National Renewable Energy Laboratory
Innovation for Our Energy Future

Transmission and Generation Capacity Expansion in NREL's ReEDS Model

FERC Wide-Area Planning Models Workshop

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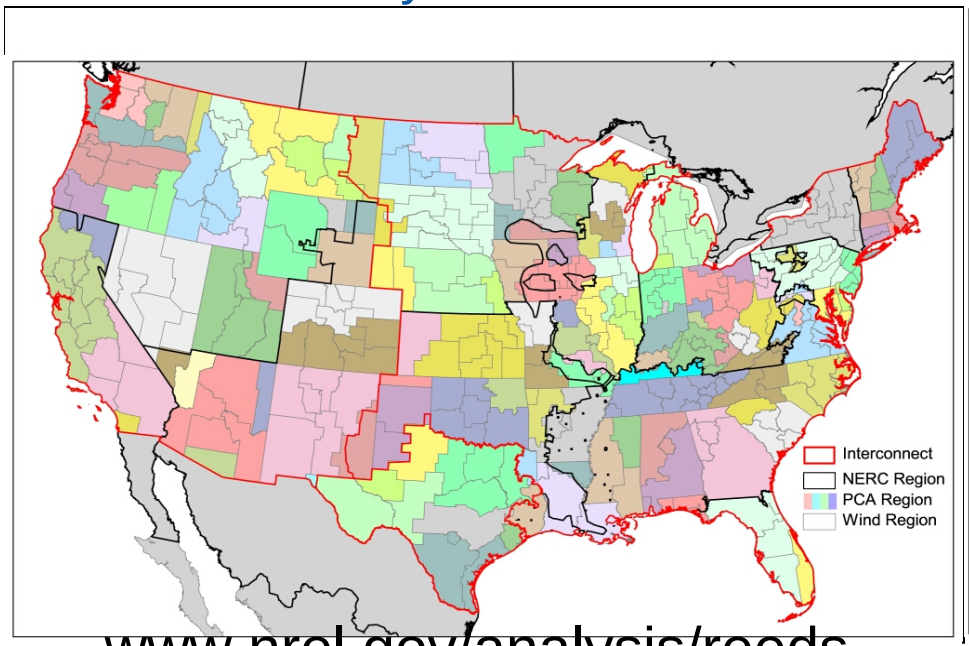
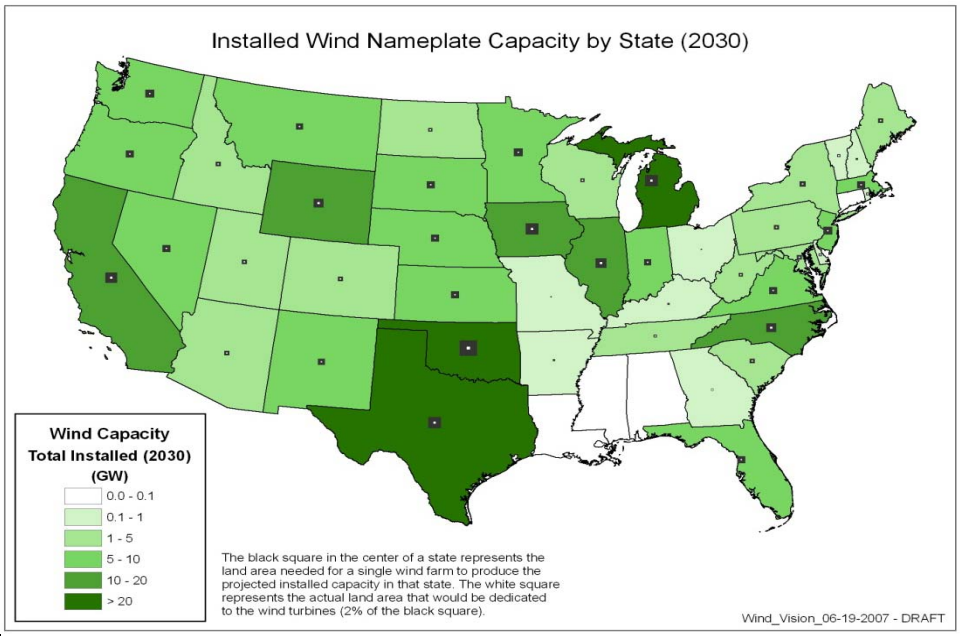
ReEDS Purpose and Use

- A multi-regional, multi-time-period model of capacity expansion in the electric sector of the U.S. for the next 40 years
- Like EIA's NEMS Electric Sector but more regions = better modeling of renewables including stochastic resource variability; plus explicit modeling of transmission requirements
- Recently provided analysis for DOE *20% Wind Energy by 2030* Report
- Currently used in combination with GridView for the Renewable Electricity Futures Study





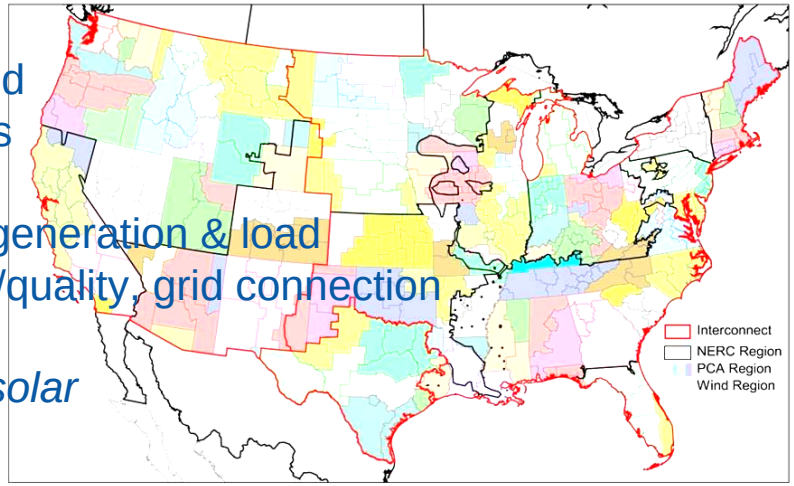
www.nrel.gov/analysis/reeds

ReEDS Overview

- **Capacity expansion & dispatch** for the US electricity sector out to 2050 including **transmission** & all generator types – AP coal, IGCC coal w/wout CCS, Gas CTs, Gas CCs w/wout CCS, oil/gas steam, nuclear, hydro, PHS, major renewables

- **Minimize total system cost** in each 2-year investment period
  - All constraints (e.g. balance load, reserves, etc.) must be satisfied
  - Investment decision based on 20 year present value cost of each technology

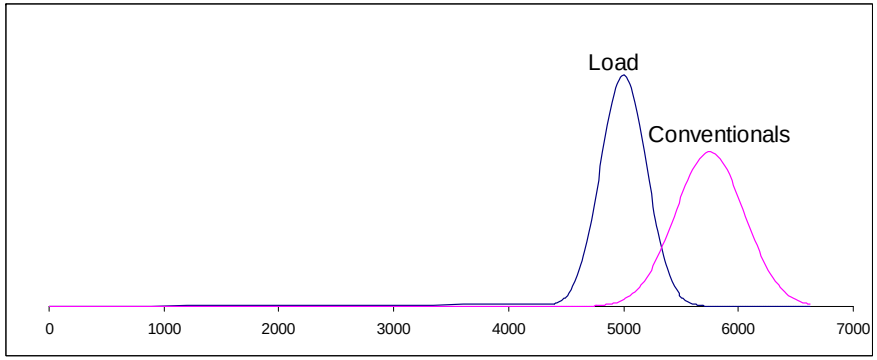
- **Multi-regional**
  - *3* interconnections – separately synchronized
  - *13* NERC subregions – fuel price differences
  - *48* states – incentives, state RPSs, etc.
  - ***134*** power control areas (PCAs) – balance generation & load
  - *356* wind/csp regions – resource availability/quality, grid connection
  - *Enables transmission capacity expansion*
  - *Enables treatment of the variability of wind/solar*

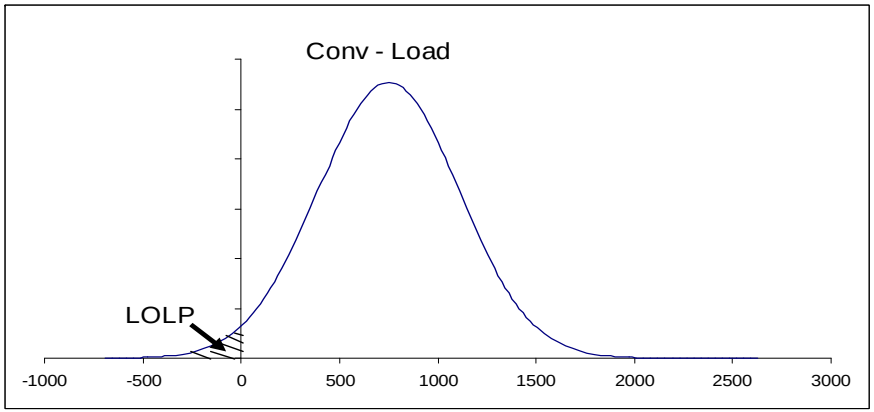


- **Temporal Resolution**
  - 17 timeslices in each year
    - 1 typical day (morning, afternoon, evening, night) in each of 4 seasons
    - 1 superpeak summer afternoon timeslice
  - Statistical treatment of variability of wind & non-dispatchable solar
    - Capacity value, additional operating reserves, curtailments

Wind and PV Capacity Value

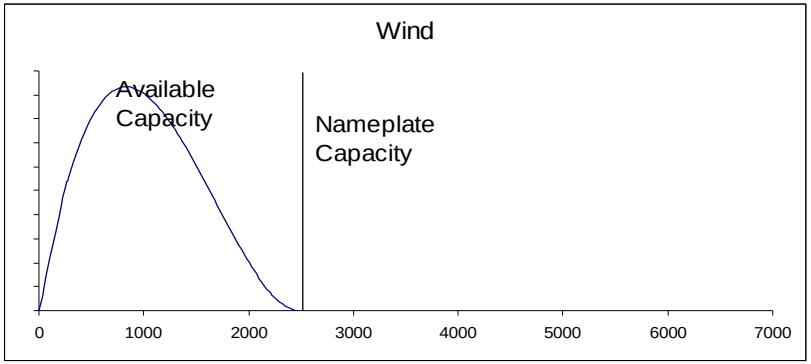
Conv - Load

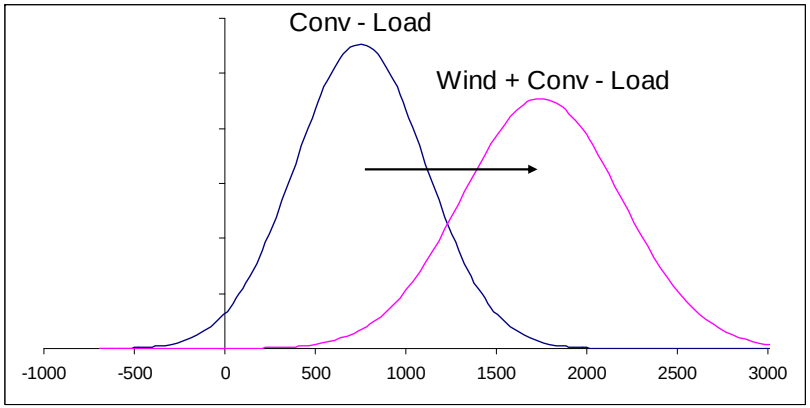


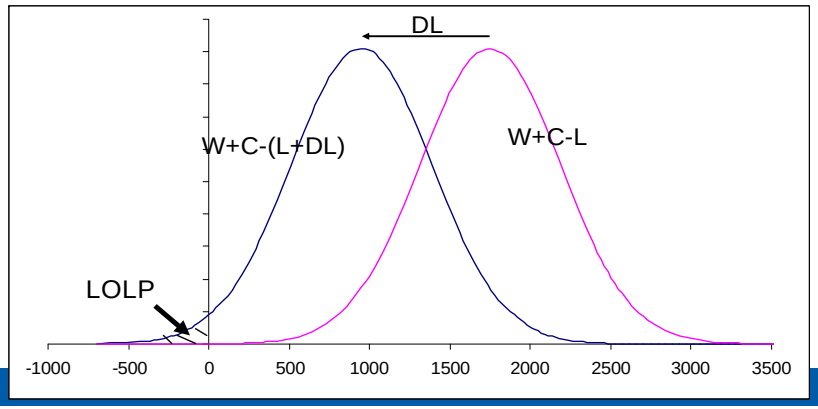


Wind Capacity Value/MW =
DL/Wind Nameplate Capacity

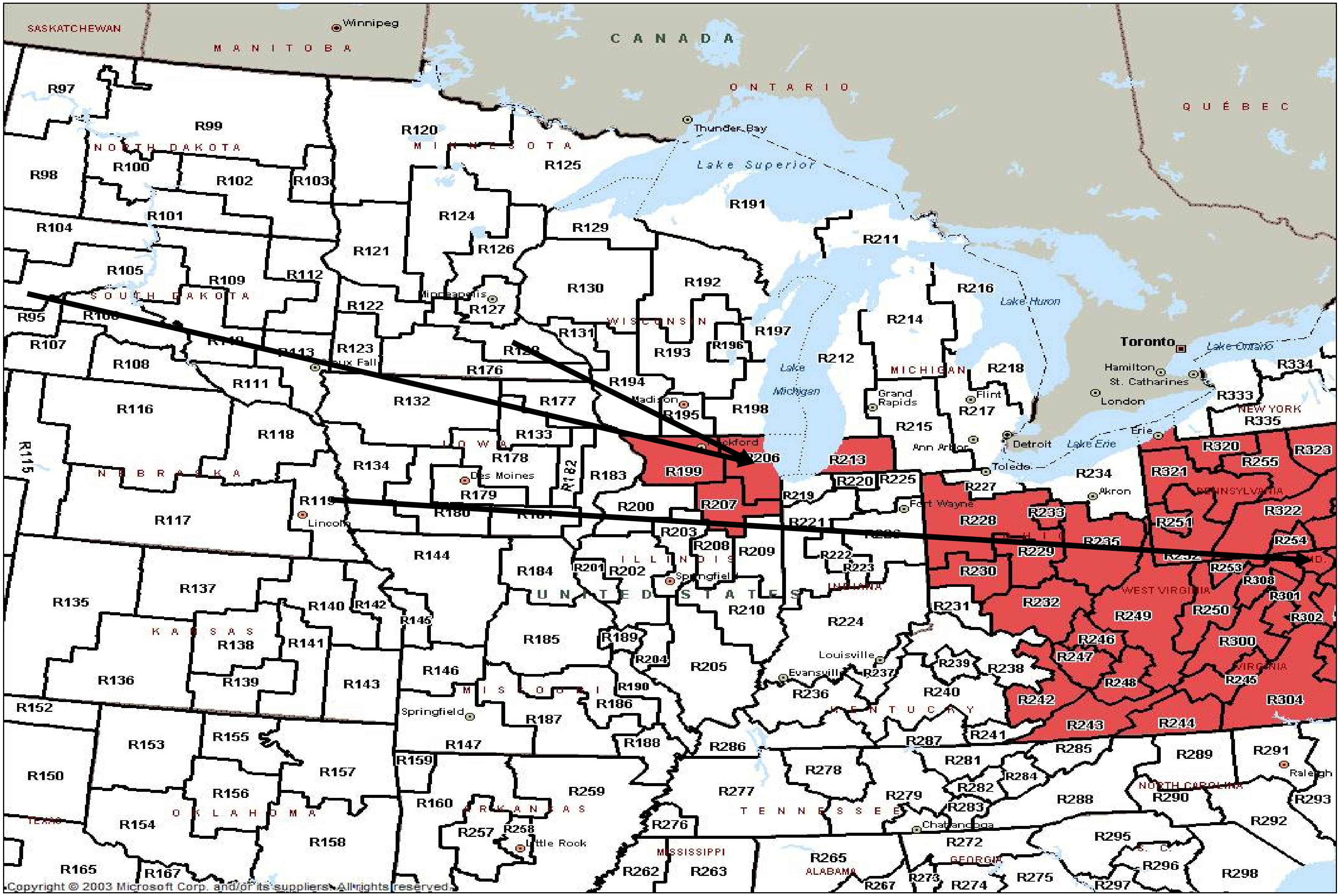
Wind



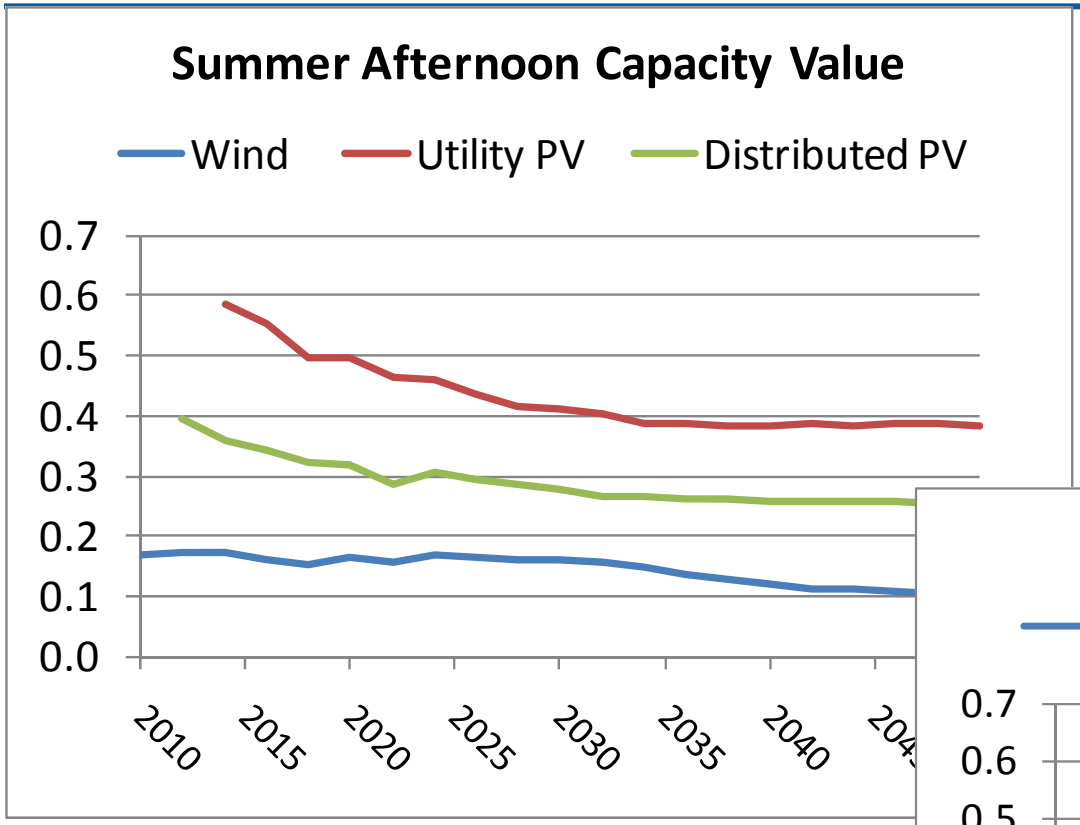


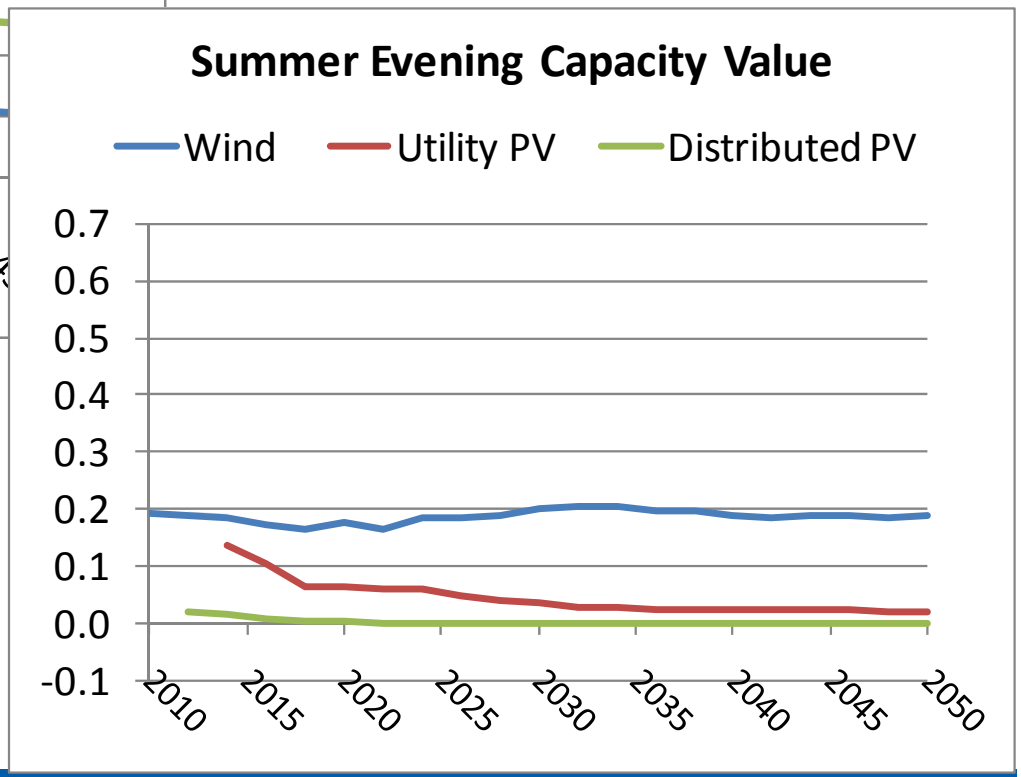


Value of Diversity



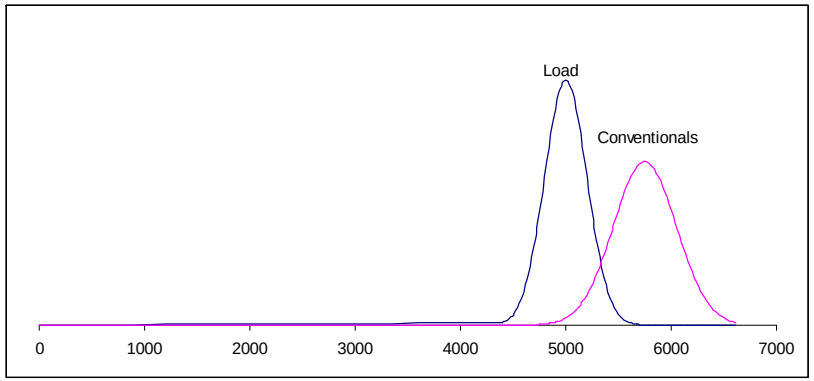
Sample Capacity Value Results

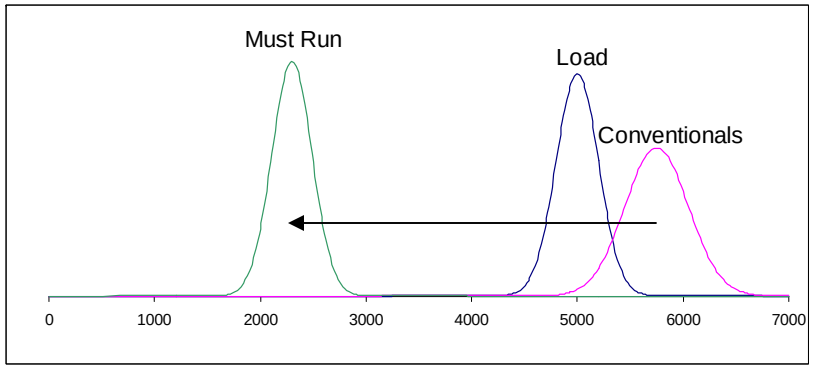


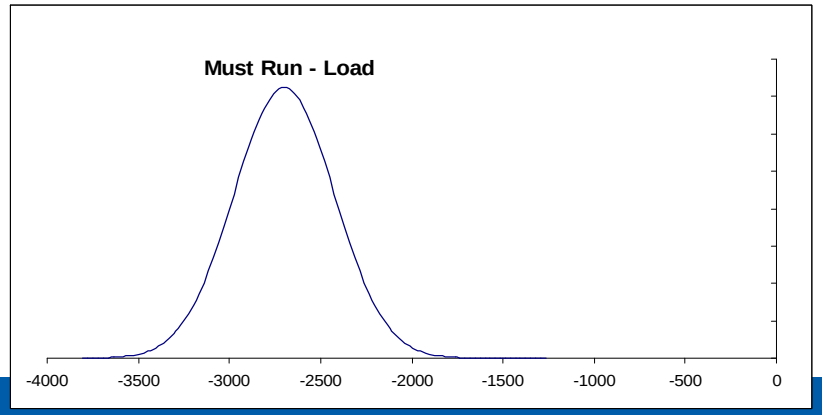


Wind and PV Curtailments

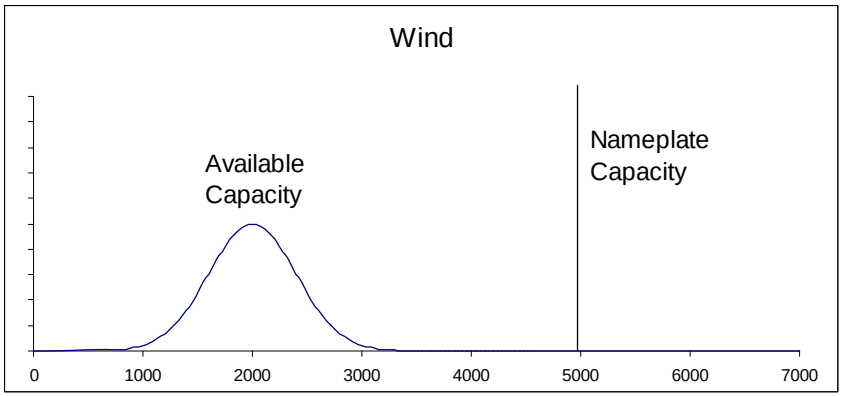
Conventionals and Load

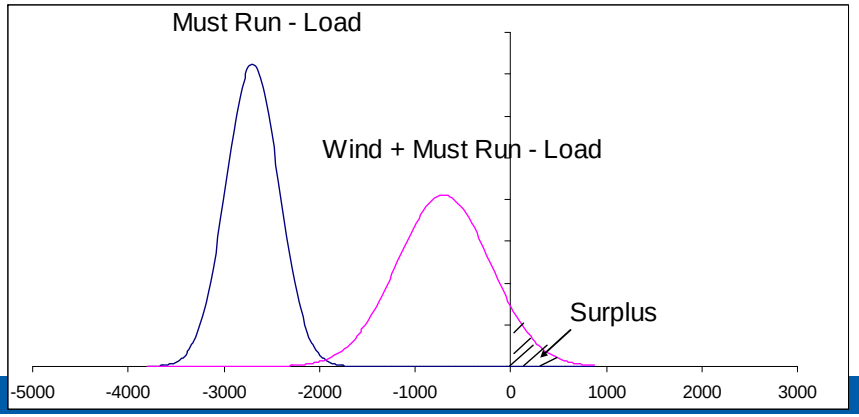






Wind





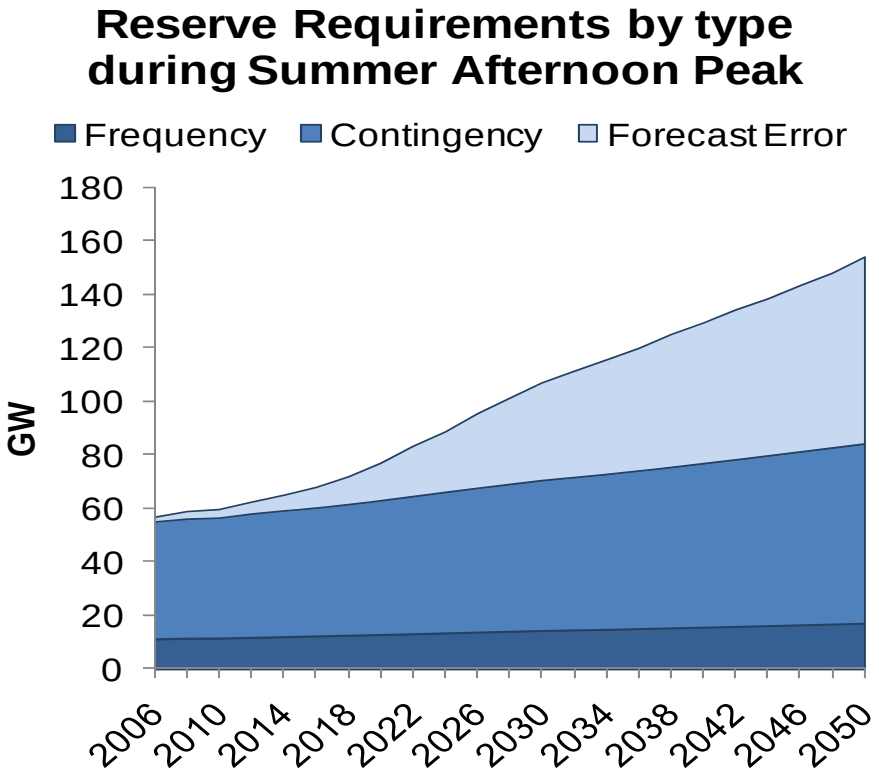
Wind and PV Induced Operating Reserve

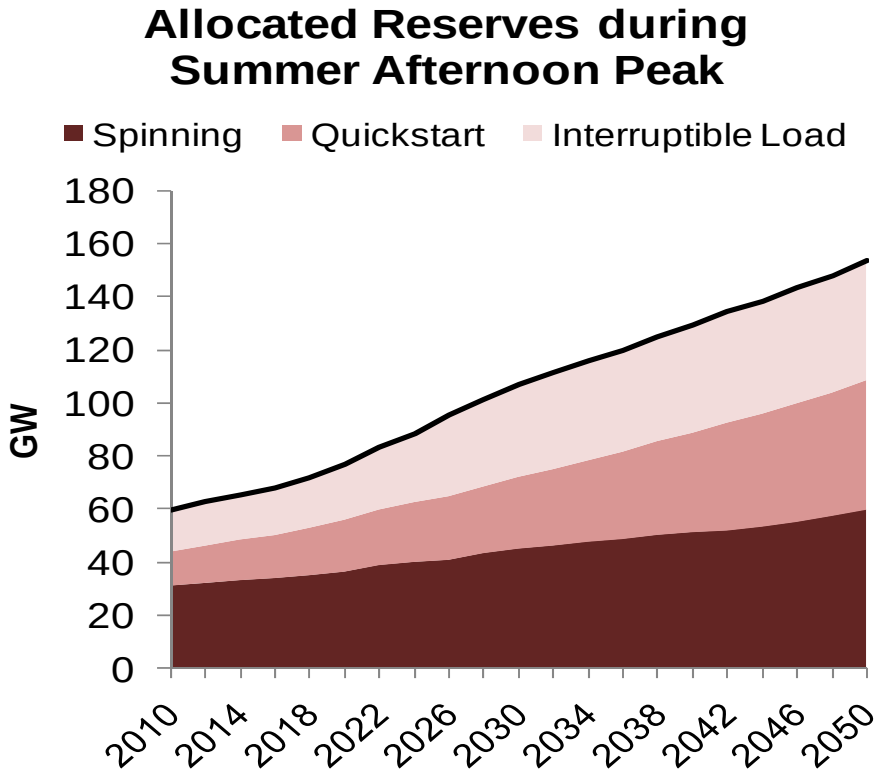
Operating reserves driven by

- contingency and regulation reserves
- Load/wind following reserves (forecast errors)

Operating reserves comprised of

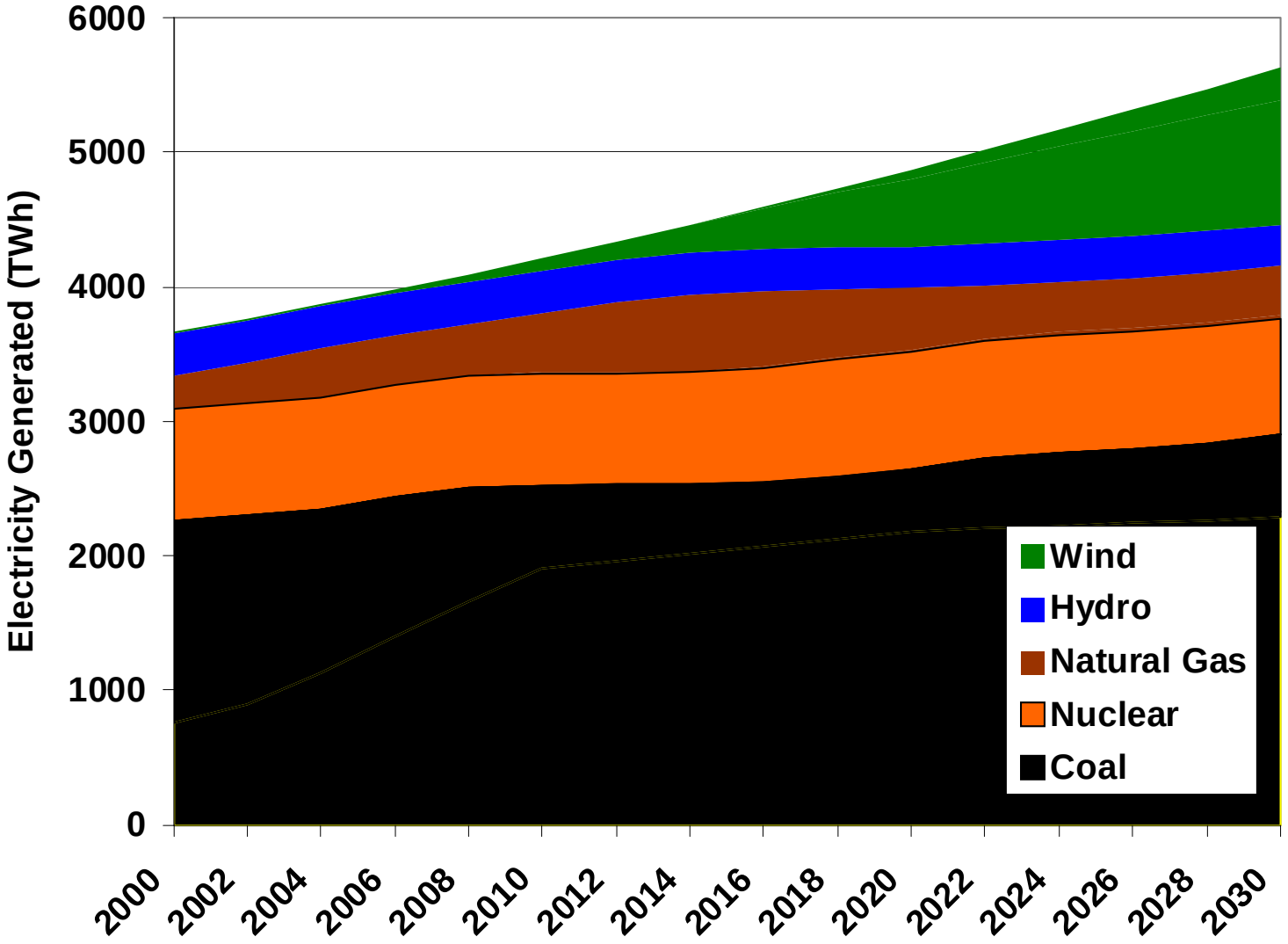
- Spinning reserves
- Quick-start capability
- Interruptible load

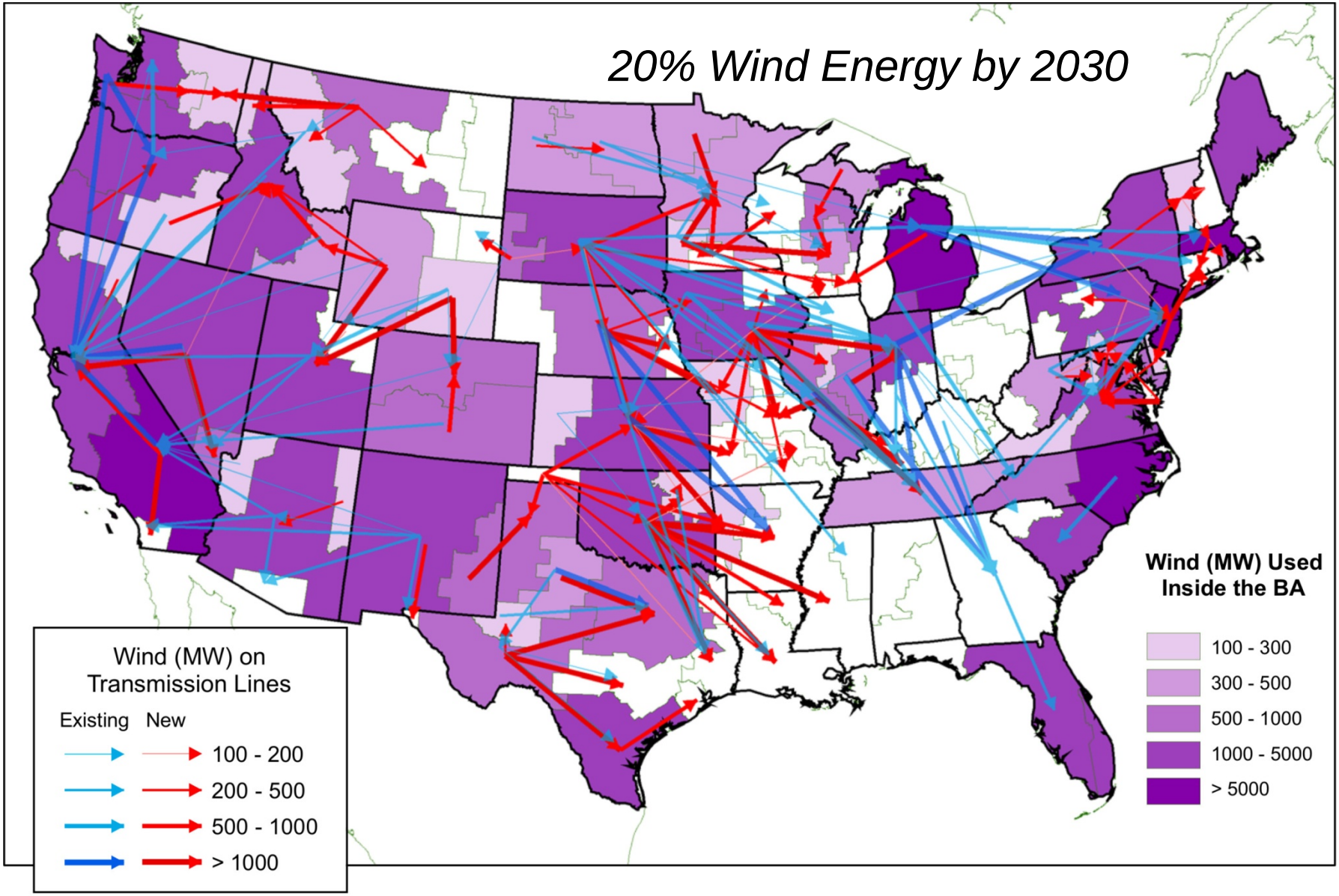




20% Wind Energy by 2030

(Results from ReEDS/WinDS model)



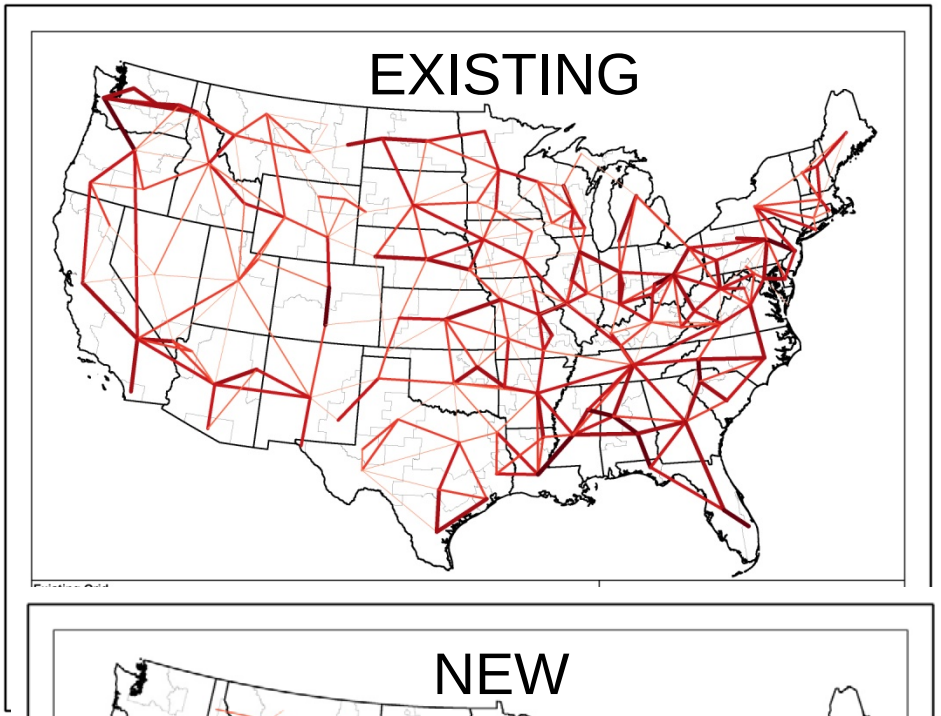


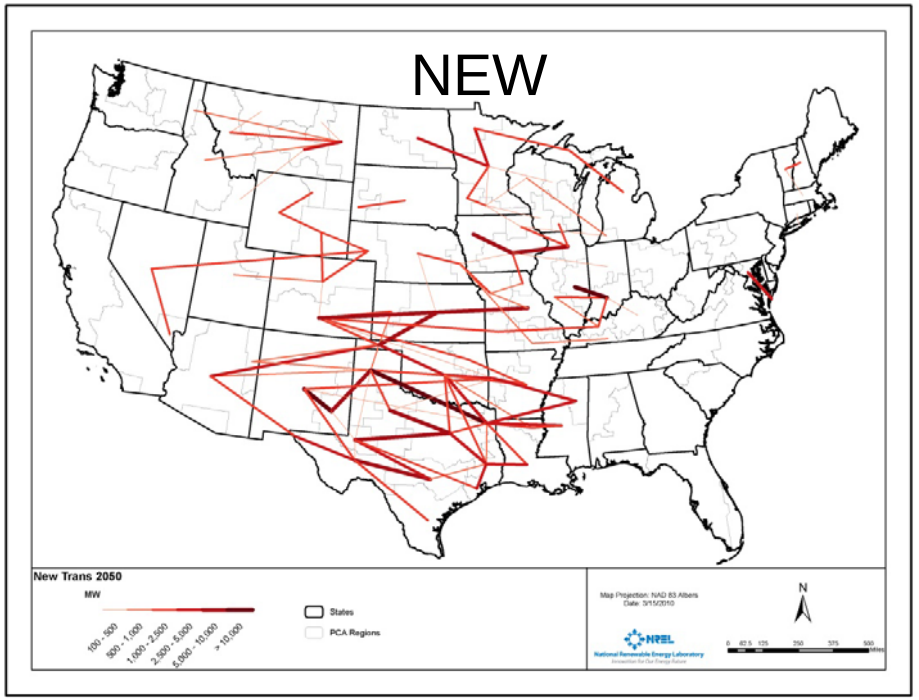
Total Between BA Transfer >= 100 MW (all power classes, land-based and offshore) in 2030. Arrows originate and terminate at the centroid of the BA for visualization purposes; they do not represent physical locations of transmission lines.

20% Wind 06-19-2007

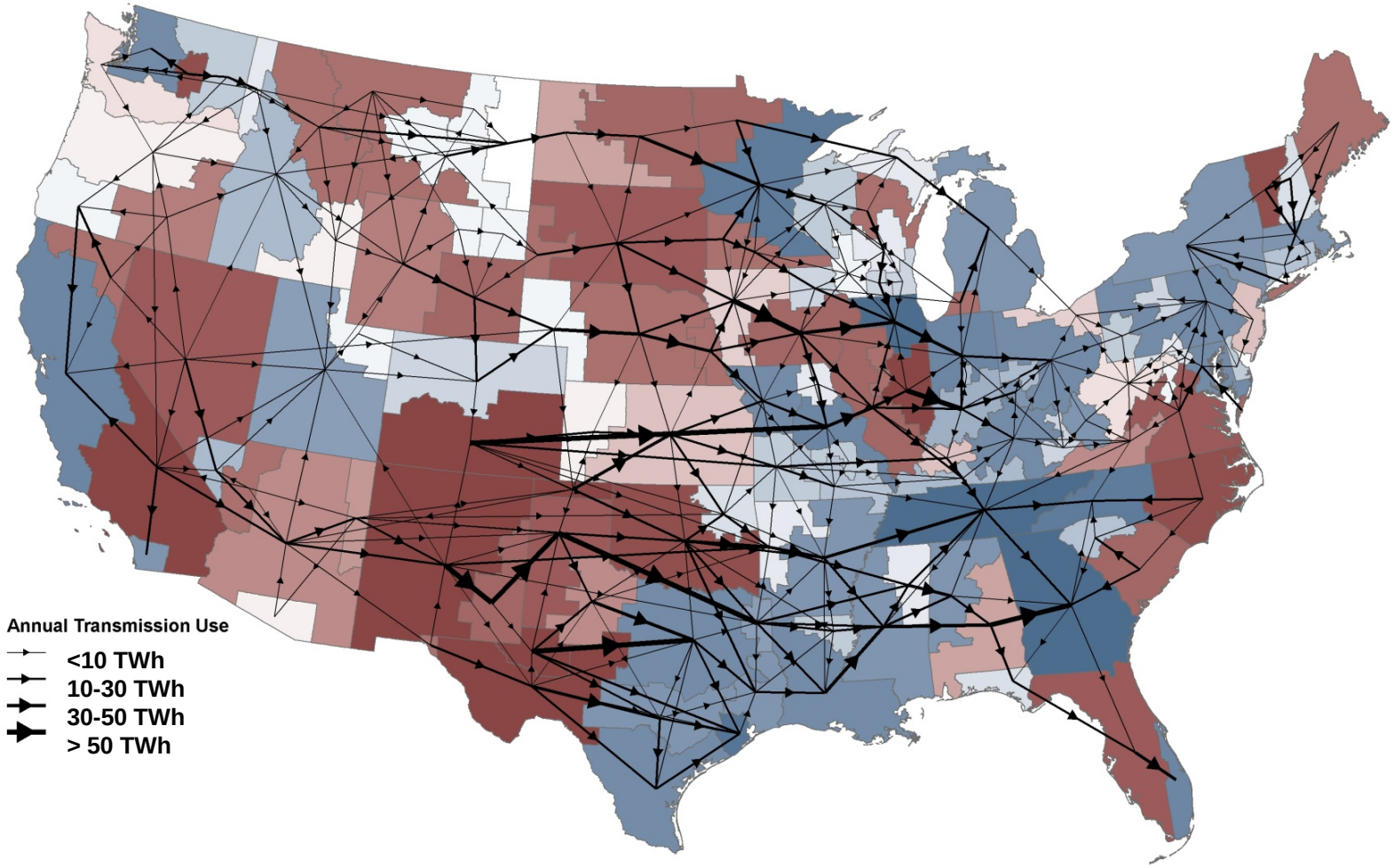
Transmission in ReEDS

- Zonal representation of existing transmission system
- Simple “truck route” simulation of flows
- Capacity expansion between PCAs
  - Costs expressed in $/MW-mile and transformer costs
  - Costs vary with region, topography, and population density
  - AC-DC-AC intertie expansions
  - Transmission expansion driven by remote resources





ReEDS 2050 Annual Electricity Flow



Red PCAs are exporters - Blue PCAs are importers

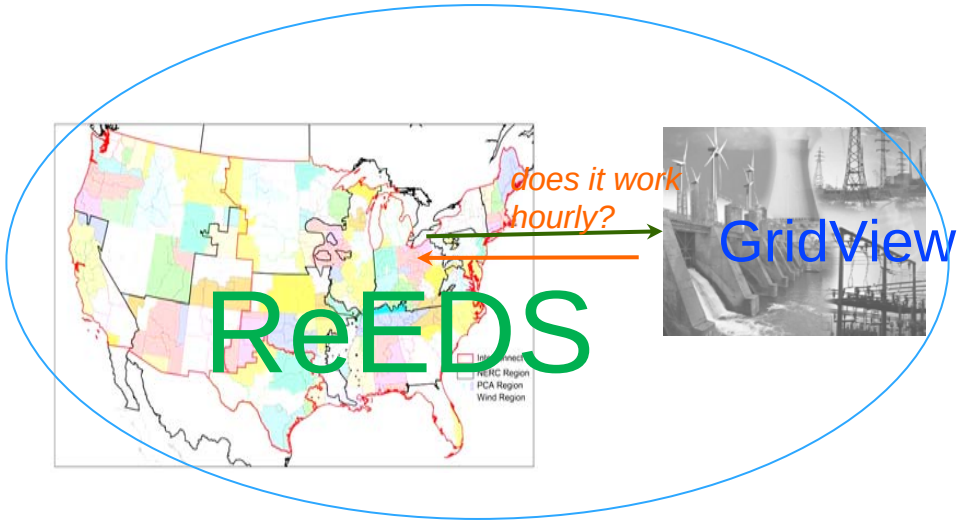
Revising ReEDS Transmission

- Implementing zonal linearized optimal power flow
  - Using existing regions
    - Static PTDF matrix
    - Dynamic PTDF matrix
    - Dynamic PTDF with new linkages
  - Using new regions
    - Collaboration with PSERC
    - Using Oh's new method for grid reduction
  - Initial Results
    - Some increase in transmission buildout costs and some decrease in remote renewables
    - Initial results appear reasonable on the surface
- Connecting to GridView

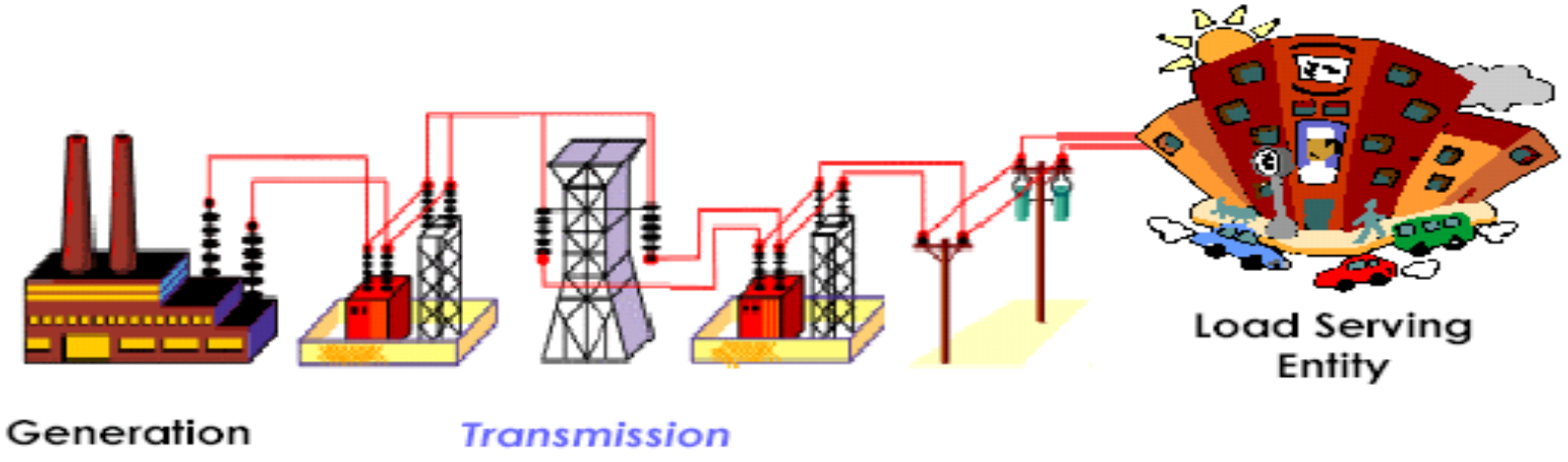
Results for PTDF transmission in ReEDS

This is a placeholder for new results expected to be available by the time of the FERC workshop

GridView



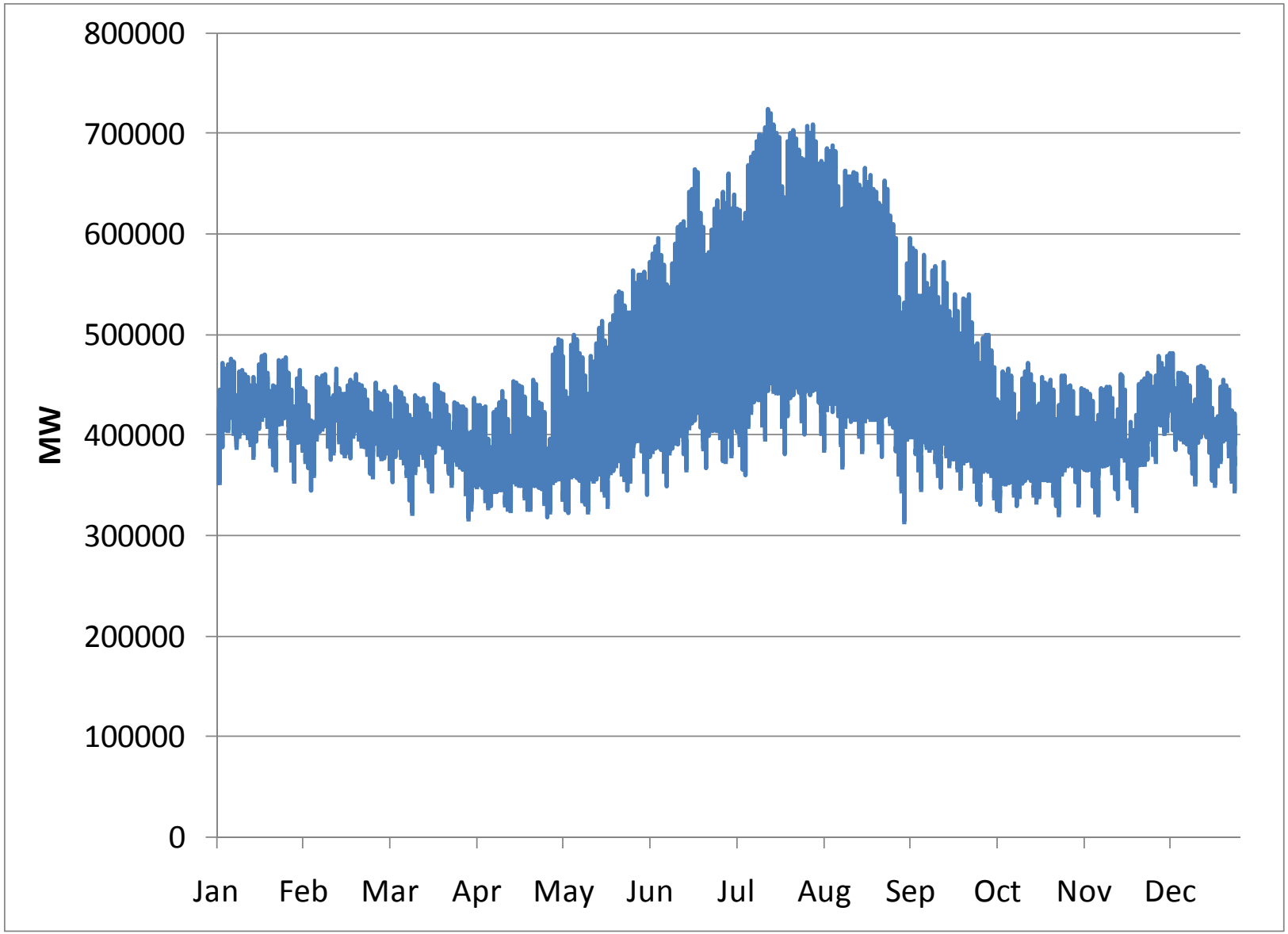
- Commercial production-cost, optimal DC power flow model available from ABB
- 8760 hour simulation with unit commitment



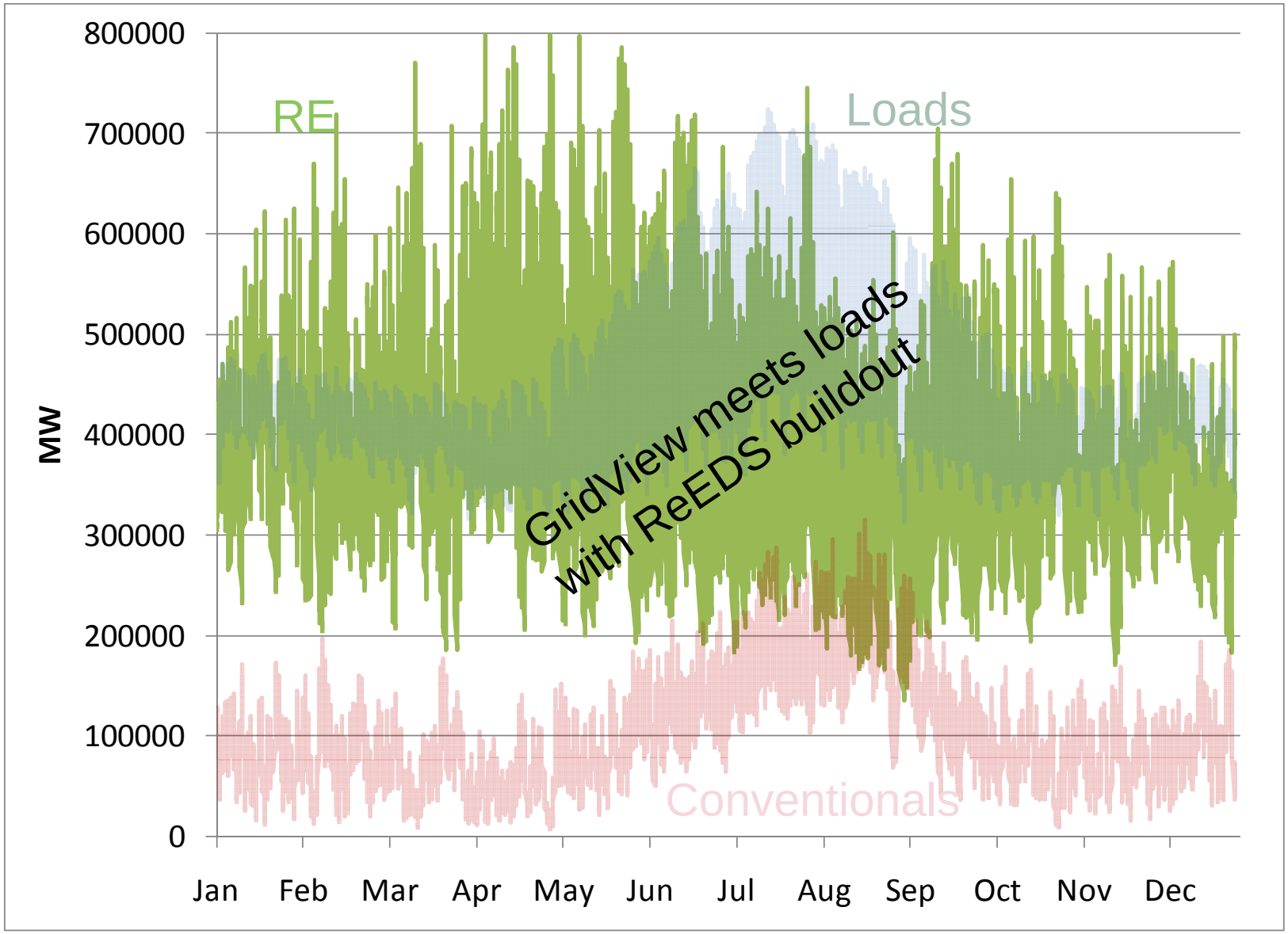
11,000 generators

85,000 transmission lines

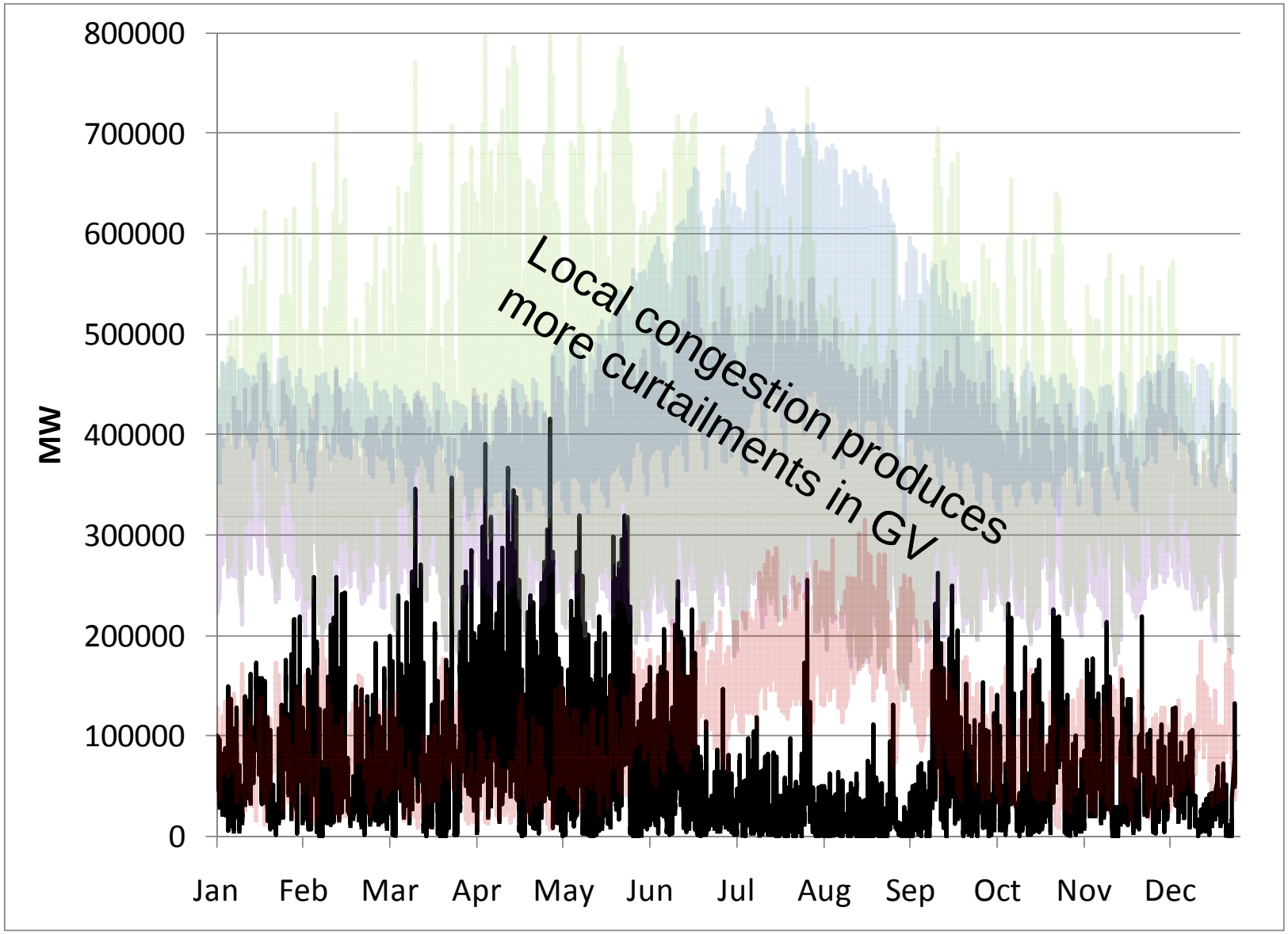
GridView - 2050 U.S. Electricity Demand



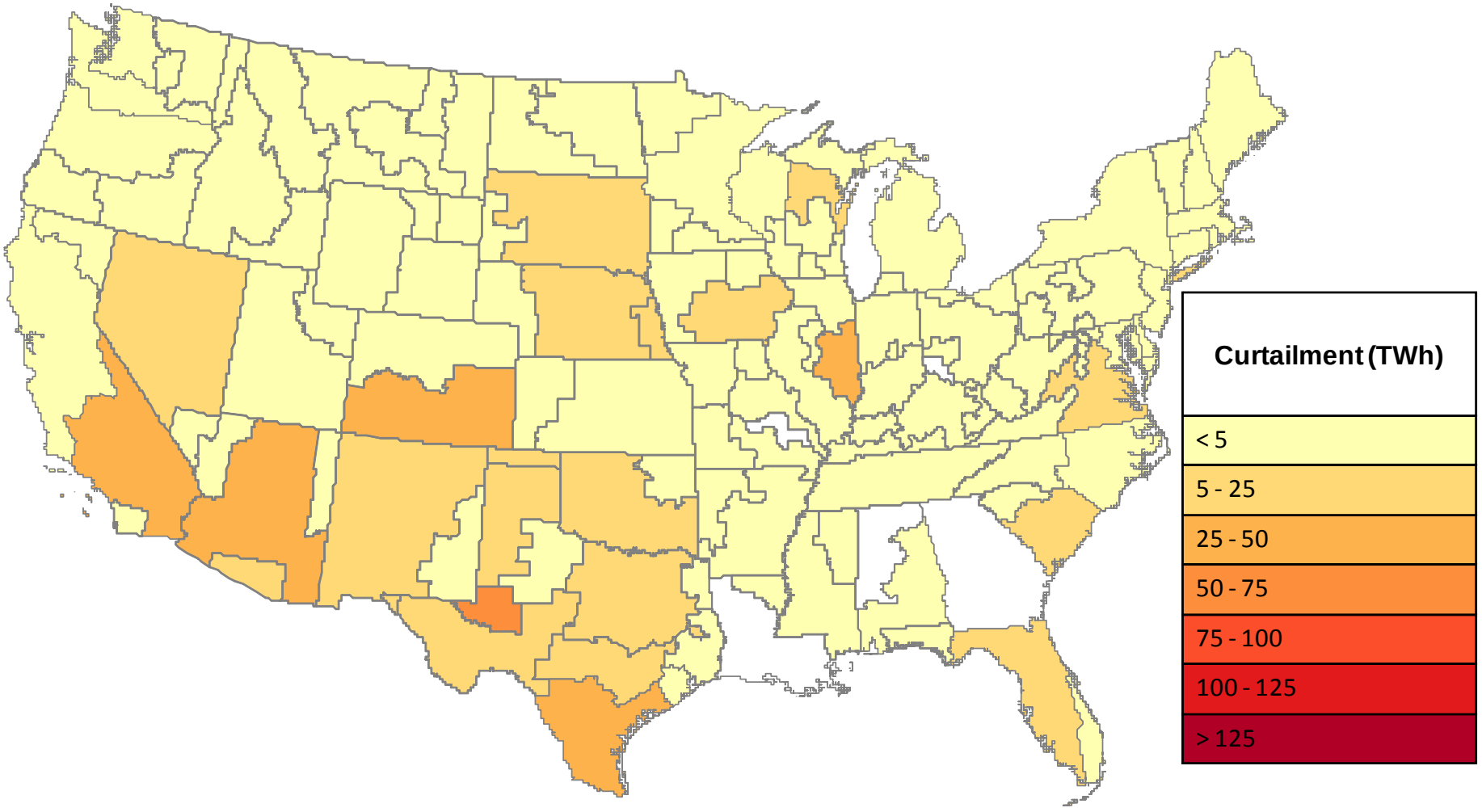
RE Generation from a High RE Scenario



Curtailments



Curtailment by PCA (TWh)



Conclusions

- Simulating renewable electric technologies requires extra-ordinary detail, including transmission buildout
- ReEDS transmission capacity expansion capabilities will be enhanced with new linearized OPF.
- GridView results suggest ReEDS' current transmission and integration representation provides valuable insights, but can be improved.