

# Modeling High-Penetration Wind Scenarios: WinDS Model Results

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Walter Short, Nate Blair, Paul Denholm,  
Donna Heimiller

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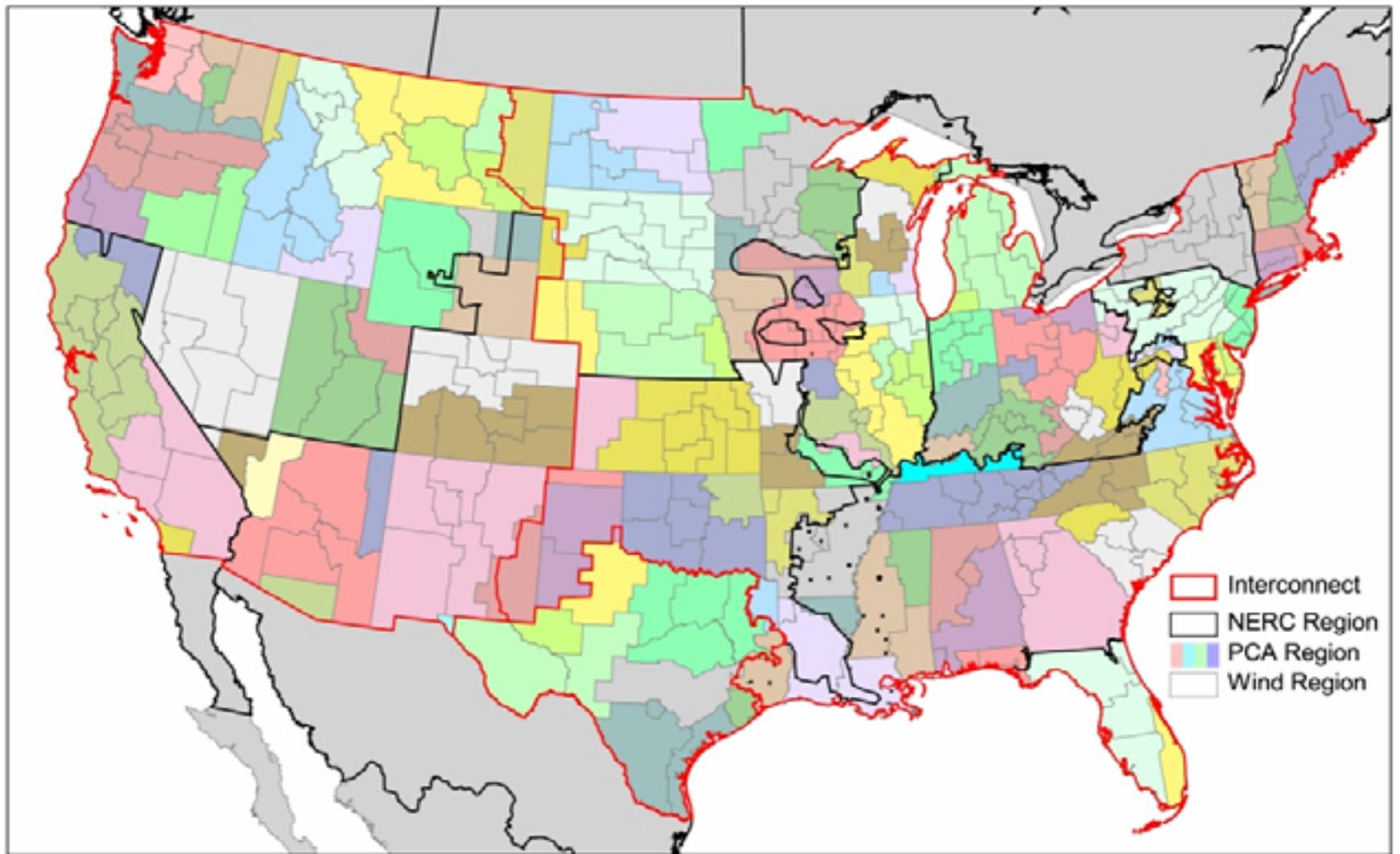
# WinDS Model

(Wind Deployment Systems Model)

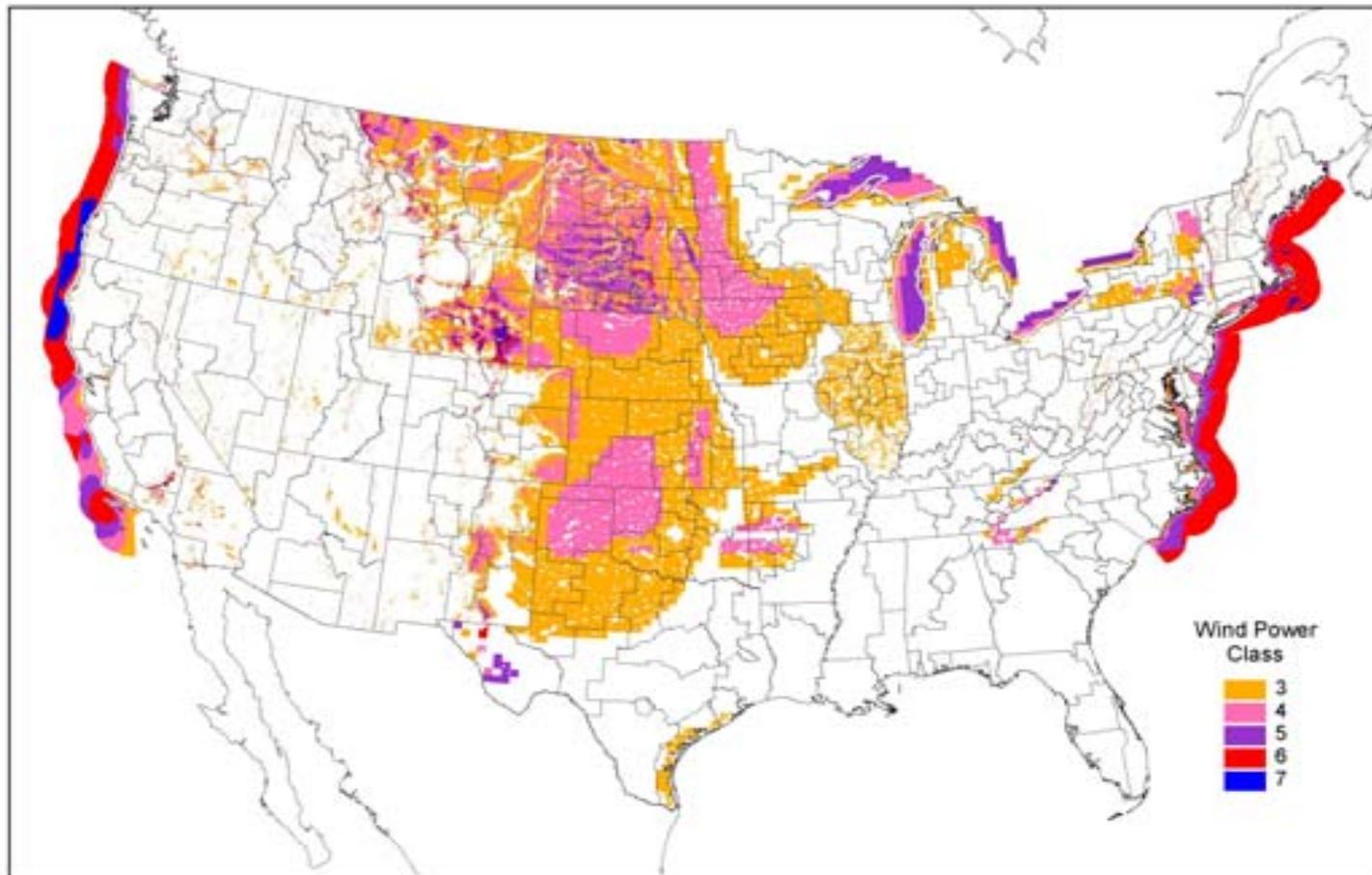
A multi-regional, multi-time-period model of capacity expansion in the electric sector of the U.S.

Designed to estimate market potential of wind energy in the U.S. for the next 20 – 50 years under different technology development and policy scenarios

# WinDS Regions



# Wind Resources in WinDS



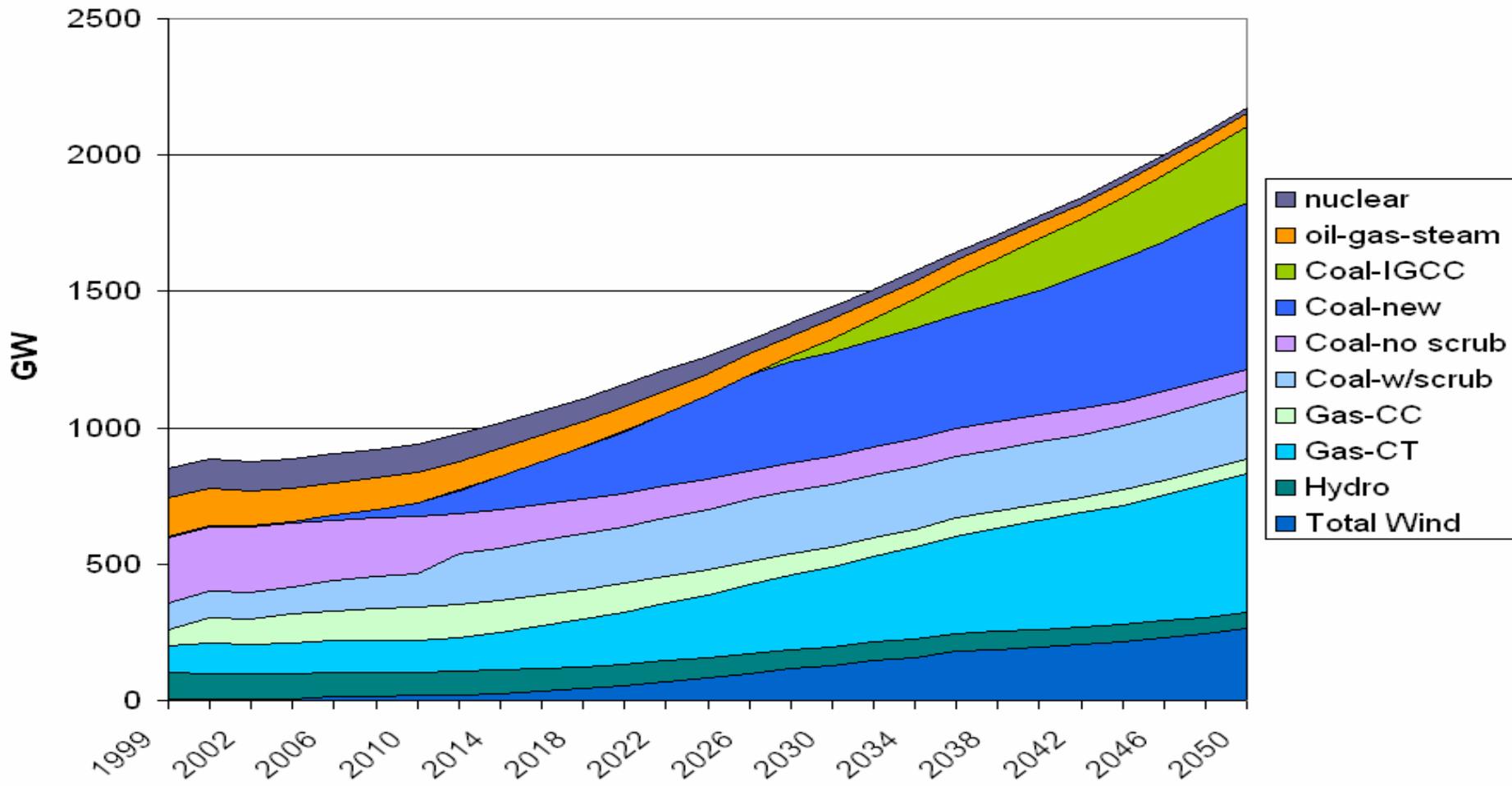
# WinDS is Designed to Address the Principal Market Issues for Wind

- Access to and cost of transmission
  - Class 4 close to the load or class 6 far away?
  - How much wind can be transmitted on existing lines?
  - Will wind penetrate the market if it must cover the cost of new transmission lines?
  - Will offshore wind close to seaboard loads penetrate?
- Resource Variability
  - How does wind capacity credit change with penetration?
  - How do ancillary service requirements increase with wind market penetration
  - How much would dispersal of wind sites help?
  - Is on-site storage cost effective?

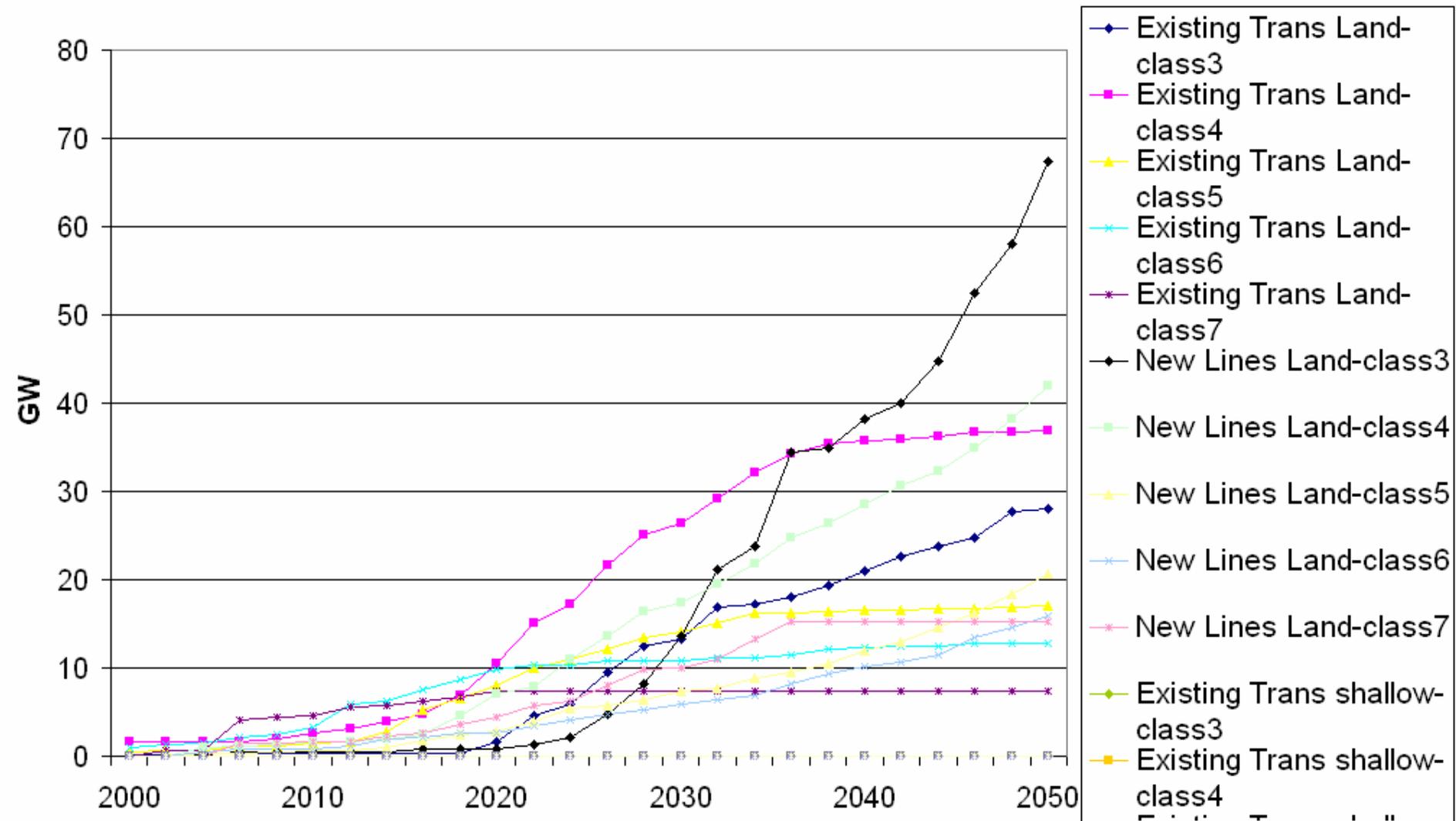
# General Characteristics of WinDS

- Linear program cost minimization for each of 26 two-year periods from 2000 to 2050
- Sixteen time slices in each year: 4 daily and 4 seasons
- 4 levels of regions – wind supply/demand, power control areas, NERC areas, Interconnection areas
- Existing and new transmission lines
- 5 wind classes (3-7), onshore and offshore shallow and deep
- All major power technologies – hydro, gas CT, gas CC, 4 coal technologies, nuclear, gas/oil steam
- State-level incentives and RPS
- Stochastic treatment of wind resource variability – planning reserves, operating reserves, surplus wind

# Base Case Electricity Capacity

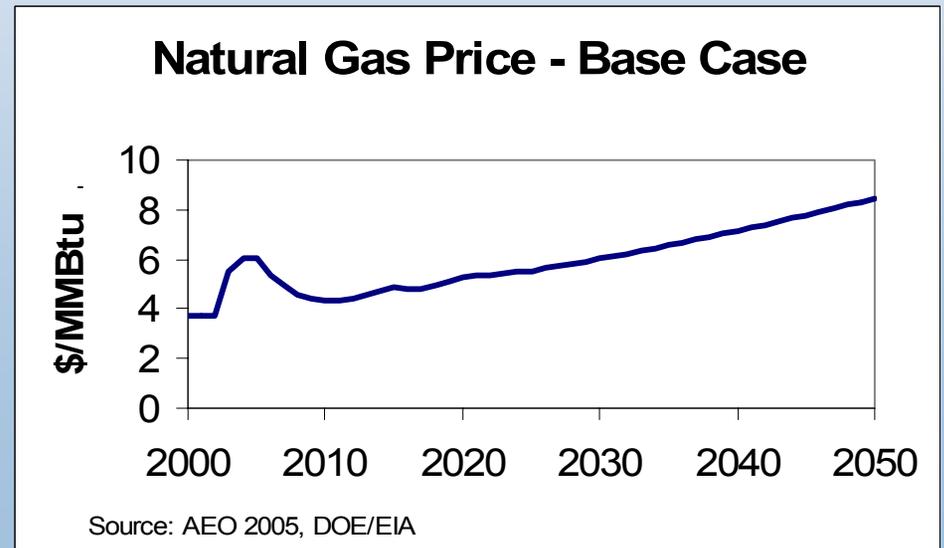
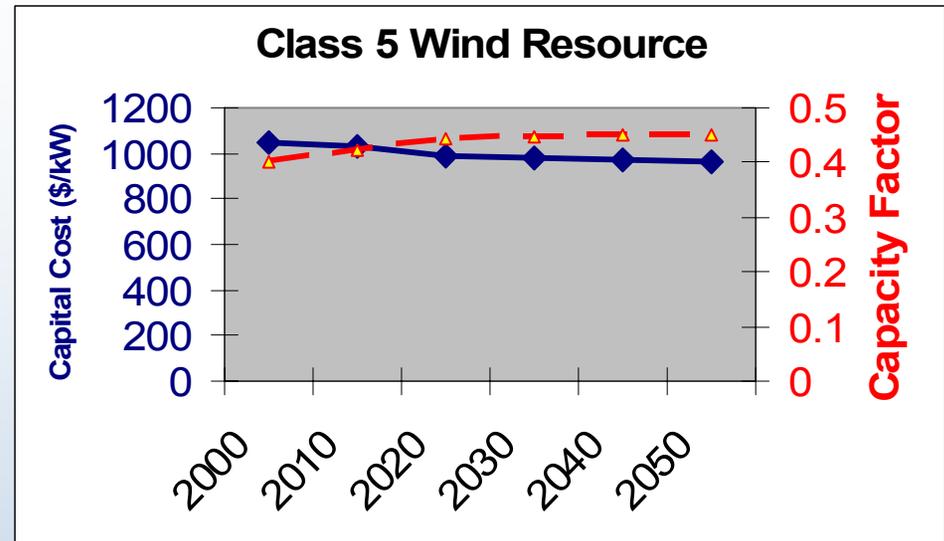


# Base Case Capacity by Wind Class



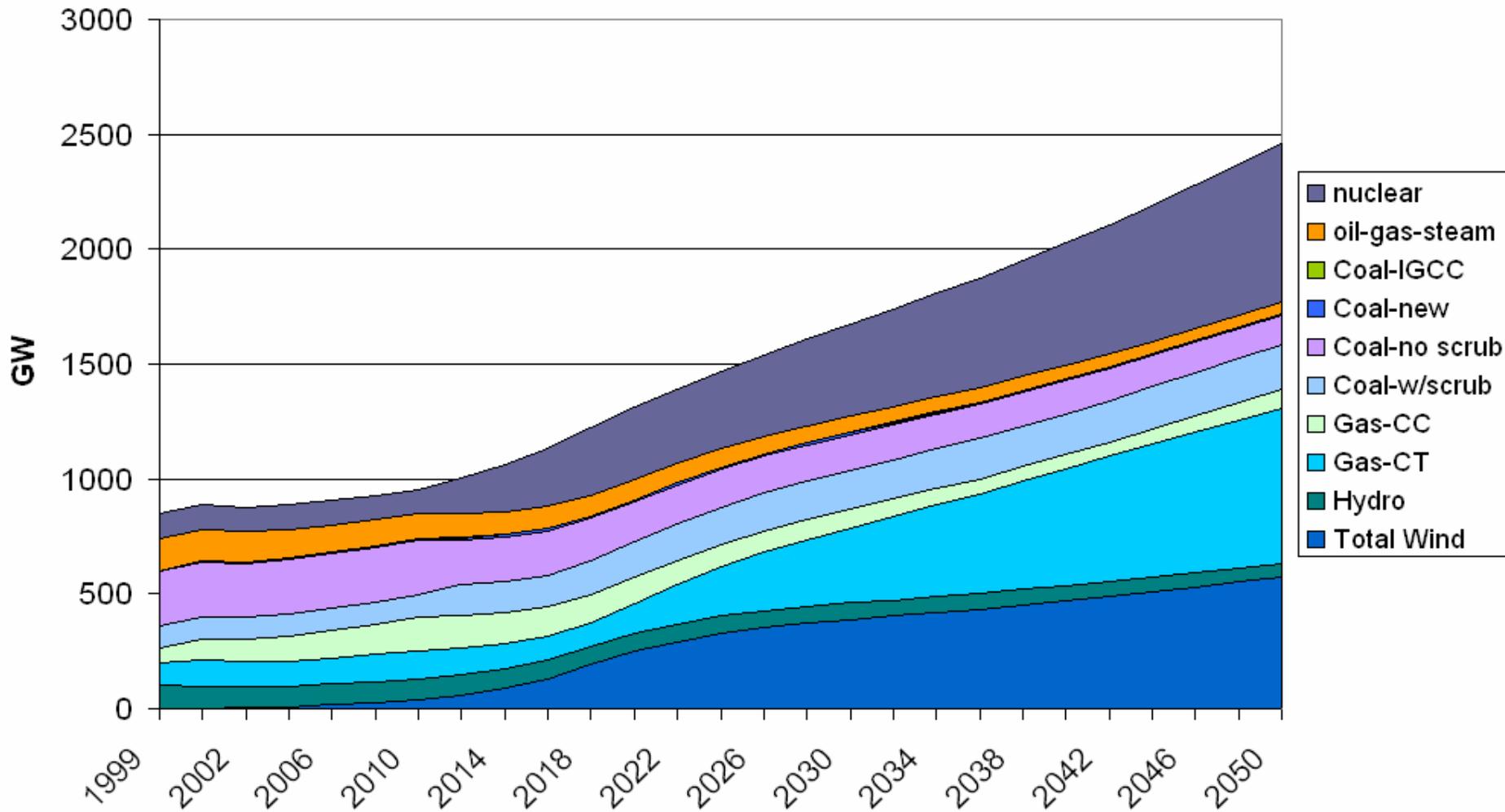
# Base Case Key Inputs

- Wind R&D-driven Cost/Performance improvements
- 8% wind learning rate
- 1.9 cent/kWh PTC through 2007
- No carbon caps/tax
- Gas prices

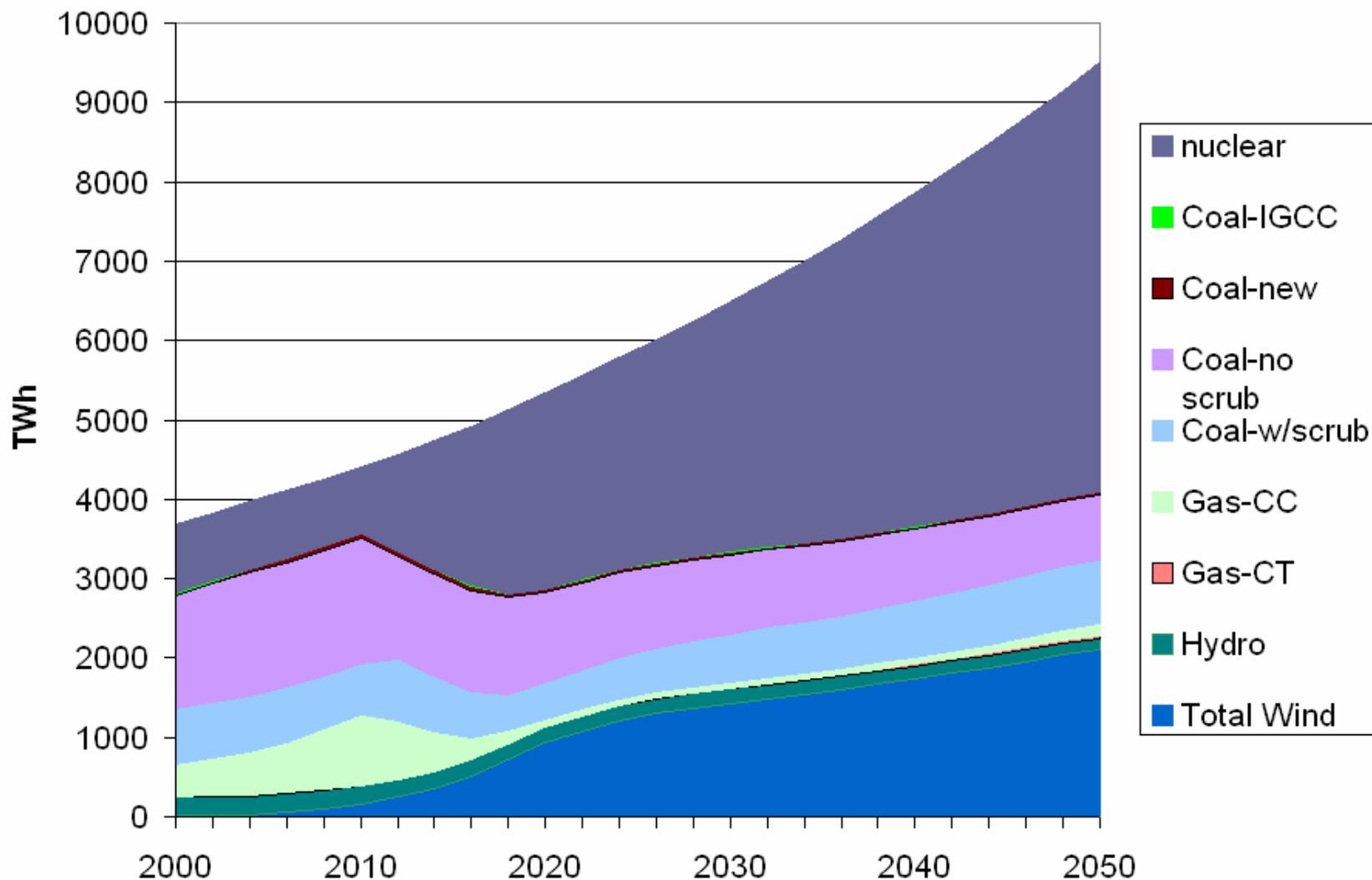


Source: AEO 2005, DOE/EIA

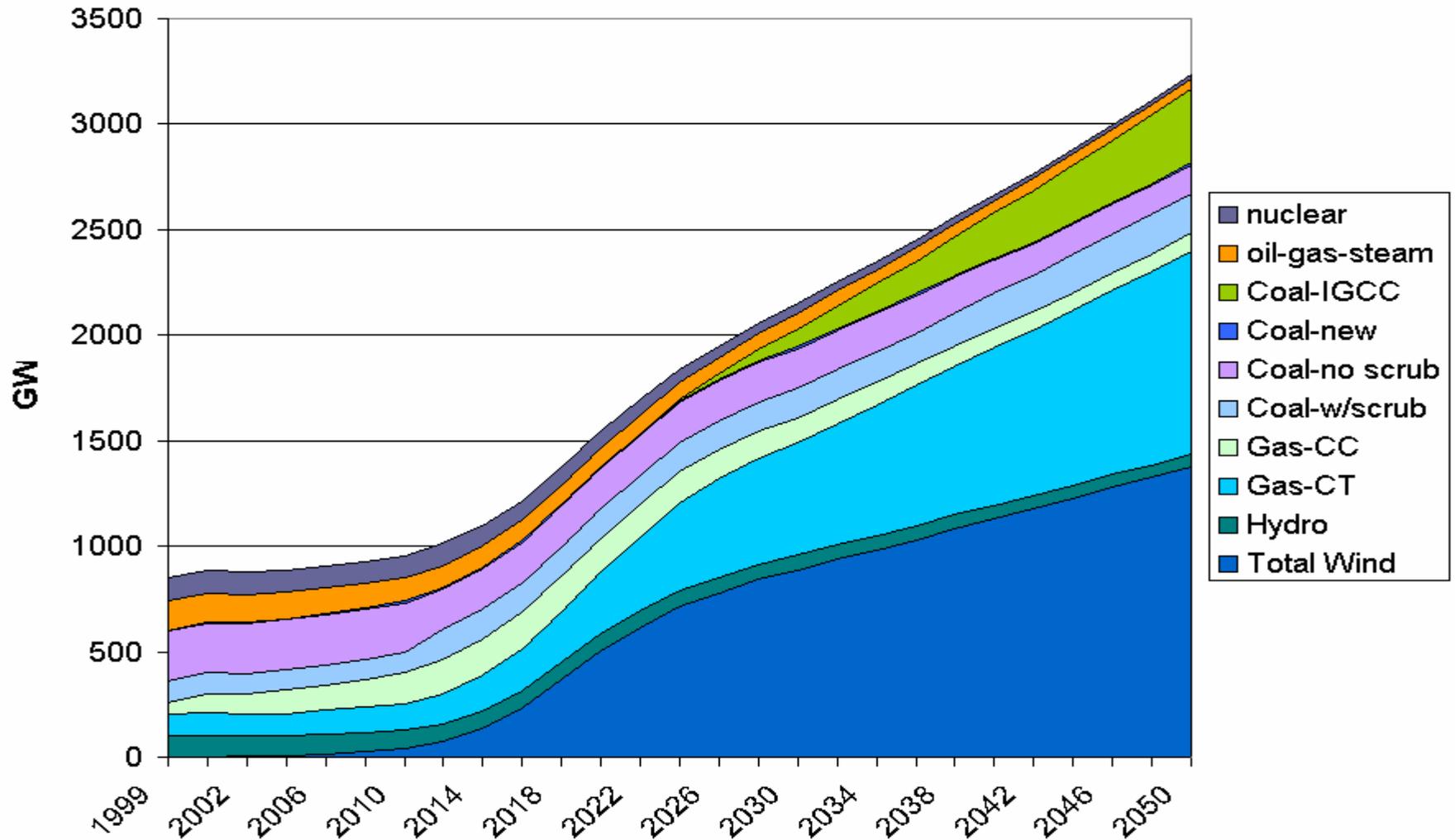
# \$100/ton Carbon Case - Capacity



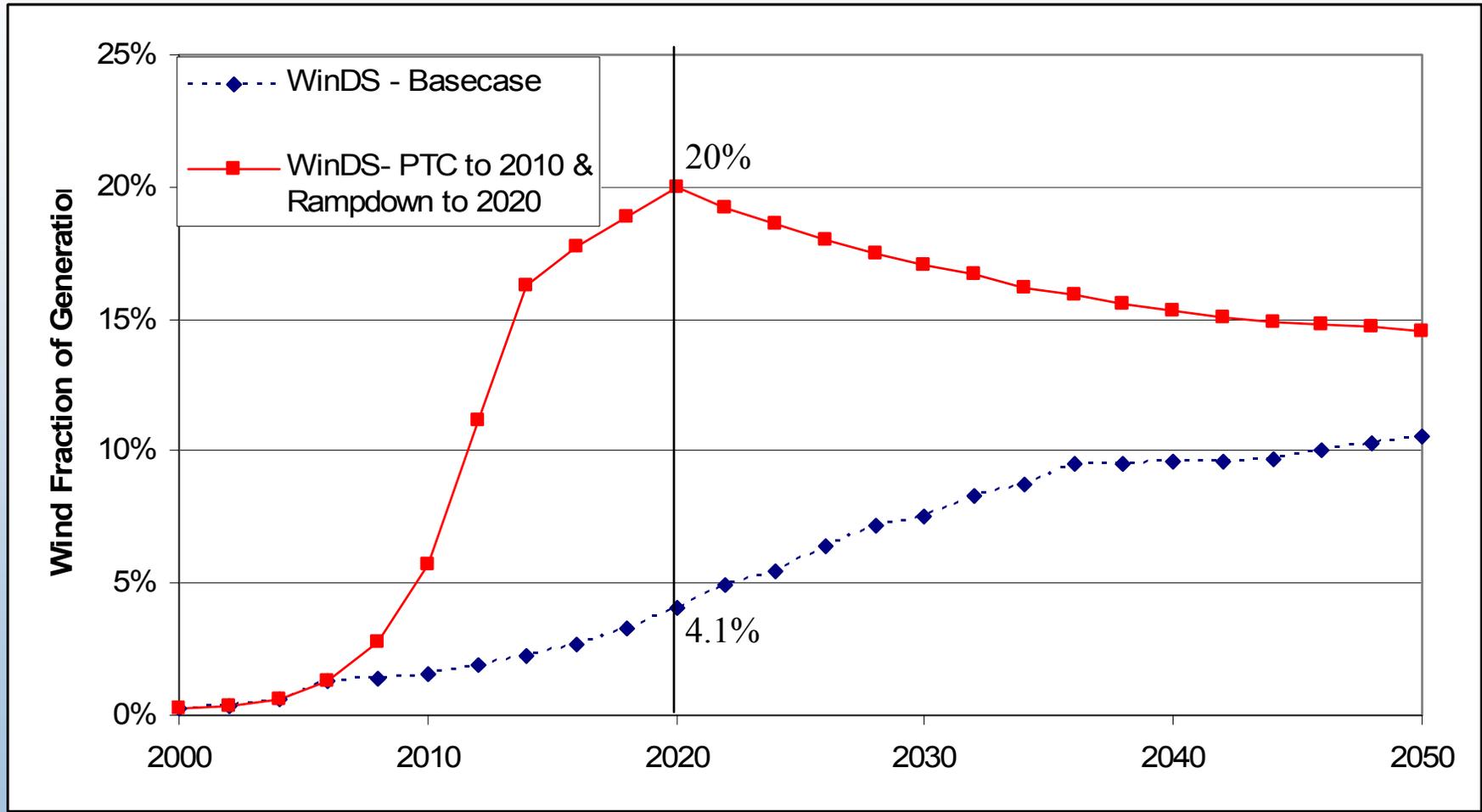
# \$100/ton Carbon Case - Generation



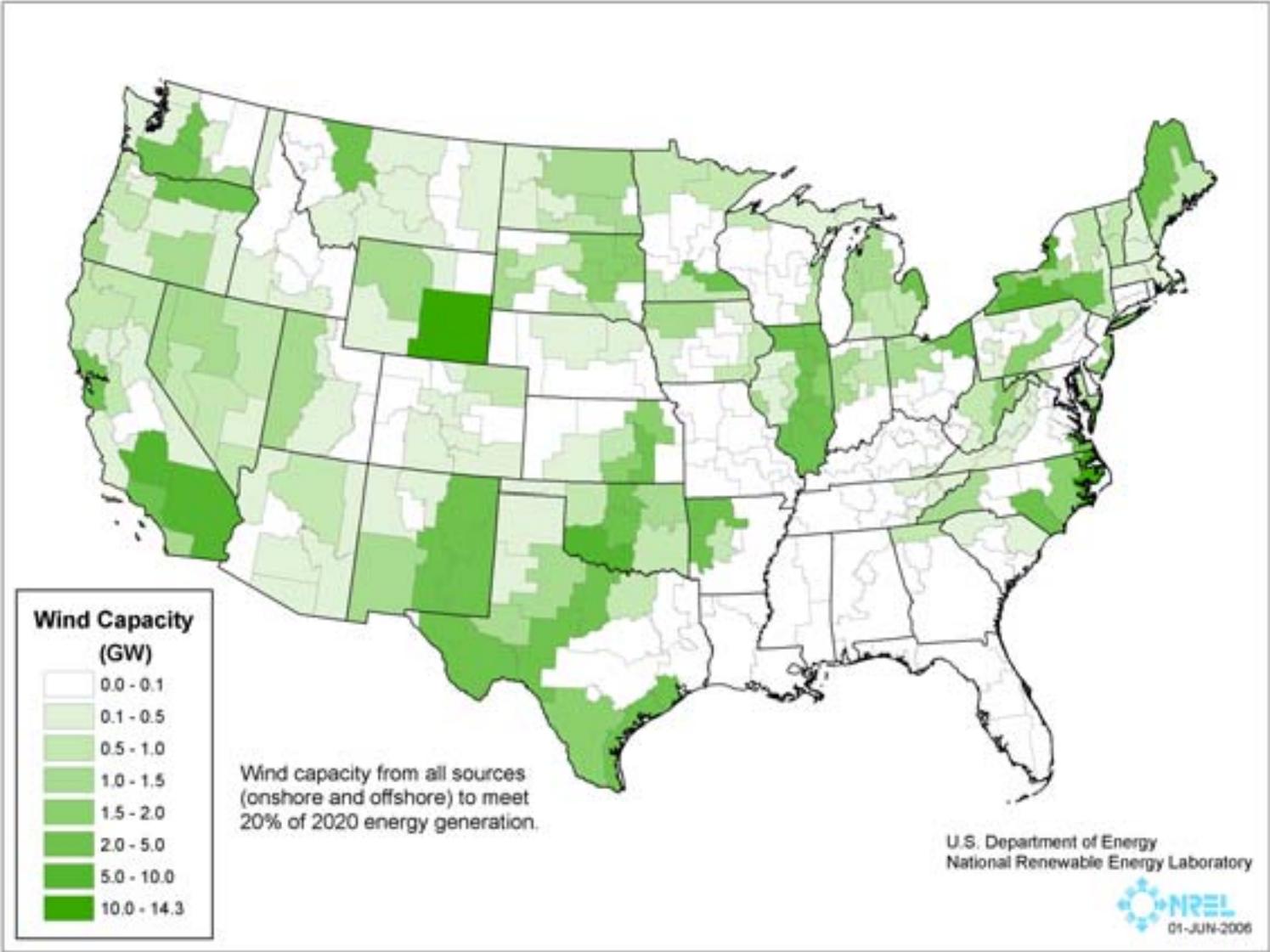
# \$100/ton Carbon – No New Nukes Capacity



# A PTC Extension to 2020 Could Result in 20% of Generation from Wind by 2020

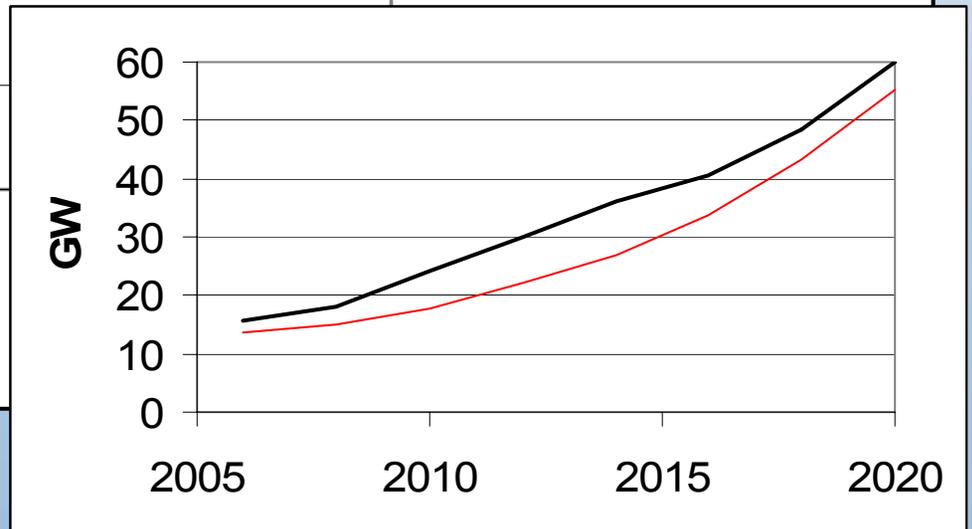
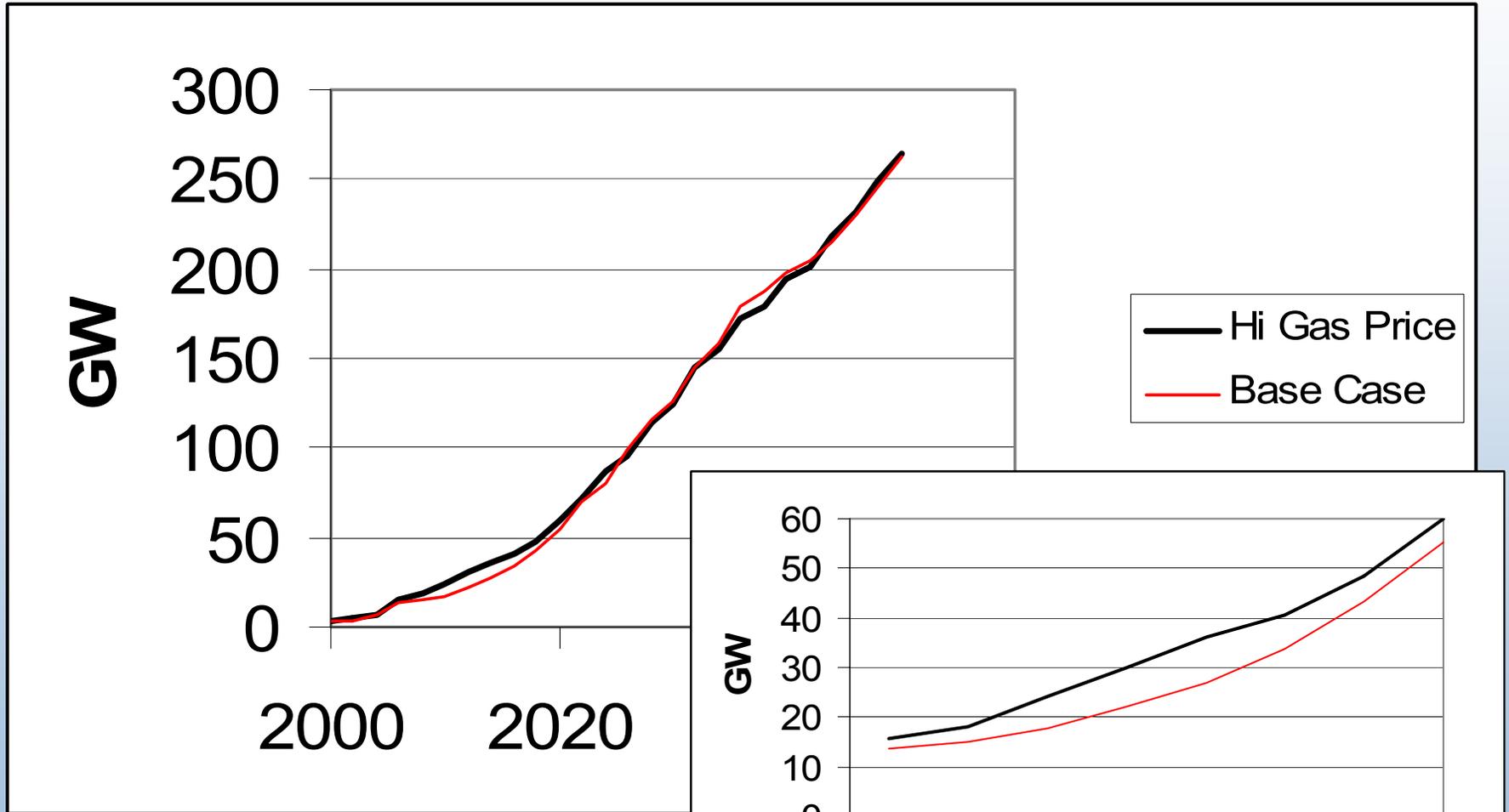


# Regional Wind Installations by 2020 with PTC\*



\* PTC to 2010 with ramp down by 2020

# High Gas Prices Do Not Increase Wind Penetration in the Long Term



# New Website (documentation and results) at: <http://www.nrel.gov/analysis/winds>

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## Energy Analysis

### Wind Deployment Systems (WinDS) Model

- WinDS Home
- Background of Model
  - Qualitative Model Description
    - Linear program formulation
    - Qualitative Details on Wind Intermittency
    - Qualitative Details on Transmission
  - Detailed Model Description
  - Model Data
  - Model Results
    - WinDS Reduced-Form Supply Curves
    - WinDS Publications

### Background of Model

#### Qualitative model description

WinDS minimizes systemwide costs of meeting electric loads, reserve requirements, and emission constraints by building and operating new generators and transmission in 26 two-year periods from 2000 to 2050. The primary outputs of WinDS are the amount of capacity and generation of each type of prime mover—coal, gas combined cycle, gas combustion turbine, nuclear, wind, etc.—in each year of each 2-year period. **Figure 1** shows an example of WinDS capacity estimates for the United States for different generation technologies over the next 50 years.

This section also includes information on the [linear program formulation](#), [qualitative details on transmission](#), and [qualitative details on wind intermittency](#).

While WinDS includes all major generator types, it was designed primarily to address the market issues of greatest significance to wind—transmission and intermittency. The WinDS model examines these issues primarily by using a much higher level of geographic disaggregation than other models. As **Figure 2** represents, WinDS uses 358 different regions in the continental United States. These 358 wind supply regions are then grouped into three levels of large regional groupings—the power control areas (PCAs), North American Electric Reliability Council (NERC) regions, and national interconnect regions. The WinDS regions were selected using the following rules and criteria:

- Build up from counties (so that electric load can be determined for each wind supply/demand region based on county population).
- Do not cross state boundaries (so that state-level policies can be modeled).
- Conform to PCAs as much as possible (to better capture the competition between wind and other generators).
- Separate major windy areas from load centers (so that the distance from a wind resource to a load center can be well approximated).
- Conform to NERC region/subregion boundaries (so that the results are appropriate for use by integrating models that use the NERC regions/subregions).
- Conform to the three major interconnects within the U.S. grid system (to limit capacity and energy transmission exchanges between the interconnects).

Much of the data inputs to WinDS are tied to these regions and derived from a detailed GIS model/database of the wind resource, transmission grid, and existing plant data. The geographic disaggregation of wind resources allows WinDS to calculate transmission distances, as well as the benefits of dispersed wind farms supplying power to a demand region.

As shown in **Figure 3**, WinDS disaggregates the wind resource into five classes ranging from Class 3 (5.4 meters/second at 10 meters above ground) to Class 7 (>7.0 m/s). WinDS also includes offshore wind resources and distinguishes between shallow and deep offshore wind turbines. Shallow-water turbines are

Figure 1. Base Case WinDS Capacity Estimates

Figure 2. Regions Within WinDS

# Backup slides follow

# Wind Capacity in the National Energy Modeling System (U.S. DOE Energy Information Administration)

- 13 large electric regions
- No new transmission
- No cost or limits on use of transmission within regions
- Wind considered a mature technology (1% learning rate on capital costs and capacity factors)
- Eliminates 91% of U.S. wind resource base
- Wind capacity factor < 20%
- Can't accurately capture wind correlation within NERC regions

