
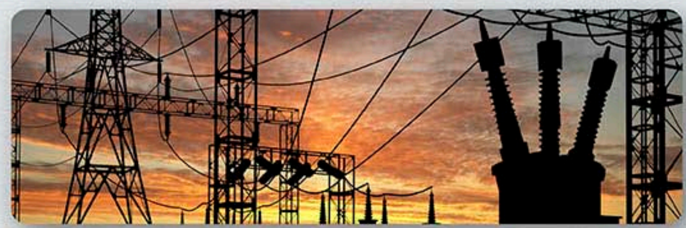


The Promise and Limits of Renewable Energy, and the Role of Electricity Storage

Victor Niemeyer
EPRI Climate Program

EPRI Climate Seminar
May 26, 2011

What are the Promises and Limits for Renewable Energy in a Low-Carbon Future?

- A national policy to curb CO_2 emissions below existing levels will initiate a competition to replace existing coal
- Wind and solar resource potential is huge, potentially matching current generation from coal
- All the more critical if nuclear and CCS are limited
- Renewable potential substantially limited by:
  - Cost
  - Variability
  - Location
  - Poor alignment of output with load
- **How much can electricity storage help overcome these limitations?**

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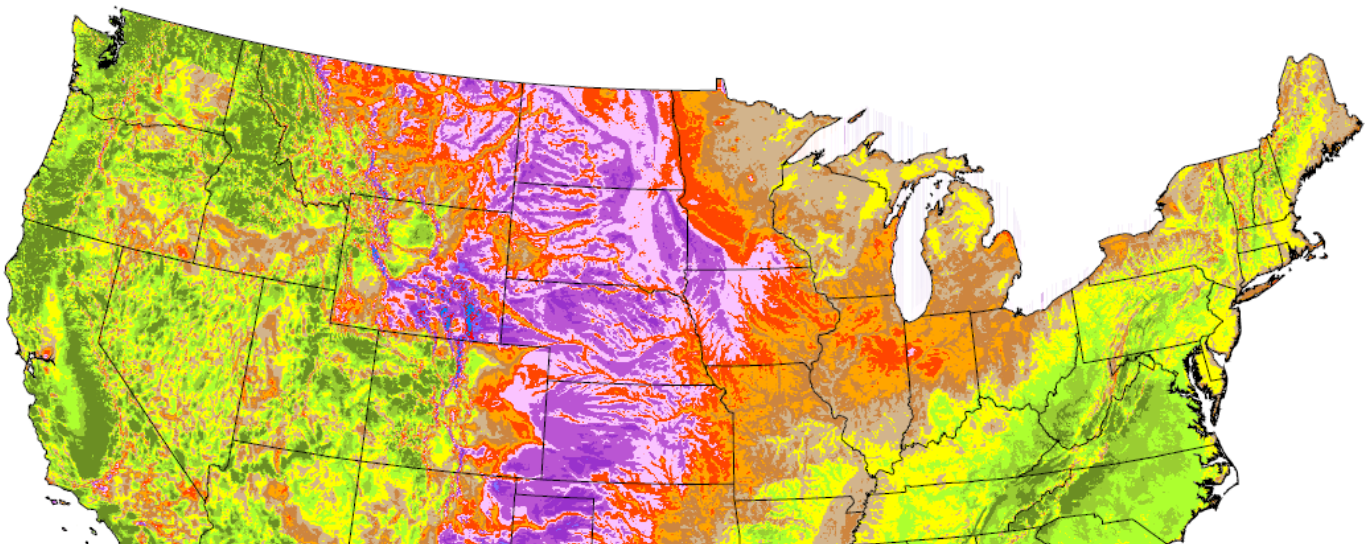
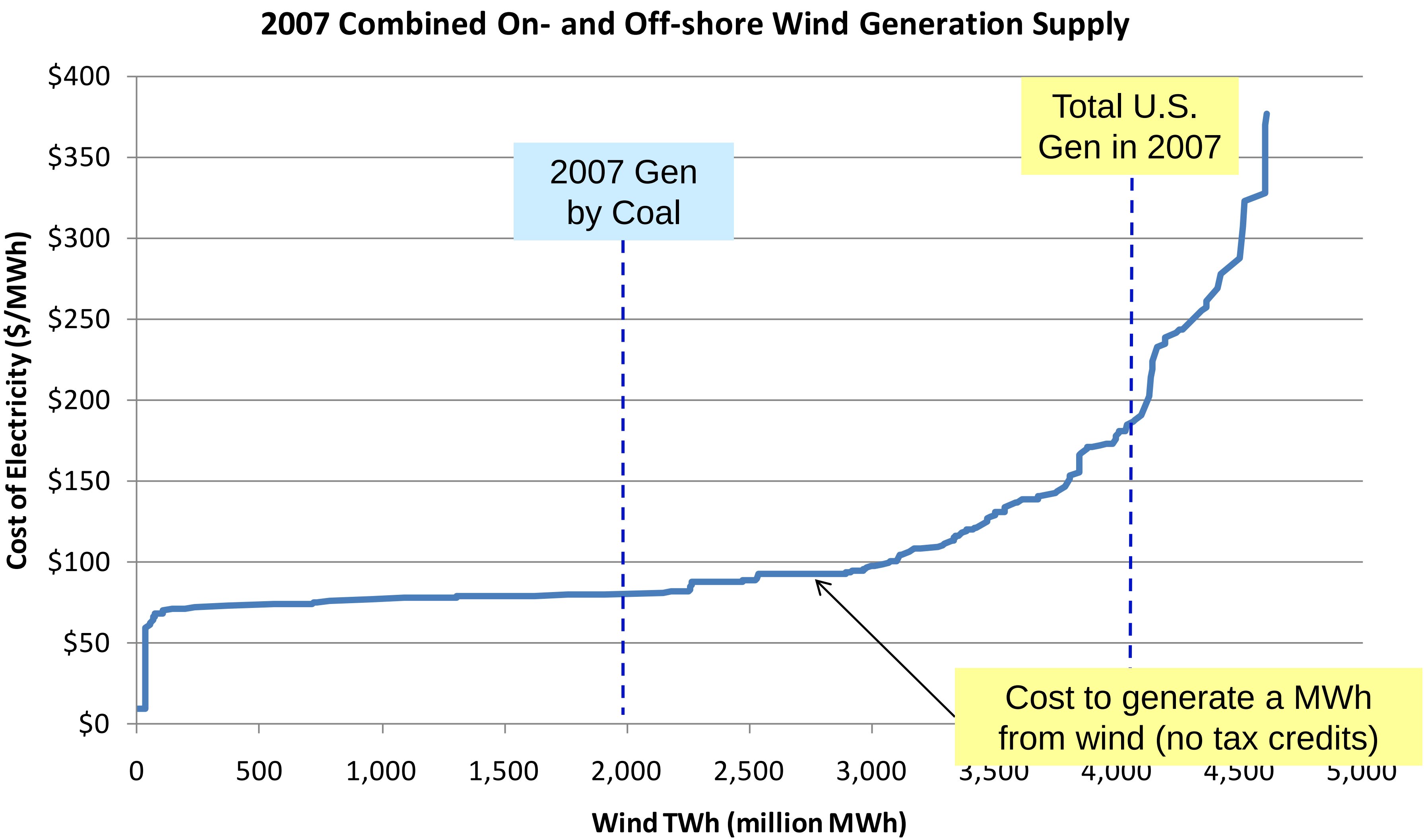
AWS Truepower Data Set Captures Location and Variability of Wind Resources



- **AWS Truepower wind data**
  - Provides simulated hourly output for typical turbine (80m height, 1.5 MW)
  - Derived from 1997-2008 meteorology

- **Based on 5300+ identified "utility-scale" sites**
  - Exclusion areas
  - 100 MW site minimum
  - Distance to grid
  - Terrain/wake effects

EPRI Wind Resource Assessment from Truepower Shows Vast Generation Potential



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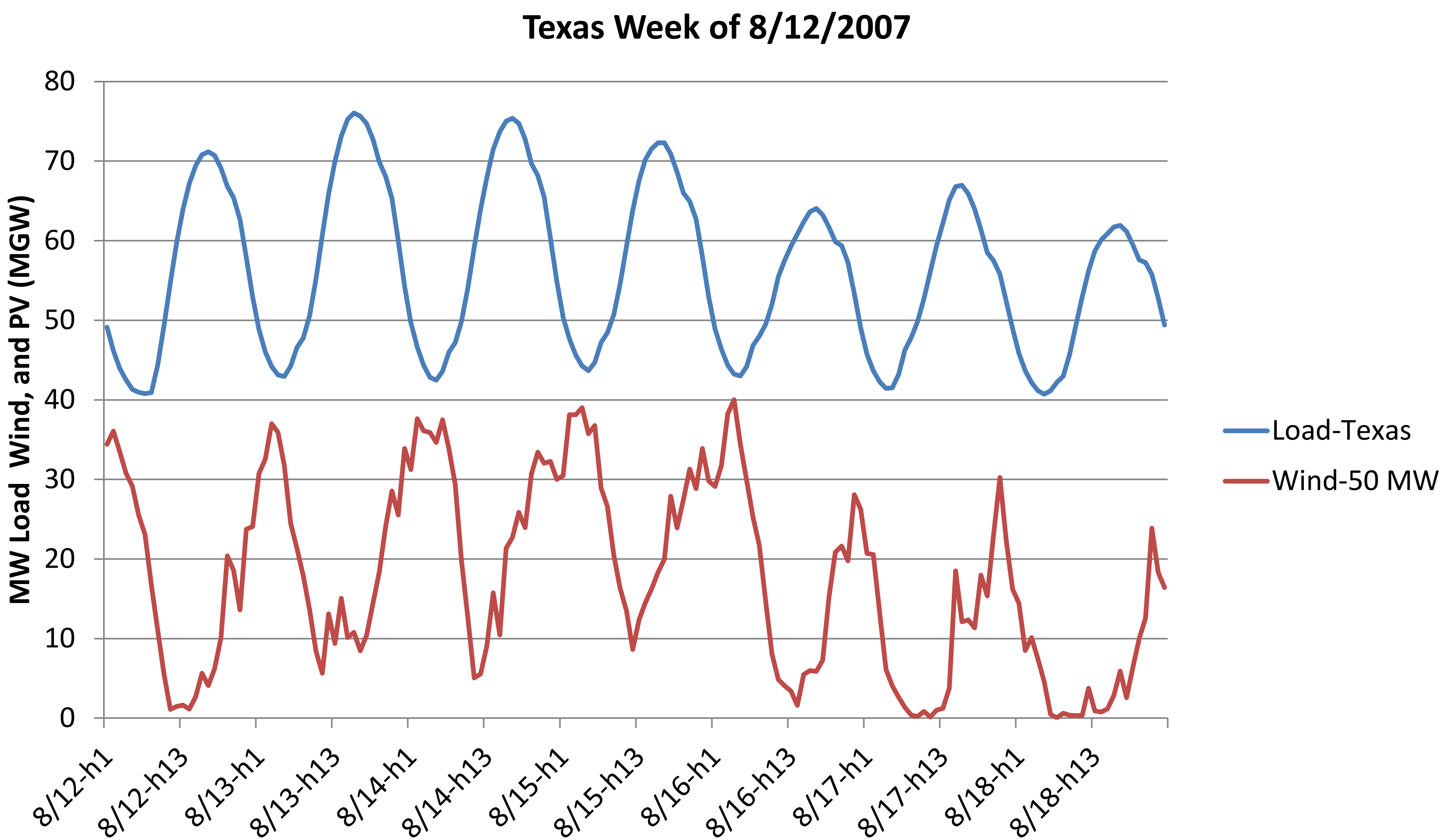
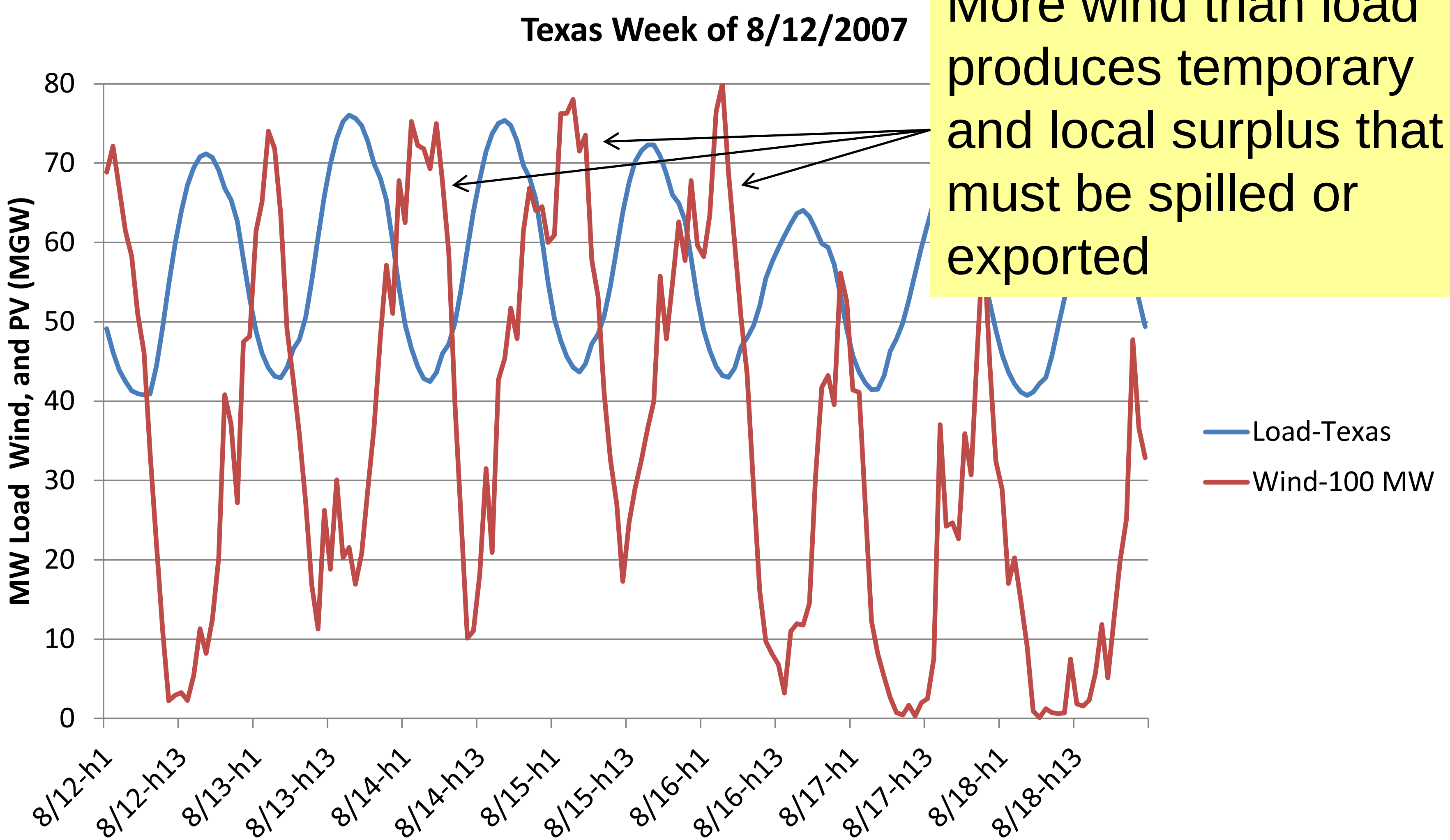
Anti-correlation of Wind with Load Creates Ramping Issues: <u>50 GW</u>

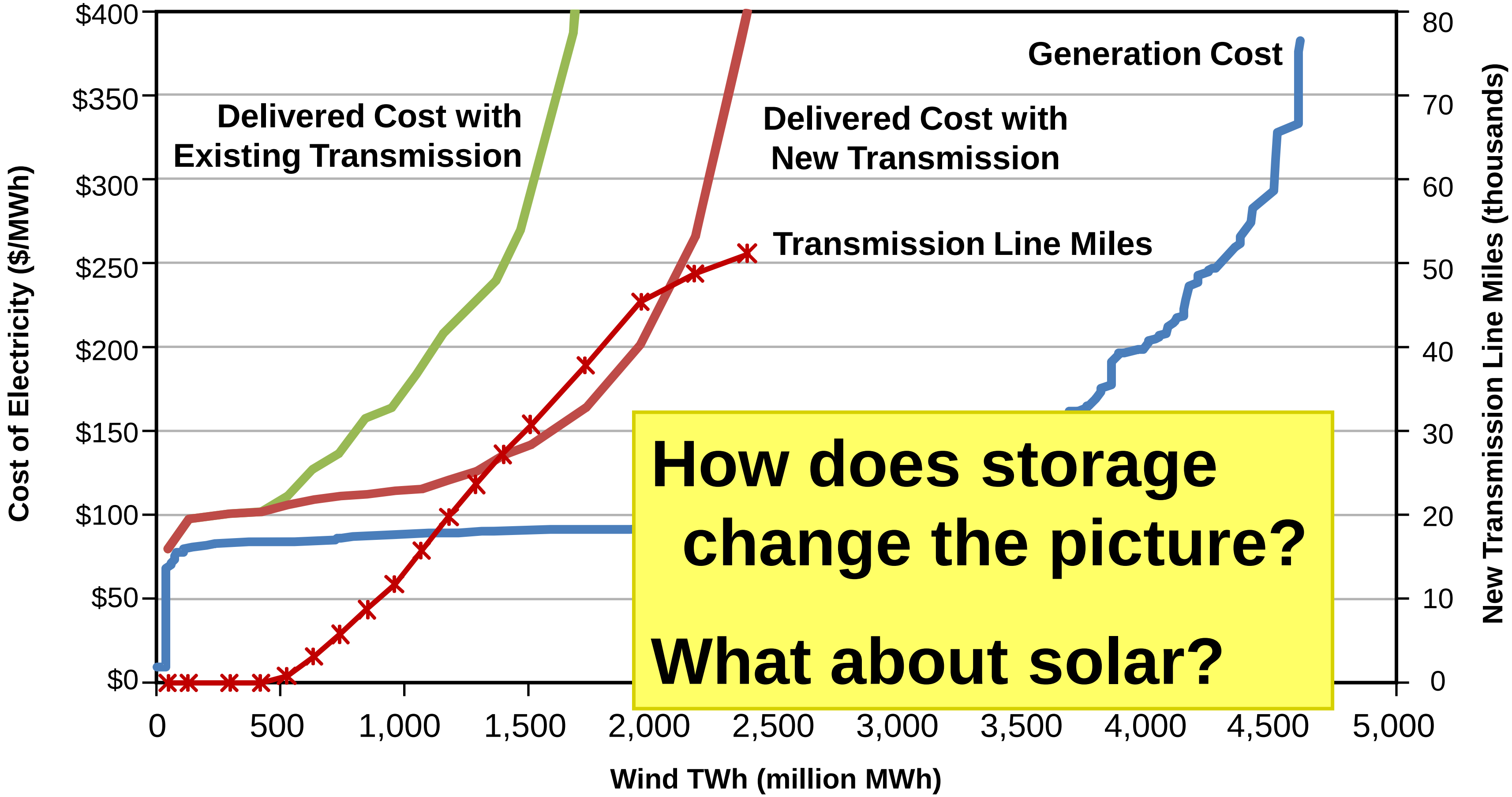


Anti-correlation of Wind with Load Also Forces Diminishing Returns to Wind Additions: 100 GW



More wind than load produces temporary and local surplus that must be spilled or exported

National Wind Energy Potential Supply Curves* (including delivery costs)



*EPRI – AWS TruePower National Wind Energy Supply Curves

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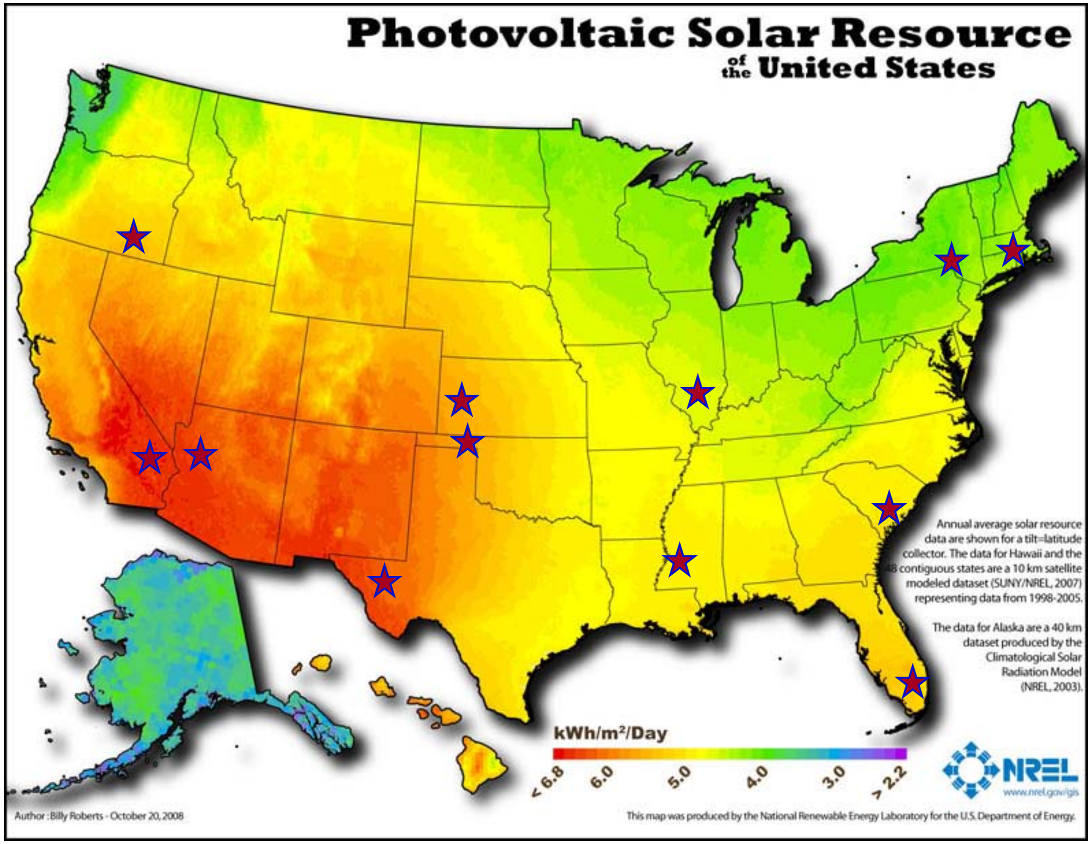
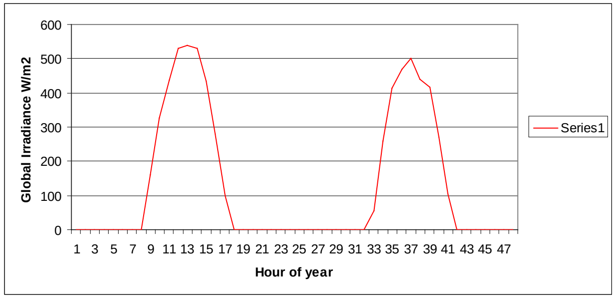
Solar Represented Here with Photo Voltaics (PV)

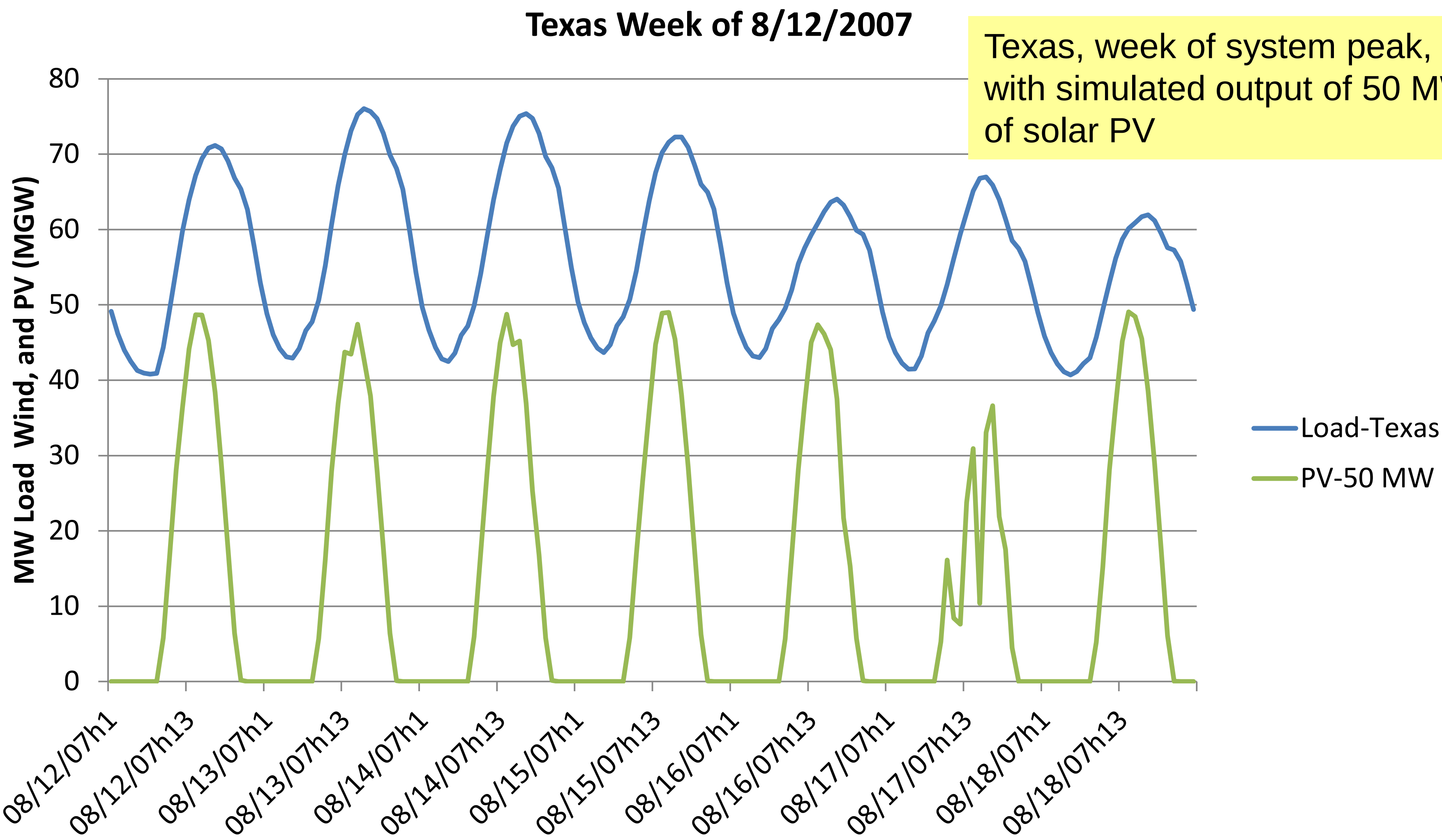


2007 Hourly Global Irradiance Data obtained from ww.solaranywhere.com

Irradiance data converted to output from south-facing tilted PV panels



Solar Shows Great Correlation with Load, But Narrow Output Bands



Texas, week of system peak, with simulated output of 50 MW of solar PV

Summary

- Lots of wind potential
- Wind limited by anti-correlation with load

- Lots of solar potential, correlated with load
- Solar output bands narrow compared to load

- Both wind and solar “go to zero”

How Can Large Scale Use of Electricity Storage Further the Use of Intermittent Generation?

- Storage is Jack of all trades providing variety of services including energy, capacity, and ancillary services
- Expect that storage can balance the intermittency of wind and solar output
  - Increase effective capacity value of wind/solar
  - Increase utilization of existing/new transmission
  - Improving the overall economics
- Following examples present preliminary analyses of the **strategic potential** for electricity storage in aggressive policy environments

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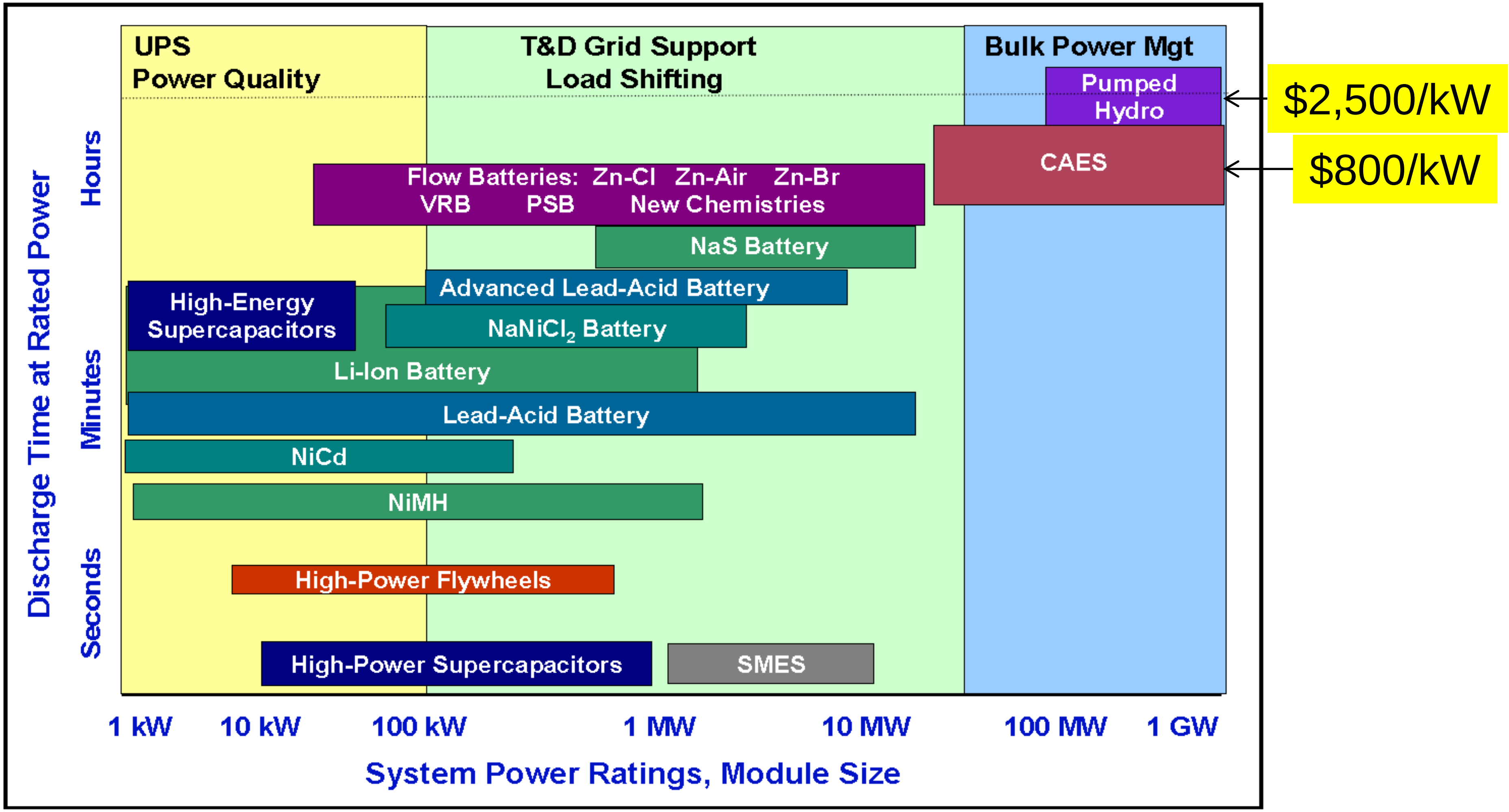
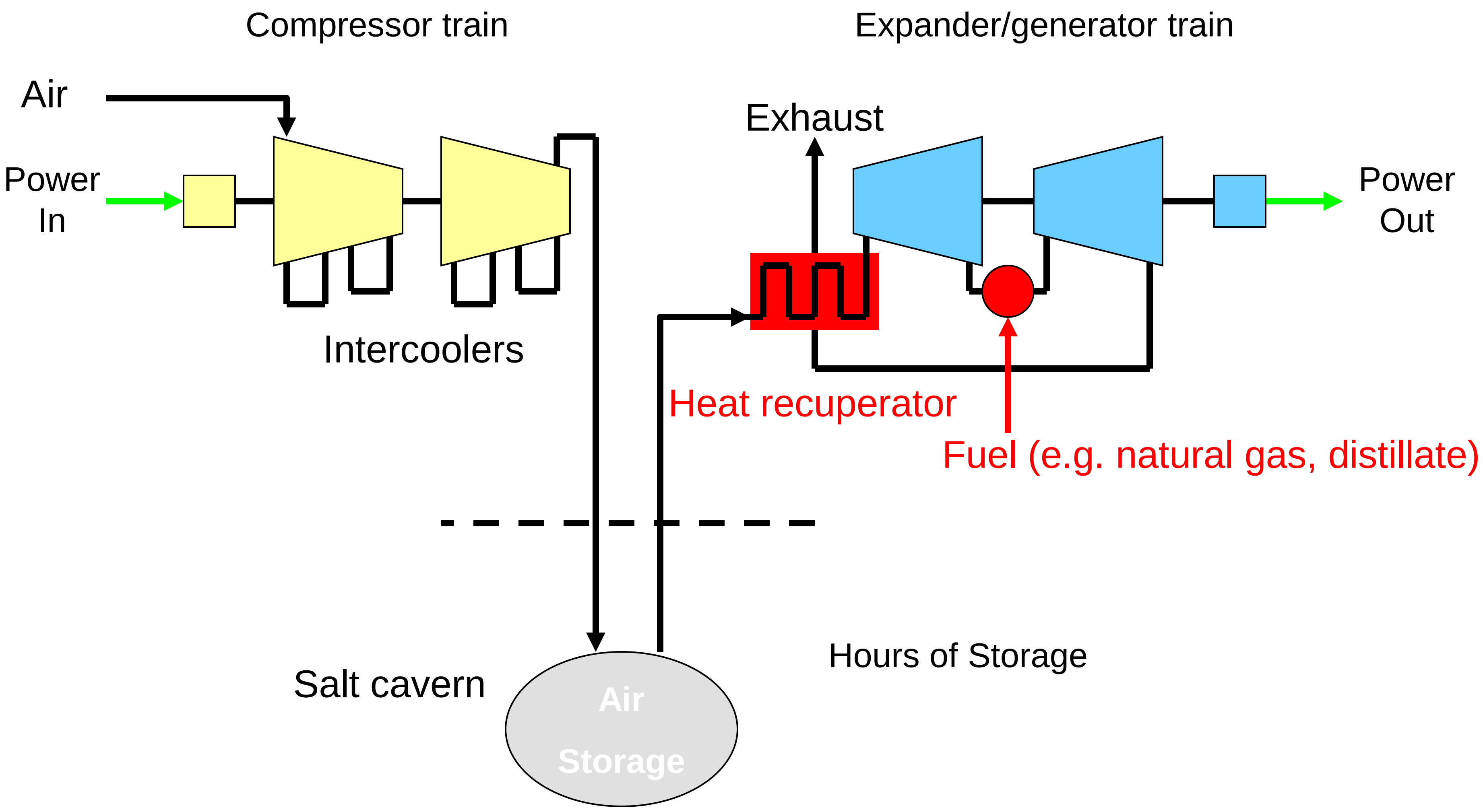
Many Candidate Storage Technologies



CAES (Compressed Air Energy Storage) Provides Good Storage Analysis Candidate

- Established technology with growing interest
- Potentially most viable multi-hour storage (cheaper than batteries and pumped hydro)
- Rapid technological development increasing efficiencies and lowering capital costs

CAES (Compressed Air Energy Storage) is a a playground for thermodynamics engineering



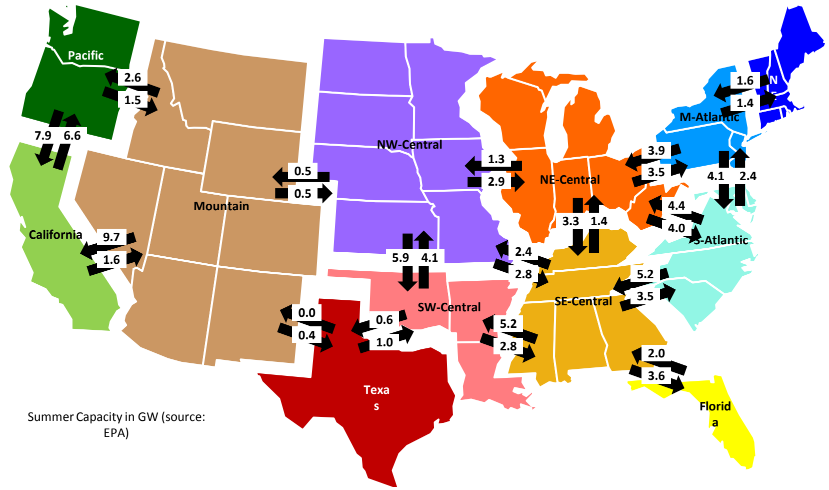
What is Surprising About CAES

- Burns gas
- Heat rates are in the 4,000 range
- Get 1 MWh out per ~0.8 MWh input
- Storage volume is cheap - $2/kW-hr incremental cost
- Compared to a combustion turbine, CAES gets approximately 3 times as much output capacity per unit of turbine capacity
  - Saving on turbine/MW greatly offsets “storage” components of a CAES system
- R&D goal is to get CAES capital costs below those of combustion turbines

RES Requirement Provides Policy Environment for Exploring Role of CAES Storage

- Simultaneous regional 8760 hourly loads and wind/solar/bioenergy potential
- Existing mix of generation and transmission capability
- New generation costs
- Future year fuel costs
- <u>RES policy goals</u>

REGEN Optimization



Mix of generation and transmission investment and operating decisions to minimize cost of electricity

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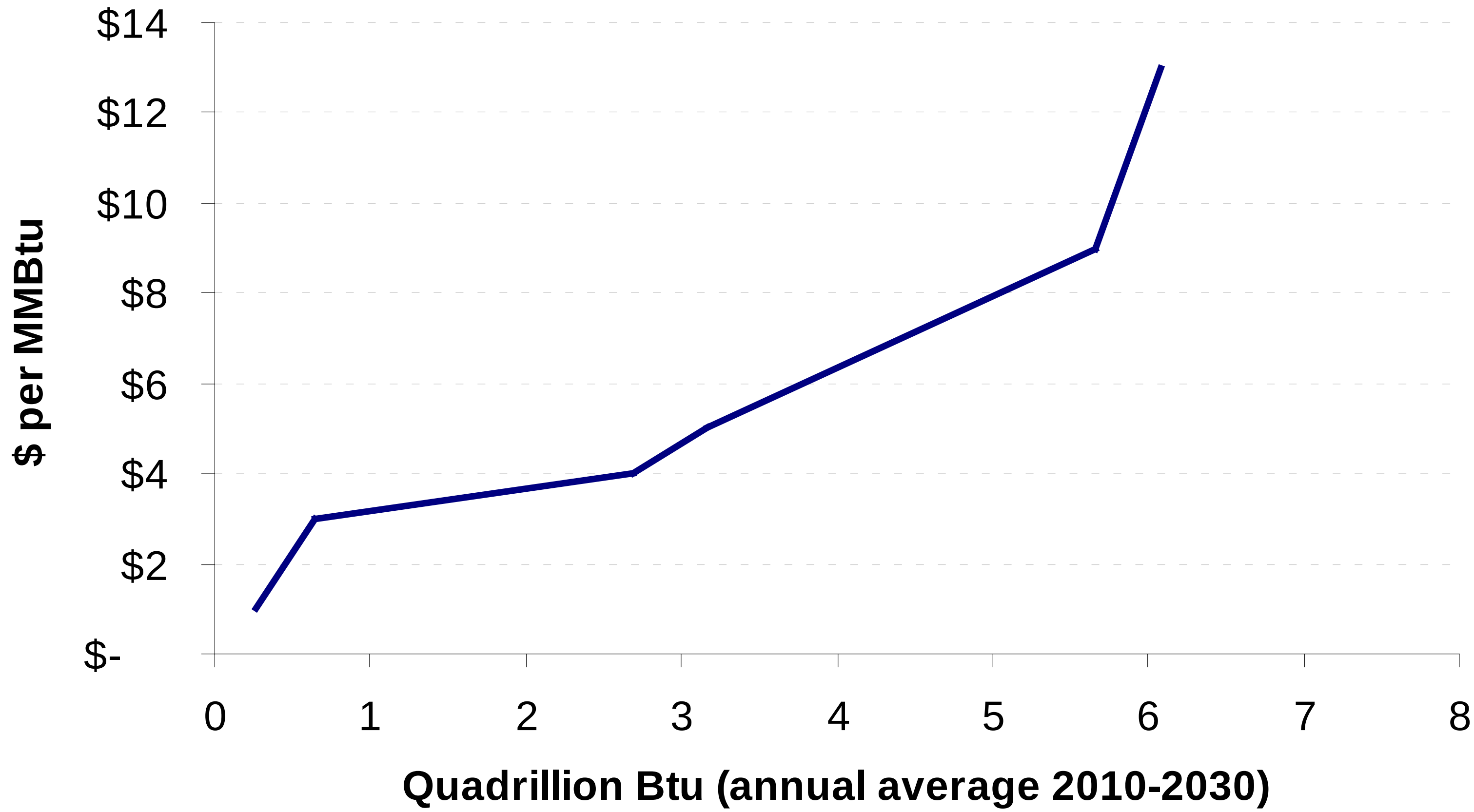
Assumptions for CAES Used in this Analysis

- Capital costs: equal to cost of new NGGTs (~$800/kW, varies by region)
- Reference storage capacity: 10 hours (10 MWh/MW of capacity)
- Efficiency is 0.81 MWh input per 1 MWh output
- Gas use at 4,100 MMBtu per MWh

- Sensitivity cases (not shown here)
  - Capital costs: 60% to %140% of NGGT
  - Storage capacity: 1 to 50 hours/kW

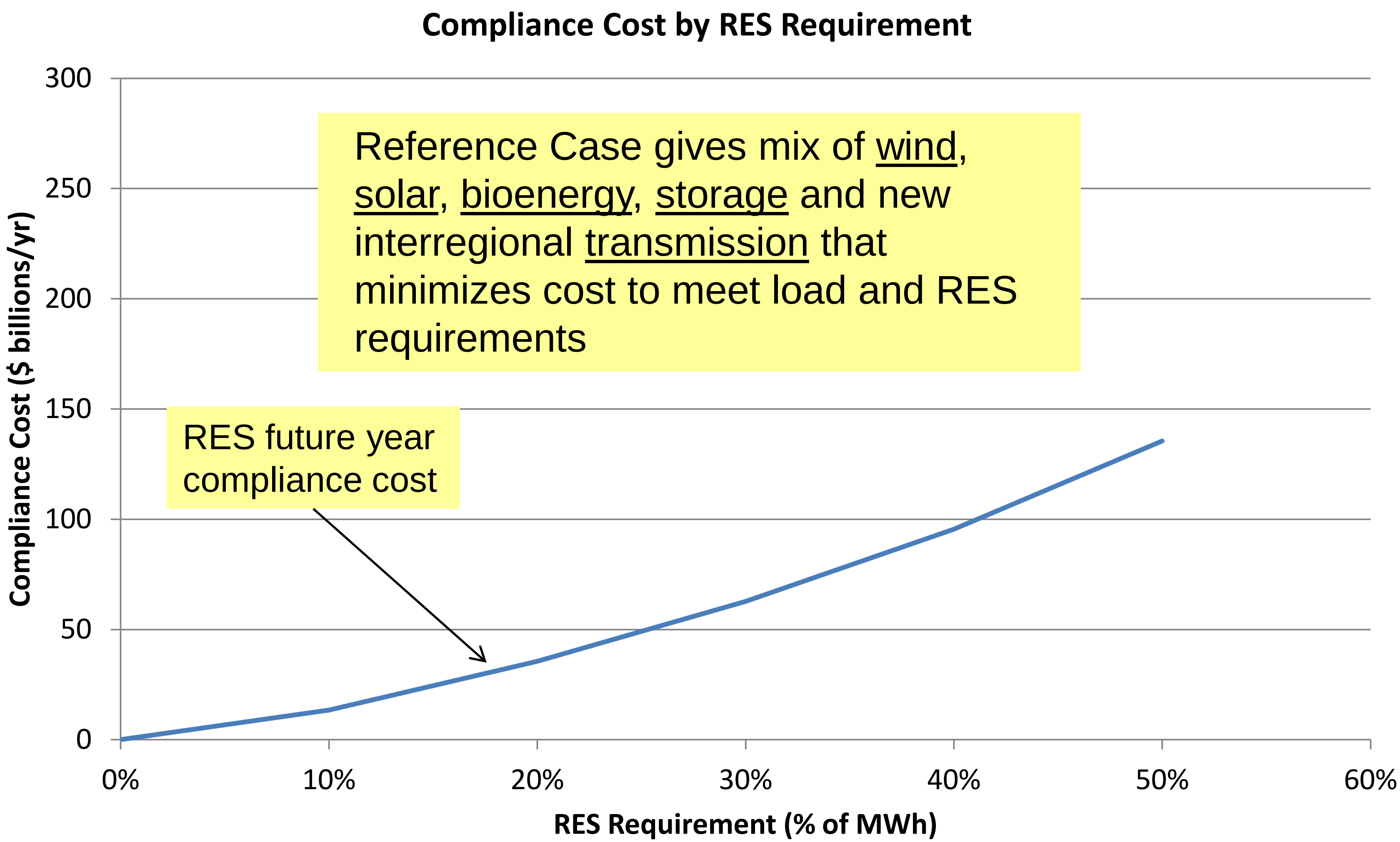
U.S. Biomass Supply for Electricity (per Steve Rose Presentation)



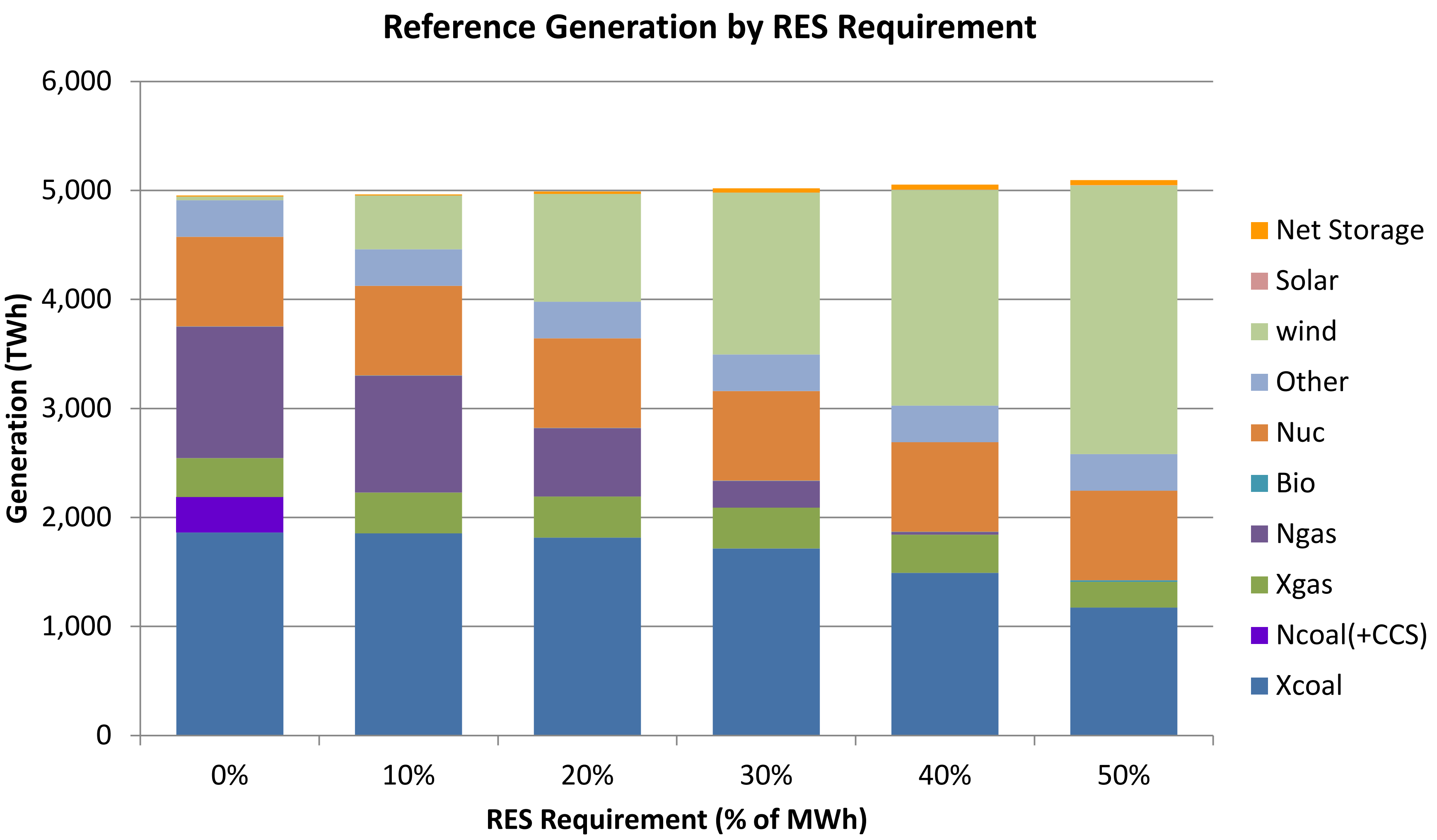
Analysis Overview and Caveat

- Static analysis captures electric system in approximation of long-run equilibrium for a hypothetical "future" year
- Shows minimum-cost mix of generation and transmission investment and operating decisions needed to meet load
- Powerful approach for
  - Assessing fundamental economic trade-offs in meeting policy objectives
  - Identifying competitive potential and market niches of different energy technologies
  - Understanding the implications of key uncertainties
- <u>Important to recognize that this static approach does not capture impacts of intertemporal optimization</u>

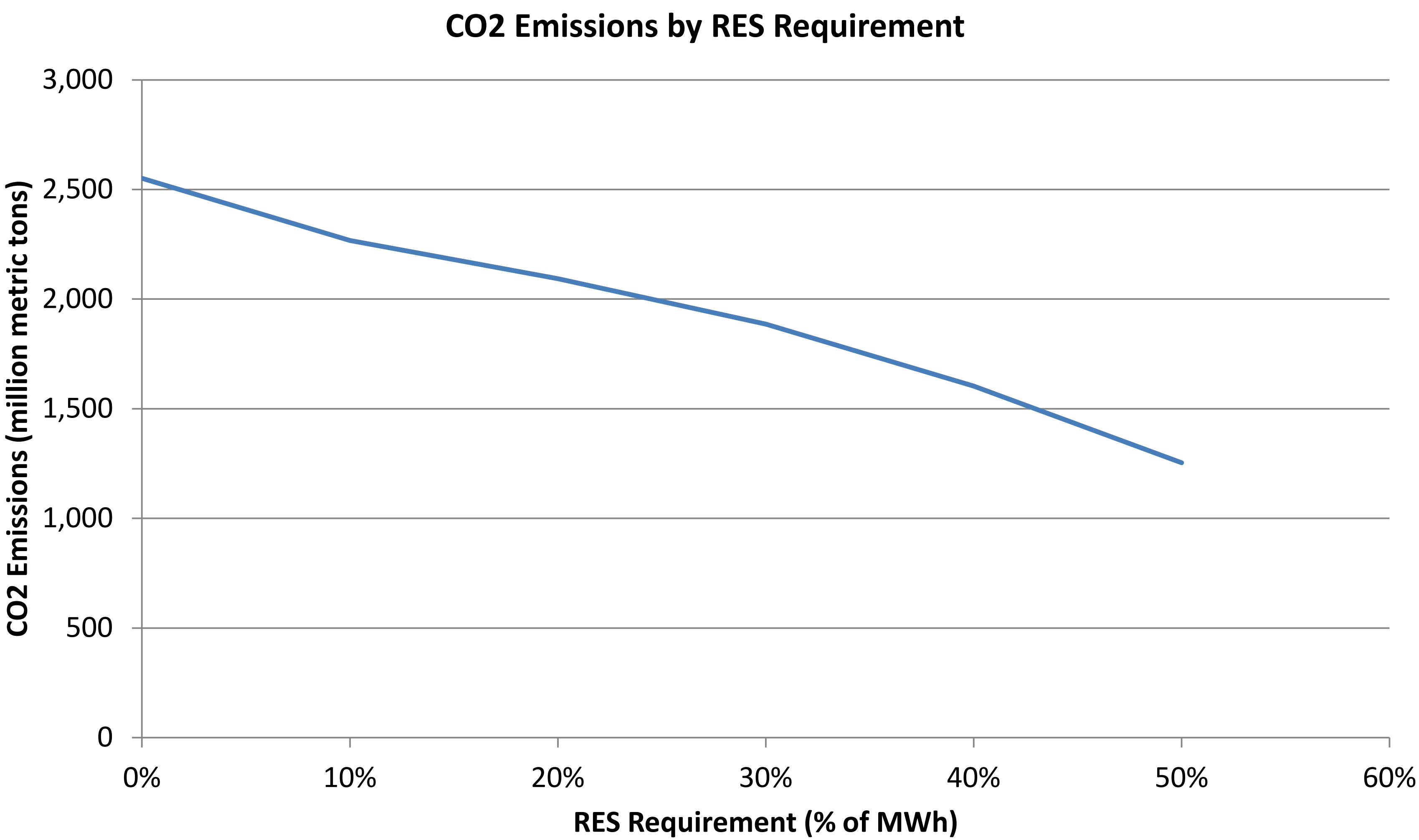
Reference Scenario Shows Cost to Electric Sector of Meeting Range of RES Requirements



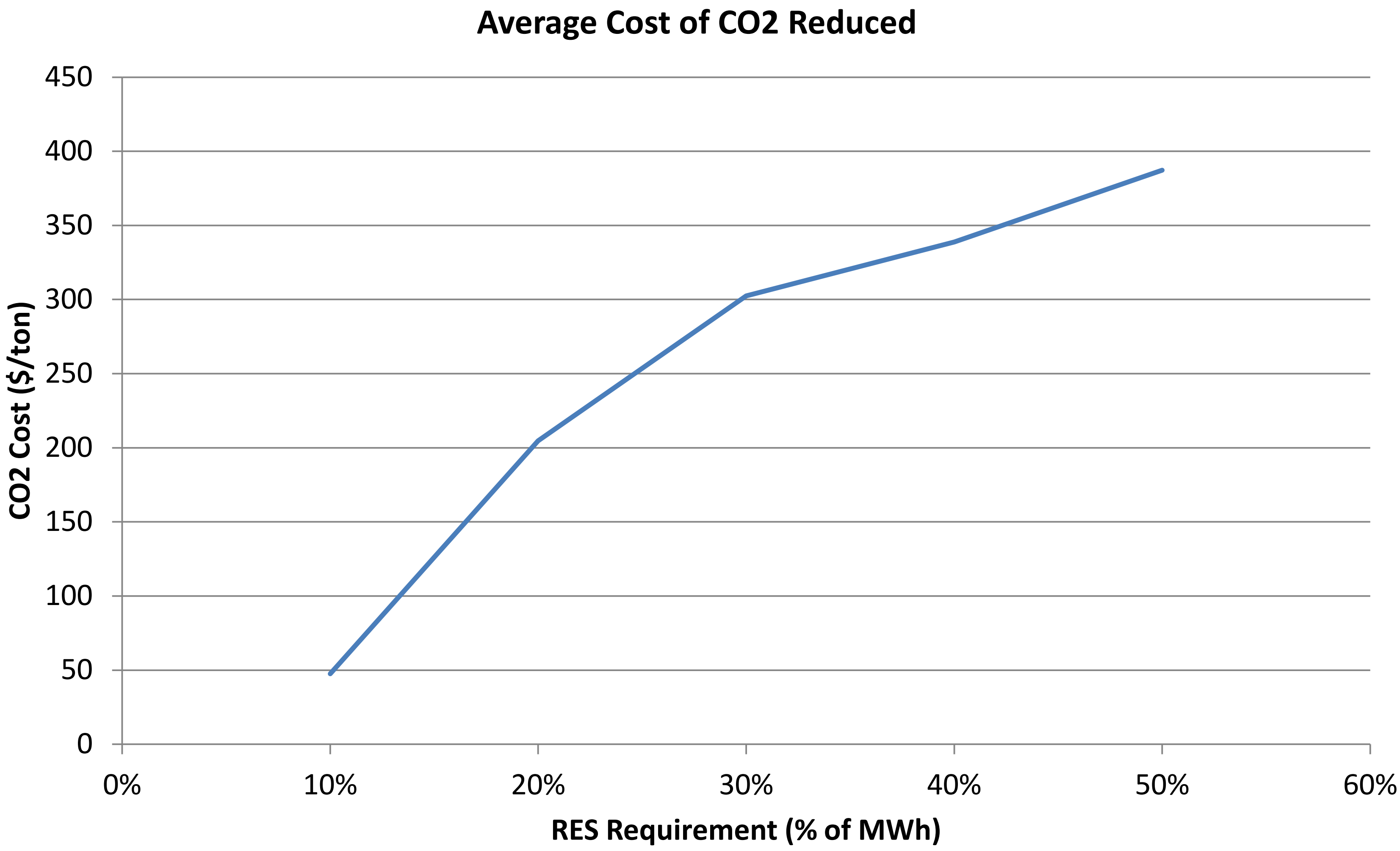
Dominant Role for Wind in Minimizing Cost of Higher RES Requirements in Reference Scenario



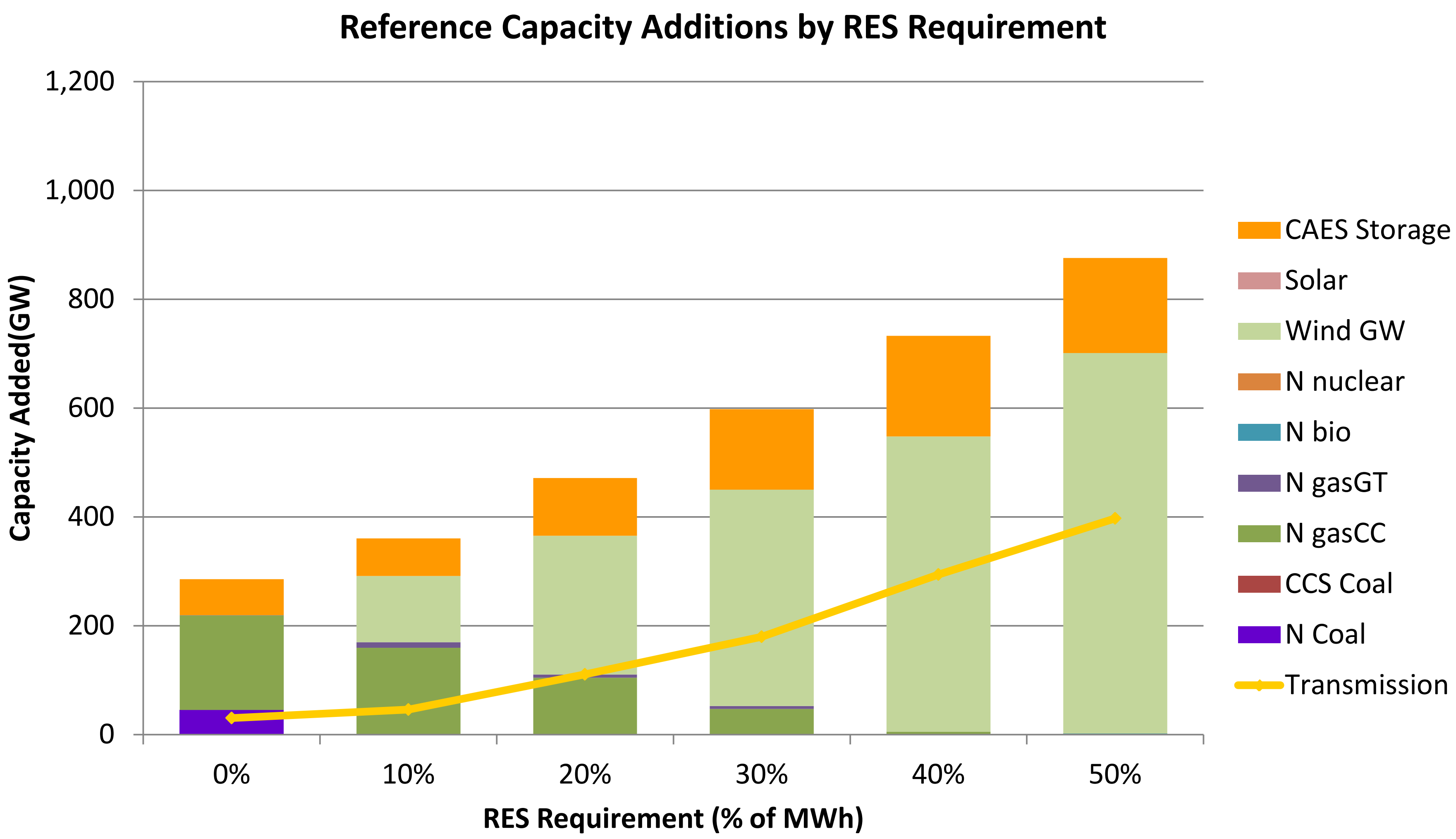
CO2 Emissions Fall Gradually as Wind Backs Out Fossil Generation



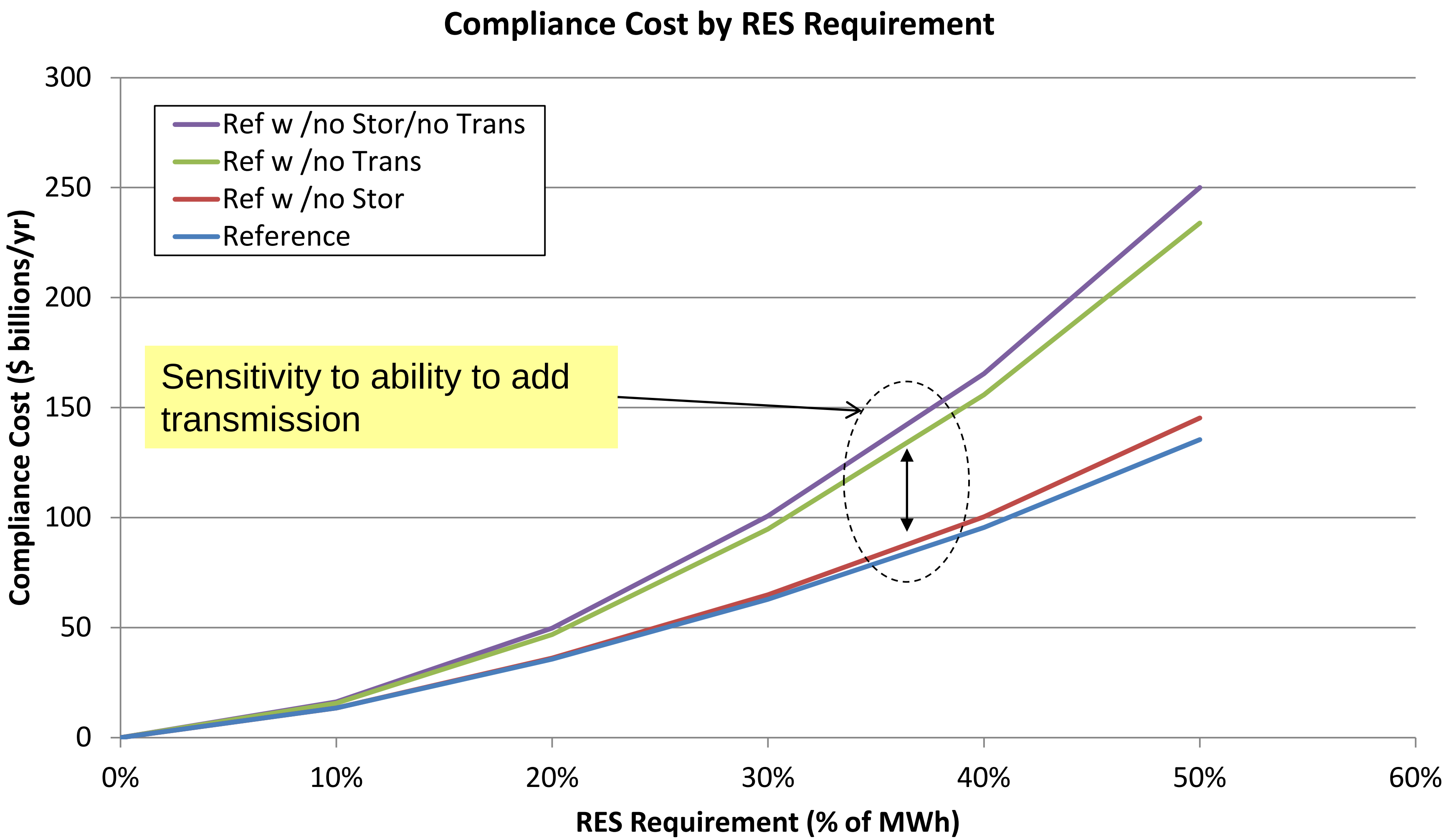
Comparing Incremental Compliance Costs and CO2 Reductions Yields CO2 Cost – not cheap!



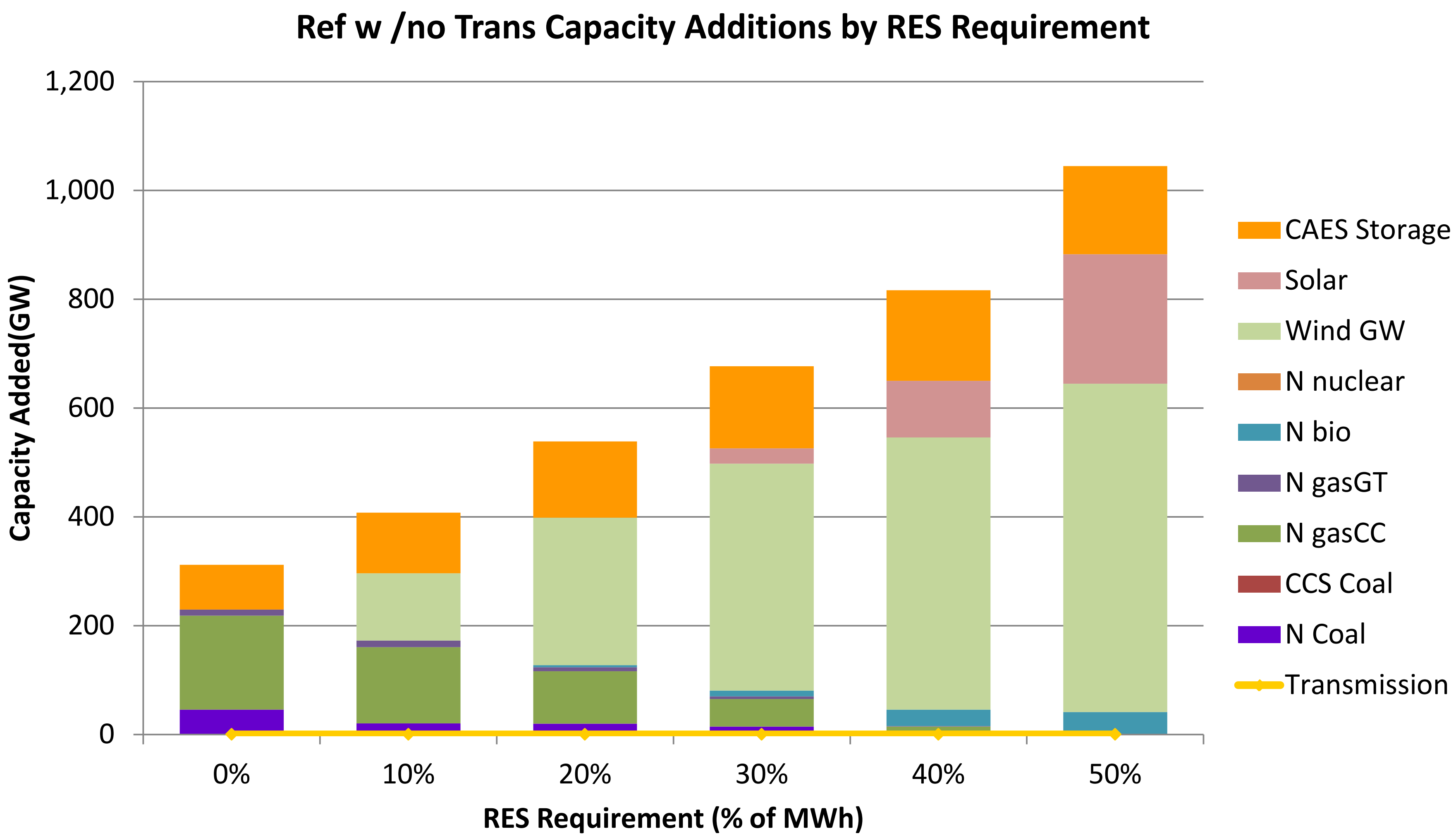
Reference Scenario Generation Additions Associated with Alternative RES Requirements



Sensitivity: How Does RES Requirement Cost Change if Can't Add New Transmission?



Restricting New Transmission Additions Creates Openings for Solar and Bioenergy



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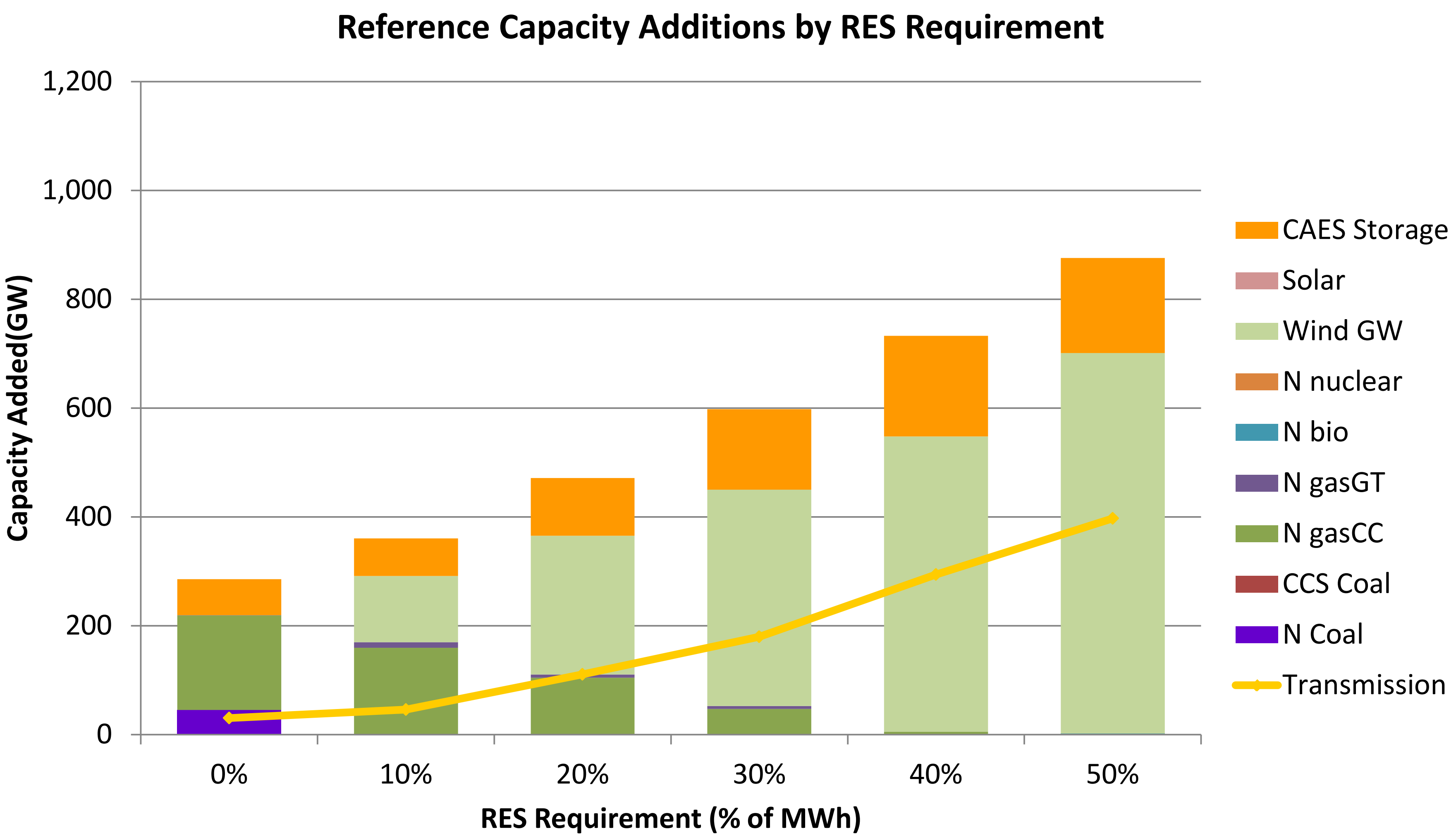
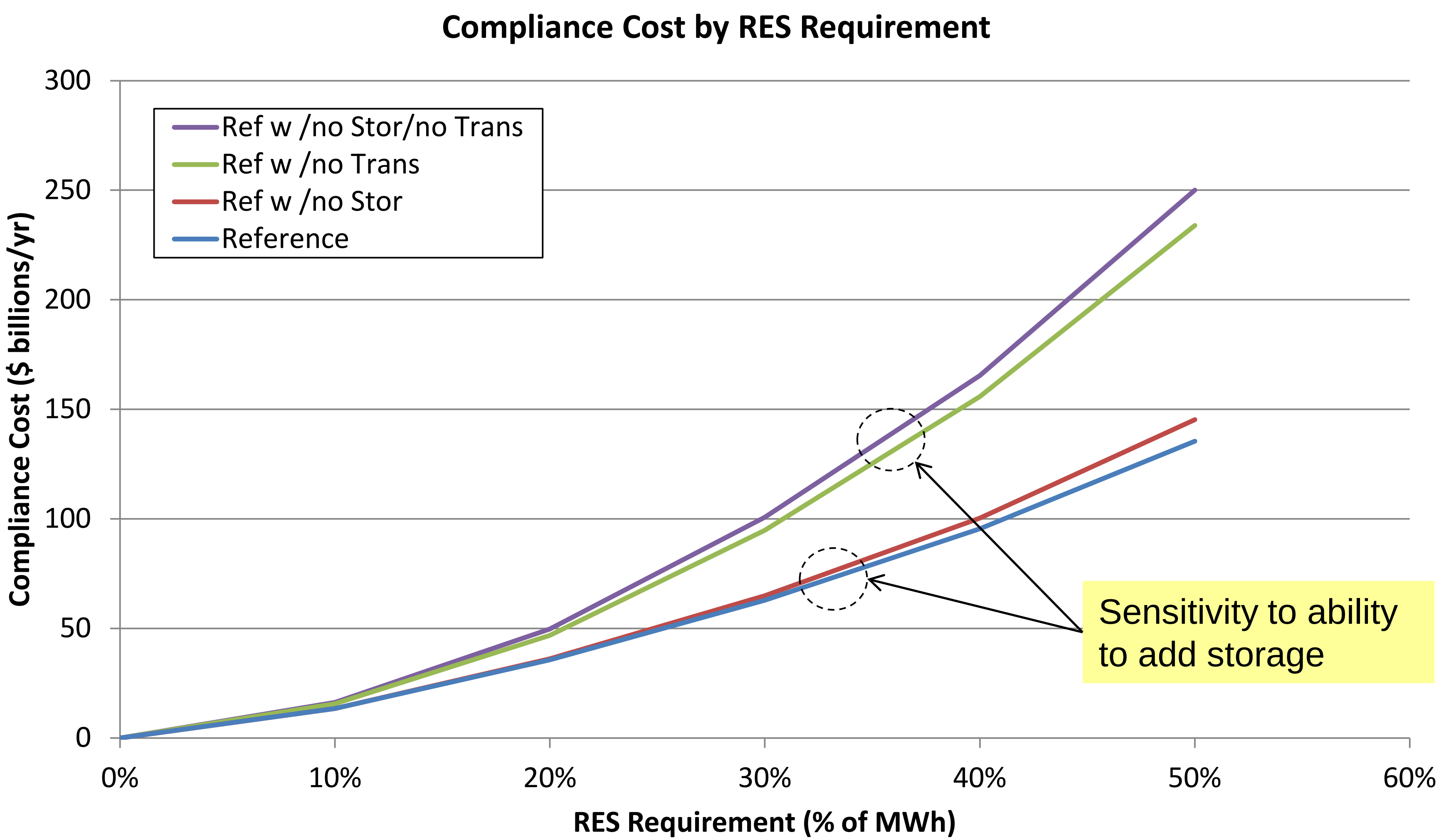
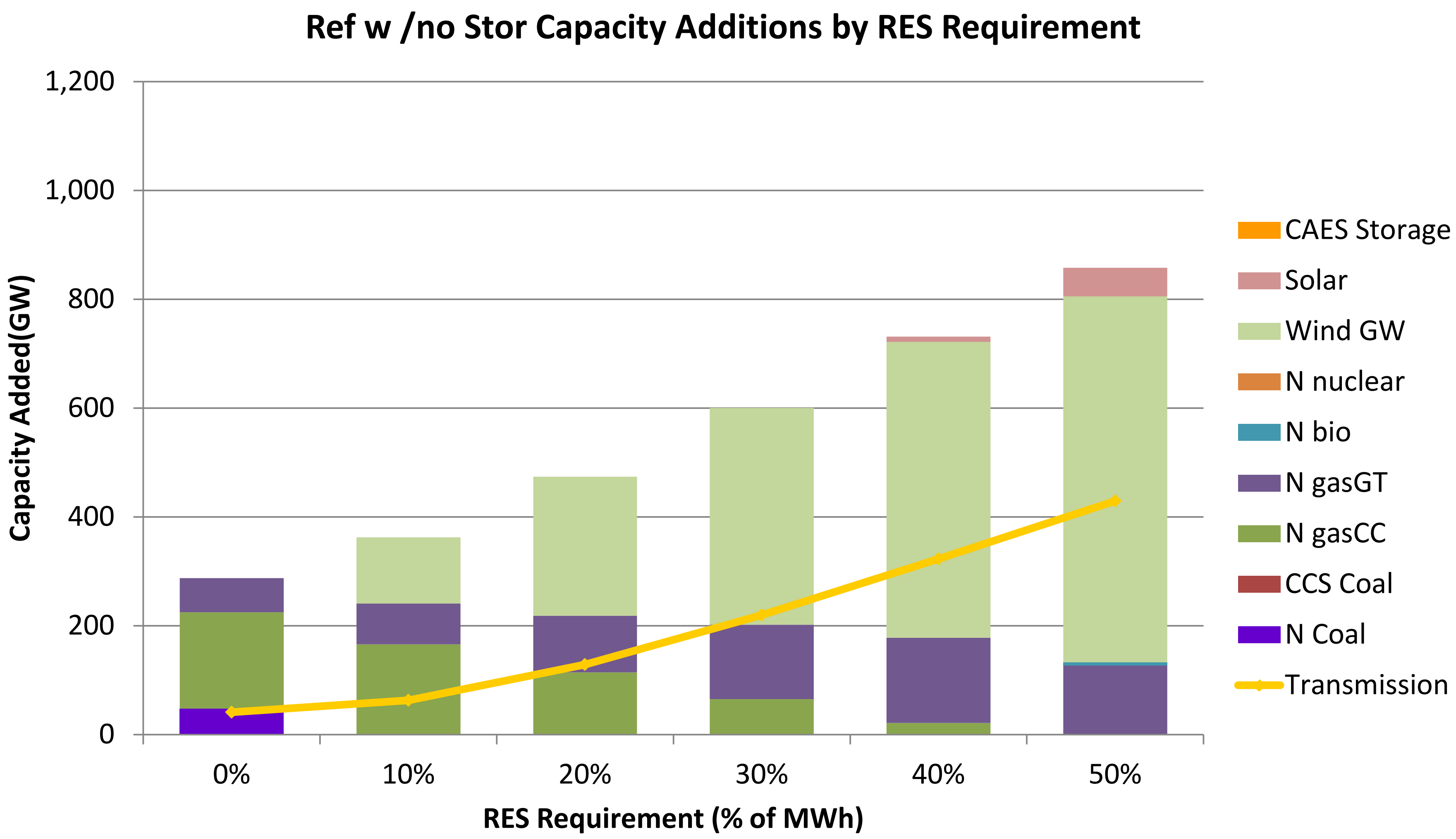
Reference Scenario Generation Additions Associated with Alternative RES Requirements



Sensitivity: How Does CAES Storage Reduce Cost of Meeting RES Requirements?

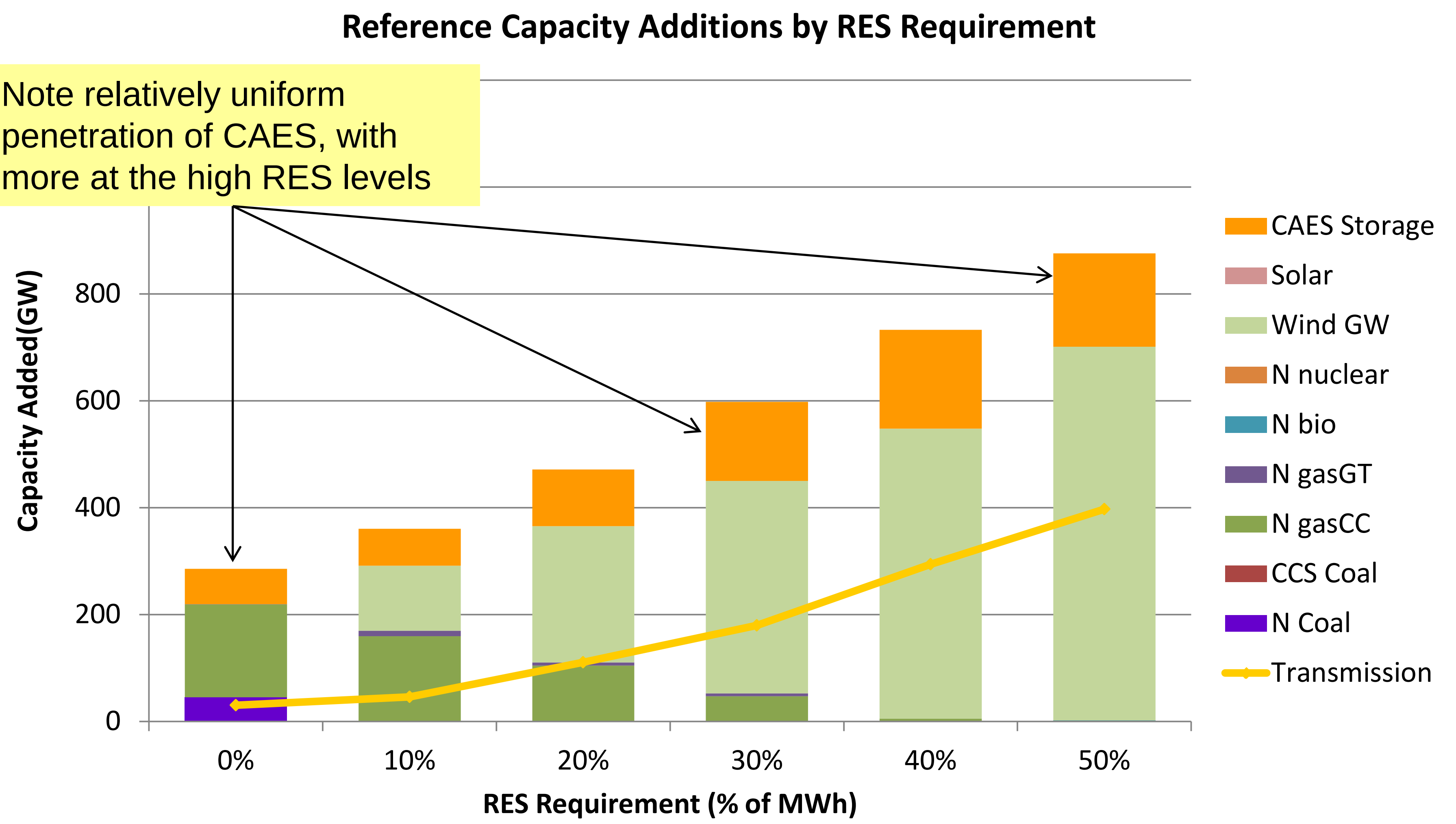


No CAES Storage Scenario Shows More Solar, and More NGGT Additions at High RES Levels

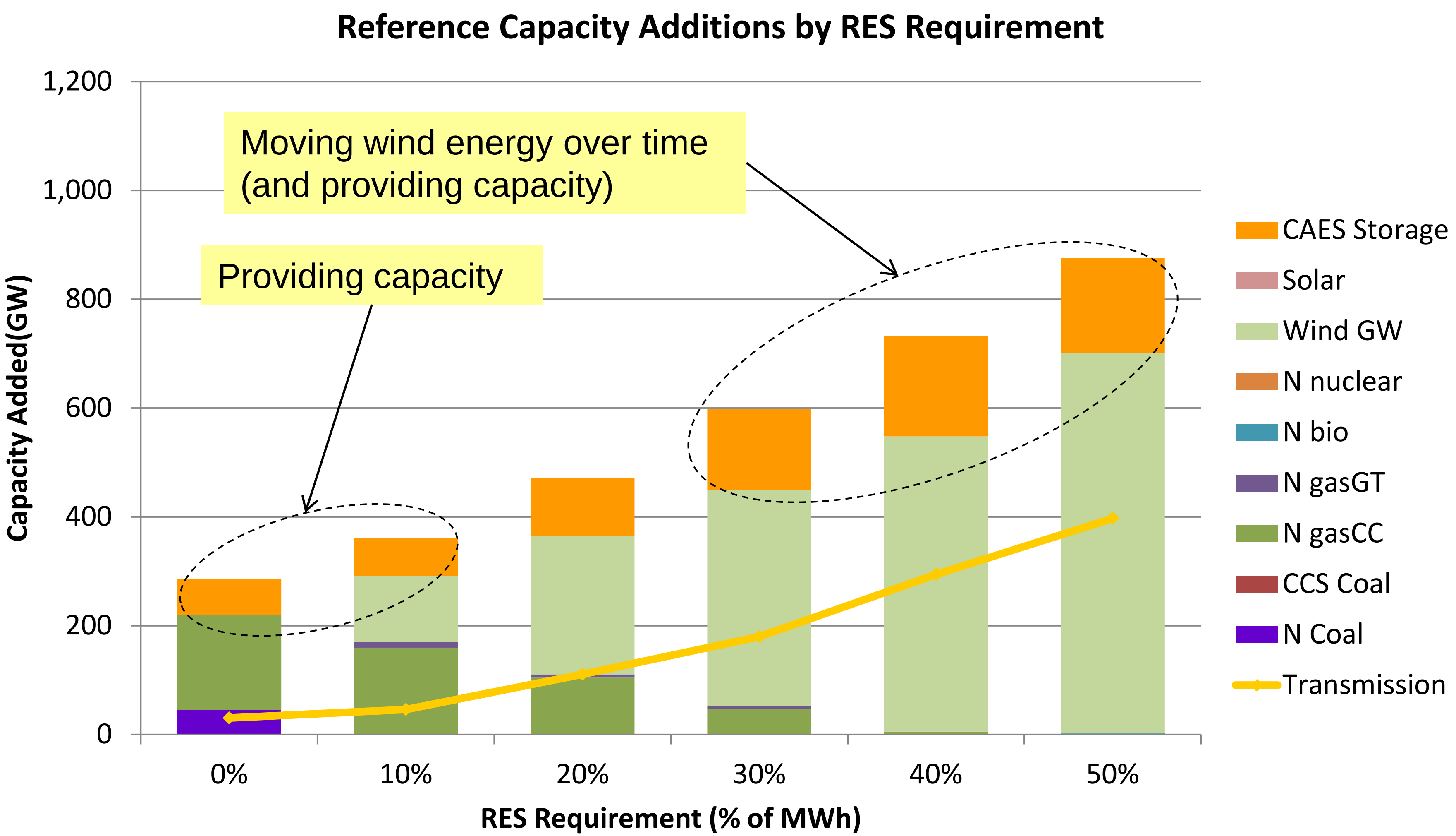


Robust Additions of CAES Storage Across Full Range of RES Requirements

Note relatively uniform penetration of CAES, with more at the high RES levels



Role for CAES Storage Changes



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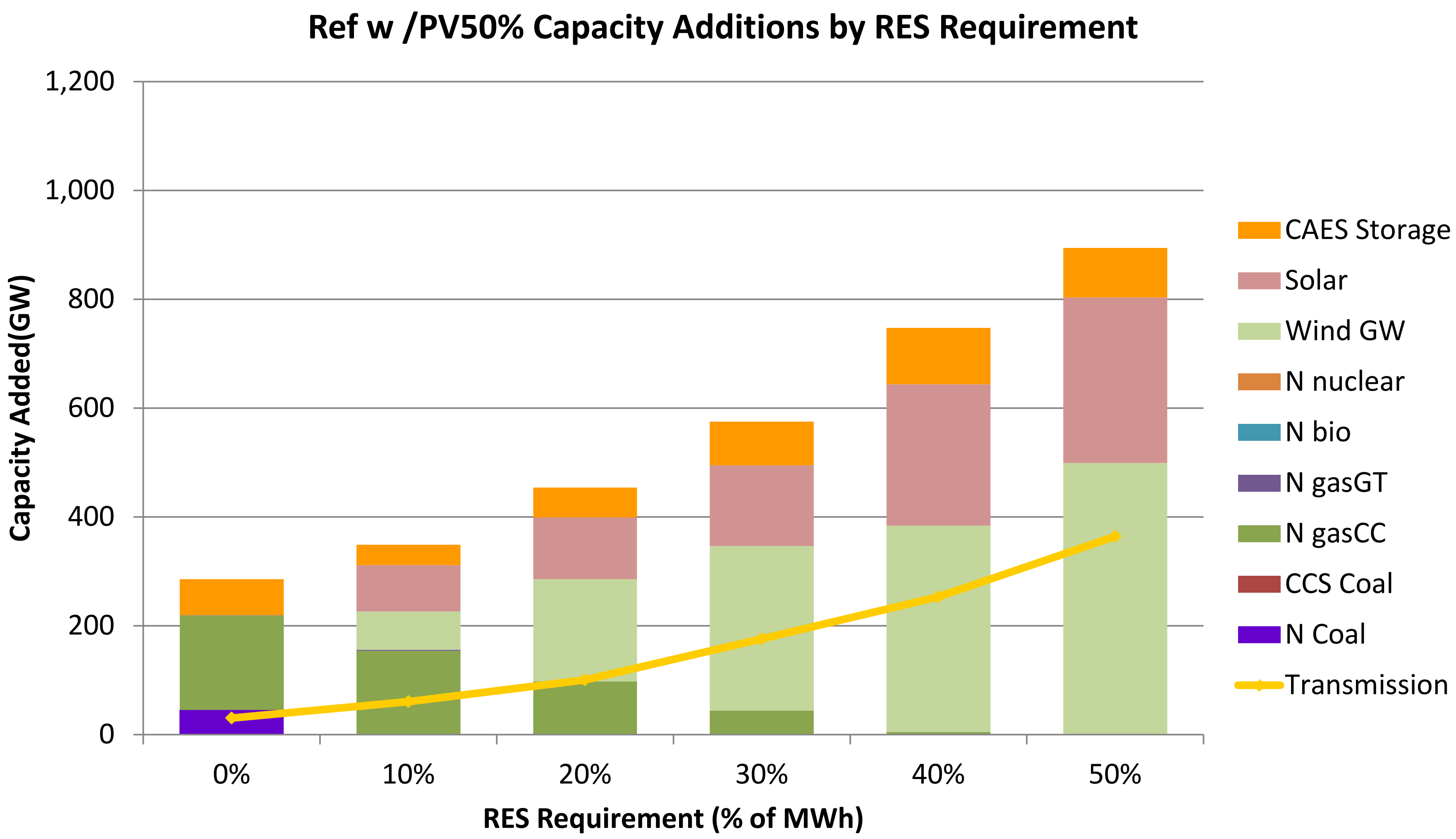
Sensitivity: Reference w 50% Cheaper Solar Shows More Solar, and Fewer CAES Additions



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Observations and Caveats

- Complexity of storage economics make assessment of its value a challenge, results here are preliminary
- Lower-bound analysis here leaves out operational value
- Absent scenarios forcing in large amounts of wind, strategic role for storage depends on its ability to compete with NGGTs in capacity market
- With large quantities of wind additions, storage competes with new transmission and solar (and bio)
  - Much greater value for storage if no new transmission,
  - …and if storage reservoirs are large
- (Much) lower cost solar displaces both storage and wind
- Everything competes with everything

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