National Electrical Manufacturers Association

WIRES

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February 16, 2017

Environmental and Energy Study Institute

Grid Innovation Caucus
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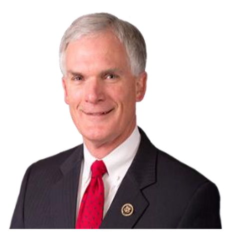


Rep. Bob Latta
(R-OH)

WIRES UNIVERSITY

Transmission 101: The Fundamentals Of High Voltage Transmission

February 16, 2017

Adriann (Andee) McCoy, Vice President, Western Region, Smart Wires

Presented by 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.

Agenda

- Basic Definitions & Components of the Grid
- Grid Operations
- 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
  - Understand some of the challenges in planning the Power System

Basic Definitions & Components of the Grid

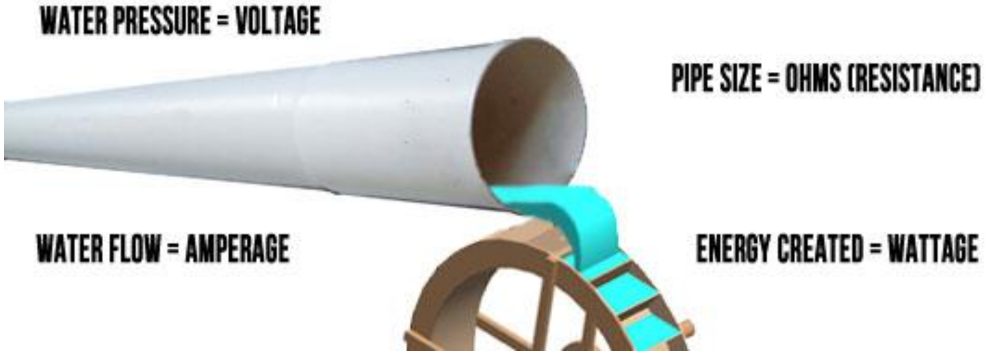
Industry Overview – Basic Definitions

"THE GRID"

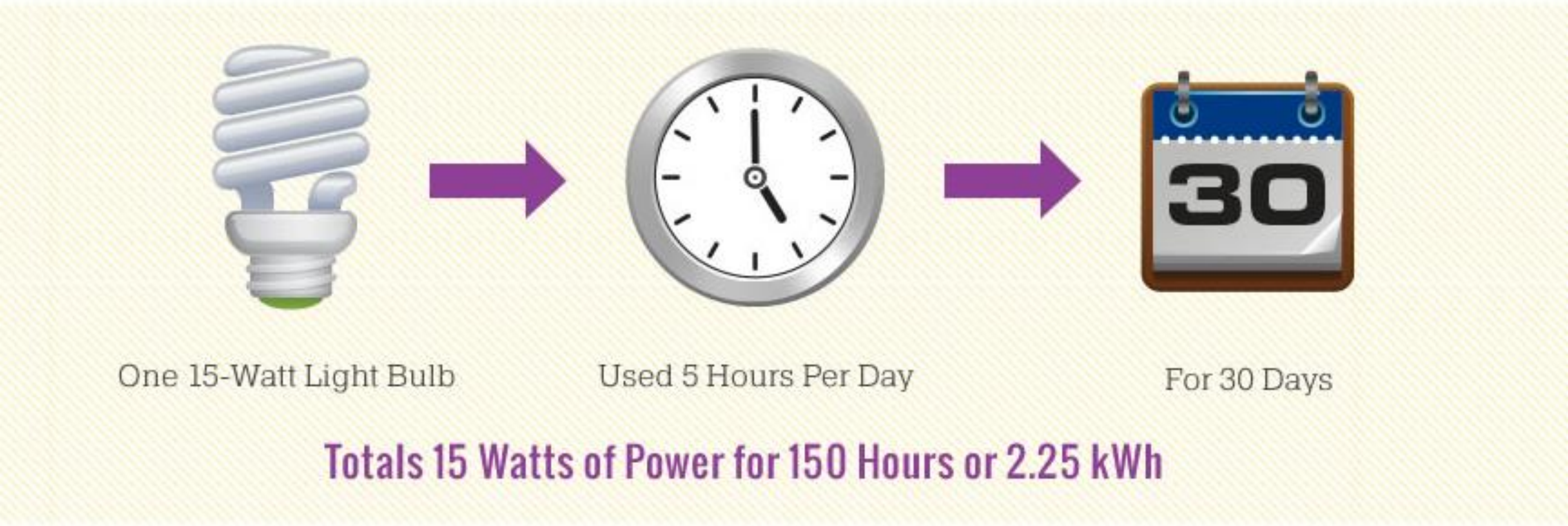
The networks that carry electricity from the plants where it is generated to consumers. This includes wires, substations, transformers, switches and more.

Industry Overview – Basic Definitions

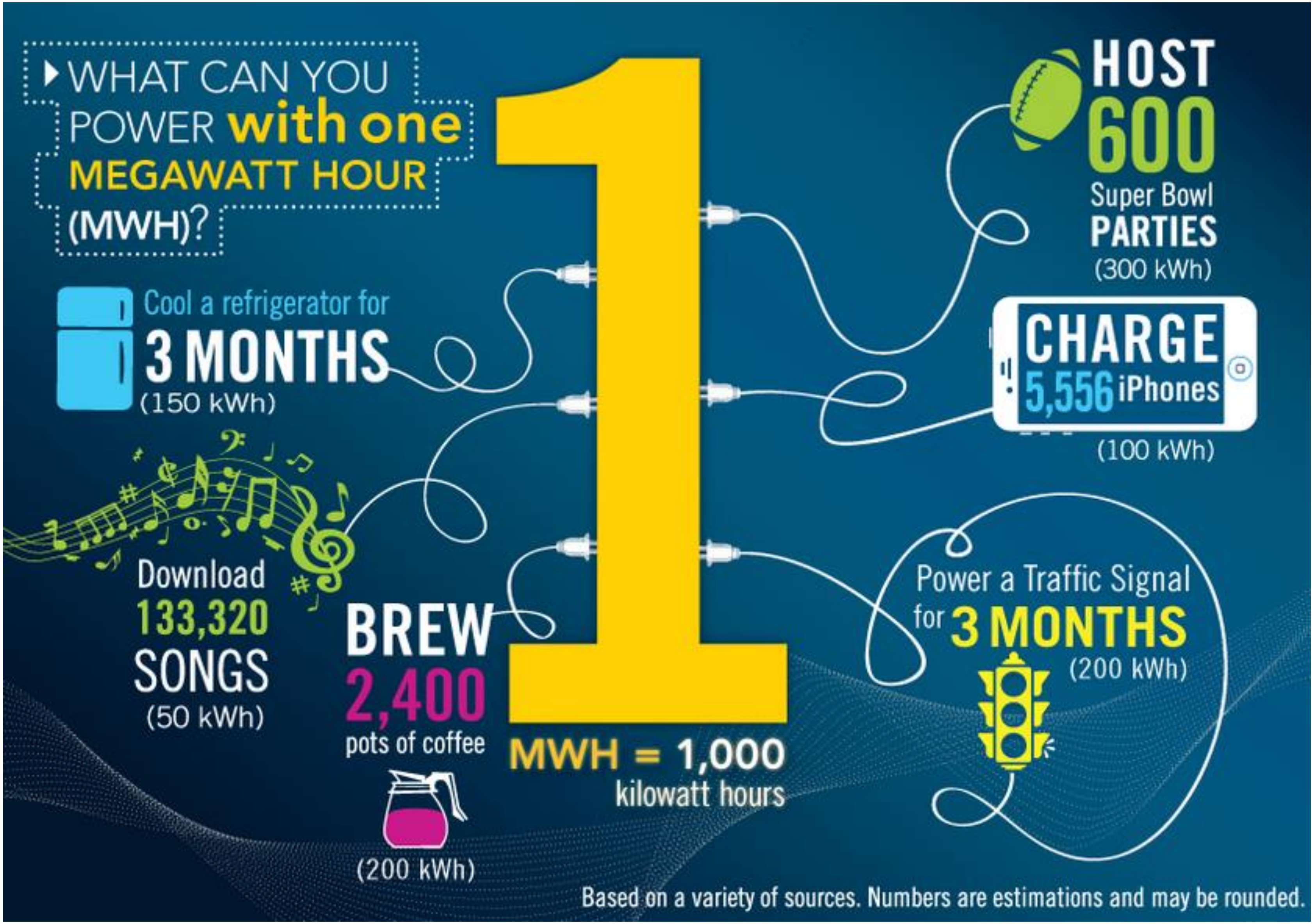
- **Voltage** – electrical "pressure" measured in volts. For power systems we typically measure in 1000's of volts or kilovolts (kv)
- **Current** – the movement of charge (electrons) through a conductor. Measured in Amperes (A)
- **Power** – Rate at which electricity is transferred. Measured in Watts 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).



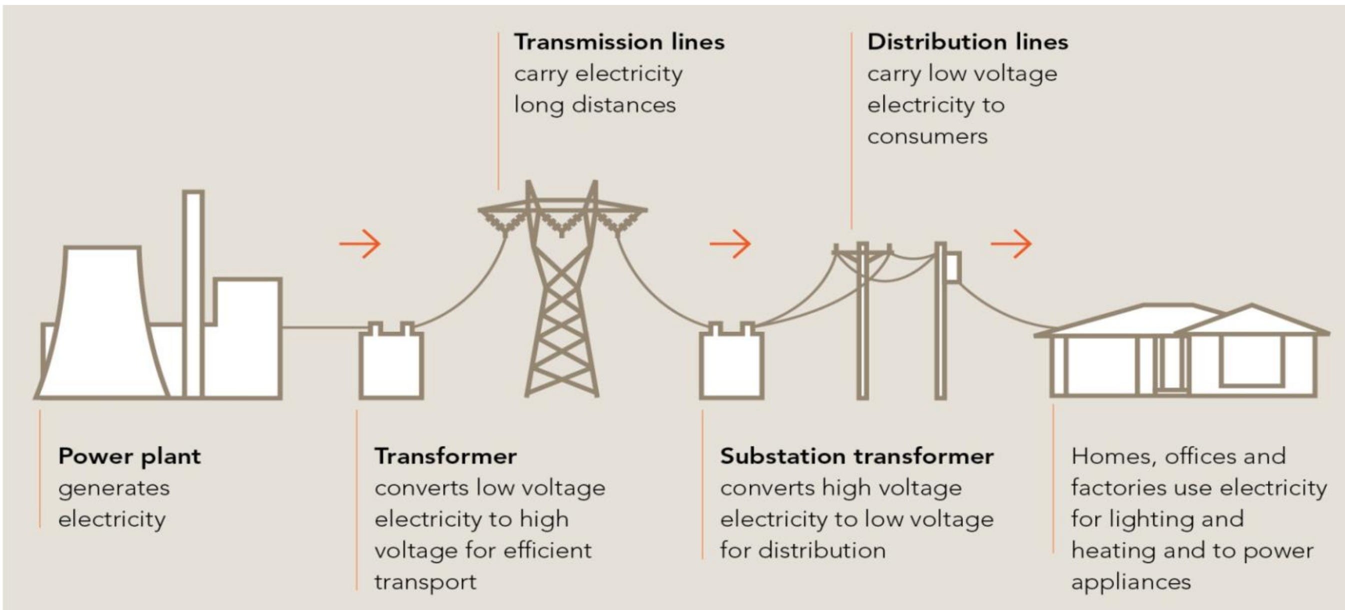
Industry Overview – Basic Definitions



Source: www.eei.org


WHAT CAN YOU POWER with one MEGAWATT HOUR (MWH)?
Cool a refrigerator for 3 MONTHS (150 kWh)
Download 133,320 SONGS (50 kWh)
BREW 2,400 pots of coffee (200 kWh)
1 MWH = 1,000 kilowatt hours
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.

Components of the Grid



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

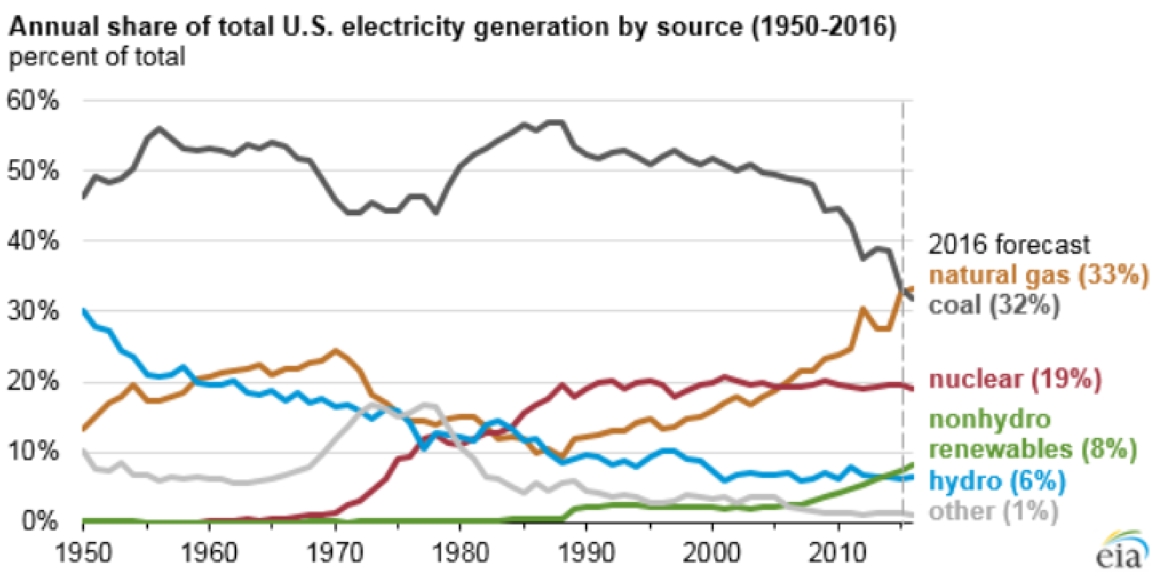
Transmission
- Power Transformation (Step Up)
- Demand/ Supply
- 115 kV – 765 kV

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

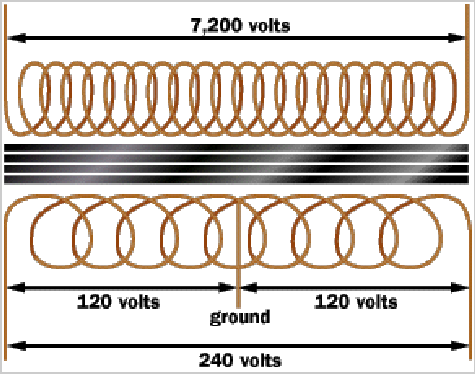


Components of the Grid – Load

- “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



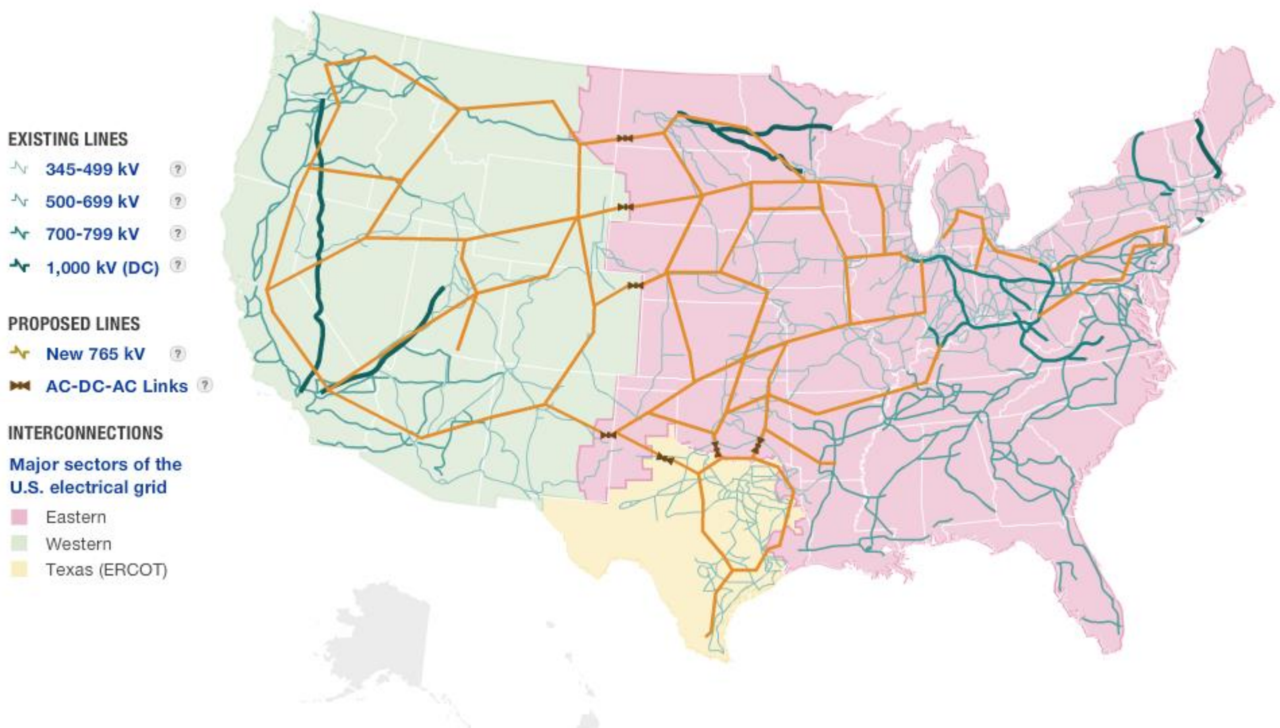
Components of the Grid – Transmission Enables Us To…

- …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

Grid Operations

Grid Operation

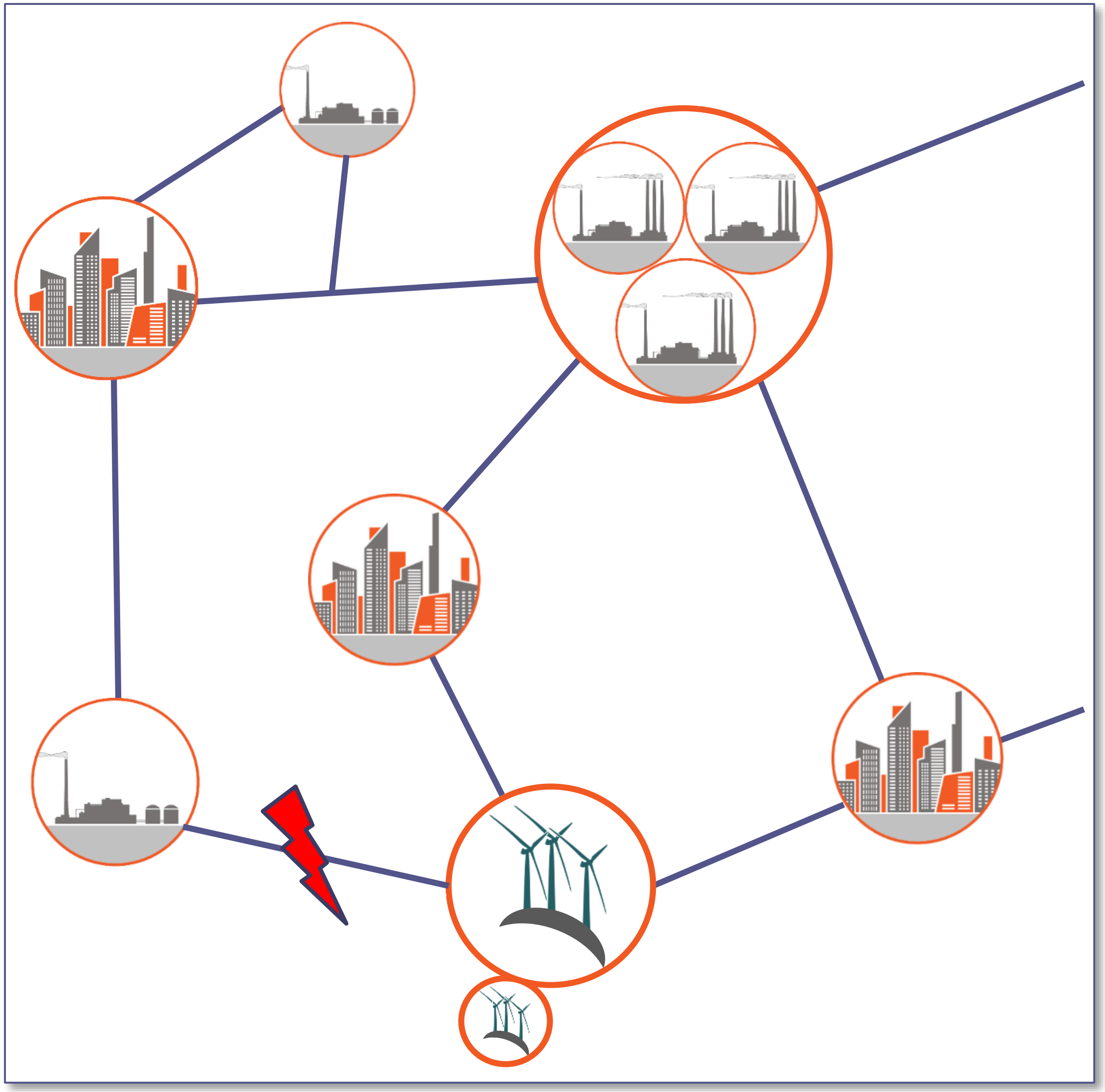
- Unlike highways, pipelines, and telecom, the flow of electricity on the AC grid can not traditionally be easily routed or controlled. Power flows via the path of least resistance. This is a critical difference in how the grid differs from other transportation mechanisms.



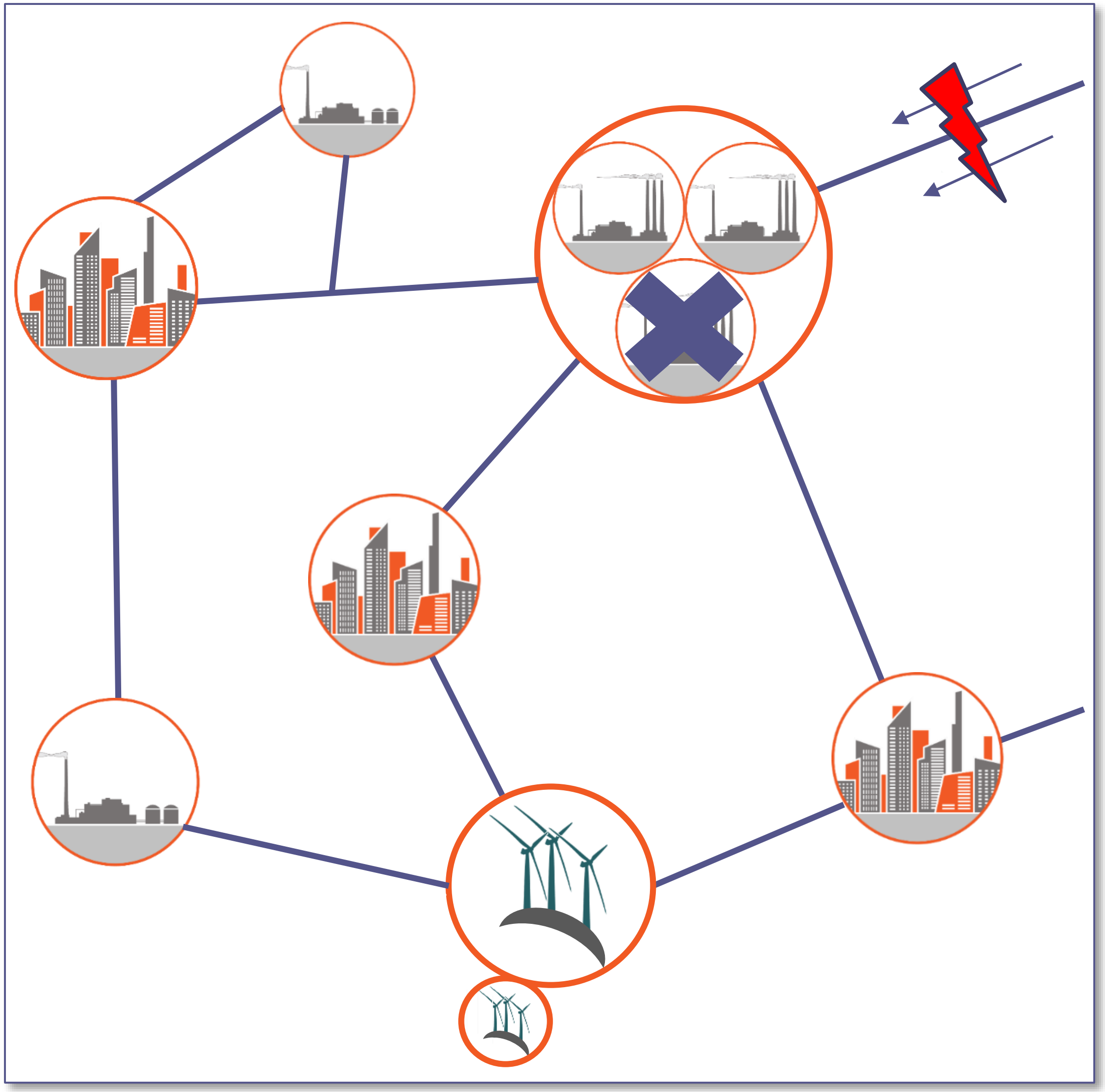
Source: American Electric Power, American Wind Energy Association, Center for American Progress, Department of Energy, Edison Electric Institute, Energy Information Administration, Electric Power Research Institute, Federal Energy Regulatory Commission, National Renewable Energy Laboratory, U.S. Environmental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

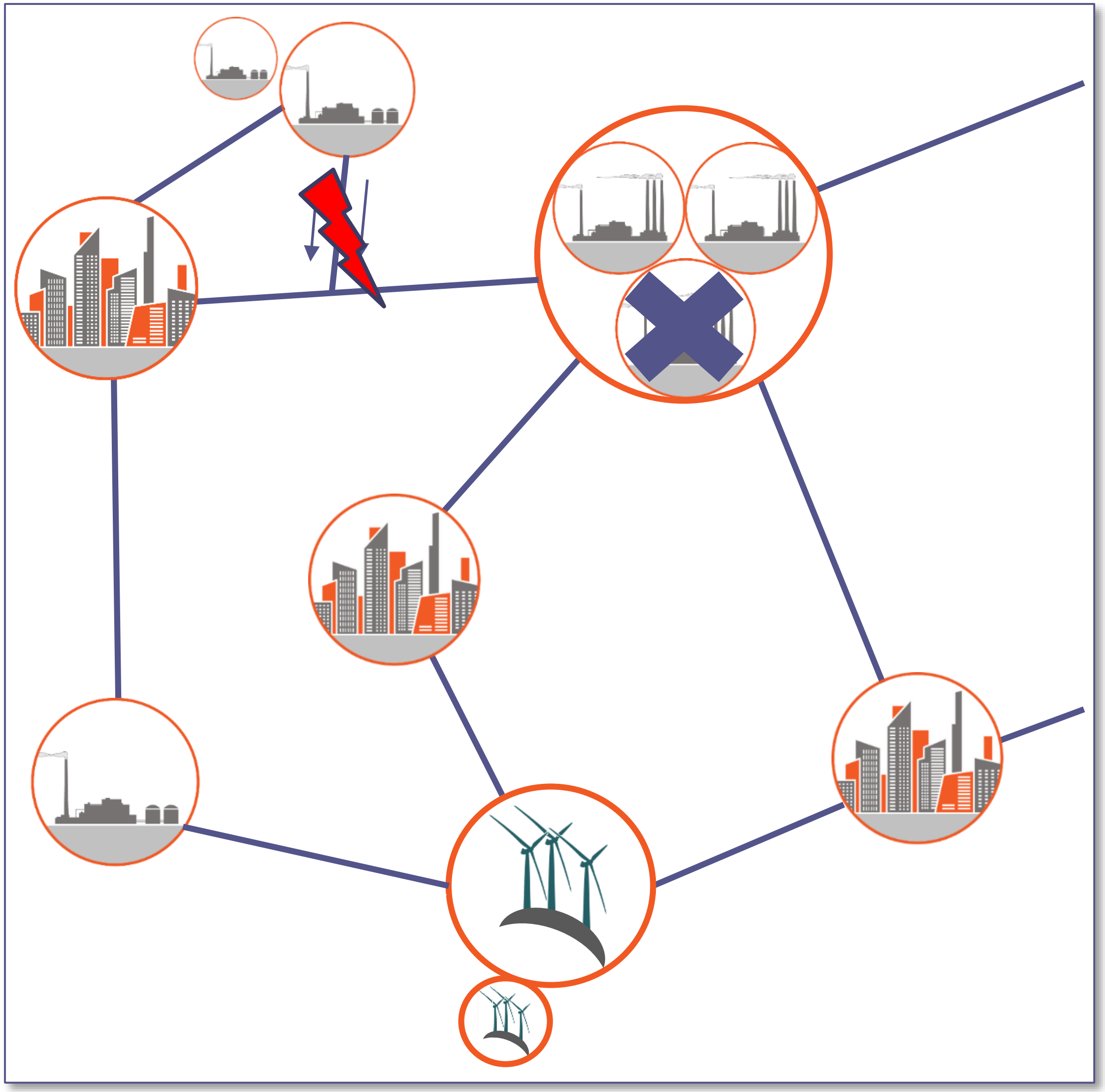
Reliability Under Changing System Needs



Reliability Under Changing System Needs



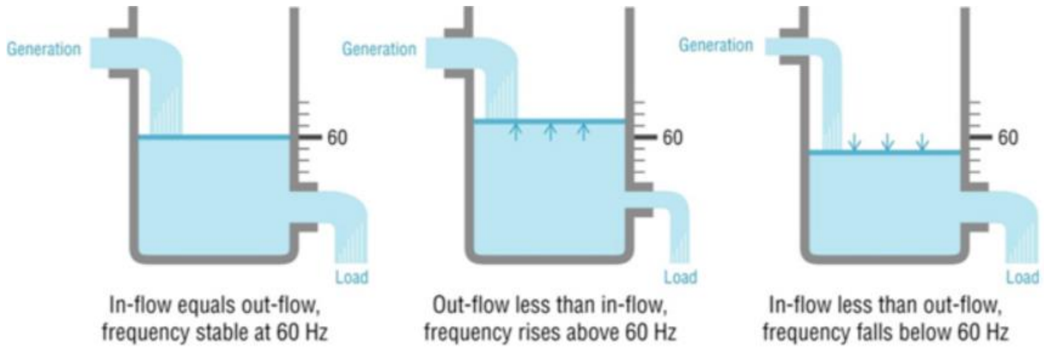
Reliability Under Changing System Needs

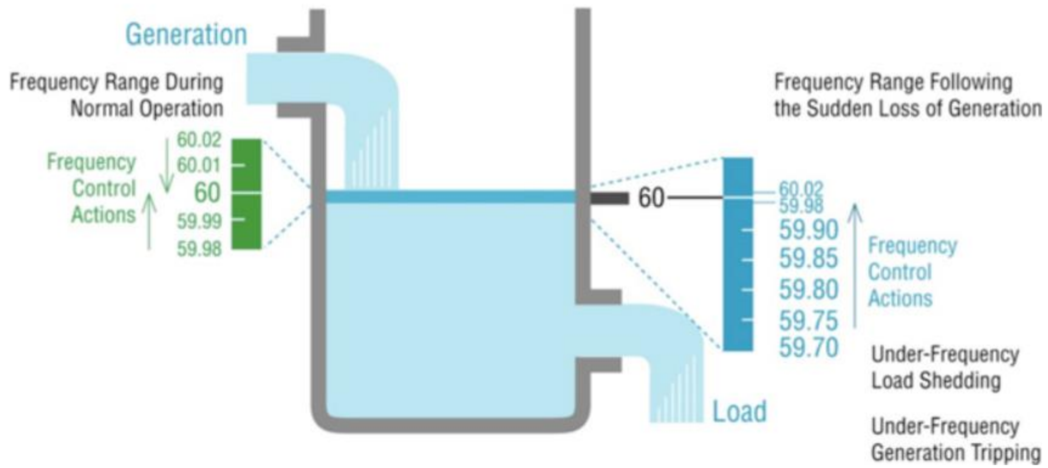


Grid Operation

- 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





Grid Operation – Smart Grid

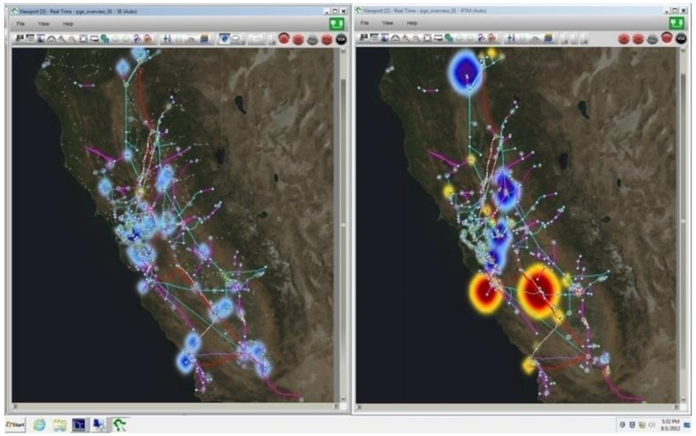
- Operators take immediate actions to isolate and mitigate issues that arise on to minimize any interruption of power

- “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
9. **Power Flow Controllers** –Allows operators to control flow of power, making better use of existing assets

Source: The New York Times

Grid Planning and Development

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 & Factors in a Transmission Planning Study

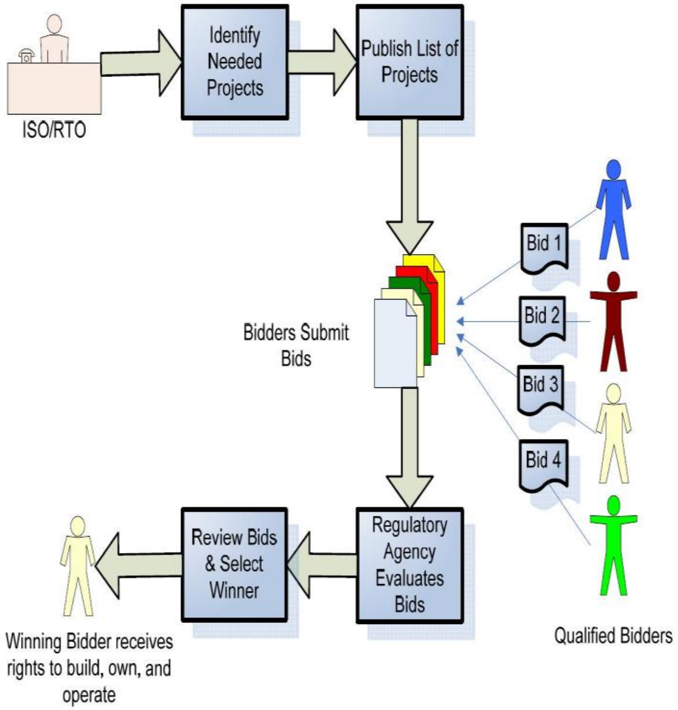
- Planning Period
- Load Forecast and transmission usage projection
- Generation Resources (Location, Type, etc.)
- Discrete Transmission Capacities
- Alternative Solutions
- Economy of Scale
- Economic and Financial Constraints
- R-O-W Limitations
- New and Emerging Technology
- Various Uncertainties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

Regional Planning

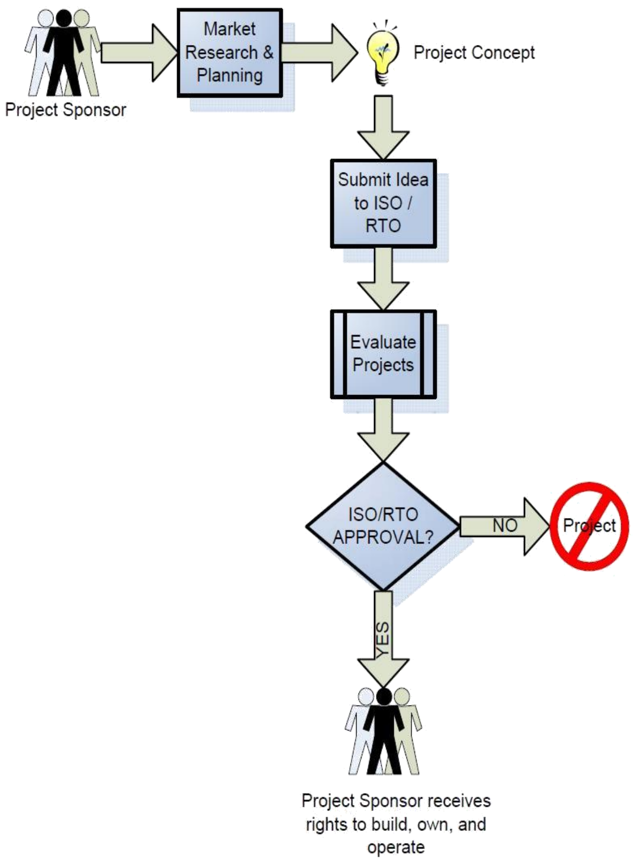
- Per FERC O. 1000 (in conjunction with O. 890), all public utility transmission providers must participate in a regional transmission planning process
- Public utility transmission providers in neighboring transmission planning regions must coordinate to determine if there are more efficient or cost-effective 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



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 are measured by high-speed monitors called PMUs that are 100 times faster than existing SCADA technology
- Overall = Improved grid reliability, efficiency and lower operating costs

Superconductors and Low Sag, High Capacity Conductors

- Superconductors are made of alloys or compounds that will conduct electricity without resistance below a certain temperature, thus eliminating inefficiencies
  - Could enable the transfer of power over long distances at residential voltages
- New conductor technologies such as ACCC conductor offer increased capacity compared to traditional conductors, with reduced thermal sag

Smart Wires Technology

- Power flow control solutions have ability to transform the way power systems are planned and operated.
- These solutions push or pull power away from overloaded lines and onto under-utilized corridors on the transmission grid by changing the reactance of the lines on which they are installed.
- System operators can dynamically control each line, based on the real-time needs of the grid.
- These solutions are quickly deployable, scalable and reusable, giving customers the opportunity to redeploy the technology as their needs change.

SMART WIRES
REIMAGINE THE GRID

Summary

- The power system is:
  - An integral component of the economy
  - Composed of generation, distribution and transmission
  - Relies on transmission to deliver cost effective generation to load centers
  - Uses the transmission backbone to enable energy markets
  - Is complicated to operate and requires constant monitoring and control
- 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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REIMAGINE THE GRID

Sources:

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

WIRES University Overview of ISO/RTOs

Mike Ross
Senior Vice President
Government Affairs and Public Relations
Southwest Power Pool

OUR MISSION

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

Northeast Blackout of 1965

POWER FAILURE BLACKS OUT NEW YORK; THOUSANDS TRAPPED IN THE SUBWAYS; LOOTERS AND VANDALS HIT SOME AREAS

State Troopers Sent Into City As Crime Rises

Some Civilians Assist Police – '65 Blackout Peaceful in Contrast

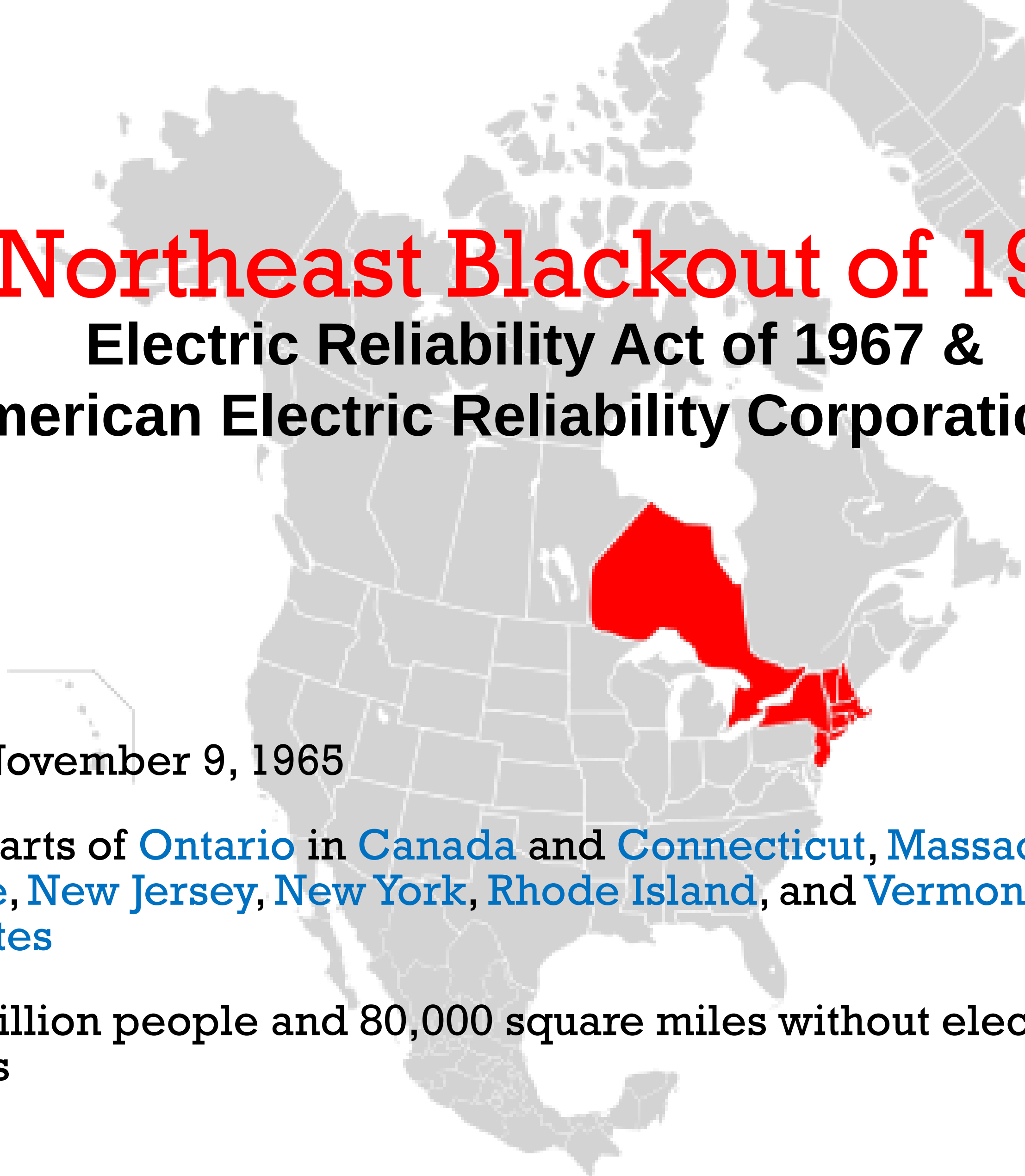
Westchester Is Also Darkened After Lightning Hits Line

Some Led Others by Flashlight, Some Knocked on Doors to Help

Lightning Bolt: How It Struck

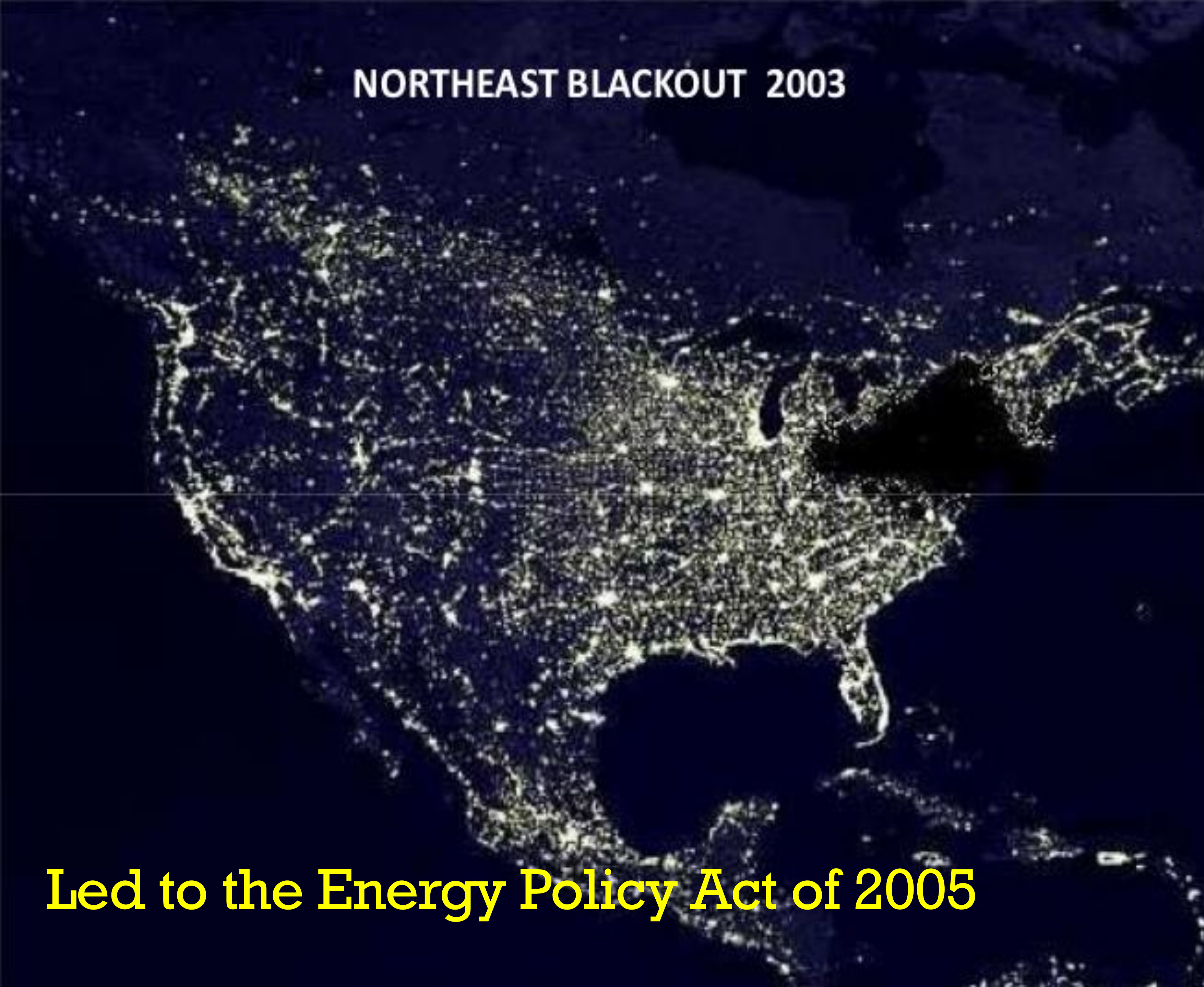
Northeast Blackout of 1965

Electric Reliability Act of 1967 &
North American Electric Reliability Corporation (NERC)



- Tuesday, November 9, 1965
- Affected parts of Ontario in Canada and Connecticut, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island, and Vermont in the United States
- Over 30 million people and 80,000 square miles without electricity for up to 13 hours

Northeast Blackout of 2003



Led to the Energy Policy Act of 2005

Our Major Services

- Reliability Coordination
- Market Operation
- Transmission Planning
- Transmission Service/Tariff Administration
- Balancing Authority
- Facilitation
- Standards Setting
- Compliance Enforcement
- Training

OUR APPROACH:
Regional, Independent, Cost-Effective and Focused on Reliability

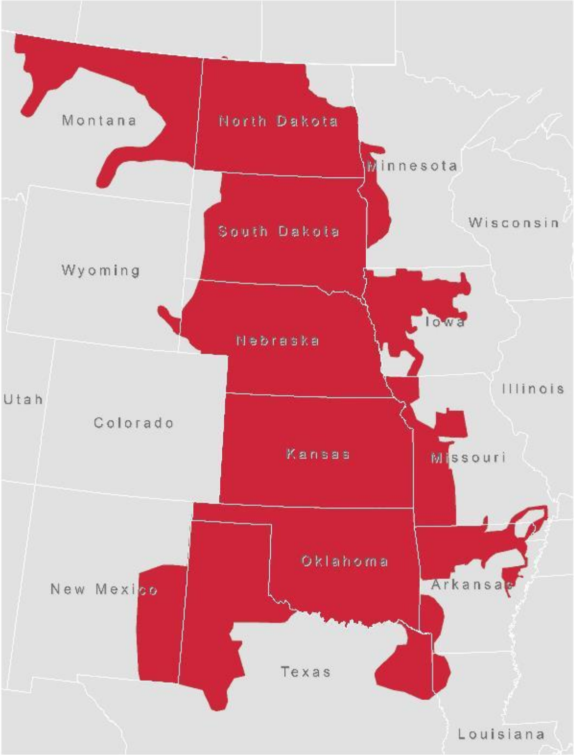
Some Activities Outside of SPP's Responsibility

- Transmission Siting
- Generation Planning/Siting
- Transmission/Generation Construction
- Transmission/Generation Permitting
- Credit/Allowance Trading Oversight

SPP

Independent System Operator (ISO) / Regional Transmission Organization (RTO) Map

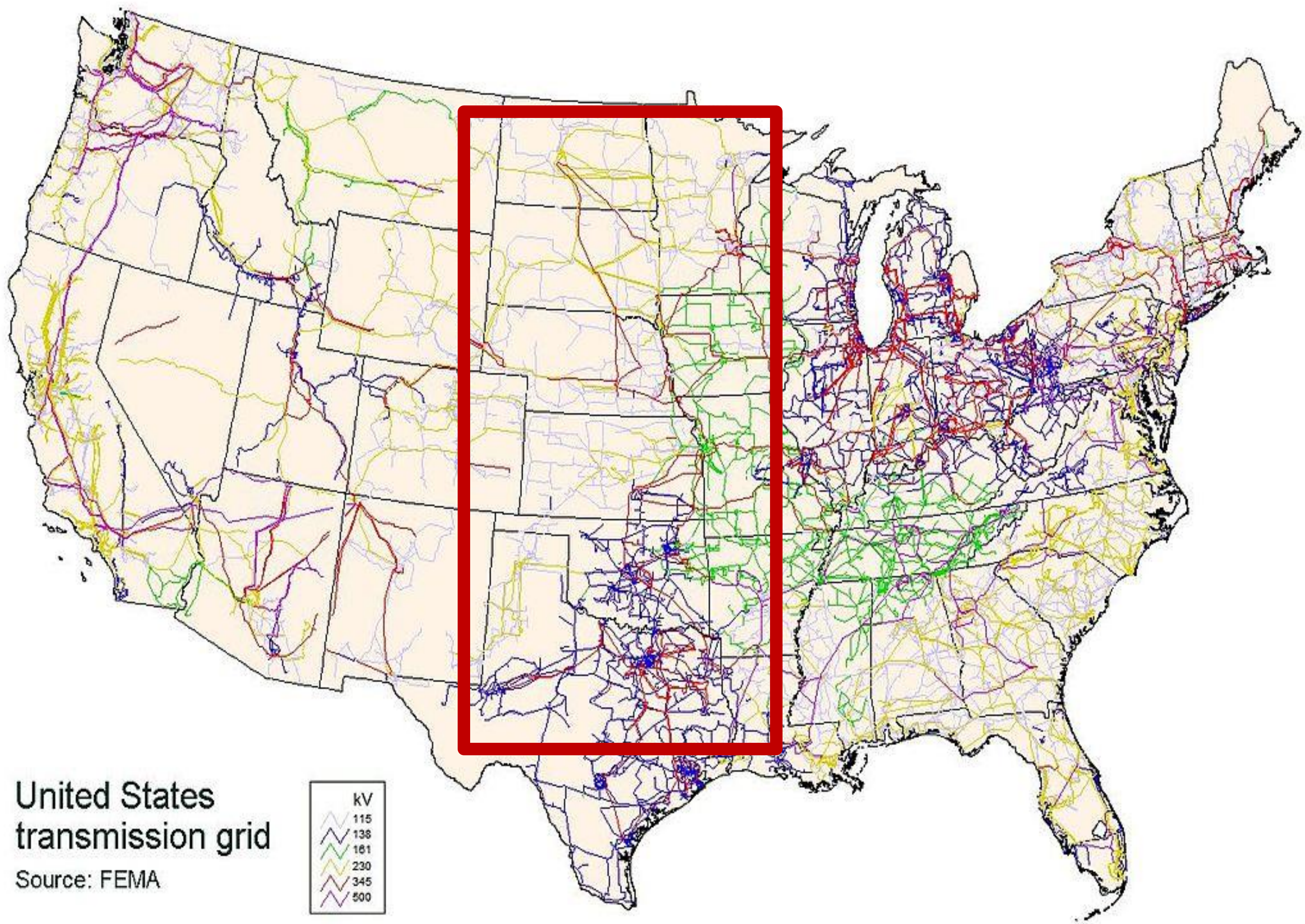
The SPP Footprint: Members in 14 States



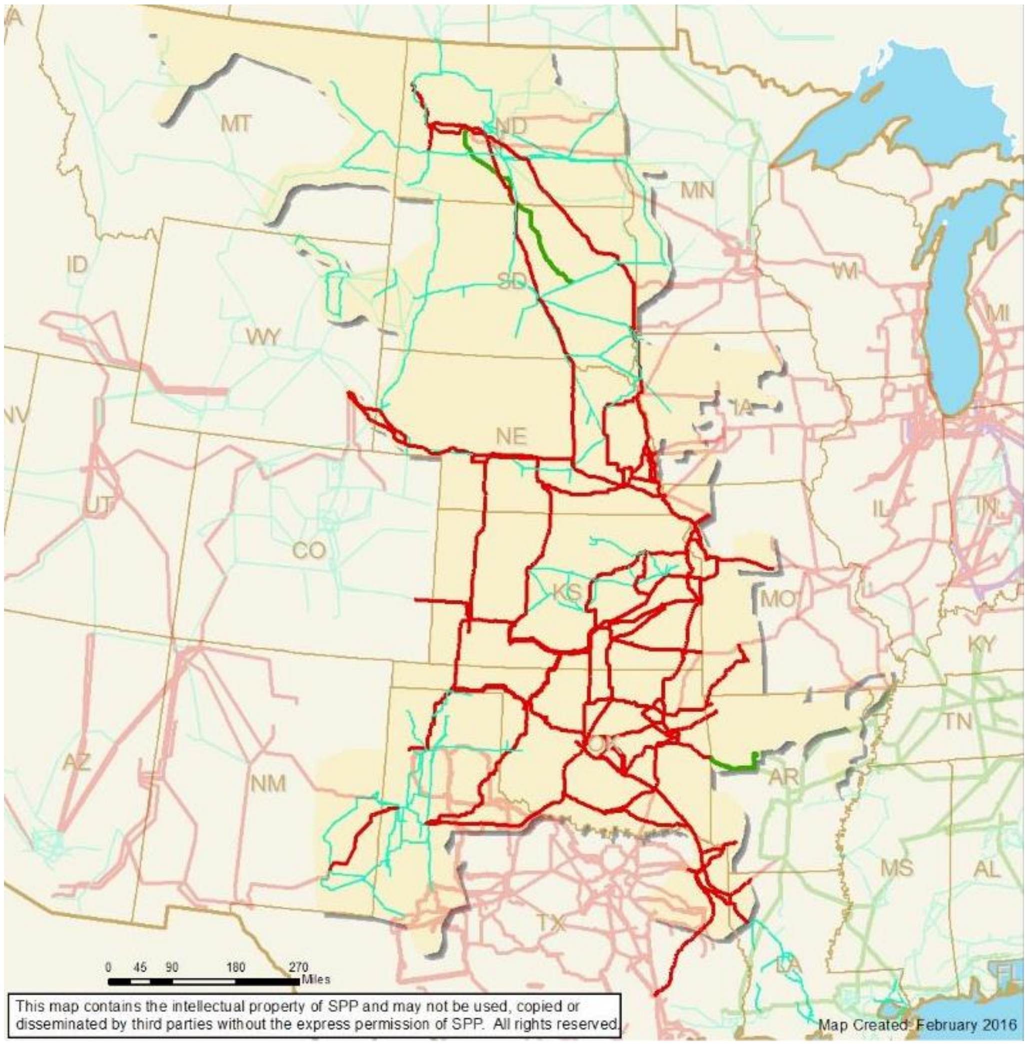
- **Arkansas**
- **Kansas**
- **Iowa**
- **Louisiana**
- **Minnesota**
- **Missouri**
- **Montana**
- **Nebraska**
- **New Mexico**
- **North Dakota**
- **Oklahoma**
- **South Dakota**
- **Texas**
- **Wyoming**

SPP

United States Electric Grid



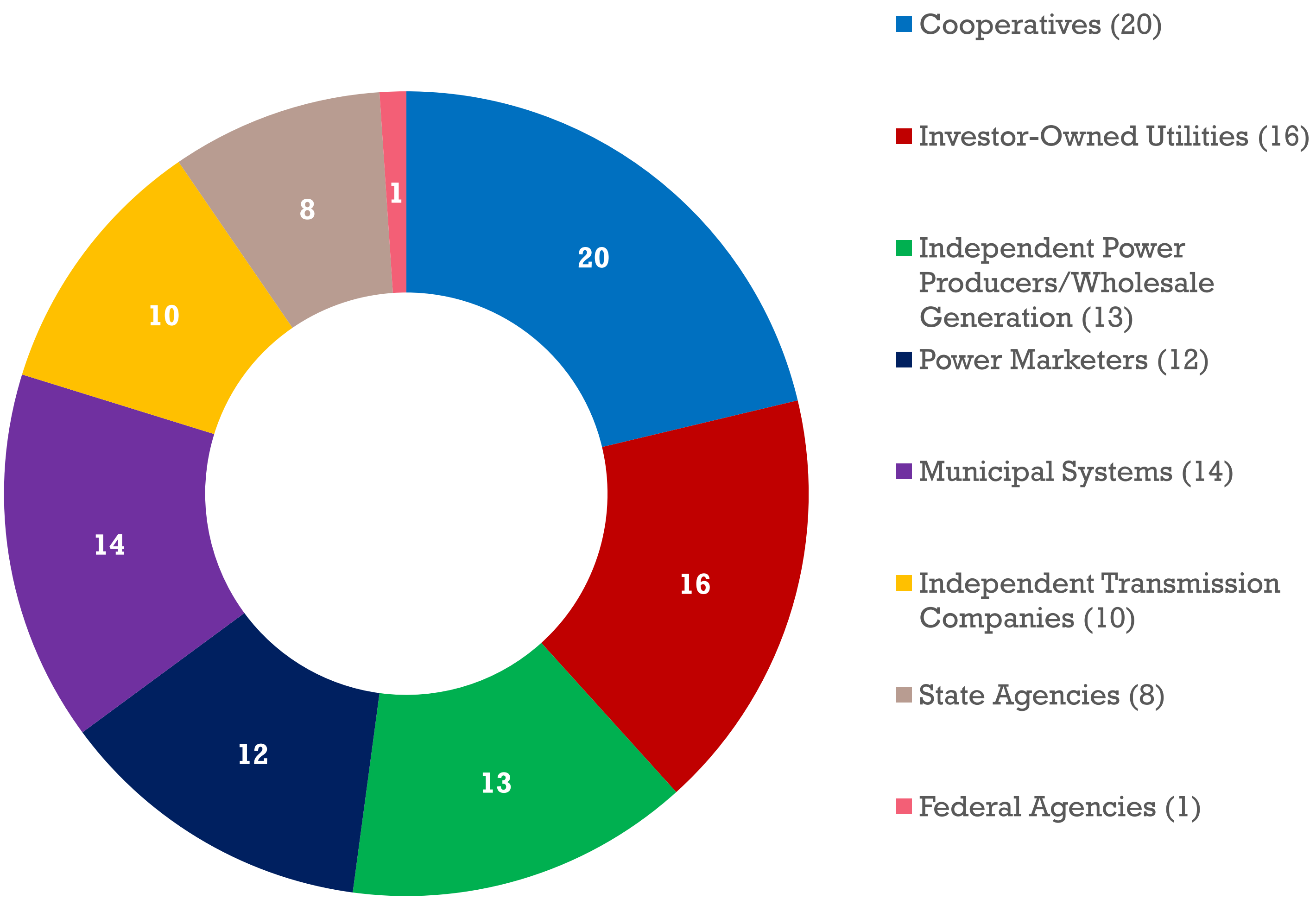
Operating Region



- Miles of service territory: 575,000
- Population served: 18M
- Generating Plants: 703
- Substations: 4,757
- Miles of transmission: 60, 944
  - 69 kV 13,532
  - 115 kV 14,269
  - 138 kV 9,117
  - 161 kV 5,647
  - 230 kV 7,608
  - 345 kV 10,772

SPP

SPP's 94 Members: Independence Through Diversity



As of August 11, 2016

REGULATORY ENVIRONMENT

- Incorporated in Arkansas as 501(c)(6) nonprofit corporation
- Federal Energy Regulatory Commission (FERC)
  - Regulated public utility
  - Regional Transmission Organization
- North American Electric Reliability Corporation (NERC)
  - Founding member
  - Regional Entity

SPP

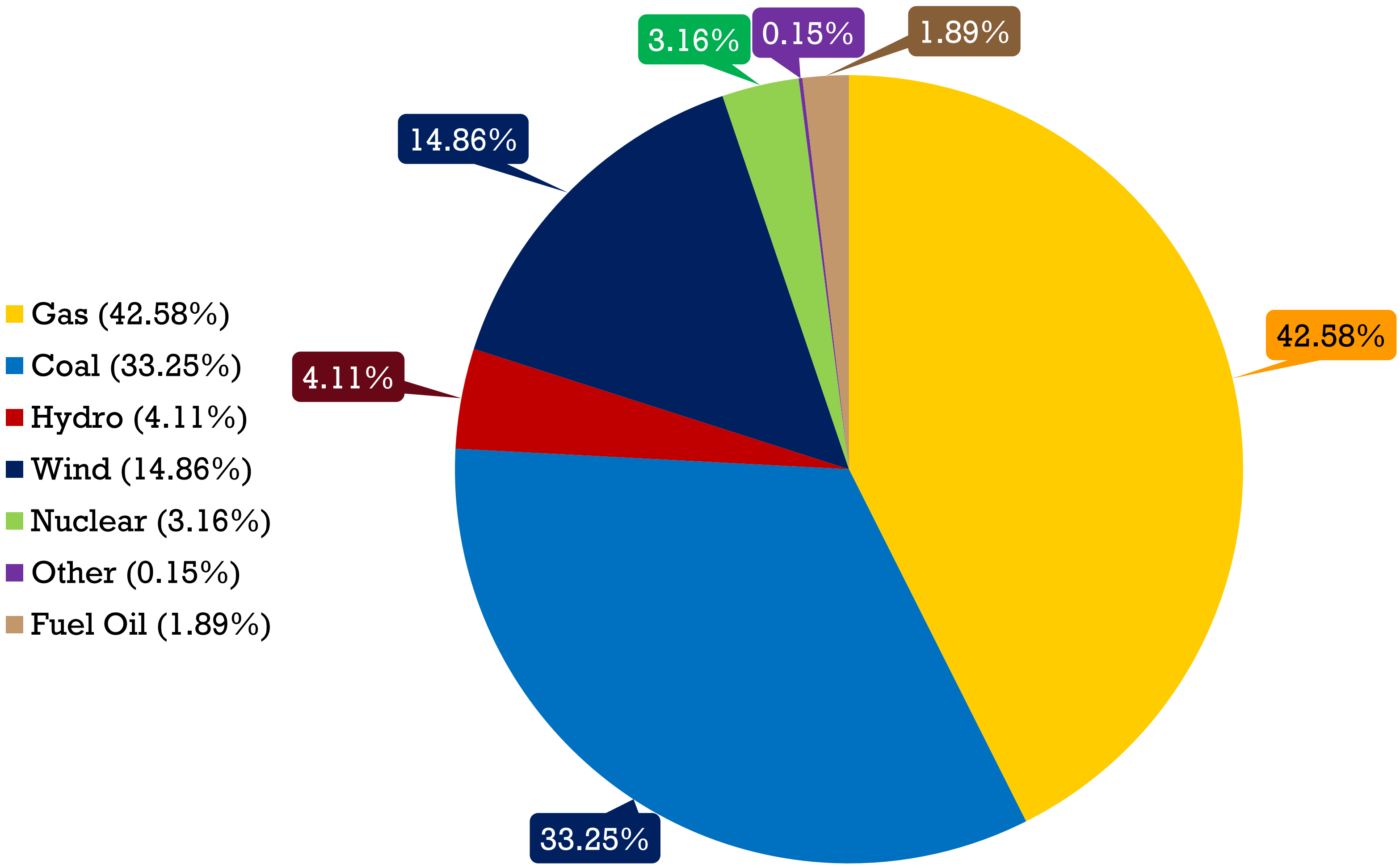
GOVERNANCE

- Independent Board of Directors
- Members Committee
- Regional State Committee
- Working Groups

Reliability Coordination: air traffic controllers of the bulk power grid

- Monitor grid 24 x 365
- Anticipate problems
- Take preemptive action
- Coordinate regional response
- Independent
- Comply with more than 5,500 pages of reliability standards and criteria

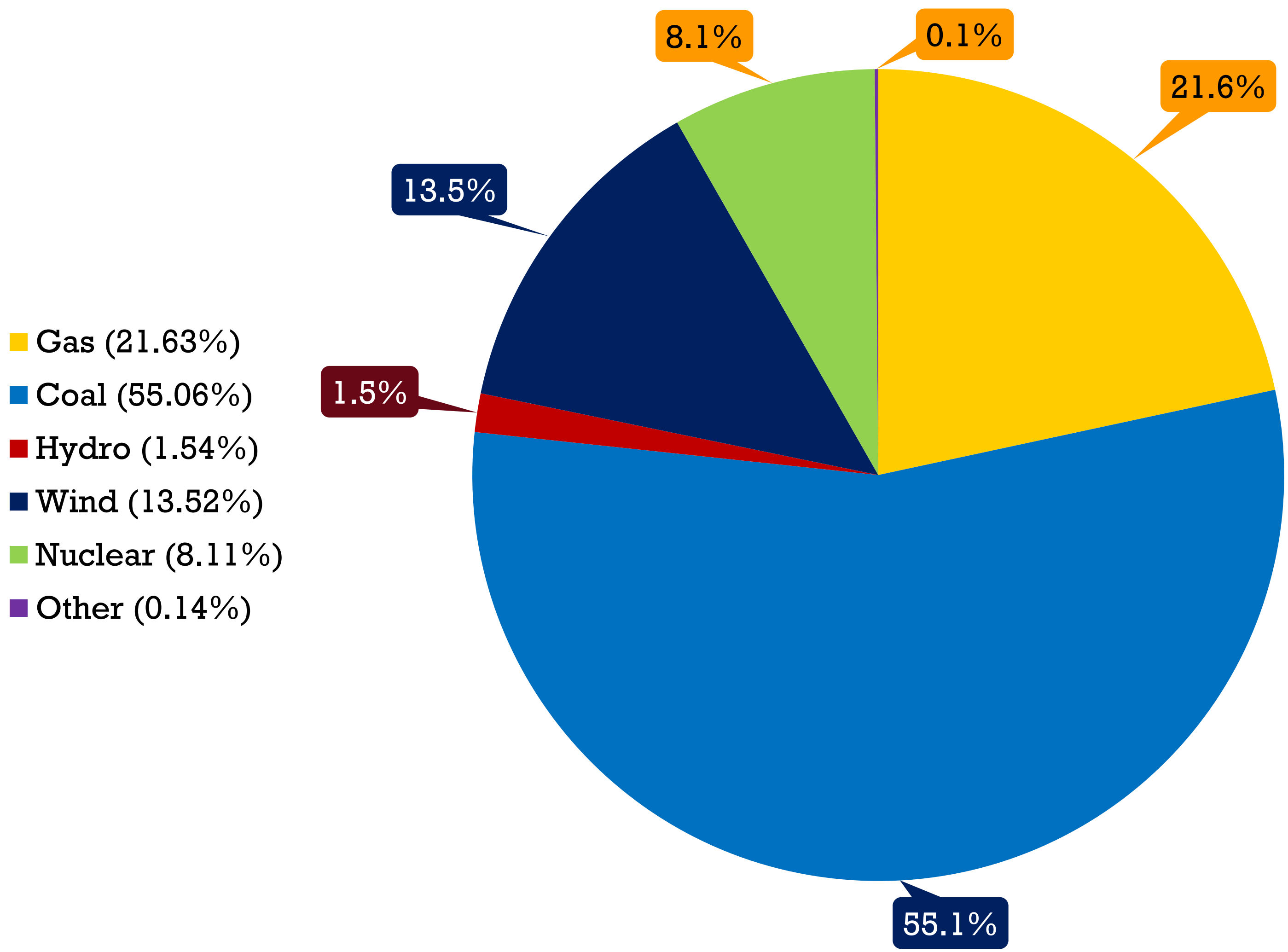
2015 Energy Capacity* by Fuel Type



* Figures refer to nameplate capacity

SPP

2015 Energy Consumption by Fuel Type



What Kind of Markets Does SPP Operate?

- Transmission Service: Participants buy and sell use of regional transmission lines that are owned by different parties.
- Integrated Marketplace: Participants buy and sell wholesale electricity in day-ahead and real-time.
  - Day-Ahead Market commits the most cost-effective and reliable mix of generation for the region.
  - Real-Time Balancing Market economically dispatches generation to balance real-time generation and load, while ensuring system reliability.

SPP

Integrated Marketplace Savings

- Market continues to provide savings even with extremely low natural gas prices
- First year net savings calculated to be $380 million
- 2015 annual net savings calculated to be $422 million
- At the end of September, 2016 the savings amount was over $1 Billion from the Integrated Marketplace

SPP

Transmission Planning

- Reliability
- Economics
- Public Policy

Integrated Transmission Planning (ITP)

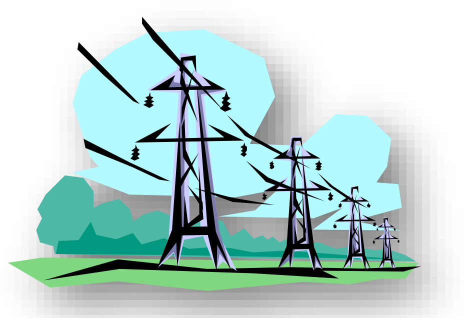
Conceptual

20-Year Assessment ← Develop EHV "highway" vision

10-Year Assessment ← Develop "highway/byway" system

Near-Term Assessment ← Develop "byway" & "local" system

Implementation



- Reliability, economic and public policy needs are evaluated in the 20 and 10-year assessments
- Reliability needs are evaluated in the near-term assessment

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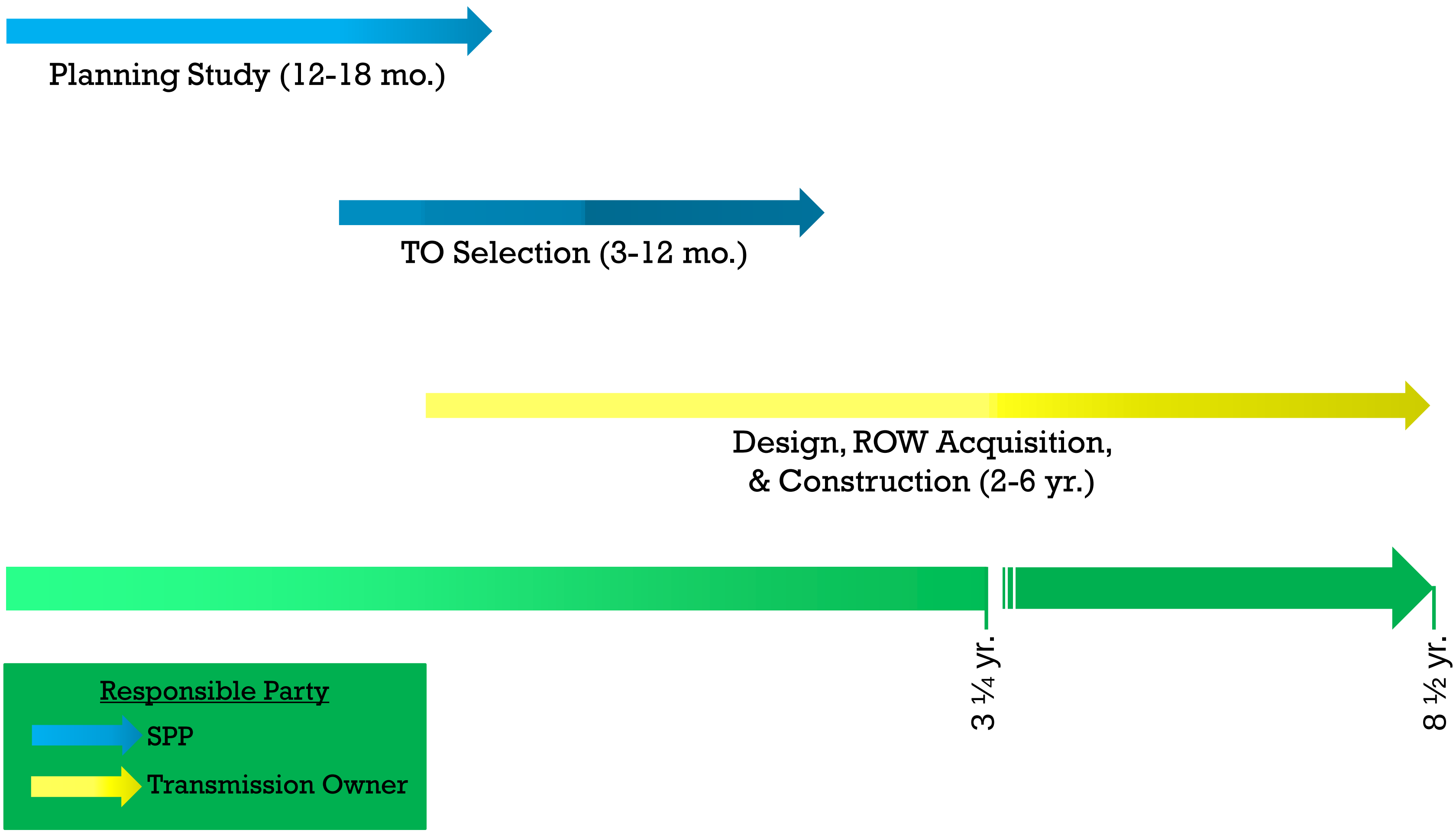
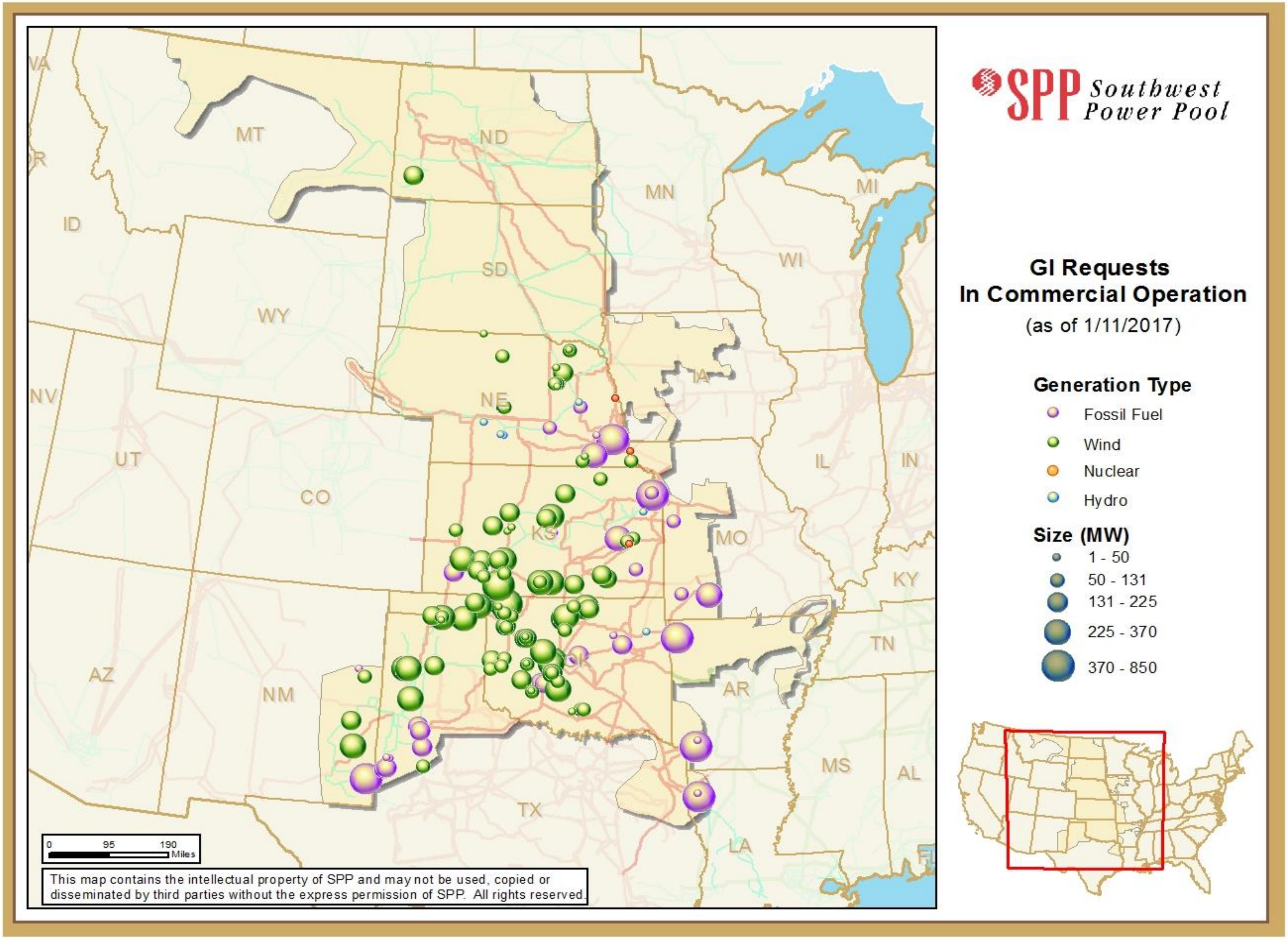
Transmission Build Cycle in SPP



Generation Expansion in SPP Over the Last Decade



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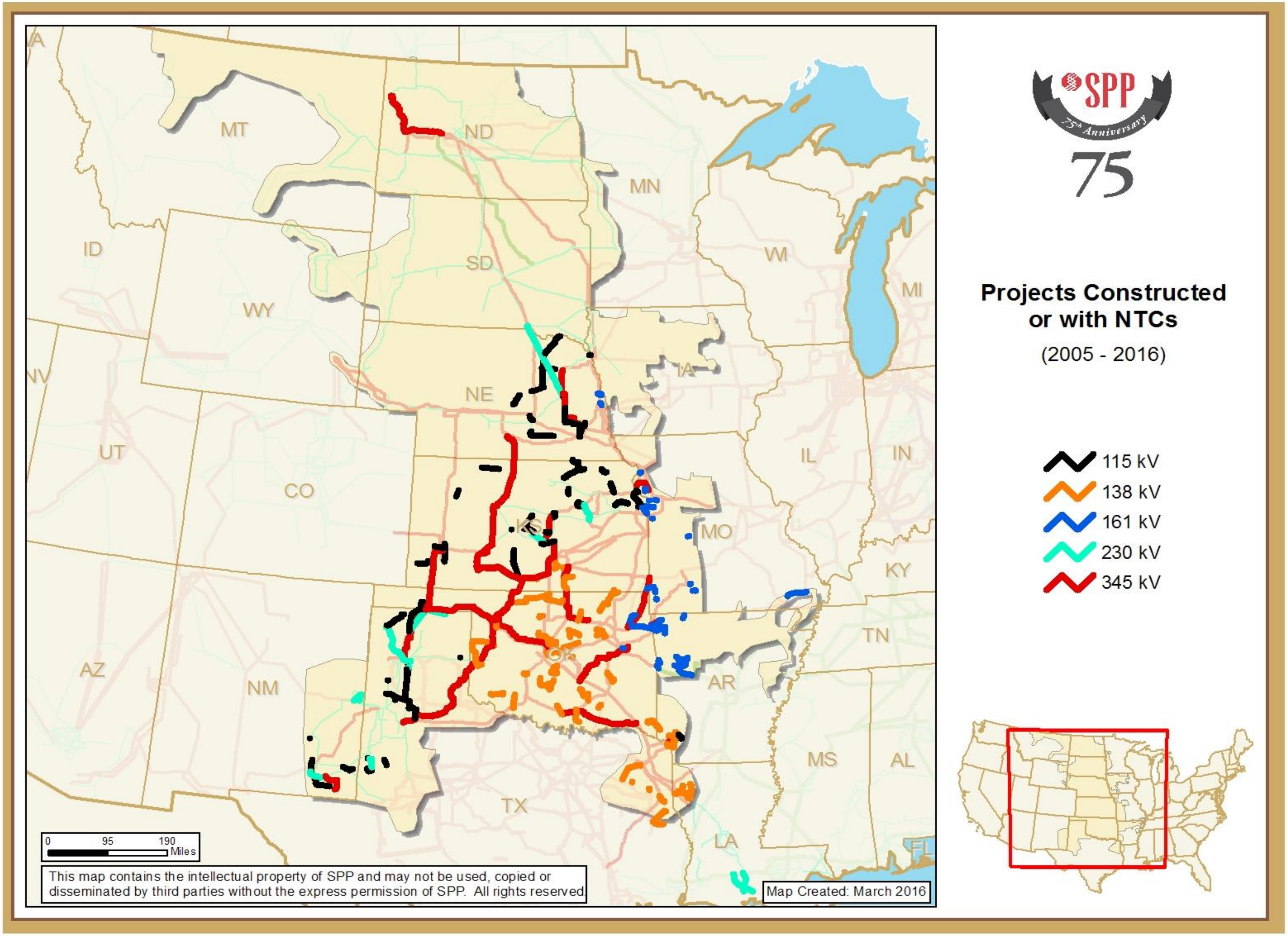
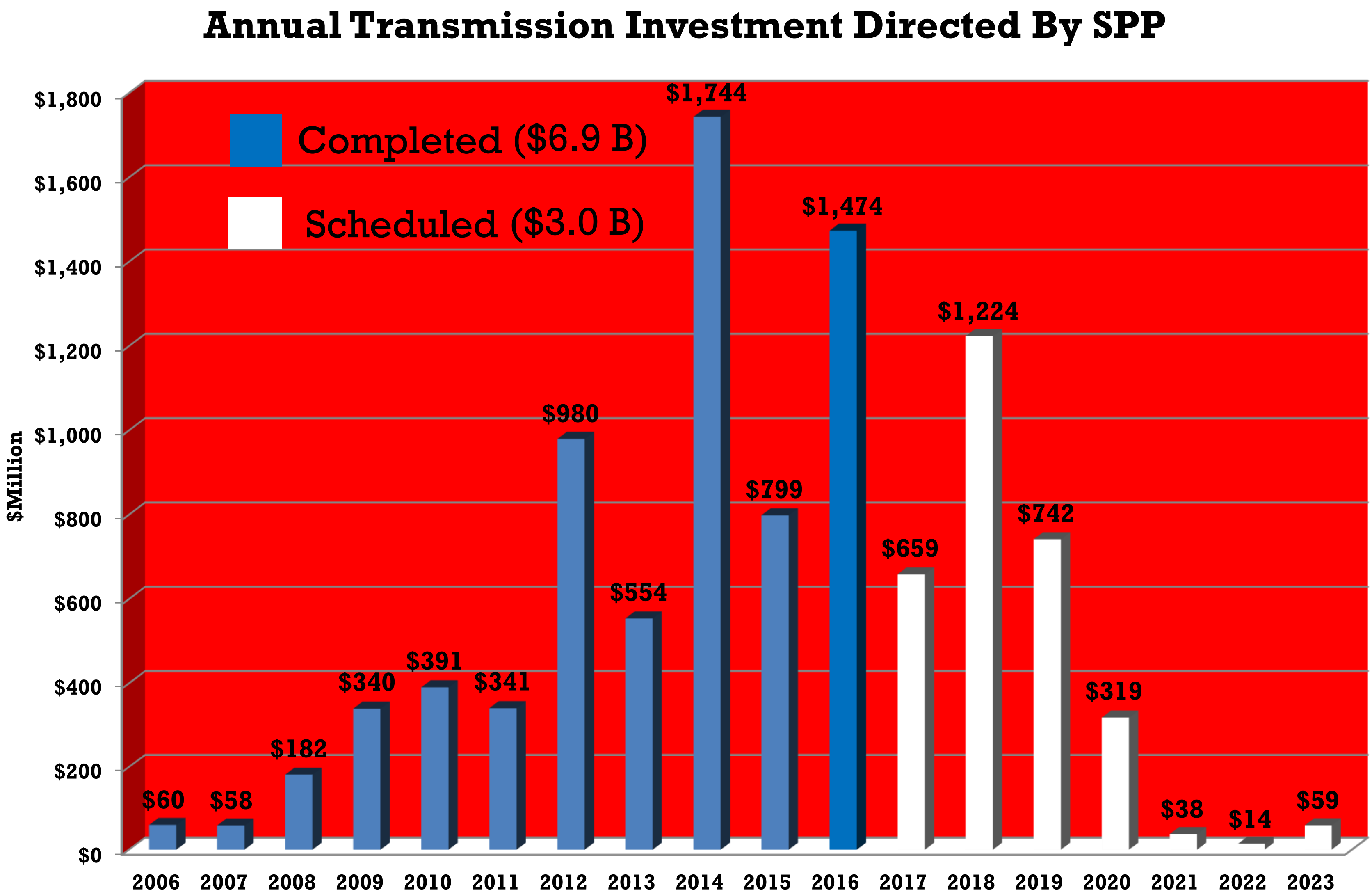
Transmission Expansion in SPP Over the Last Decade



Transmission Investment Directed By SPP



Who Pays for Transmission Projects?

- Sponsored: Project owner builds and receives credit for use of transmission lines
- Directly-assigned: Project owner builds and is responsible for cost recovery and receives credit for use of transmission lines
- Highway/Byway: Most SPP projects paid for under this methodology

Voltage	Region Pays	Local Zone Pays
300 kV and above	100%	0%
above 100 kV and below 300 kV	33%	67%
100 kV and below	0%	100%

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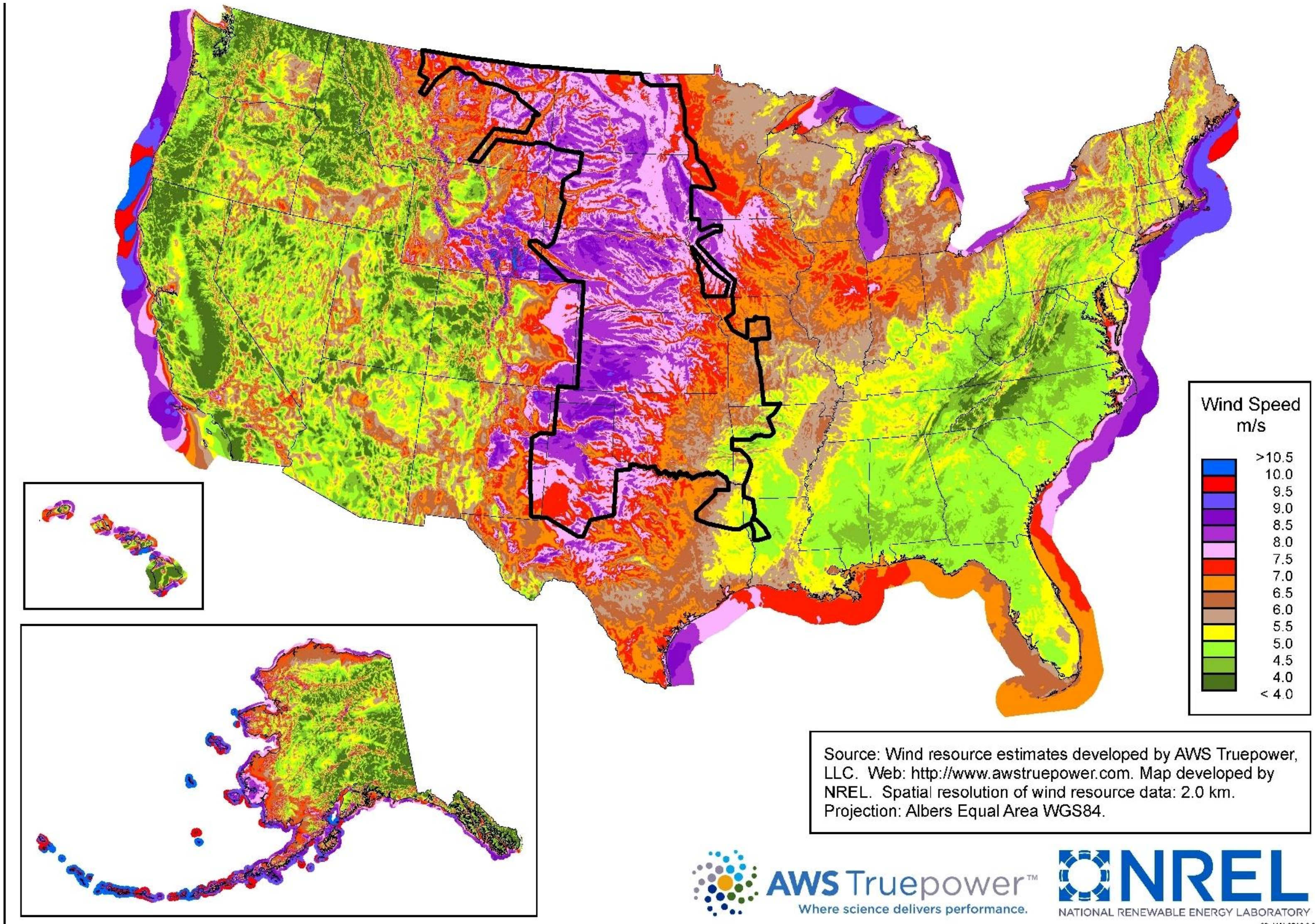
Renewables in SPP

The highest wind speed in the country is within SPP Balancing Authority



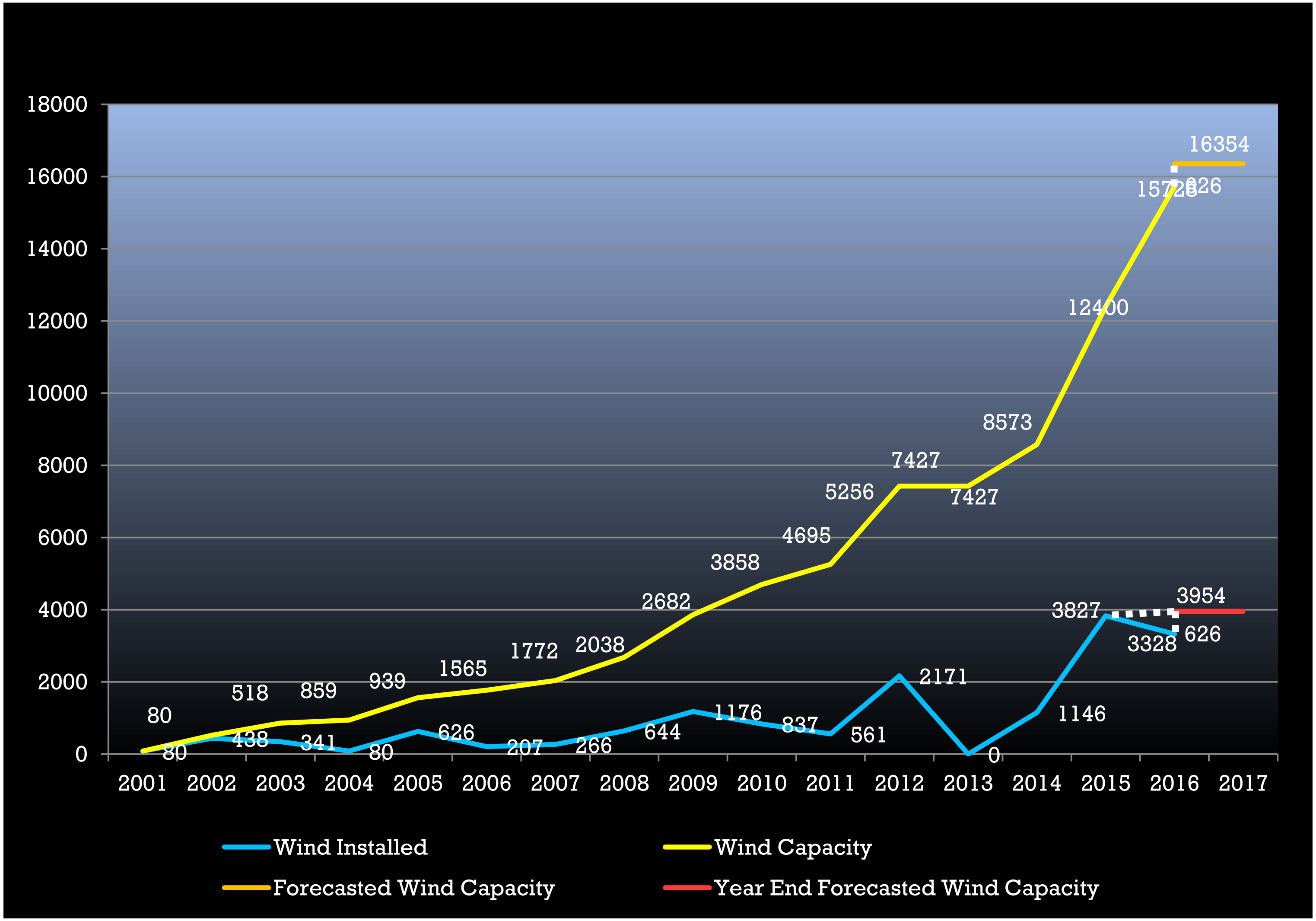
SPP

Wind Energy Development

- SPP's "Saudi Arabia" of wind: Kansas, Oklahoma, Nebraska, Texas Panhandle, and New Mexico
  - 60,000-90,000 MW potential
  - More wind energy than SPP uses during peak demand
- 15,782 MW capacity of in-service wind*
- 34,730 MW wind in all stages of development*
  - Includes Generation Interconnection queue and executed Interconnection Agreements

* December 2016

Wind Capacity has grown significantly



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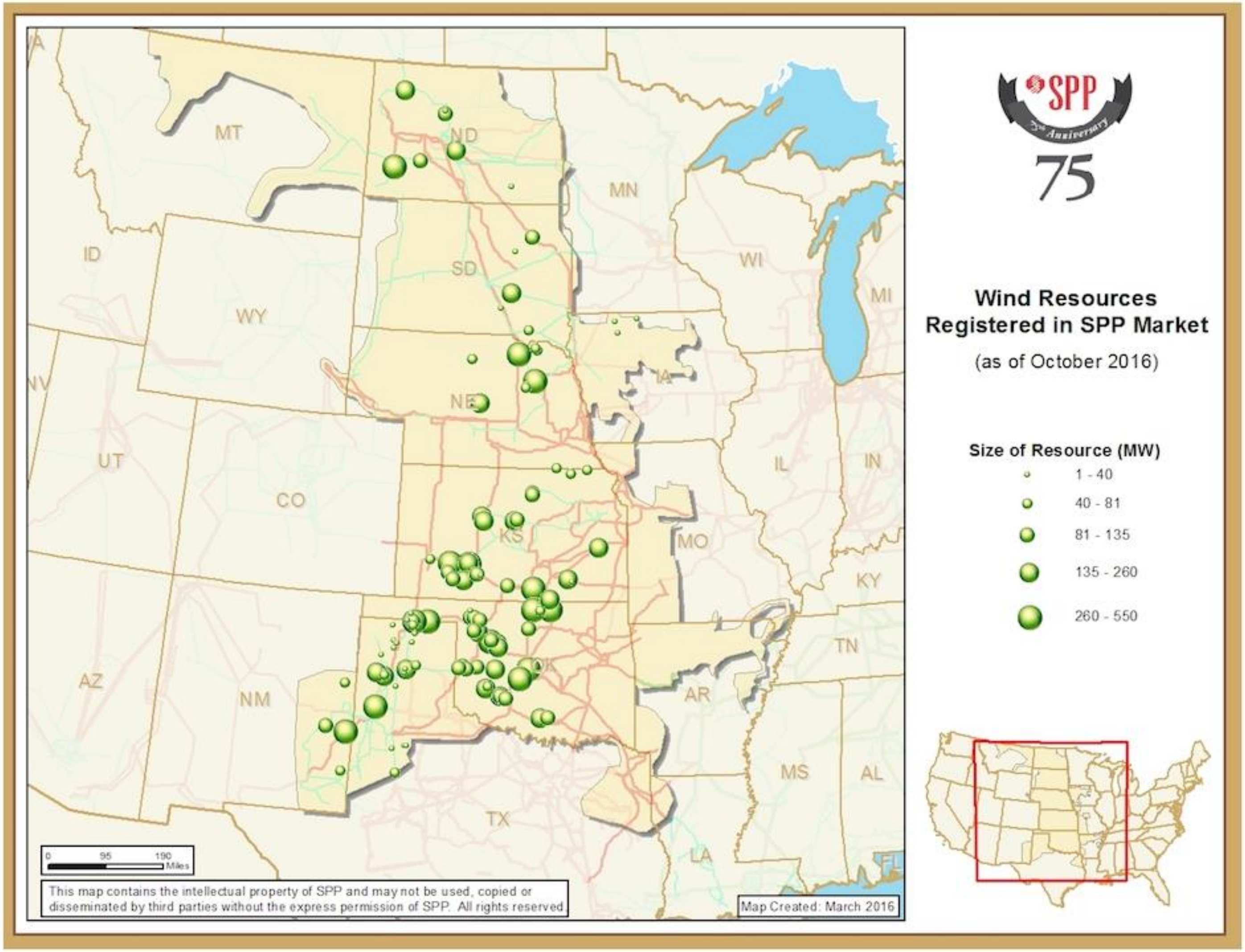
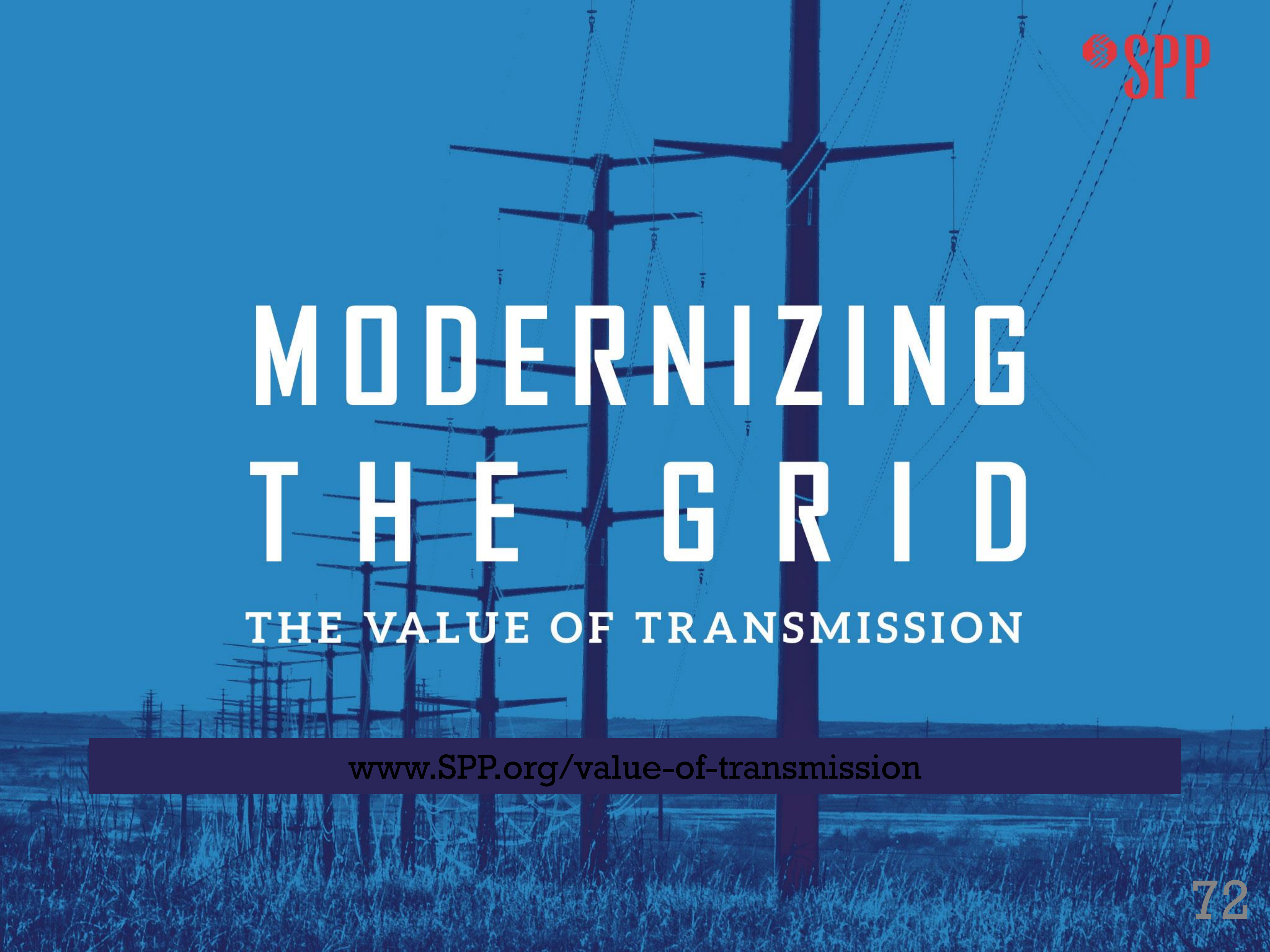
Wind units are concentrated in the middle of the footprint



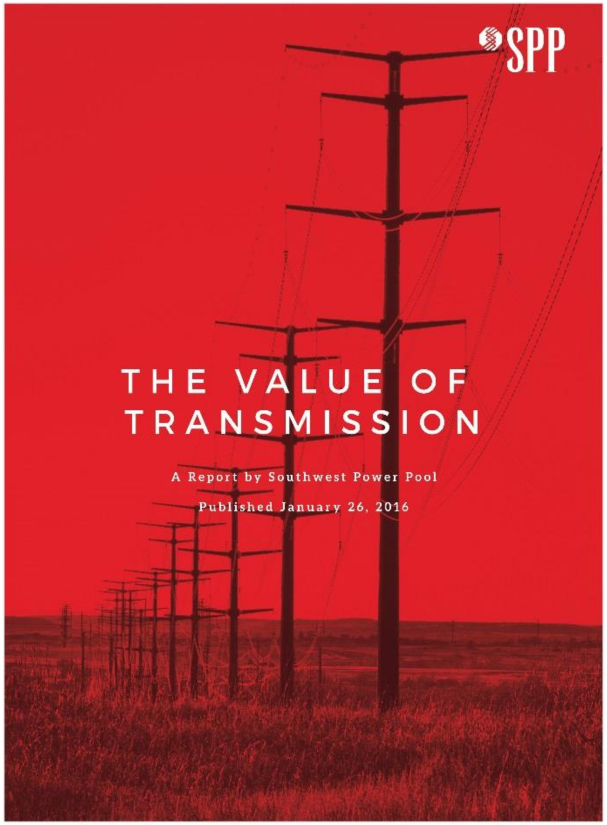
Renewables impacts to SPP

- Peak Wind Penetration level: 49.17% April 2016
- Peak instantaneous Wind generation: 12,336 MW December 2016
- High impact on congestion and loading of the transmission system
- Wind can cause capacity issues by
  - Not showing up during times of high demand, contributing to capacity shortages
  - Showing up too high during times of low demand, contributing to "Min Gen" issues
  - Uncertainty complicating unit commitments
- Short-term, intra-hour changes in wind also require reserves to maintain balance between generation and obligations
- Wind forecast is crucial for SPP to have the right generation online at the right time, while maintaining the reliability and economic efficiency of the regional transmission grid.


SPP
MODERNIZING
THE GRID
THE VALUE OF TRANSMISSION
www.SPP.org/value-of-transmission

SPP's Value of Transmission Study

- Evaluated 348 projects from 2012-14, representing $3.4B of transmission investment
- Evaluated benefit metrics
  - Adjusted Production Cost (APC) Savings
  - Reliability and Resource Adequacy Benefits
  - Generation Capacity Cost Savings
  - Market Benefits
  - Other industry and SPP-accepted metrics
- APC Savings alone calculated at more than $660k/day, or $240M/year.
- Overall NPV of all benefits for considered projects are expected to exceed $16.6B over 40 years.



For every $1 of transmission investment made in 2012-2014, SPP expects at least $3.50 of benefit to be provided to rate-payers

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MISO Planning Overview

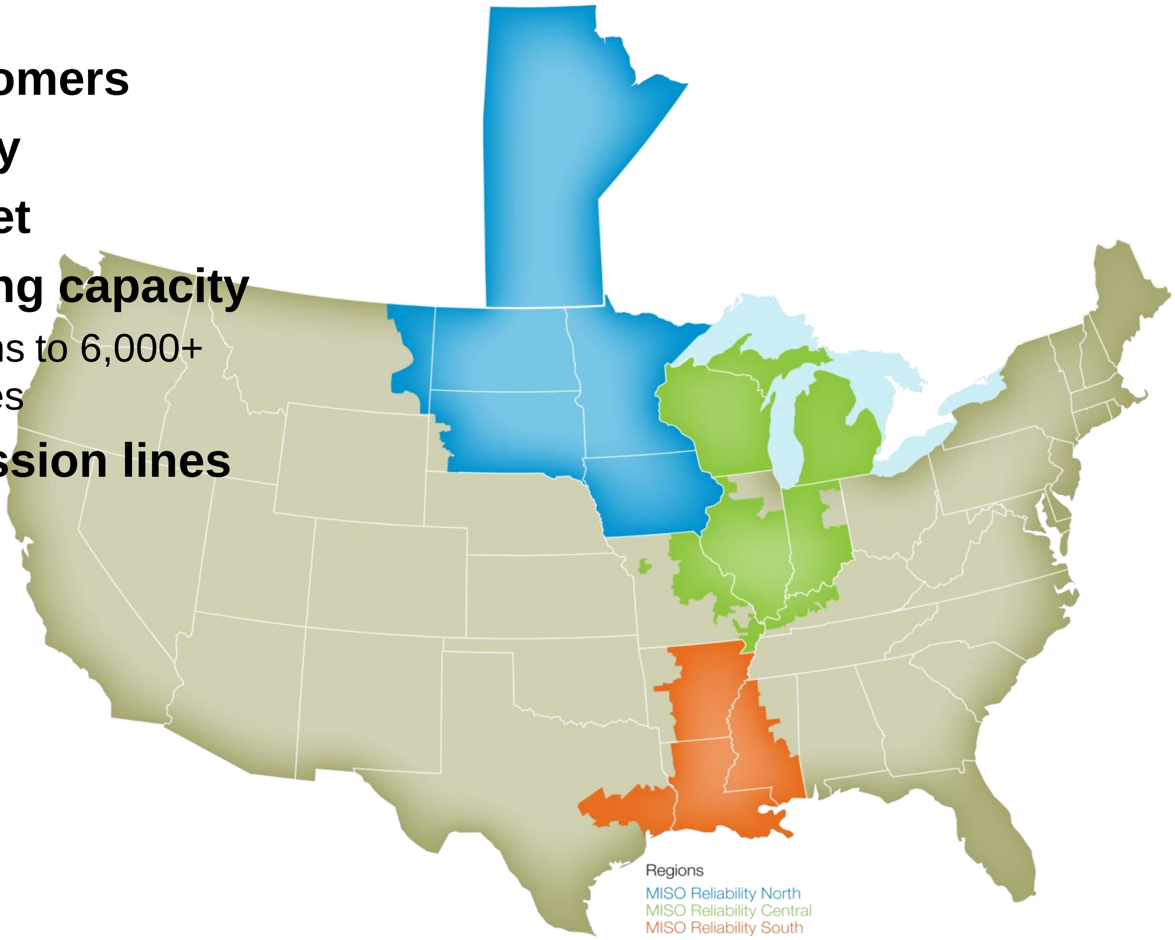
Clair Moeller, Executive VP
Mid-Continent ISO

February 16, 2017

MISO Overview

- Independent, non-profit organization responsible for maintaining reliable transmission of power
- First Regional Transmission Organization (RTO) approved by the Federal Energy Regulatory Commission (FERC)

- **42 million end-use customers**
- **99.99% system reliability**
- **$25 billion energy market**
- **192,000 MW of generating capacity**
  - Send operating instructions to 6,000+ generators every 5 minutes
- **65,800 miles of transmission lines**
- **52 Members**
- **426 Market Participants**
- **Jurisdictions**
  - 15 States
  - 1 Canadian Province
  - City of New Orleans



MISO Planning Objectives

MISO Board of Directors Planning Principles

Develop a transmission plan that meets all applicable NERC and Transmission Owner planning criteria and safeguards local and regional reliability through identification of transmission projects to meet those needs

Make the benefits of an economically efficient electricity market available to customers by identifying transmission projects which provide access to electricity at the lowest total electric system cost expansion plan that meets reliability needs, policy needs, and economic needs

Analyze system scenarios and make the results available to state and federal energy policy makers and other stakeholders to provide context to inform regarding choices

Fundamental Goal

The development of a comprehensive expansion plan that meets reliability needs, policy needs, and economic needs

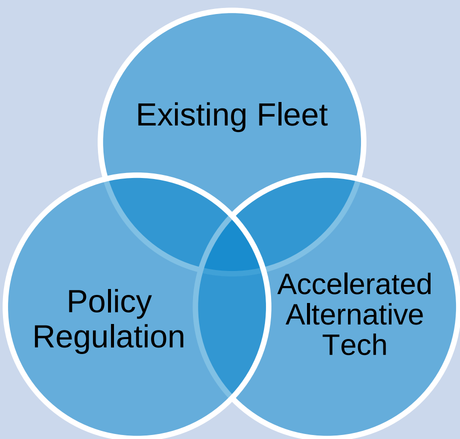
Provide an appropriate cost allocation mechanism that ensures that costs of transmission projects are allocated in a manner roughly commensurate with the projected benefits of those projects

Coordinate planning processes with neighbors and work to eliminate barriers to reliable and efficient operations

Support state and federal energy policy requirements by planning for access to a changing resource mix

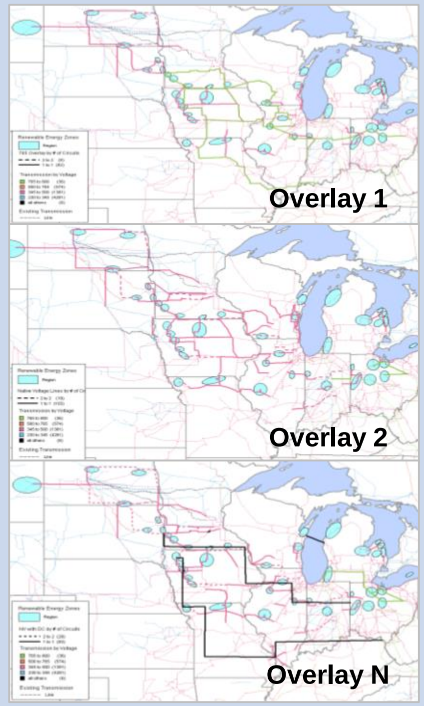
MISO's value-based transmission planning process seeks to ensure appropriate transmission projects are in place given an evolving resource portfolio

Future Development



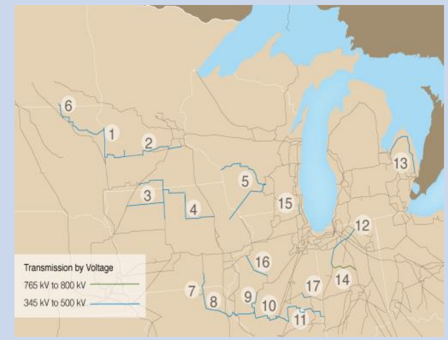
A variety of policy and economic based Futures provides multiple long-term views of future resource mix

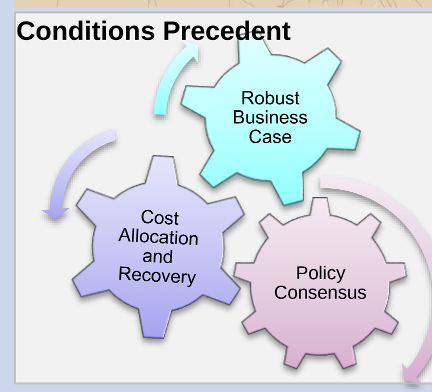
Long-term Transmission Strategy



Long-term overlay roadmaps guide near-term transmission decisions

Regional Transmission Plan Development





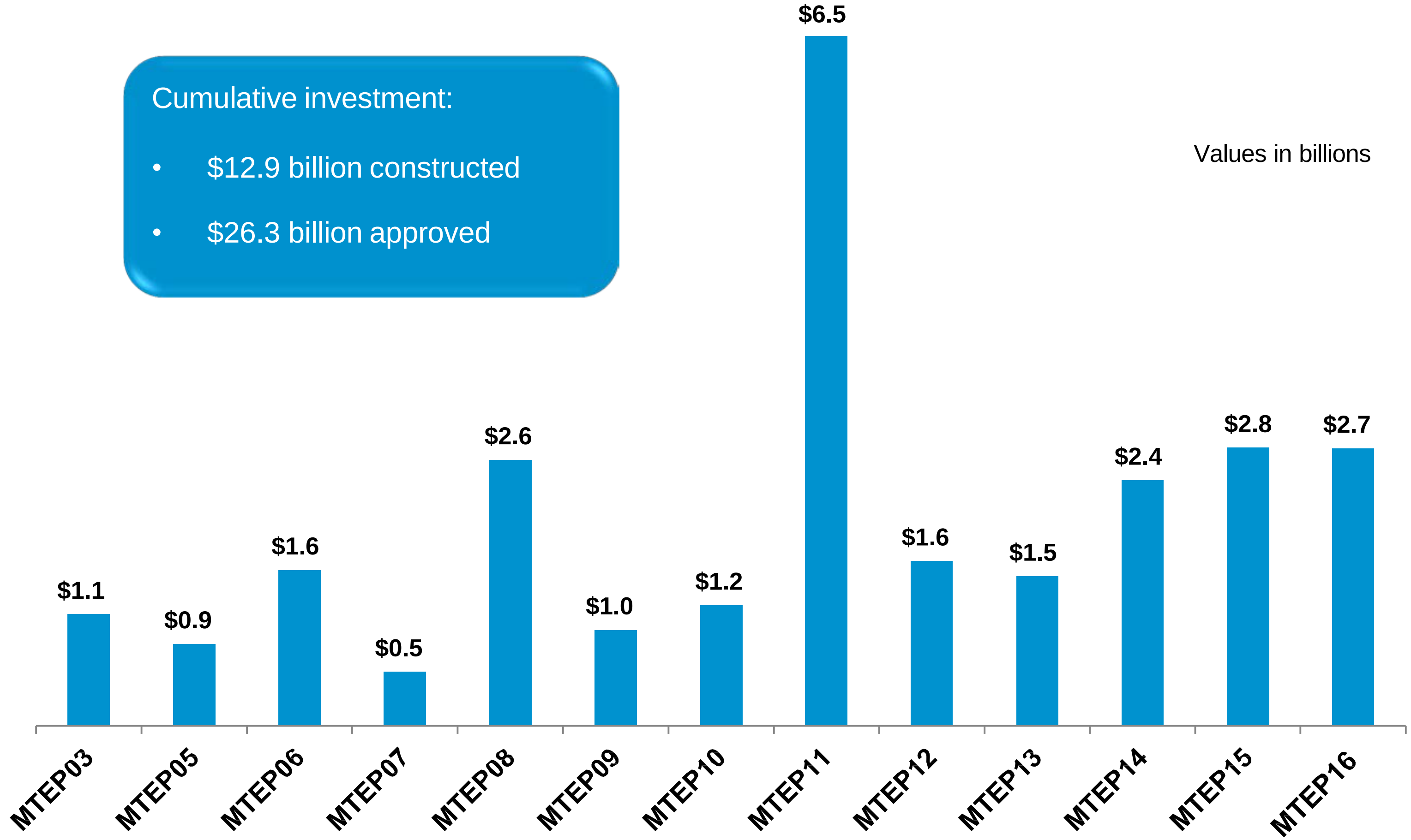
Long-term Strategy and conditions precedent frame regional transmission plan

The graphics are for illustrative purposes ONLY

Through that process MISO has facilitated significant transmission investment in its region

Cumulative investment:

- $12.9 billion constructed
- $26.3 billion approved



MISO

Some aspects of the electric and gas industries are regulated by FERC, while others are regulated by state utility commissions

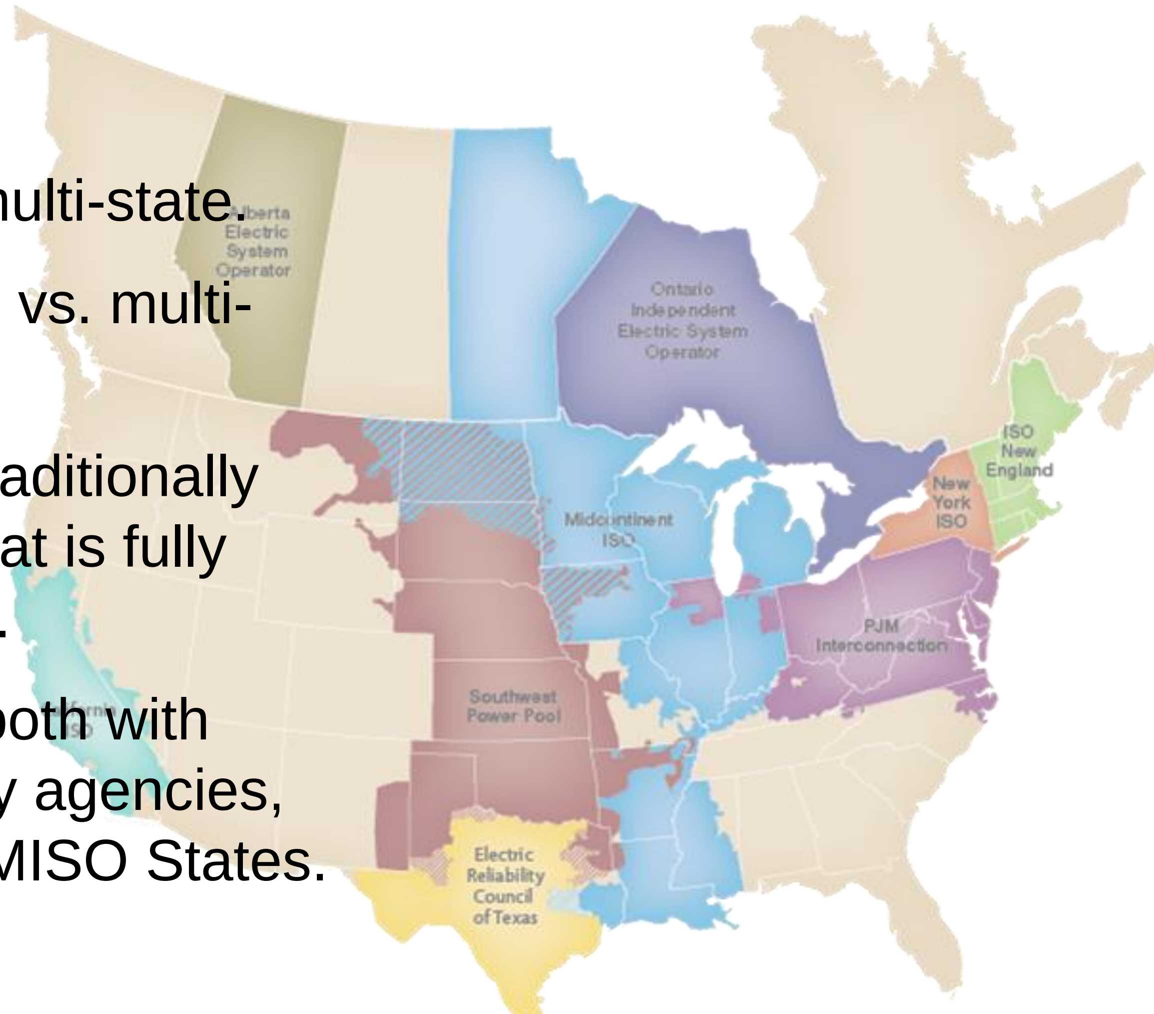
Electricity: Who regulates what?	
Generation of the commodity	Unregulated in some areas; states in others, but never FERC
Siting/ construction of generation & transmission	States
Wholesale sales, rates & transmission	FERC
Retail sales & distribution	States
Reliability of high voltage transmission system	FERC

Natural gas: Who regulates what?	
Production of the commodity	Unregulated*
Siting and construction of interstate pipelines and storage	FERC
Transportation, including rates for services	FERC
Sales of gas in interstate commerce	FERC
Local distribution companies	States

*While gas producers are subject to safety/environmental standards, they do not have state-designated "territories" as many electricity generators do, and there is no price or rate regulation at the state or federal levels.

MISO coordinates extensively with state regulatory agencies to ensure current and future energy needs are met

- RTO scope - single vs. multi-state.
- State geography – single vs. multi-RTO.
- MISO spans 15 largely traditionally regulated states – one that is fully within the MISO footprint.
- Significant coordination both with individual state regulatory agencies, and the Organization of MISO States.



2017 OPPORTUNITIES AND CHALLENGES… A VIEW FROM PJM INTERCONNECTION

WIRES UNIVERSITY

Congressional Briefing

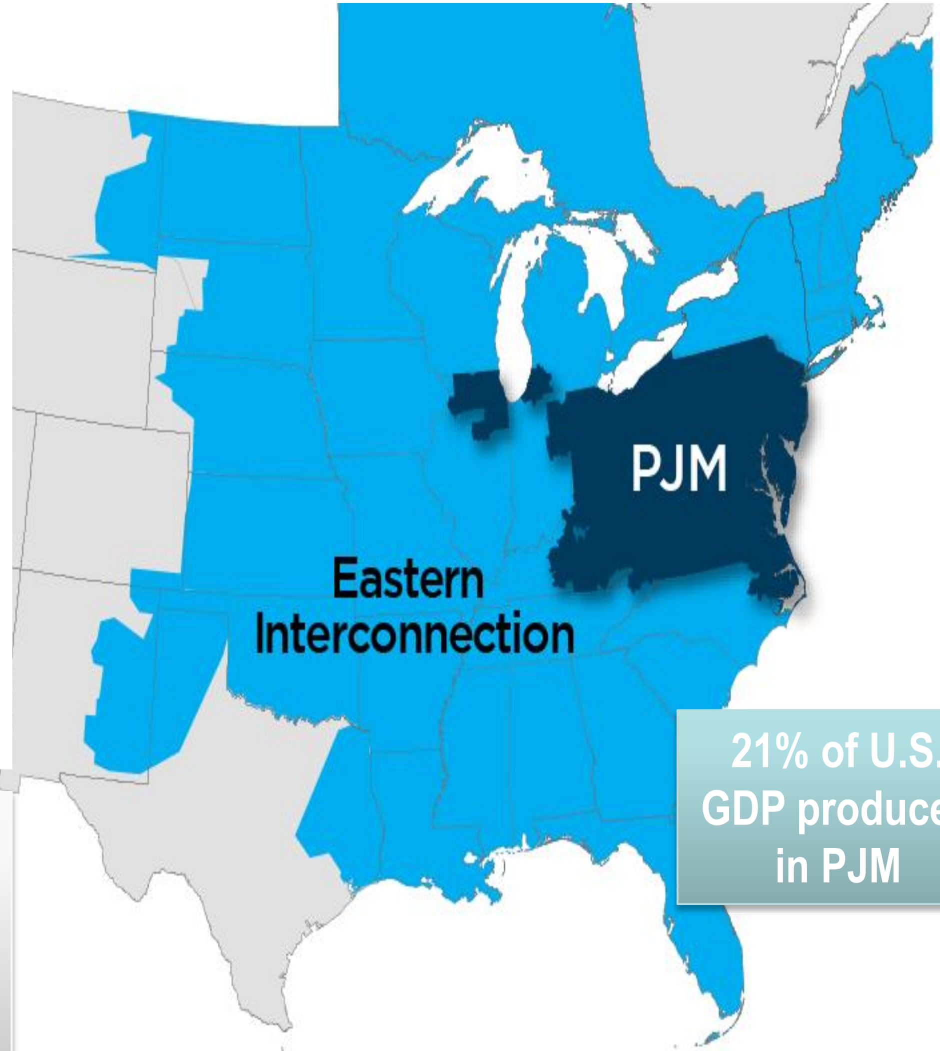
February 16, 2017

Craig Glazer
Vice President-
Federal Government Policy
PJM Interconnection

PJM as Part of the Eastern Interconnection

Member companies	960+
Millions of people served	61
Peak load in megawatts	165,492
MW of generating capacity	171,648
Miles of transmission lines	81,736
2014 GWh of annual energy	792,580
Generation sources	1,304
Square miles of territory	243,417
States served	13 + DC

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



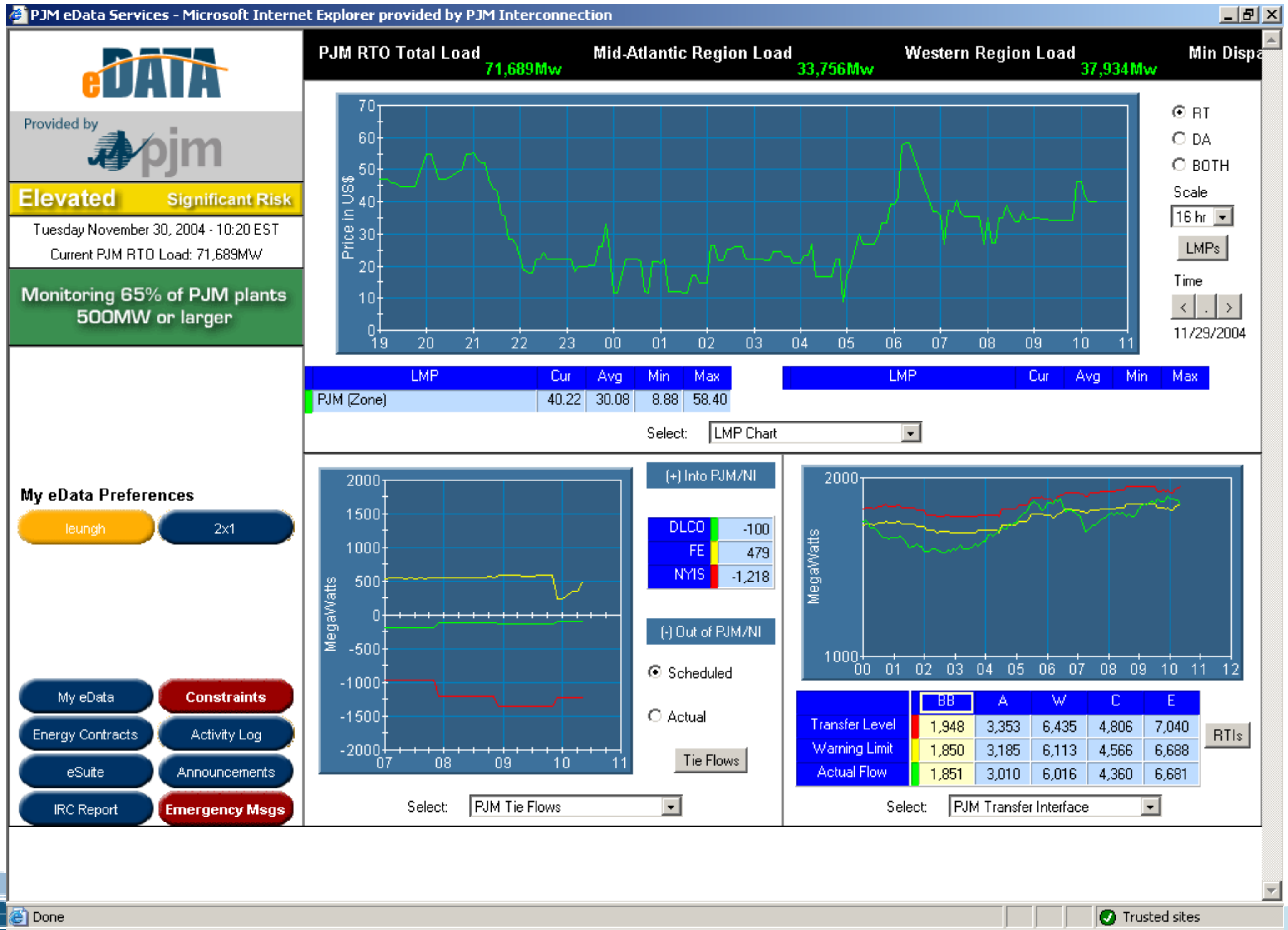
21% of U.S. GDP produced in PJM

As of 5/2016

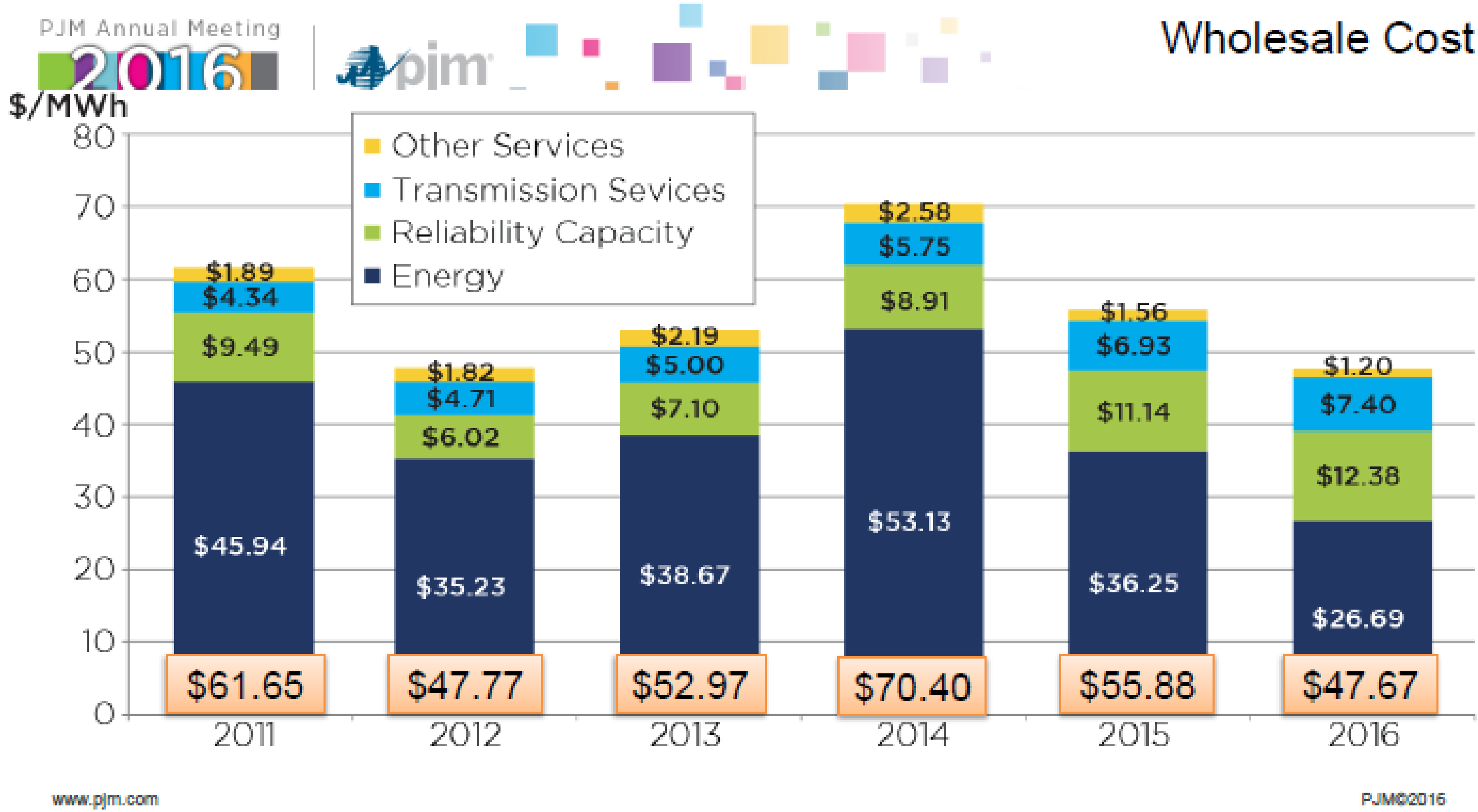
PJM – Focus on Just 3 Things

ISO RTO Council

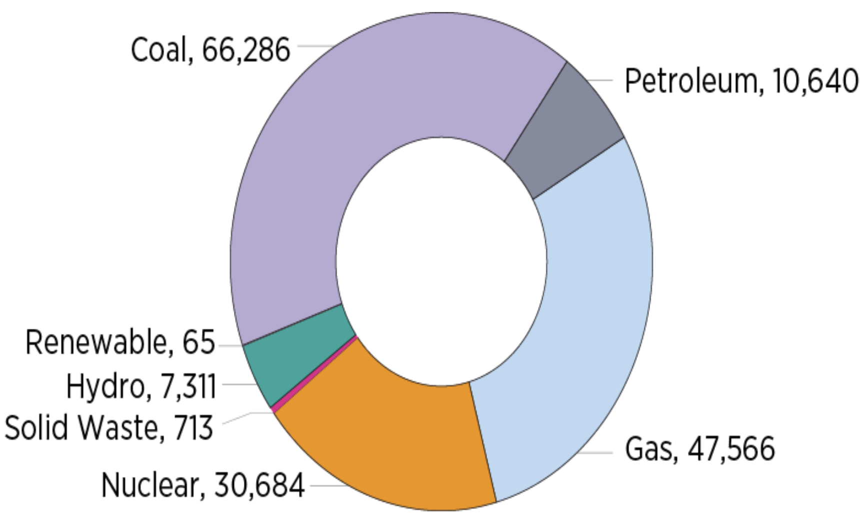
eData


PJM eData Services - Microsoft Internet Explorer provided by PJM Interconnection
PJM RTO Total Load 71,689Mw
Mid-Atlantic Region Load 33,756Mw
Western Region Load 37,934Mw
Min Dispa
Provided by pjm
Elevated Significant Risk
Tuesday November 30, 2004 - 10:20 EST
Current PJM RTO Load: 71,689MW
Monitoring 65% of PJM plants 500MW or larger
Price in US$
RT
DA
BOTH
Scale
16 hr
LMPs
Time
11/29/2004
LMP Cur Avg Min Max
PJM (Zone) 40.22 30.08 8.88 58.40
Select: LMP Chart
My eData Preferences
leungh
2x1
MegaWatts
(+) Into PJM/NI
DLCO -100
FE 479
NYIS -1,218
(-) Out of PJM/NI
Scheduled
Actual
Tie Flows
Select: PJM Tie Flows
BB A W C E
Transfer Level 1,948 3,353 6,435 4,806 7,040
Warning Limit 1,850 3,185 6,113 4,566 6,688
Actual Flow 1,851 3,010 6,016 4,360 6,681
RTIs
Select: PJM Transfer Interface
My eData
Constraints
Energy Contracts
Activity Log
eSuite
Announcements
IRC Report
Emergency Msgs
Done
Trusted sites

Wholesale Cost

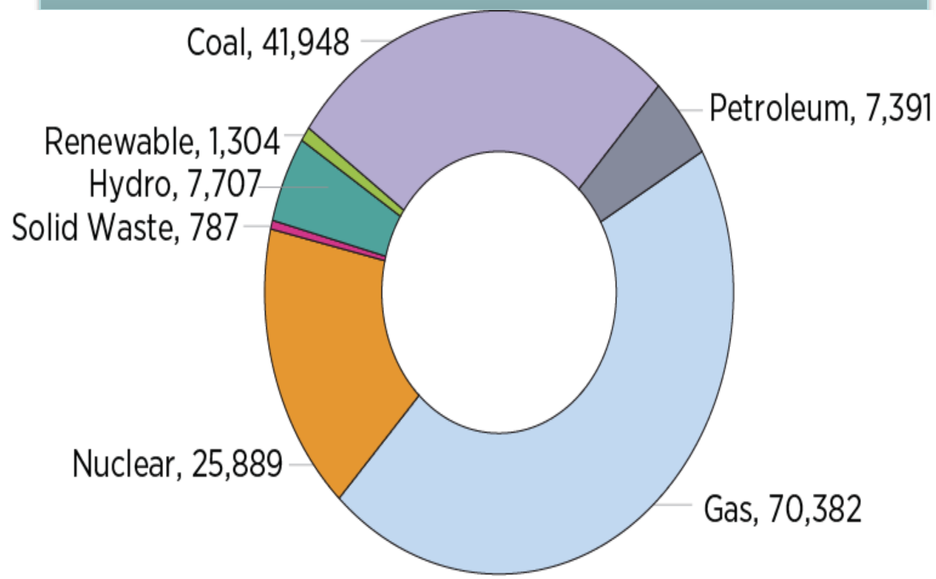


2007 PJM Installed Capacity (MW)



Iron in the Ground (ICAP)

Cleared Capacity for 2019/2020 Delivery Year (MW)



(UC
AP)

POLICY CHOICES…

The Long and Winding Road…

- Transmission: Built to support major generation projects
- Connect distant generation to load; Distribution: One way delivery of power to the home
- Grid Costs: Rate-based to the home utility's customers
- ROI: Little focus on transmission as a stand alone business element

Policy Choice #1

Is the grid an enabler or a competitor?

Grid as an Enabler?

- Accept the grid as a natural monopoly
- Drive solutions through regulation
- Provide incentives for innovation

Policy Choice #1 (cont'd)

Grid as a Competitor?

- Grid development must compete with generation or demand side
- Grid entrepreneurs take risk: no guaranteed ROI
- Grid pricing reflects competitive outcomes: Bid solutions into the marketplace (RPM)

Policy Choice #2: A Strong or Weak Grid?

Characteristics of the "Strong" Grid:

- Generation distance from load
- Meet the needs for future transmission expansion
- Costs socialized to reflect interconnected nature of the grid
- Broad regional approach

Policy Choice #2-The Alternative:

The localized grid…

- Generation closer to load
- Centralized focus on development of DSR, energy efficiency and renewables
- Transmission/distribution grid as an enabler of alternative generation
- Transmission focused on meeting state/local needs

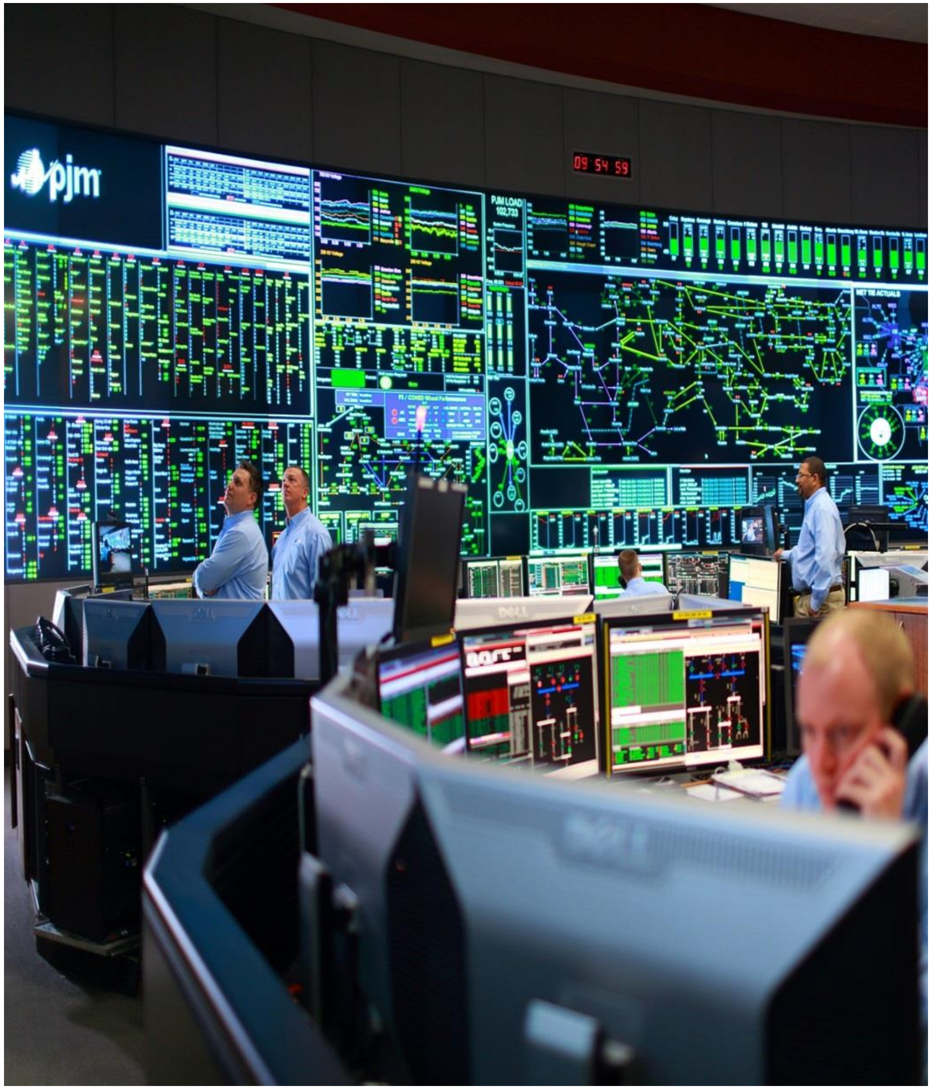
An Added Complication:

Who Decides?

Who Decides?

- States:
  - State Energy Policies: Governors/legislators
  - State PUCs
- FERC
  - FERC Order 1000
- Environmental Agencies
  - Non-attainment areas
  - RGGI et al.

PJM's Control Room



LET'S TALK…

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National Electrical Manufacturers Association
WIRES
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Environmental and Energy
Study Institute
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