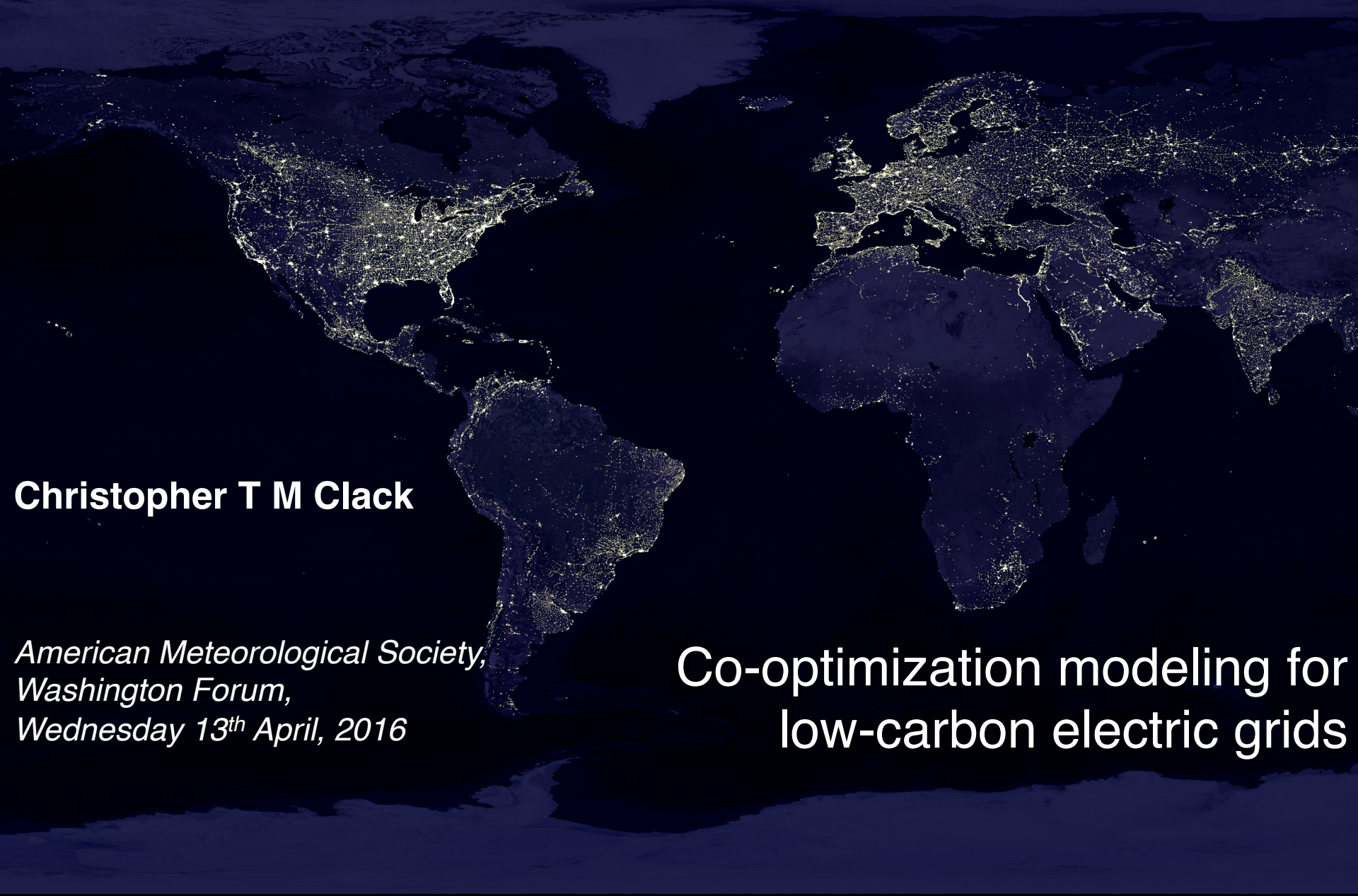


Christopher T M Clack

American Meteorological Society,
Washington Forum,
Wednesday 13th April, 2016

Co-optimization modeling for low-carbon electric grids

CIRES

Cooperative Institute for Research in Environmental Sciences
UNIVERSITY OF COLORADO **BOULDER** and **NOAA**

Background

- Co-optimization facilitates the solution to multiple objective problems.

- Critical objectives for electric grid planning: *transmission, generation, demand, storage, capacity diversity, load diversity, weather diversity, cost of energy, loss of load expectation, frequency response.*

- For low carbon electric grids, weather affects each of the different objectives.

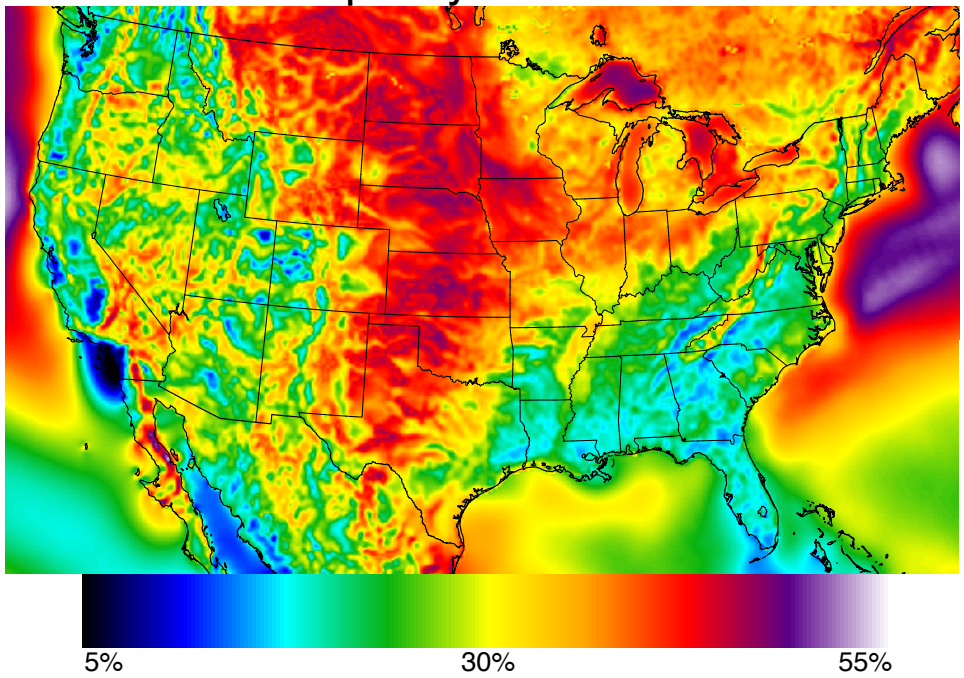
- Many of the difficulties with integrating renewables lessen as larger geographic scales are obtained.

Background

- Planning for high levels of wind and solar energy is more efficient when done early.
- An incremental approach that begins low RE targets levels leads to divergence from optimal and increases in over/under supply.
- Modeling can allow quantification of the divergence from optimal.
- Numerous co-optimization models exist (e.g., ReEDs, SWITCH, Univ. of Iowa, NEM, MARKAL, NEWS), but each were designed for specific tasks.
- An effort to discover the full benefits of coordinated planning is an important need for a modernized grid.

Weather *is* Critical

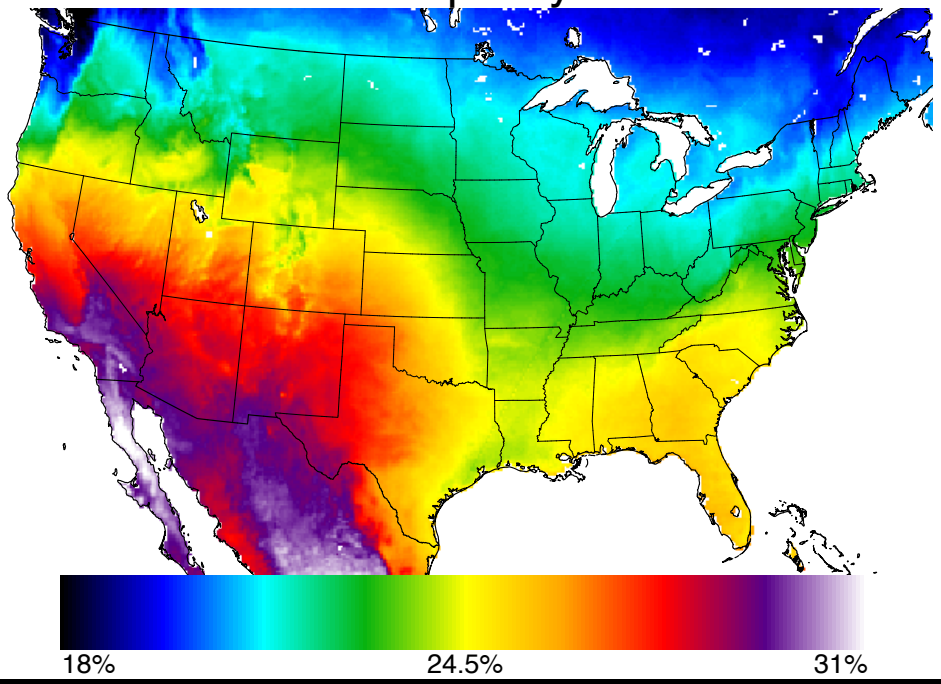
Wind Capacity Factors at 90m



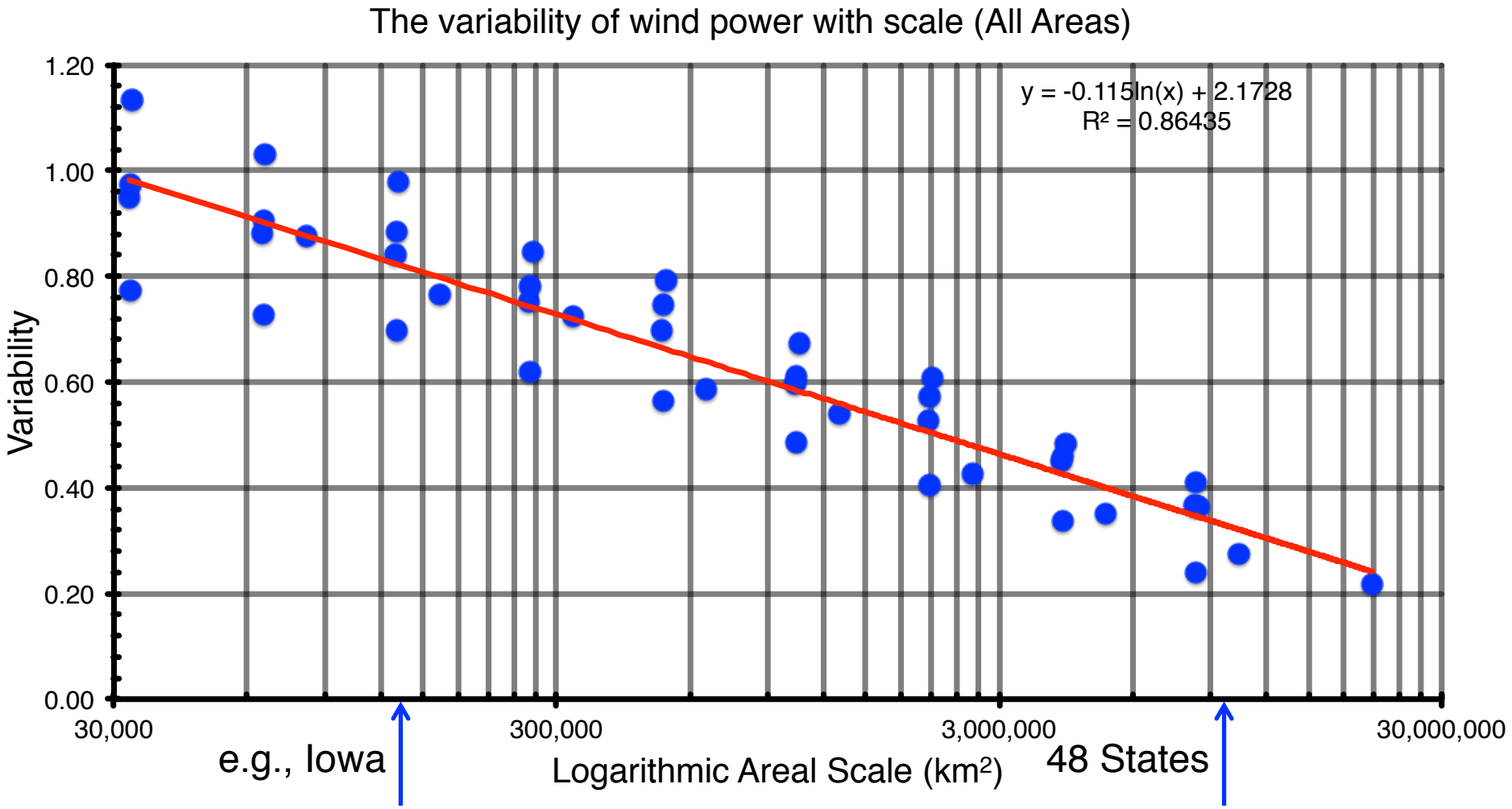
- Utilizes RUC, RAP, and HRRR
- Power estimates take into account: icing, snow cover, REWS, turbulence, downtimes, and more.

- A decade at 13-km (2006-2015)
- Three years at 3-km (2012-2015)
- Three years overlap 3-km and 13-km different model physics.

Solar PV Capacity Factors

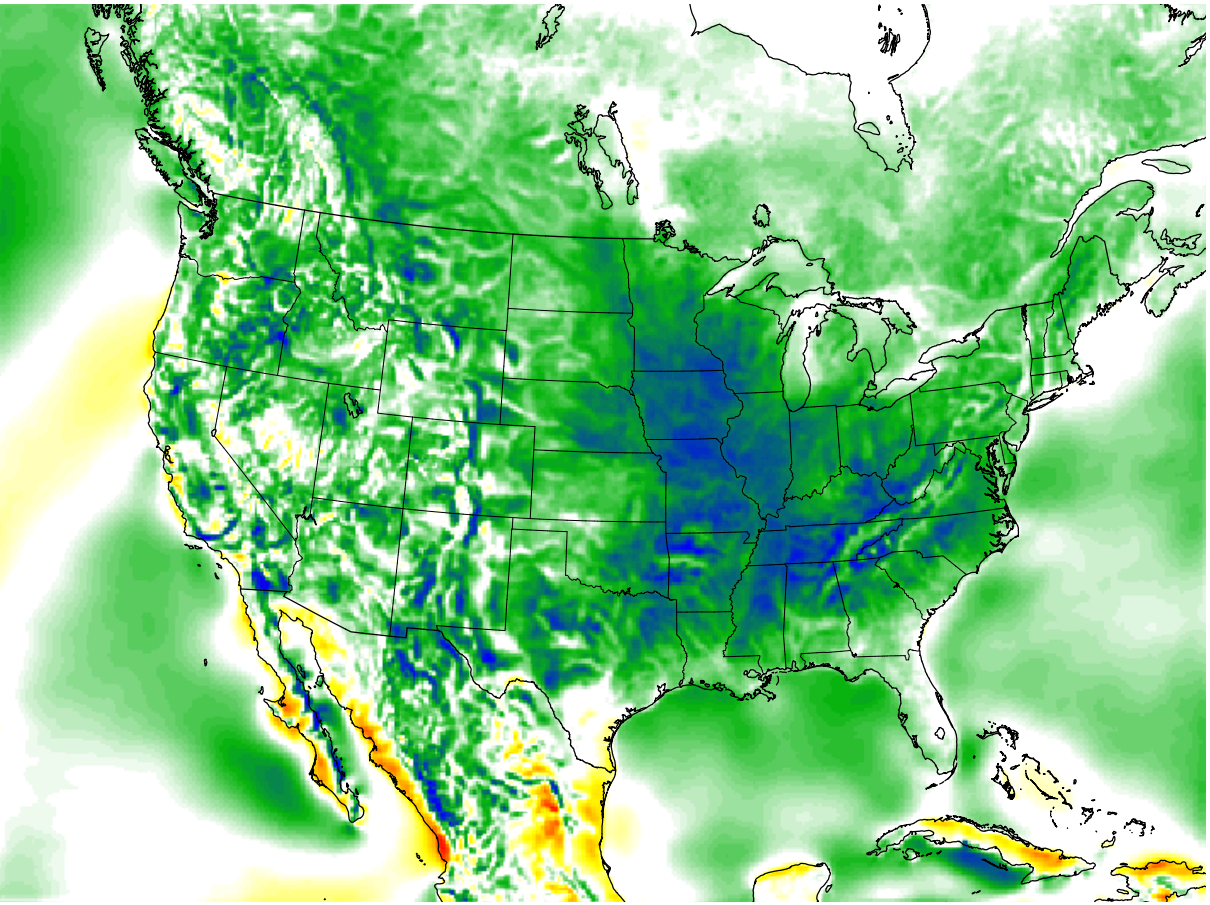


Wind *is* variable



Variability here is defined as the average coefficient of variation over a geographic region when divided up into isolated regions

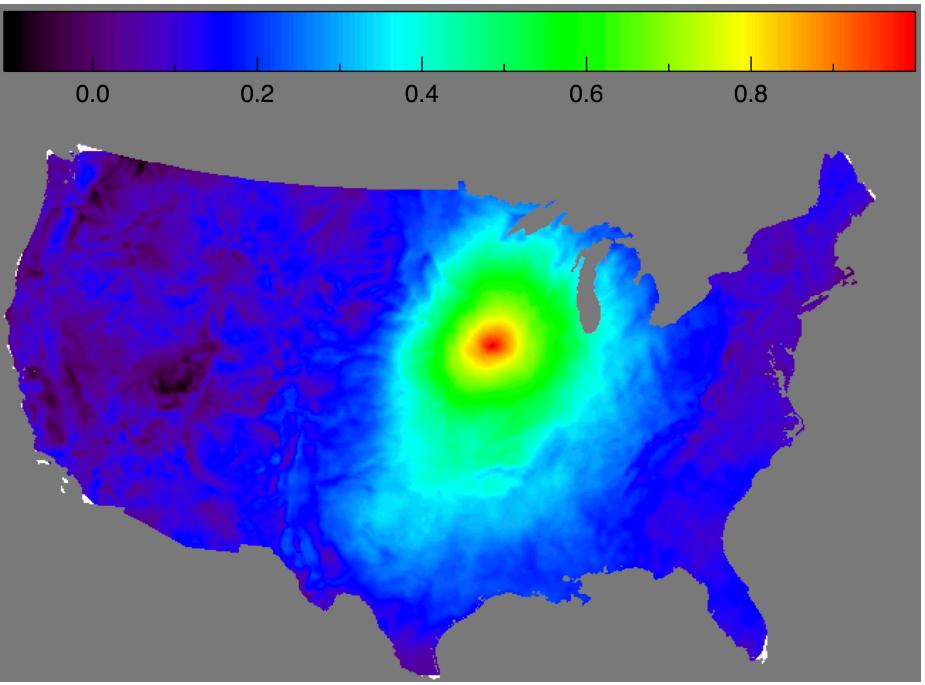
Do Weather & Demand Correlate?

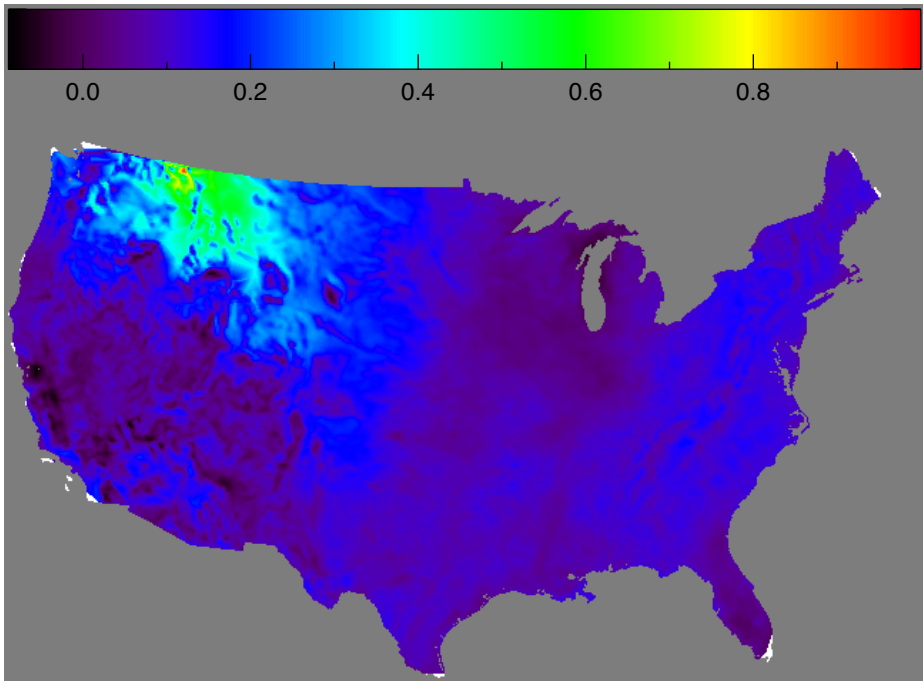


- Wind correlation to the national electric demand. Hour by hour for 2006 through 2008.
- Red / orange have positive correlation.
- Blue / green have negative correlation.
- White is neutral correlation.

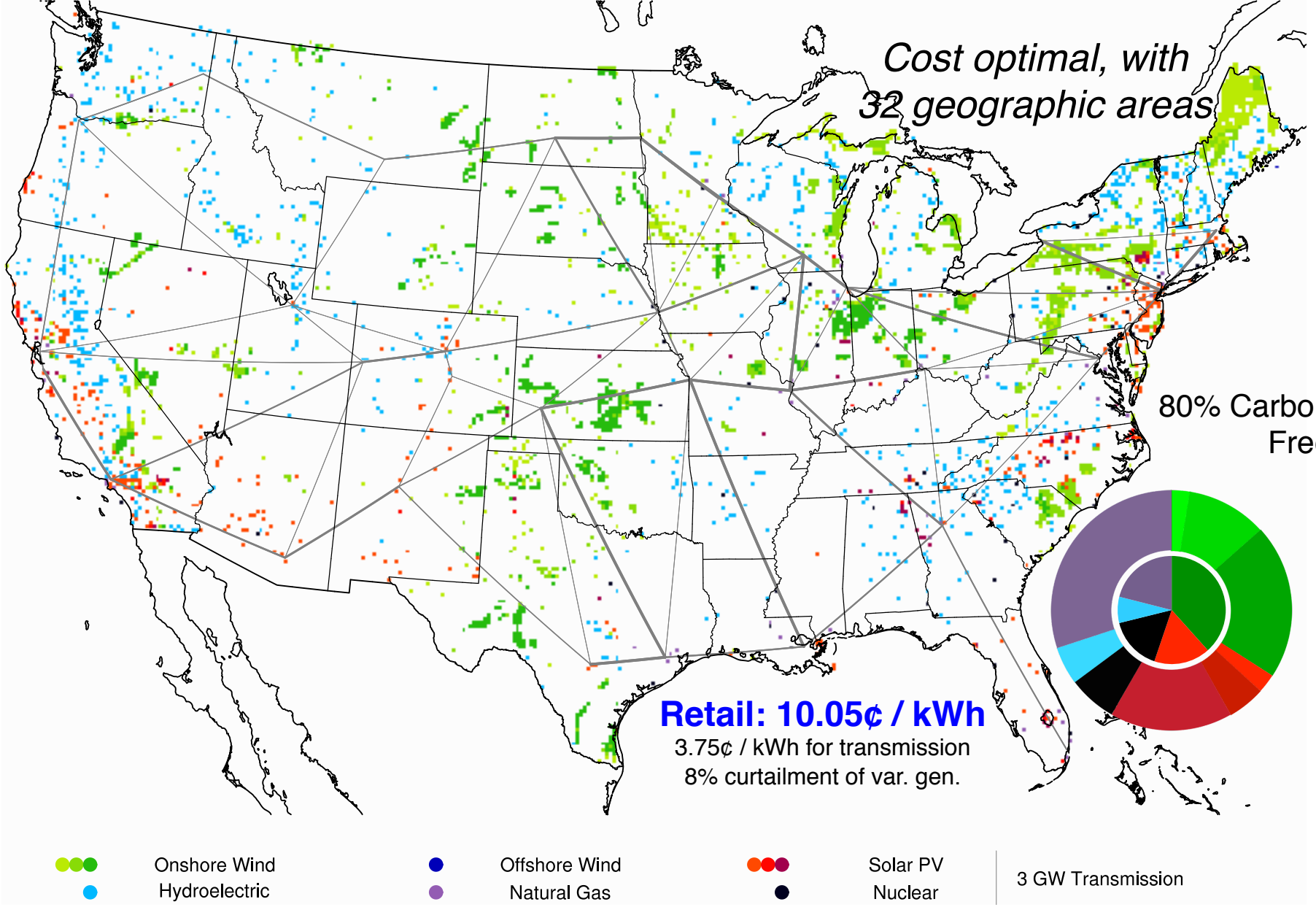
Complexities arise because as (wind) generators are added the correlation map changes [statistical cumulants] as both the resource and demand are altered. Co-optimization deals with this implicitly. Geographic scale helps with this too.

Wind sites can be correlated





- Correlation between wind (and solar) resources is locational dependent.
- Without continuous time series of data for resource planning, co-located sites can unexpectedly lessen the value of existing and new generators.
- NEWS takes all these aspects into account, implicitly, within the co-optimization. Partly, by geographic scale, but also with high temporal resolution data.



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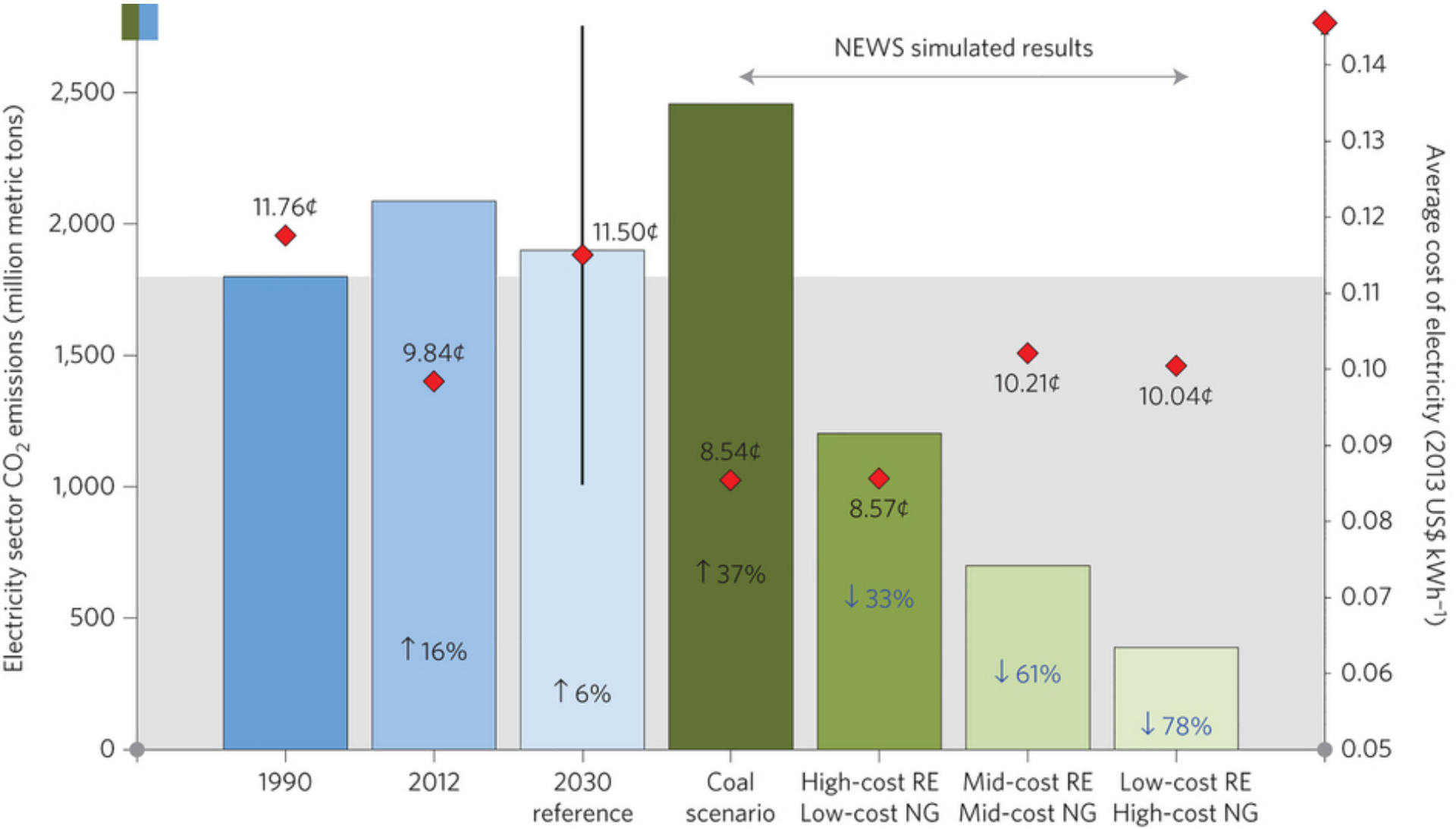
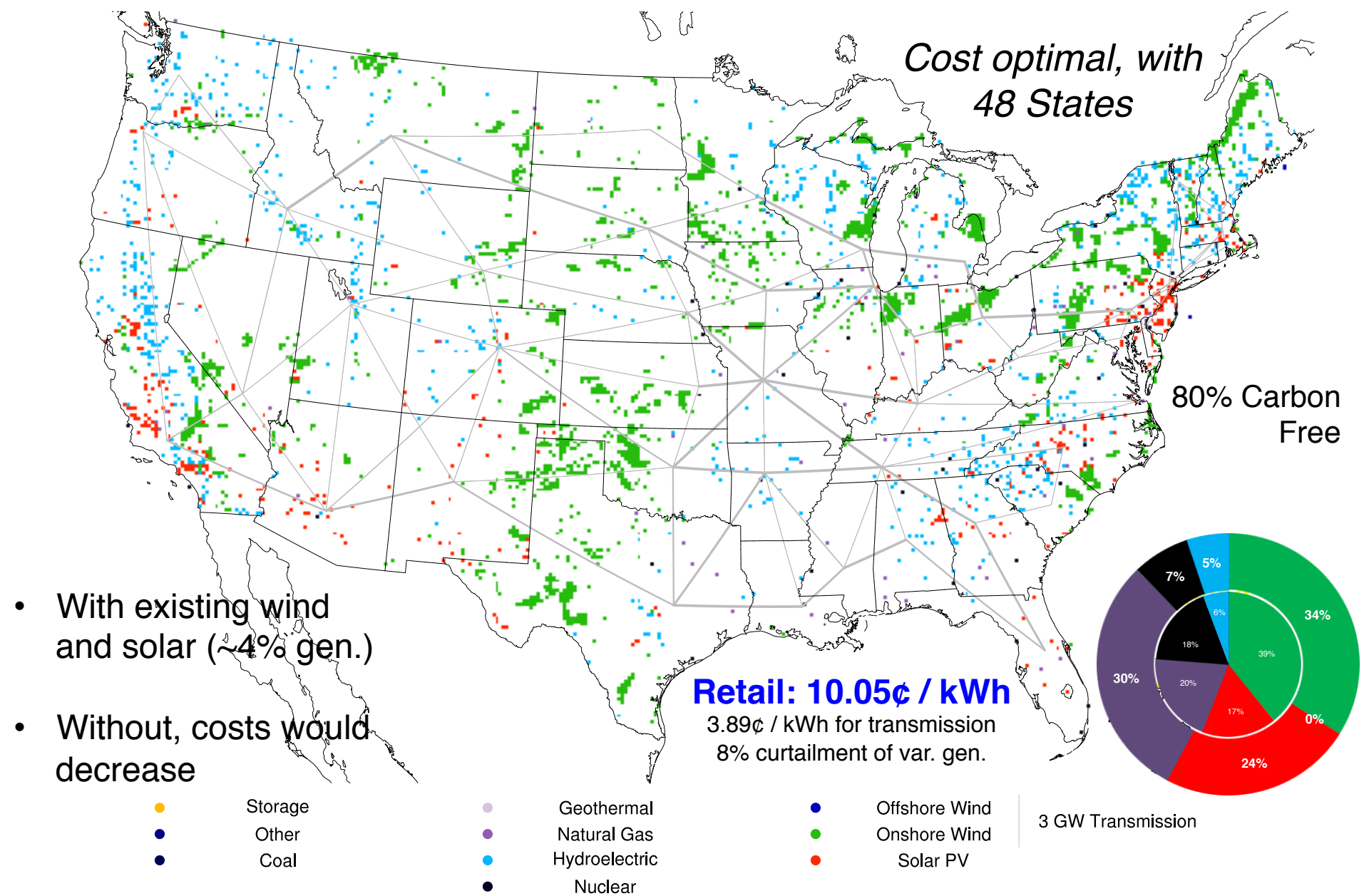
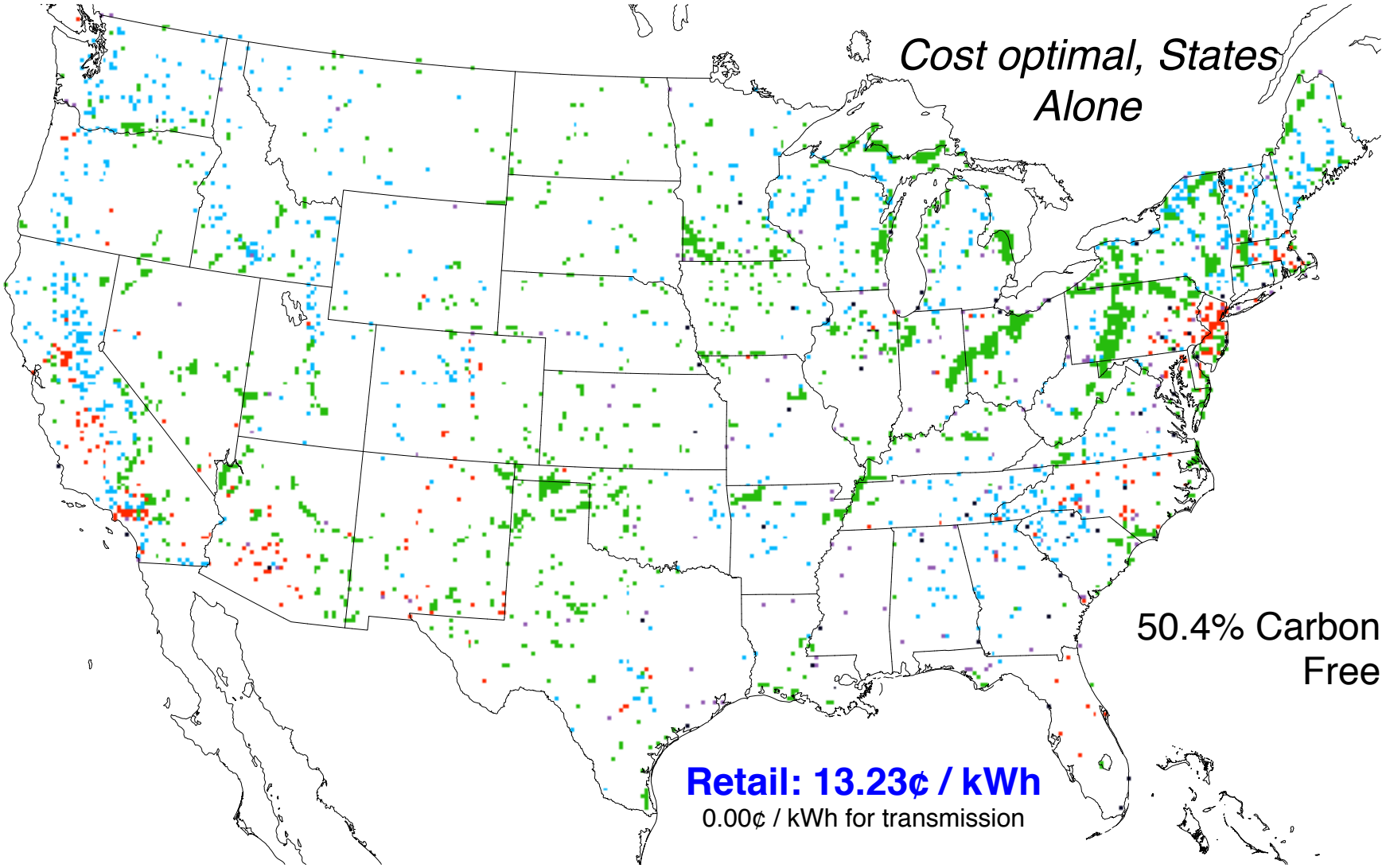
Modeled Cost of Electricity for National Electric Systems



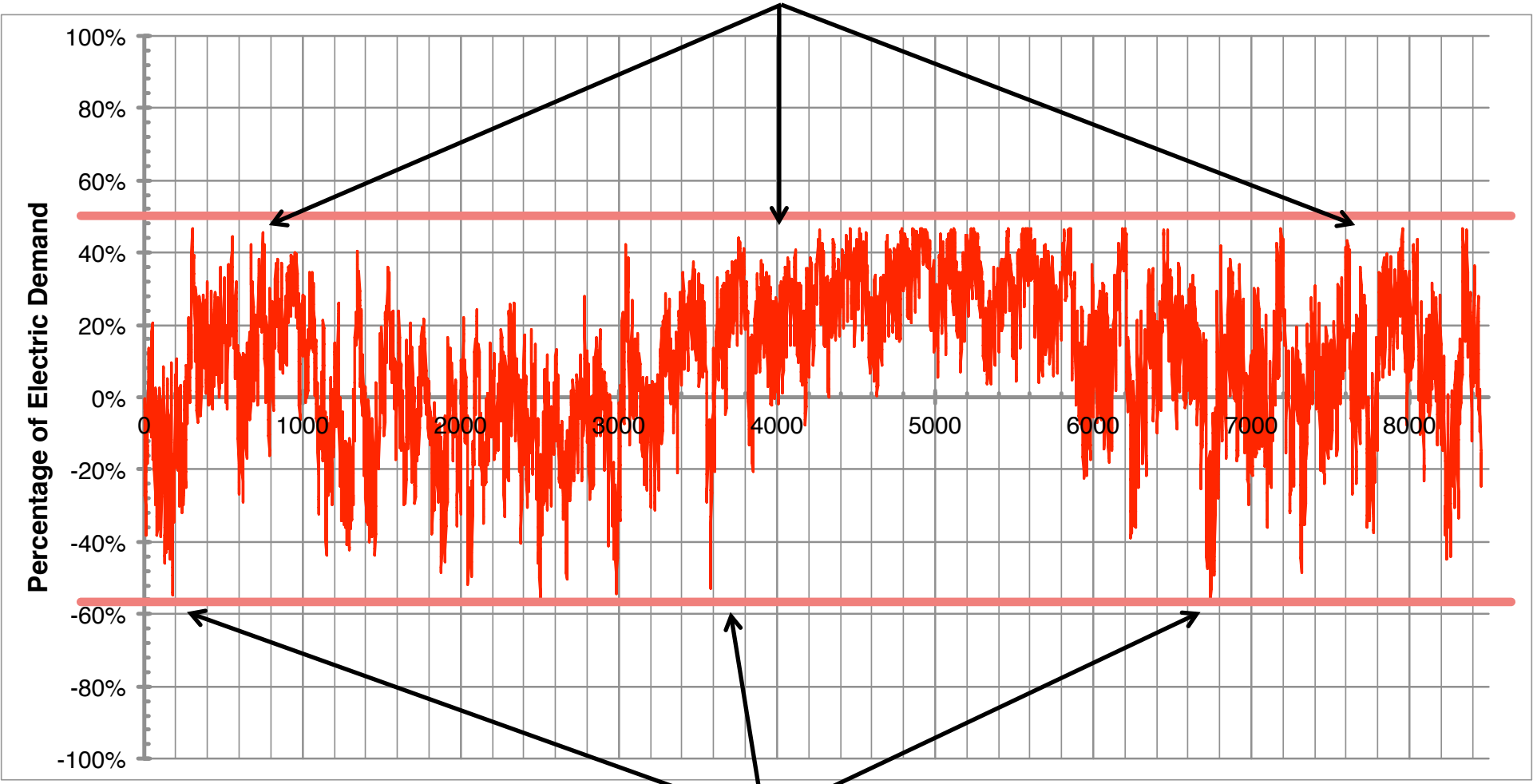

Cost optimal, with
48 States
80% Carbon
Free
- With existing wind and solar (~4% gen.)
- Without, costs would decrease
Retail: 10.05¢ / kWh
3.89¢ / kWh for transmission
8% curtailment of var. gen.
5%
7%
6%
34%
18%
39%
30%
20%
17%
0%
24%
Storage
Other
Coal
Geothermal
Natural Gas
Hydroelectric
Nuclear
Offshore Wind
Onshore Wind
Solar PV
3 GW Transmission


Cost optimal, States Alone
50.4% Carbon Free
Retail: 13.23¢ / kWh
0.00¢ / kWh for transmission
Storage
Other
Coal
Geothermal
Natural Gas
Hydroelectric
Nuclear
Offshore Wind
Onshore Wind
Solar PV

Forecasting needed also

Dispatchable Generation Necessary

48 State Solution



Curtailment Necessary

Conclusions

- Co-optimization model allows energy industry participants to evaluate the potential for weather-driven renewable energy technologies.

- Important features must be included. Such as the geographic scale, temporal resolution, cost allocations for transmission, capacity diversity, LOLE, demand diversity, wind and solar statistical cumulants, and policy drivers to facilitate smarter deployment.

- Atmospheric sciences touches on each of these areas to varying degrees and needs to be considered with respect to any build out scenario to avoid suboptimal grid designs.

- NEWS is the first model to do all of these aspects for 8,760 hours for the whole US with 13-km weather and demand data, along with features of a possible national electric system (with HVDC). http://www.nature.com/nclimate/journal/vaop/ncurrent/full/nclimate2921.html