

# Impact of wind generation on CO<sub>2</sub> emissions in NYS

Thomas Bourgeois

Pace Energy and Climate Center

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# Important assumptions

- Types of electricity generation being displaced by wind
  - Does wind displace hydroelectric, natural gas, oil, nuclear, coal?
- Capacity factor
  - What is wind's capacity factor in NYS?
- Impact on spinning reserves
  - Do intermittent generation sources require additional spinning reserves, offsetting CO<sub>2</sub> emissions savings?
- Boundary assumptions in life cycle analyses

# Generation Displacement: Unit Commitment

- NYISO adjusts unit commitment based on current wind generation and day-ahead forecast.
- Available wind energy is used before other types of energy generation.
- However, load following may be conducted by inefficient units. (Load following power plants continually adjust their power output to meet fluctuating demand.)

# Fuel Displacement\*

- Most relevant modeling scenario assumptions:
  - Wind is accurately forecast one day ahead.
  - Wind is scheduled before hydropower; thermal units are scheduled after hydropower.
- Fossil fuel displacement under this scenario:
  - 65% from natural gas
  - 15% from coal
  - 10% from oil
  - 10% from electricity imports

\* Source: GE study commissioned by NYSERDA (2005)

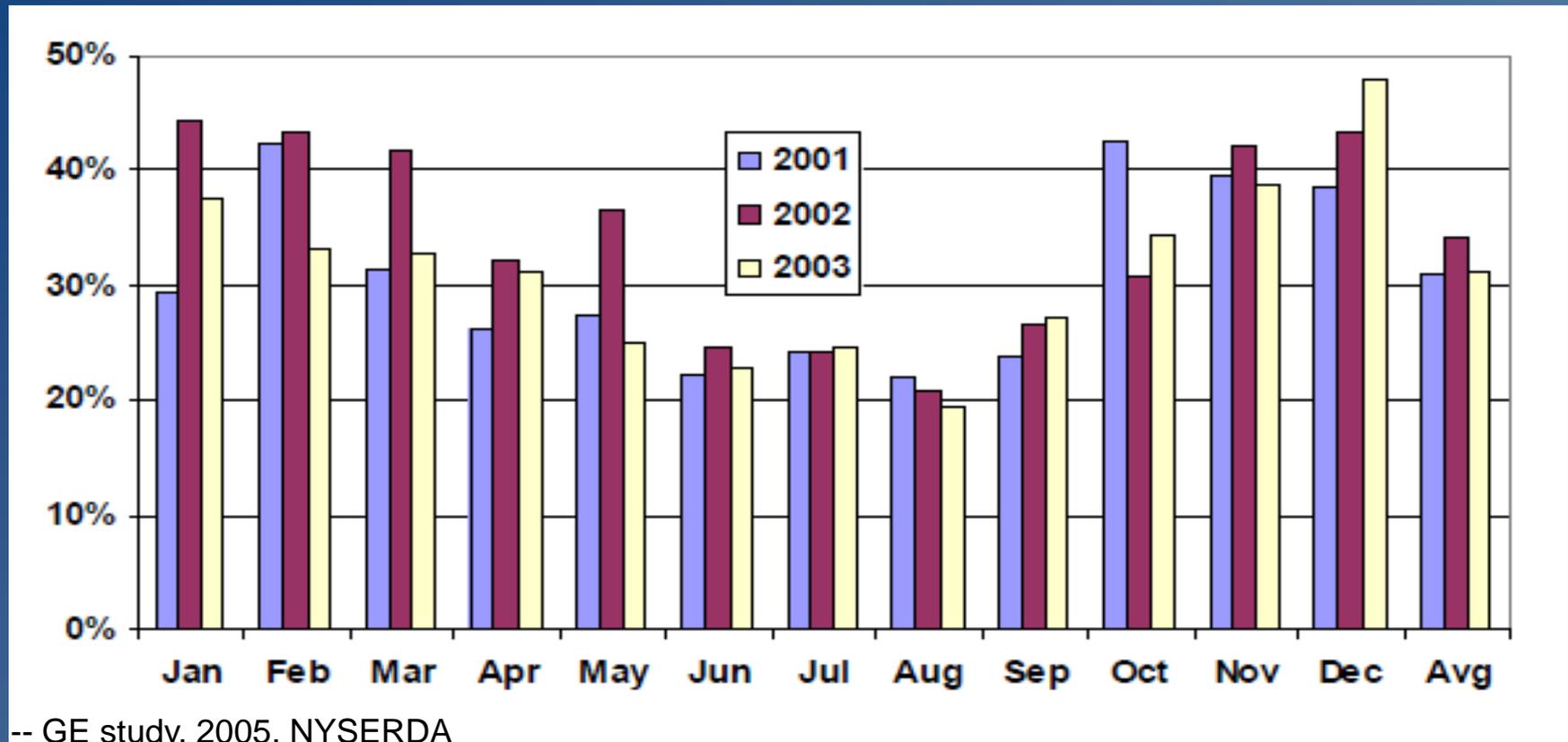


# Capacity Factor

- Nameplate capacity: Maximum amount of energy a turbine can generate.
- Capacity factor: Percentage of nameplate capacity that wind turbines actually produce, due to wind variability.
  - NYS average capacity factor for installed wind is 20% - 25%.
  - NYS modeled average capacity factor for 3,300 MW future installed wind capacity is 30%.\*

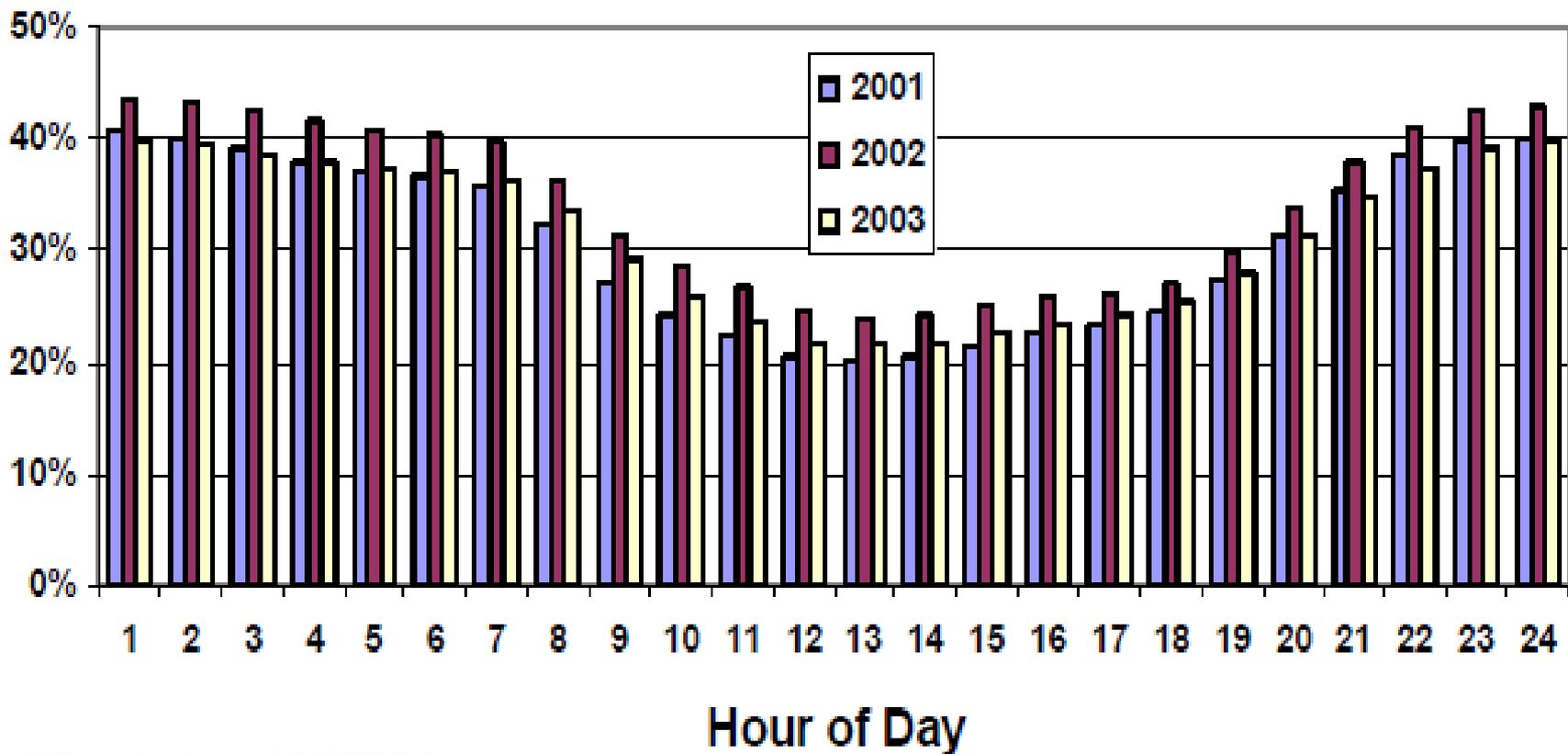
\* GE study, 2005, NYSERDA

# Projected average monthly capacity factor for NYS, given 3,300 MW wind build-out:



Projection based on actual NYS wind data from the years 2001 through 2003. The annual average capacity factor was roughly 30%.

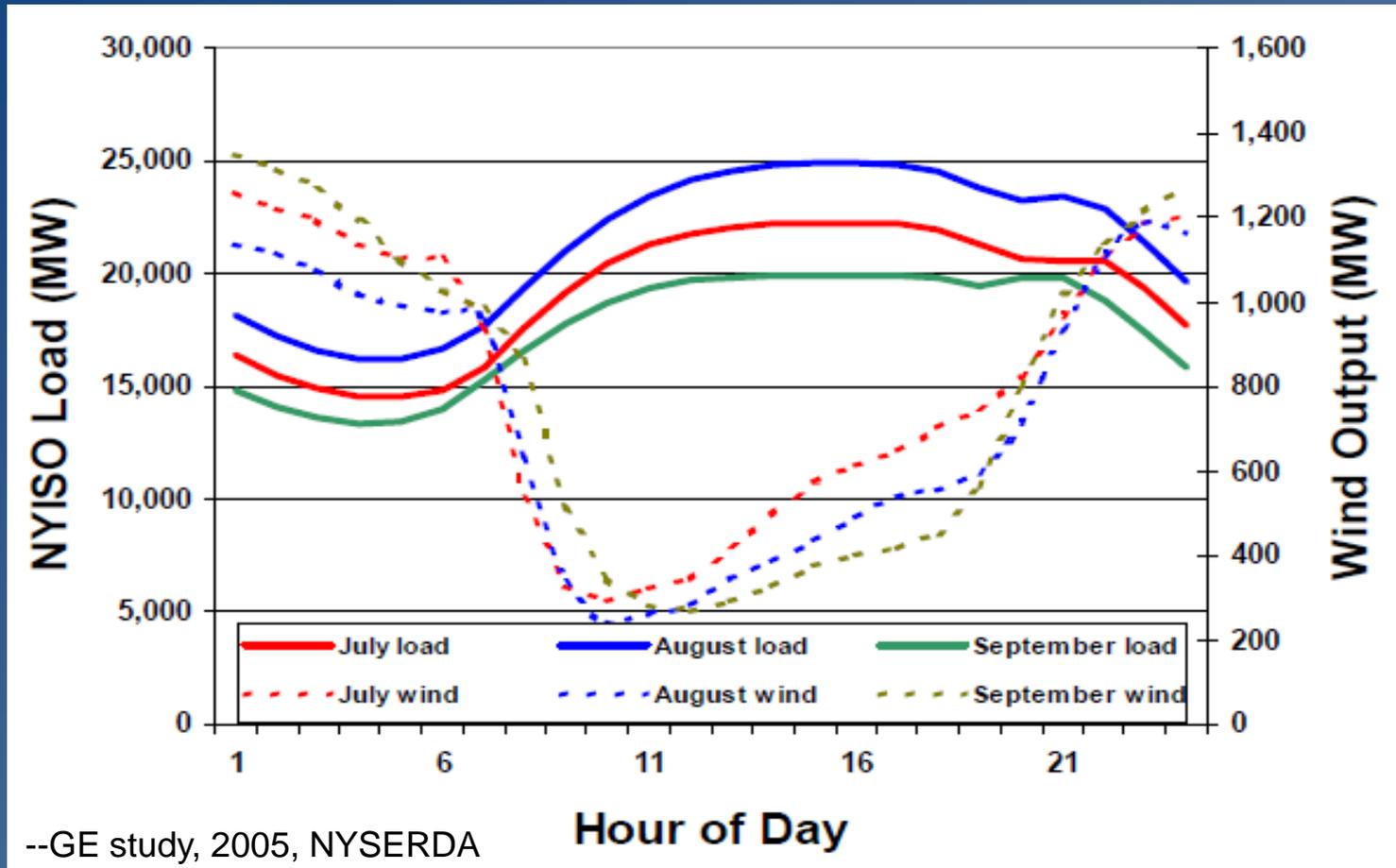
# Projected average hourly capacity factor for NYS, given 3,300 MW wind build-out:



--GE study, 2005, NYSERDA

Peak demand periods are when the most polluting thermal plants are typically used.

# Wind is out of sync with peak demand



Seasonally: wind generation peaks during the winter months, while electricity demand peaks in the summer.

Hourly: wind generation peaks at night when electricity demand is lowest.

# Spinning Reserves

- Minnesota wind integration study (2006)
  - No need for increased spinning reserves at wind penetration levels of 15%, 20%, and 25%.\*
- New York wind integration study
  - NYSERDA report (GE, 2005) states that no increase to spinning reserves is needed, assuming 10% effective wind penetration or 3,300 MW generation capability.

\* Minnesota study results may not be entirely transferable to New York, due to possible differences in the MN and NYS grid operating systems

# Life Cycle Analysis (LCA)

- An evaluation of impacts caused by the entire life cycle of the generation technology and fuel, from “cradle to grave.”
- General assessment criteria:
  - Energy inputs and pollution outputs of resource extraction, manufacturing process, transportation of material, operation and maintenance, and disposal.

# Wind Energy LCA Comparison

## Results from wind energy LCAs:

Study Source	Size of Wind Turbine	Capacity Factor	Energy Payback	Life Cycle GHG emissions
Italy (2006)	660 kW	19%	< 1 year*	19.4-40.8 lbs CO <sub>2</sub> eq/MWh
France (2009)	4.5 MW	N/A	0.58 years*	34.8 lbs CO <sub>2</sub> eq/MWh
Midwest USA (1998)	324-750 kW	24-35%	17:1 - 39:1**	19.6 – 44.5 lbs CO <sub>2</sub> eq/MWh

\*Energy payback period: Amount of time it would take for wind turbine energy production to offset energy consumed during entire life cycle.

\*\*Energy payback ratio: Amount of energy produced per energy consumed during entire life cycle.

# Wind vs. other generation sources

Results of a wind LCA conducted by Energy Center of Wisconsin:

Generation Source	Energy Payback Ratio	Life Cycle GHG emissions
Natural Gas	4:1	1022.7 lbs CO <sub>2</sub> eq/MWh
Coal	11:1	2146.7 lbs CO <sub>2</sub> eq/MWh
Nuclear Fission	16:1	33.06 lbs CO <sub>2</sub> eq/MWh
Wind	23:1	30.86 lbs CO <sub>2</sub> eq/MWh

Source: Meier, P. J., and G. L. Kulcinski. *Life-Cycle Energy Cost and Greenhouse Gas Emissions for Gas Turbine Power*. Madison: Energy Center of Wisconsin, 2000.



# Wind vs. other renewable energy sources

## New Study: “Electricity From Renewable Resources: Status, Prospects and Impediments”

Generation Source	Life Cycle GHG Emissions
Geothermal	33.06 lbs CO <sub>2</sub> eq/MWh
Biopower from cultivated feedstocks	33.06 to 114.6 lbs CO <sub>2</sub> eq/MWh
Solar PV	46.28 to 156.5 lbs CO <sub>2</sub> eq/MWh
Wind	4.4 to 63.9 lbs CO <sub>2</sub> eq/MWh

- 2009 analysis of multiple LCAs
- Author: National Academy of Sciences, National Academy of Engineering, and National Resources Council
- LCAs studied used wind capacity factors of 20% - 40%.
- 2002 NYS average CO<sub>2</sub> emissions: 860 lbs CO<sub>2</sub>/MWh

# Thank You

**Thomas Bourgeois**

Pace Energy and Climate Center

914-422-4013

[tbourgeois@law.pace.edu](mailto:tbourgeois@law.pace.edu)



# Definition of Terms

- **Spinning Reserves:** Energy generators that are idling in a ready state in case a energy source abruptly quits generating electricity.
- **Load Following Plants:** Power plants that continually adjust their power output to meet demand.
- **Unit Commitment:** Day-ahead scheduling of electric generating units.