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The Changing Energy Sector: Challenges and Opportunities

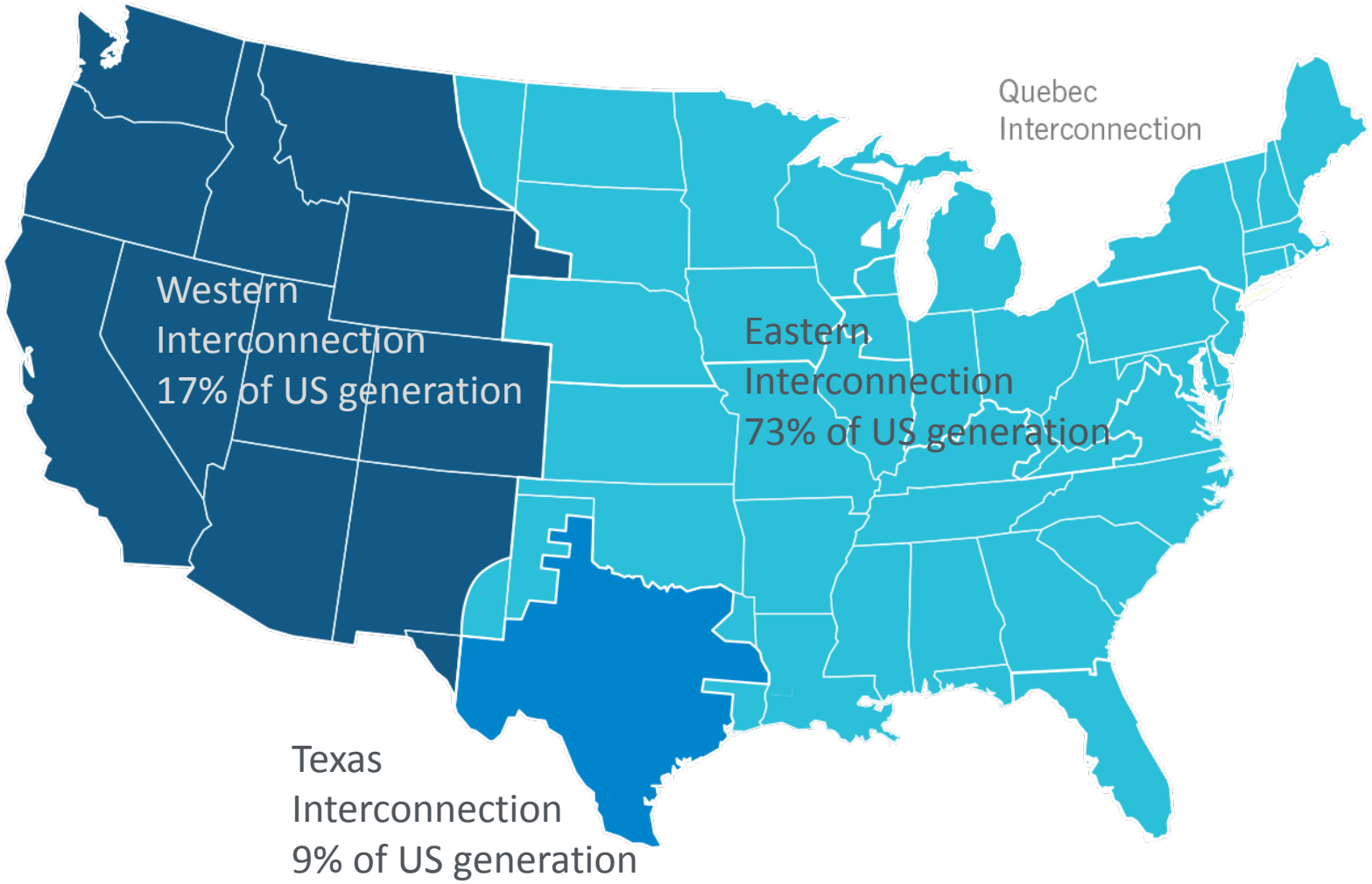
David Hurlbut

September 7, 2016
Golden, Colorado

Topics

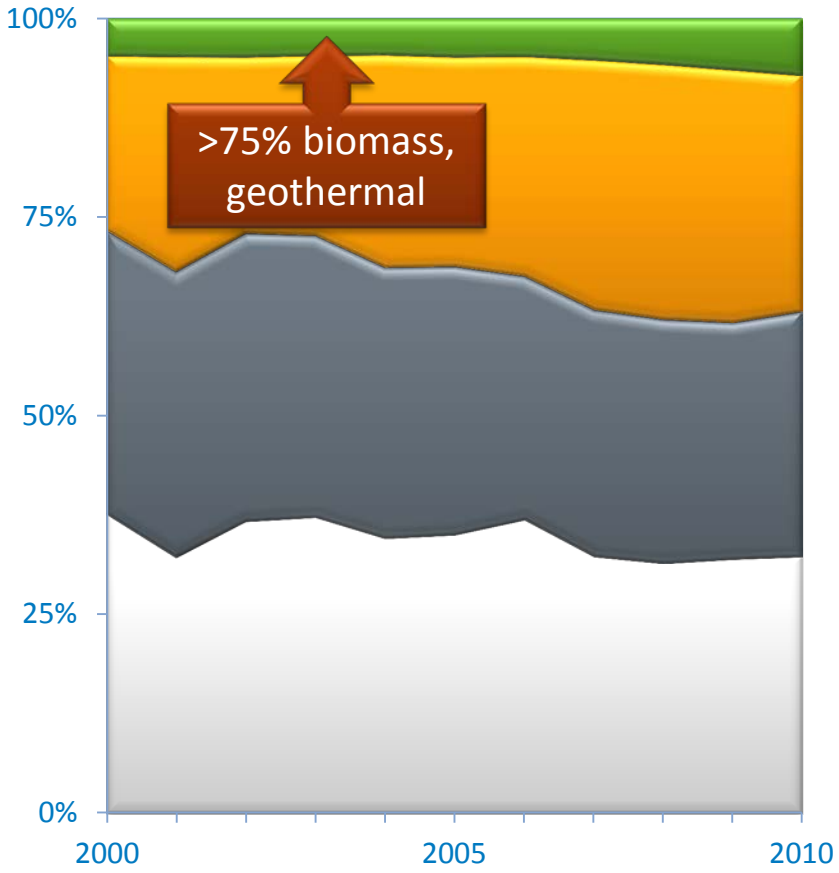
- Long-term transition from coal
- Regional renewable energy development patterns
- Potential for repurposing existing transmission
- RPS demand in the West

Major U.S. electric grids

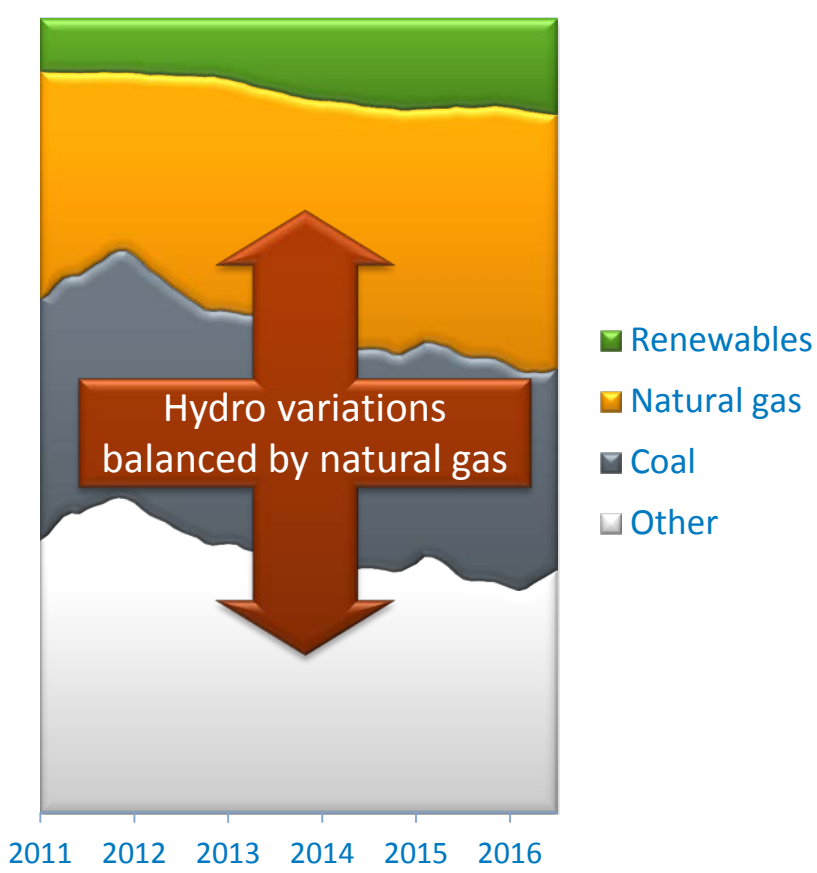


Western Interconnection

Annual net generation



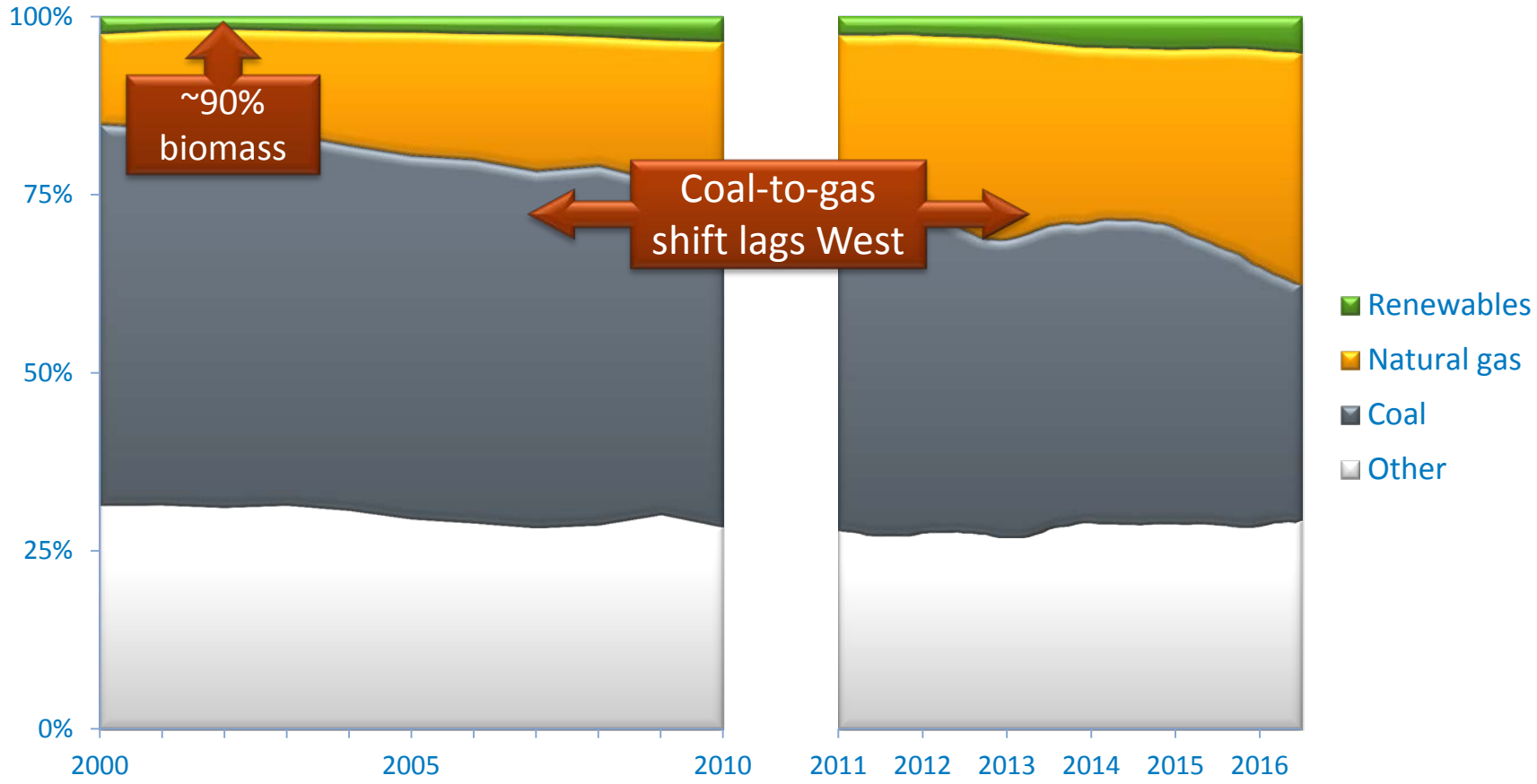
Rolling 12-month total



Eastern Interconnection

Annual net generation

Rolling 12-month total

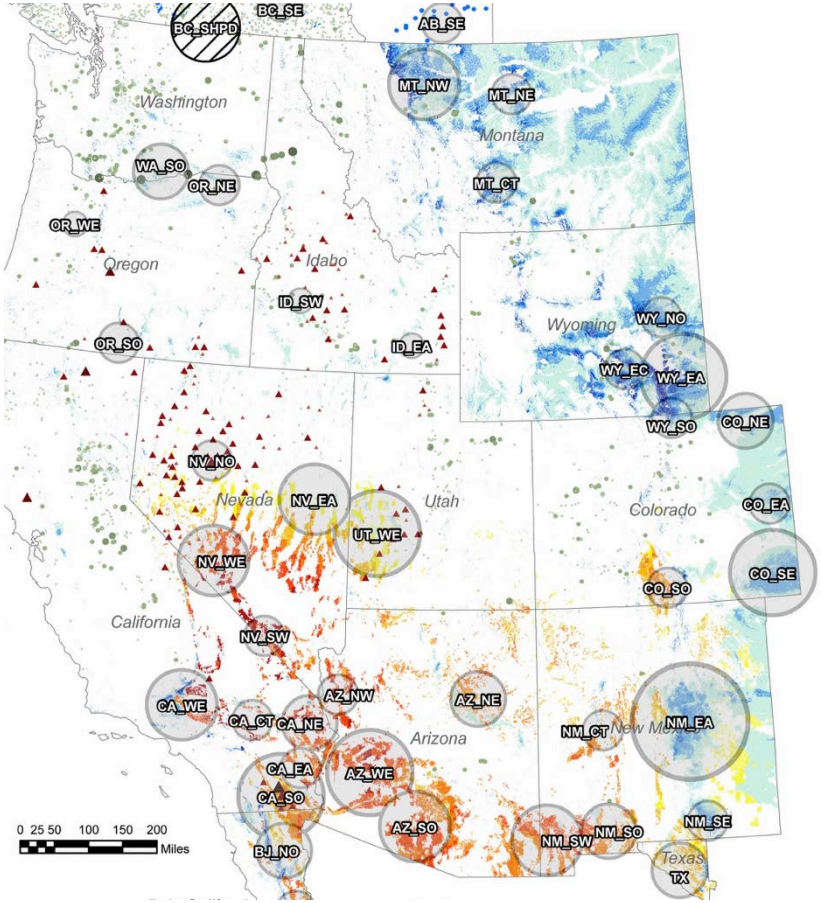


Observations

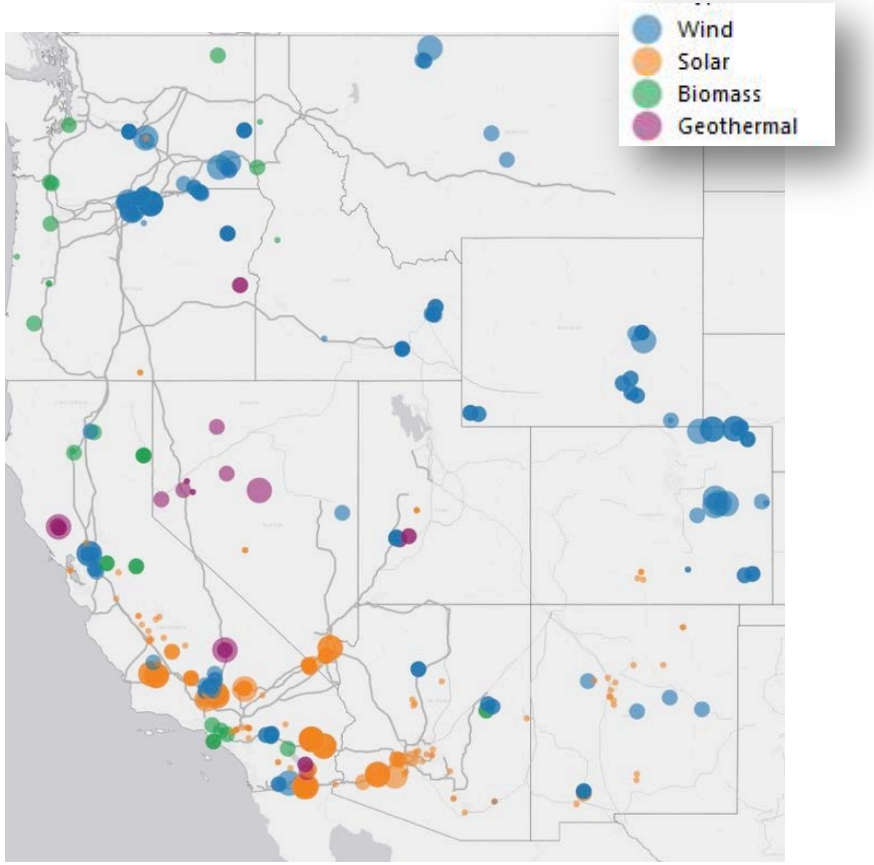
- Eastern Interconnection is reducing generation from coal and increasing generation from natural gas
  - Additional scheduling flexibility could increase opportunities for renewables, especially wind
  - Currently RE is 5% of the East's generation mix, compared to 12% for the Western Interconnection
- In the Western Interconnection, natural gas makes up much of the variation in hydro

Development is largely following expected patterns

WREZ Resource Map



Generation from renewables (2015)



Map shows transmission lines 345 kV and larger

Development is largely following expected patterns

Resource potential

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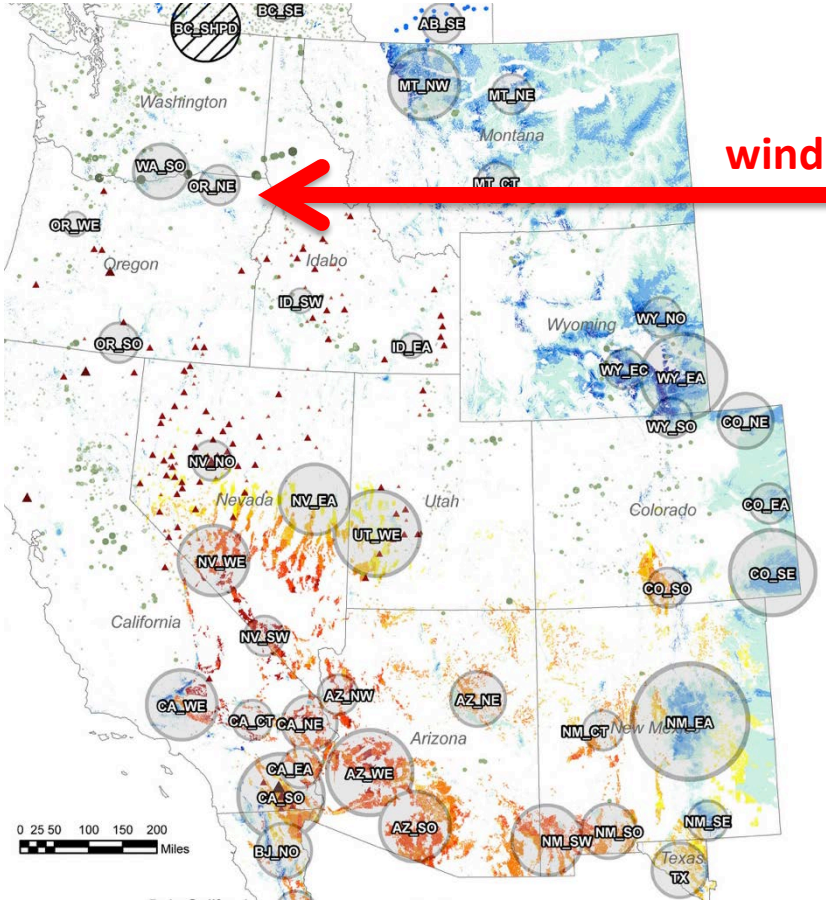
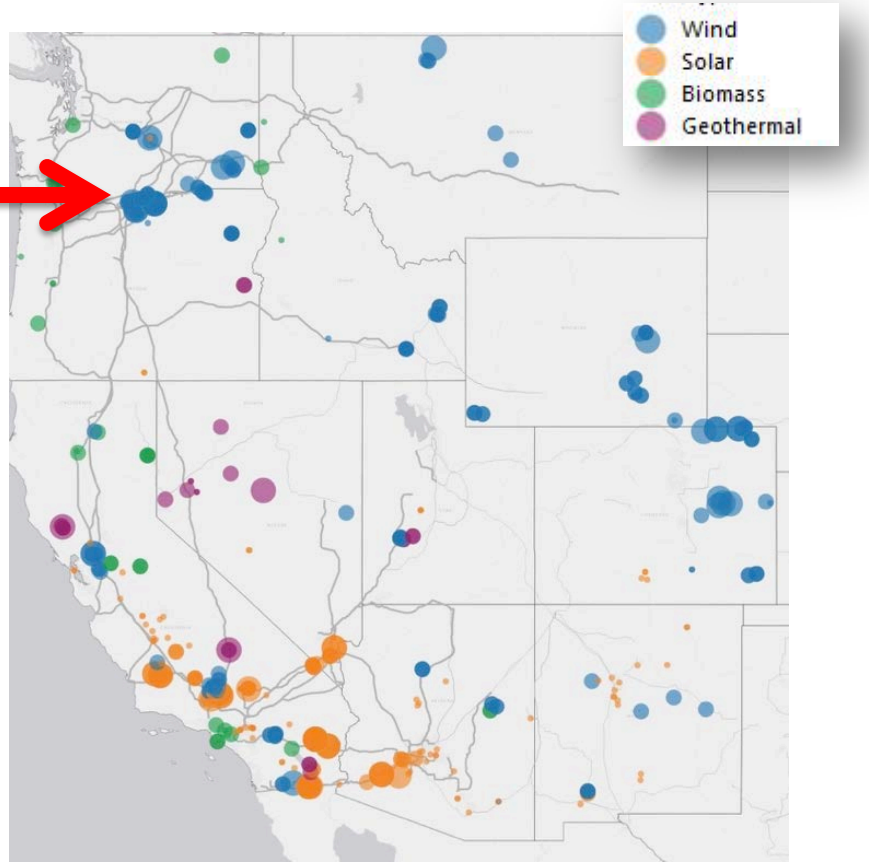


wind



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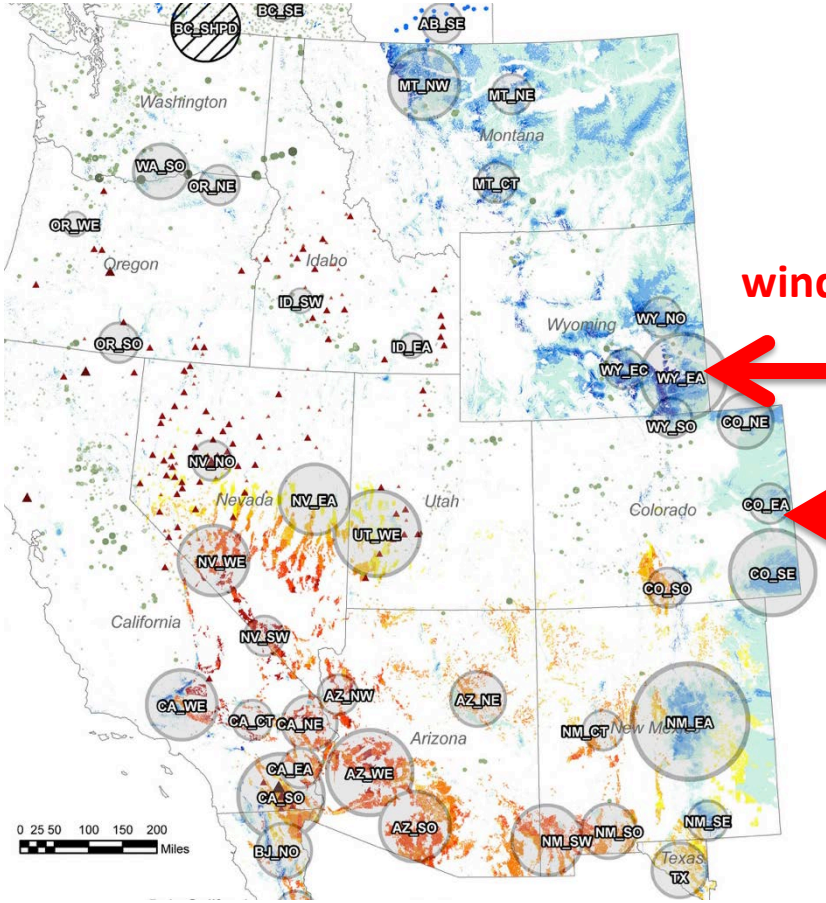

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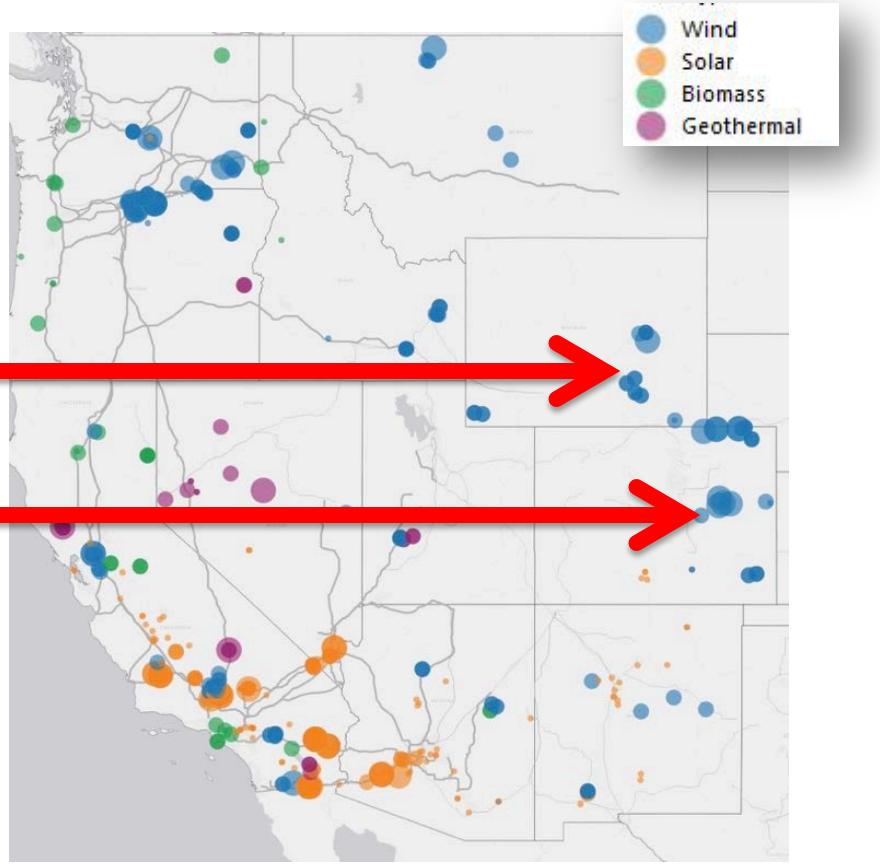

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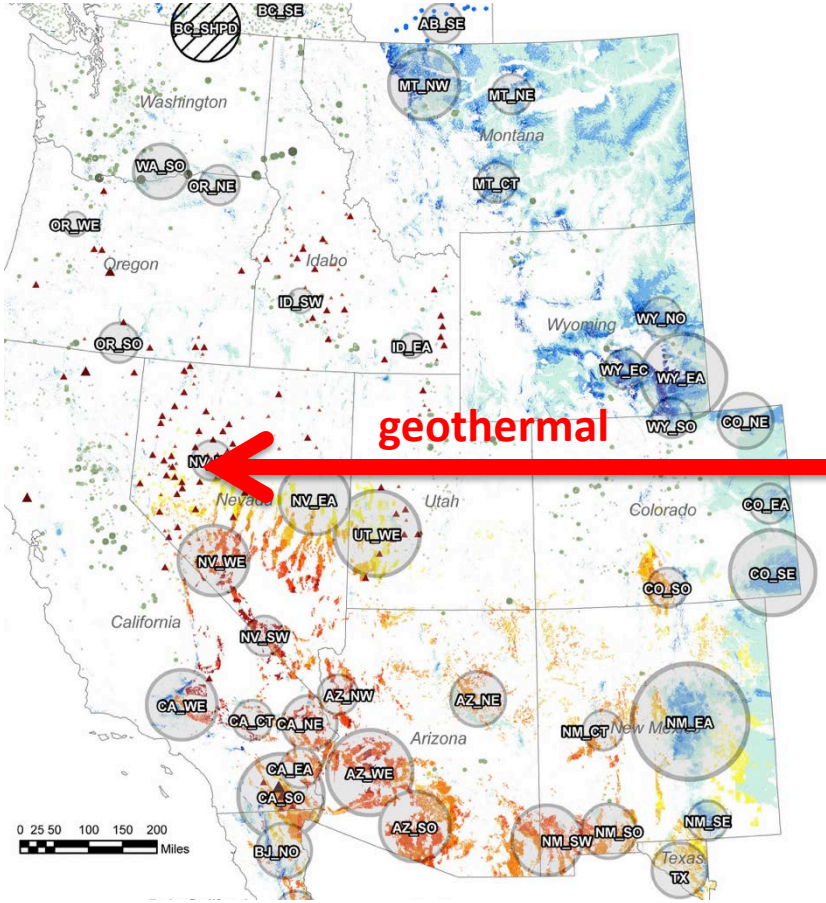
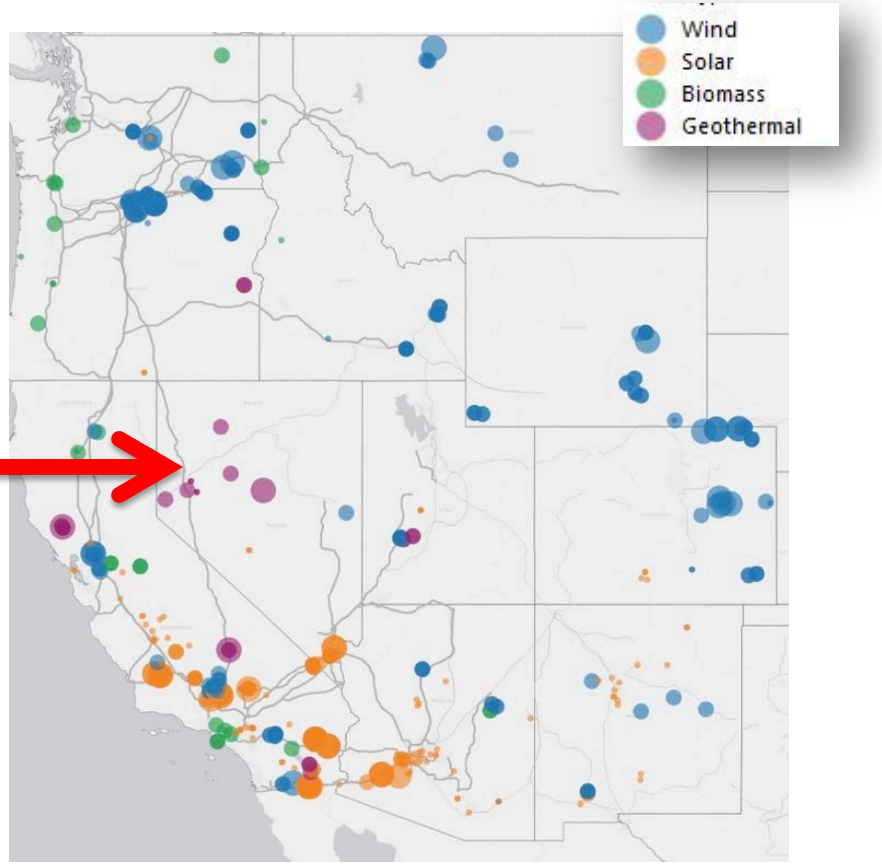


geothermal



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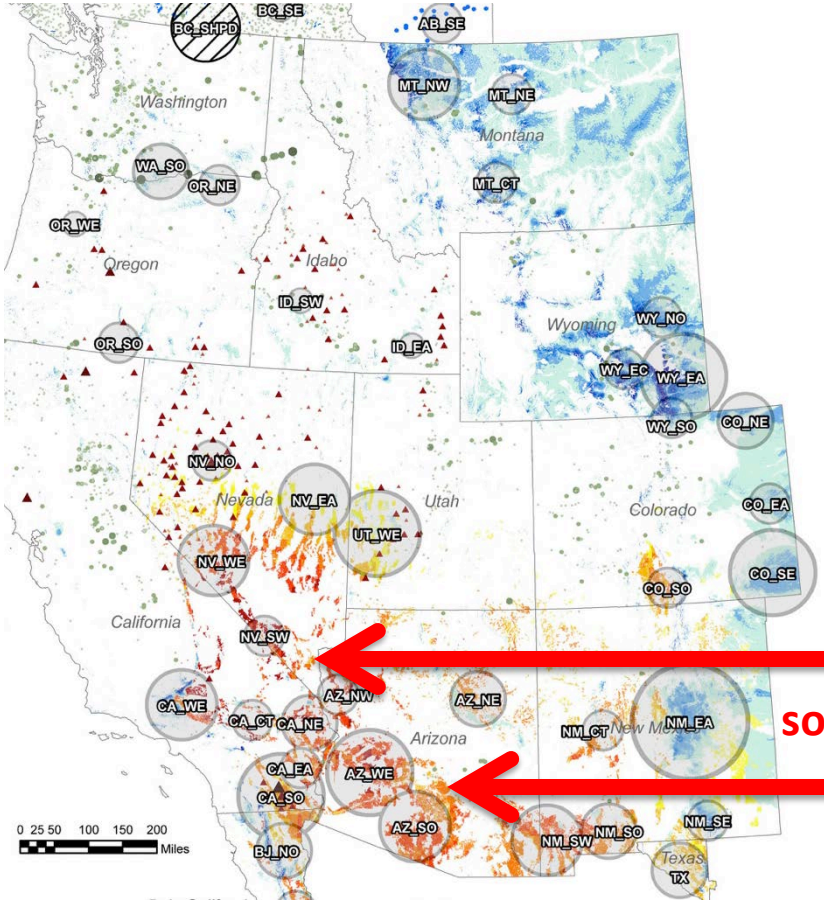
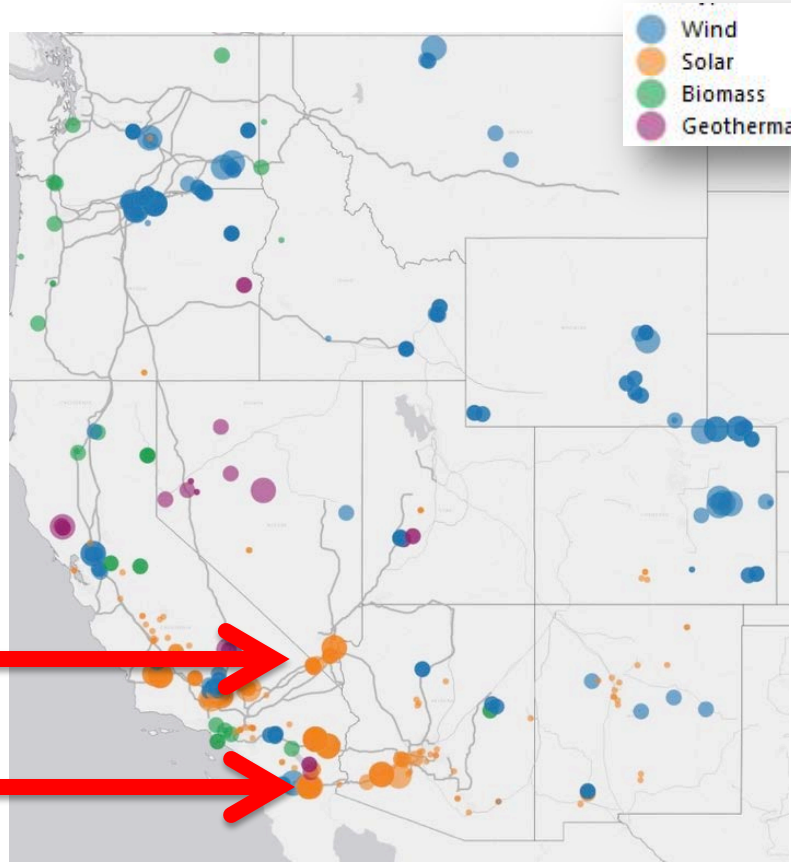
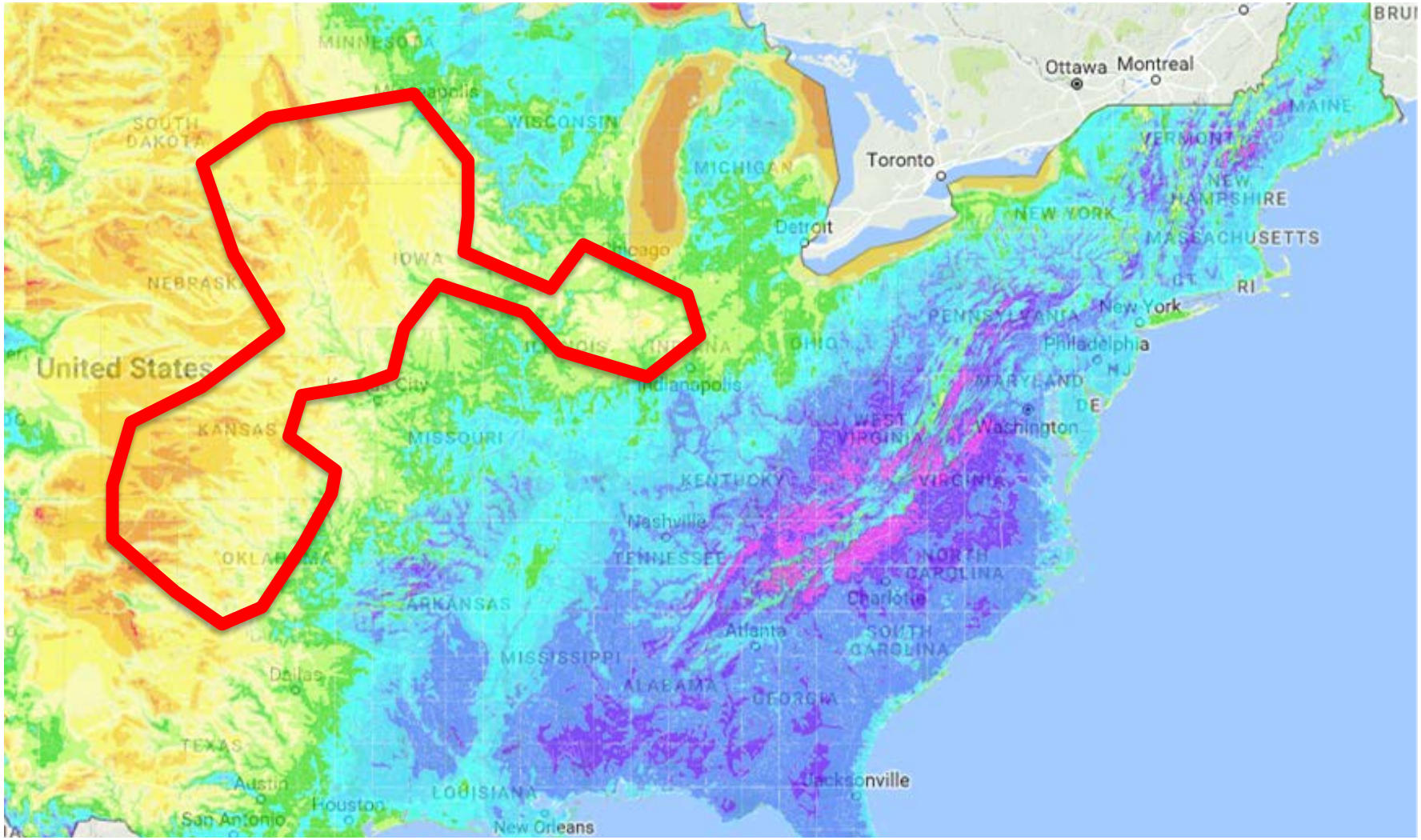




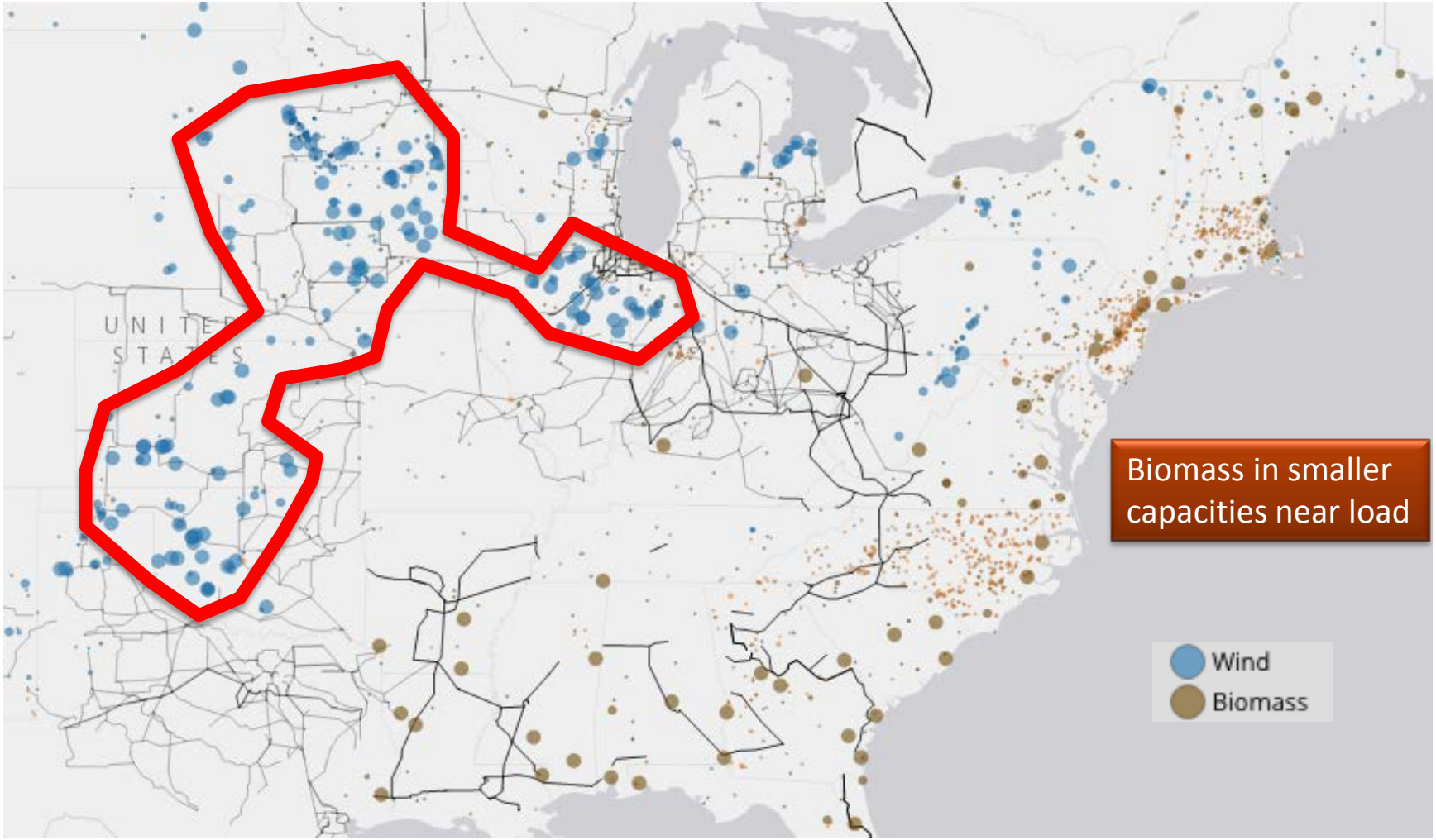
solar

Map shows transmission lines 345 kV and larger

Eastern Interconnection wind resource potential



Eastern Interconnection renewable development

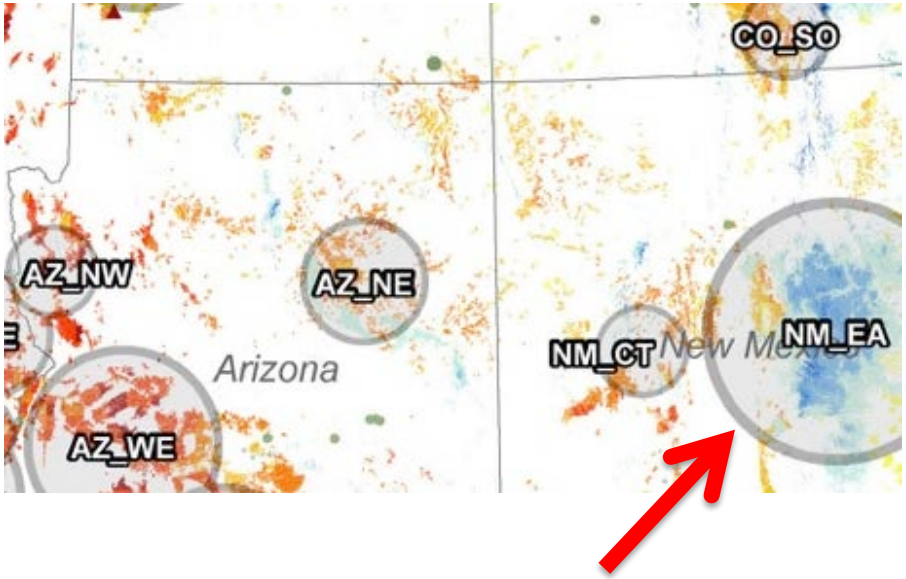


Observations

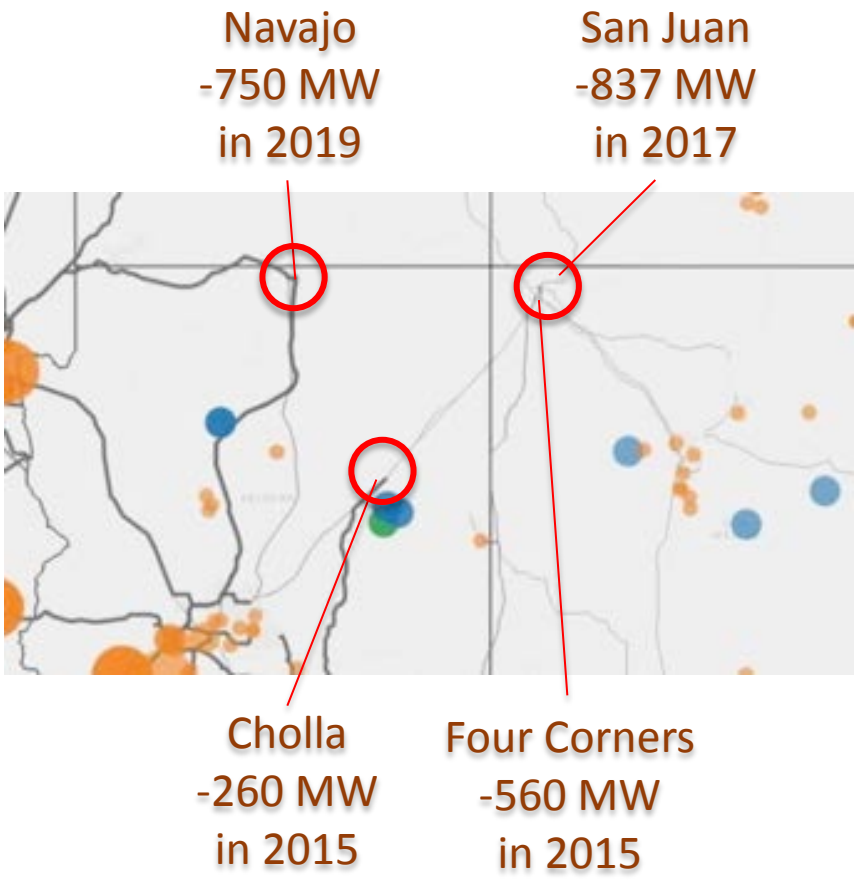
- Most development has been consistent with resource assessment, favoring access to nearby load via existing transmission
- Wind resources in New Mexico, Montana, Wyoming and the Dakotas are relatively underdeveloped in relation to their quantity and likely productivity
  - In-state native load is relatively small
  - Little existing transmission capability to reach large loads
- Utility-scale renewable energy development has a strong tendency to follow existing transmission, even if it means foregoing the best resource areas

Potential for re-purposing existing transmission

Renewable resources



Known coal reductions



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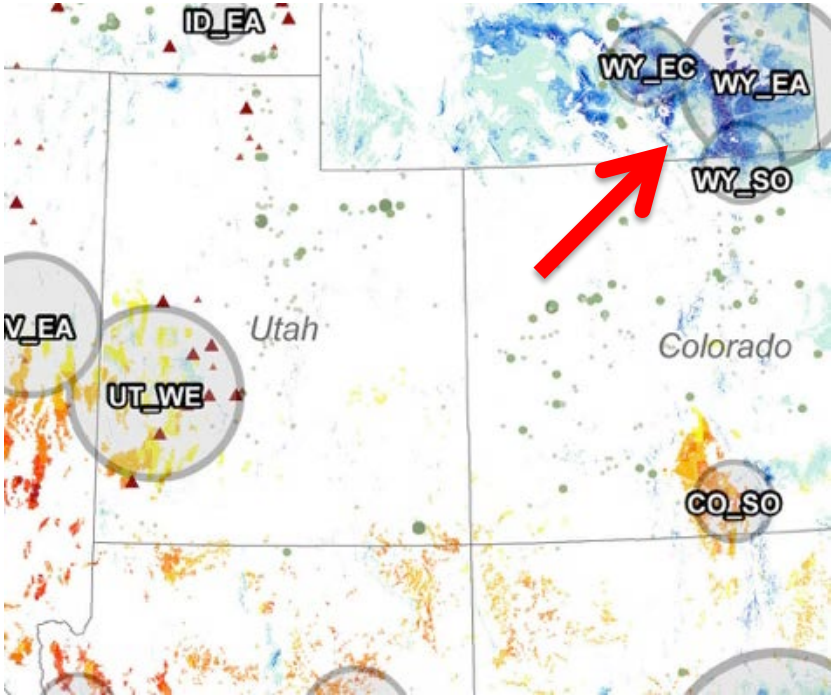
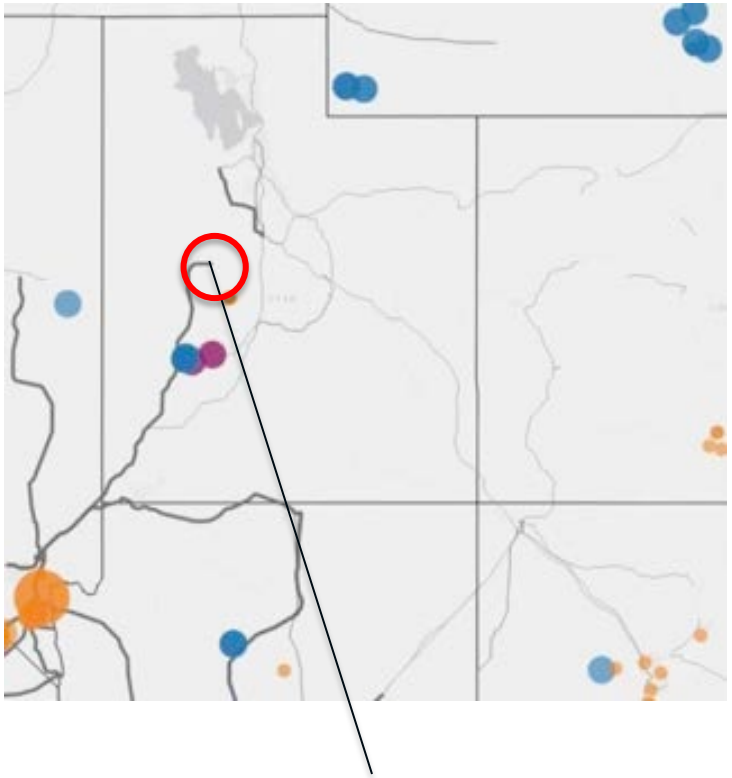


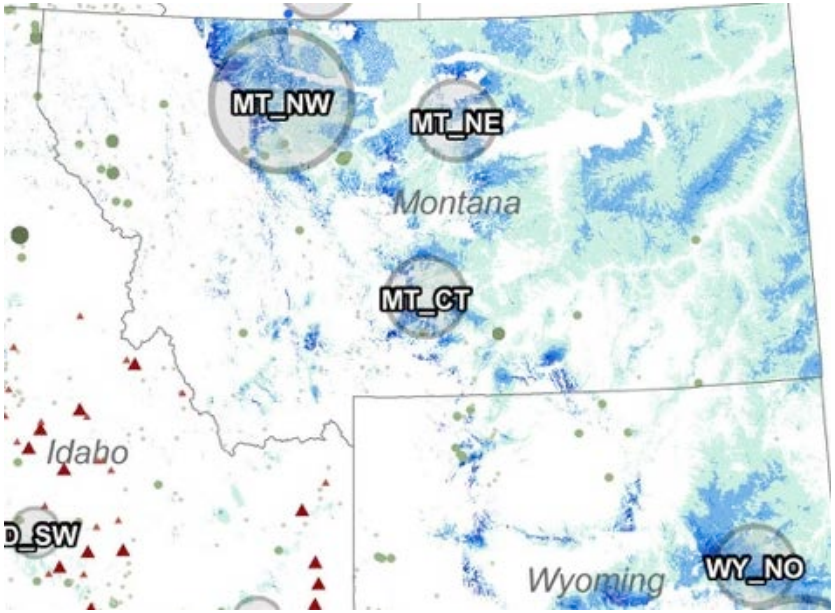
Potential coal reduction



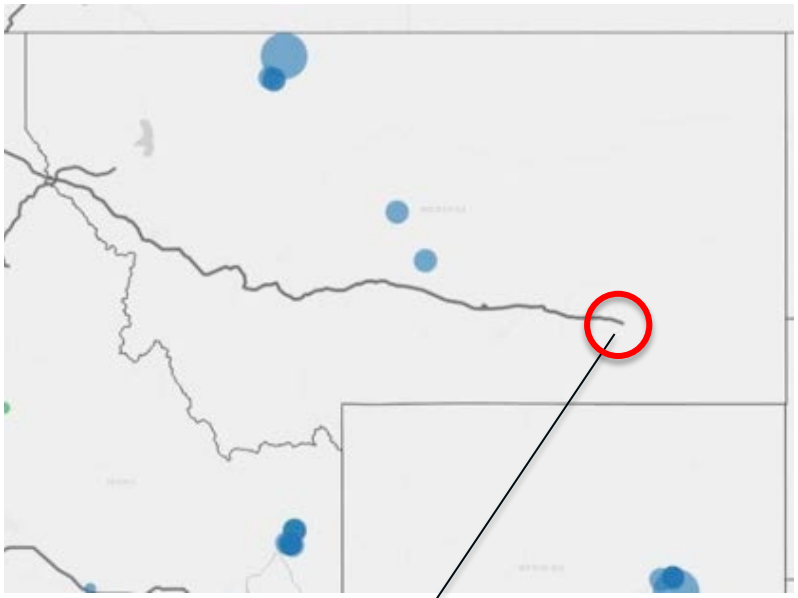
Intermountain
as much as -1.8 GW in 2025

Potential for re-purposing existing transmission

Renewable resources



potential coal reduction



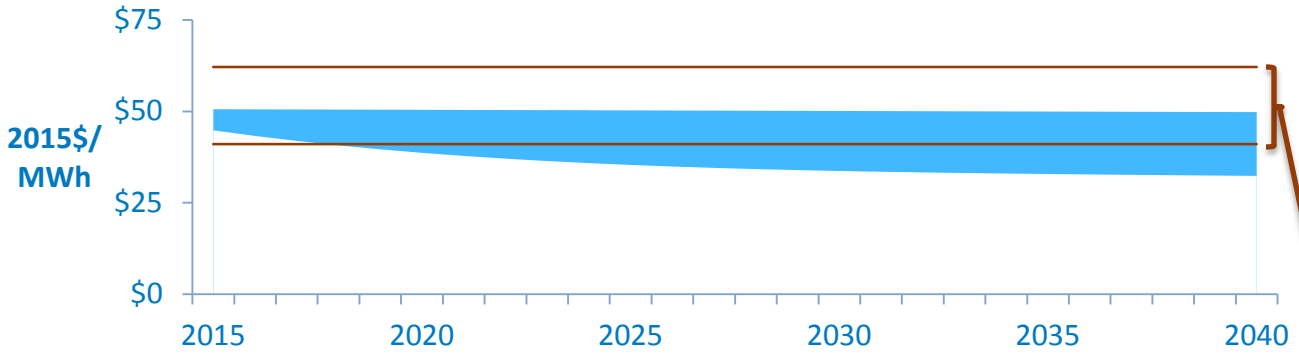
Colstrip
614 MW in 2025

Observations

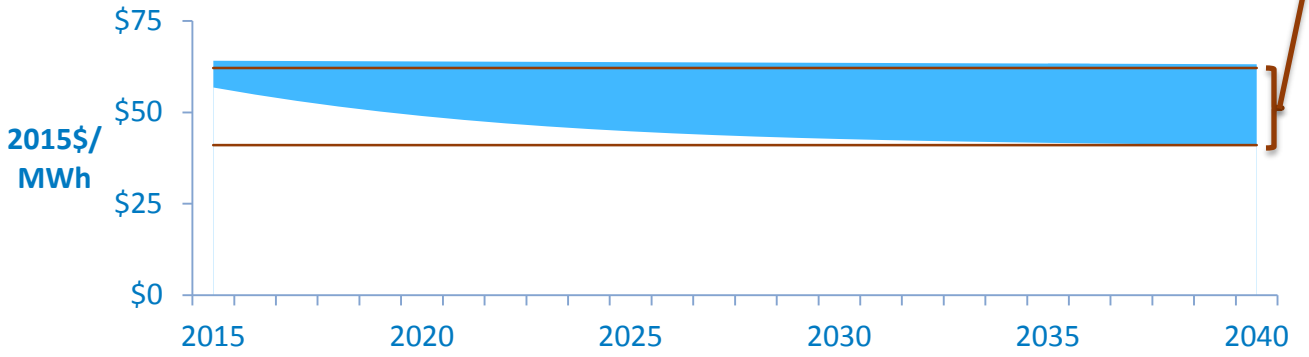
- Potential for repurposing existing transmission to link California with other western markets
  - Navajo-Four Corners
    - Proximate to New Mexico wind, but would need interconnecting lines (coincident with Sec. 368 corridor)
  - Central Utah
    - Proximate to Wyoming wind, but would need interconnecting lines (coincident with Sec. 386 corridors)
    - Very close to wind, solar, geothermal that could form a diverse, multi-resource renewable energy portfolio
  - Eastern Montana
    - Proximate to Montana, Wyoming, S. Dakota wind, but would need interconnecting lines
    - Some Sec. 368 corridors for westward connections, but not from South Dakota

Busbar cost trends for wind (excluding PTC)

80-meter turbines, 8.3 m/s average wind speed



100-meter turbines, 6.5 m/s average wind speed



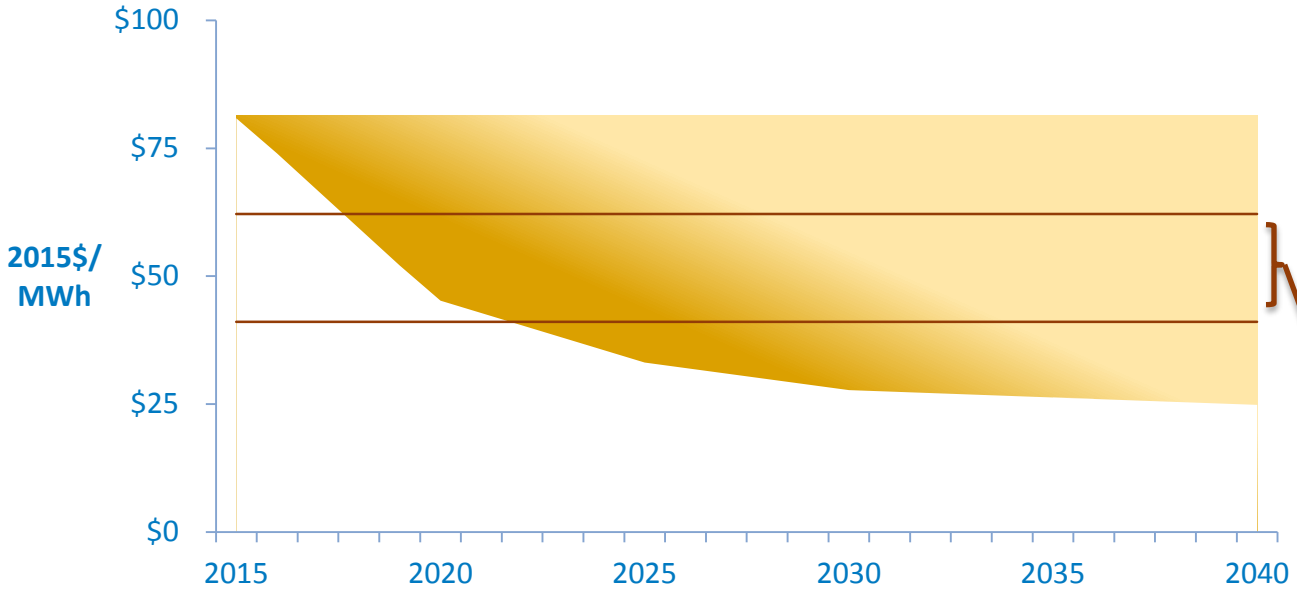
Combined cycle benchmark:

- **new build**
- **6.5 heat rate**
- **70% capacity factor**
- **total variable cost= 105% of fuel cost**
- **(low) wet cooling, fuel $3/mmBtu**
- **(high) dry cooling, fuel $5/mmBtu**

NREL, 2016 Annual Technology Database and Standard Scenarios

Busbar cost trends for utility-scale solar

single-axis tracking, 28% capacity factor (excludes ITC)



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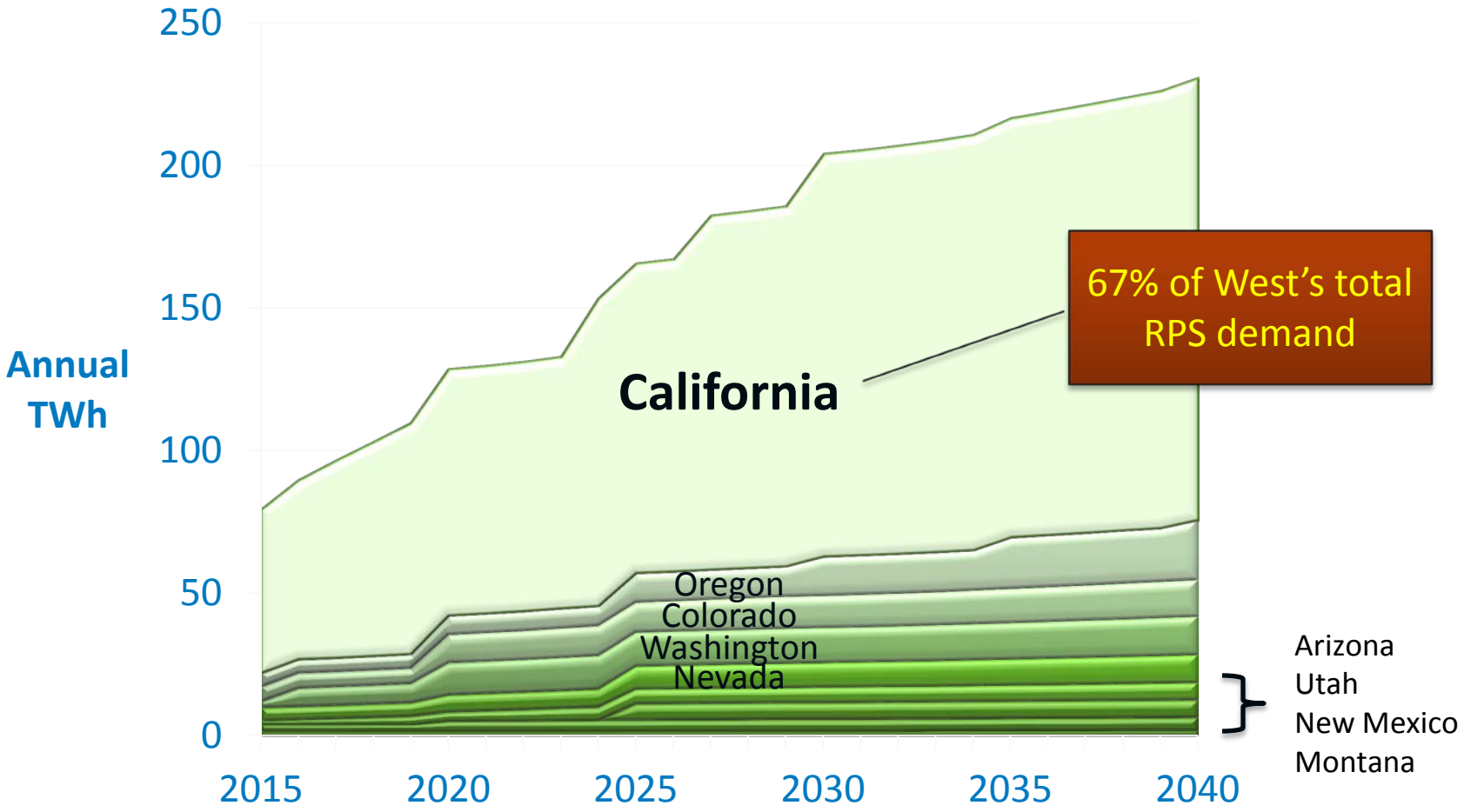
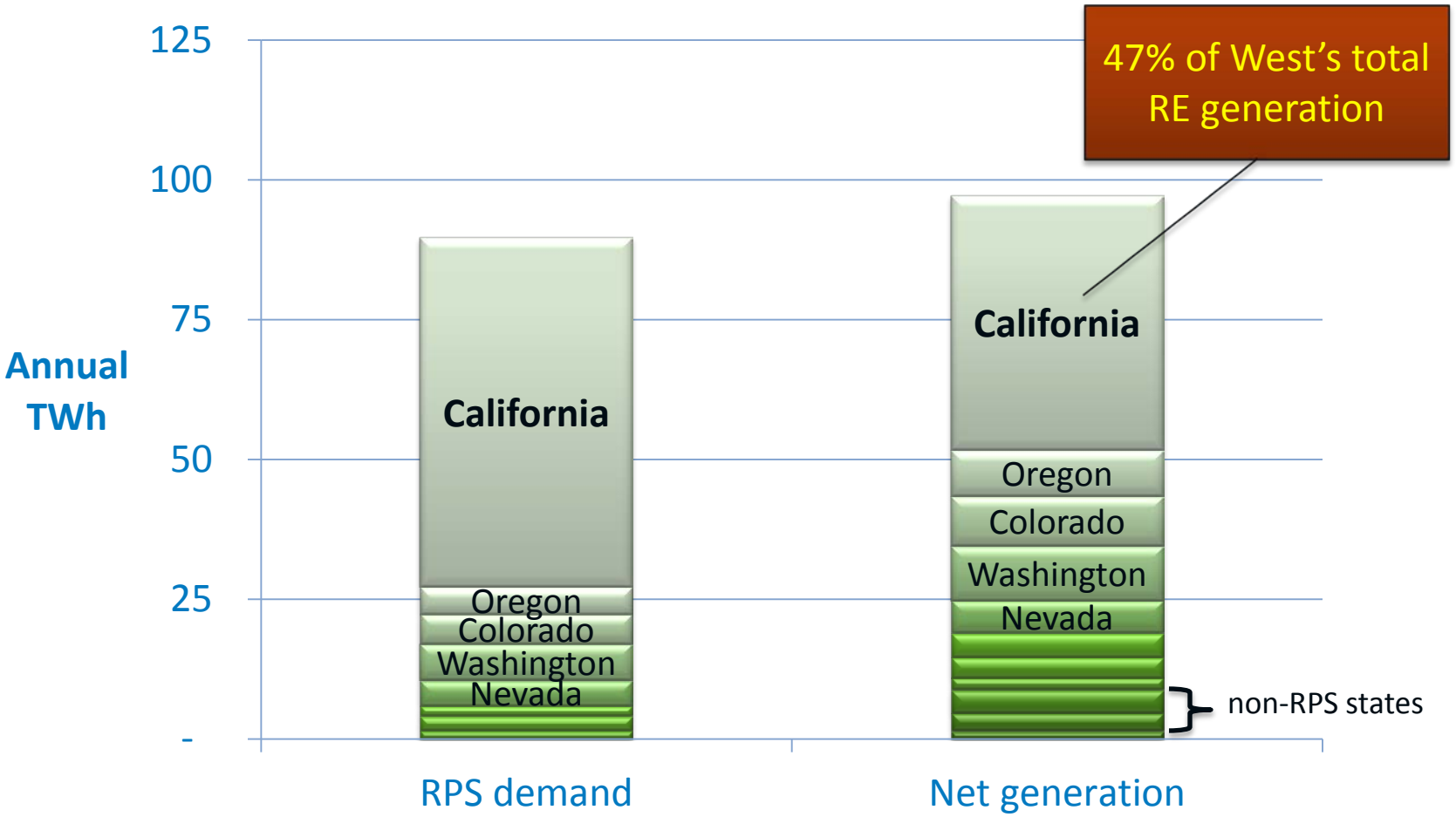
Total demand for renewables under existing state laws



Lawrence Berkeley National Laboratory, RPS Demand Projections, July 2016 (ex. Utah)
NREL projections, Sept. 2016 (Utah)
Projections exclude carve-outs for distributed generation

2016 RPS demand and net generation from renewables



12 months ending July 2016
EIA Form 923 database (wind, solar, geothermal, biomass)

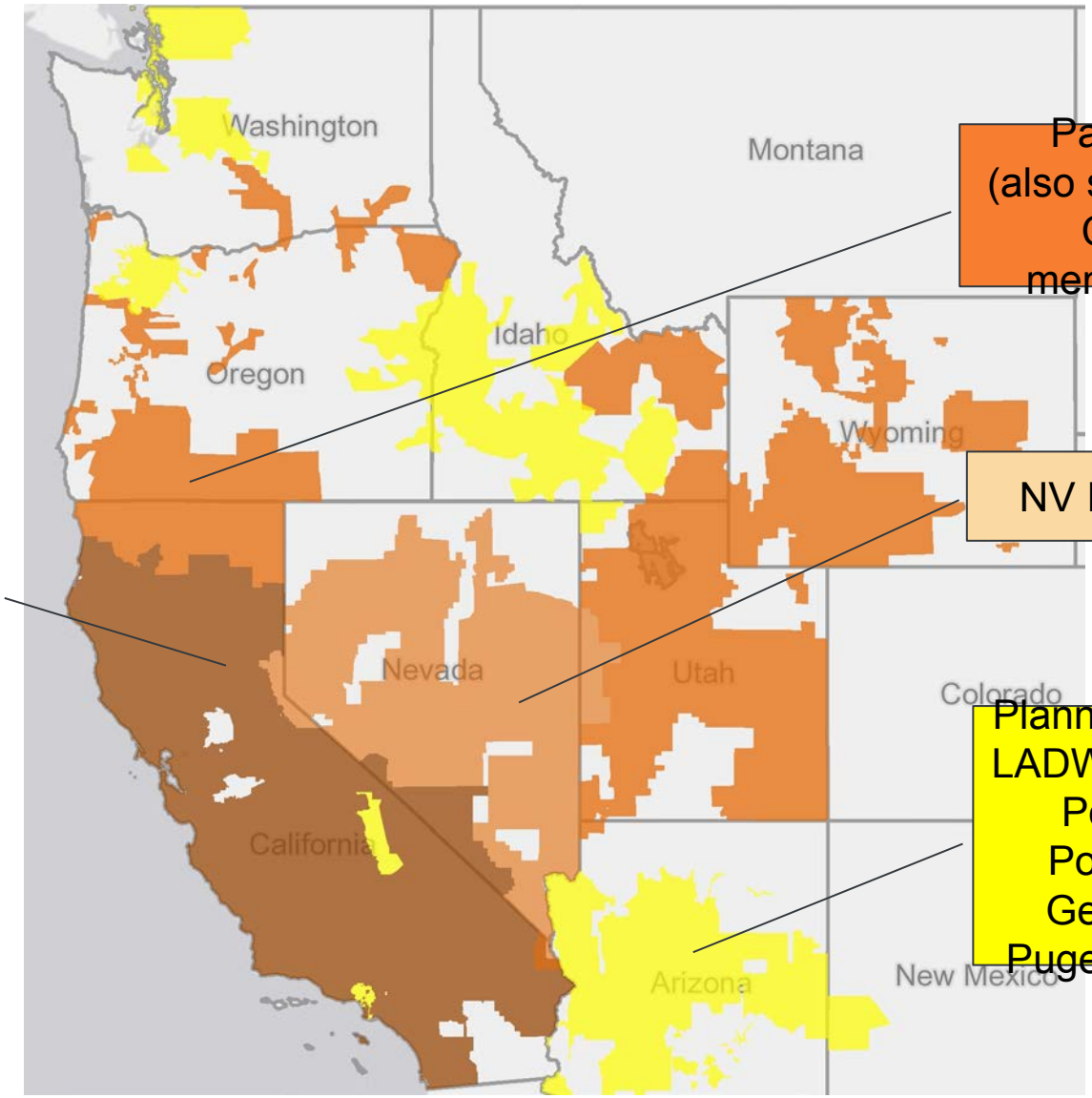
Observations

- California has twice as much RPS demand as all other western states combined
  - Magnitude of demand will tend to create new supply, *provided that California is a buyer in the Western market*
  - Existing development is not a reliable indicator of what supply would look like if California were in the market
- Every western state is generating more RE than required under its RPS for 2016, except California
  - While a given state's RPS requirement and its generation from renewables do not necessarily map to one another, the supply/demand balances suggest that western states except California tend to be natural suppliers more than they tend to be natural demand centers
  - Some state surpluses are already going to California

Observations

- Much of California's new in-state renewable capacity is solar
  - Has resulted in occasional (and increasingly frequent) overgeneration at midday, with "dumping" of PV-generated energy at very low prices
  - Unless midday surplus solar generation can be used, California might have less of an appetite for new solar
- Renewable energy trade tensions?
  - Western states outside of California have long wanted access to California markets (but imports have been discouraged)
  - California wants to use the rest of the West as an outlet for surplus solar (but small load levels make this a challenge)
  - Energy imbalance market could provide a platform for new regional protocols that could simultaneously address excess solar generation in California and provide non-California resources with market access (but the protocols don't yet exist)

Energy Imbalance Market footprint



PacifiCorp (also studying full CAISO membership)

NV Energy

California Independent System Operator

Planned: APS, LADWP, Idaho Power, Portland General, Puget Sound

Thank you!

david.hurlbut@nrel.gov

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