

SPP RENEWABLE INTEGRATION

Casey Cathey, P.E.

Manager, Operations Engineering Analysis & Support



SouthwestPowerPool

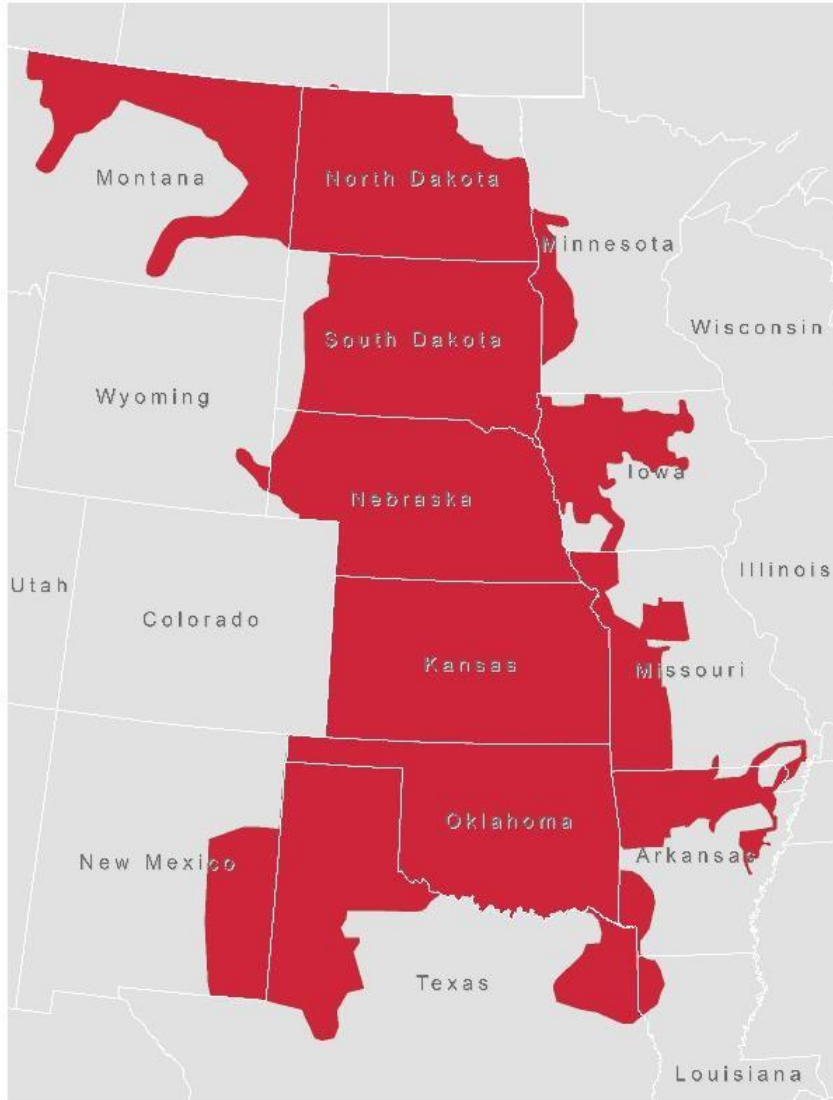


SPP.org



southwest-power-pool

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 MARKET

Integrated Marketplace

- Buy/sell wholesale electricity in DA and RT
 - Energy
 - Operating Reserves
 - Regulation Up
 - Regulation Down
 - Spinning
 - Supplemental

Key Market Processes:

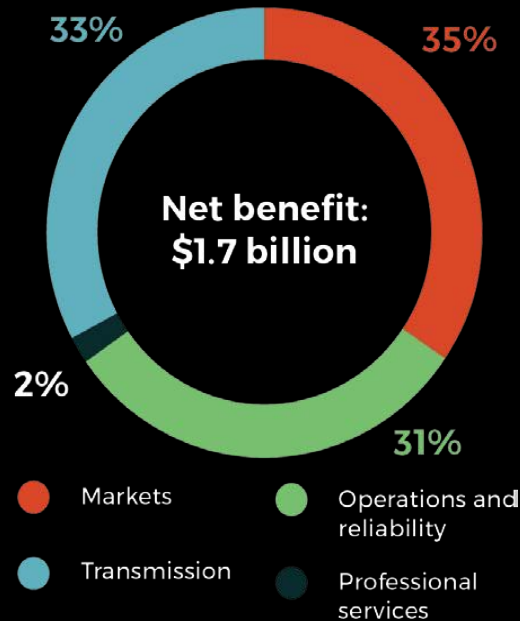
Multi-day Reliability Assessment, DA Market, Reliability Unit Commitment, RTBM, Settlements, TCR Market

SPP MARKET FACTS

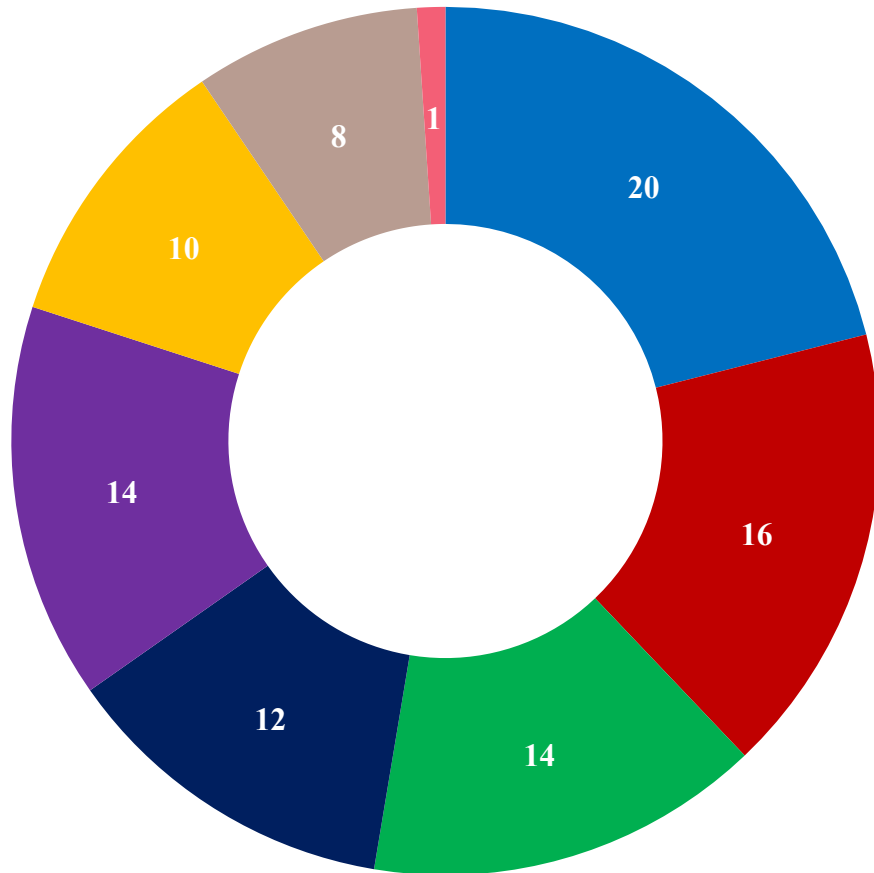
- 185 participants
- 785 generating Resources
- 2016 Marketplace Settlements = \$15.8 billion
- 50,622 MW coincident peak load (7/21/16)
- Wind penetration record: 54.47% (4/24/17)
- Renewable penetration record: 57.52%

THE VALUE OF

Transmission planning market administration reliability coordination and other services provide net benefits to SPP's members in excess of more than \$1.7 billion annually at a benefit-to-cost ratio of 11-to-1.



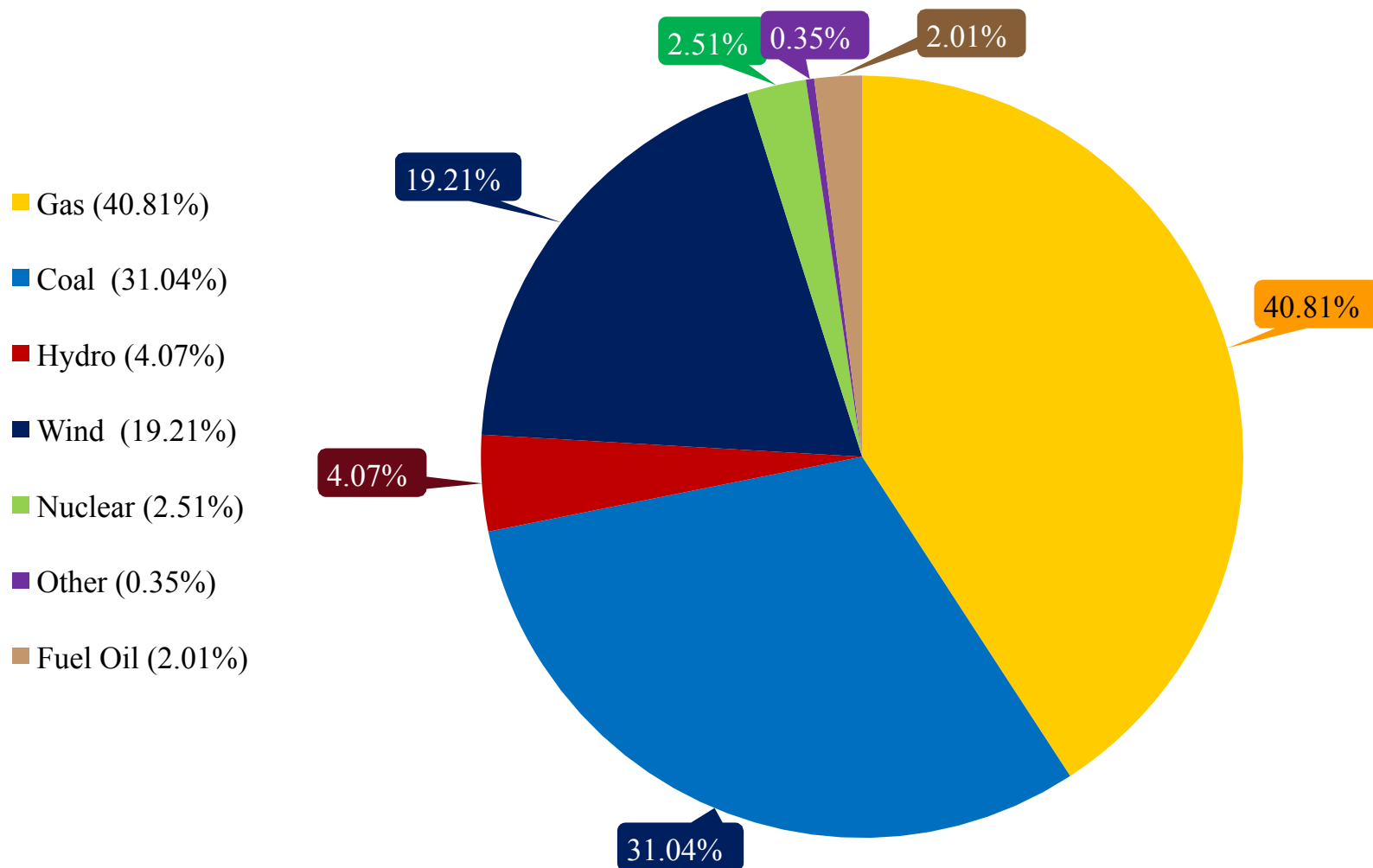
95 MEMBERS: INDEPENDENCE THROUGH DIVERSITY



- Cooperatives (20)
- Investor-Owned Utilities (16)
- Independent Power Producers/Wholesale Generation (14)
- Power Marketers (12)
- Municipal Systems (14)
- Independent Transmission Companies (10)
- State Agencies (8)
- Federal Agencies (1)

As of April 12, 2017

TOTAL ENERGY CAPACITY* BY FUEL TYPE

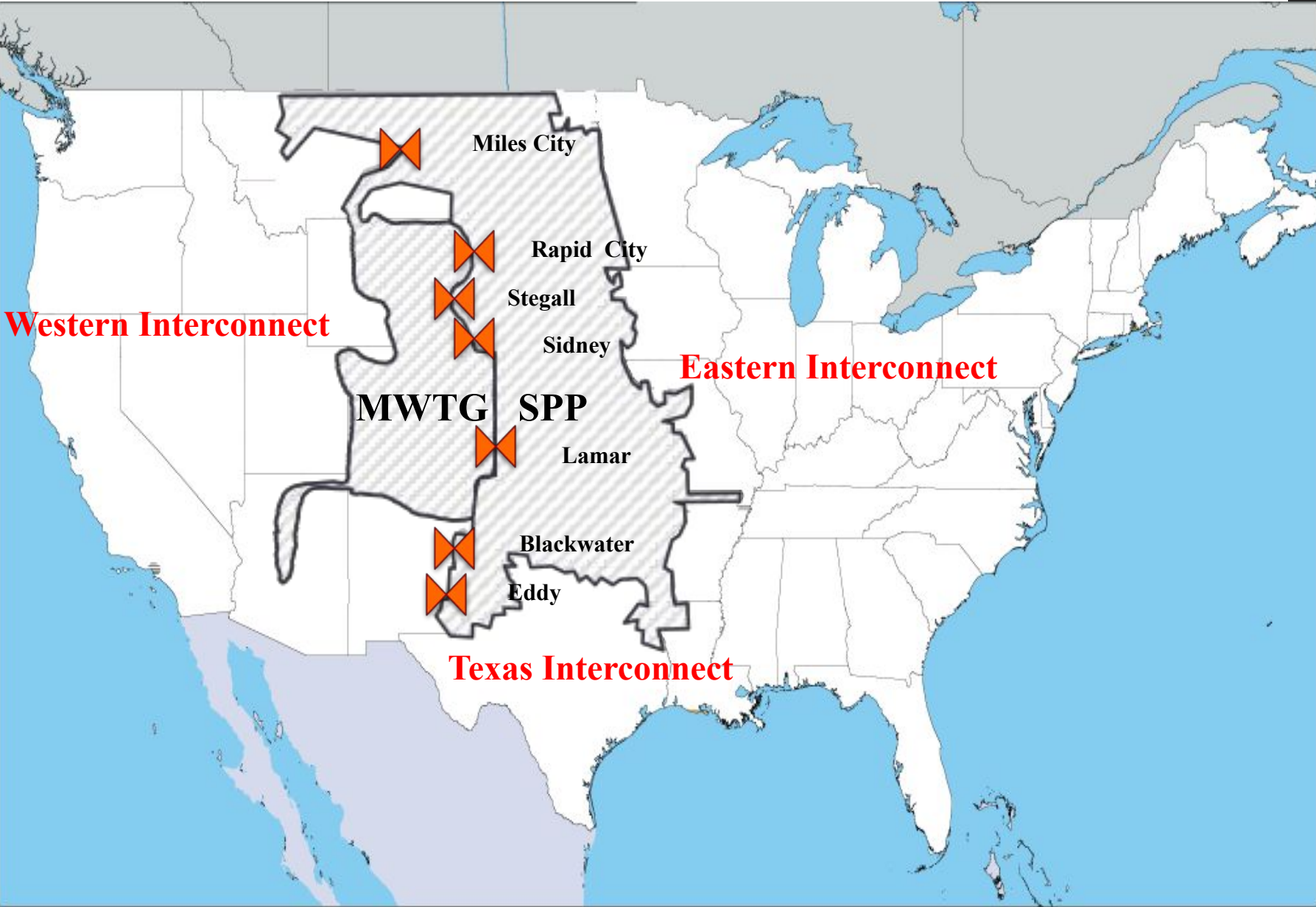


* Figures refer to nameplate capacity as of 1/1/17

THE SPP FOOTPRINT TOMORROW

*SPP IN DISCUSSIONS
WITH THE WEST*

MWTG AND SPP FOOTPRINT (WITH DC TIES)



MWTG

STATISTICS

- **8 States: Wyoming, Montana, Nebraska, South Dakota, New Mexico, Colorado, Utah, Arizona**
- **10 Transmission Systems:**
 - Black Hills Corp (IOUs)
 - Black Hills Colorado Electric Co.
 - Black Hills Power, Inc.
 - Cheyenne Light Fuel & Power
 - Public Service of CO (IOU)
 - Colorado Springs Utilities (Muni)
 - Basin Electric Power Coop (Cooperative)
 - Platte River Power Authority (Muni)
 - Tri-state G&T (Cooperative)
 - WAPA Loveland Area Projects “LAP” (Federal PMA)
 - WAPA Colorado River Storage Project “CRSP” (Federal PMA)
- **12 CP load of 12.4 GW (approx. 28% increase)**
- **6.4 million customers (approx. 35% increase)**
- **15,700 miles of transmission (approx. 24% increase)**

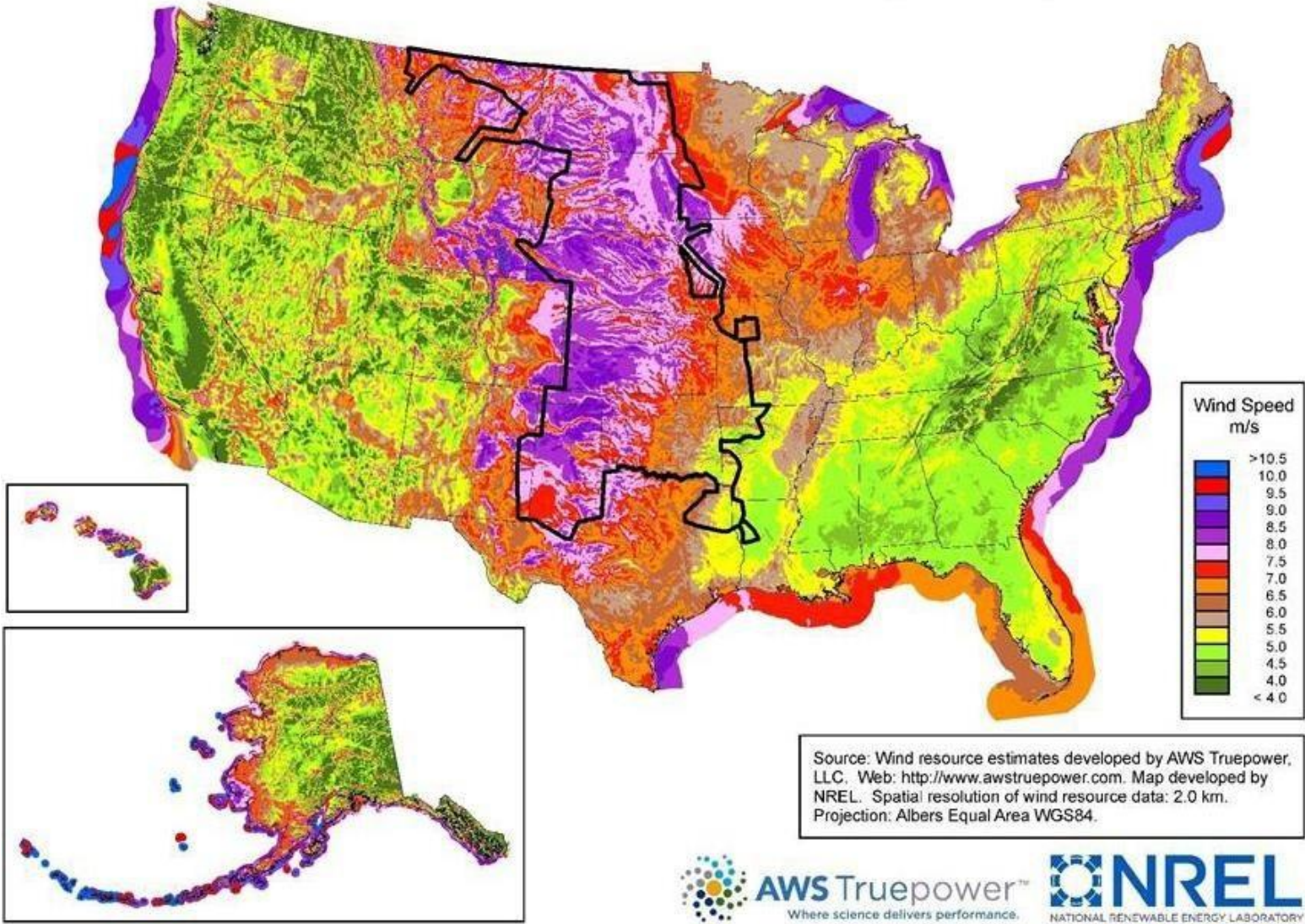
VARIABLE
RESOURCE
INTEGRATION
AND
CHALLENGES

WHAT'S NEXT FOR WIND IN SPP?

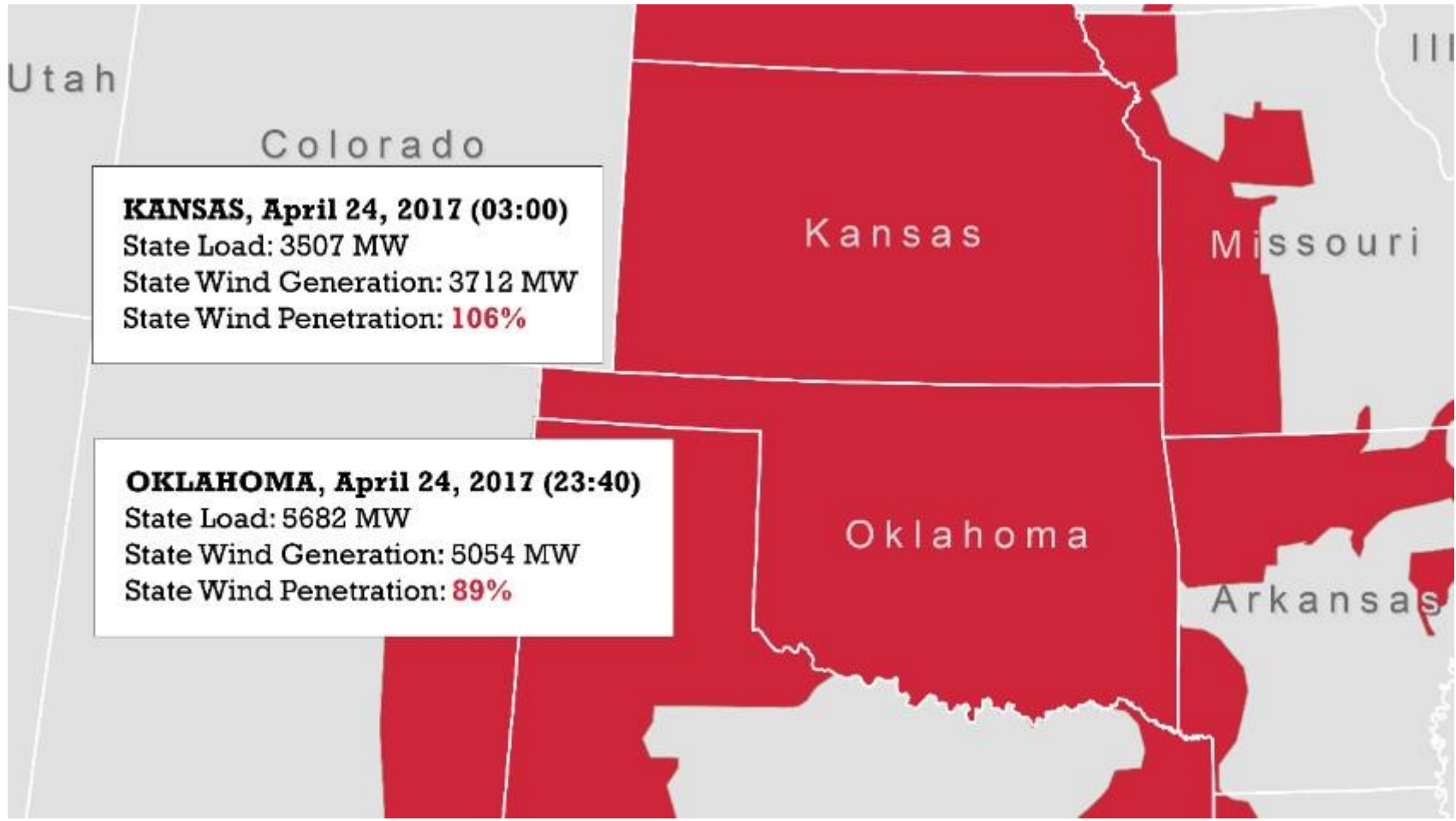
- SPP's "Saudi Arabia" of wind: Kansas, Oklahoma, Nebraska, Texas Panhandle, and New Mexico
 - 60,000-90,000 MW potential
 - More wind energy than SPP uses during peak demand
- 17,885 MW capacity of in-service wind
- 43,839 MW wind in all stages of development
 - Includes 36,790 MW in the Generation Interconnection queue and 7,049 MW of executed Interconnection Agreements

WIND SPEED MAP – SPP FOOTPRINT

United States - Land-Based and Offshore Annual Average Wind Speed at 80 m



BREAKING STATE RENEWABLE RECORDS

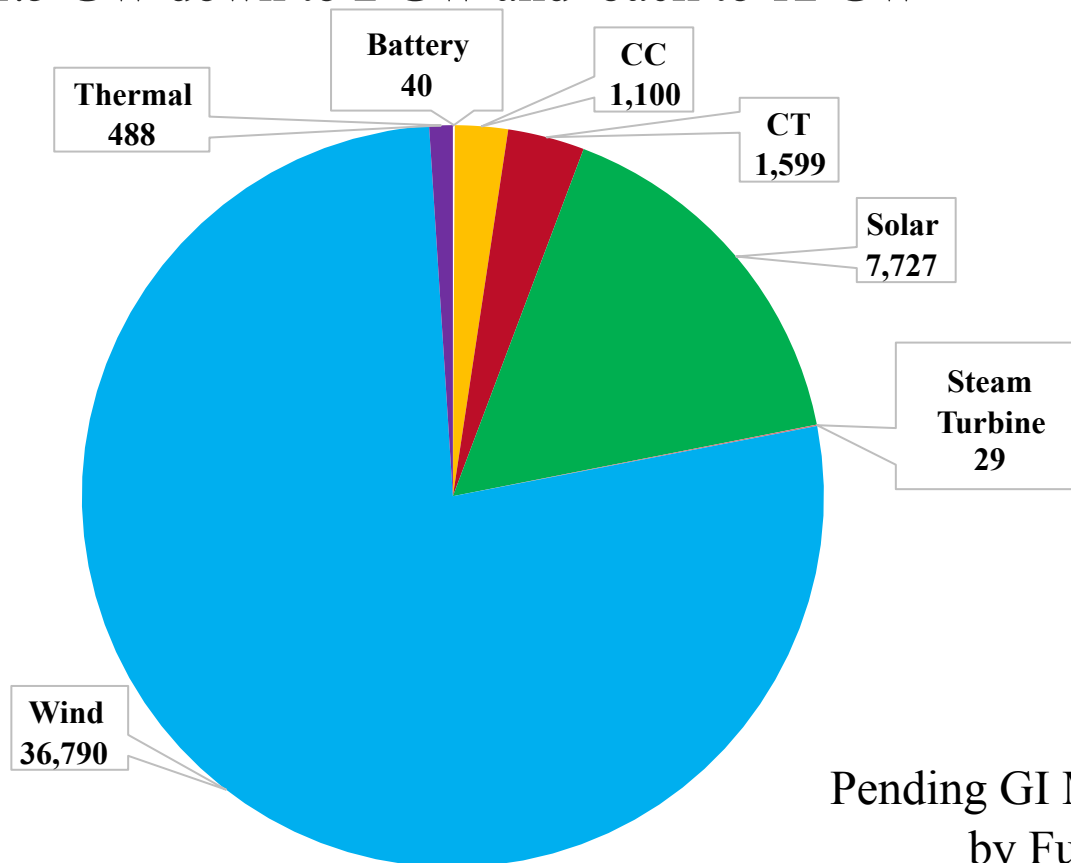


SPP WIND NUMBERS

- **177 windfarms (9,112 turbines) connected to SPP's system**
- Largest is 400 MW (Grand Prairie in Nebraska, Holt County)
- **Windfarm PTC beginning to expire**
 - pricing is going from negative (25-35) to zero \$
- **Maximum output 13,342 MW**
- Recent 4hr ahead forecast error approximately **4%**
 - However, with increased wind, the MW error amount continues to increase although SPP continuously improves forecast accuracy
- **Maximum historical ramp in one hour totaled 3700 MW**
- **Max penetration level forecasted at 63%, however, congestion and Energy pricing curtailed wind output**
- Average wind penetration for 2017 averaged 22% of Energy

INSTALLED WIND

- Wind in the queue totals ~37 GW
- Expect to be over 20 GW by 2020
 - More than our minimum load, just below 20GW
- Wind swing in one day has been over 10GW
 - From 12.5 GW down to 2 GW and back to 12 GW

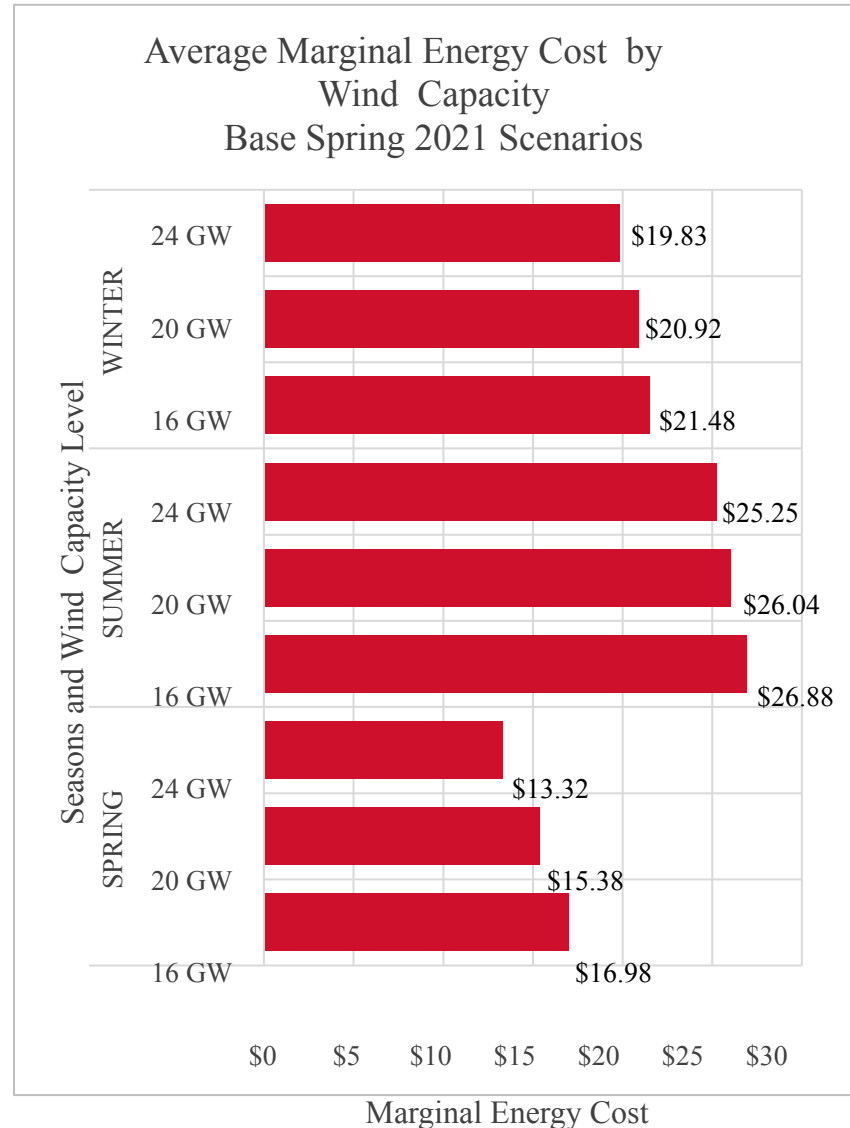


Pending GI MW Requested
by Fuel Type
8/16/2017

FUTURE LMP MARKET SENSITIVITIES

- Scenarios run for 2021 loads and varying fuel mixes
- Increased wind capacity from base 2017 levels (16 MW) to 20 and 24 GW levels
- Market pricing, clearing, and generator usage was assessed

LMP Prices dropped from almost \$2 to over \$3 per MW seasonally as wind increased from 16 to 24 GW



SPP WIND CHALLENGES

- Capacity management
 - Must be able to replace capacity when the wind is not there
- Thermal congestion
 - Honor thermal limitations mostly on transmission lines and transformers
- Ramping
 - Wind moves and SPP requires ramp to forecast and react quickly and reliably to balance
- Voltage support
 - Providing the proper voltage support locally, with high region-wide wind transfers
- Primary frequency response (PFR) / System inertia
 - Ensure the Interconnect is not at risk with further reduction of PFR or System inertia

EFFORTS TO CONTINUE SUSTAINABILITY

- Integrating RT voltage stability tools for member access
- Preparing to host a replicated data server analysis
- Working with the membership to install more PMUs
- Monitoring system inertia and primary frequency response
- Potential expansion of geographic load footprint
- Potential Market Design Enhancements
- Working tools to integrate RT transient stability
- Working to streamline renewable policies within the SPP Tariff

MARKET ENHANCEMENTS

MARKET ENHANCEMENTS THAT SUPPORT INTERMITTENT RESOURCE INTEGRATION

- NDVER to DVER Conversion
- Enhanced VER Data for Forecasting
- DVER Regulation Enhancement
- Regulation-up for Market Design VERs
- Stored Energy Resources
- Fast Start Resources
- 30 Minute Product
- Ramp Product
- Primary Frequency Response – Future Consideration
- System Inertial Response – Future Consideration

Our Mission

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