
SPP Southwest Power Pool
HELPING OUR MEMBERS WORK TOGETHER
TO KEEP THE LIGHTS ON... TODAY AND IN THE FUTURE.
Updated March 2018

INTERCONNECTIONS SEAM STUDY

IEEE West Michigan Chapter

Grand Rapids, Michigan

April 11, 2019

Jay Caspary, Director – Research, Development & Tariff Services

SouthwestPowerPool SPPorg southwest-power-pool

Our Mission

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

OUR BEGINNING

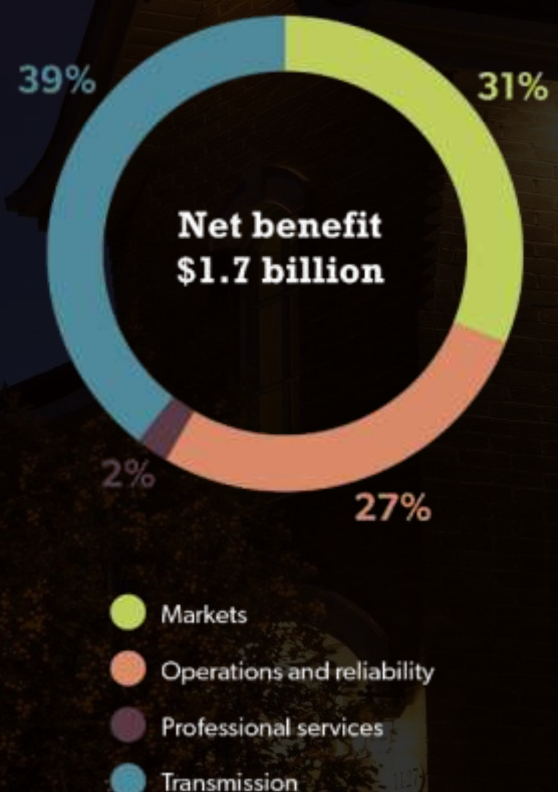
- In 1941, 11 member utilities pooled electricity to power aluminum plant at Jones Mill needed for critical defense
- Maintained after WWII to continue benefits of regional coordination

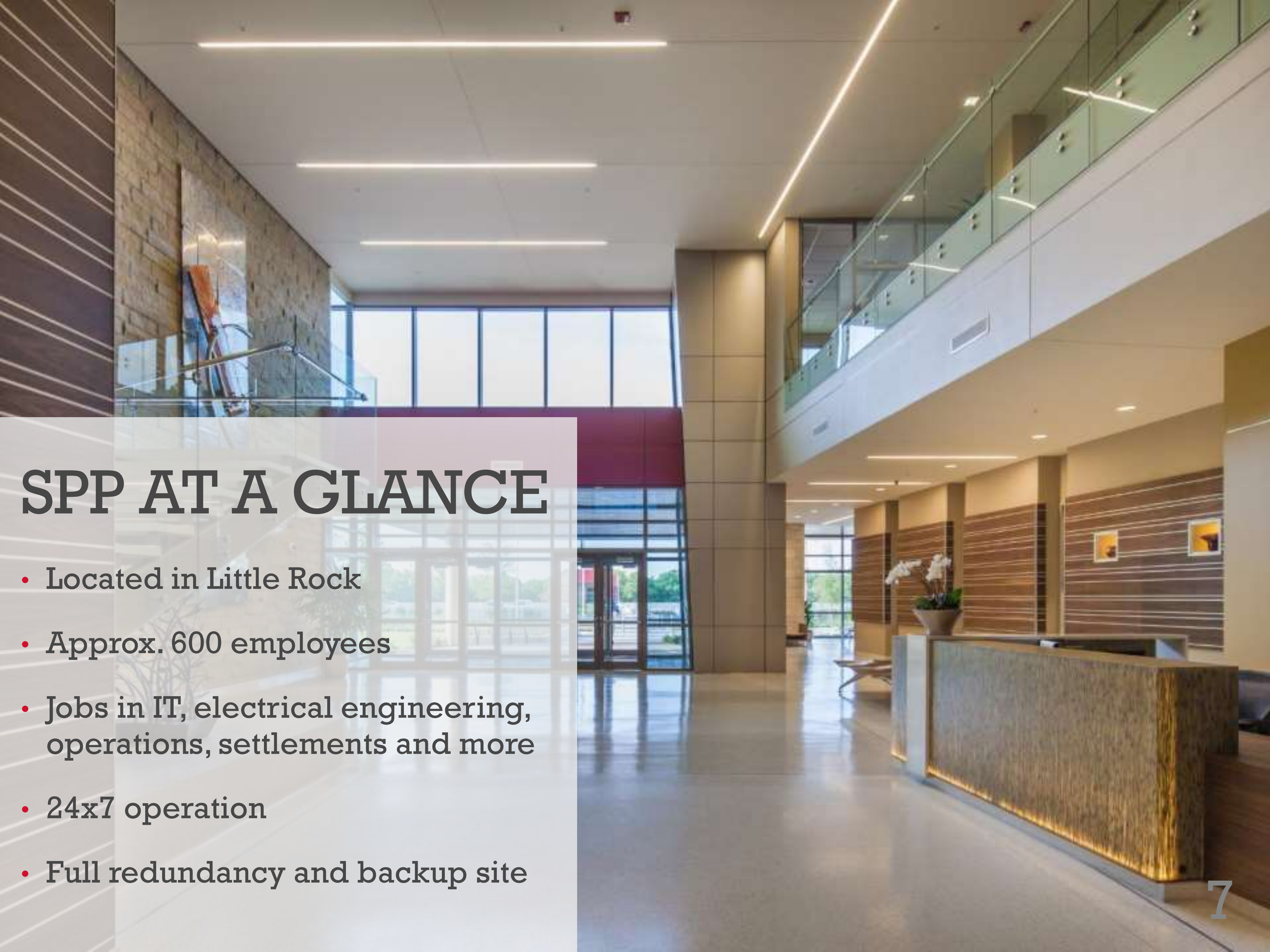
THE SPP DIFFERENCE

- Relationship-based
- Member-driven
- Independence Through Diversity
- Evolutionary vs. Revolutionary
- Reliability and Economics Inseparable

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.
- A typical residential customer using 1,000 kWh saves $6.02/month because of the services SPP provides.





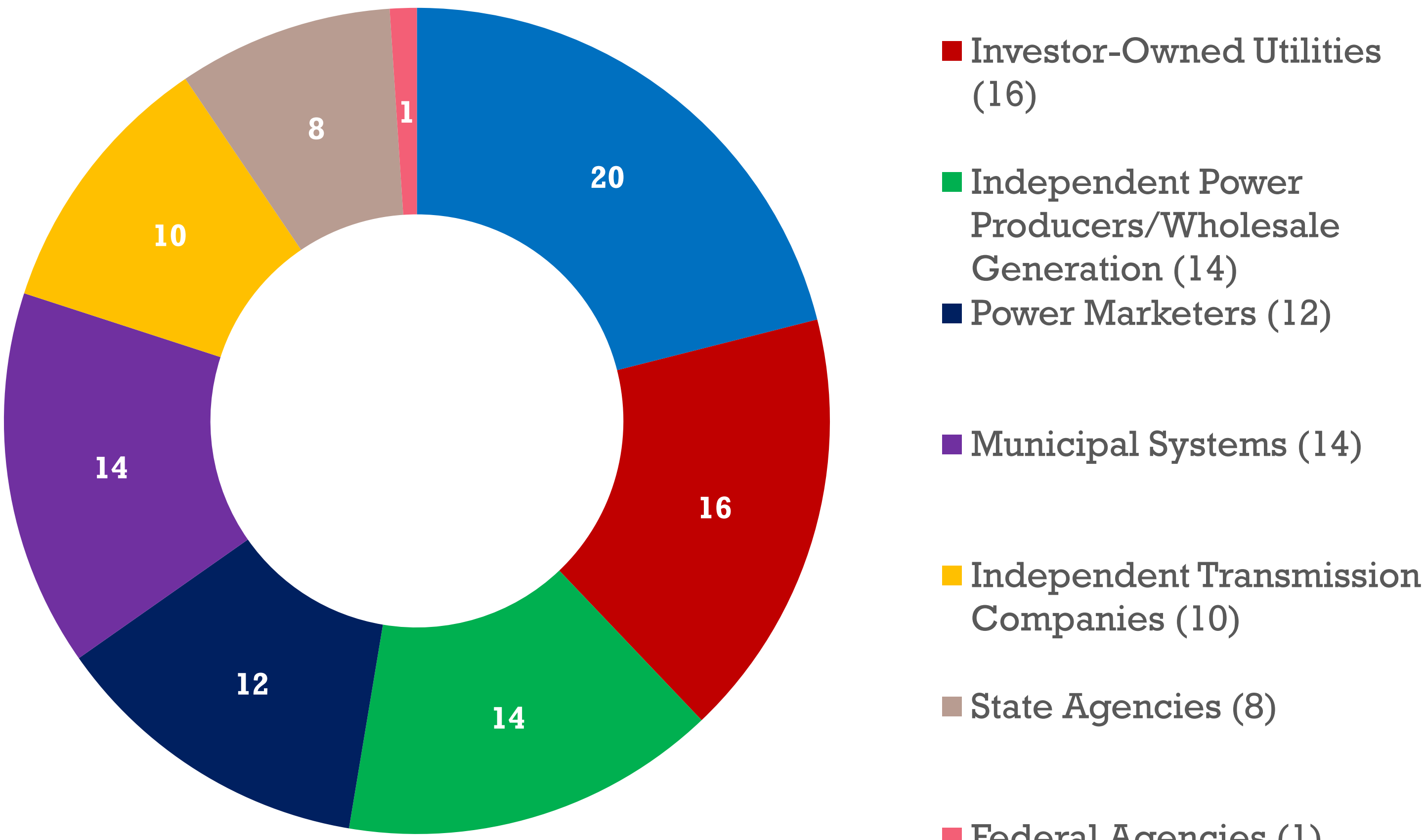
SPP AT A GLANCE

- Located in Little Rock
- Approx. 600 employees
- Jobs in IT, electrical engineering, operations, settlements and more
- 24x7 operation
- Full redundancy and backup site

SPP CORPORATE CENTER

NORTH AMERICAN INDEPENDENT SYSTEM OPERATORS (ISO) AND REGIONAL TRANSMISSION ORGANIZATIONS (RTO)

SPP'S 95 MEMBERS: INDEPENDENCE THROUGH DIVERSITY



As of April 12, 2017

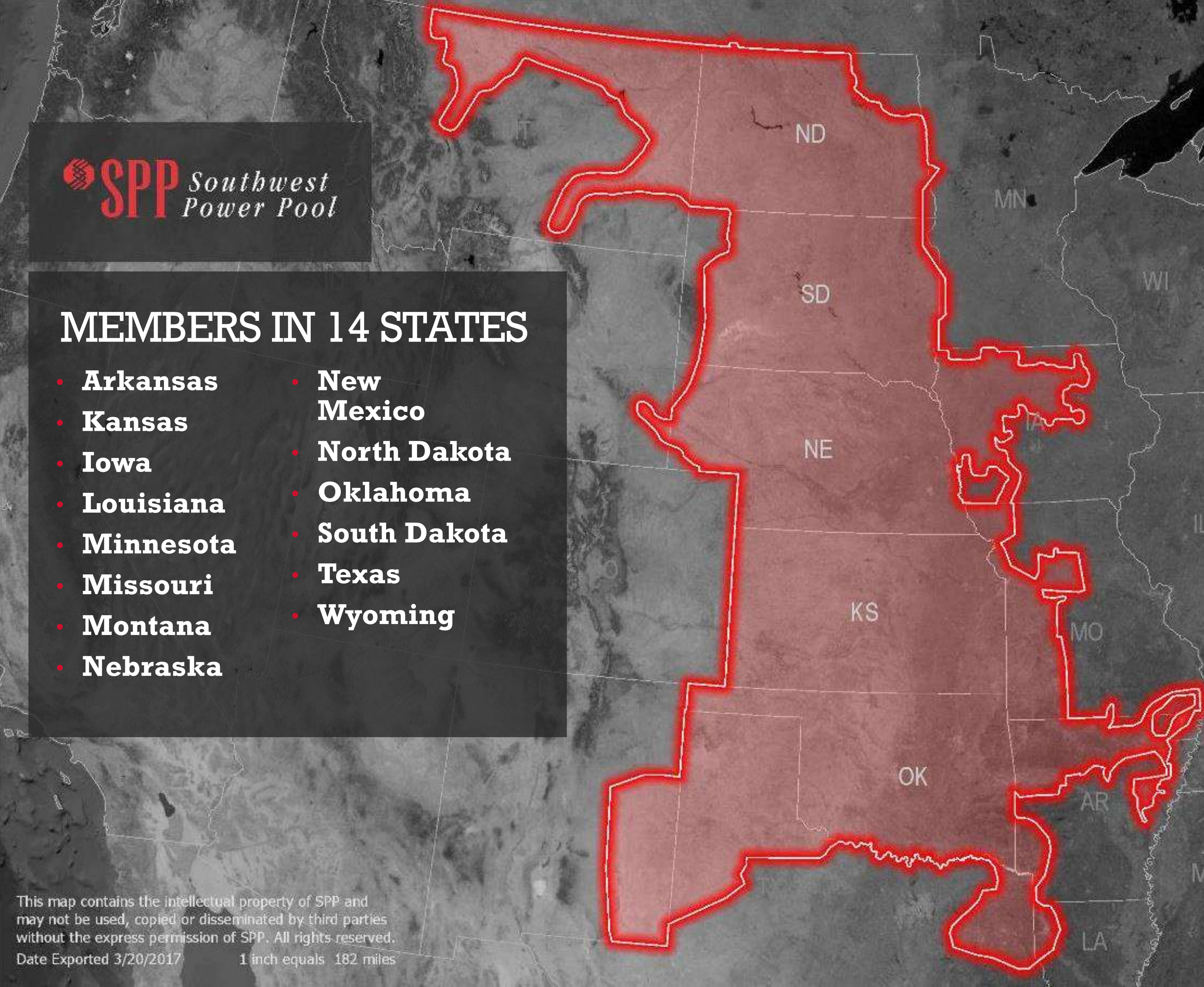
SPP MANAGES THE GRID IN 5 OF THE TOP 100 CITIES IN AMERICA:

Kansas City, Oklahoma City, Tulsa, Omaha, and Wichita

SPP *Southwest Power Pool*

MEMBERS IN 14 STATES

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



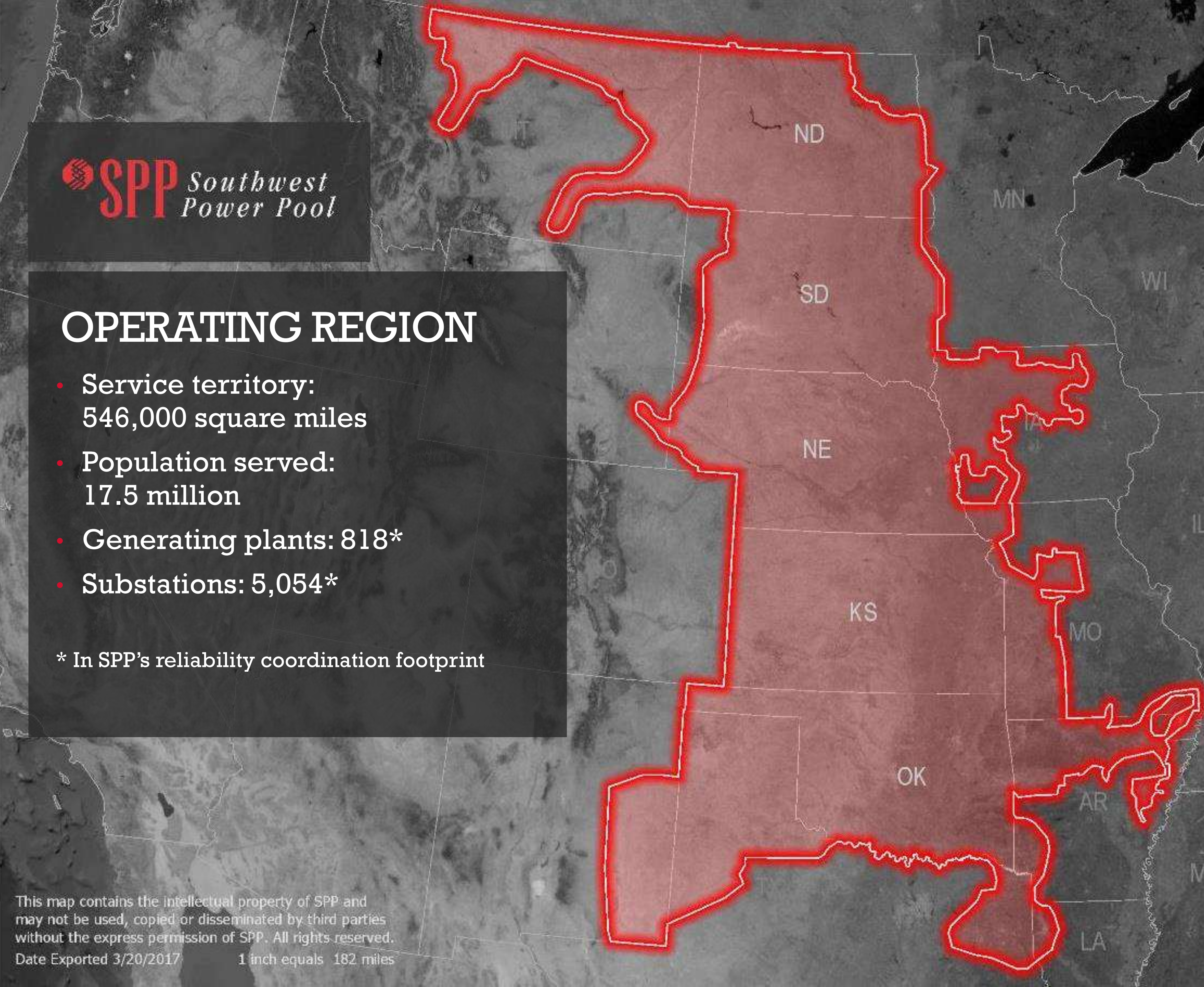
SPP

SPP Southwest Power Pool

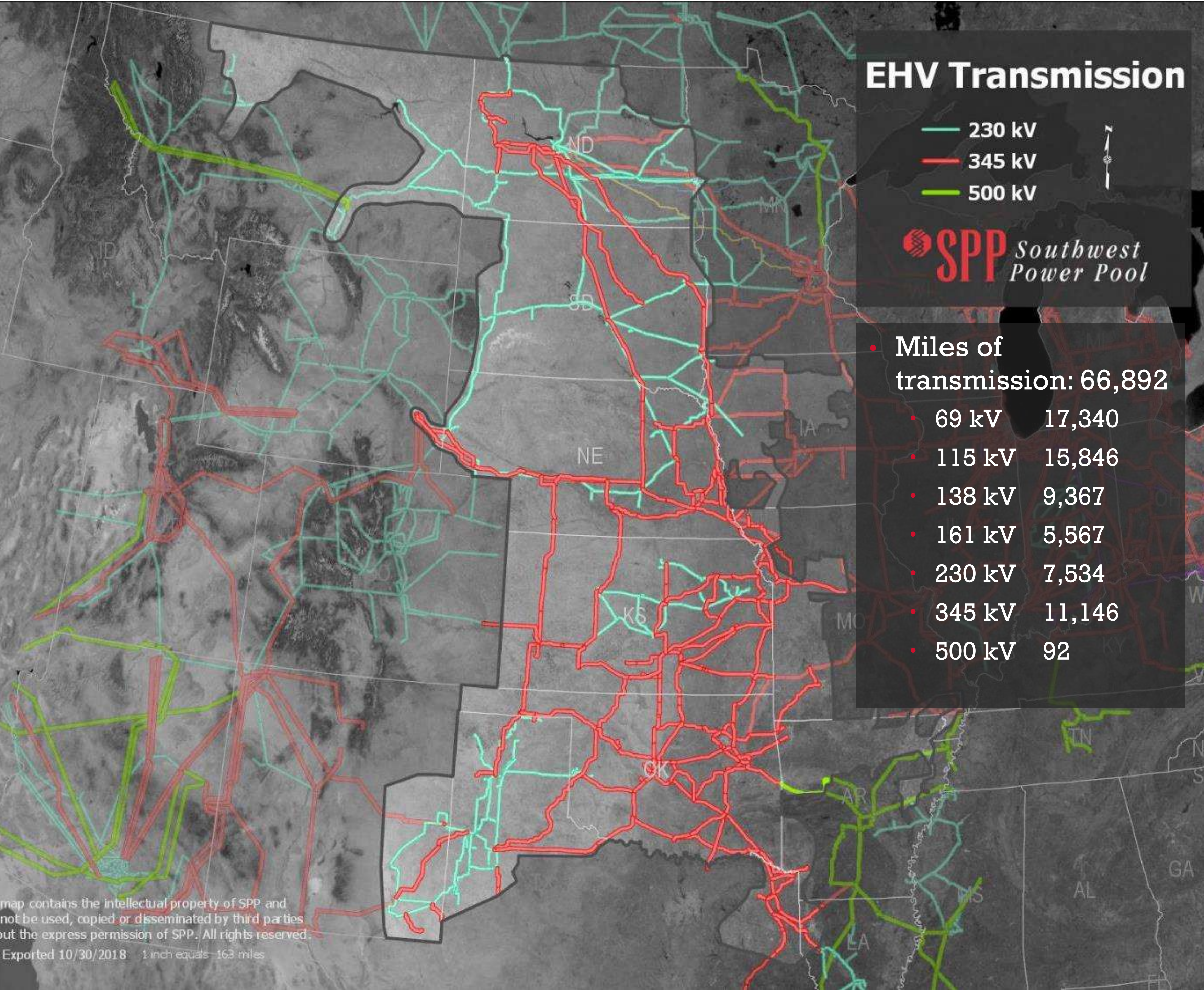
OPERATING REGION

- Service territory: 546,000 square miles
- Population served: 17.5 million
- Generating plants: 818*
- Substations: 5,054*

* In SPP's reliability coordination footprint



EHV Transmission



- Miles of transmission: 66,892
  - 69 kV 17,340
  - 115 kV 15,846
  - 138 kV 9,367
  - 161 kV 5,567
  - 230 kV 7,534
  - 345 kV 11,146
  - 500 kV 92

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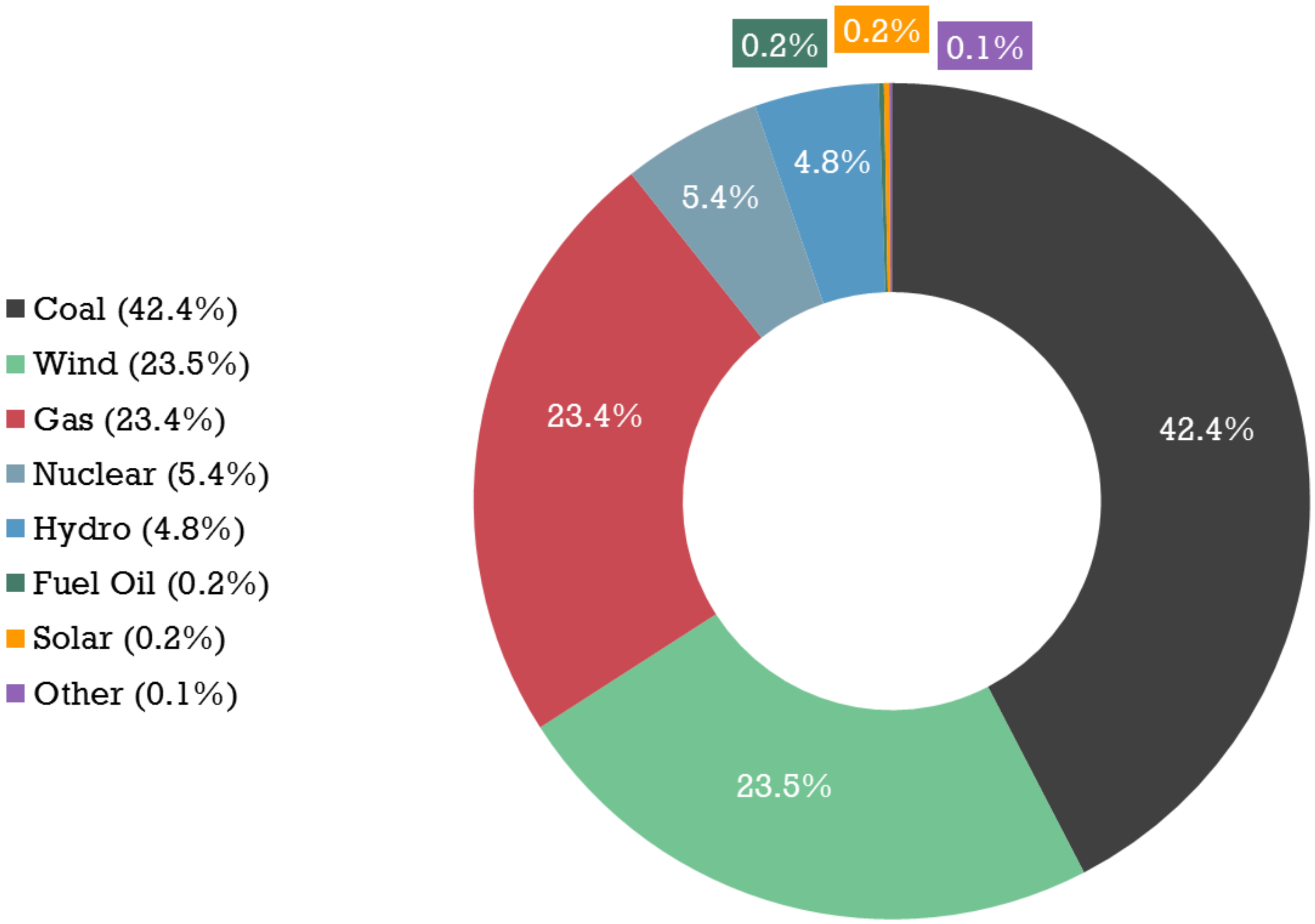
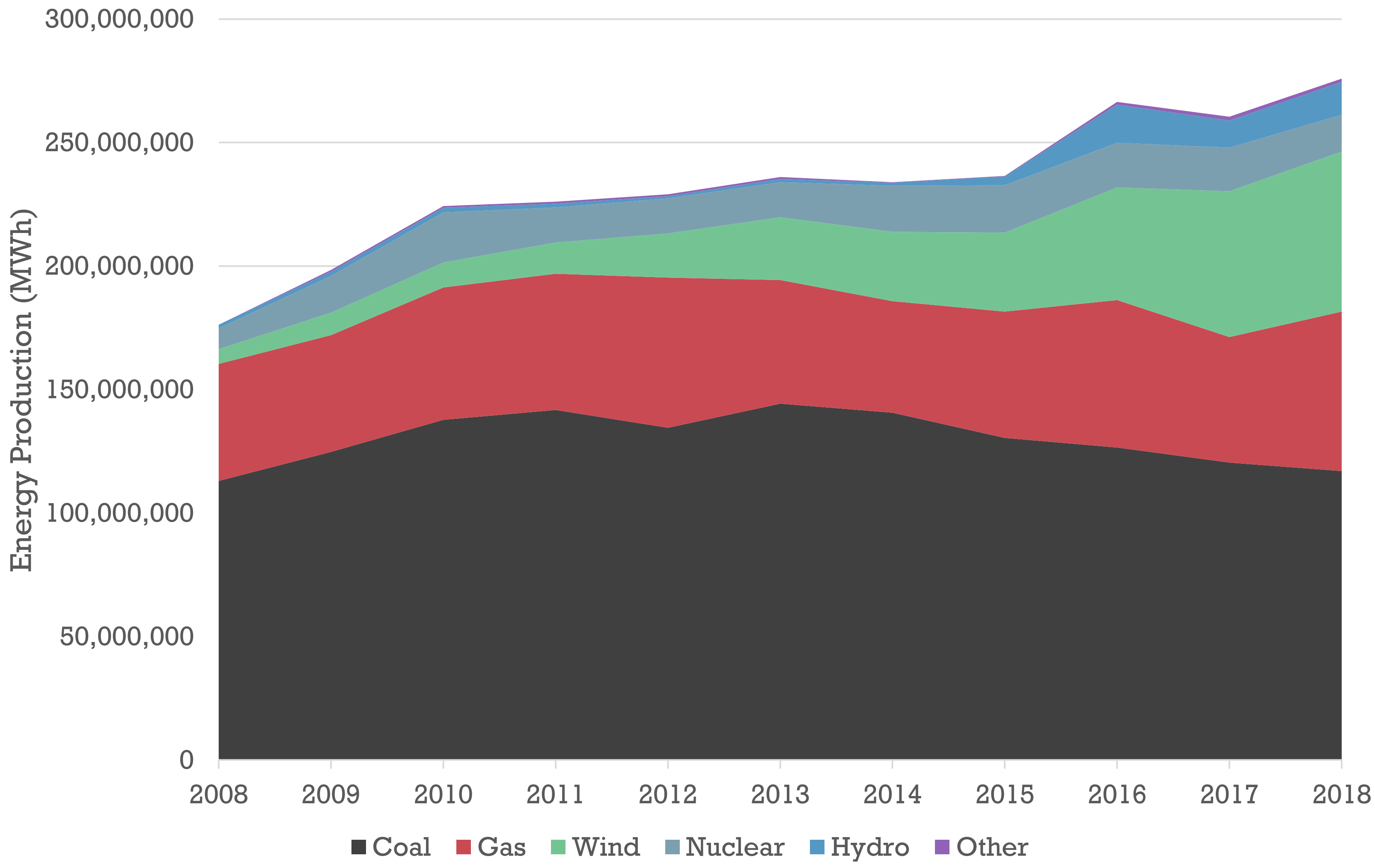
2018 ENERGY PRODUCTION BY FUEL TYPE (275,887 GWH TOTAL)



ENERGY PRODUCTION
BY GENERATION TYPE OVER TIME



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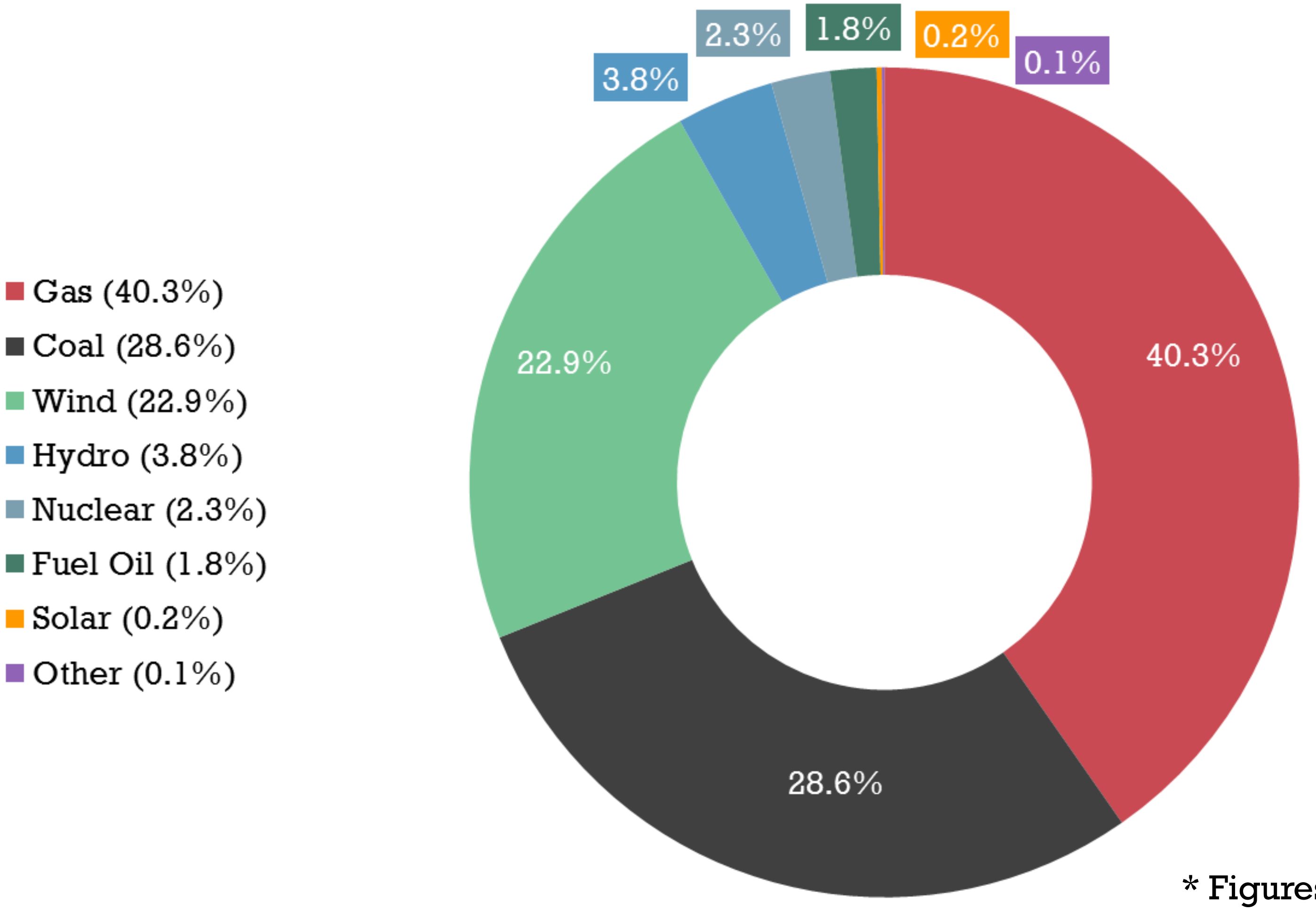
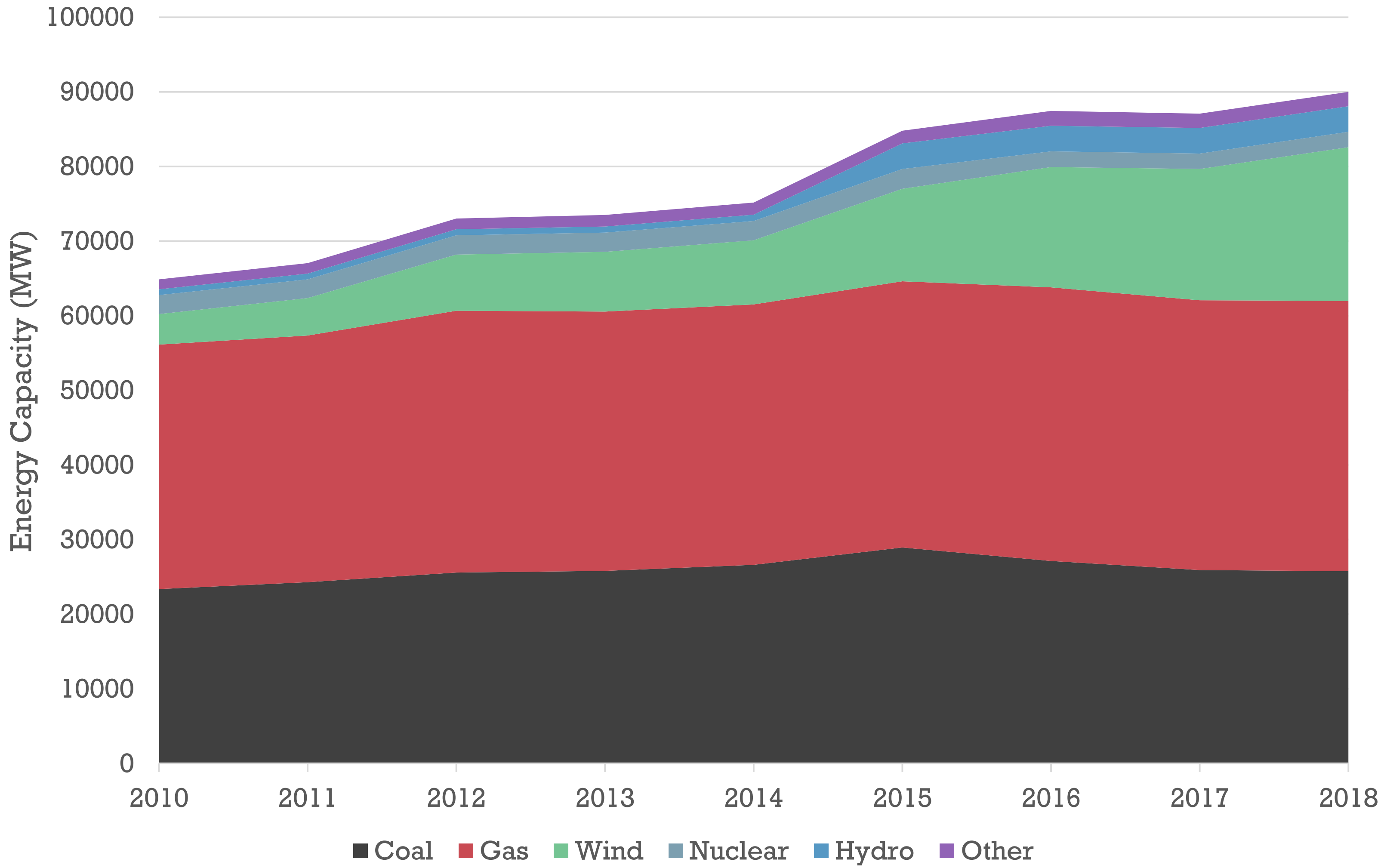
GENERATING CAPACITY* BY FUEL TYPE (89,999 MW TOTAL)



* Figures refer to nameplate capacity as of 1/1/19

ENERGY CAPACITY
BY FUEL MIX OVER TIME



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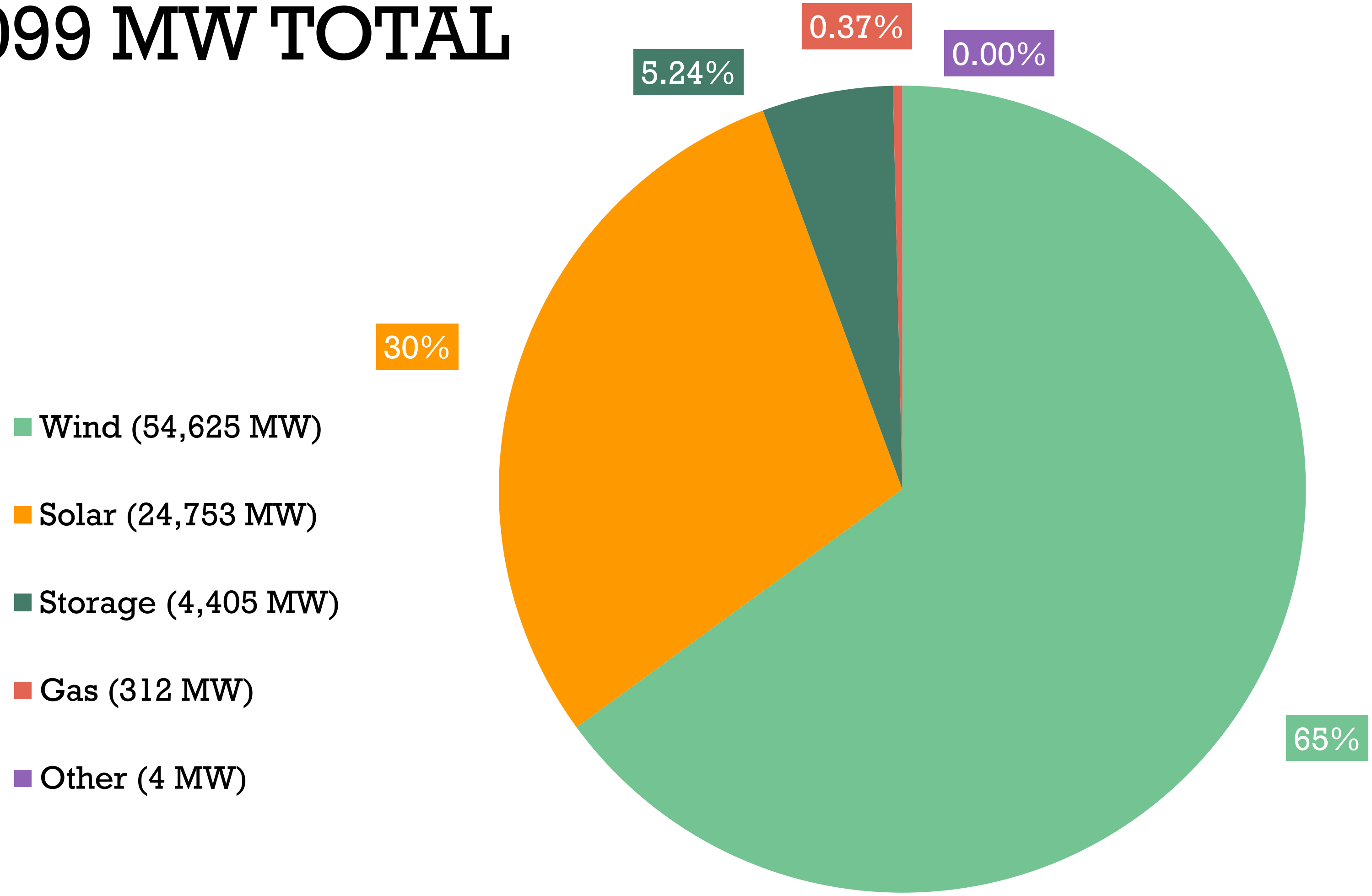
GENERATOR INTERCONNECTION REQUESTS UNDER STUDY (BY FUEL TYPE): 84,099 MW TOTAL



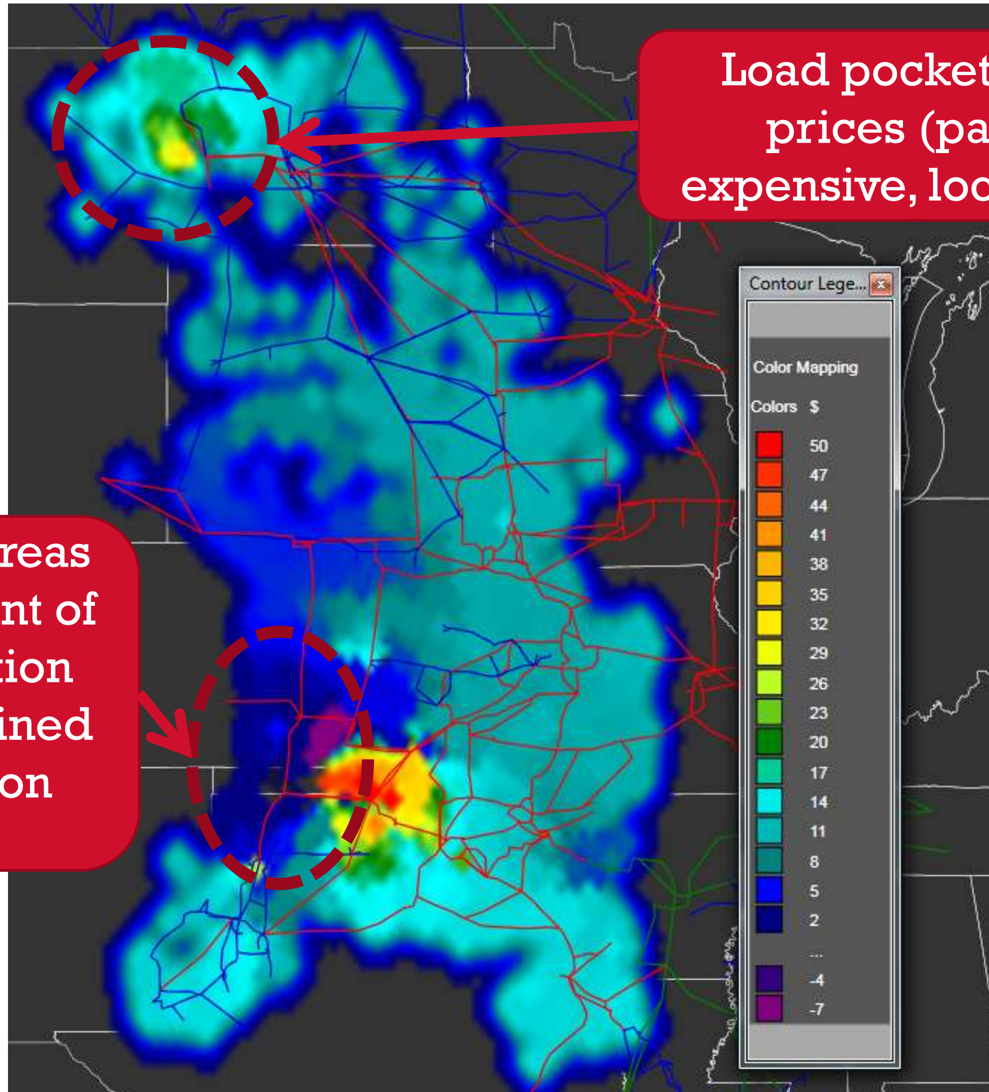
As of February 5, 2019

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

CONGESTION PREVENTS ACCESS TO GENERATION

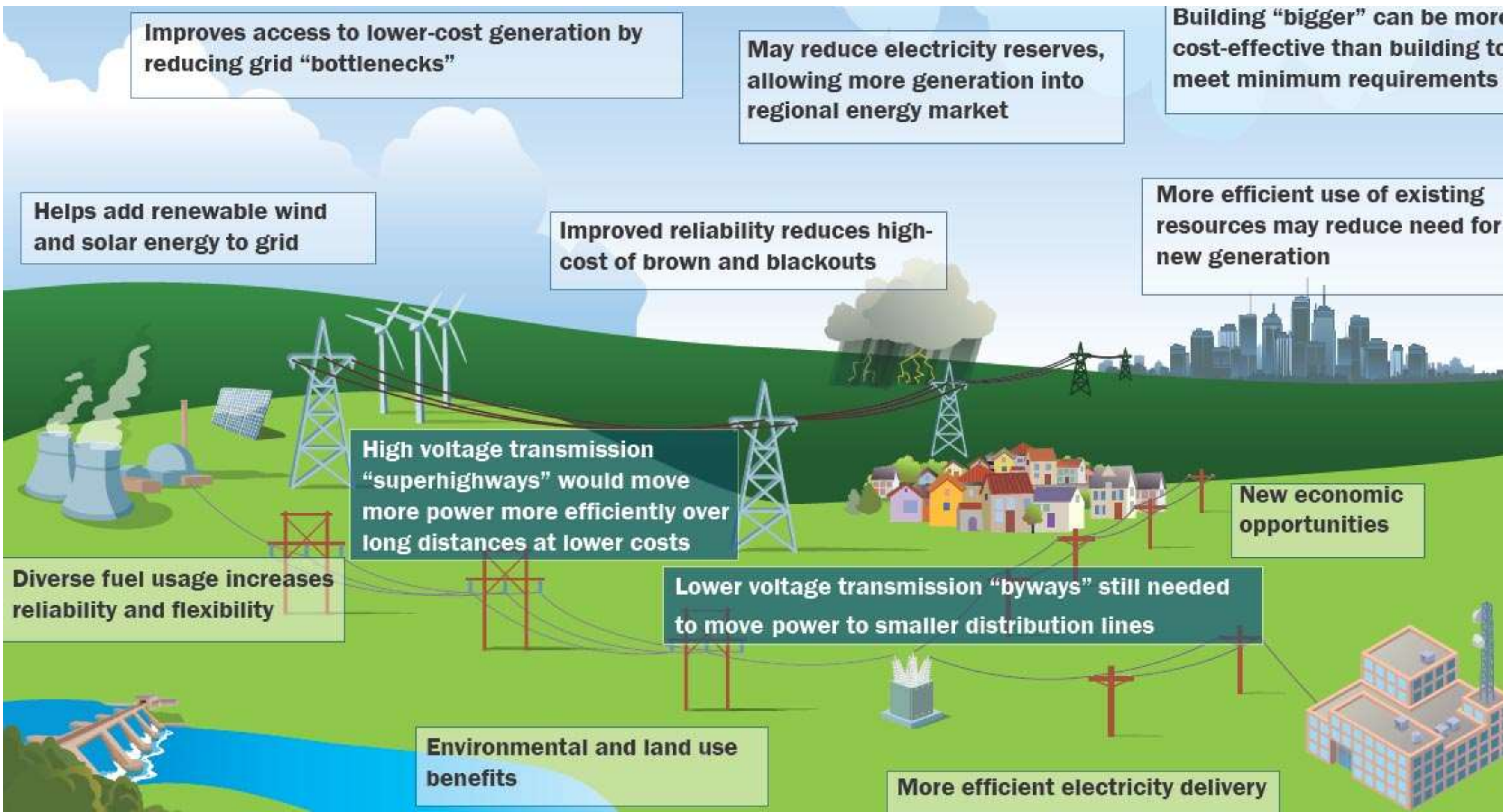
Load pockets see higher prices (pay for more expensive, local generation)



Low prices in areas with high amount of cheap generation (wind), constrained by transmission outlets

WHY WE NEED MORE TRANSMISSION?

- In the past, built least-cost transmission to meet local needs
- Today, proactively building "highways" to benefit region



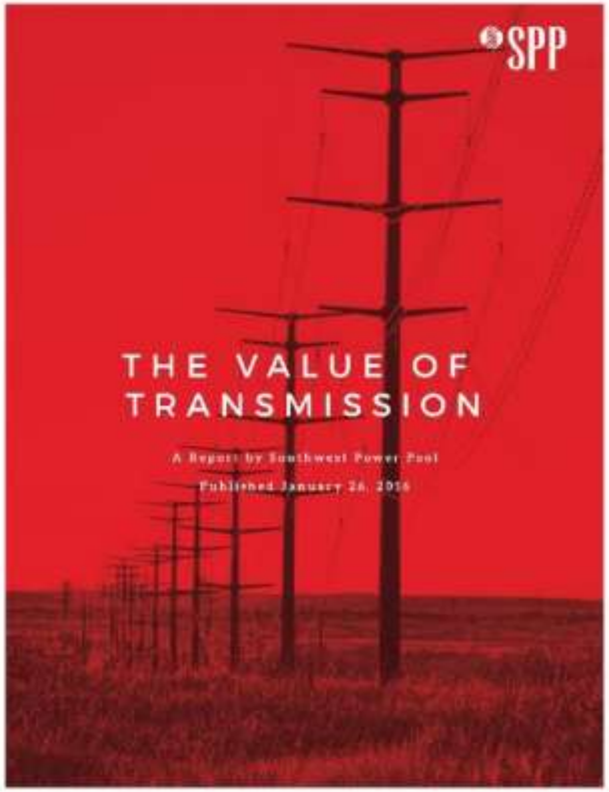
SPP-directed Transmission Investment

$7.7B in completed projects and $1.9B in scheduled projects, driven by Regional State Committee and Highway/Byway Cost Allocation

SPP'S 2015 VALUE OF TRANSMISSION STUDY

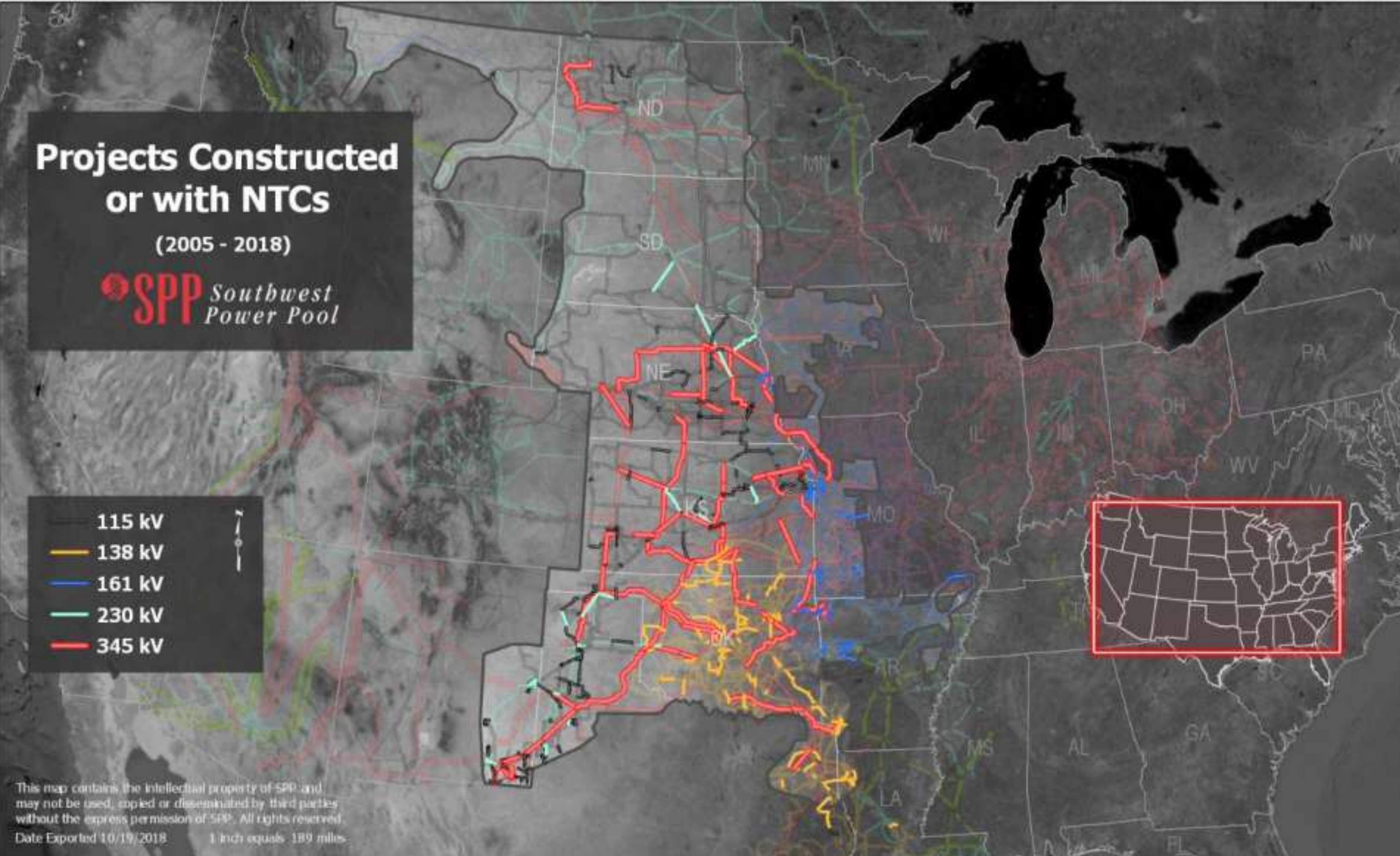
Study Scope:

- Assessed 348 projects from 2012-14, representing $3.4B of transmission investment
- Based on the first year of operation of Integrated Marketplace from March 2014 through February 2015
- APC Savings 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.



BENEFIT-COST RATIO OF 3.5 TO 1

SPP


Projects Constructed or with NTCs
(2005 - 2018)
SPP Southwest Power Pool
115 kV
138 kV
161 kV
230 kV
345 kV
ND
SD
NE
KS
OK
MN
IA
MO
AR
LA
WI
IL
IN
OH
MI
PA
NY
WV
MS
AL
GA
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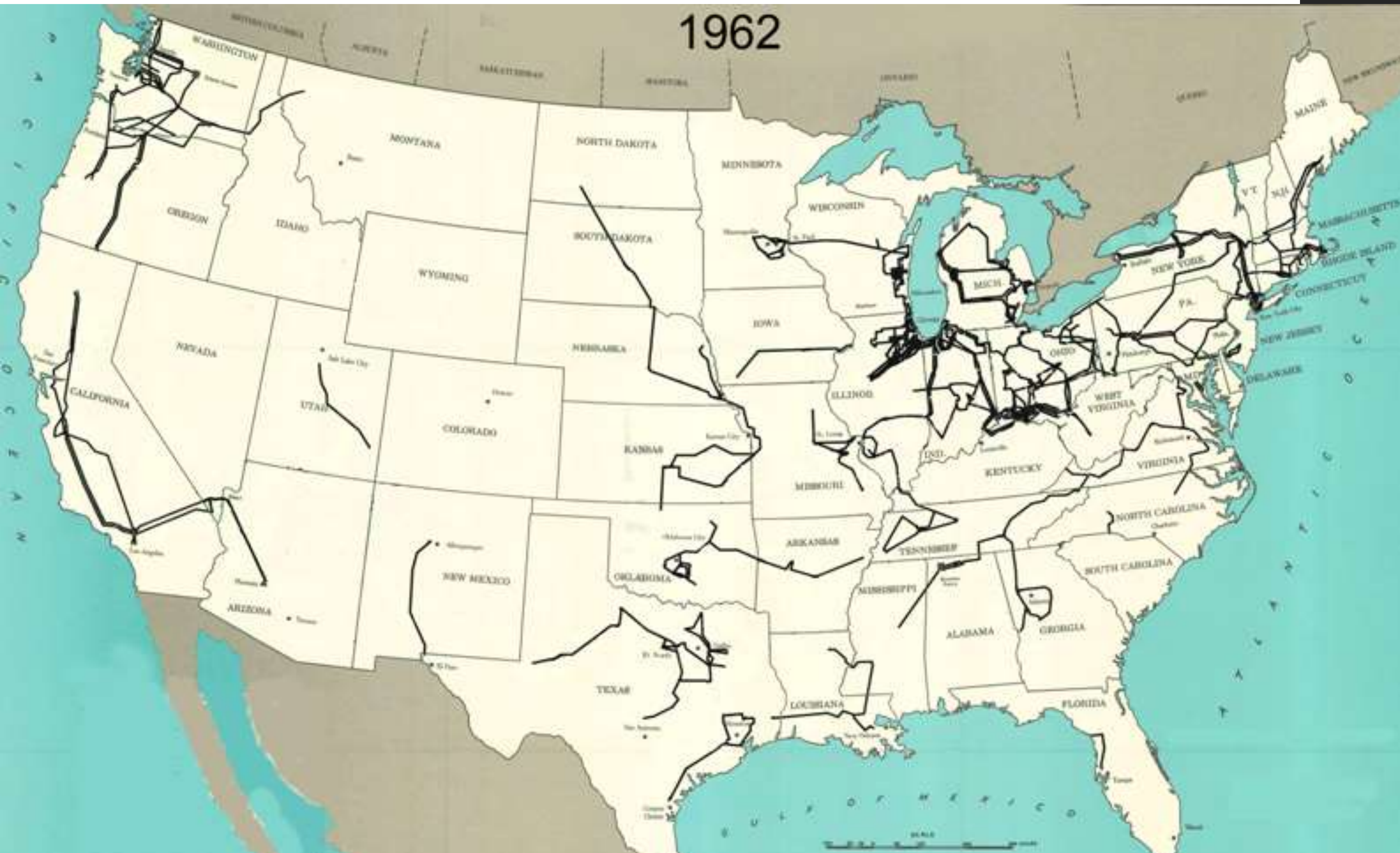
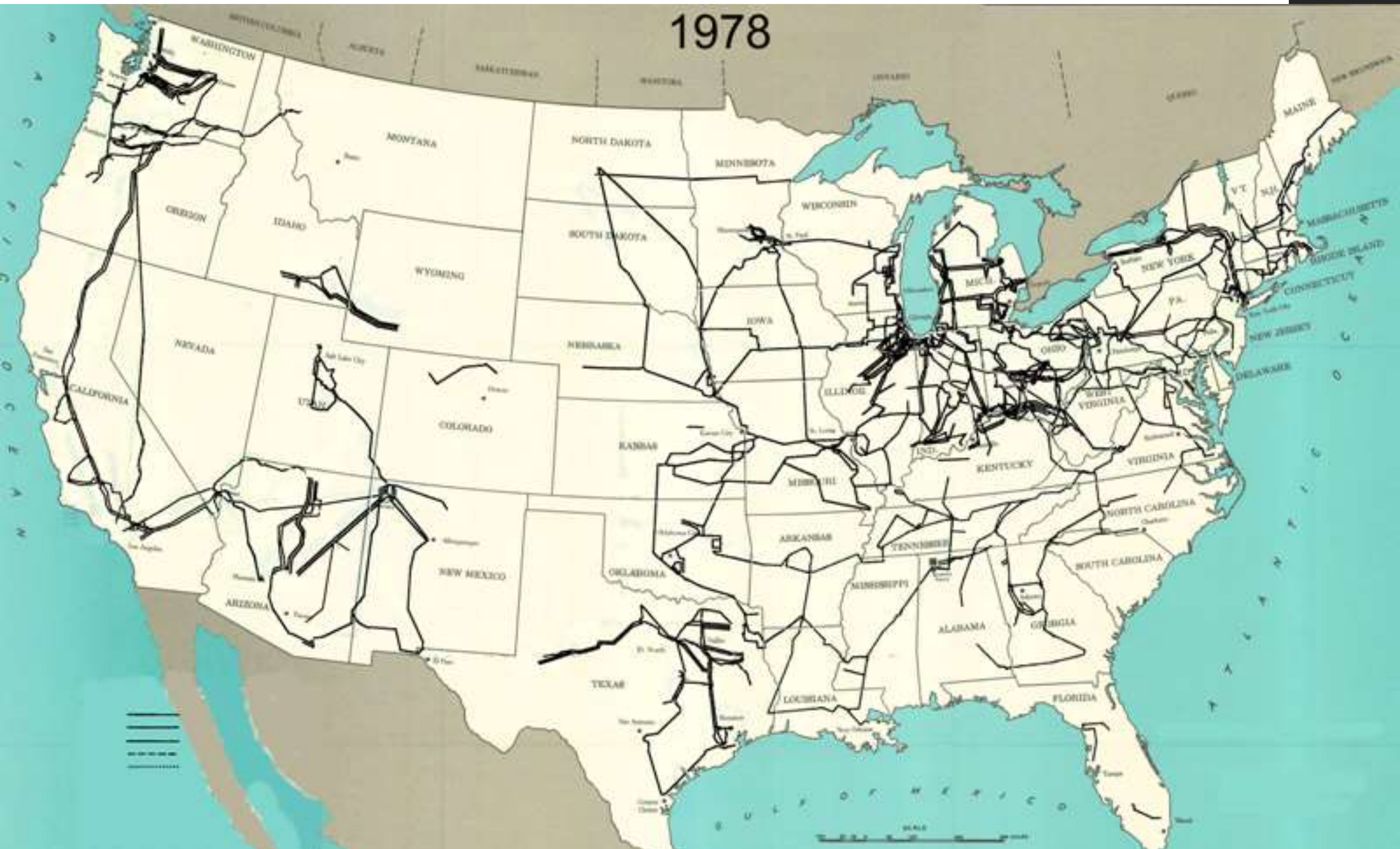
Date Exported 10/19/2018
1 inch equals 189 miles

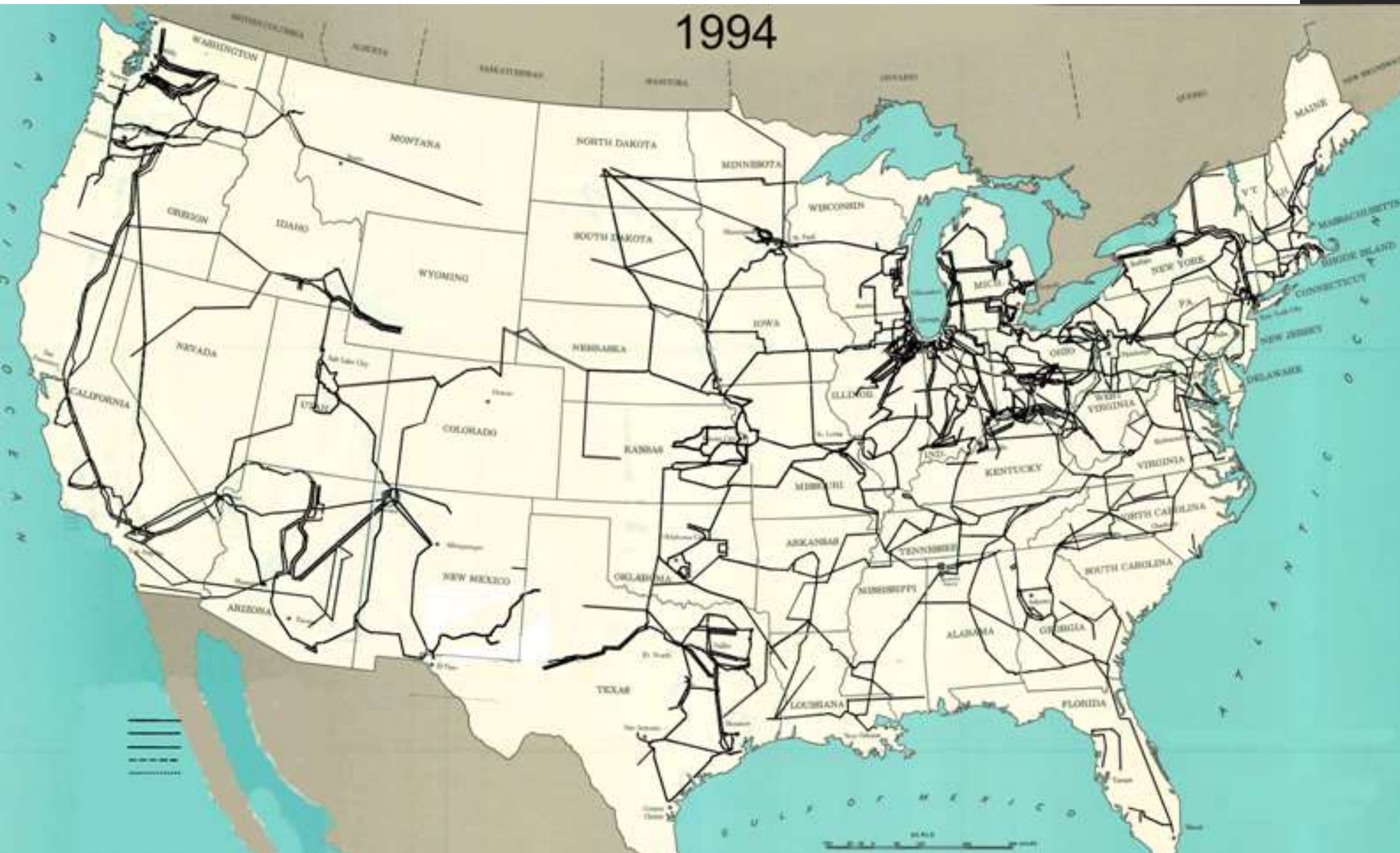
345 KV+ TRANSMISSION GROWTH AT A GLANCE



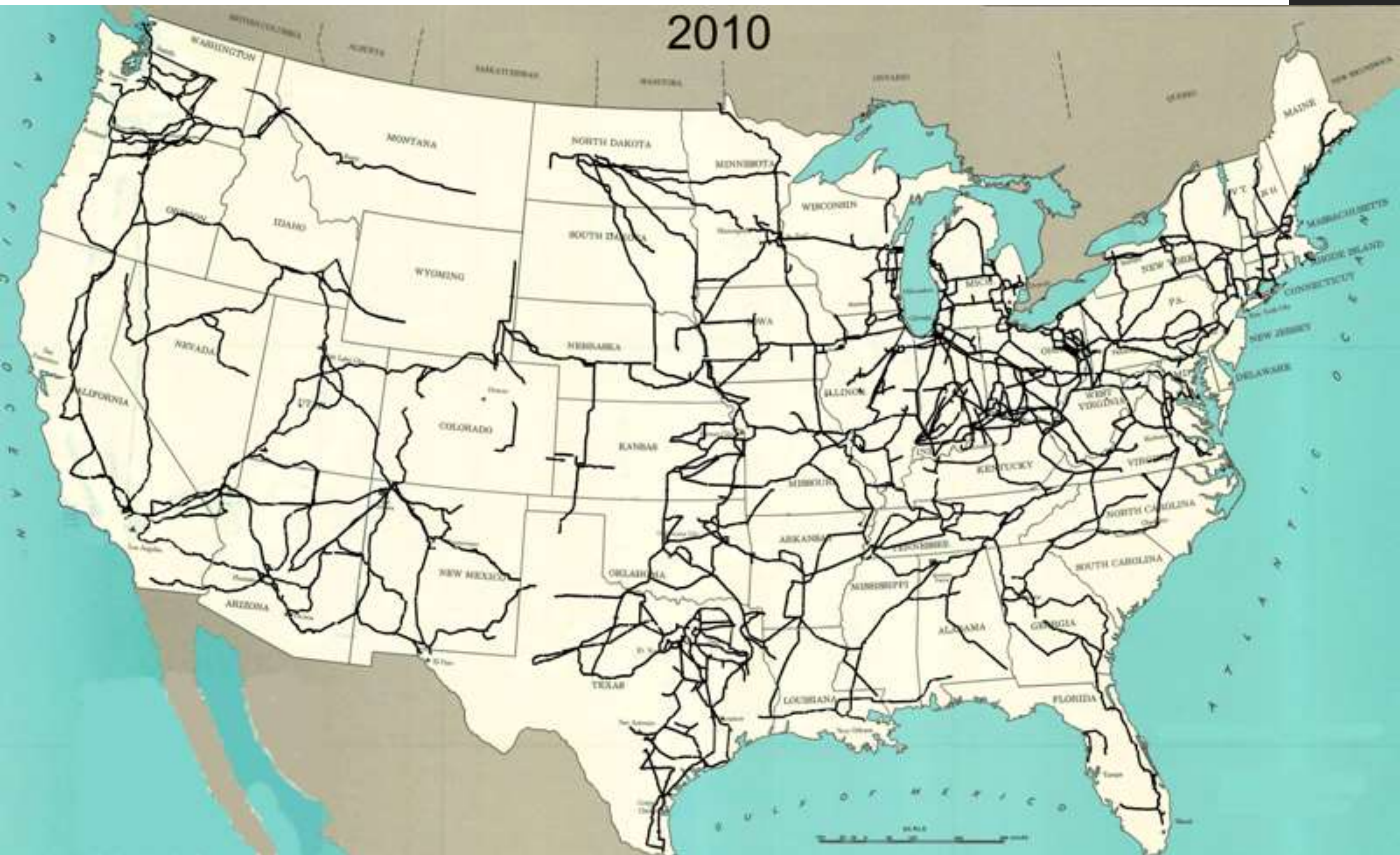
345 KV+ TRANSMISSION GROWTH AT A GLANCE



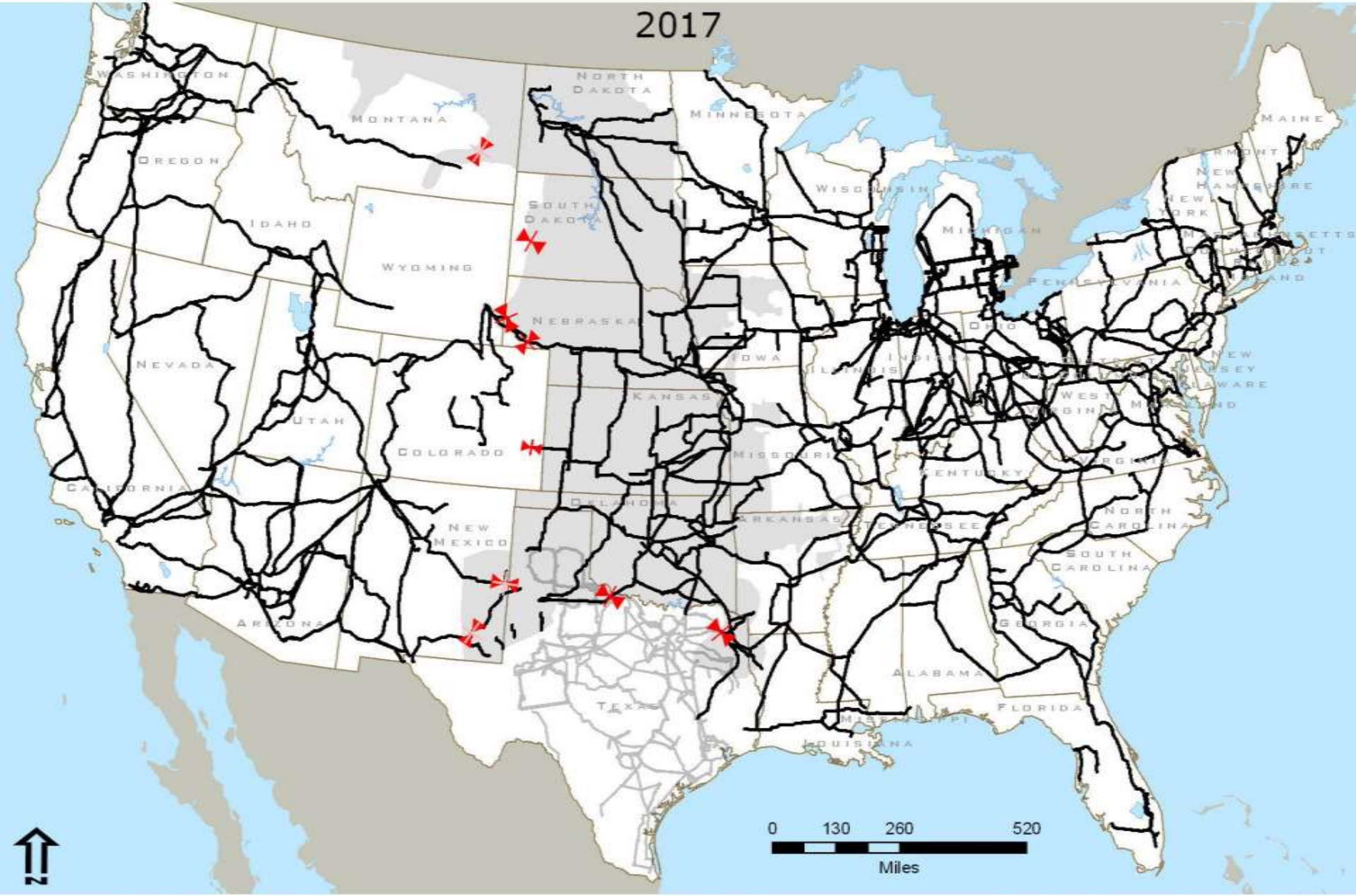
345 KV+ TRANSMISSION GROWTH AT A GLANCE



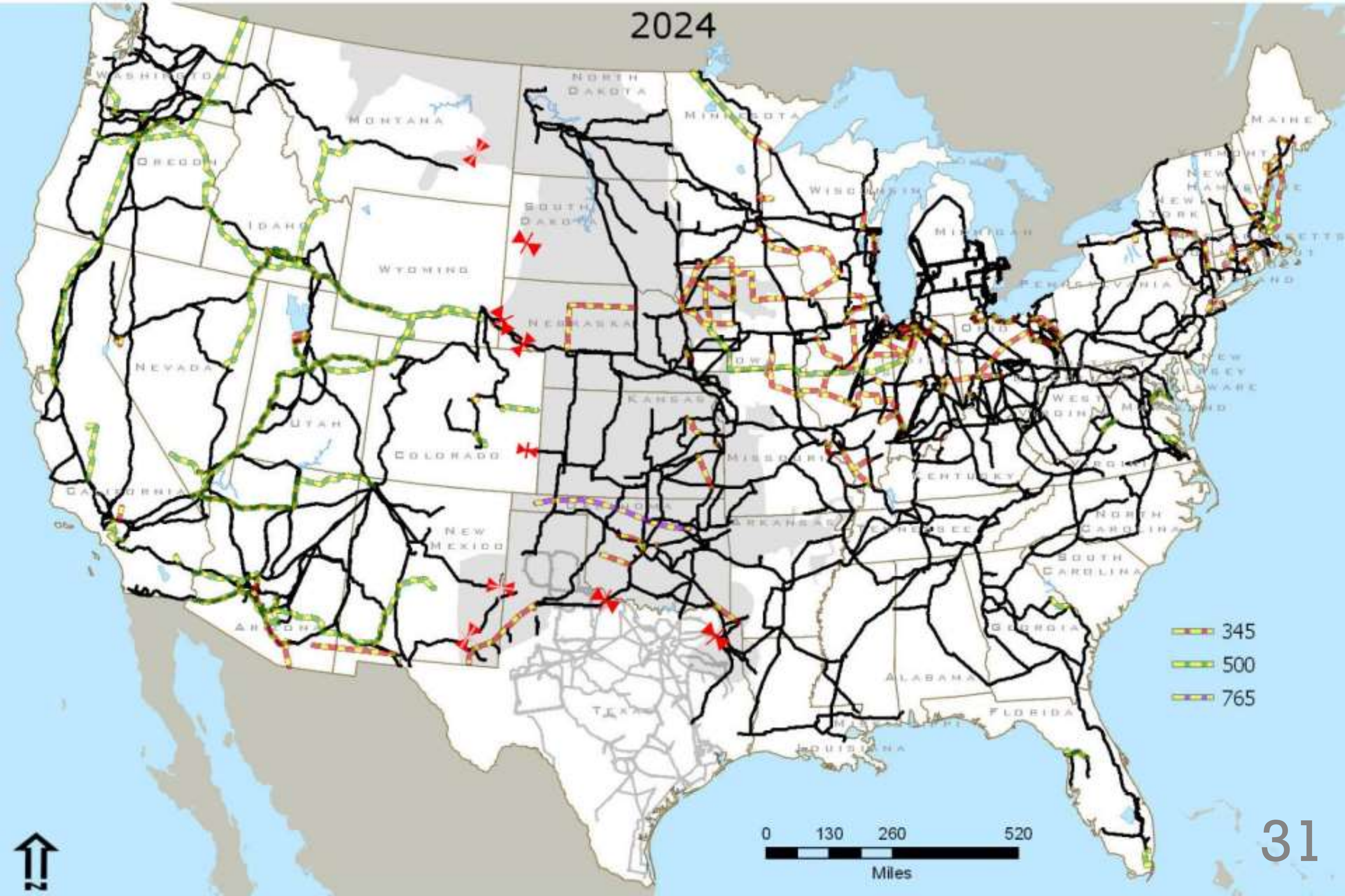
345 KV+ TRANSMISSION GROWTH AT A GLANCE



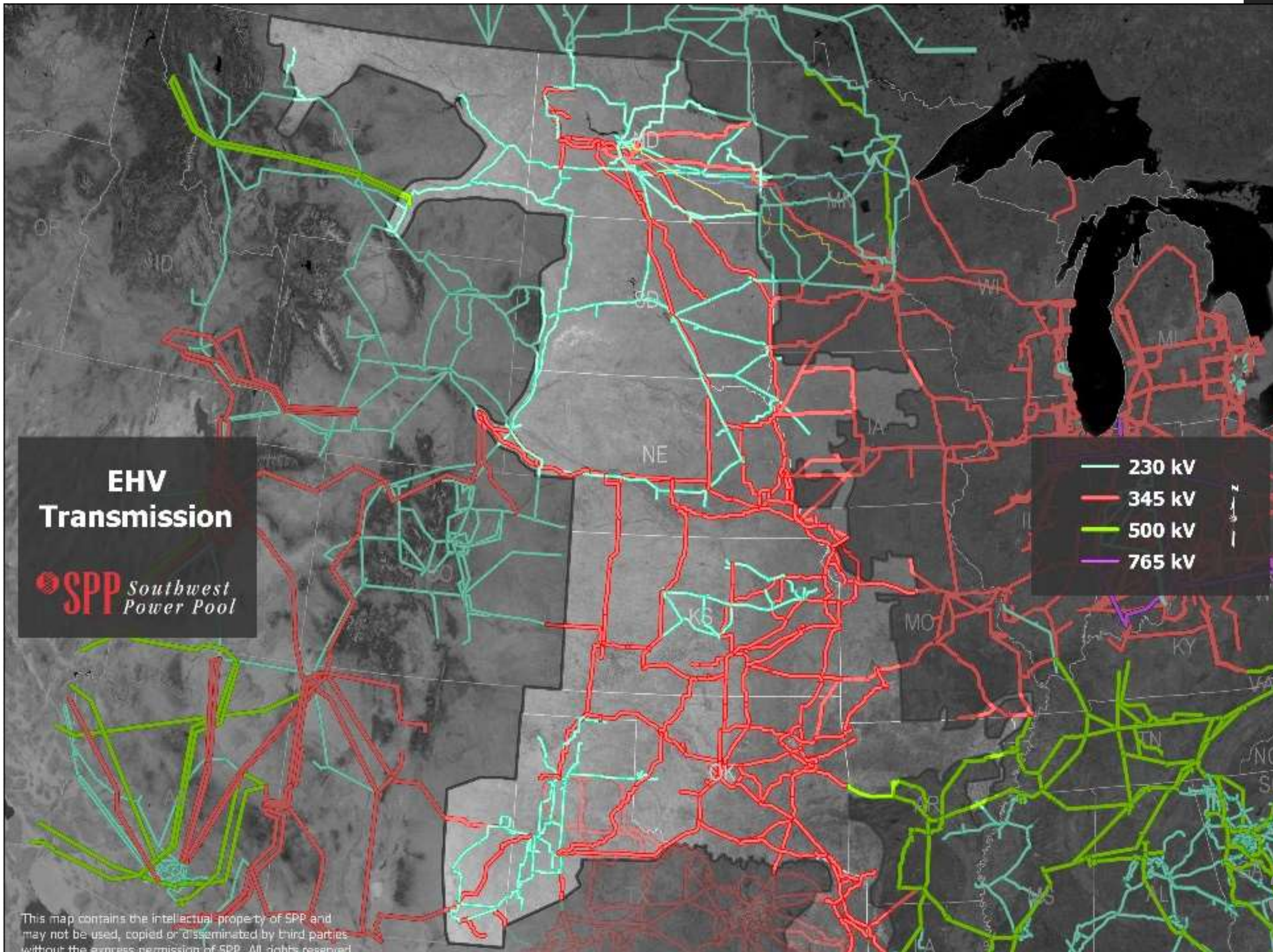
345 kV+ Transmission Growth at a Glance



345 kV+ Transmission Growth at a Glance



OPPORTUNITIES TO RIGHT SIZE SELECT AGING 230KV?



SPP

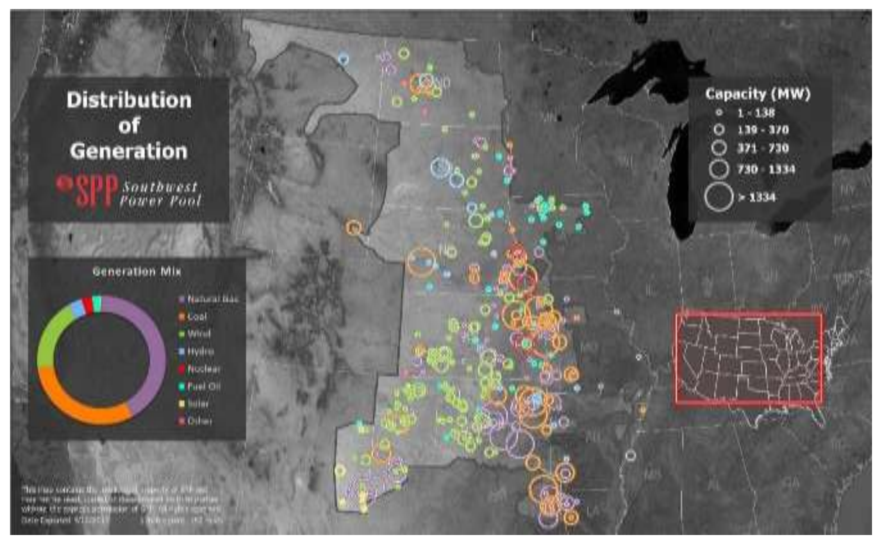
WIND, SOLAR & ENERGY STORAGE

- **Wind**
  - Installed: 21,578 MW 4/1/2019
  - Wind Turbines: 11,000 4/1/2019
  - Wind Peak: 16,382 MW 12/20/2018
  - GI Queue: 61 GW 4/6/2019
  - Wind Penetration % of Load: 63.96% 4/30/2018

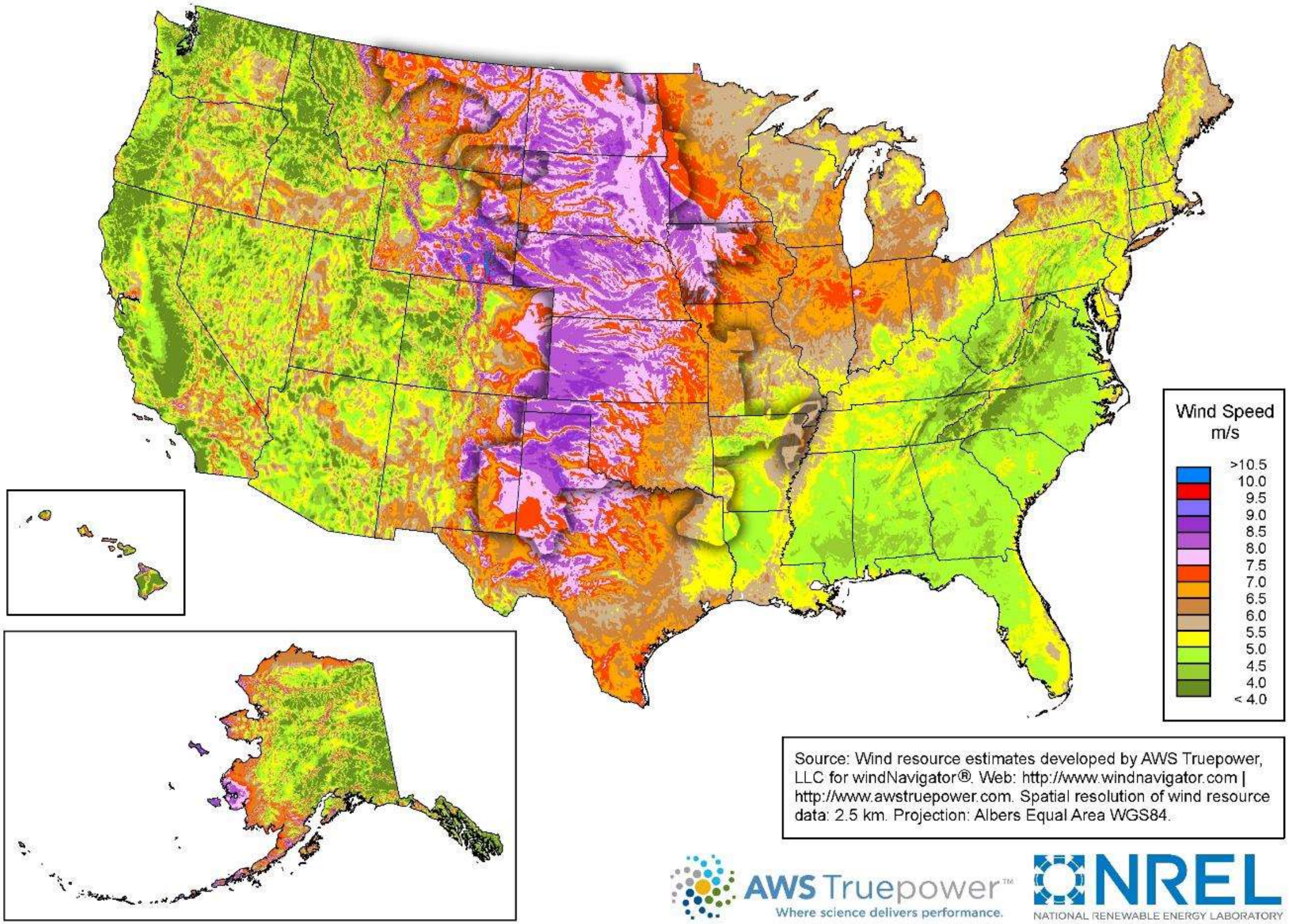
- **Solar**
  - SPP Market: 215 MW 4/1/2019
  - GI Queue: 25 GW 4/6/2019

- **Energy Storage**
  - Installed: 10MW/20MWh 4/1/2019
  - GI Queue: 4,373 MW 4/6/2019

- **Total Renewable Energy Penetration**
  - 69.44% 4/29/2018

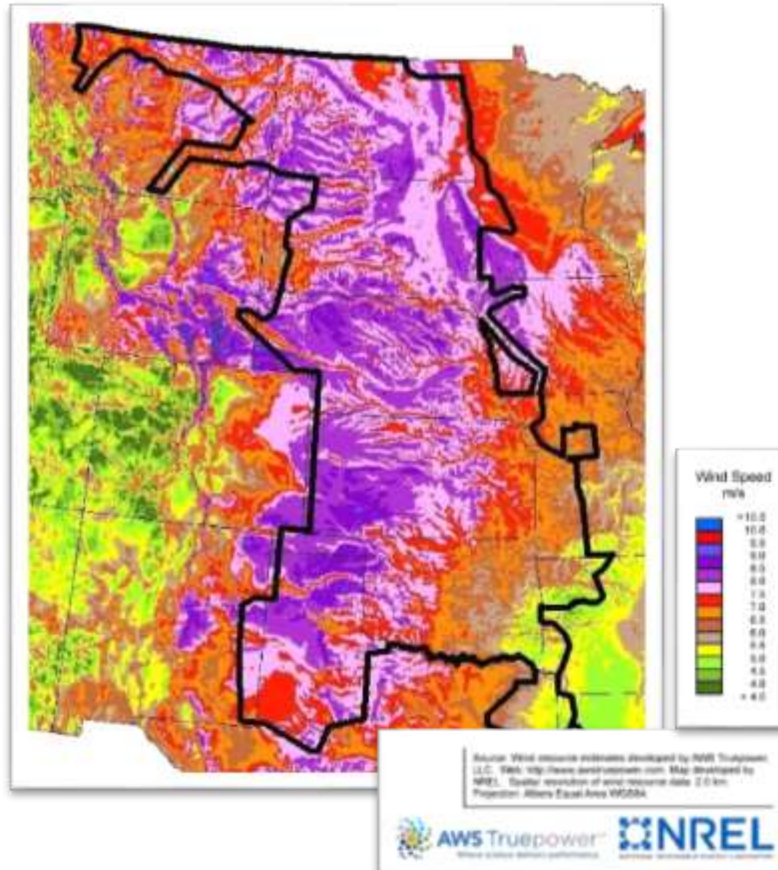


ANNUAL AVERAGE WIND SPEEDS



WIND ENERGY IN SPP

- Maximum Wind Penetration:
  - Instantaneous: 64% (4/30/18)
    - Despite Over 1GW Curtailments
  - Hourly Average: 63% (4/29/18)
  - Daily Average: 54% (4/29/18)
  - 2018
    - >60%, 10 days
    - >50%, 70 days
- Max wind swing in a day: >10 GW (12.5 GW → 2 GW → 12 GW)
- Max 1-hour Wind Ramp: 3,700 MW



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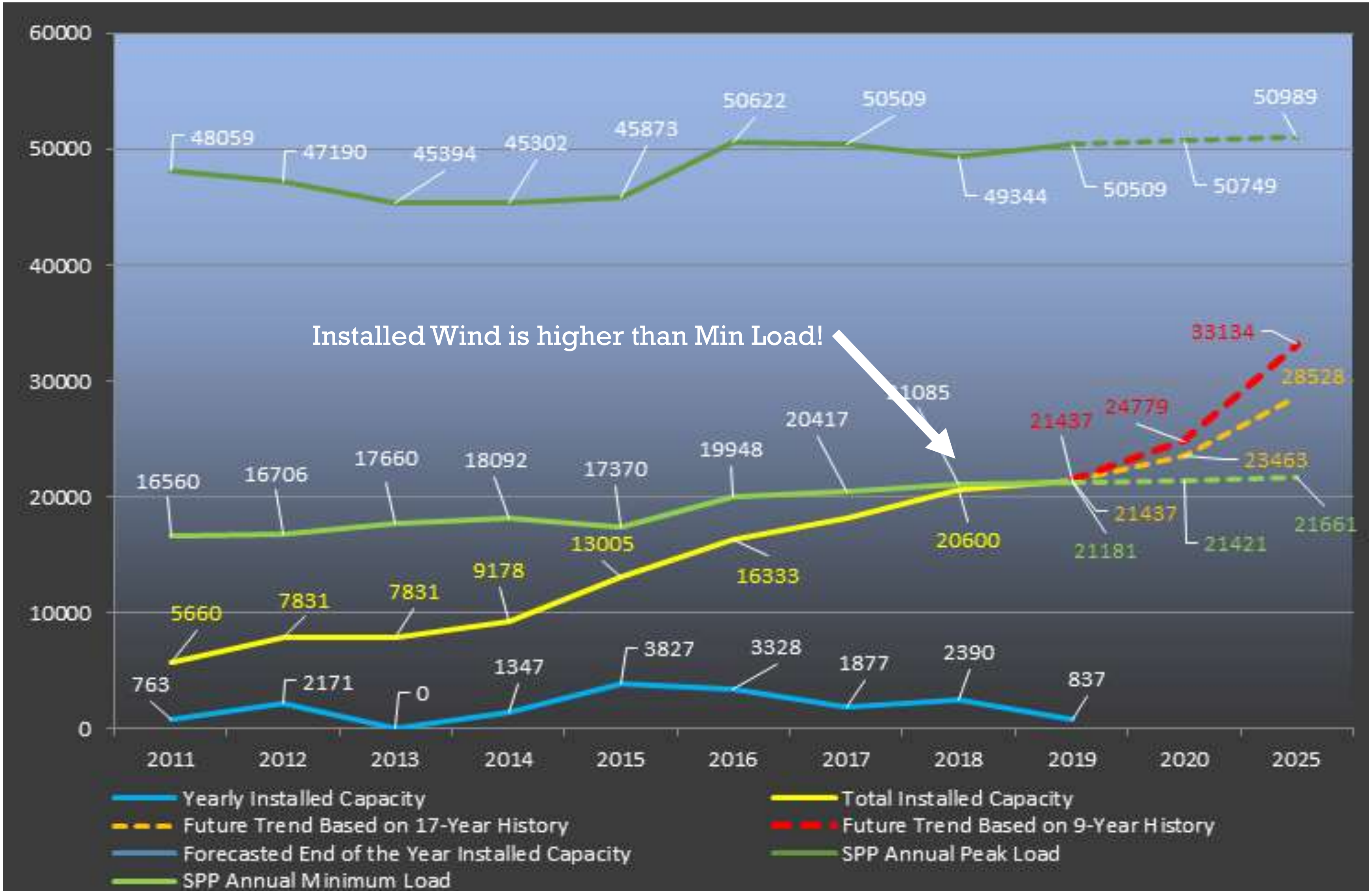
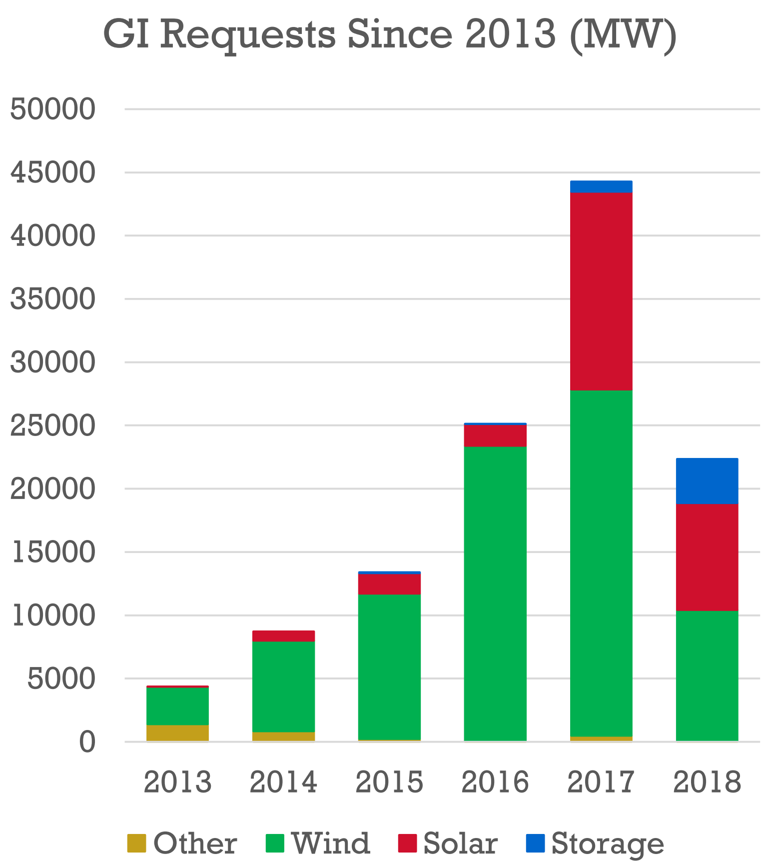
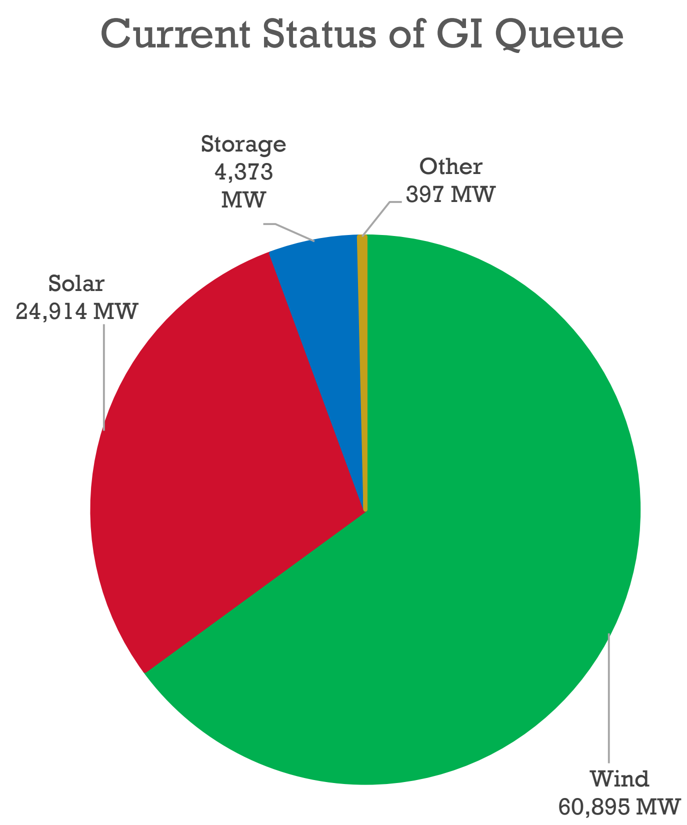
WIND CAPACITY INSTALLED BY YEAR

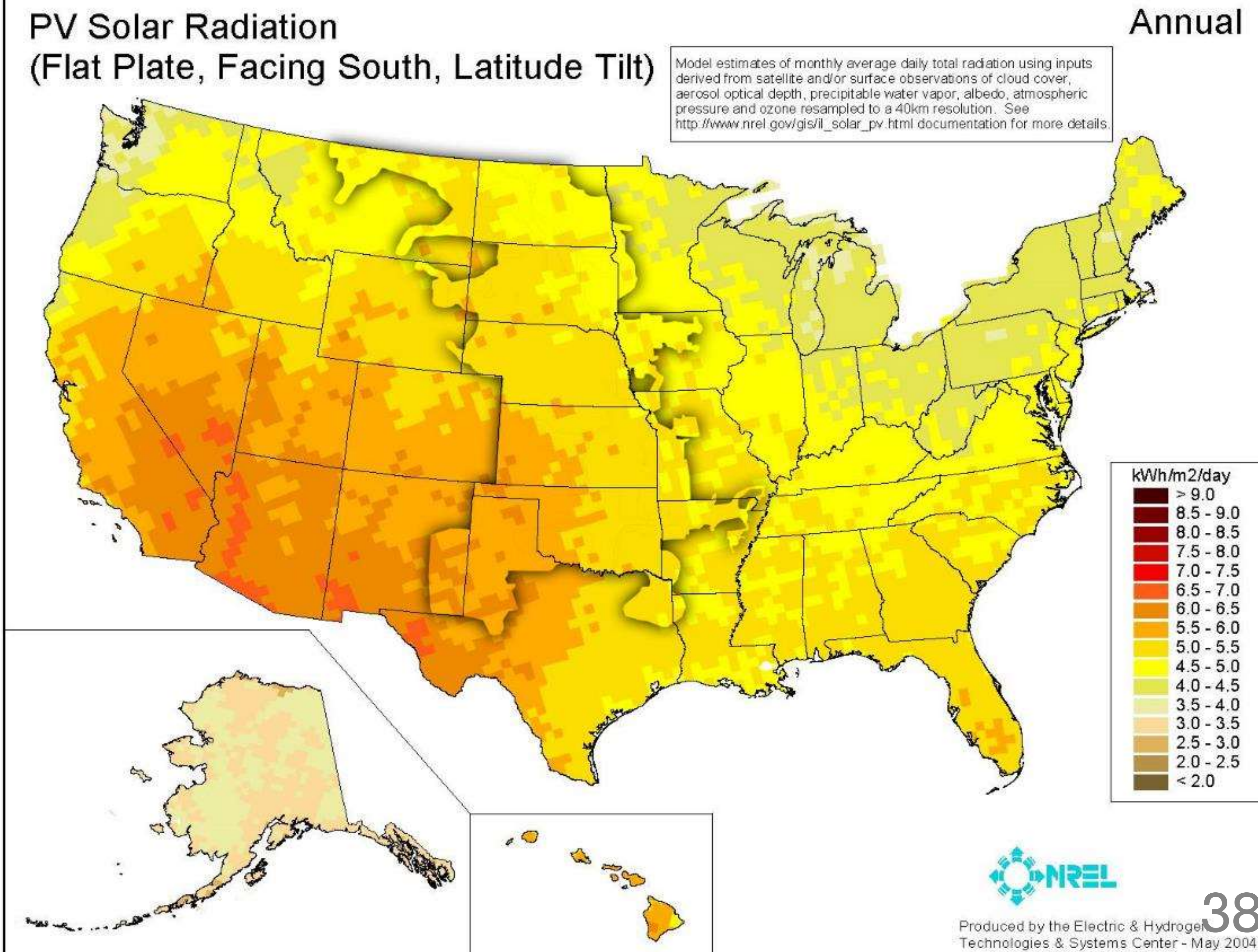


SPP

SPP's Generator Interconnection Queue

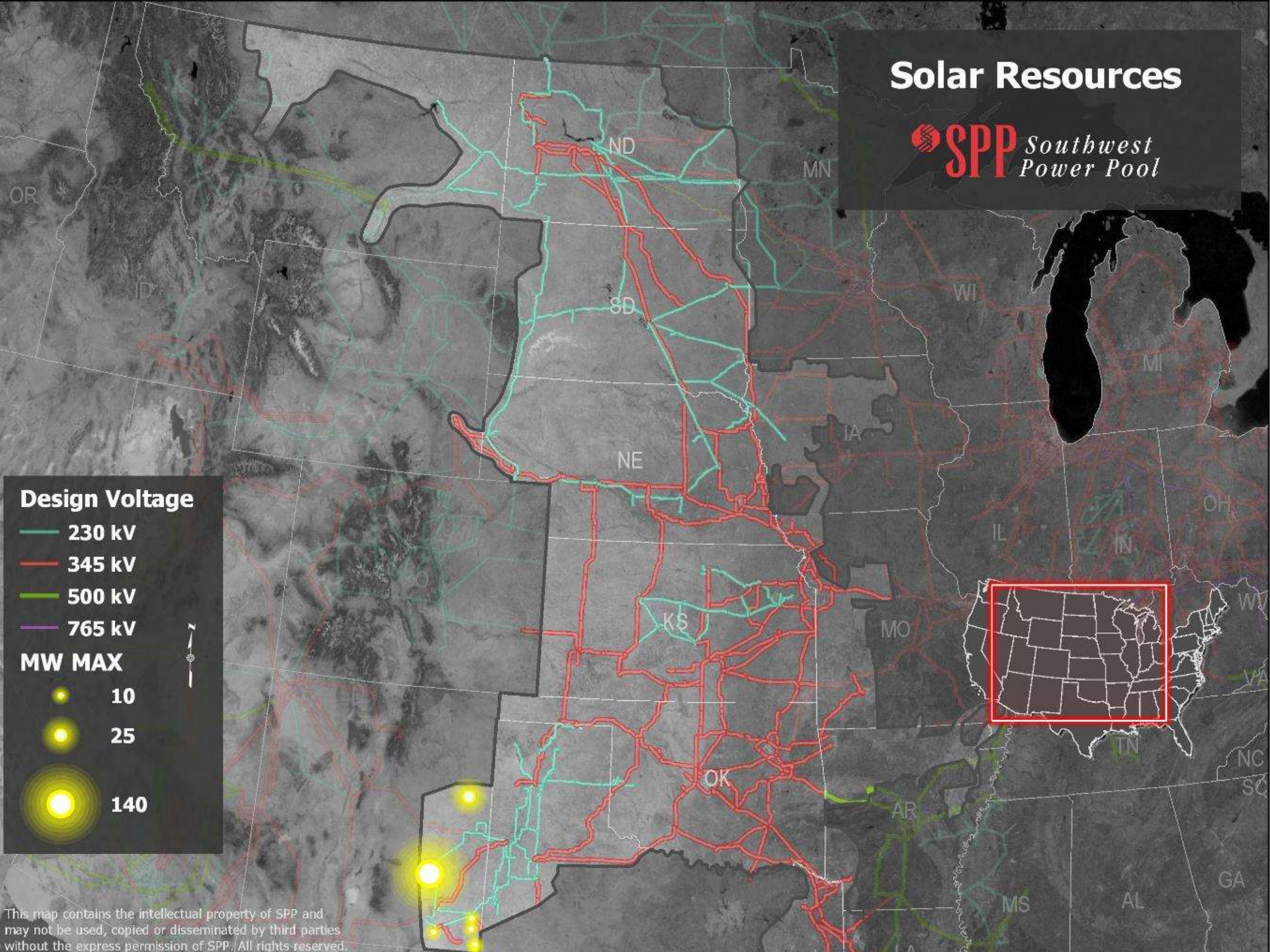





PV Solar Radiation
(Flat Plate, Facing South, Latitude Tilt)
Annual
Model estimates of monthly average daily total radiation using inputs derived from satellite and/or surface observations of cloud cover, aerosol optical depth, precipitable water vapor, albedo, atmospheric pressure and ozone resampled to a 40km resolution. See http://www.nrel.gov/gis/il_solar_pv.html documentation for more details.
kWh/m2/day
> 9.0
8.5 - 9.0
8.0 - 8.5
7.5 - 8.0
7.0 - 7.5
6.5 - 7.0
6.0 - 6.5
5.5 - 6.0
5.0 - 5.5
4.5 - 5.0
4.0 - 4.5
3.5 - 4.0
3.0 - 3.5
2.5 - 3.0
2.0 - 2.5
< 2.0
NREL
Produced by the Electric & Hydrogen Technologies & Systems Center - May 2004

SOLAR IN SPP

- Solar installed today: 215 MW
- Solar in all stages of study and development: 24.9 GW
- Many solar projects are being co-located with battery projects


Solar Resources
SPP Southwest Power Pool
Design Voltage
230 kV
345 kV
500 kV
765 kV
MW MAX
10
25
140
OR
ID
ND
SD
NE
KS
OK
MN
WI
IA
MO
AR
MI
IL
IN
OH
TN
MS
AL
GA
NC
SC
WV
VA
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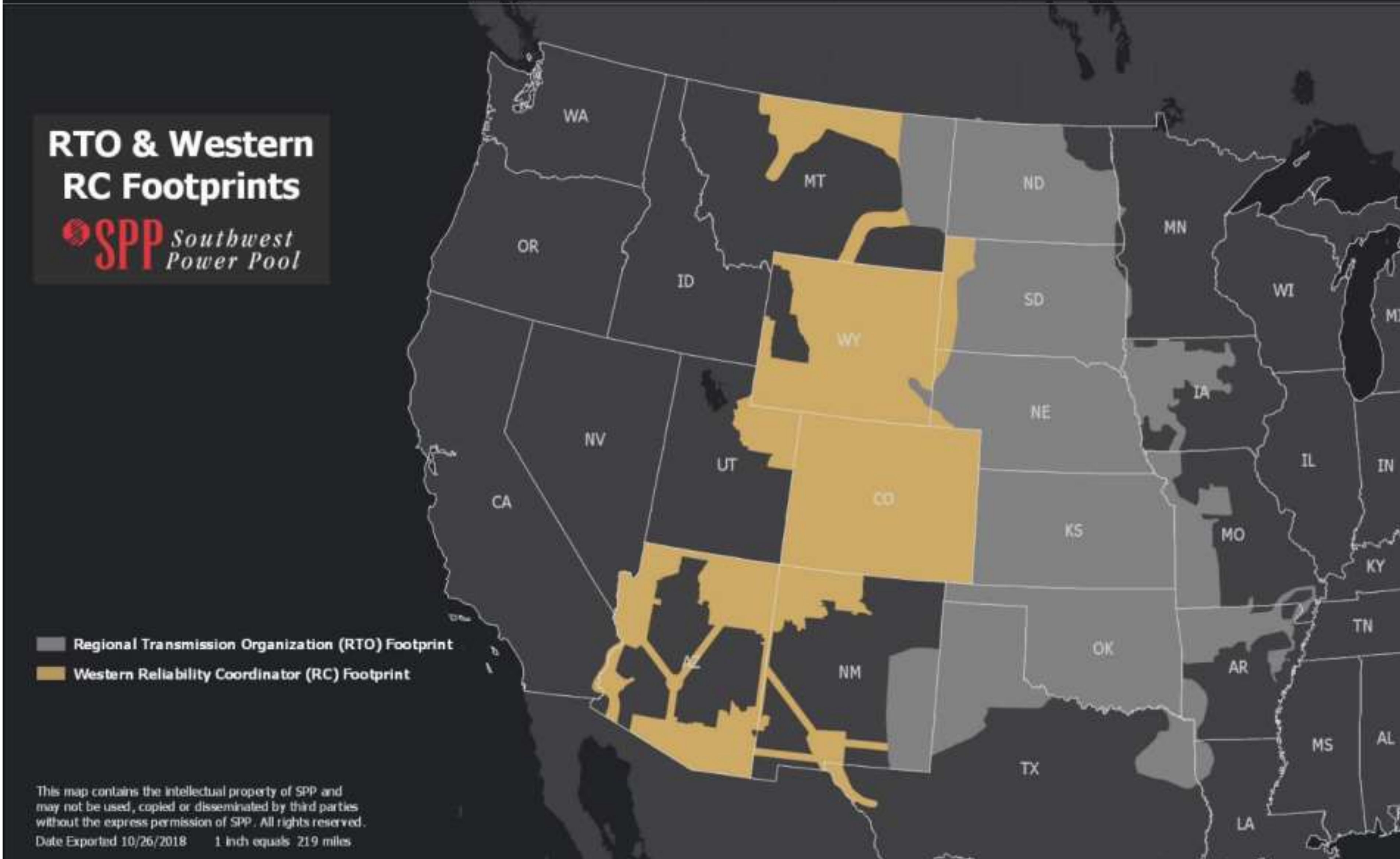


Arizona Electric Power Cooperative, Black Hills Power and Black Hills Colorado, Cheyenne LFP, City of Farmington NM, Colorado Springs Utilities, El Paso Electric, Intermountain Rural, Platte River Power Company, Public Service Company of Colorado, Tri-State G&T, Tucson Electric, WAPA RMR and WAPA DSW, Arlington Valley, Griffith

Former Mountain West Participants

Southwest Power Pool

NREL-LED, DOE-FUNDED INTERCONNECTIONS SEAM STUDY

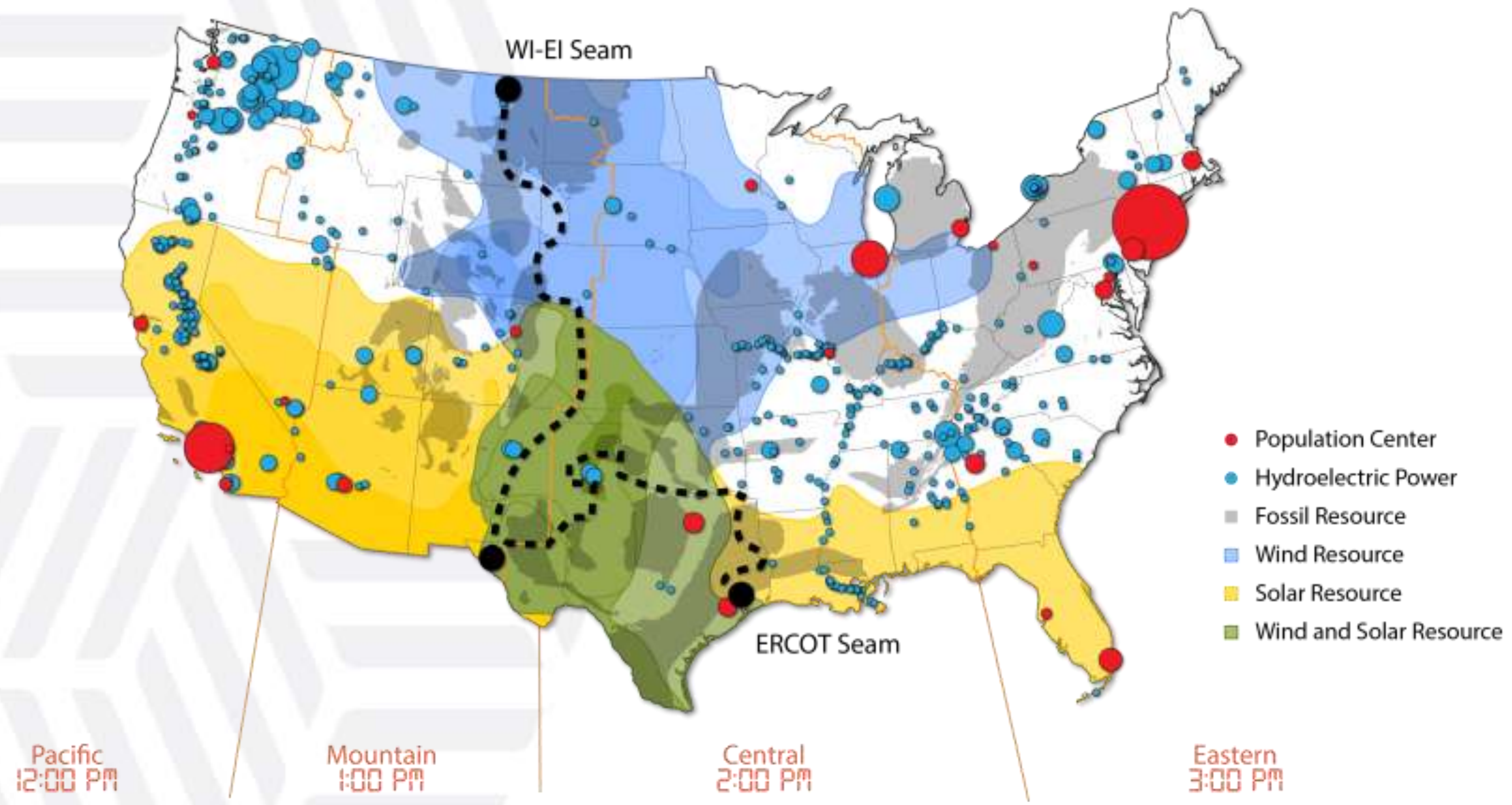
NREL Interconnections Seam Study

Aaron Bloom and Joshua Novacheck

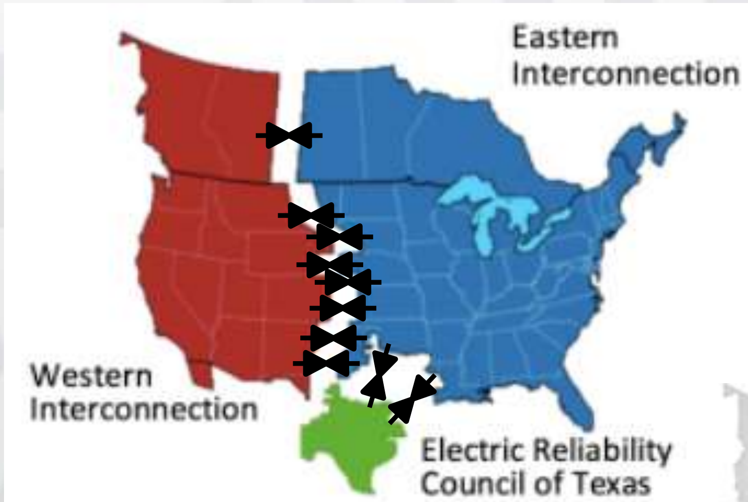
UVIG Spring Workshop, Tucson, AZ

March 2018

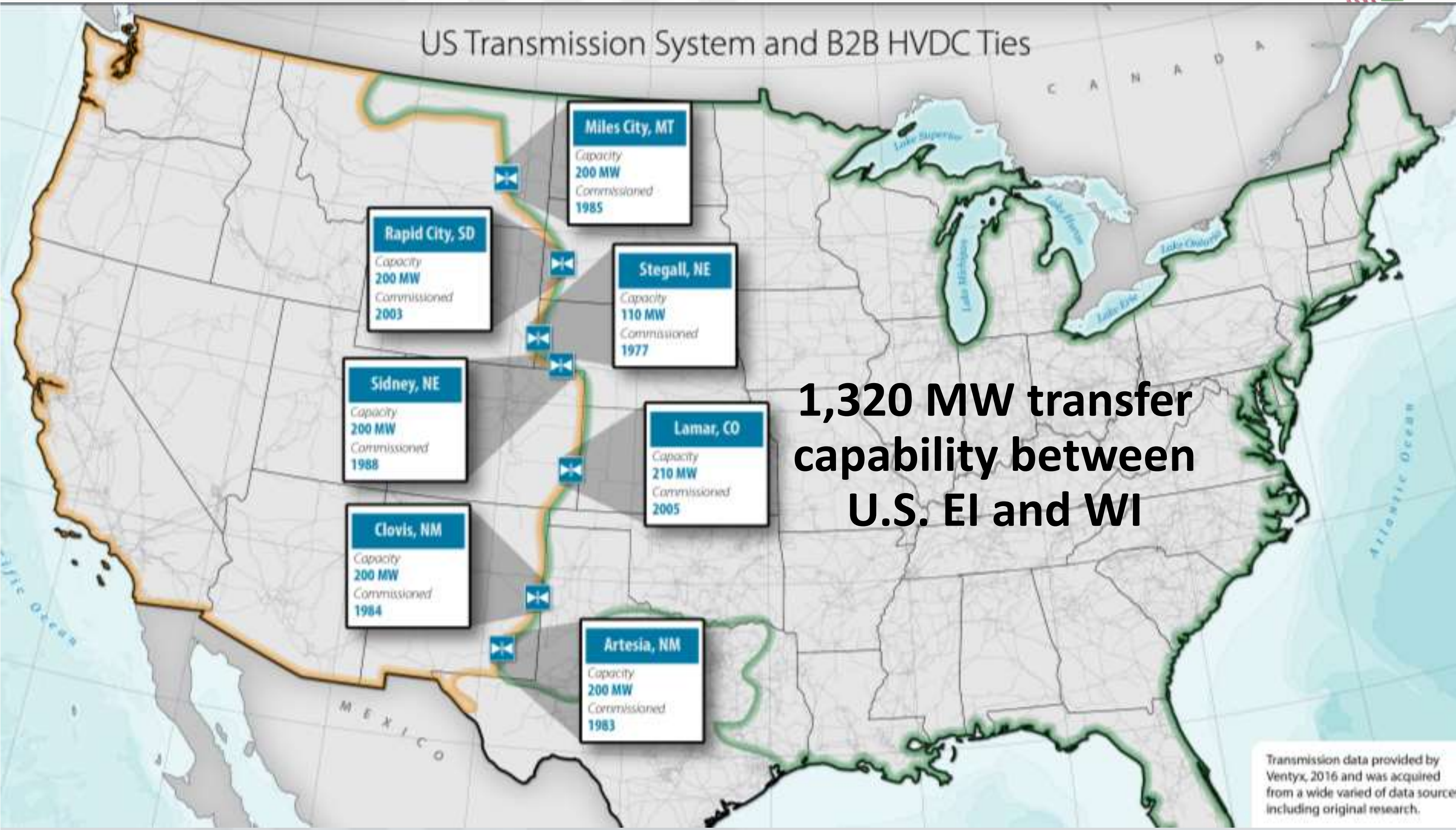
The Interconnections Seam Study



Eastern Interconnection Seams



- U.S. Interconnections are tied together with HVDC Back-to-Back Ties
- All EI ties in U.S are on the SPP Seam



1,320 MW transfer capability between U.S. EI and WI

Partners are Everything

SPP Southwest Power Pool

MISO

NREL NATIONAL RENEWABLE ENERGY LABORATORY

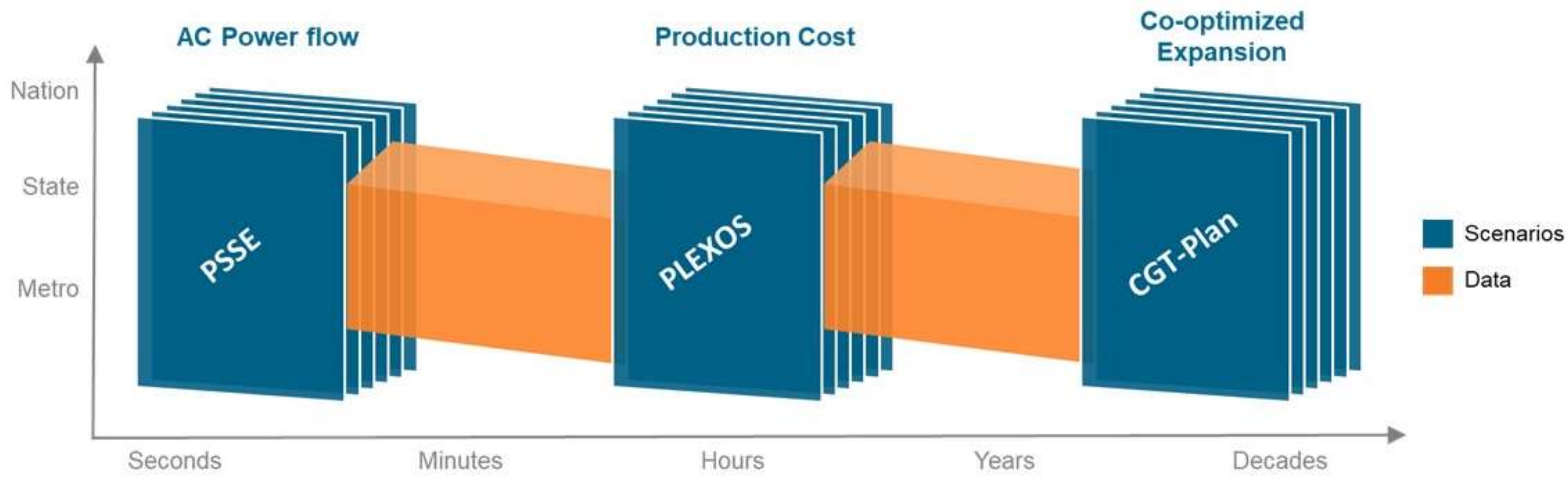
Western Area Power Administration

Iowa State University

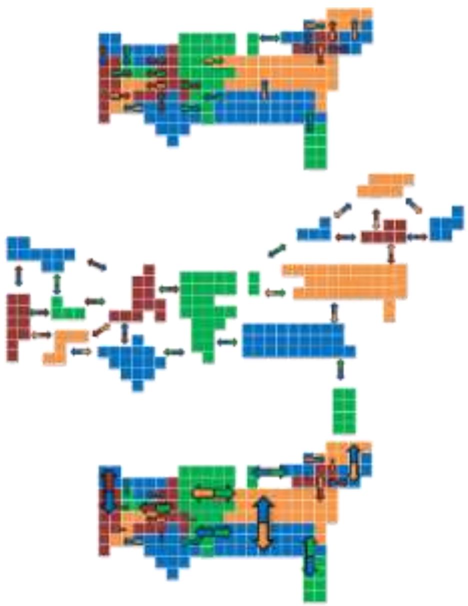
Pacific Northwest National Laboratory

More Data, Better Resolution

- 1,000 times more wind and solar data, from GBs to TBs
- Transmission models have moved from 10s of nodes to nearly 100,000
- Every generator in North America, and many more around the world
- It’s not just the data, it’s the tools to use the data: ReV (above)



Integrated Power System Models and Data

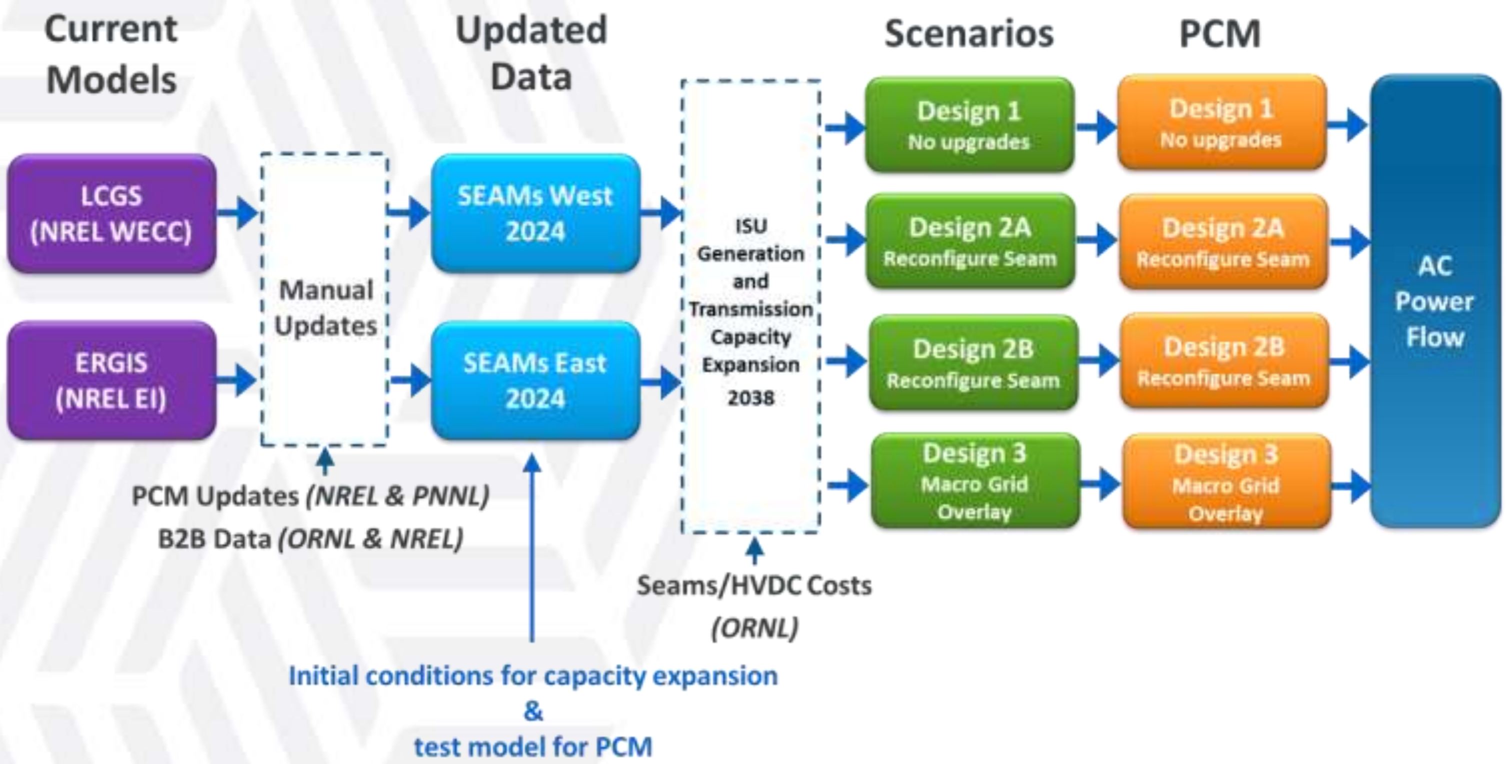


New algorithms enable more accurate models that solve in days not weeks.

Advanced

Computational Methods

Modeling Approach



Conceptual Scenarios

Scenario Name	Description
Design 1	Existing B2B facilities are replaced at their current (2018) capacity level and new AC transmission and generation are co-optimized to minimize system wide costs.
Design 2a	Existing B2B facilities are replaced at a capacity rating that is co-optimized along with other investments in AC transmission and generation.
Design 2b	Three HVDC transmission segments are built between the Eastern and Western Interconnections and existing B2B facilities are co-optimized with other investments in AC transmission and generation.
Design 3	A national scale HVDC transmission network, Macro Grid, is built and other investments in AC transmission and generation.

Research Environments

The four conceptual transmission designs were studied under two different system conditions

Base Case

High Variable Generation

TRC Driven Assumptions

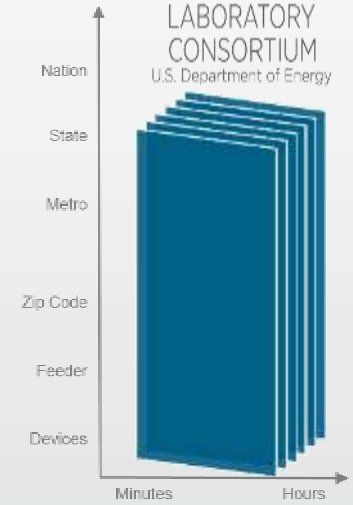
- North American Eastern and Western Interconnections
- Retire generation based on economic performance
- Run for 15 years, with 7 investment periods
- Fuel cost forecasts according to AEO 2017 (med-gas)
- Gen investment base costs & maturation rates from NREL ATB 2016
- Transmission base costs according to EIPC/B&V
- Gen & trans regional cost multipliers from EIPC/WECC
- Use of 169 bus model (68 EI, 101 WI)
- 4 regions: West, Northwest, Midwest, East
- Wind uses 100-m tower CFs ~ 0.45-0.50
- Gen capacity investment limited to 40GW/yr
- Demand growth per NEEM & WI (E3) per state
- DG growth per AEO 2016, 3% per yr
- New nuclear, offshore wind, geothermal, concentrating solar power, and carbon capture technologies were not studied

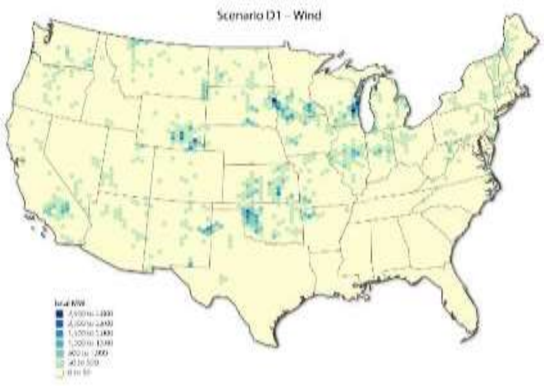
Production Cost Models

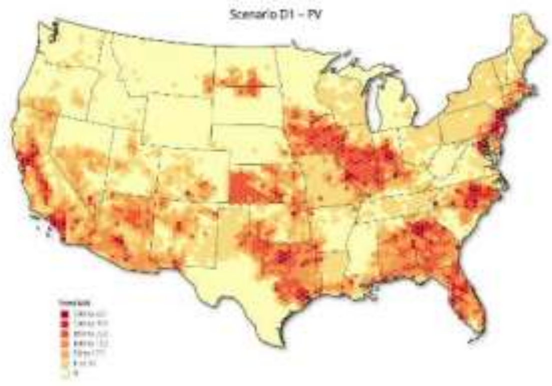
Production Cost

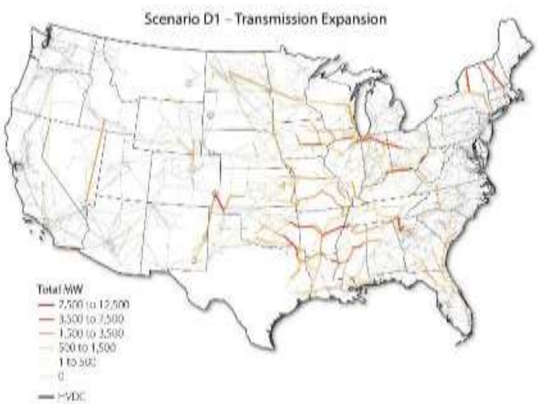
GRID MODERNIZATION LABORATORY CONSORTIUM
U.S. Department of Energy

- Simulate the unit commitment and economic dispatch of a power system
- Approximate the daily operations of an IOU or RTO/ISO (Day ahead and Real Time)
- Used to simulate an entire year of hourly operations
- Calculates the cost of producing electricity
- Linearized DC Power flow



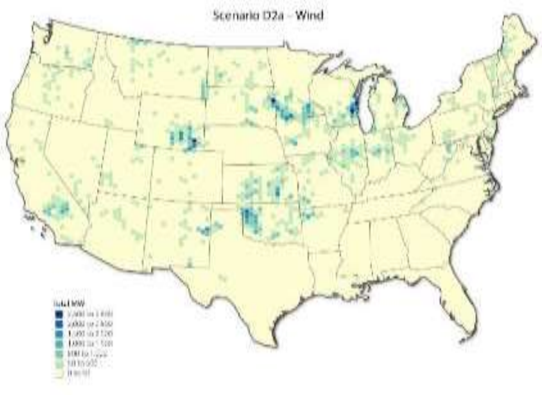


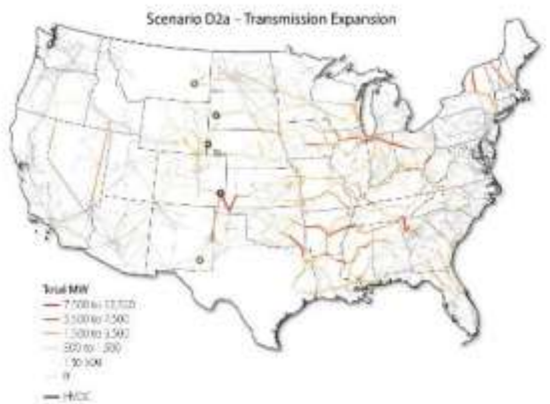




Design 1

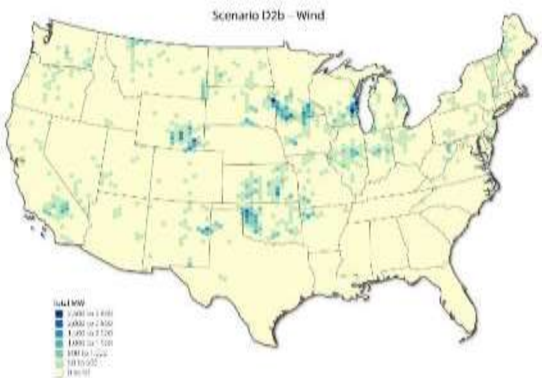
Base Case

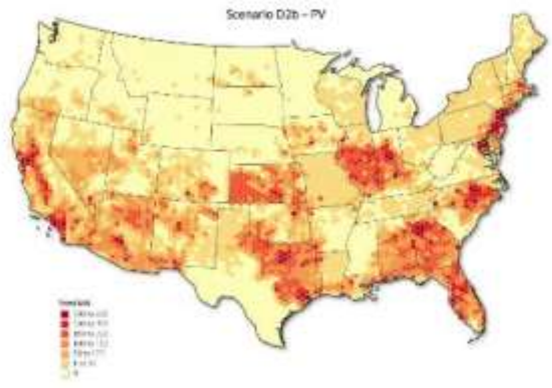




Design 2a

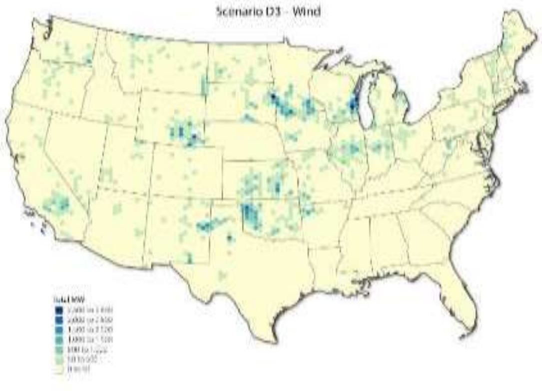
Base Case

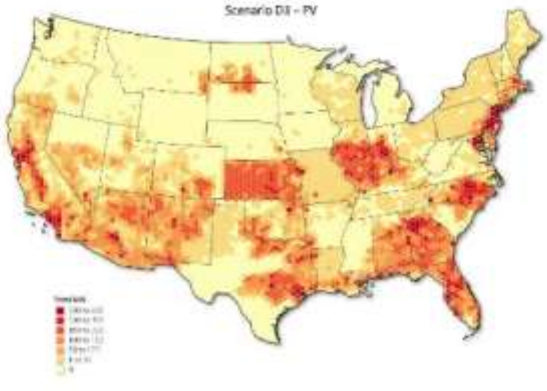




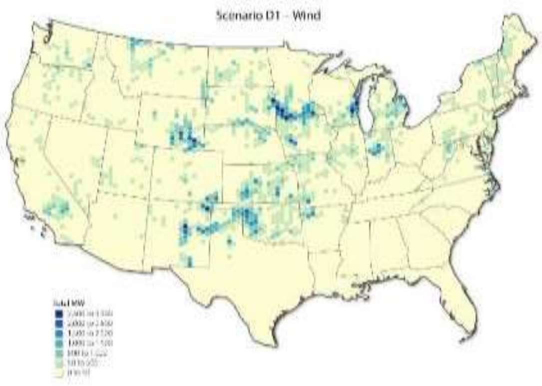
Design 2b

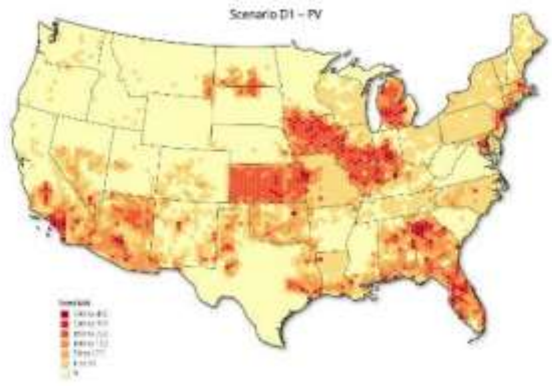
Base Case



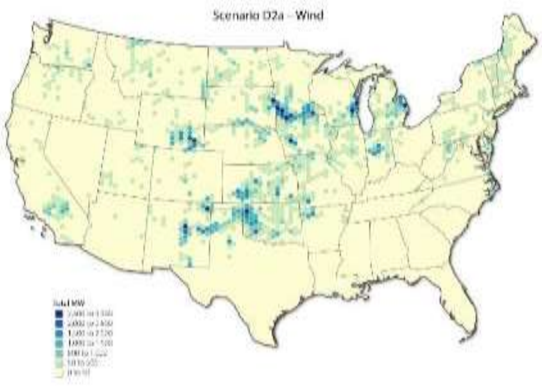


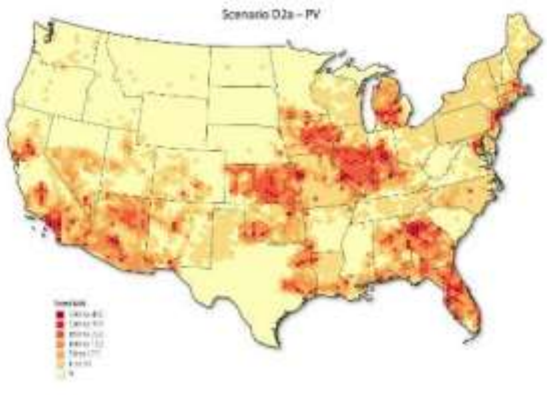
Design 3
Base Case





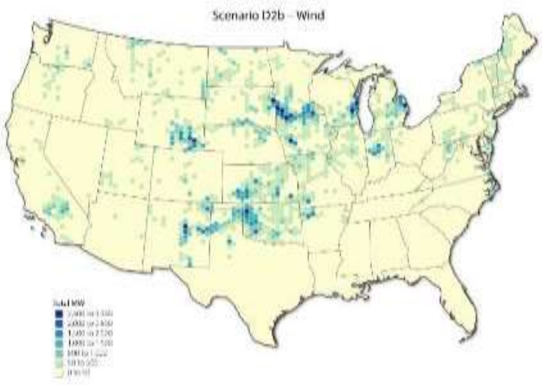
Design 1
High VG Case

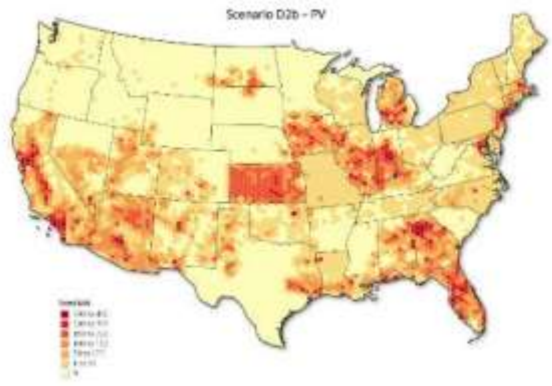




Design 2a

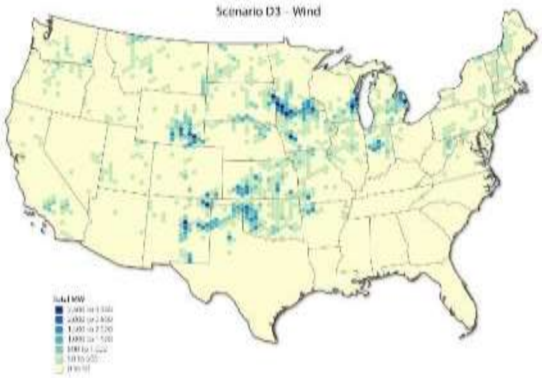
High VG Case

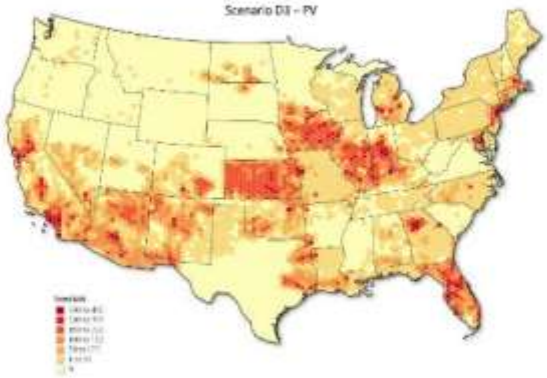




Design 2b

High VG Case





Design 3
High VG Case

Installed Capacity (GW)

	2024	Base Case				High VG Case			
		D1	D2a	D2b	D3	D1	D2a	D2b	D3
Coal	266	120	113	111	115	65	37	29	32
Hydro	198	198	198	198	198	198	198	198	198
Natural Gas	443	437	431	418	421	467	453	450	448
Nuclear	132	132	132	132	132	132	132	132	132
Solar	64	281	277	271	278	246	241	241	239
Wind	94	320	324	326	324	450	487	488	487

Transmission Capacity Additions (GW)

GRID MODERNIZATION LABORATORY CONSORTIUM
U.S. Department of Energy

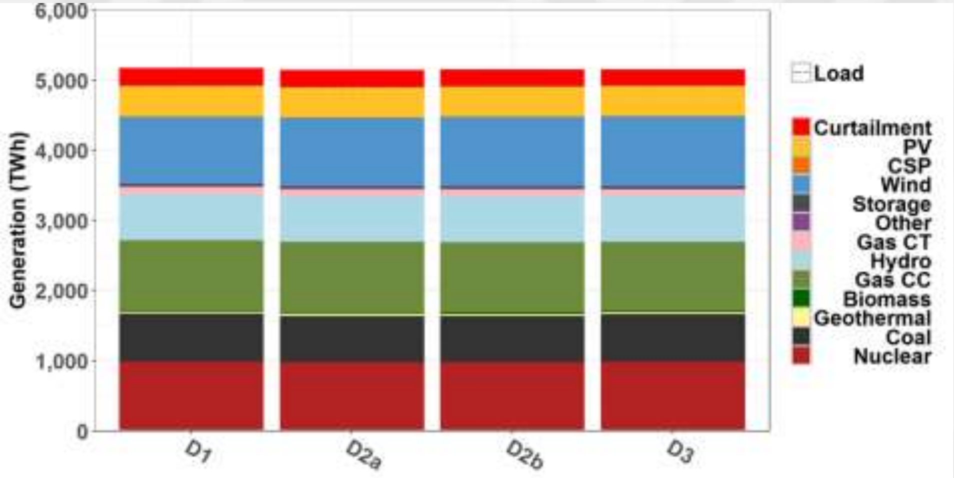
	Base Case				High VG Case			
	D1	D2a	D2b	D3	D1	D2a	D2b	D3
AC Transmission	92	95	89	84	228	251	235	195
HVDC Transmission	0	7	20	58	0	26	36	126

Expansion Overview

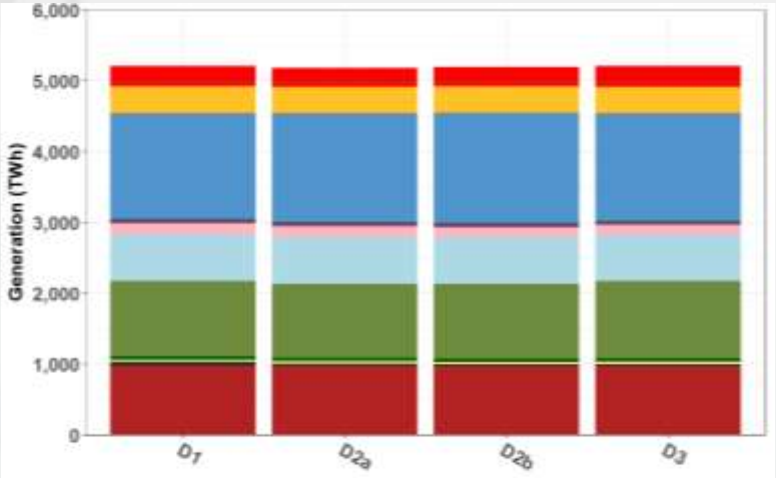
- All cases imagine a future where it is feasible to build multi-region transmission
- Design 1 is the only case without new HVDC and without new transmission across the Seam
- The generation mix changes substantially in all cases
- Results are known to be imperfect, yet informative
- Substantial AC transmission is added in all cases
- All cases meet the same Resource Adequacy target (15% planning reserve margin). Details here: https://lib.dr.iastate.edu/etd/16128/

Annual Generation

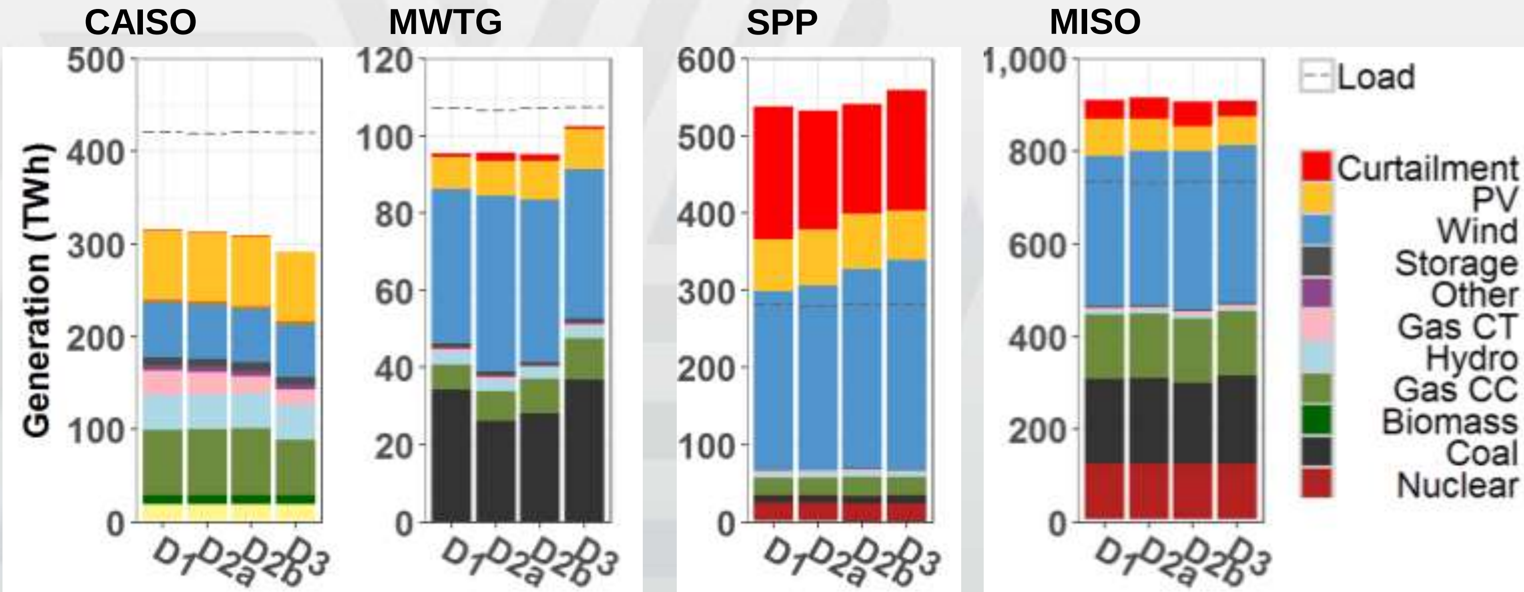
- Base Case



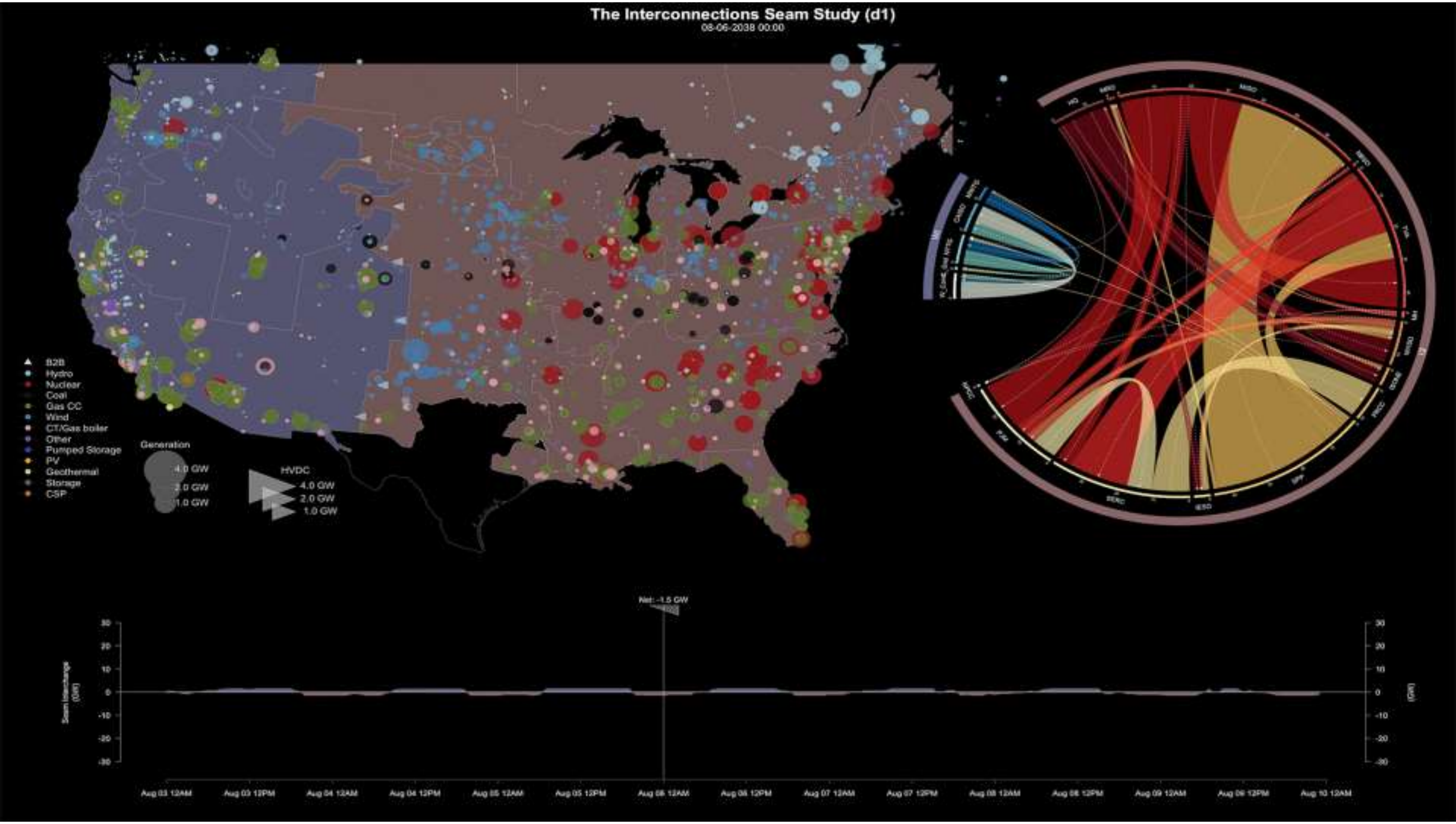
- High VG Case

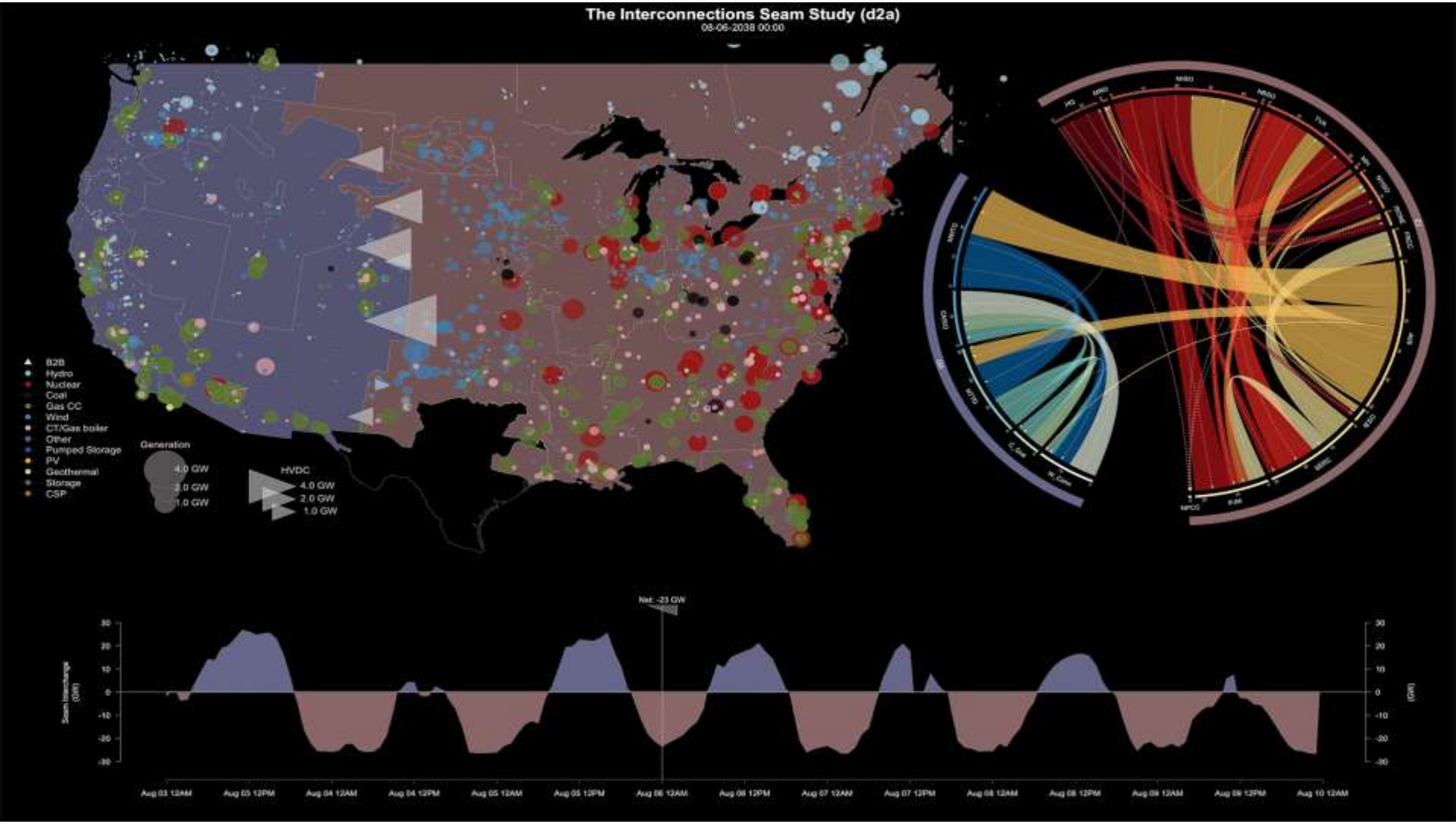


Regional Generation Base Case

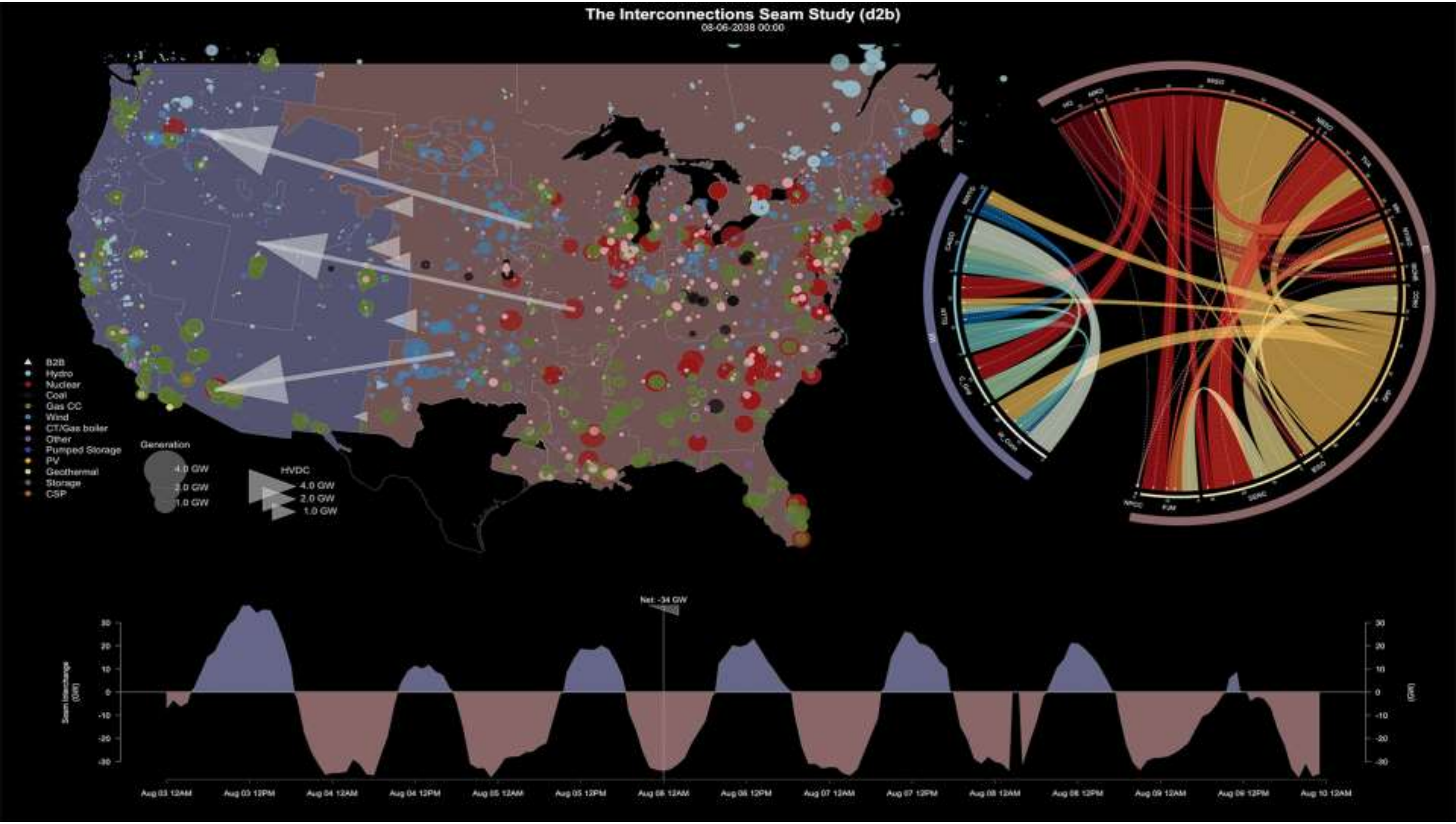


2038 Peak Week High VG


The Interconnections Seam Study (d1)
08-06-2038 00:00
B2B
Hydro
Nuclear
Coal
Gas CC
Wind
CT/Gas boiler
Other
Pumped Storage
PV
Geothermal
Storage
CSP
Generation
4.0 GW
2.0 GW
1.0 GW
HVDC
4.0 GW
2.0 GW
1.0 GW
Net: -1.5 GW
Seam Interchange (GW)
(GW)
30
20
10
0
-10
-20
-30
Aug 03 12AM
Aug 03 12PM
Aug 04 12AM
Aug 04 12PM
Aug 05 12AM
Aug 05 12PM
Aug 06 12AM
Aug 06 12PM
Aug 07 12AM
Aug 07 12PM
Aug 08 12AM
Aug 08 12PM
Aug 09 12AM
Aug 09 12PM
Aug 10 12AM



The Interconnections Seam Study (d2a)
08-06-2038 00:00
B2B
Hydro
Nuclear
Coal
Gas CC
Wind
CT/Gas boiler
Other
Pumped Storage
PV
Geothermal
Storage
CSP
Generation
4.0 GW
2.0 GW
1.0 GW
HVDC
4.0 GW
2.0 GW
1.0 GW
Net: -23 GW
Seam Interchange (GW)
30
20
10
0
-10
-20
-30
Aug 03 12AM
Aug 03 12PM
Aug 04 12AM
Aug 04 12PM
Aug 05 12AM
Aug 05 12PM
Aug 06 12AM
Aug 06 12PM
Aug 07 12AM
Aug 07 12PM
Aug 08 12AM
Aug 08 12PM
Aug 09 12AM
Aug 09 12PM
Aug 10 12AM



The Interconnections Seam Study (d2b)
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B2B
Hydro
Nuclear
Coal
Gas CC
Wind
CT/Gas boiler
Other
Pumped Storage
PV
Geothermal
Storage
CSP
Generation
4.0 GW
2.0 GW
1.0 GW
HVDC
4.0 GW
2.0 GW
1.0 GW
Net: -34 GW
Seam Interchange (GW)
30
20
10
0
-10
-20
-30
Aug 03 12AM
Aug 03 12PM
Aug 04 12AM
Aug 04 12PM
Aug 05 12AM
Aug 05 12PM
Aug 06 12AM
Aug 06 12PM
Aug 07 12AM
Aug 07 12PM
Aug 08 12AM
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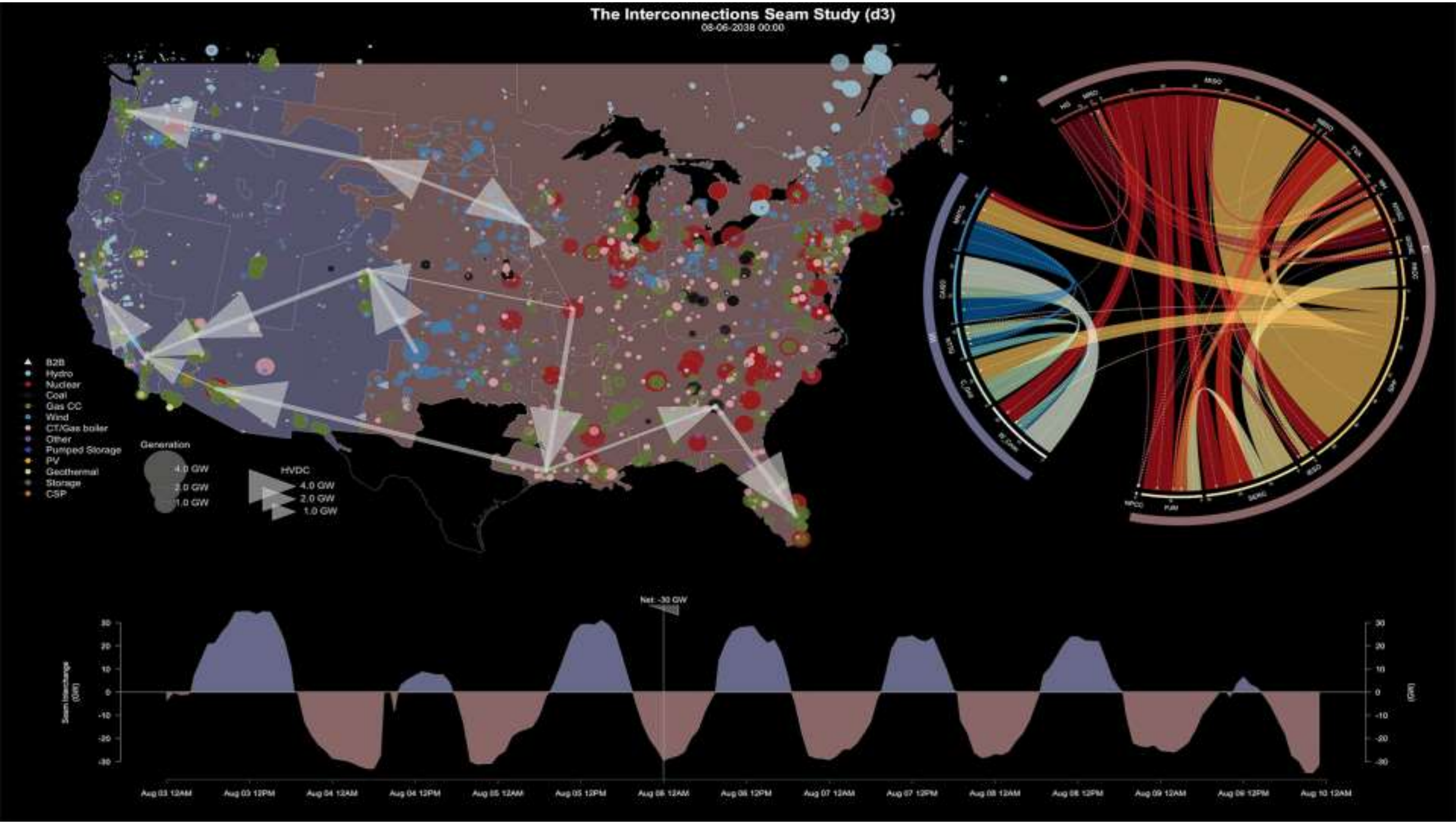
Aug 09 12AM
Aug 09 12PM
Aug 10 12AM



The Interconnections Seam Study (d3)
08-06-2038 00:00
B2B
Hydro
Nuclear
Coal
Gas CC
Wind
CT/Gas boiler
Other
Pumped Storage
PV
Geothermal
Storage
CSP
Generation
4.0 GW
2.0 GW
1.0 GW
HVDC
4.0 GW
2.0 GW
1.0 GW
Net: -30 GW
Seam Interchange (GW)
Aug 03 12AM
Aug 03 12PM
Aug 04 12AM
Aug 04 12PM
Aug 05 12AM
Aug 05 12PM
Aug 06 12AM
Aug 06 12PM
Aug 07 12AM
Aug 07 12PM
Aug 08 12AM
Aug 08 12PM
Aug 09 12AM
Aug 09 12PM
Aug 10 12AM

Total Costs 2024-2038 (NPV $B)

$$\text{BCR} = \frac{\text{Change in Total non-Transmission Costs}}{\text{Change in Transmission Investment Costs}}$$

Example, D1 vs D2a Current Policy: 4.01/3.19= 1.26

	Base Case							High VG Case						
ECONOMICS, NPV $B	**D1**	**D2a**	**Delta**	**D2b**	**Delta**	**D3**	**Delta**	**D1**	**D2a**	**Delta**	**D2b**	**Delta**	**D3**	**Delta**
Line Investment Cost	23.5	26.69	3.19	31.5	8	37.7	14.2	61.21	73.89	12.68	74.88	13.67	80.1	18.89
Generation Investment Cost	493.6	494.7	1.1	492.5	-1.1	494.2	0.6	704.03	703.32	-0.71	696.99	-7.04	700.51	-3.52
Fuel Cost	855.1	852.7	-2.4	851.2	-3.9	845.6	-9.5	753.8	738.98	-14.82	737.3	-16.5	736.12	-17.68
Fixed O&M Cost	416.4	415.6	-0.8	413.7	-2.7	413.8	-2.6	455.6	450.2	-5.4	448.95	-6.65	450.23	-5.37
Variable O&M Cost	81	81.1	0.1	81.2	0.2	81.2	0.2	64.5	63.9	-0.6	64.27	-0.23	64.39	-0.11
Carbon Cost	0	0	0	0	0	0	0	171.1	164.2	-6.9	162.6	-8.5	162.5	-8.6
Regulation-Up Cost	31.6	30.97	-0.63	31.13	-0.47	30.02	-1.58	33.29	31.63	-1.66	29.96	-3.33	26.63	-6.66
Regulation-Down Cost	45.1	44.2	-0.9	44.42	-0.68	42.85	-2.26	4.76	4.52	-0.24	4.29	-0.47	3.81	-0.95
Contingency Cost	23.9	23.42	-0.48	23.54	-0.36	22.71	-1.2	24.41	23.19	-1.22	21.97	-2.44	19.52	-4.89
Total Non-transmission Cost (Orange)	1,947.00	1,943.00	-4.01	1,937.70	-9.01	1,930.00	-16.34	2,211.49	2,179.94	-31.55	2,166.33	-45.16	2,163.71	-47.78
15-yr B/C Ratio (Orange/Green)			1.26		1.13		1.15			2.48		3.3		2.52

2038 Production Costs

	Base Case				High VG Case			
Design	D1	ΔD2a	ΔD2b	ΔD3	D1	ΔD2a	ΔD2b	ΔD3
Emissions	0	0	0	0	24.3	-1.5	-1.6	-1.1
Fuel	98.3	-0.4	-0.9	-3.2	83.0	-2.3	-2	-0.1
Start & Shutdown	2.8	-0.1	-0.1	-0.3	3.1	-0.4	-0.6	-0.5
VO&M	6.5	-0.1	-0.1	-0.1	4.9	-0.1	-0.1	-0.1
Total	107.6	-0.6	-1.2	-3.6	115.2	-4.2	-4.1	-1.8

Benefits

- All designs produce benefits that exceed costs.
- Results should be viewed directionally, not definitively.
- Comparisons are made to D1, which includes significant AC expansion, but no cross seam expansion.
- Full asset life is assumed to be 35 years, over the long run, the benefit may be significantly higher.
- Not appropriate to assume 2038 savings will stay the same until retirement, they may increase or decrease depending on the rest of the system.

	Benefit-to-Cost Ratio 2024-2038	
	Base Case	High VG Case
D1	-	-
D2a	1.26	2.48
D2b	1.13	3.3
D3	1.15	2.52

	Production Cost Savings 2038 ($B)	
	Base Case	High VG Case
D1	-	-
D2a	-0.6	-4.2
D2b	-1.2	-4.1
D3	-3.6	-1.8

Areas for Improvement

- Refine multi-model integration to remove modeling seams, e.g. capacity and network translation, and retirements.
- Study more designs: no new transmission, synchronize systems, all of North America
- Analyze multiple weather years of simulation to inform resilience to weather.
- Conduct comprehensive stability and contingency analysis

Observations

- Further analyses are warranted since status quo appears to be least desirable scenario among HVDC alternative futures
- Significant AC expansion is needed 2024-2038 absent any changes to EI-WECC Seams facilities.
- EHV/UHV voltages for backbone AC facilities need further analysis and consideration given preliminary results. Study results do not capture big economies of scale for 765kV, let alone double circuit 345kV, vs single circuit 345kV assumed in SPP and MISO.
- Transmission expansion costs are understated since they are based on equivalized EHV models and don't consider substations as well as integration to underlying existing AC systems. Significant system reconfiguration would be required for any of these futures.
- HVDC designs are not optimized given preselected nodes
- Harmonized models and datasets are an important and valuable step in shaping future dialogue and assessments

Next Steps

- Need to investigate relocated B2B ties and HVDC terminals, as well as potential AC and Hybrid Seam scenarios
- Update models to reflect expected / potential utility and merchant projects: Grain Belt Express, Power From The Prairie Project which includes Soo Green HVDC, significant EHV AC projects, etc.
- Update models to reflect expected resource retirements, 100% renewable/clean energy mandates and electrification futures
- Need to scope supplemental analyses to inform regional planning and shape dialogue about next steps:
  - DOE's North American Resiliency Model initiative
  - Shared vision to provide a roadmap to address aging infrastructure

Southwest Power Pool

THE FUTURE OF SPP HVDC TIES

SPP HVDC Lifetime Expectancy

Tie	State	Age	Rated MW
Stegall	NE	41	100
Eddy County	NM	38	200
Oklaunion	TX	4[1]	200
Blackwater	NM	36[2]	200
Miles City	MT	36	200
Sidney	NE	30	200
Welsh	TX	23[3]	600
Rapid City	SD	15	200
Lamar	CO	13	210

1 New LCC converter station built in 2014
2 LCC refurbishment in 2009
3 LCC refurbishment 2017

table 1. Major components and their typical lifetimes.

Component	Expected Lifetime (Years)
Converter and SVC transformers	40
Thyristor valves	30
HVdc controls and protection (analog)	25
HVdc controls and protection (digital)	15
Valve hall cooling	20
Thyristor valve cooling systems (wet surface cooling tower)	15
Thyristor valve cooling systems (dry surface cooling tower)	20
dc smoothing reactors (air core)	25
dc smoothing reactors (oil filled)	35
dc filters	20
Ground electrode	40

SPP

Questions Needing To Be Addressed

- Significant changes have occurred within the EI and WI interconnected systems over the past four decades
  - Major stations and EHV outlet installed
  - Equipment life expectancy approaching
  - EHV transmission projects in process and UHV projects near seam getting approved
- Refurbish?
- Replace?
- Relocate?
- Bypass?
- Increase Capacity?
- New HVDC Lines?

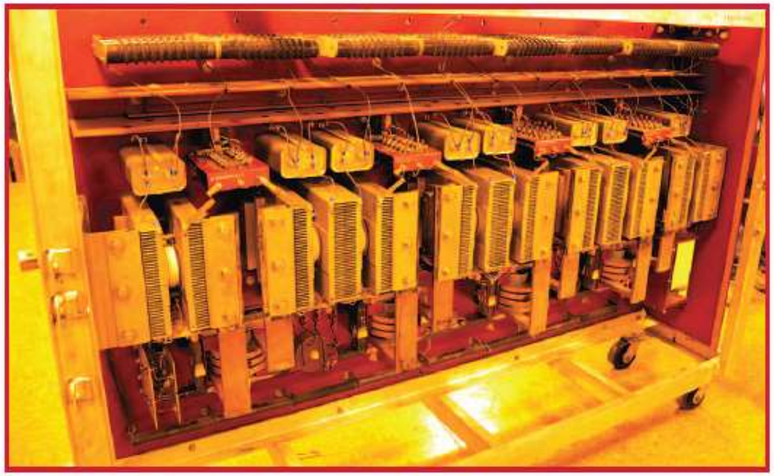


figure 5. A 1980s air-cooled thyristor valve module. (Photo courtesy of Gene Wolf.)

Much more analysis required to determine the correct answer!

SPP

TESTIMONY AT RESILIENCY HEARING ON JANUARY 23RD 2018 AT U.S. SENATE COMMITTEE ON ENERGY AND NATURAL RESOURCES

"…it is clear we need an in-depth understanding of the resilience of our electricity and related infrastructure in order to know how best to either modify existing market structures or build new resiliency standards into the system.

To that end, I propose that DOE undertake a detailed analysis that: 1) integrates into a single North American energy infrastructure model of the ongoing resilience planning efforts at the local, state, and regional level, including interconnections that reach into Canada and Mexico…

I believe building this resilience model should be the top priority for DOE's Office of Electricity Delivery and Energy Reliability over the coming years."

Bruce J. Walker
Assistant Secretary
Office of Electricity Delivery and Energy Reliability
U.S. Department of Energy
January 23, 2018

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APPENDIX

MILESTONES

1968 Became NERC Regional Council

1980 Implemented telecommunications network

1991 Implemented operating reserve sharing

1994 Incorporated as nonprofit

1997 Implemented reliability coordination

MILESTONES

1998 Implemented tariff administration

2004 Became FERC-approved Regional Transmission Organization

2007 Launched EIS market

2009 Integrated Nebraska utilities

2010 FERC approved Highway/Byway cost allocation methodology and Integrated Transmission Planning Process

MILESTONES

2012 Moved to new Corporate Center

2014 Launched Integrated Marketplace

Became regional Balancing Authority

2015 Integrated System joins SPP

SPP

ISO/RTO GROWTH SINCE 1996