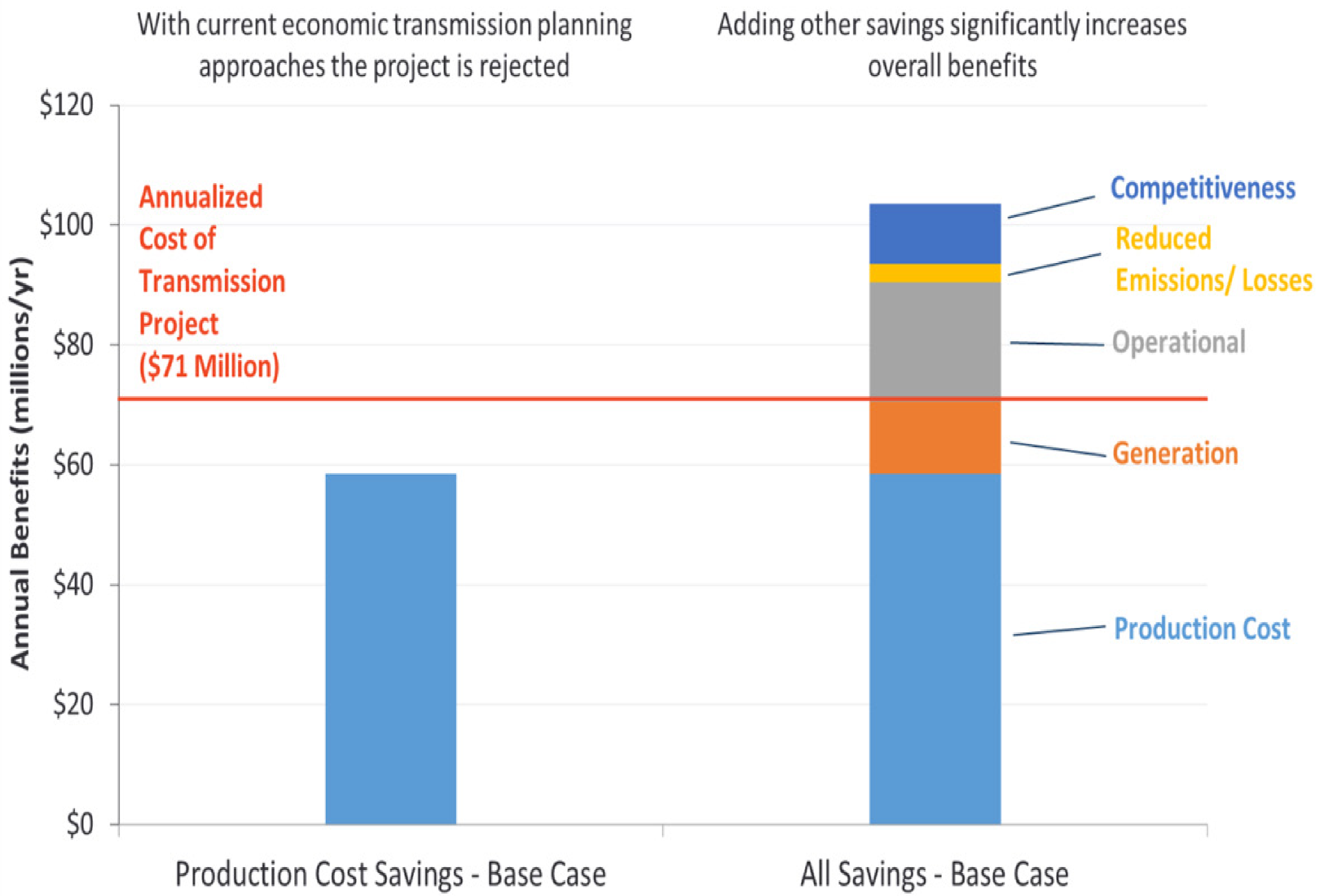


- Transmission accounts for 10% of customer bills but will greatly affect at least half of the other 90%
- Omitting many transmission-related benefits (or assuming they are zero) ignores the costs and risk imposed on customers through a higher overall cost of power

Checklist of Transmission Benefits

Benefit Category	**Transmission Benefit (see Appendix for descriptions and detail)**
Traditional Production Cost Savings	Production cost savings as currently
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 <u>or</u> c. reduced planning reserve margin
3. Generation Capacity Cost Savings	a. Capacity cost benefits from reduced peak energy losses
	b. Deferred generation capacity investments
	d. Access to lower-cost generation resources
4. Market Benefits	a. Increased competition
	b. Increased market liquidity
5. Environmental Benefits	a. Reduced emissions of air pollutants
	b. Improved utilization of transmission corridors
6. Public Policy Benefits	Reduced cost of meeting public policy goals
7. Employment and Economic Stimulus Benefits	Increased employment and economic activity; Increased tax revenues
8. Other Project-Specific Benefits	Examples: storm hardening, fuel diversity, flexibility, reducing the cost of future transmission needs, wheeling revenues, HVDC operational benefits

Example: Why Considering all Transmission Benefits is Important



Inadequate Transmission Imposes High Risks

- Most transmission planning efforts do not adequately account for <u>short- and long-term risks</u> and uncertainties affecting power markets
  - Economic transmission planning generally evaluates on only "normal" system conditions
    - Ignores the high cost of short-term <u>challenges and extreme market conditions</u> triggered by weather, outages, fuel supply disruption, unexpected load growth
  - Planning does not adequately consider the full range of long-term scenarios and does not capture the extent to which a less robust and flexible transmission infrastructure will <u>foreclose lowest-cost options</u>
- Costs of inadequate infrastructure typically are not quantified but, under some circumstances, can be much greater than the costs of the transmission investments

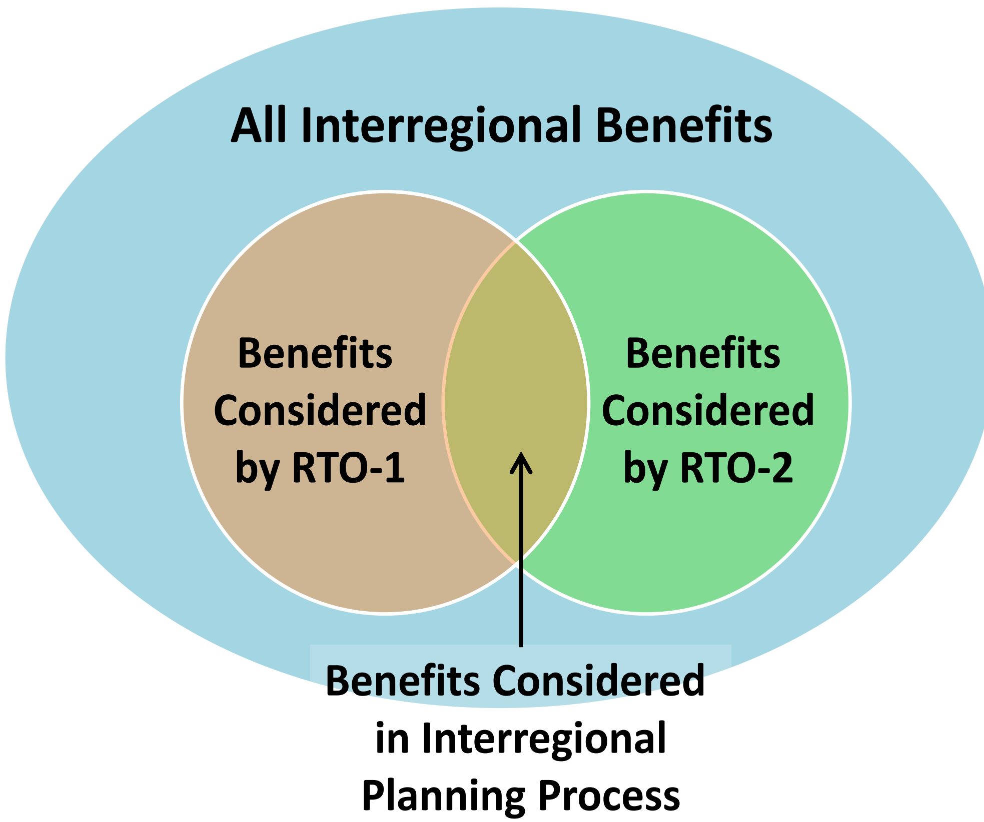
Inadequate Transmission Imposes High Risks

Planning processes largely ignore 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 outcomes
  - "Wait and see" approaches limits options, so can be very costly in the long term;
  - The industry needs to plan for short- and long-term uncertainties more proactively
- "Least regrets" planning mostly focuses on identifying those projects that are beneficial under most circumstances
  - 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

Ineffective Inter-Regional Transmission Planning

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



Experience already shows that few (if any) interregional projects will be found to be cost effective under this approach

Multiple threshold tests create additional hurdles

Ineffective Inter-Regional Transmission Planning

Need is compartmentalized into "reliability," "market efficiency," "public policy," and "multi-value" projects within most regional planning processes.

Projects Considered in MISO-PJM Planning:
(as Ordered by FERC)

Project Type in RTO-1 / Project Type in RTO-2	Reliability	Market Efficiency	Public Policy	Multi-Value
Reliability	Yes	no	no	no
Market Efficiency	no	Yes	no	no
Public Policy	no	no	Yes	no
Multi Value	no	no	no	no

Creates additional barriers at the interregional level by limiting projects to be of the same type in both regions

Eliminates many projects from consideration

Recommendations for State and Federal Policy Makers

Policy makers, including industry regulators, play a key role in influencing the scope of regional and interregional transmission planning efforts. We therefore recommend that they encourage planners to:

- Consider the full range of transmission-related benefits
- Better document and understand the high risks and high costs of an insufficiently robust and flexible grid
- Move from compartmentalizing projects into “reliability,” “economic,” and “public policy” projects to considering the multiple values provided by all transmission investments
- Improve interregional planning processes to avoid least-common-denominator approaches and consider the multiple but different values that projects can provide to individual regions

Additional Reading / About Brattle

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 2014, forthcoming April 23, 2014 at www.wiresgroup.com

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://www.wiresgroup.com/res_benefits_of_transmission.html

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

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

The Brattle Group **provides consulting and expert testimony in economics, finance, and regulation to corporations, law firms, and governmental agencies around the world**

WIRES

DRIVERS OF TRANSMISSION INVESTMENT:

Thinking of Transmission as a Technology Partner

Presented by:

Julia Frayer
London Economics International –
Transmission and Other Resources and Technologies
(Distributed Generation, Demand Response, Energy Efficiency & Storage)

WIRES - a national coalition of entities dedicated to investment in a strong, well-planned and environmentally beneficial electricity high voltage transmission system in the US.

London Economics International LLC

Drivers of Transmission Investment: *Thinking of Transmission as a Technology Partner*

Prepared for WIRES University by London Economics International LLC

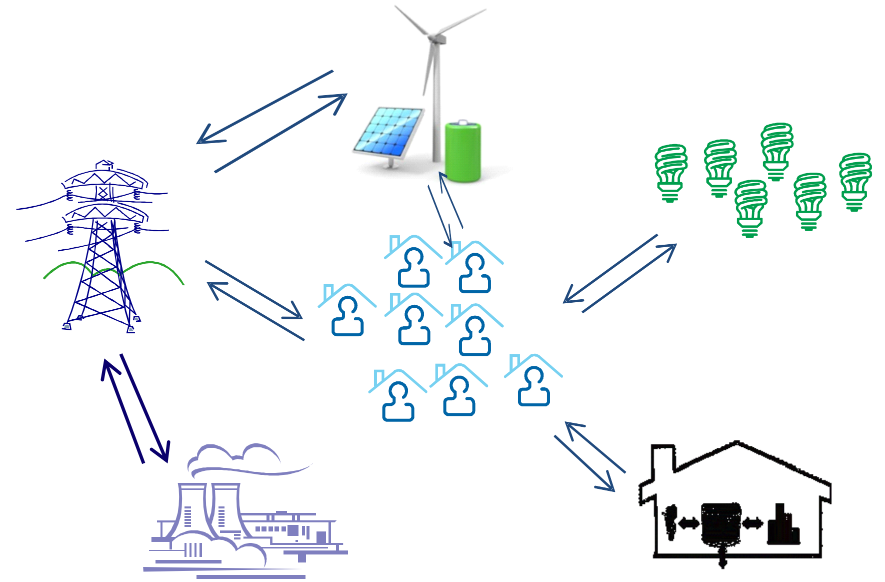
Julia Frayer, Managing Director
April 21, 2015
Washington, DC

LONDON ECONOMICS

The electric power system is an integrated machine: reliable service at the lowest cost requires that we maintain and invest in both generation and wires infrastructure

- **Transmission and market resource alternatives (generation and other non-transmission components) together create the functional ability for consumers to have electricity on demand**
  - transmission depends on generation being available and operating and consumers' demanding electricity service
  - Likewise, generation is useful only if there is a transmission system that connects the generator to customers (load)

Today's Electricity System



Modern energy network is a bi-direction communication between users vs. resources AND between resources themselves

- **Transmission and generation are in fact components of a single system -- consumers receive reliable electricity service specifically as a result of the co-existence of generation and transmission**

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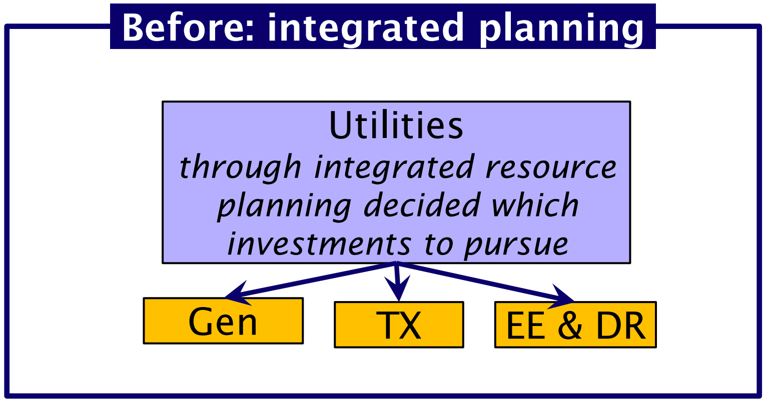
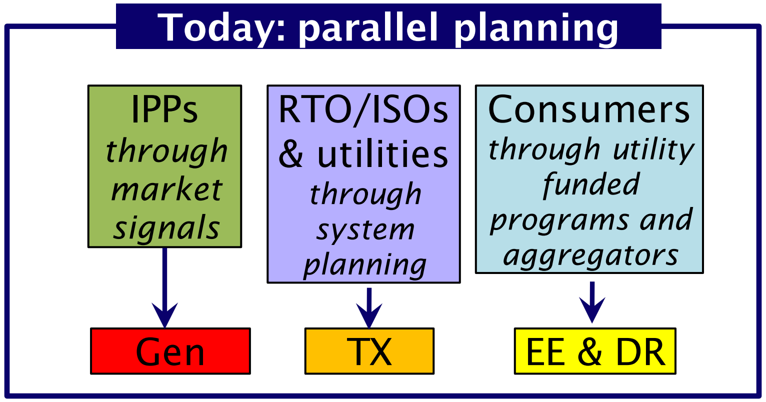
Deregulation changed the investment decision points within the system planning process





- **A common misnomer: transmission can be substituted for through generation investment or more demand side management or energy efficiency**
  - Some transmission can be deferred by some MRAs – but not all transmission
  - Even if we were to have high levels of distributed generation and energy efficiency, we would need the "integrated system" un order to provide electricity on demand
- **A common observation: often, we see transmission investment spurring new generation investment, and new generation opportunities serving as catalysts for more transmission investment**
  - Many times, such interdependencies are observed in the technical planning stages but never evaluated or fully recognized in the evaluation stage
  - Economic techniques within system planning need to move beyond conventional frameworks of analysis in order to help identify and leverage such inter-dependencies

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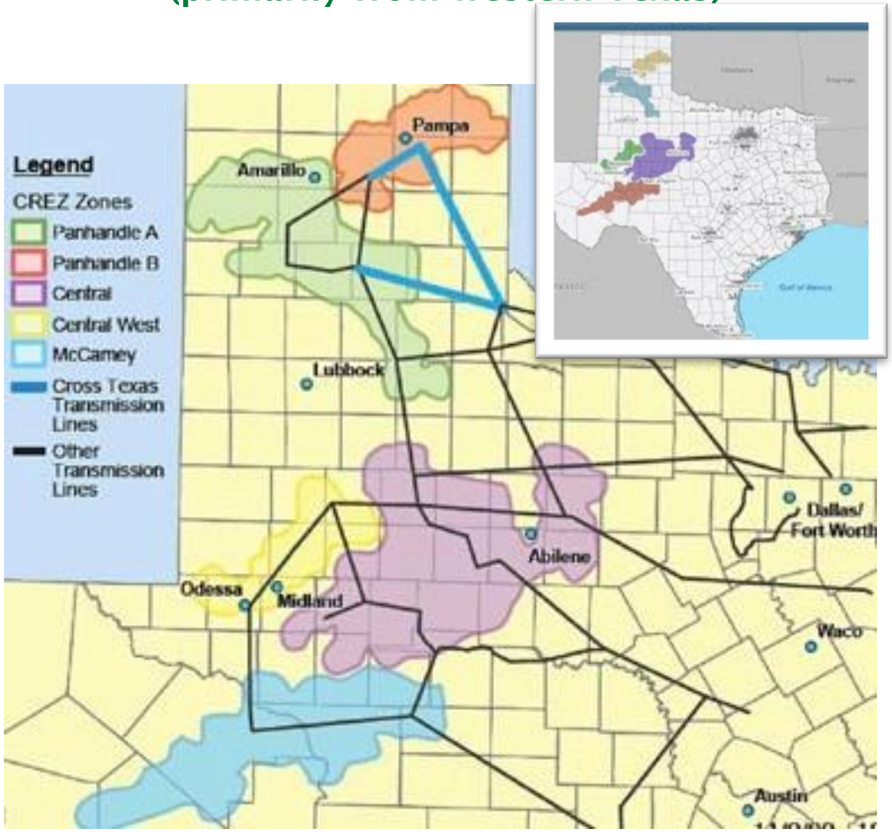
In the US, we have multiple, real-world examples of new transmission leading to new generation investment

Tehachapi Renewable Transmission Project

Tehachapi is an example of a transmission investment serving as a complement to, and in fact a catalyst for, new generation

Competitive Renewable Energy Zones

With CREZ, the construction of new transmission lines was designed to bring over 18,000 MW (nameplate) of wind generation to market (primarily from Western Texas)



Transmission may create positive externalities – if quantified they may suggest that even more transmission investments may have been appropriate

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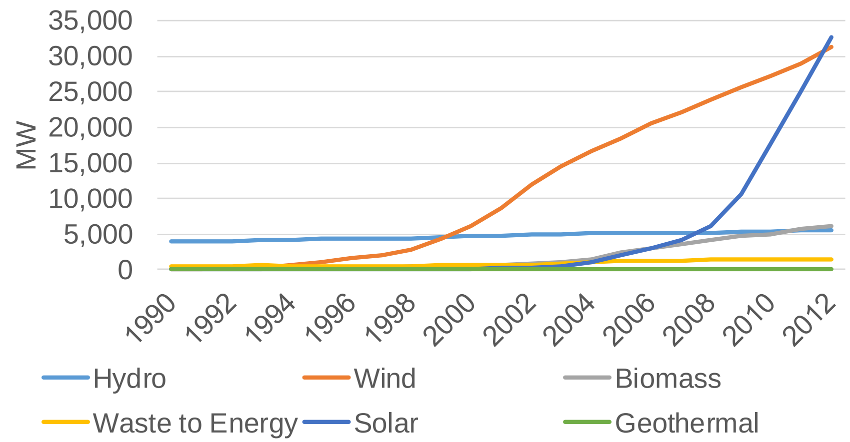
Even in markets where distributed generation has grown to high penetration levels, transmission investment is continuing

- **Rapid growth of renewable based power generation was fueled by Germany's ambitious renewables energy policies**
  - Wind generation build out came first in the late 1990s but solar DG growth has been dramatic since 2010
- **As of 2014, Germany had 35 GW of solar capacity and forecast to reach 52 GW in the future (total generating capacity for the system is ~190 GW)**
- **But solar is not enough… Germany has aggressive offshore wind goals**
  - complements solar based on season and time of day production profiles
  - German system plan to interconnected 12.9 GW by 2020
- **Recent studies by the German network regulator ("BNetzA") show that the German grid is under increasing strain, as growing amounts of power have to be transported over long distances**

Germany: renewable capacity, 1990-2012 (MW)



Source: Bundesministerium fuer Wirtschaft und Energie

European Network of Transmission System Operators for Electricity ("ENTSO-E") is responsible for developing a 10 yr. network plan:

- 100 transmission projects of pan-European significance identified - resolve bottlenecks associated with renewable resources is key
- total investment costs amount to €104 billion
- €23 billion of total for subsea cables
- €30 billion of total is expected to be spent on investments in Germany

Adding smart grid does not necessarily eliminate the need for the "transmission grid" - In fact, smart grid works better if the transmission connections are reinforced

Smart Meters and Home Energy Management Systems

- Smart meters provide the Smart Grid interface between you and your energy provider
- A home EMS allows tracking of energy use. For instance, the home owner can see the energy impact of various appliances and electronic products – and thereof consider sensibly evaluate reductions in use

Smart Appliances

- Smart appliances are able to respond to signals from your energy provider to avoid peak period use during high priced times of the day
- A type of smart "appliance" is the plug-in electric vehicle

Power Generation

- Rooftop solar electric systems and small wind turbines can be deployed on site
- The Smart Grid will help to connect all these mini-power generating systems to the grid, and provide the data infrastructure to balance the consumption and supply of on-site generation

A smart home: science fiction or tomorrow?

Source: https://www.smartgrid.gov/the_smart_grid/smart_home

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Transmission and market resource alternatives can be compared using four basic dimensions of service: what, when, where, and how?

		Transmission	Energy Efficiency	Demand Response	Utility-scale Generation	Distributed Generation	Energy Storage	Smart Grid - Distribution
What	Energy	●	◑	◑	●	◕	●	●
	Capacity	●	◑	◑	●	◑	◕	○
	Ancillary Services	●	○	◑	●	◕	●	◑
	Reduce system losses	●	◑	◑	○	◔	◔	◔
When	Long lifespan	●	◕	○	◕	●	●	●
	Continuous basis	●	◕	○	◑	○	●	●
Where	Regional	●	◑	◑	●	◔	◔	○
	Local	●	●	●	●	●	●	●
	Micro	●	●	●	○	●	●	●
How	System/Wholesale	●	○	○	●	○	●	○
	Customer/Retail	○	●	●	○	●	○	●
	TOTAL	●	◑	◔	◕	◑	◕	◑

LONDON ECONOMICS

LEI compiled six precepts related to investment analysis of transmission and market resource alternatives

Precept 1: A feasible MRA should be judged on the same criteria for reliability and economic benefits as proposed transmission

Precept 2: In order to fairly compare feasible investment options, the evaluation framework must assess a broad set of benefits and costs

Precept 3: The ability of MRAs to consistently meet the technical (reliability) needs of the system are sometimes overlooked for the sake of policy – technical feasibility should be a requirement, not an option

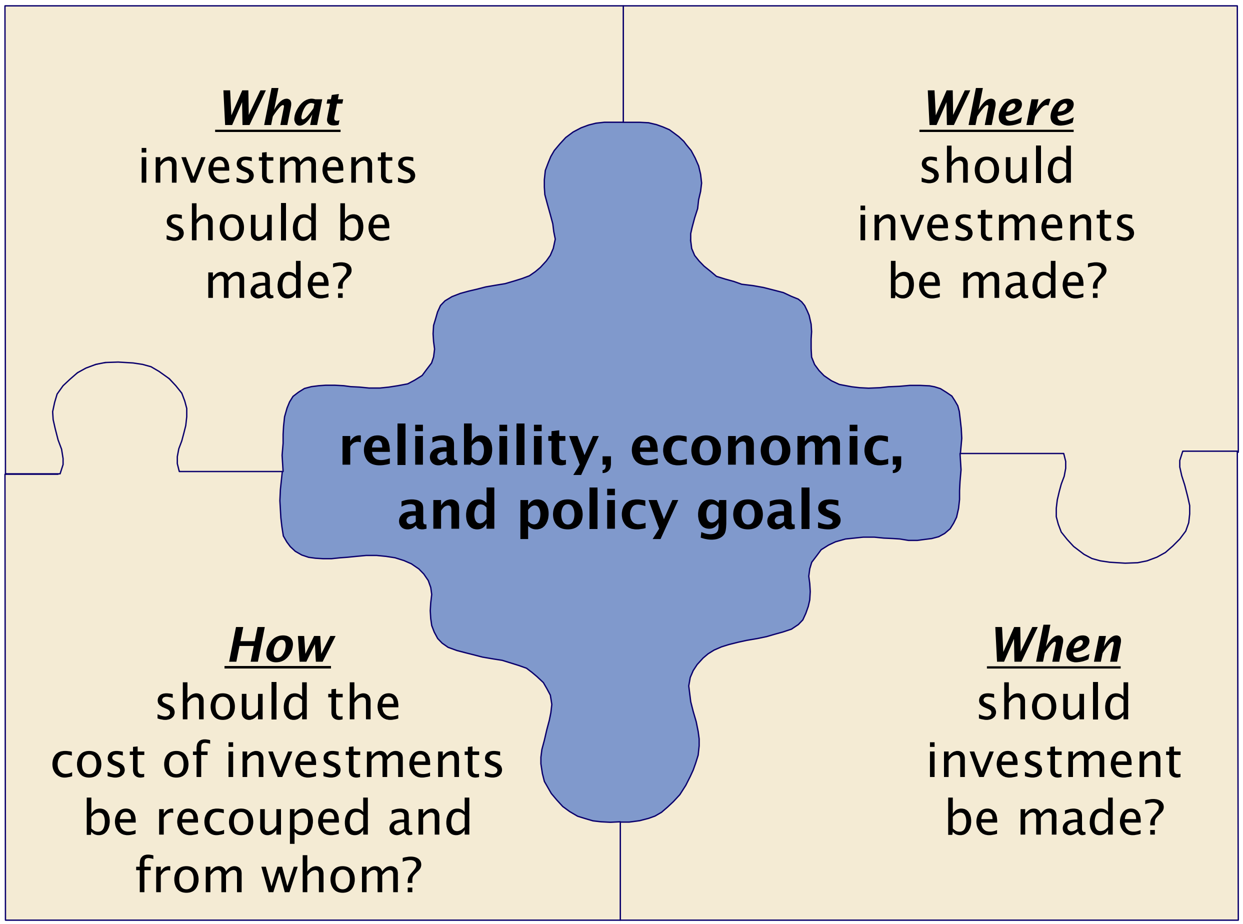
Precept 4: MRAs and transmission are not equals in the services and benefits they provide – a more comprehensive (inclusive) analysis of various benefits should be undertaken in order to optimize planning decisions

Precept 5: Economic cost-benefit analysis should consider the dynamic evolution of the system, consistent with rational expectations. Such an analysis may show potential for complementarity between transmission and certain MRAs, which would justify the need for more investment

Precept 6: A robust cost-benefit analysis should measure and quantify these uncertainties and risks - insurance value may be quite significant

LE LONDON ECONOMICS

Transmission, as an integral part of the power system, is an enabler of economic activity and many of our leisure activities - it deserves effective planning



- **Costs and benefits analyzed under a common framework – in dollar terms – including quantification positive externalities (benefits to others) and negative externalities (costs to others)**
- **Forward-looking analysis is robust and internally consistent – impacts of investments "endogenous"**
- **Uncertainty dealt with – identified & measured**
- **Complementarities recognized between different investment options and technologies**

Honorable Martin Heinrich
United States Senator (NM)
Member
Energy & Natural Resources Committee

WIRES - a national coalition of entities dedicated to investment in a strong, well-planned and environmentally beneficial electricity high voltage transmission system in the US.

Honorable Jerry McNerney
United States Representative (CA)
Member
House Committee on Energy & Commerce
Co-Founder
Grid Innovation Caucus

WIRES - a national coalition of entities dedicated to investment in a strong, well-planned and environmentally beneficial electricity high voltage transmission system in the US.

CYBER SECURITY CHALLENGES / PHYSICAL THREATS

Presented by:

Hon. Caitlin Durkovich
Assistant Secretary
Infrastructure Protection
Department of Homeland Security

WIRES - a national coalition of entities dedicated to investment in a strong, well-planned and environmentally beneficial electricity high voltage transmission system in the US.

CYBER SECURITY CHALLENGES / PHYSICAL THREATS

Presented by:

Joe Doetzl
Chief Information Security Officer
& Head of Cyber Security for Enterprise Software
ABB

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Joe Doetzl: April 21, 2015

Cyber Security of the Electric Grid

Generation
Making the Product

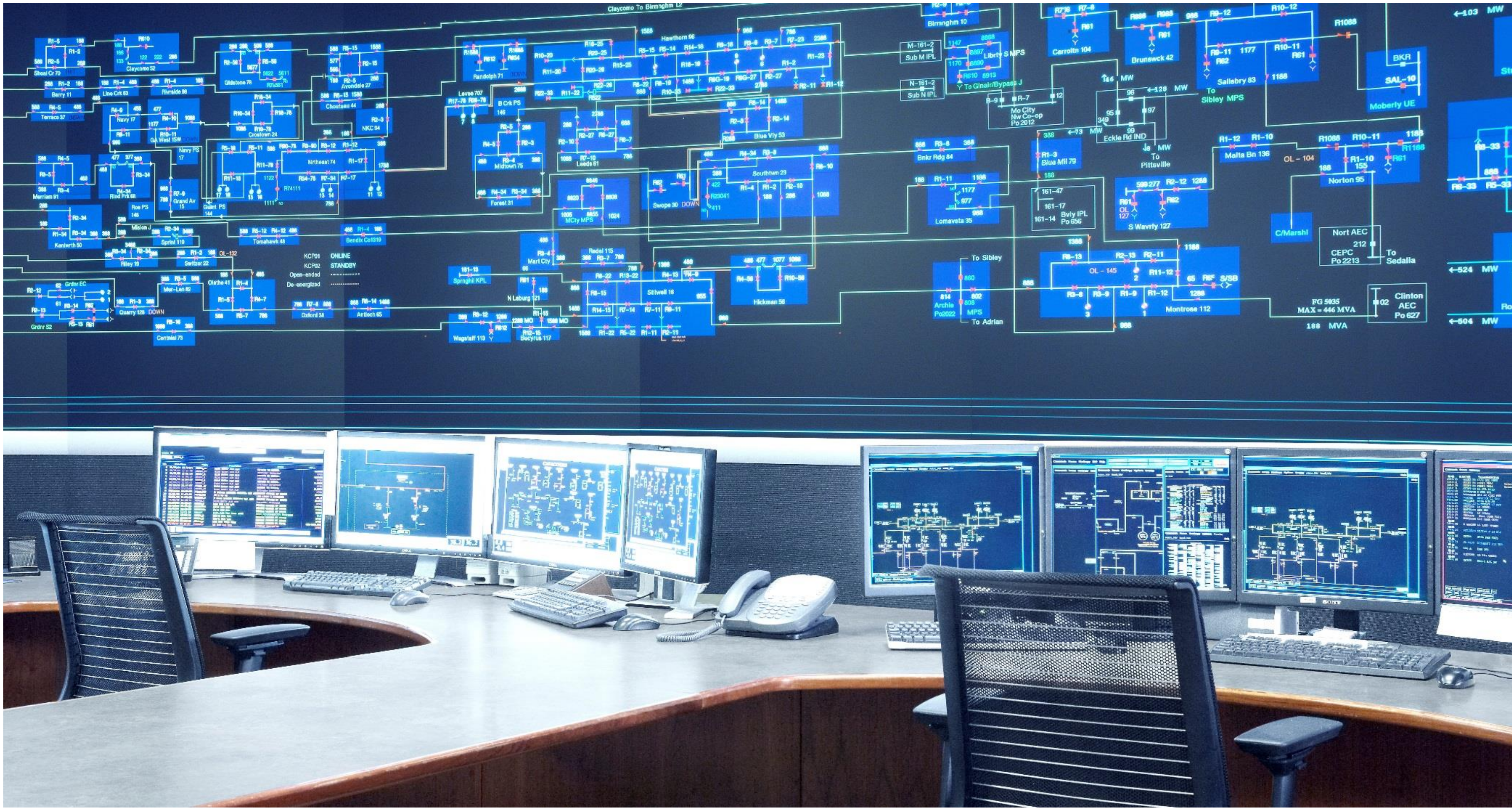
Generation
Typically Large and Remote

Transmission
Getting it from source to customer (Load)

ABB

Transmission
Substation

Control Center
Making it all happen in “Real Time”



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Power and productivity
for a better world™

WIRES

TRANSMISSION INFRASTRUCTURE & EPA'S CLEAN POWER PLAN

Presented by:

Steven Fine
Vice President
ICF International

WIRES - a national coalition of entities dedicated to investment in a strong, well-planned and environmentally beneficial electricity high voltage transmission system in the US.

Transmission Infrastructure and EPA's Proposed Clean Power Plan

WIRES University
The Survey Course

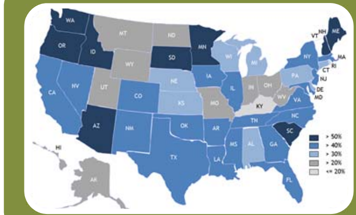
April 21, 2015

Steve Fine
ICF International

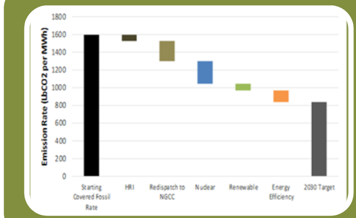
EPA’s Clean Power Plan - The Bottom Line

- The CPP is not just another air regulation — it has the potential to rearrange the US power map
- EPA’s reduction requirements for states differ widely
- State policy design matters – and is yet to be determined
- CPP-driven retirements and changes in generating resource patterns can alter transmission flows and impact transmission security and overall system reliability
- Transmission will play a large role in enabling the system to adjust large swings in underlying generation

Clean Power Plan Essential Information



Proposed CPP regulates existing units through state-level CO_2 emission rate standards.

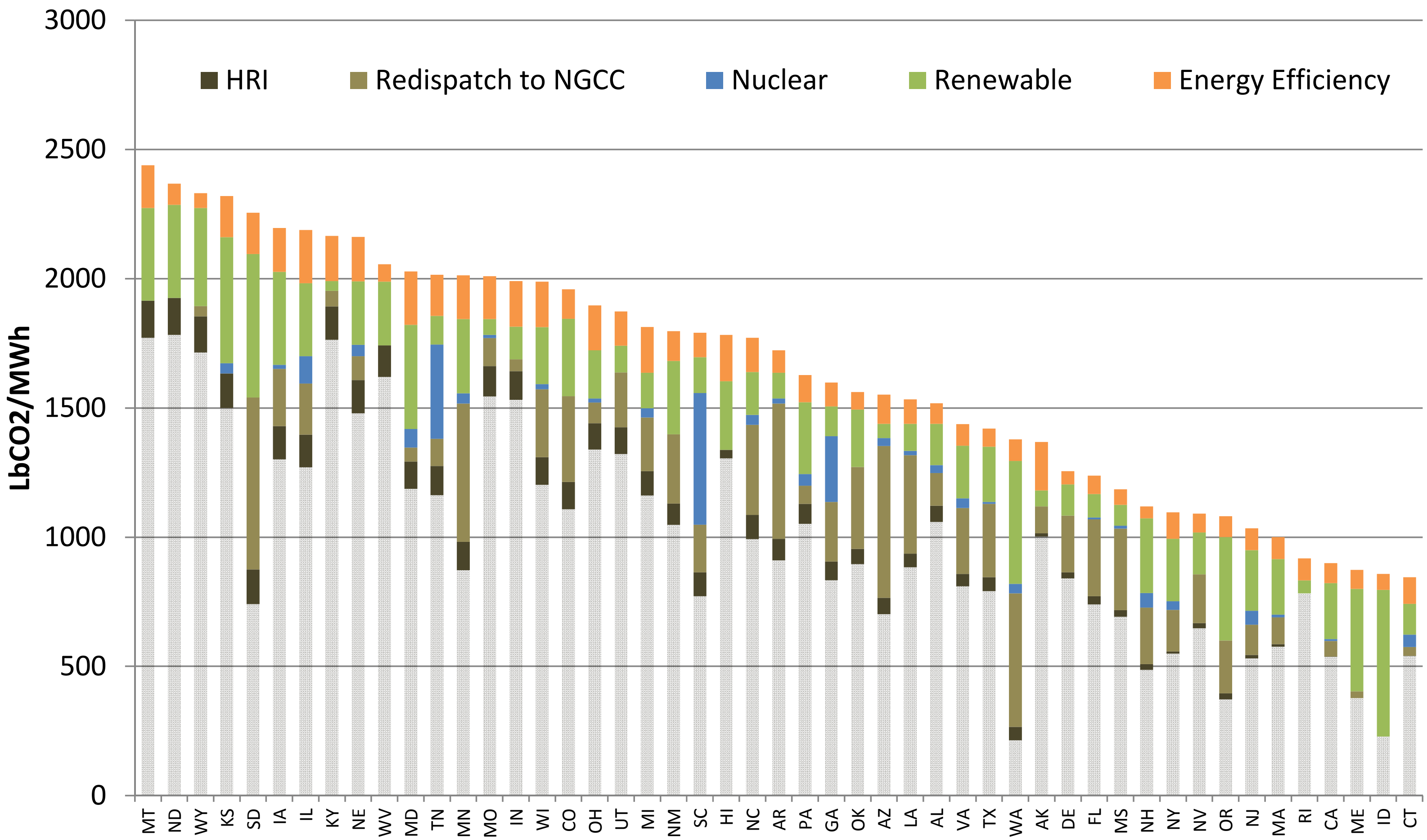


EPA modeled four building blocks of compliance for each state, including system re-dispatch from coal to natural gas and increased renewable generation, both of which would directly affect transmission flows.

Each state can determine its own compliance plan. To the extent that states rely on these building blocks to comply, the recent trend of coal retirements will likely continue or accelerate.

The final rule is expected this summer. Initial state plans are due in 2016, with final plans due for states acting alone in 2017 and for states in multi-state compliance groups in 2018. The glide path for emissions reductions could begin as early as 2020.

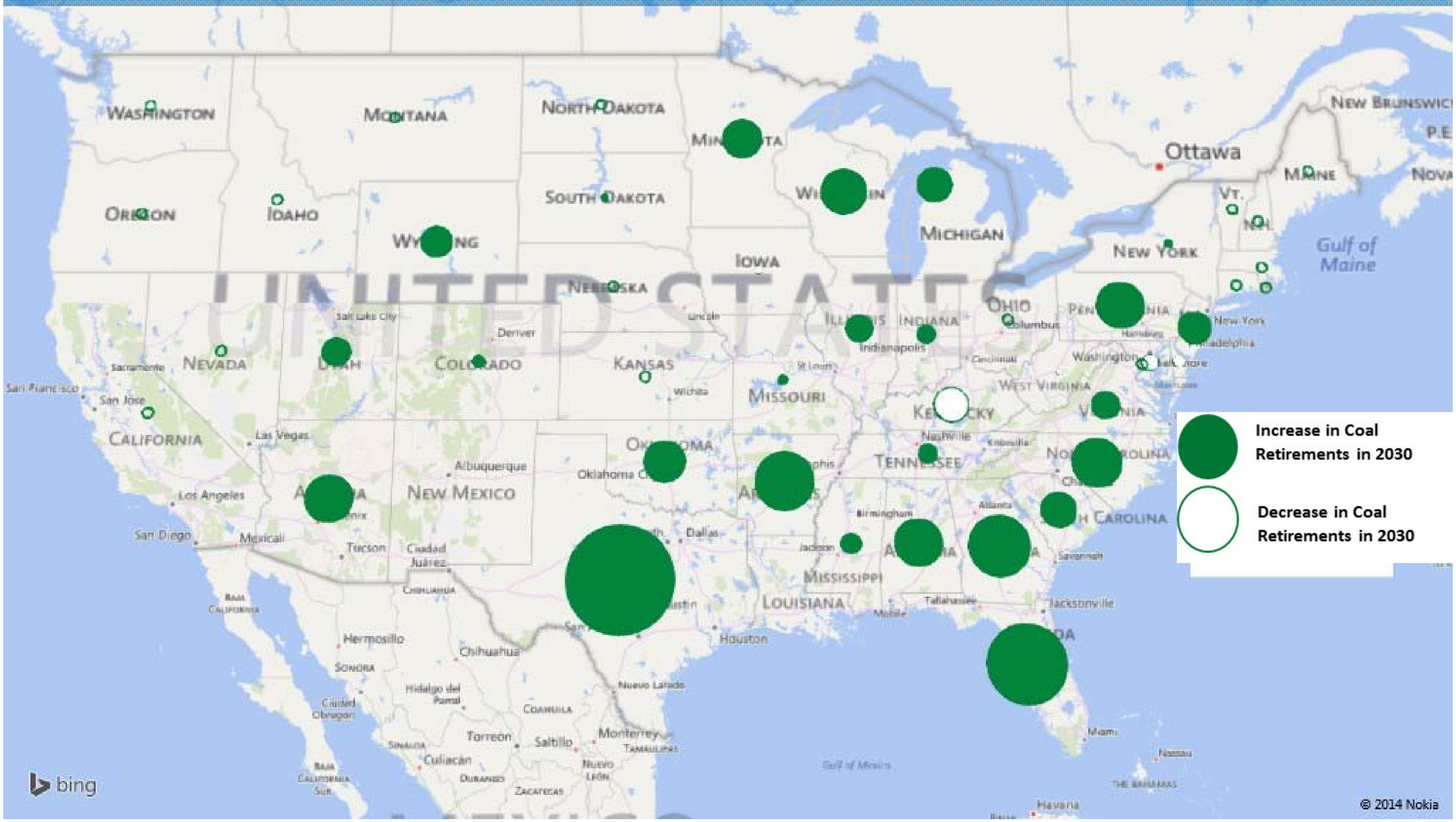
Building Block Contributions Vary by State



CPP Proposal Effects: More Coal Retirements

Change in coal retirements, EPA Base Case to Option 1 State Case

Size of bubbles in the map indicate higher or lower levels of increase or decrease

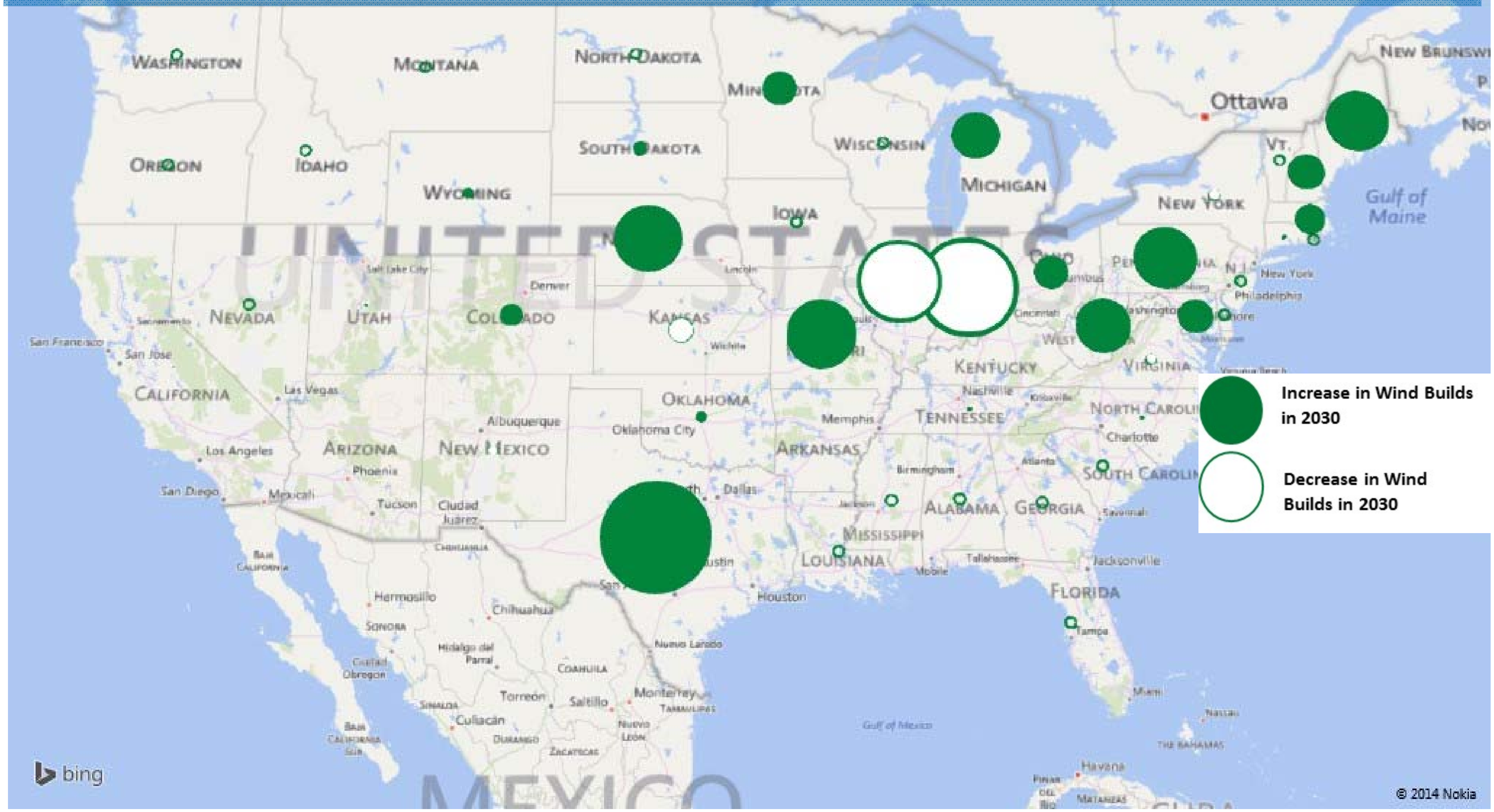


Source: EPA Regulatory Impact Analysis, “Option 1 – State” Case available at
http://www.epa.gov/airmarkets/programs/ipm/cleanpowerplan.html

Likely CPP Effects: Renewables Almost Double

Change in wind additions, EPA Base Case to Option 1 State Case

Size of bubbles in the map indicate higher or lower levels of increase or decrease

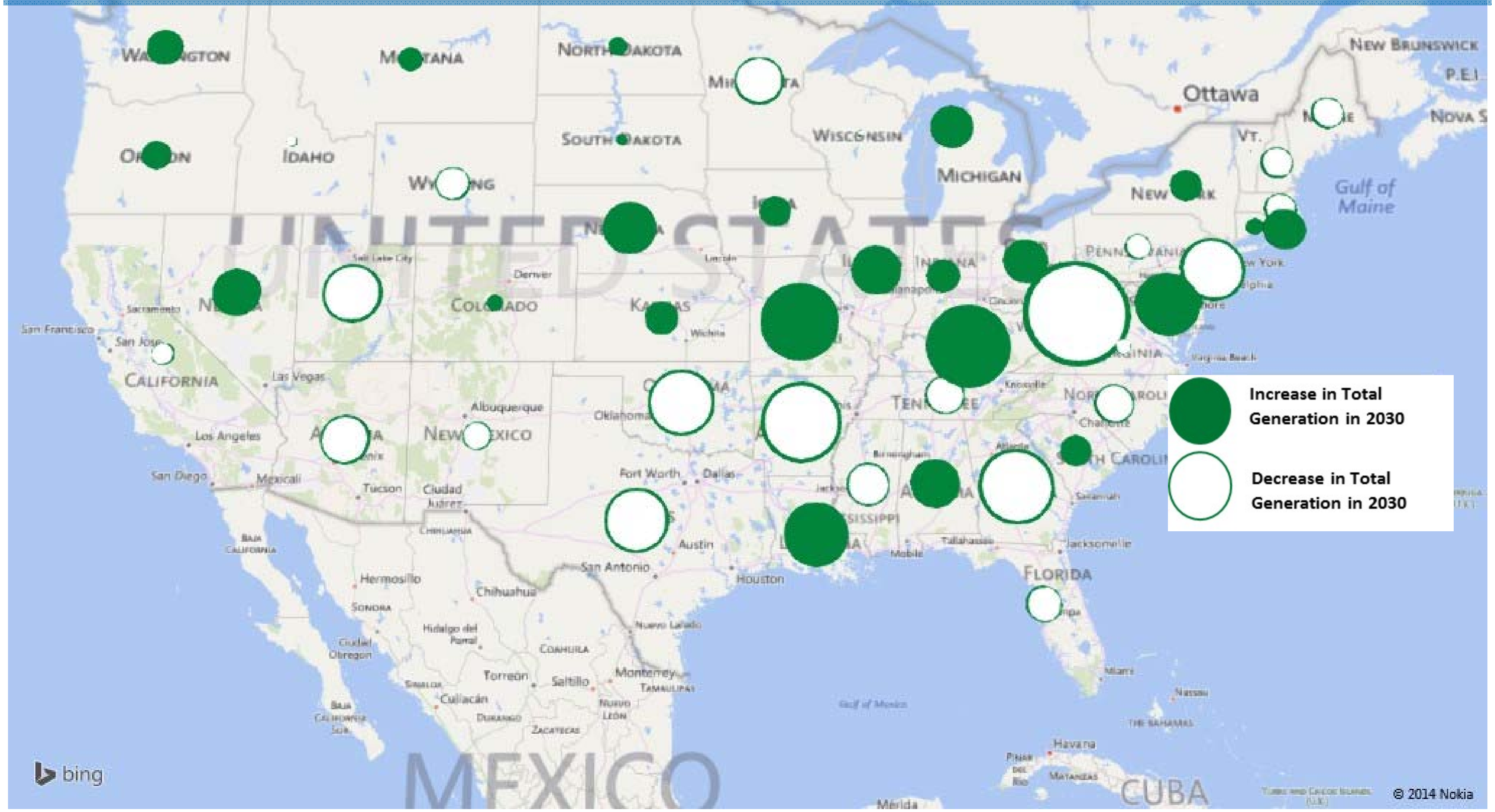


Source: EPA Regulatory Impact Analysis, “Option 1 – State” Case available at
http://www.epa.gov/airmarkets/programs/ipm/cleanpowerplan.html

Likely CPP Effects: Imports Increase In Certain Areas

Change in total generation, EPA Base Case to Option 1 State Case

Size of bubbles in the map indicate higher or lower levels of increase or decrease

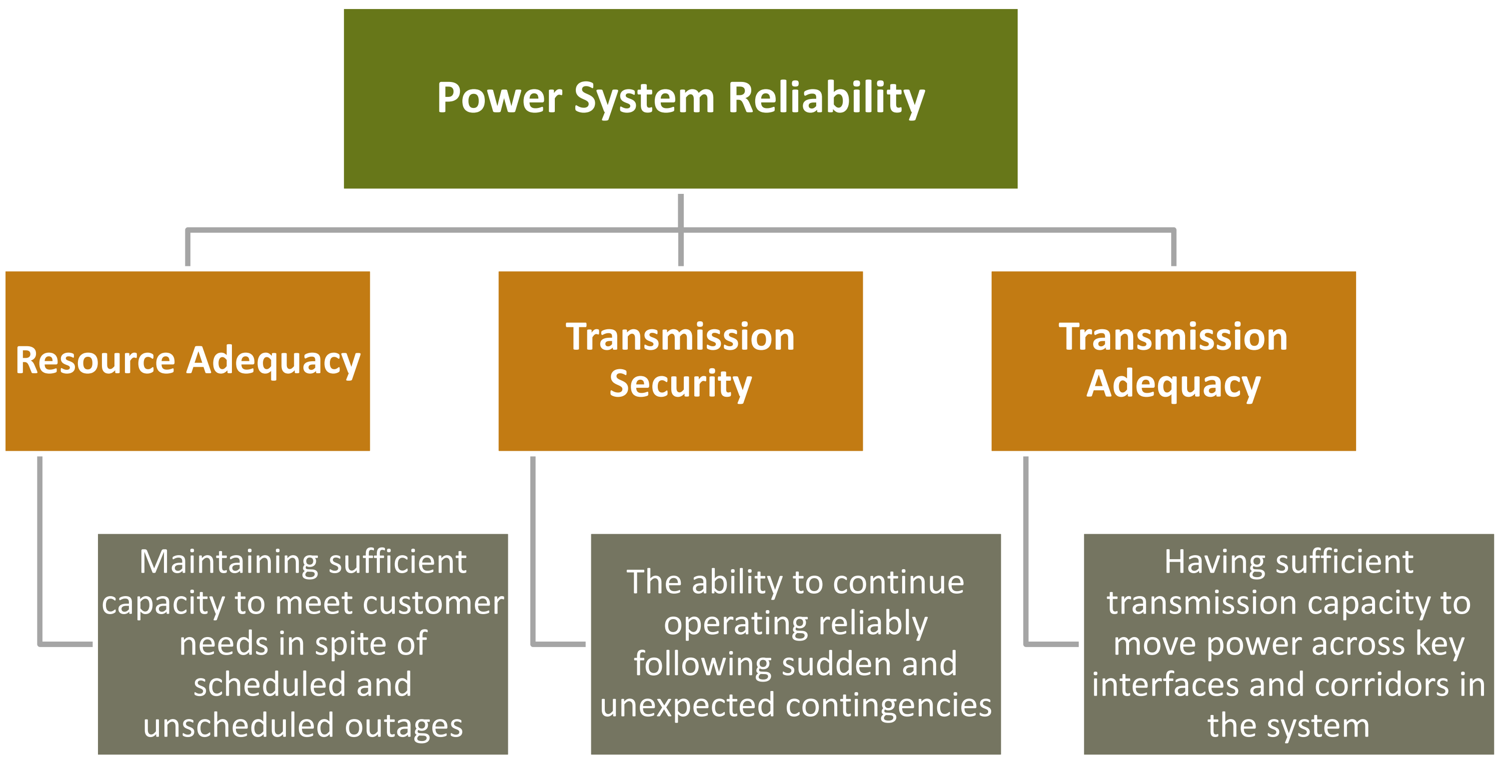


Source: EPA Regulatory Impact Analysis, “Option 1 – State” Case available at
http://www.epa.gov/airmarkets/programs/ipm/cleanpowerplan.html

What Could These Changes Mean for Reliability?

And more specifically, <u>transmission security</u>

- Significant retirements and changes in generating resource mix, locations and dispatch can cause changes in transmission flow patterns /substation voltages.



System Operators Have Expressed Some Concerns on Potential CPP-Driven Transmission Challenges

Examples from ISO/RTO published or filed comments based on their own studies or views

ERCOT

"…[CPP] could result in transmission reliability issues due to the loss of generation resources in and around major urban centers…will likely require significant upgrades to the transmission infrastructure."

SPP

"…the SPP region will experience numerous thermal overloads and low voltage occurrences…even with generation capacity added to replace the assumed EGU retirements, additional transmission infrastructure will be needed to maintain reliable operation of the grid…assessment revealed 38 overloaded elements that SPP would be required to mitigate with transmission planning solutions."

WECC

"The expected reduction in traditional base-load resources will impact essential reliability services (e.g., voltage and frequency support, system inertia)."

Transmission will serve as means of compliance for Clean Power Plan

- Variety of potential state programs and compliance options will lead to changes in capacity mixes, dispatch, and flows
- Uncertainty around the impacts and potential needs that result as EPA finalizes the rule, courts consider legal challenges, and states develop programs
- Transmission is an integral part of the answer as the resource mix changes

WIRES

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ICF INTERNATIONAL

WIRES

TRANSMISSION INFRASTRUCTURE & EPA'S CLEAN POWER PLAN

Presented by:

Carl Monroe
Executive Vice President & Chief Operating Officer
Southwest Power Pool

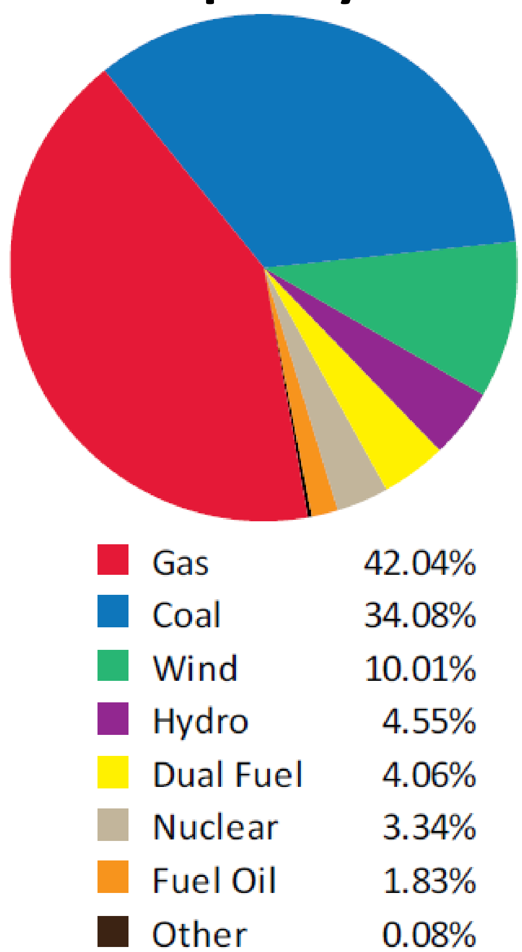
WIRES - a national coalition of entities dedicated to investment in a strong, well-planned and environmentally beneficial electricity high voltage transmission system in the US.

Helping our members work together to keep the lights on... today and in the future

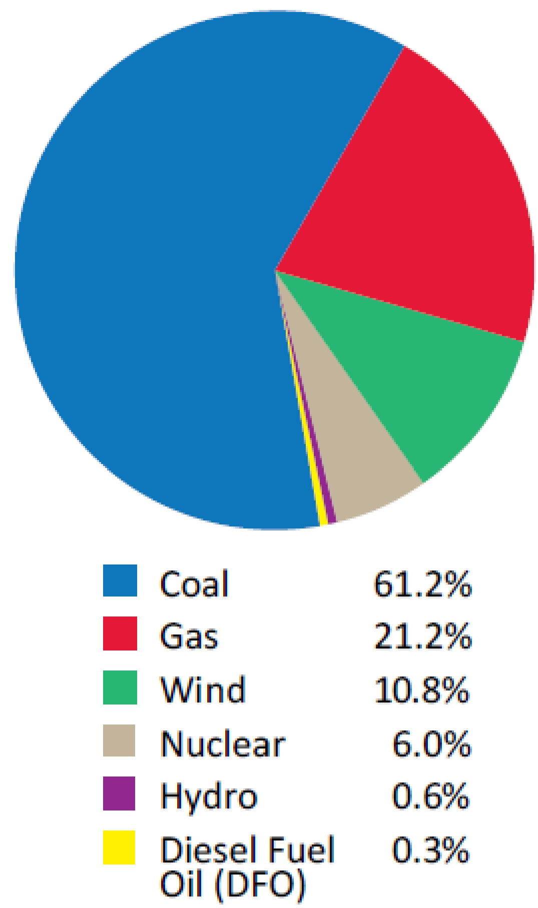
SPP Southwest Power Pool

2013 Energy Capacity and Consumption

Capacity

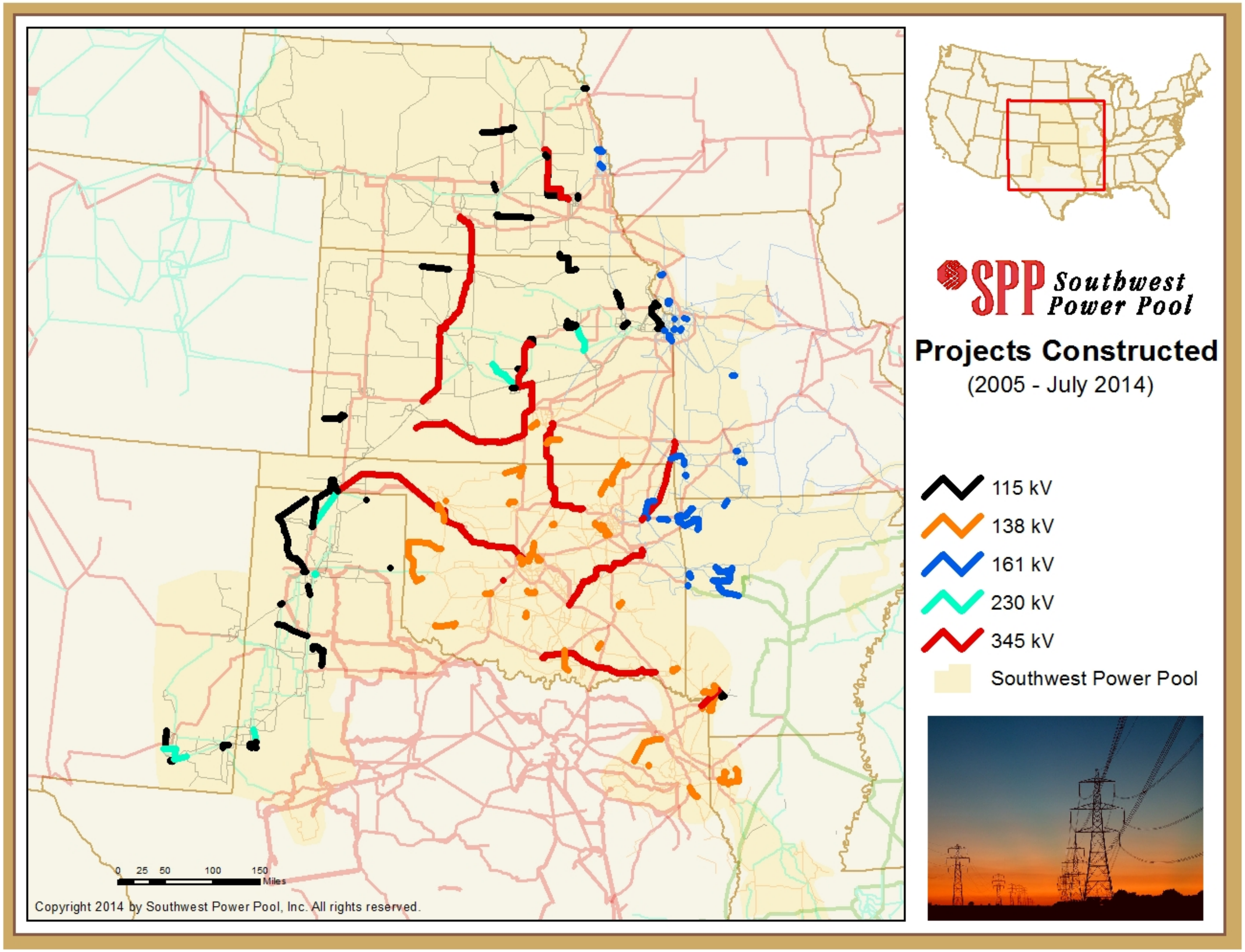


Consumption

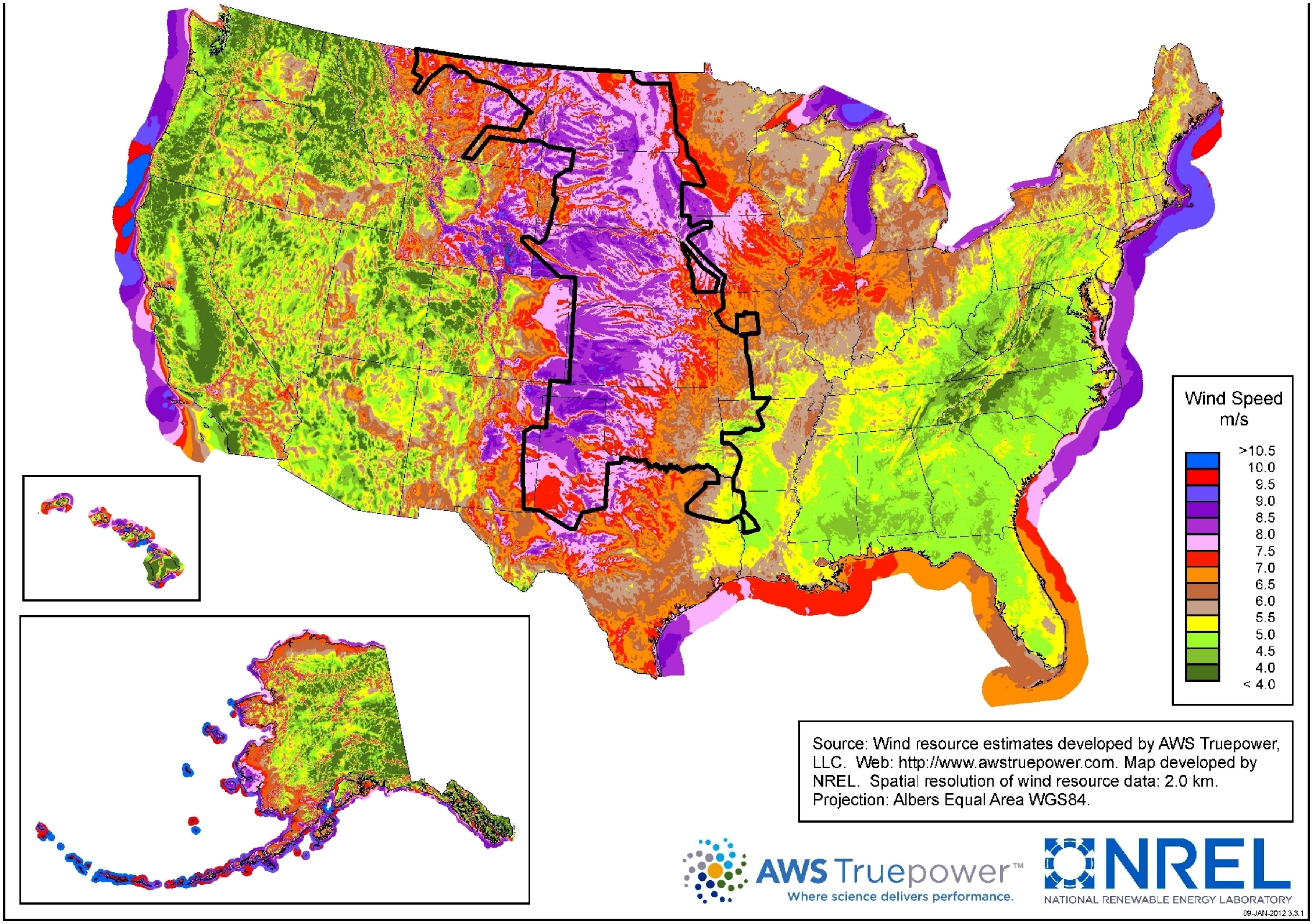


12% annual planning capacity requirement

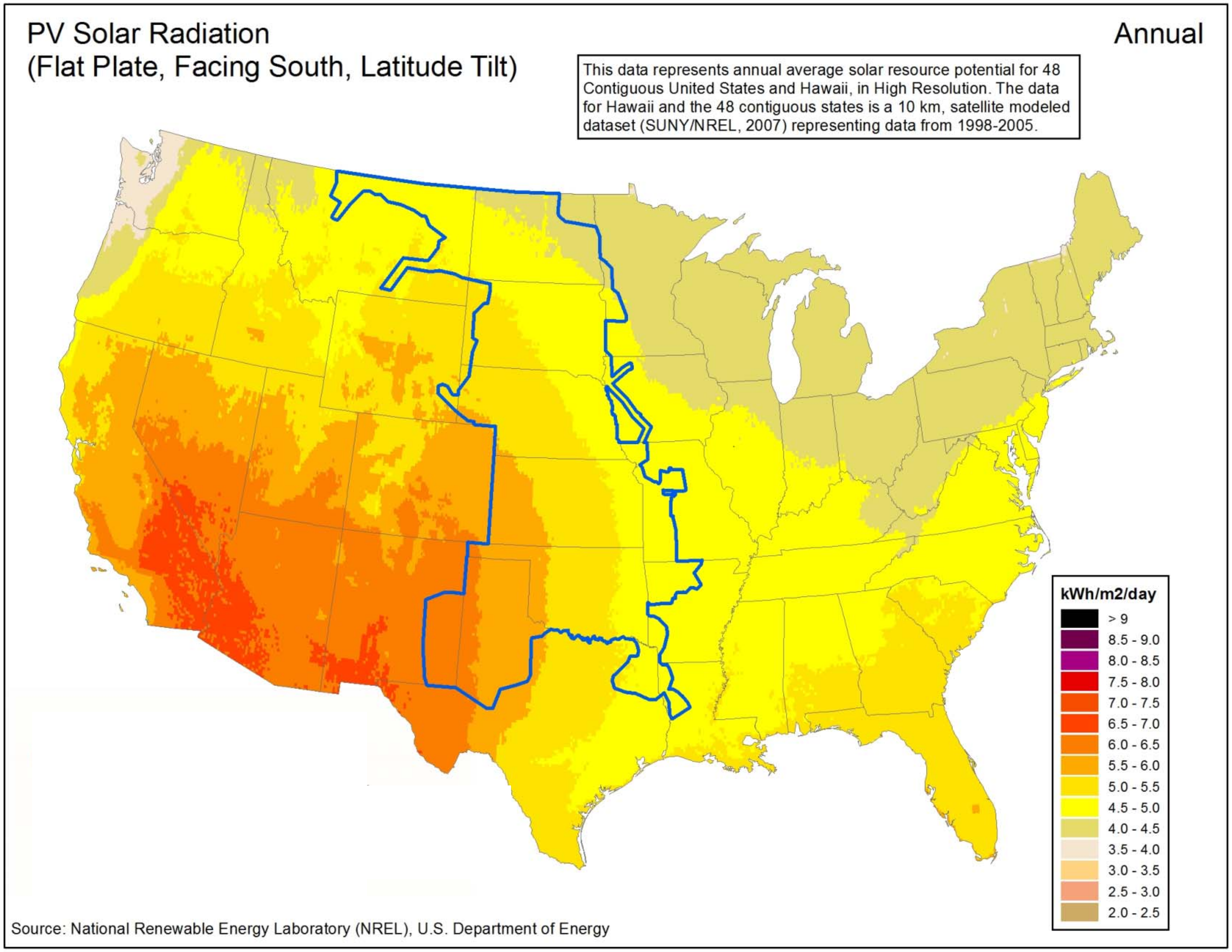
Projects Constructed 2005-2014



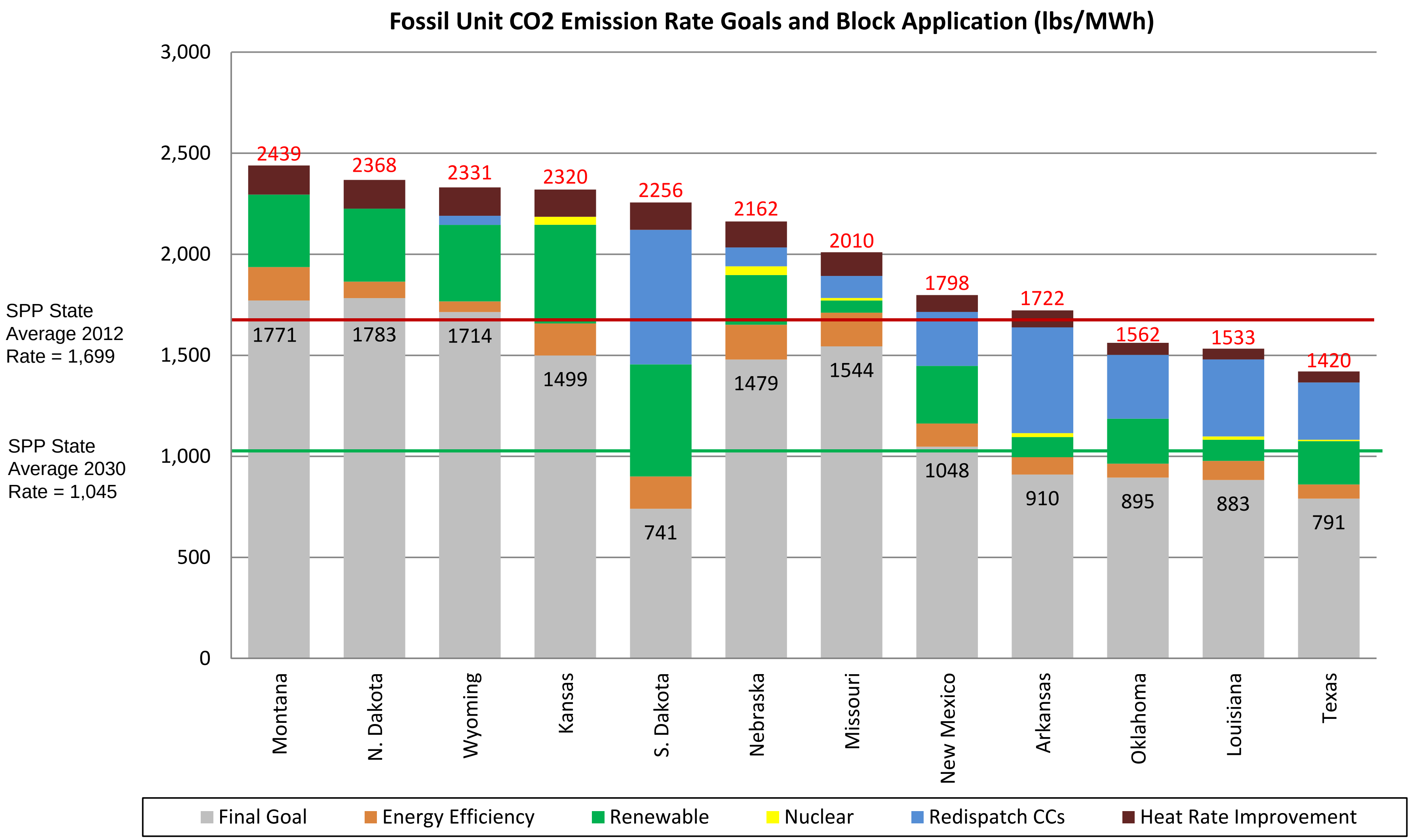
Annual Average Wind Speed - 80 meters



Solar in the U.S.

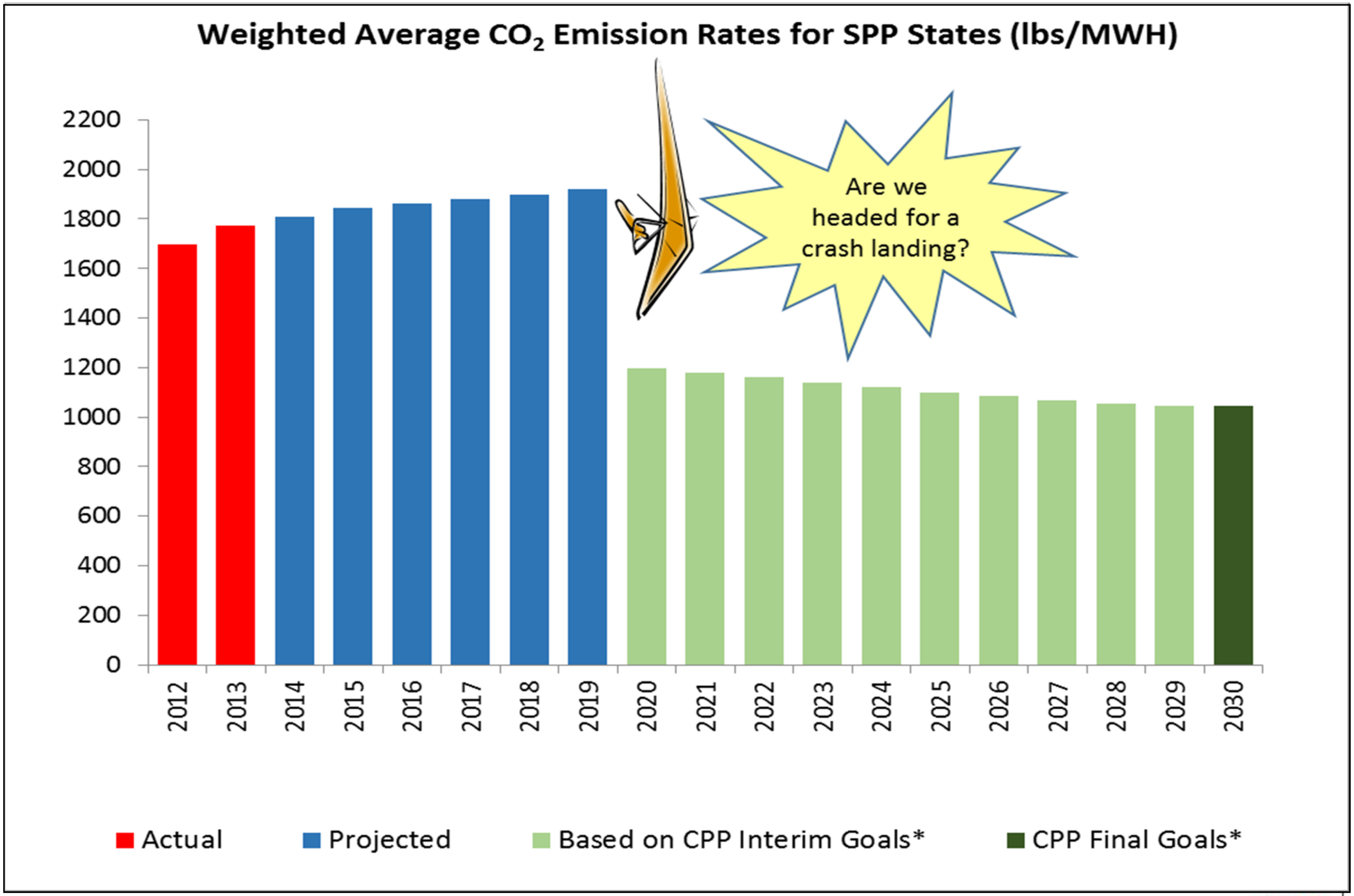


EPA's 2030 Goals for States in SPP



*Includes Future States with IS Generation in SPP (N. Dakota, S. Dakota, Montana, and Wyoming)

EPA's Proposed Glide Path



*Includes states with IS generation that will be in SPP by 2015 (N. Dakota, S. Dakota, Montana, and Wyoming)

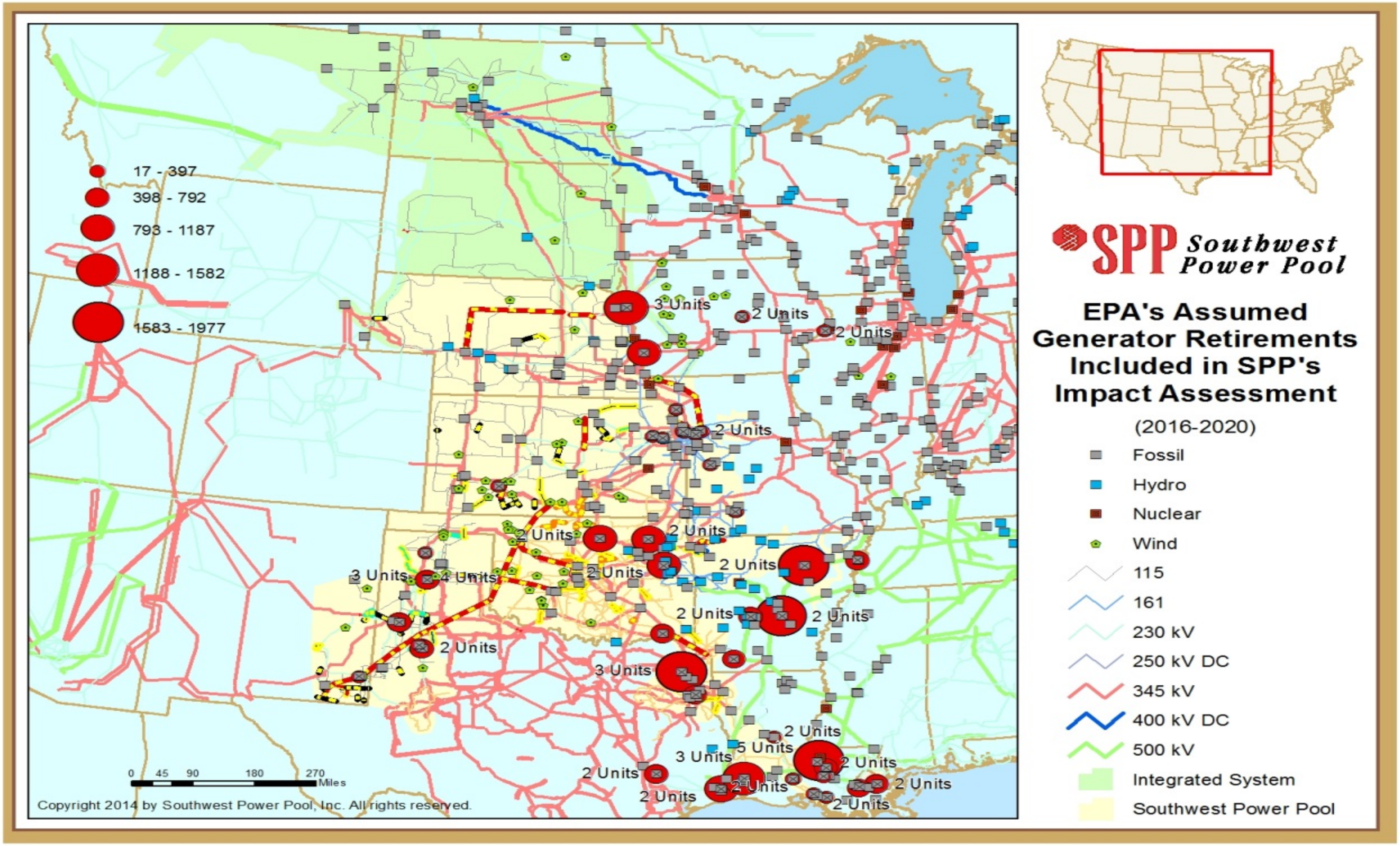
SPP's CPP Impact Assessments

- SPP performed two types of assessments
  - Transmission system impacts
  - Reserve margin impacts
- Both assessments modeled EPA's projected EGU retirements within the SPP region and surrounding areas
- Transmission system impact assessment performed in two parts
  - Part 1 assumed unused capacity from existing and currently planned generators would be used to replace retired EGUs
  - Part 2 relied upon both currently planned generation and additional new generation needed to replace retired EGUs

Transmission System Impact Assessment Results

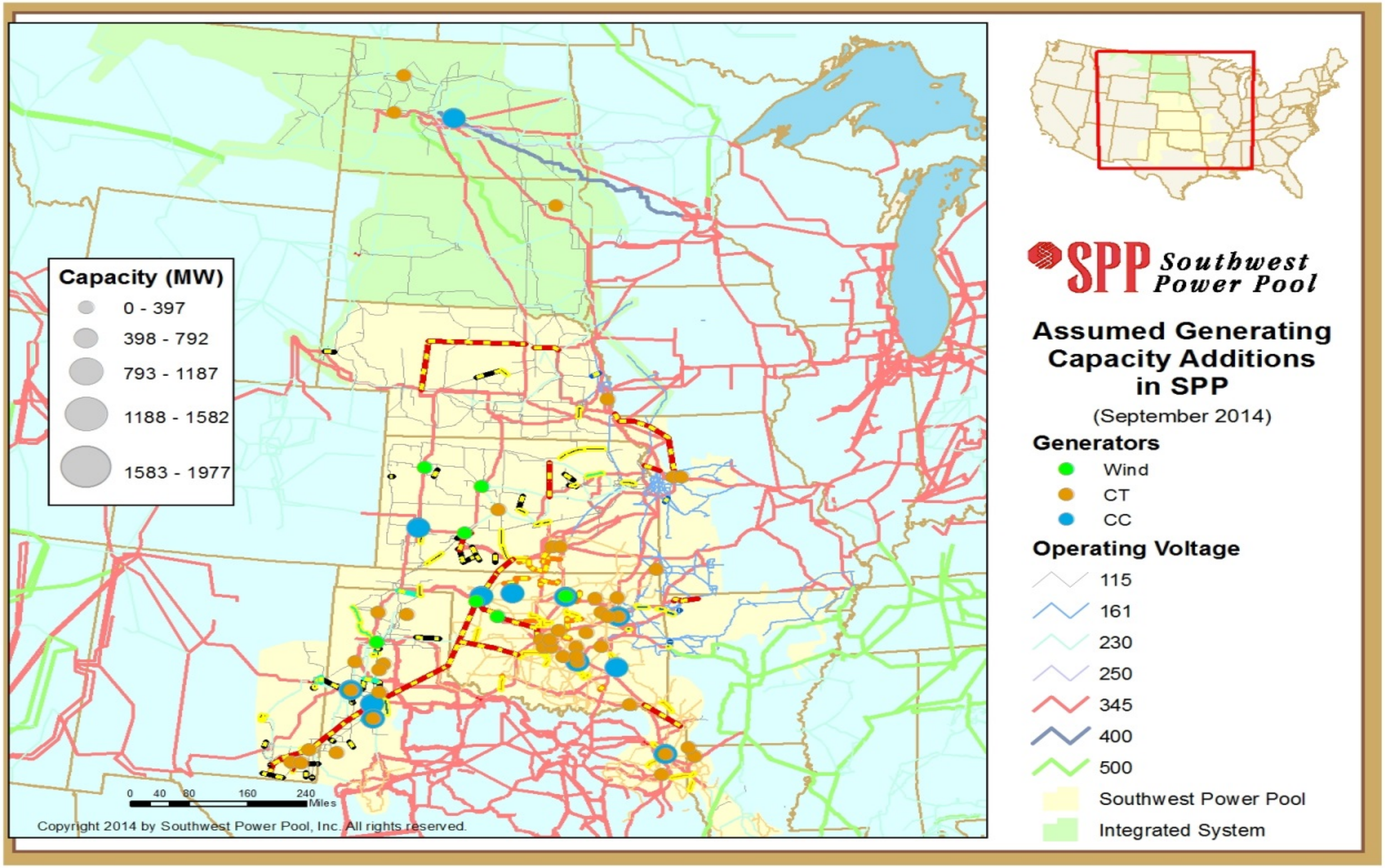
- Part 1 – "what happens if CPP compliance begins and EGU retirements occur before generation and transmission infrastructure is added"
  - Extreme reactive deficiencies of approximately 5,200 MVAR across SPP system
  - Will result in significant loss of load and violations of NERC reliability standards
- Part 2 – "what happens during CPP compliance after replacement generation capacity is added but before requisite transmission infrastructure is added"
  - Loading on 38 facilities in SPP exceeds equipment ratings
  - Some overloads so severe that cascading outages would occur
  - Would result in violations of NERC reliability standards

EPA's Projected 2016-2020 EGU Retirements

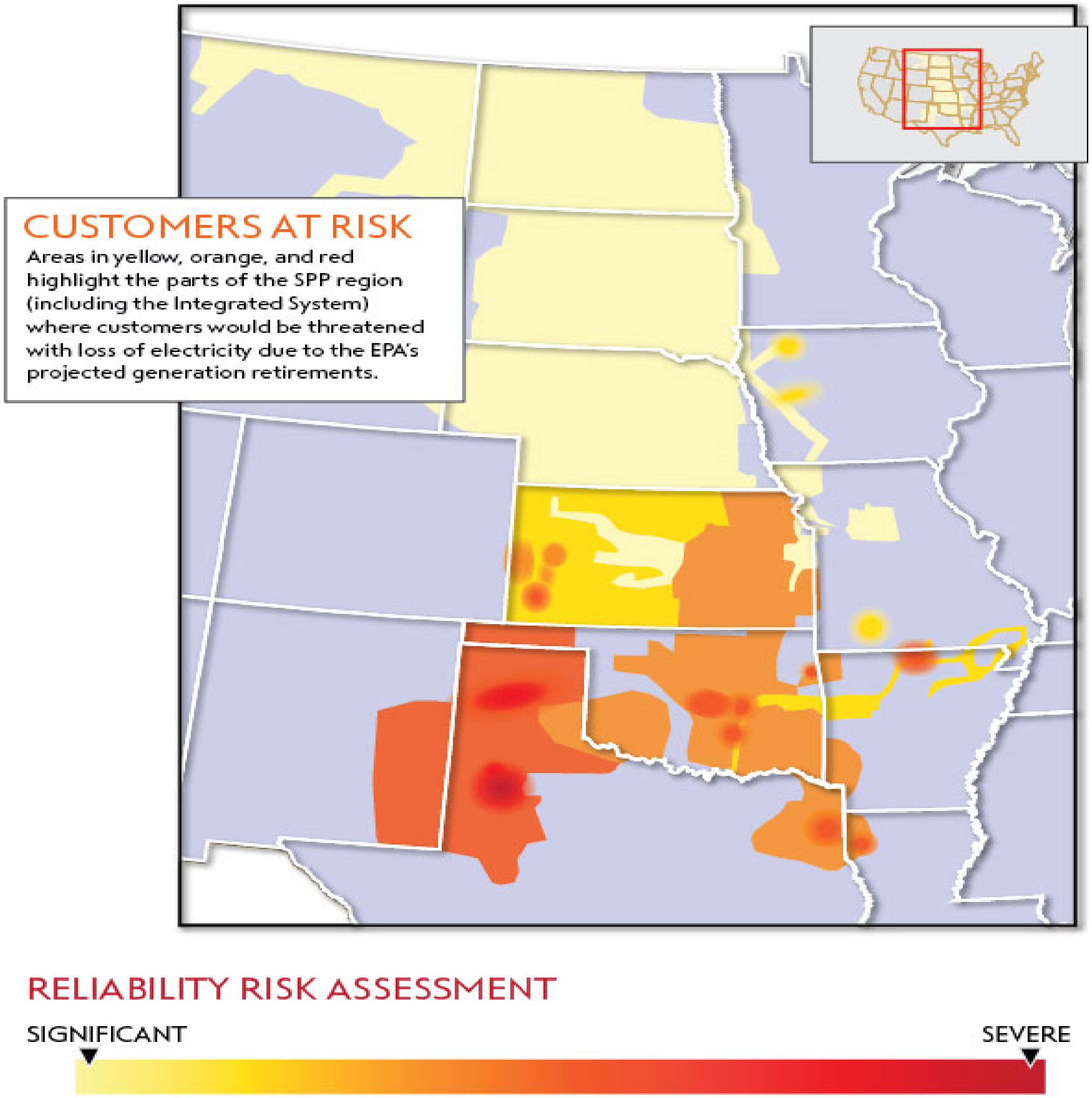


*Excludes committed retirements prior to 2016
**Extracted from EPA IPM data
***THESE RETIREMENTS ARE ASSUMED BY EPA – NOT SPP!

New Generating Capacity Added in Part 2 of SPP's TSIA

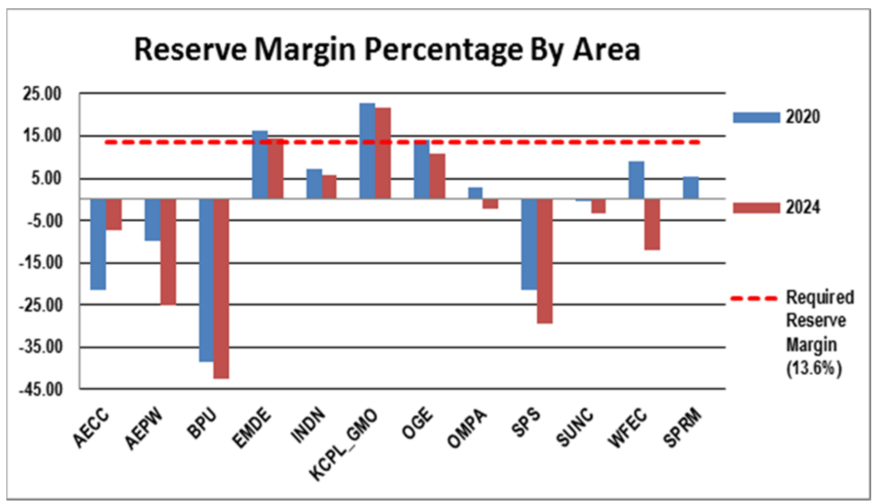


Reliability Risks Identified by TSIA



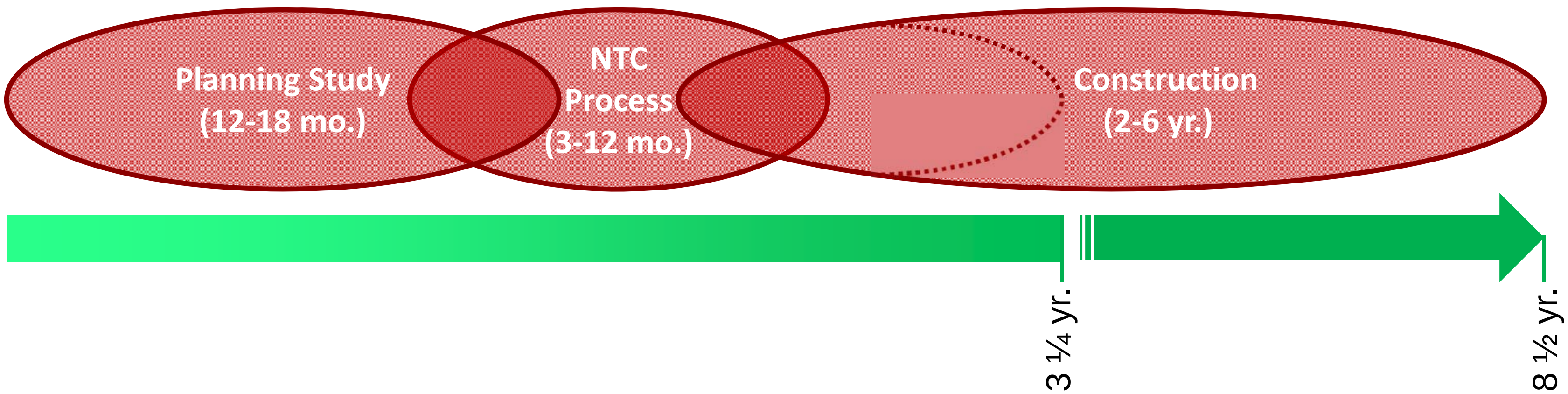
SPP Reserve Margin Assessment

- Used current load forecasts, planned generator retirements, planned new generator capacity, and EPA's assumed retirements
- SPP's minimum required reserve margin is 13.6%
- By 2020, anticipated reserve margin would be 4.7%, a capacity margin deficiency of approximately 4,600 MW
- By 2024, anticipated reserve margin would be -4.0%, a capacity margin deficiency of approximately 10,100 MW

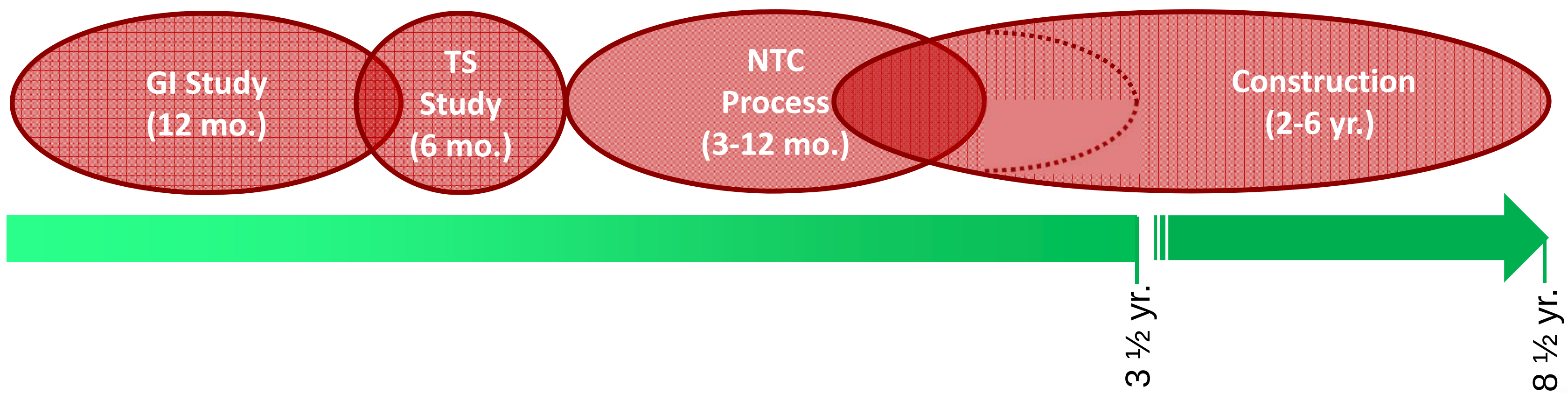


Transmission Build Cycle in SPP

Transmission Planning Process



GI and Transmission Service Process



SPP's Conclusions

- Significant new generating capacity not currently planned will be needed to replace EPA's projected retirements
  - EPA projects about 9,000 MW of retirements in the SPP region by 2020 – almost 6,000 MW more than SPP is currently expecting!
- New transmission infrastructure will be needed, both to connect new generation to grid and to deliver energy reliably
  - Currently takes up to 8.5 years to study, plan, and construct transmission in SPP
  - Up to $2.3 million per mile for 345 kV transmission construction
- More comprehensive reliability analysis is needed before final rules are adopted
- Sufficient time is needed to comply in a reliable fashion

Objectives of SPP's 2015 CPP Assessment

- Evaluate the impact of the EPA Clean Power Plan Act – Section 111(d) on existing resources and resource expansion plans to meet compliance on a regional and state level
- Model, monitor, and report on compliance final goal through....
  - The utilization of carbon pricing to drive generation towards the carbon emission goals
  - A reasonable resource plan that meets the carbon emission goals
  - Other measures
- Develop an indicative timeline of actions and activities that need to take place in order to ensure reliable compliance

SPP Southwest Power Pool

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TRANSMISSION GRID FUTURECASE: EXECUTIVE ROUNDTABLE

Honorable Phillip Moeller, Commissioner
Federal Energy Regulatory Commission

Greg Lemler
Vice President, Transmission Operations
Pacific Gas & Electric

Michael Skelly, Founder & President
Clean Line Energy Partners

Wade Smith
President and COO
American Electric Power Texas

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