Advancing Wind Power in Illinois Conference 2011

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Hot Topics Plenary Panel Session
System-Wide Emissions Implications of Increased Wind Penetration

Friday, July 22, 2011, 3:00 PM

System-Wide Emissions Implications of Increased Wind Penetration

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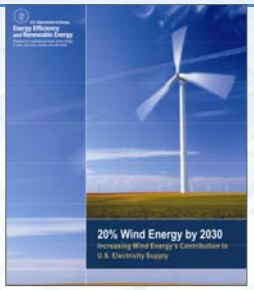
Motivation

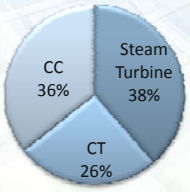
- DOE's Wind and Water Power Program
- 20% Wind Energy by 2030: Increasing Wind Energy's Contribution to U.S. Electricity Supply
  - 7,600 million metric tons of CO_2 emissions would be avoided by 2030
  - 15,000 million metric tons of CO_2 emissions would be avoided through 2050
- Some argue that increased wind generation may not decrease emissions due to higher fossil plant emissions caused by increased cycling
  - Startup and shutdown events
  - Varying the output within the load range
- Wind integration studies are criticized for not accounting for these cycling effects.
- We incorporate cycling events into an analysis on emissions from an electric power system with increased wind penetration.



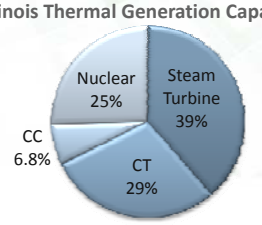
Methodology

- Unit commitment
  - Minimize total operating cost (including startup costs)
  - Fixed at the day-ahead stage
  - Incorporates a wind forecast (deterministic or stochastic)
- Economic dispatch
  - Minimizes operating cost for committed units for the actual wind generation
- Emissions model
  - Operational periods (includes cycling effects)
  - Startup periods
- Data
  - Load, generator, and the wind series data from 2006
  - Simple 10 unit power system
    - 23 simulation scenarios for 91 days
      - Wind penetration levels
      - Forecast uncertainty
      - Operating reserve levels
  - Illinois power system
    - 209 thermal units + 1 hydro unit

10 unit Thermal Generation Capacity



Illinois Thermal Generation Capacity



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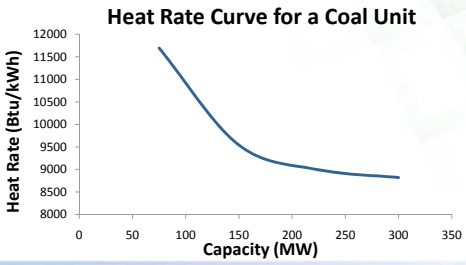
Emissions Model- Operational Periods

- Cycling: operating at less than designed output decreases efficiency
- Heat rate curves account for the cycling effect
  - As power generation decreases, the heat rate increases resulting in the same amount of fuel producing less power due to cycling
- EPA AP-42 emission factors convert fuel use to emissions
- Account for various firing and control technologies



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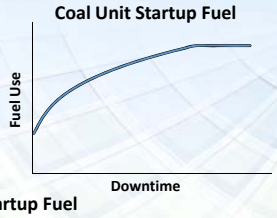
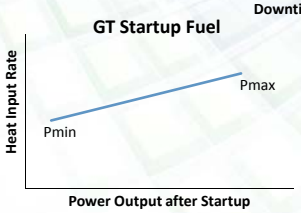
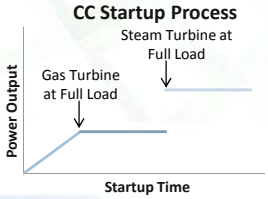
Emissions Model- Startup Periods

- NO_x and CO emitted at higher rates during startups
- Coal
  - Fuel used to bring the unit online depends on how long the unit has been offline (hot and cold starts)
- Natural Gas Combustion Turbines
  - Average startup time is approx. 20 minutes
  - Startup fuel depends (linearly) on the power to which the unit is ramped up
  - 34 lb of NO_x and 56 lb of CO per startup
- Natural Gas Combined Cycle
  - Assume 1 GT:1 ST and unit always starts up to rated capacity of the GT
  - NO_x and CO emissions increase linearly with startup time







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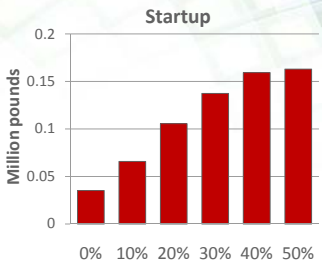
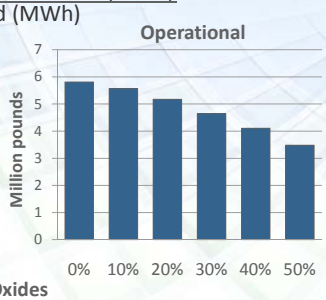
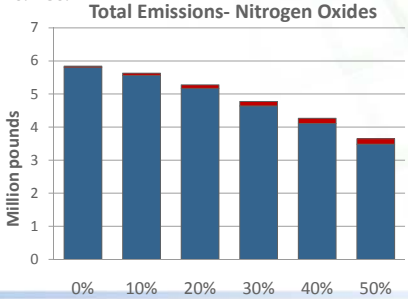
Emissions Results- 10 unit model

- Wind Energy Penetration = $\frac{\text{Total Amount of Wind Energy Produced (MWh)}}{\text{Total Electricity Demand (MWh)}}$







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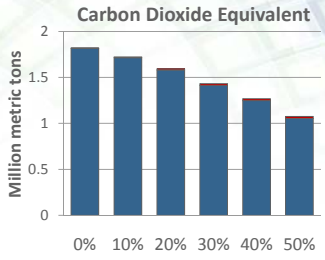
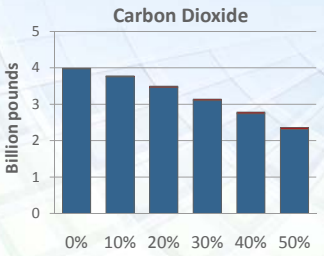
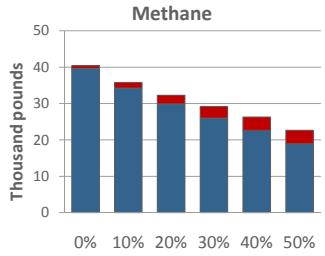
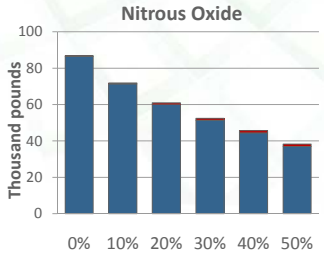
Emission Results for Wind Penetration Levels- 10 unit model



Reduction with 20% Wind	
CO_2e	12%
CO_2	12%
N_2O	30%
CH_4	20%
NO_x	10%

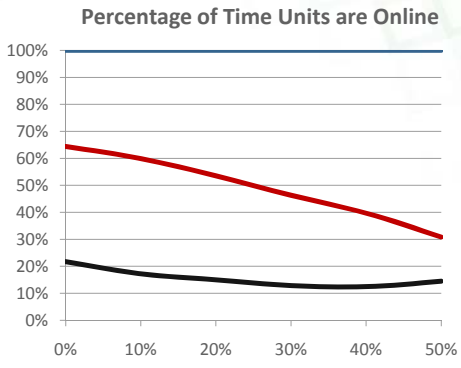


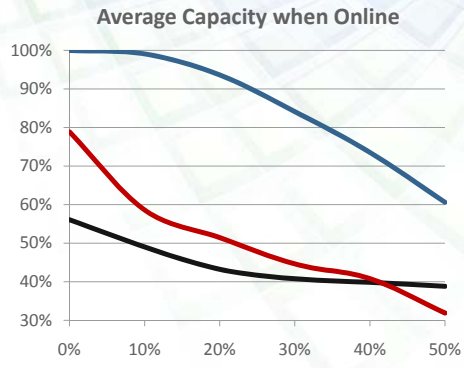




Dispatch Results- 10 unit model

- Combined cycle and gas turbine units operate less frequently with increased wind
- Units operate at lower efficiencies when wind penetration is increased





Steam Turbine Combustion Turbine Combined Cycle

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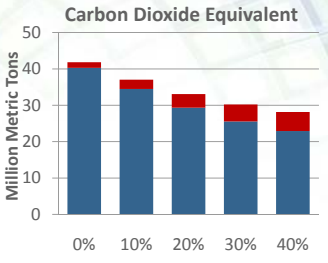
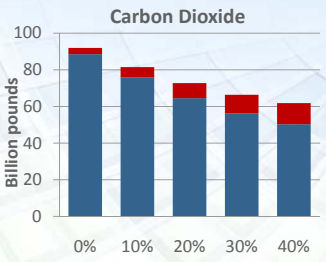
Conclusions from 10 unit model

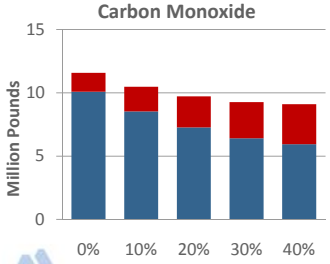
- Emissions decrease with increasing wind penetration
  - CO_2e, CO_2, CH_4, N_2O, PM, NO_x, SO_x
  - Cycling effects are much smaller than the reduction in emissions due to displacement of fossil-fired generation
- CO emissions increase with increasing wind
  - Increase in the number of startups with increasing wind
- Changing forecast uncertainty did not significantly affect results (stochastic vs. deterministic)
- Using a perfect forecast did not affect the results significantly
- Changing the reserve level from 40% to 0% did not affect results significantly

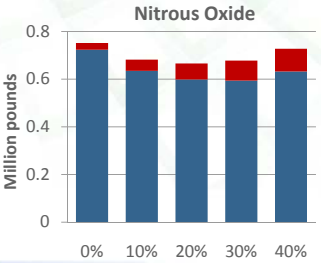
Preliminary Illinois Emission Results





Reduction with 20% Wind	
CO_2e	21%
CO_2	21%
N_2O	11%
CH_4	17%





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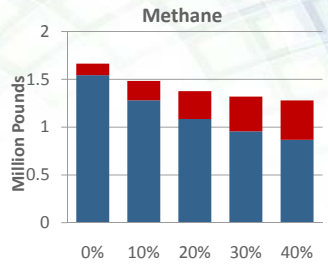
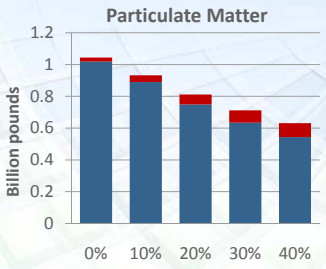
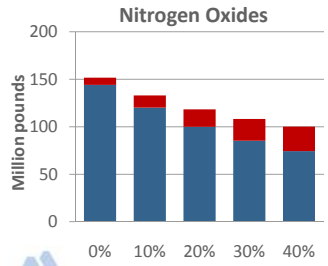
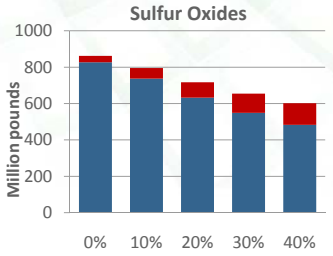


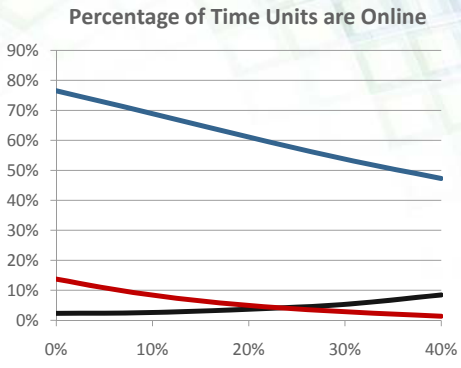


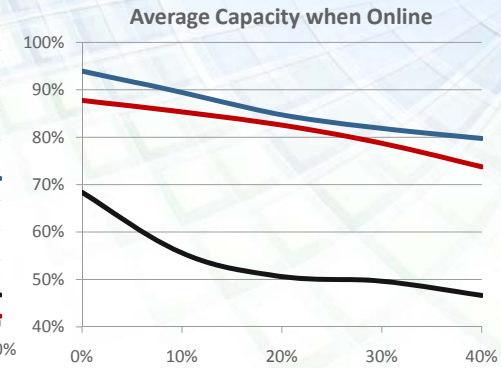
Reduction with 20% Wind	
CO	16%
PM	22%
NO_x	22%
SO_x	17%

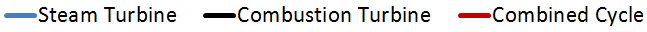




Preliminary Illinois Dispatch Results







Questions?