SPP RENEWABLE INTEGRATION

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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

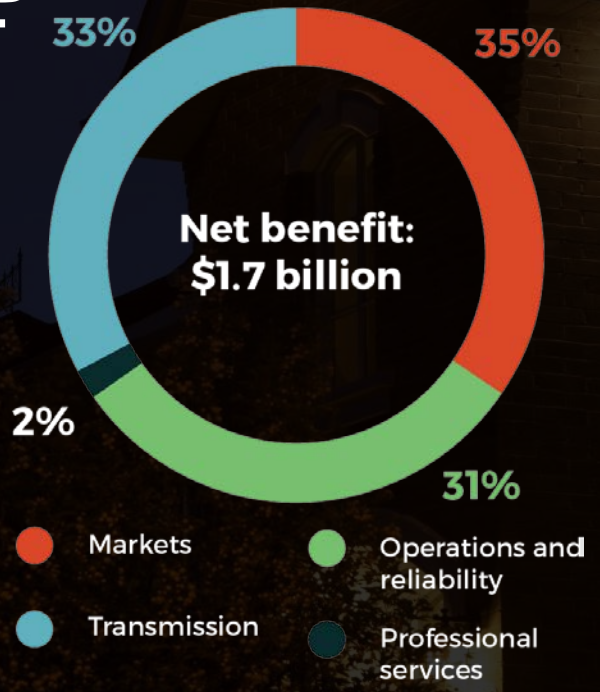
Key Market Processes:
Multi-day Reliability Assessment, DA Market, Reliability Unit Commitment, RTBM, Settlements, TCR Market

SPP MARKET FACTS

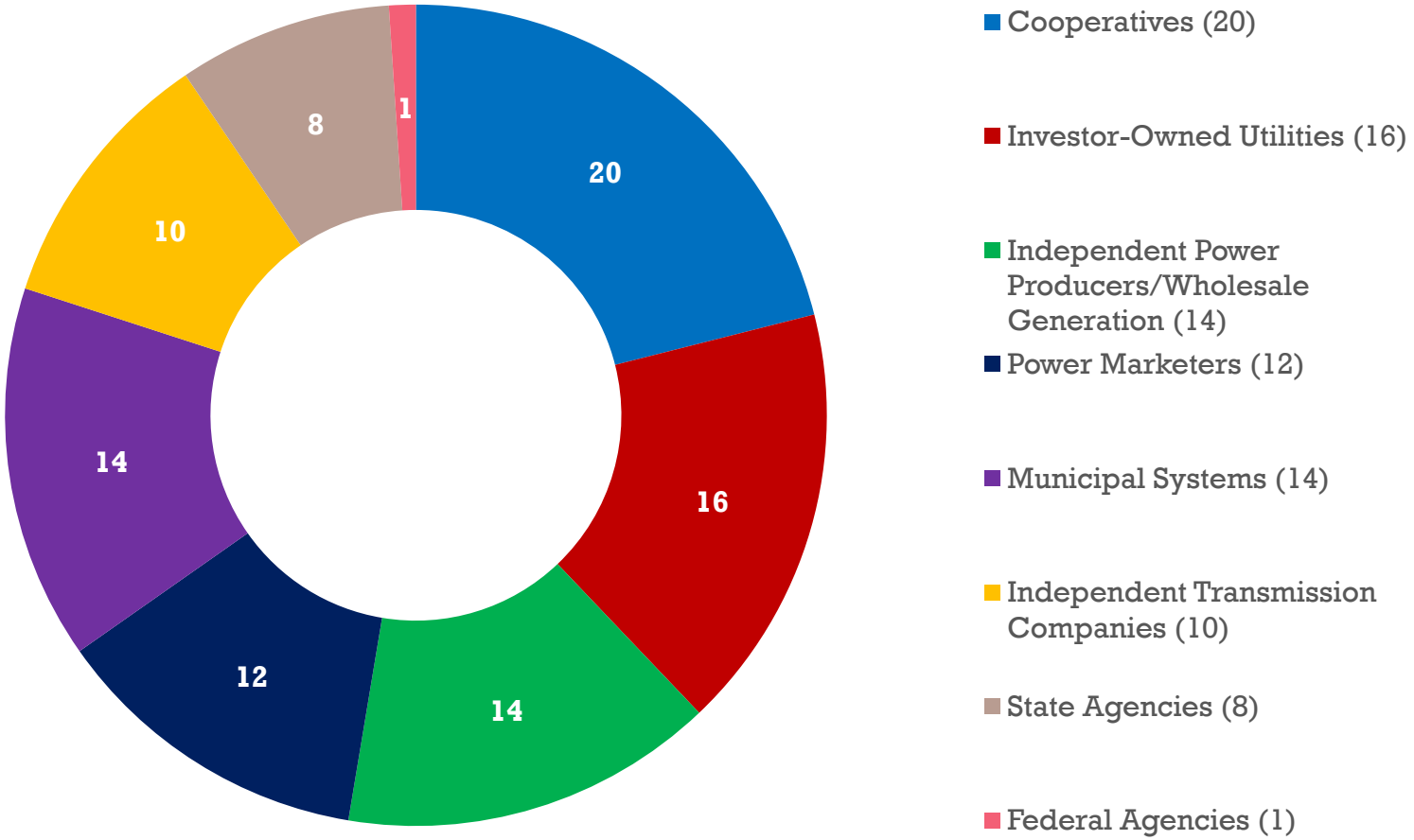
- 185 participants
- 785 generating Resources
- 2016 Marketplace Settlements = $15.8 billion
- 50,622 MW coincident peak load (7/21/16)
- Wind penetration record: 54.47% (4/24/17)
- Renewable penetration record: 57.52%

THE VALUE OF SPP

- 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.

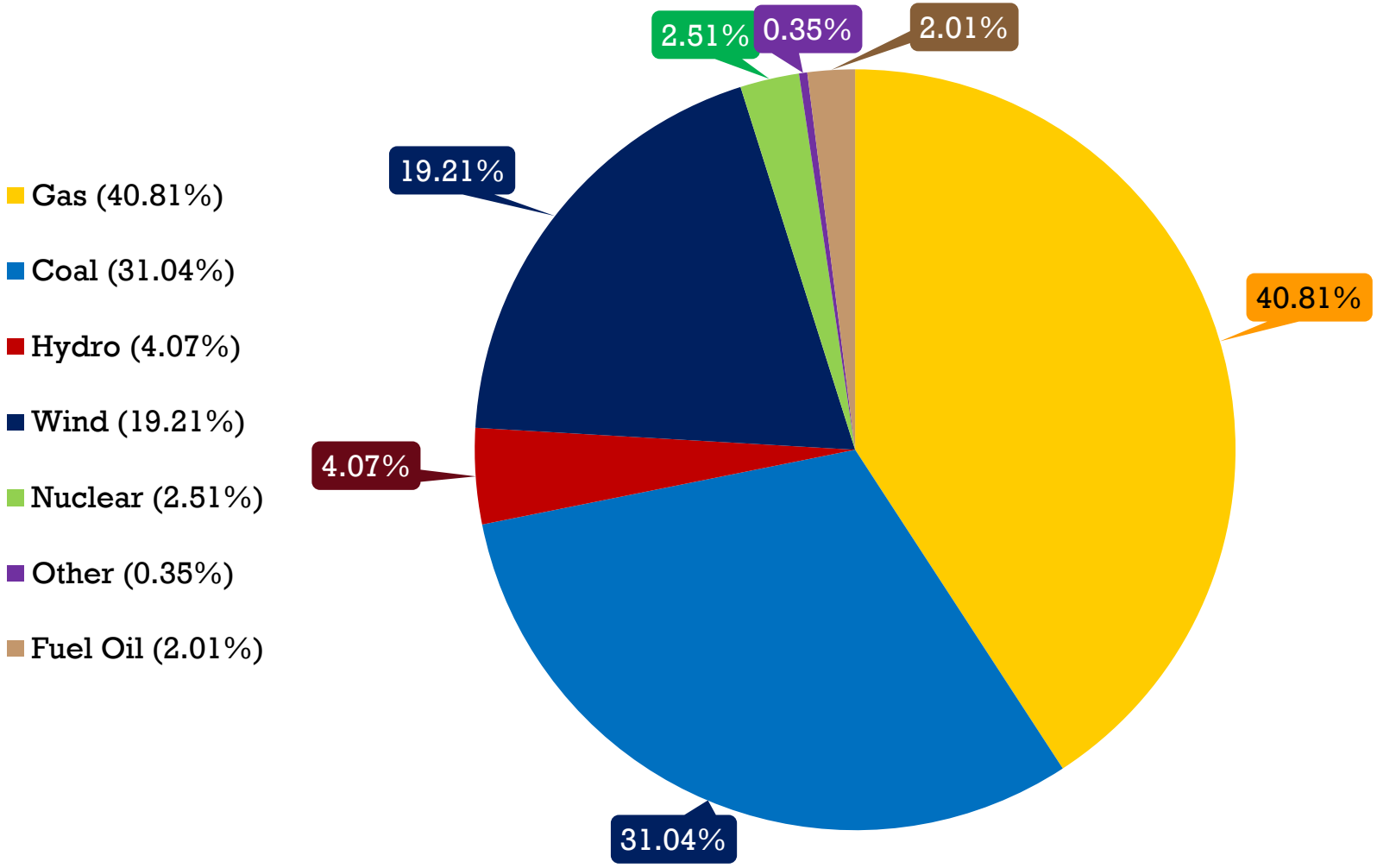


95 MEMBERS: INDEPENDENCE THROUGH DIVERSITY



As of April 12, 2017

TOTAL ENERGY CAPACITY* BY FUEL TYPE

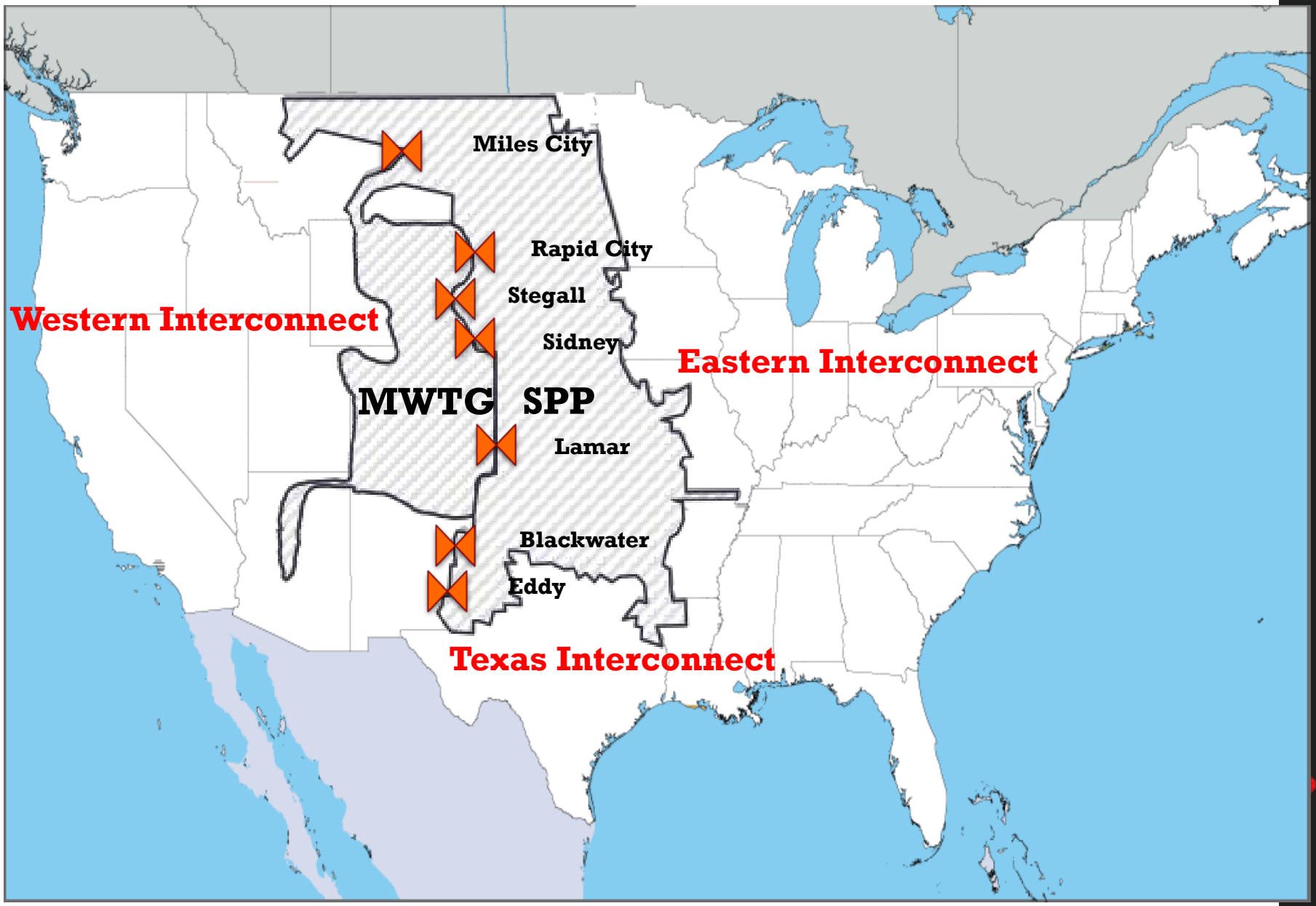


* Figures refer to nameplate capacity as of 1/1/17

THE SPP FOOTPRINT TOMORROW

SPP IN DISCUSSIONS WITH THE WEST

MWTG AND SPP FOOTPRINT (WITH DC TIES)



MWTG STATISTICS

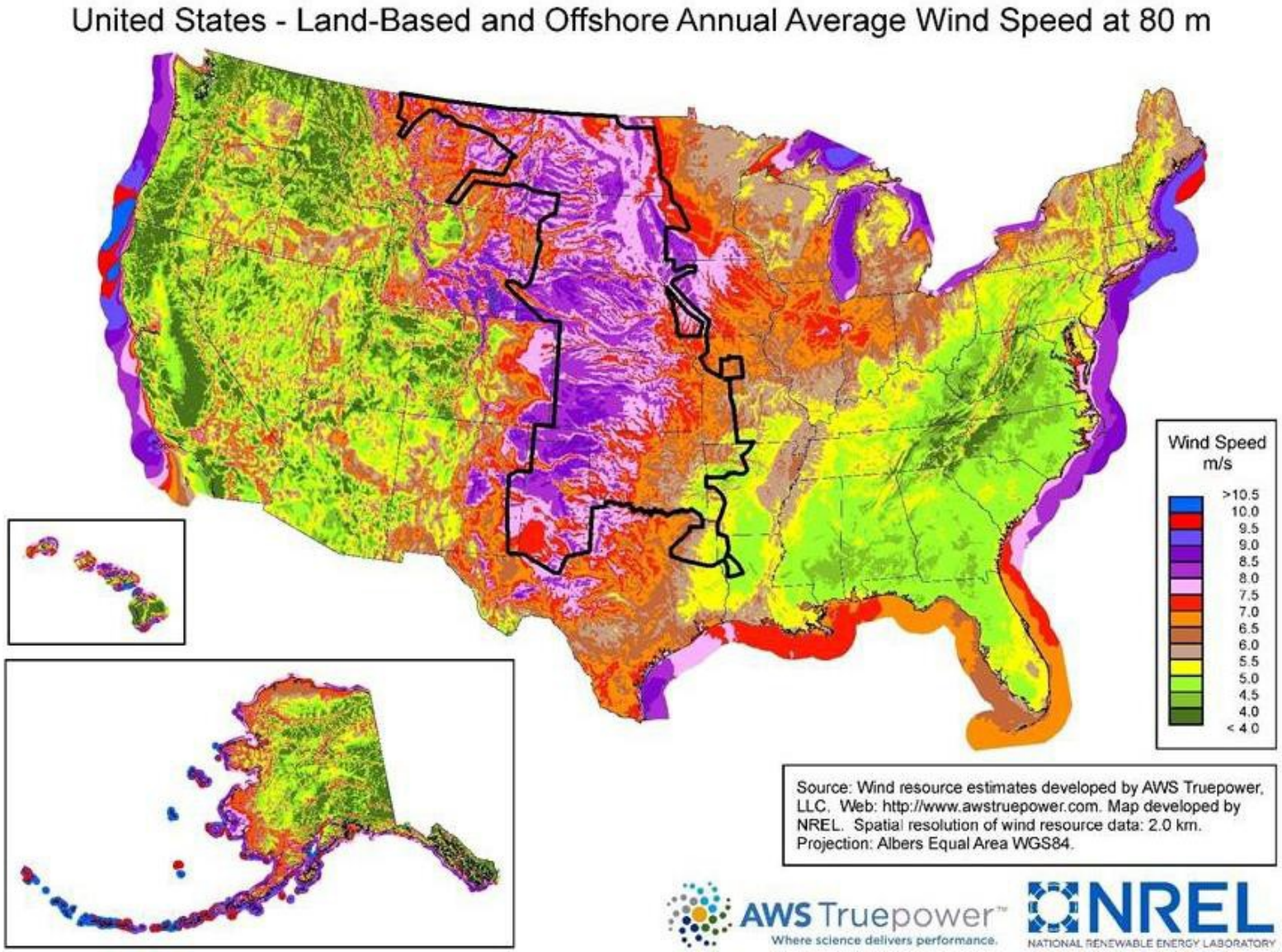
- **8 States: Wyoming, Montana, Nebraska, South Dakota, New Mexico, Colorado, Utah, Arizona**
- **10 Transmission Systems:**
  - Black Hills Corp (IOUs)
    - Black Hills Colorado Electric Co.
    - Black Hills Power, Inc.
    - Cheyenne Light Fuel & Power
  - Public Service of CO (IOU)
  - Colorado 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

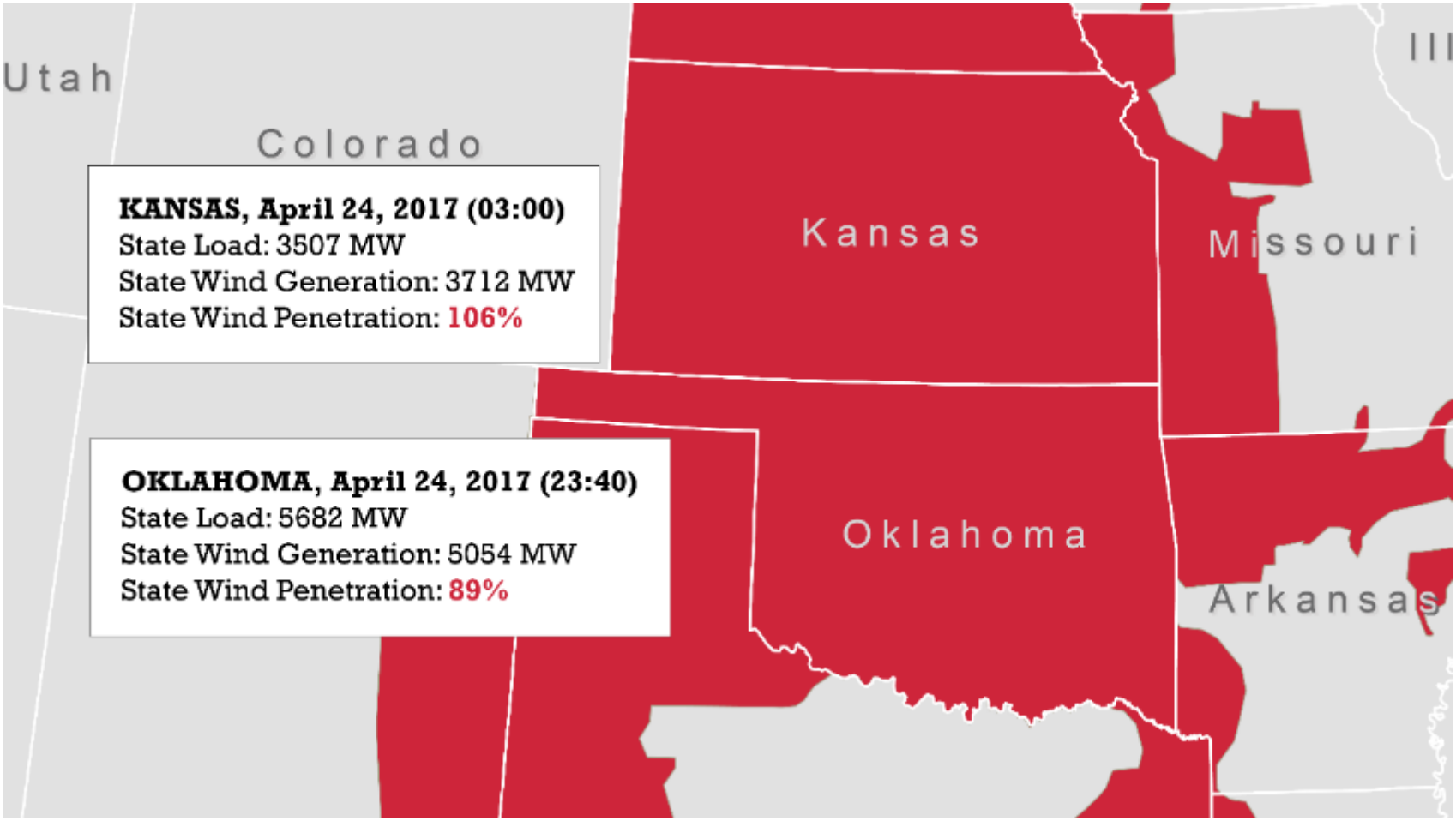
WHAT'S NEXT FOR WIND IN SPP?

- 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



BREAKING STATE RENEWABLE RECORDS

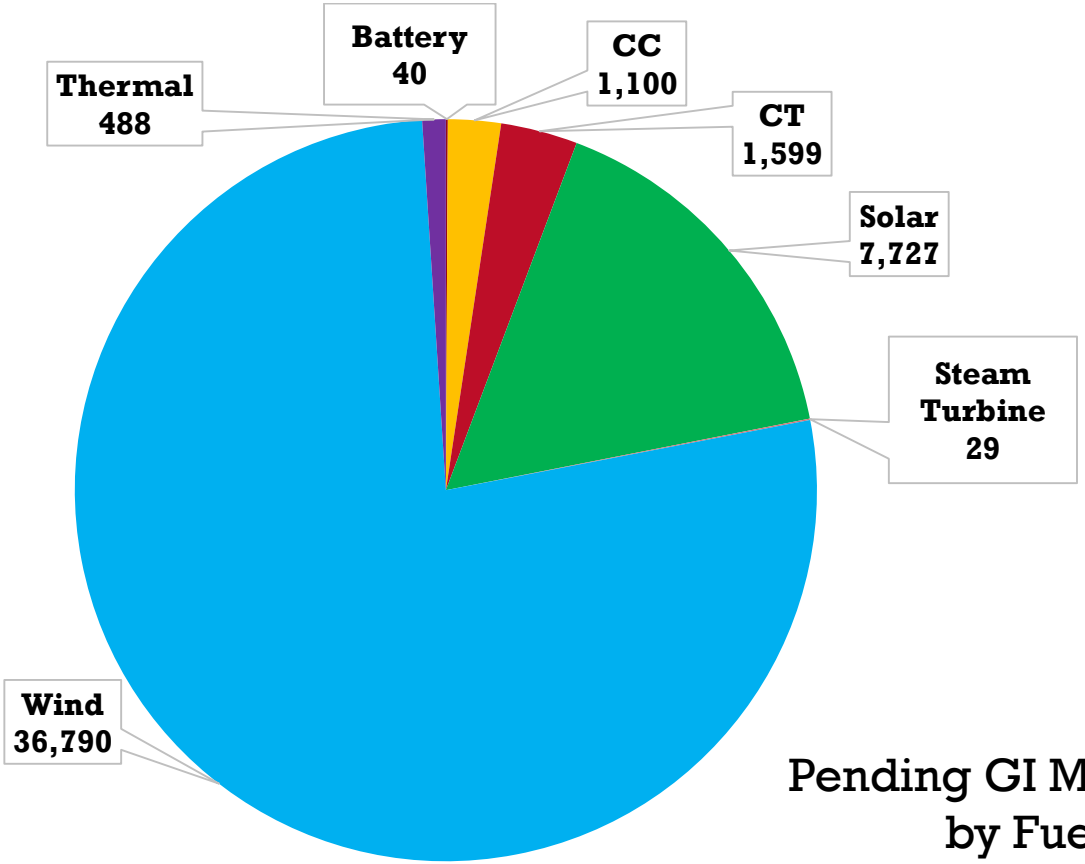


SPP WIND NUMBERS

- **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

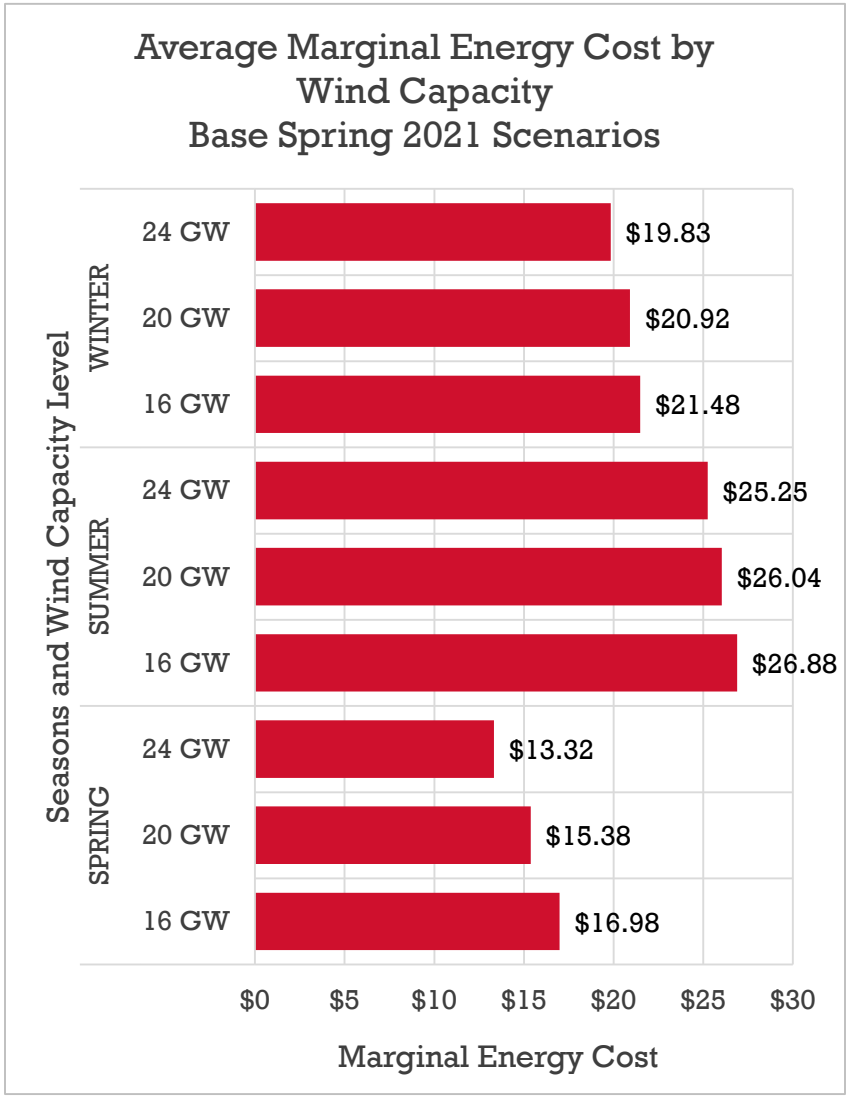
- Wind in the queue totals ~37 GW
- Expect to be over 20 GW by 2020
  - More than our minimum load, just below 20GW
- Wind swing in one day has been over 10GW
  - From 12.5 GW down to 2 GW and back to 12 GW



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
- Preparing to host a replicated data server for member access
- Working to integrate RT transient stability analysis tools
- Working to streamline renewable policies within the SPP Tariff
- 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

MARKET ENHANCEMENTS

MARKET ENHANCEMENTS THAT SUPPORT INTERMITTENT RESOURCE INTEGRATION

- NDVER to DVER Conversion
- Enhanced VER Data for Forecasting
- DVER Regulation Enhancement
- Regulation-up Market Design for 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.