

Emission Impact of Fossil Fuel Unit Cycling



UWIG Spring Meeting

Greg Brinkman

April 14, 2011

PIX 15668



Wind Impacts on Emissions?

Previous studies:

- Hypothesized that emission reductions from wind are not as high as expected due to unit cycling.
- Some evidence exists, but no studies have modeled system from generator properties through dispatch.

Western Wind and Solar Integration Study (WWSIS) (phase 2 plan):

- Understand interaction between wind/solar penetration and thermal unit cycling.
- Step-by-step approach to emissions.
 - Gather unit-specific data on emissions.
 - Characterize impacts of part-load operation, ramping, startups.
 - Include these properties in unit commitment and dispatch modeling.

EPA Continuous Emission Monitors (CEMs)

Hourly emission measurements on almost all fossil fuel units in the United States.

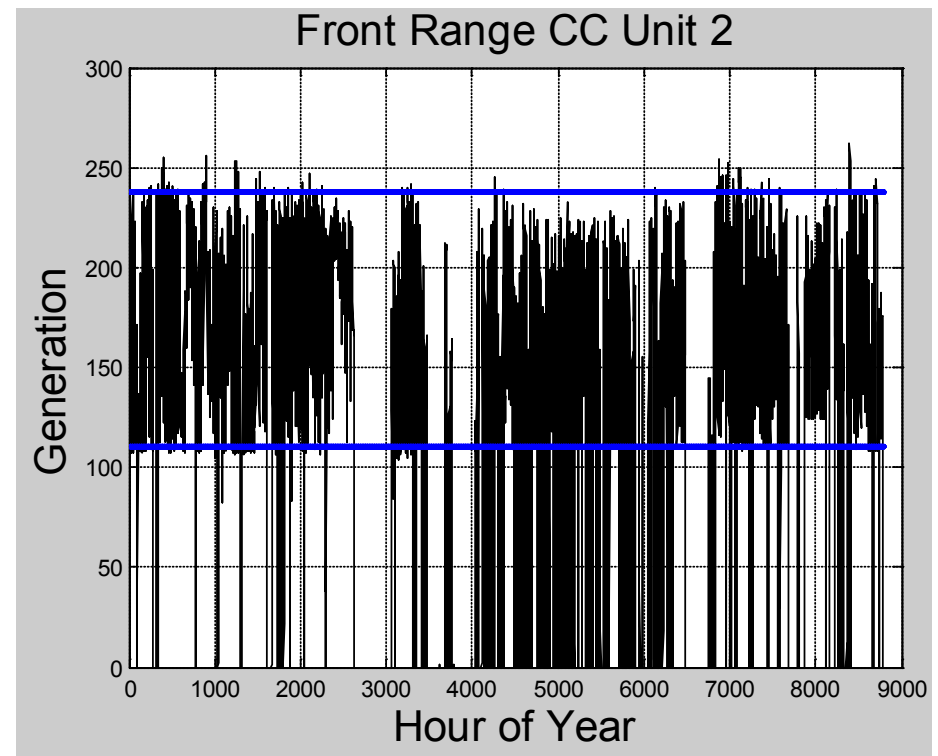
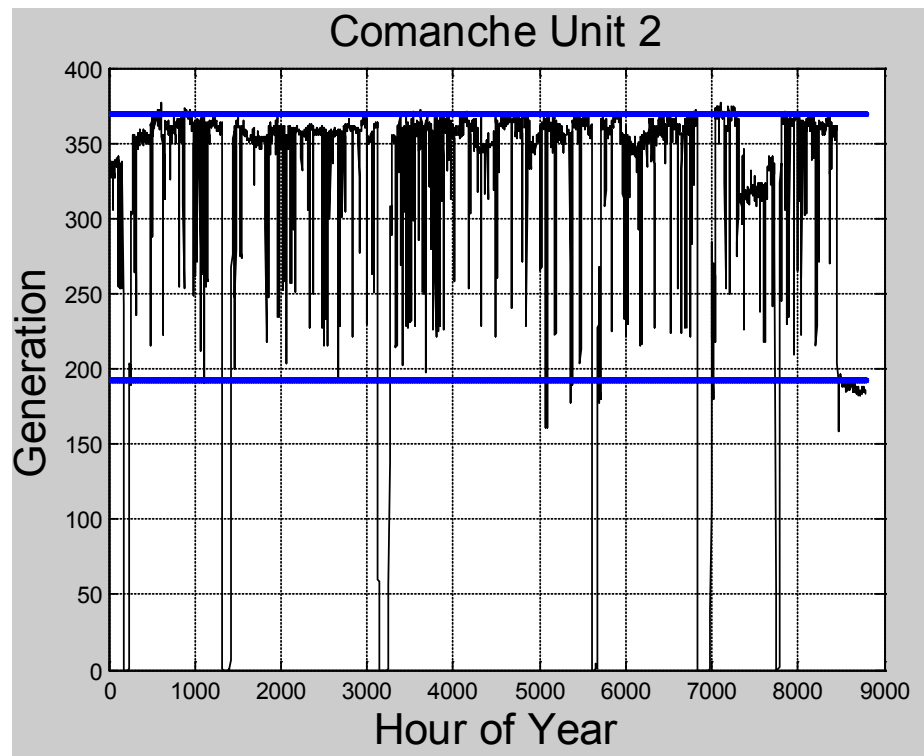
Use CEM data to find unit-specific data:

- Heat rate (and CO₂ emissions) as a function of generation.
- Emissions (NO_x, SO₂) as a function of generation.
- Some information will depend on how system operator chooses to operate it, not technical limits:
 - Minimum/maximum generation.
 - Maximum ramp Rate.

Data from year 2008.

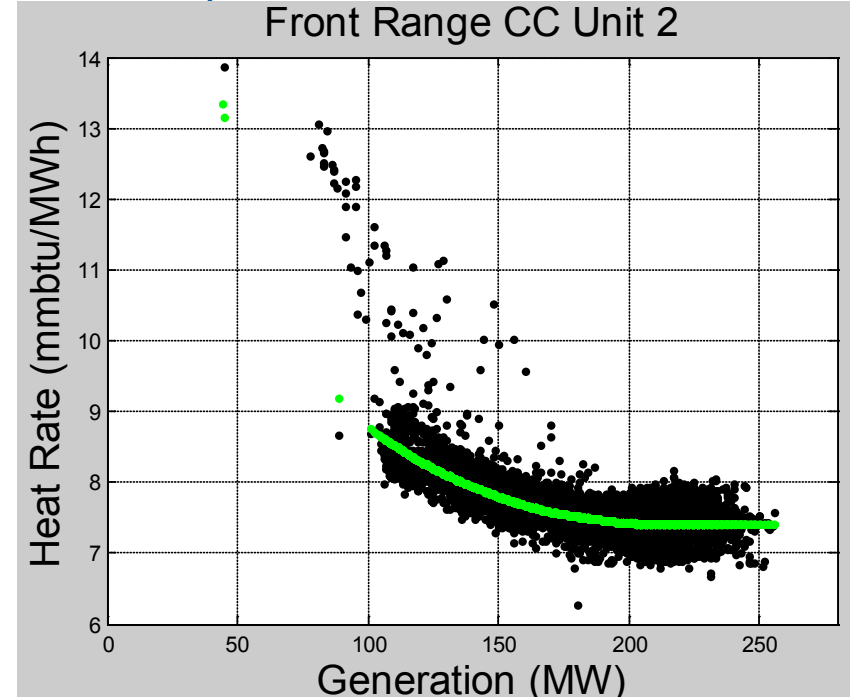
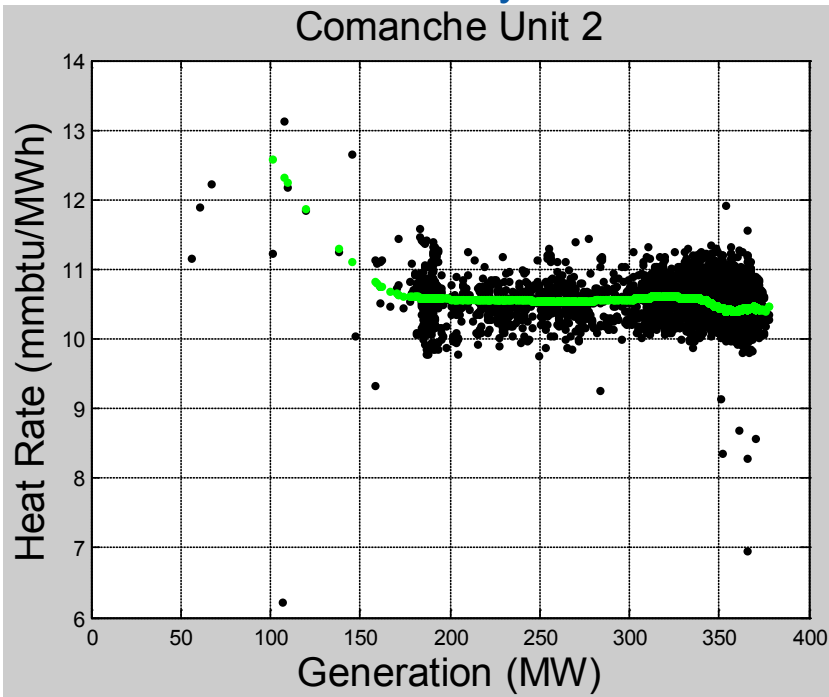
Maximum and Minimum Generation

- Eliminate hours immediately after startup (first and second hours)
- Maximum and minimum generation are the 98th and 5th percentile values



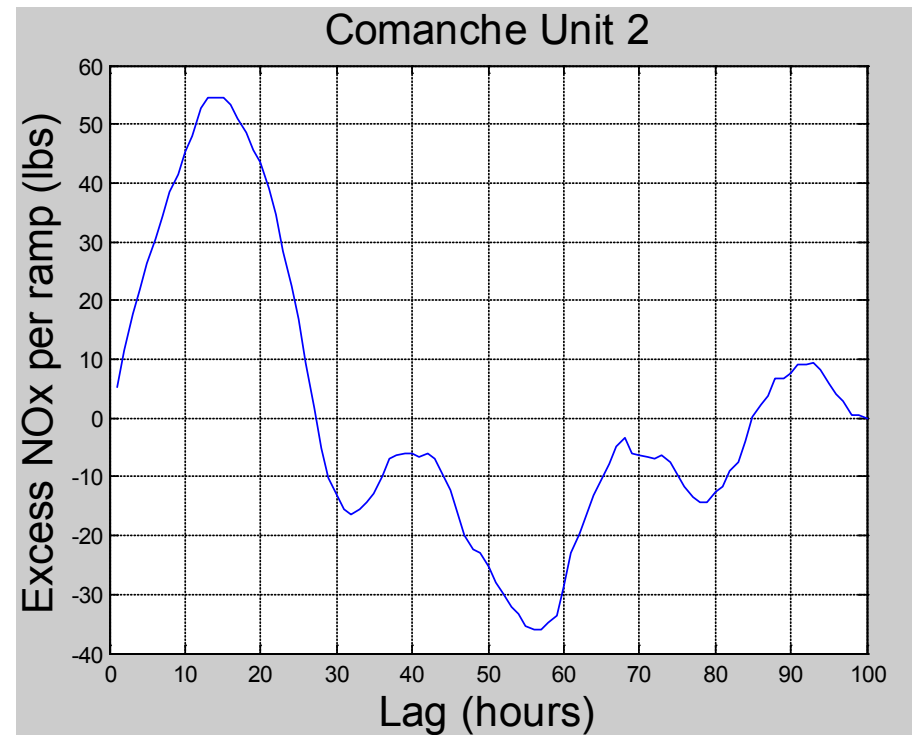
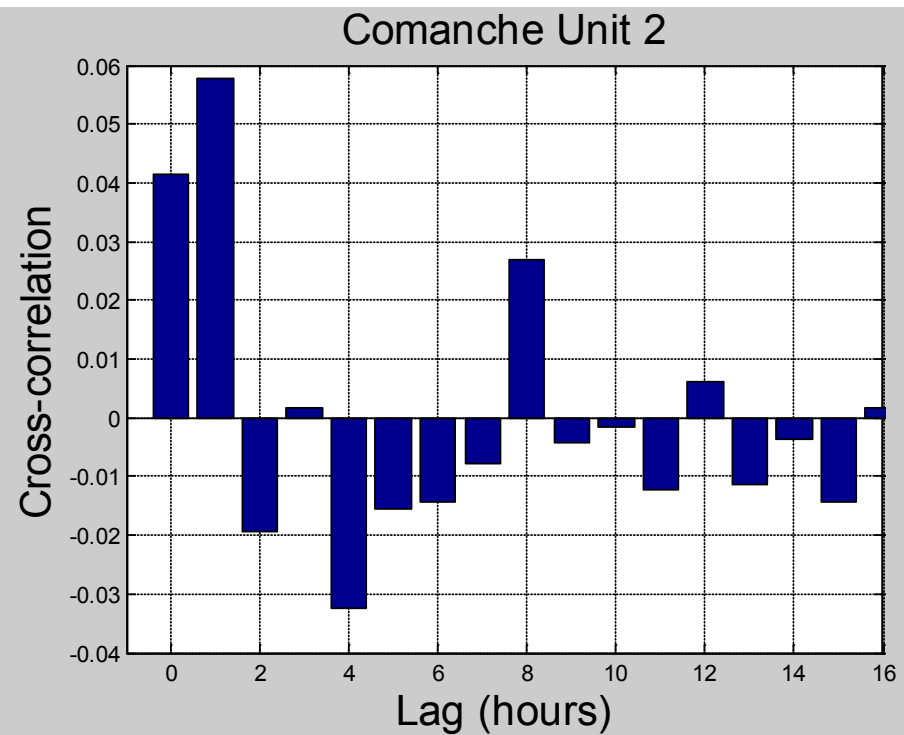
Heat Rate and Emission Curves

- Local linear fit for every unit.
- Compile emissions at full load and 50% of full load.
- Residuals used for subsequent analysis.
- Eliminate units with obviously clustered data, caused by:
 - Installation of pollution control equipment during year;
 - Part-time operation of pollution control equipment;
 - Combined cycle units in various modes of operation.



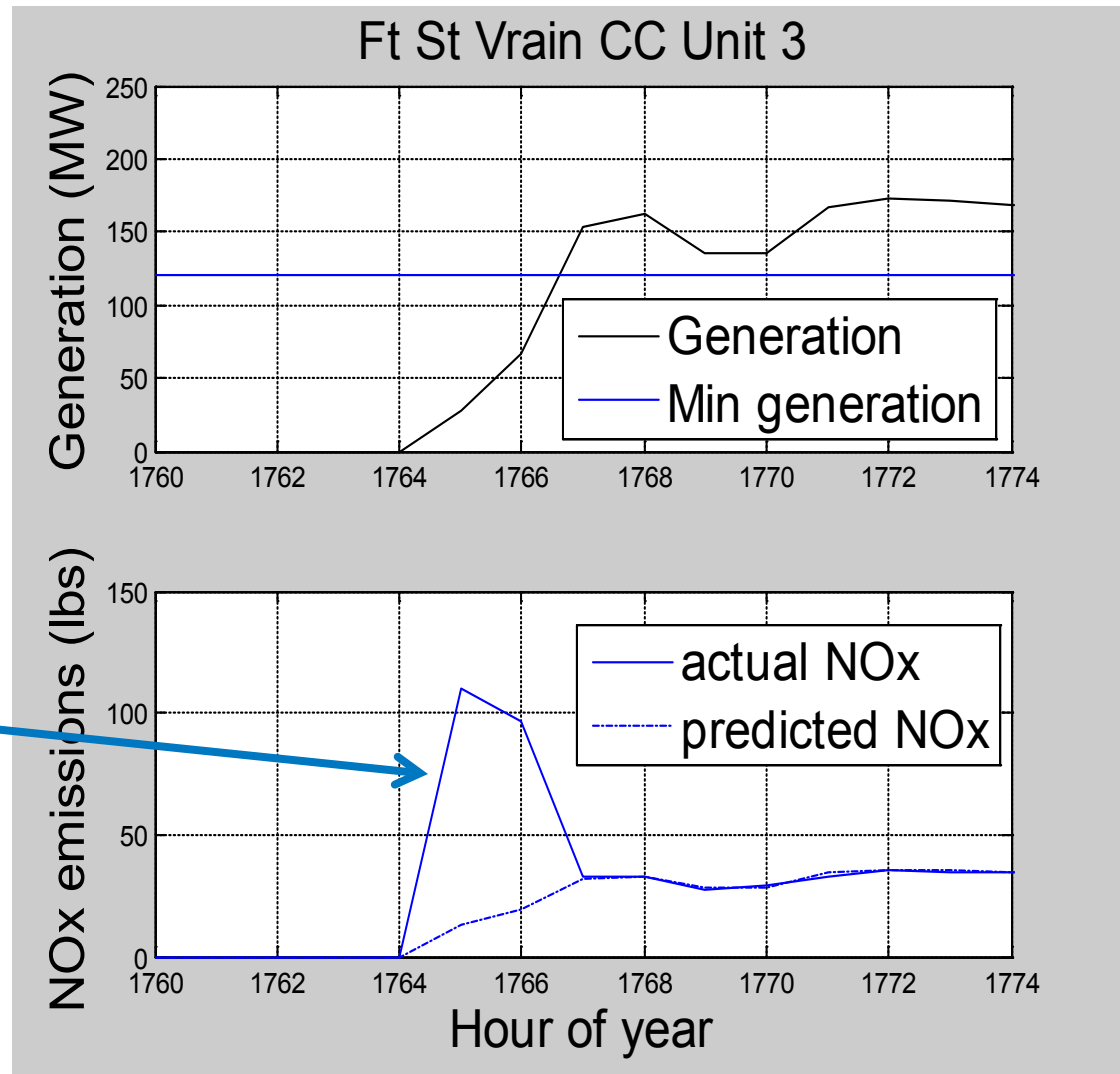
Time-Lagged Pollution Control Failures?

- Lagged cross-correlation between unit ramp rate and the change in emission residuals (see figure on left):
 - Should identify if pollution control problems are impacted by ramping.
- If evidence of a correlation exists, sum the residuals for all hours impacted by ramping (within 10 hours of a 5% hourly ramp) and average to determine excess emissions caused by ramping (see figure on right).



Startup Emissions

- Add up residuals from all hours prior to and following a startup until unit reaches its minimum generation level.
- Integral between the predicted and actual NO_x curves.



Results (explanation)

All results are generation-weighted averages by type —

Part-load penalty:

- Percentage increase in emissions (lbs) per unit of generation (MWh) when the unit is operating at 50% of maximum generation (compared to maximum generation).

Ramping penalty:

- Ratio of the increased emissions due to a 5% hourly ramp to the emissions from the unit during one hour of full-load operation.

Startup penalty:

- Ratio of the increased emissions due to a startup to the emissions from the unit during one hour of full-load operation.



Results (heat input or CO₂)

| Unit type | Part-load penalty | Ramping penalty | Startup penalty |
|-----------|-------------------|-----------------|-----------------|
| Coal | 5.1% | 0.4% | 110% |
| Gas CC | 15.6% | 0.3% | 32% |
| Gas CT | 12.4% | 0.3% | 32% |

Results (NO_x, SO₂)

| Unit type | Part-load penalty | Ramping penalty | Startup penalty |
|-------------------------|-------------------|-----------------|-----------------|
| Coal (NO _x) | 1.2% | 2.8% | 290% |
| Gas CC | 30%** | 0.7% | 950%** |
| Gas CT | 19% | 0.8% | 670%** |
| Coal (SO ₂) | 5.4% | 13.4% | 270% |

**These numbers are highly sensitive to input assumptions (percent loading) and/or a small number of extreme outliers (some are bad fits).

Conclusions and Future Work

Coal units affected less by part-load, ramping, and starting —

- Relative to full-load operation.

Still needs refinement —

- Sensitivity to outliers?
- Sensitivity to other parameters?
 - Part-load fraction.
 - Ramping threshold.

How does wind/solar impact emissions?

- WWSIS phase 2 will use unit-specific data for these parameters.
- Likely results:
 - CO₂ and SO₂ reductions will be close to what is expected and depend on whether coal or gas is on margin.
 - NO_x reductions may be less than expected, depending on how units are committed:
 - Gas unit startups may be important indicator.



Employees of the Alliance for Sustainable Energy, LLC, under Contract No, DE-AC36-0BG02830B with the U.S. Dept. of Energy have authored this work. The United States Government retains and the publisher, by accepting the article for publication, acknowledges that the United States Government retains a non-exclusive, paid-up, irrevocable, worldwide license to publish or reproduce the published from of this work, or allow others to do so, for United States Government purposes.