Implications of Climate Change for Regional Air Pollution, Health Effects and Energy Consumption Behavior: Selected Emissions Results*

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Outline

- Project components
- Health effects of pollution emission from utilities sector
- Climate change effects analyzed
- Analytical framework
- Results

The project involves four modeling efforts:

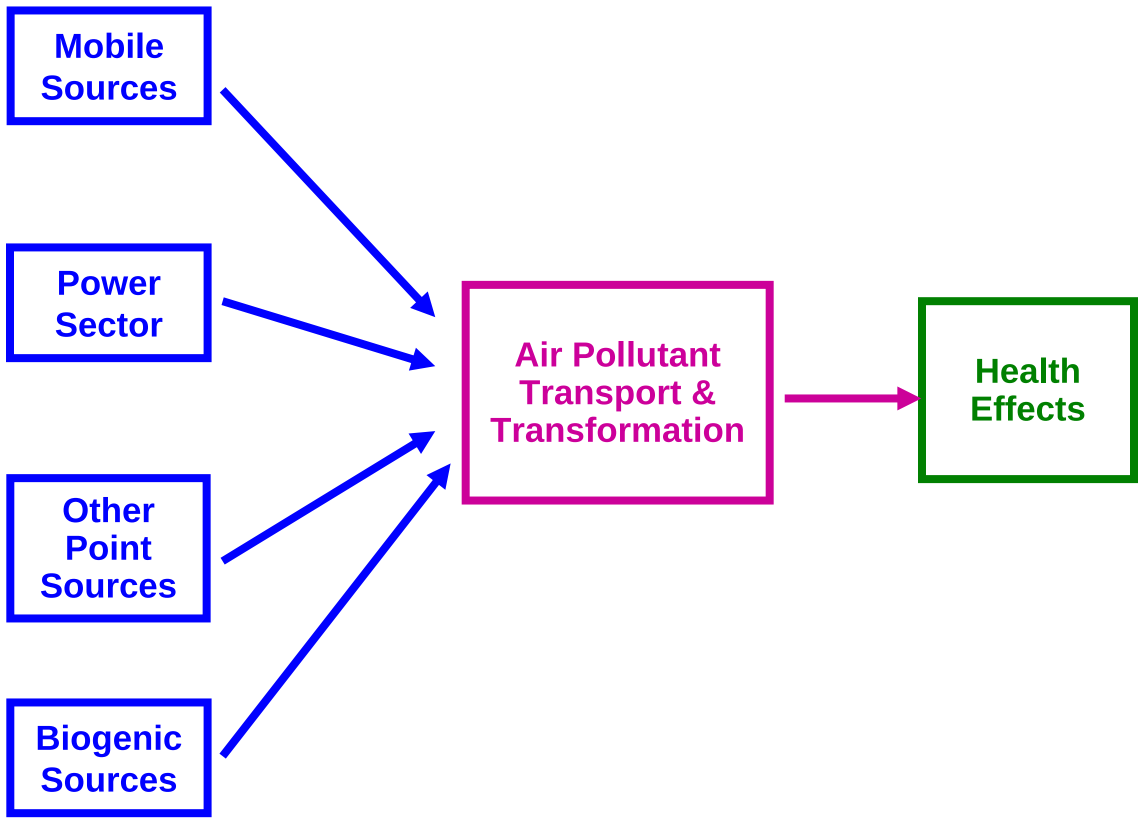
- Hourly Electricity Load Modeling and Forecasting (GWU)
- Electricity Generation and Dispatch Modeling
- Regional Air Pollution Modeling
- Health Effects Characterization

Significant Public Health Threats of Emissions from Utility Sector

- In US, utility sector accounts for 22% and 67% of total emission of NO_x and SO_2 emission (NET, 2002)

- Reactions of primary pollutants (NO_x and SO_2) with other chemicals forming secondary pollutants, i.e., PM_{10}, $PM_{2.5}$ and O_3, which pose substantial threats to public health
  - Every 10 ppb increase in daily maximal ozone concentration results in the death of all causes (except accidents) increases by 0.36% (Thurston et al. 99) and 0.41% (Samet et al. 2000)
  - Every 100ppb increase in the previous week O_3 leads to an increase of 0.52% and 0.64% in daily mortality rate and cardiovascular and respiratory mortality, respectively (Bell et al. 2005)

Climate Change Effects Analyzed



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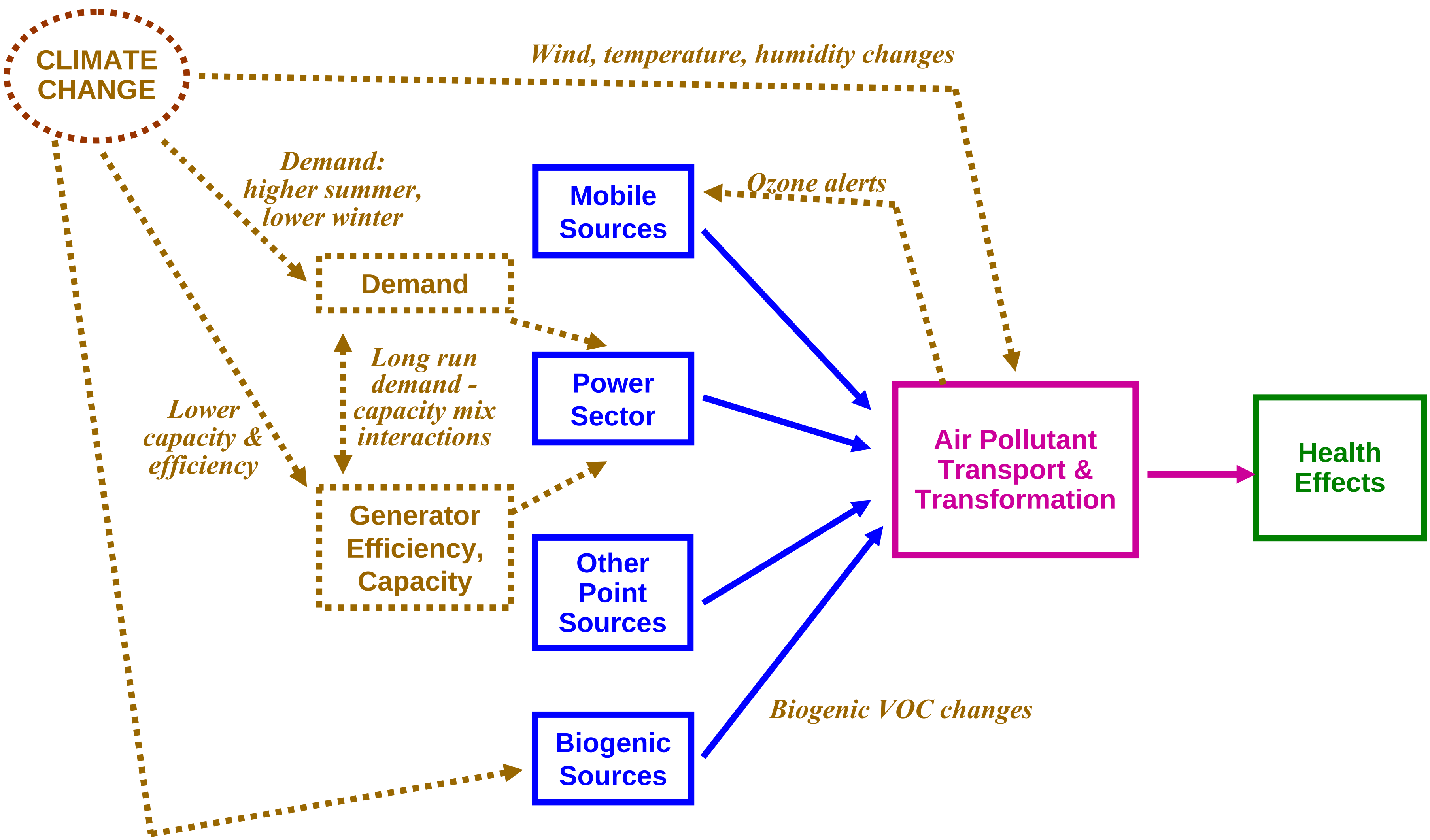
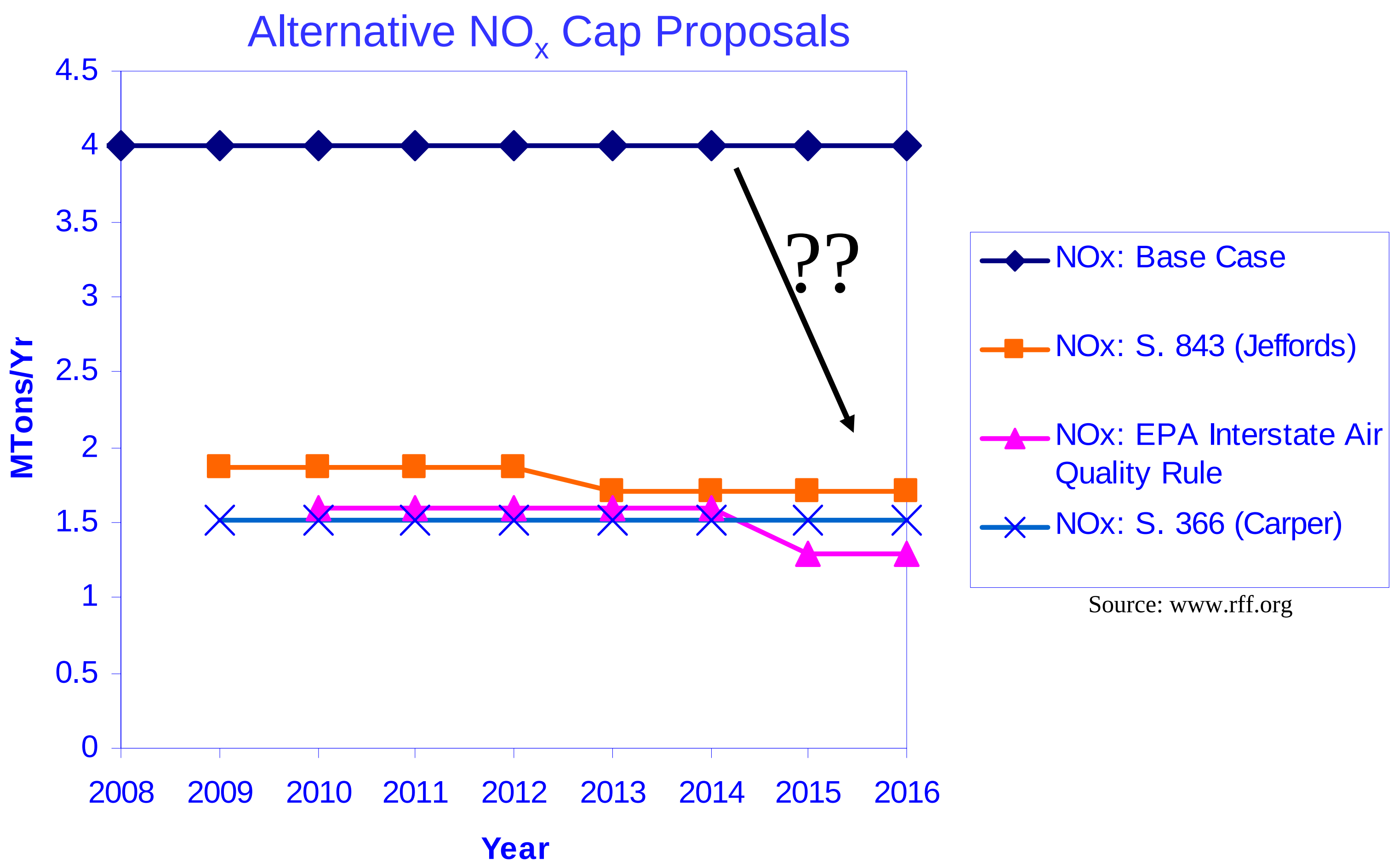


Effects of Climate Change on Components of Power System

	Short Run Effects	**Long Run Adaptations**
Power Demands:	**ΔUse of equipment** *(e.g., air conditioner hours)*	**ΔMix of equipment** *(e.g., #, size of air conditioners)*
Generator Characteristics:	**ΔThermal capacity & efficiency** *(e.g., Carnot)*; **ΔWater supply**	**ΔMix of generators** *(fuel sources, peak vs. baseload)*

Result: Changes in Amounts, Timing, & Location of Emissions

The Largest Emissions Uncertainty: Size of Emissions Cap and New Source Review Policy



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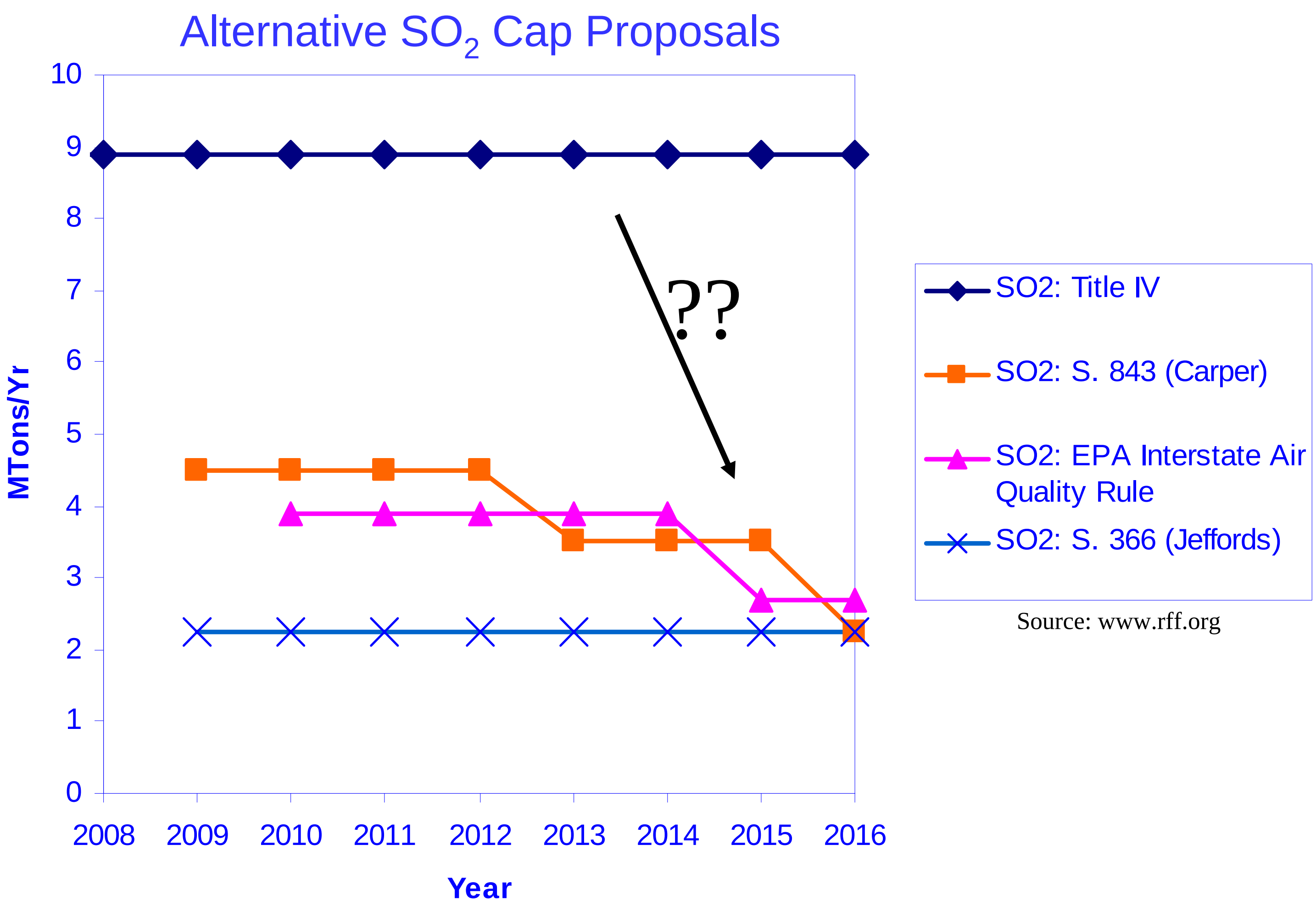


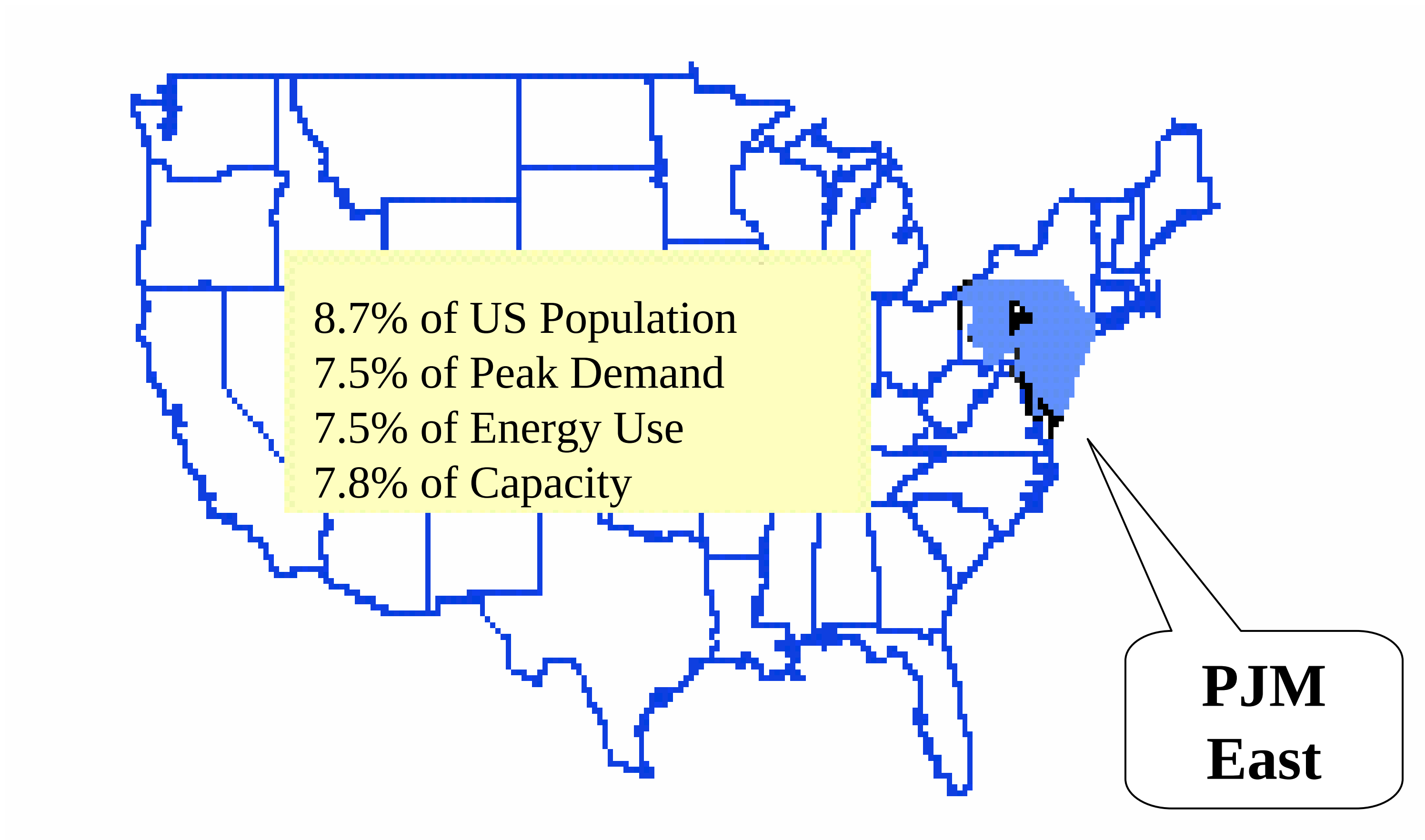
Source: www.rff.org

Given a cap, climate warming:

- *might* alter distribution of emissions over year (2^{nd} order compared to cap size?)
- *will* increase electricity generation and emissions control costs

PJM Interconnection

- Largest wholesale electricity market in the world
- Power from coal, oil, gas, nuclear and hydroelectric resources



Simulation of Power Sector Emission Responses

- *First*, Short-run analysis:
  - fixed generation capacity
  - short-run load response to temperature

- Impact of 2 ^{o}F warming upon PJM market:
  - Year 2000 demands
  - 879 generating units (from EPA, DOE data bases)
  - Year 2000 ozone season, with detail on ozone episode Aug. 7-9, 2000

- Assumptions:
  - Statistical models of electricity demand
    - as *f*(day, hour, lagged demand, temp)
  - Thermal plant efficiency from literature, Carnot calculations, *e.g.*,
    - Gas turbine heat rate increases 0.07% / 1^{o} F increase
    - Steam plants heat rate increases 0.06% / 1^{o} F increase
  - Capacity using reported winter and summer capacities:
    - Average 0.23% decrease / 1^{o} F increase

Simulation Summary

- Approach: LP Market simulation (perfect competition)
  - – Generators compete to sell electricity, subject to markets for NO_x allowances and transmission
  - – Considers existing generating units load, NO_x cap (SIP call), and transmission network (Kirchhoff's Voltage and Current Laws)
  - – Hourly simulation of Aug. 7-9; ten-period approximation for remainder of season
- Results for entire season:
  - – 4.3% increase in average hourly demand in ozone season
  - – No change in total NO_x (due to cap)
  - – Fuel cost increases:
    - – 21% due to load increase alone
    - – 0.4% due to generator efficiency decrease
    - – 22% total

2 ºF Increase:
Electricity Demand & Generator Performance Impacts

Aug. 7-9, 2000

Base Case

Tons NO_x	Tons SO_x	\$M FuelCost
2,691	9,220	35

Generator Performance Impact Alone

Tons NO_x	Tons SO_x	\$M FuelCost
+0.076%	-0.001%	+0.25%

+5.1% Demand Impact Alone

Tons NO_x	Tons SO_x	\$M FuelCost
+5.0%	+5.5%	+19.9%

2 ºF Increase:
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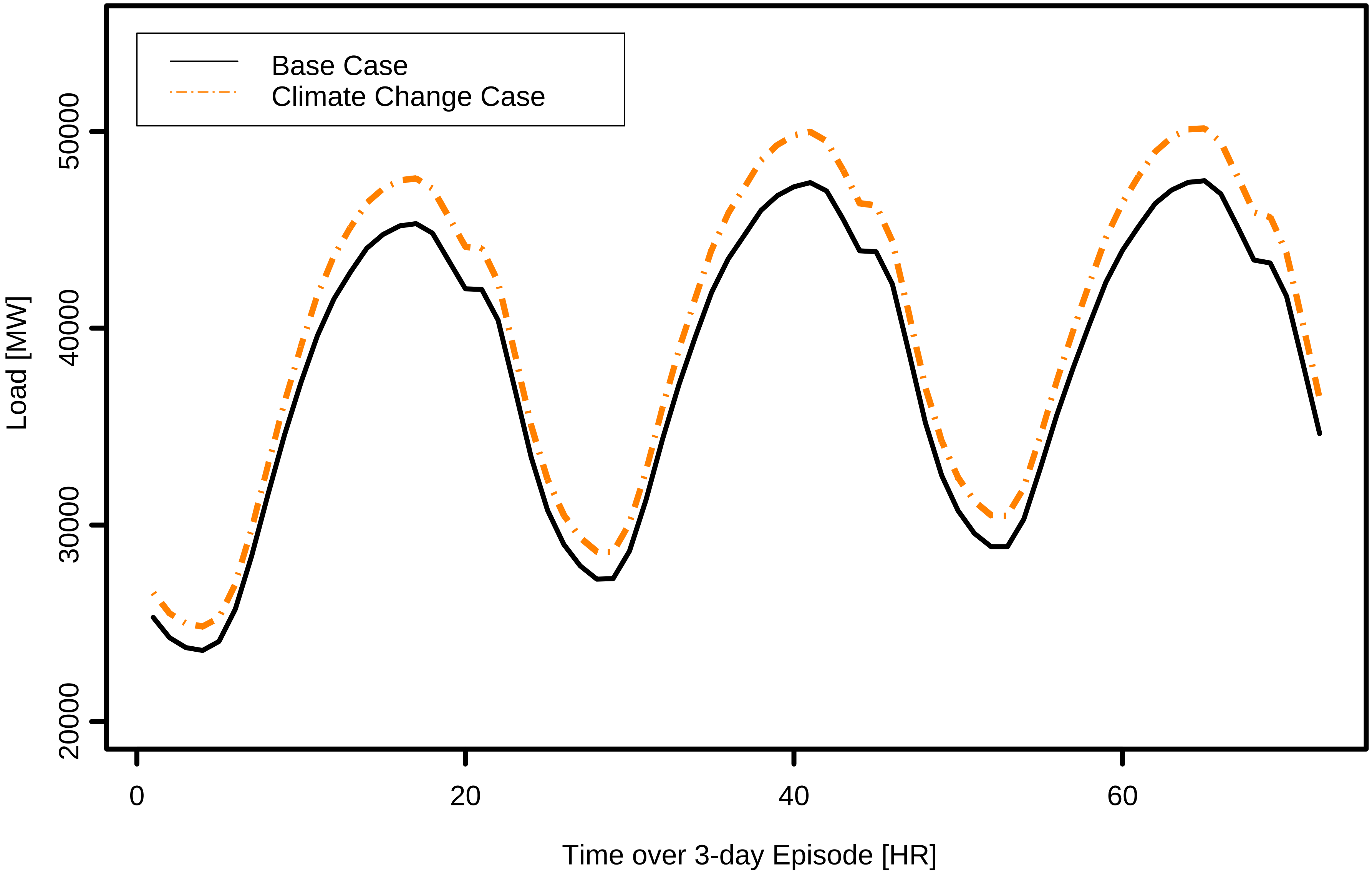
Joint Generator & Demand Impact

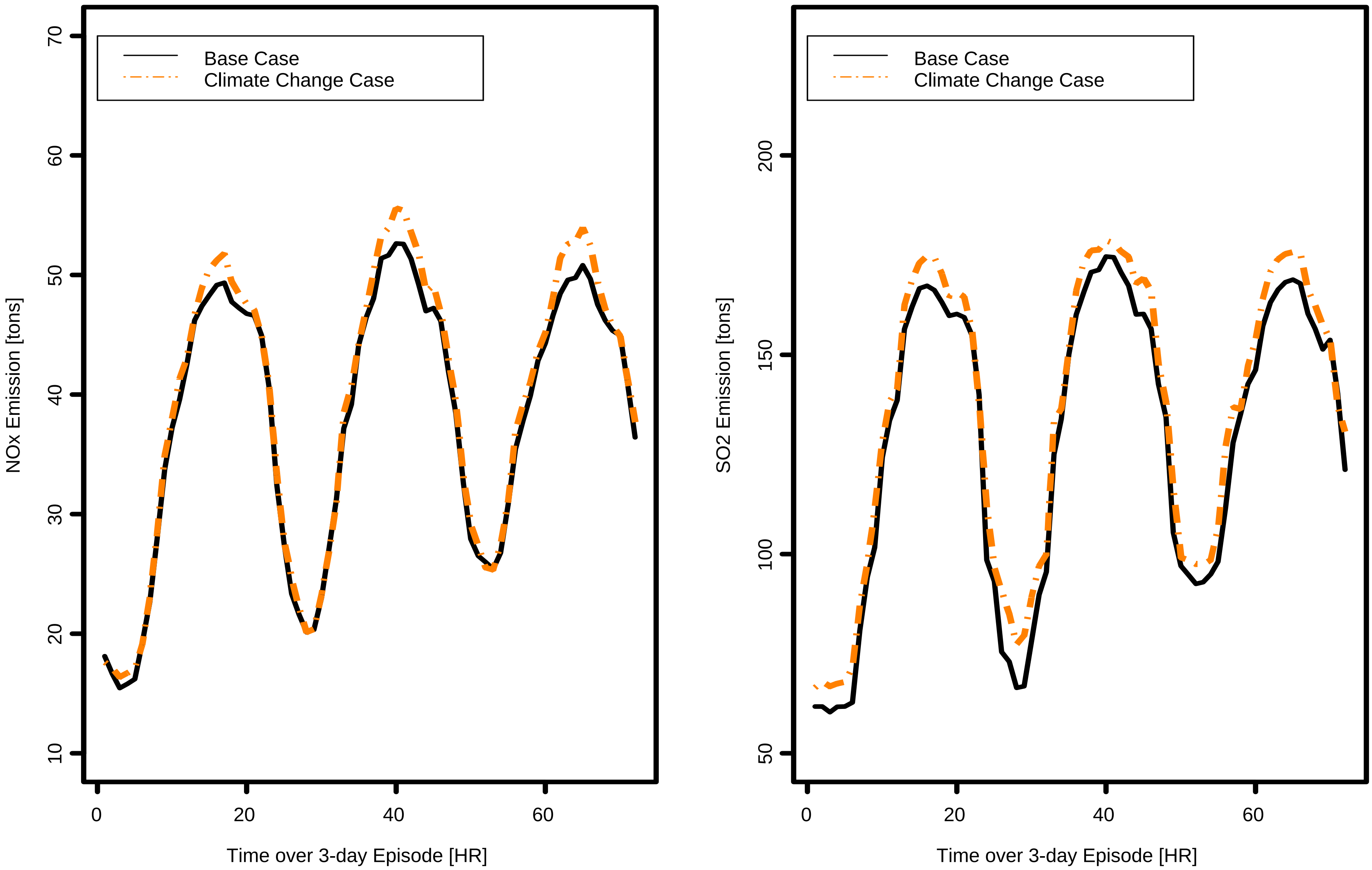
Tons NO_x	Tons SO_x	$M FuelCost
+4.9%	+5.4%	+20.3%

Total PJM Load, Aug. 7-9

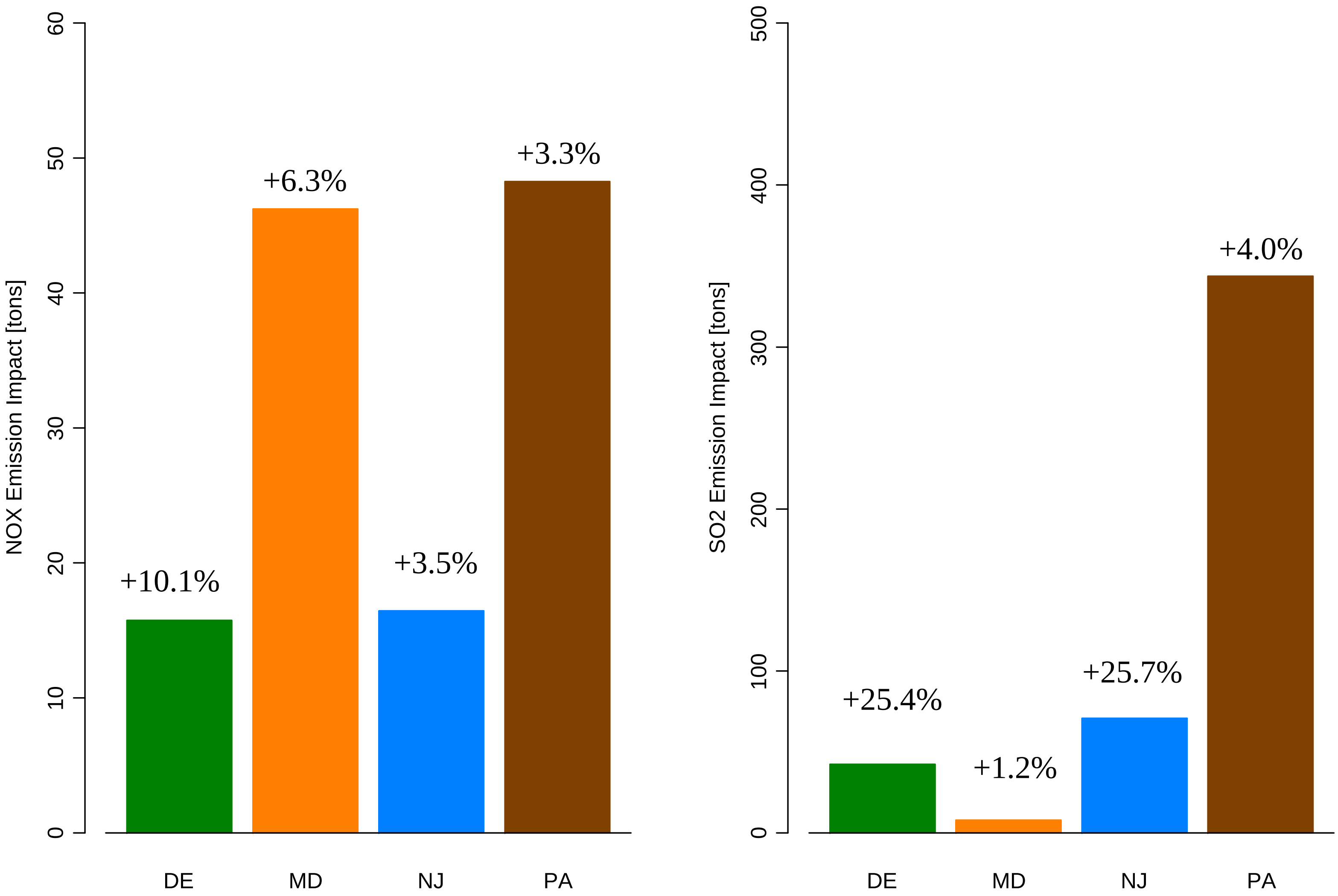
(ΔLoad= +5.1% due to 2º F increase)



PJM Emissions, Aug. 7-9
$(\Delta NO_x = +4.9\%;\ \Delta SO_2 = +5.4\%)$



State-Level Emission Impact, Aug. 7-9



- ***ΔNO_x in southern part of region; ΔSO_2 in eastern (populous) part***

Long-Run Analysis

- Shifts in electricity demand distributions as a result of changes in air conditioner penetration and use in residential and commercial sectors (NEMS Electricity Market Model demand modules)

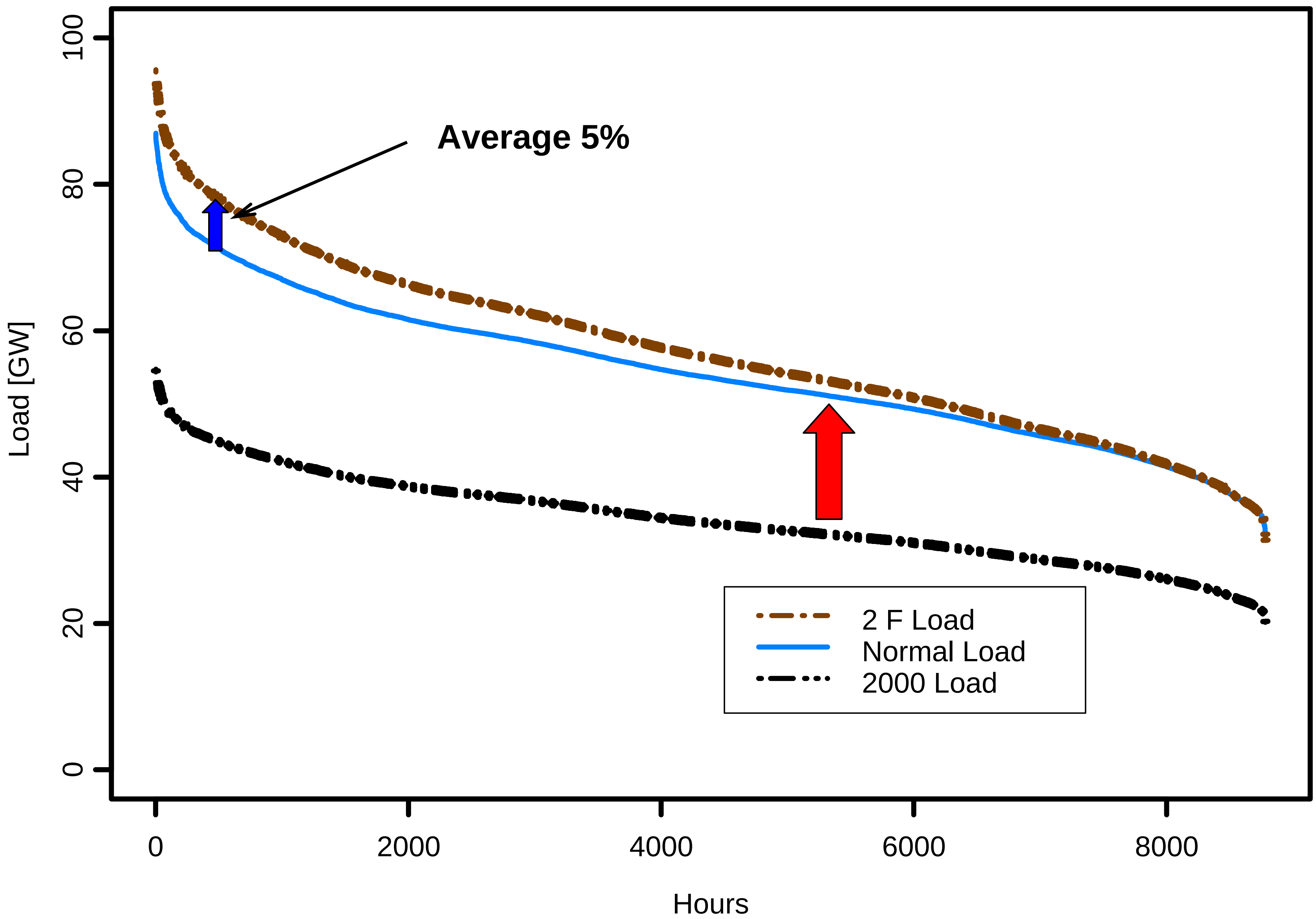
- Shifts in generation mix as a result of changes in generator efficiencies and load shapes (peakier loads imply proportionally more combustion turbines)

- Sitting scenarios for emissions sources in Mid-Atlantic/Midwest region

Long Run Emission Responses in PJM

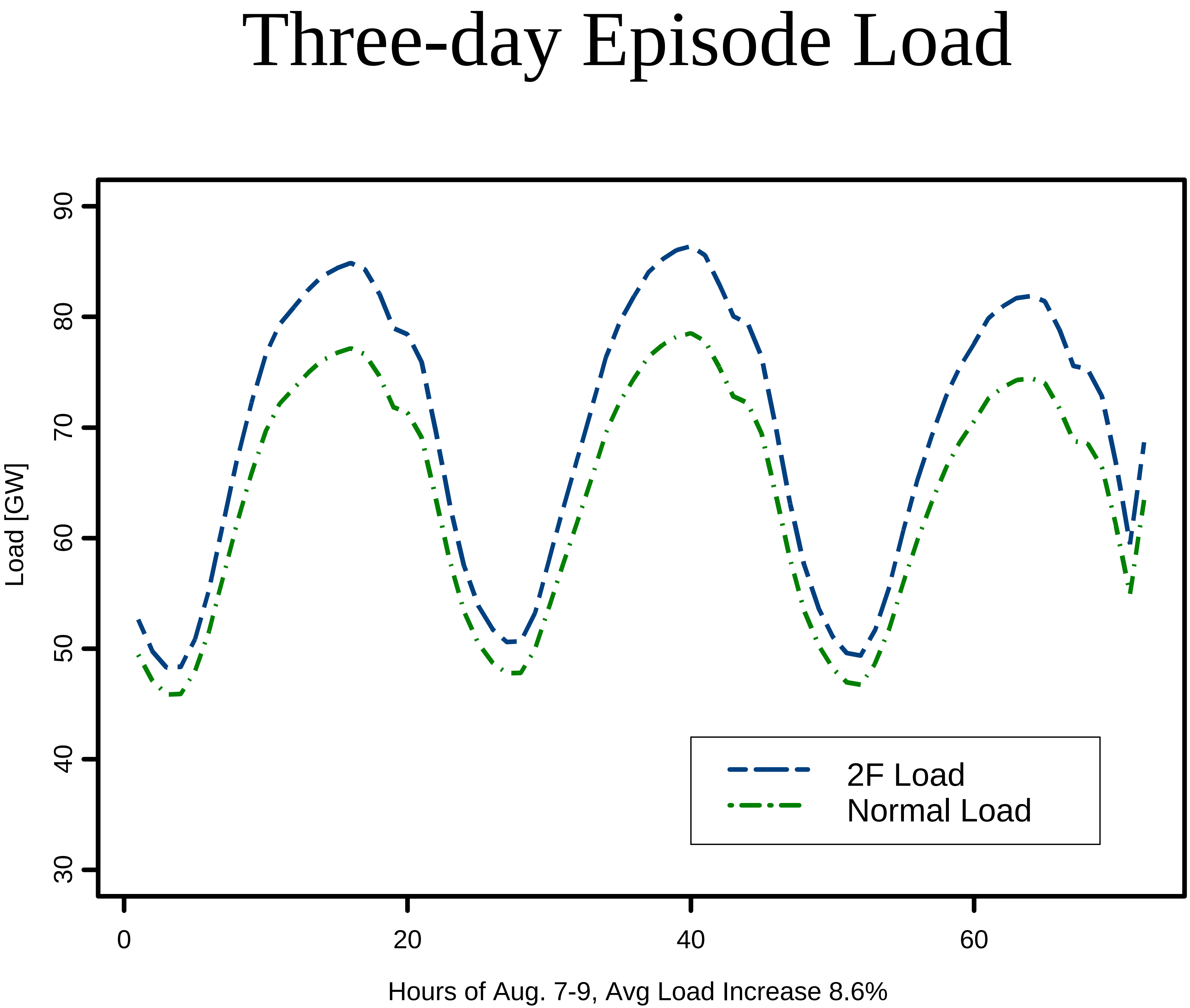
- Impact of 2 ^{o}F warming upon Pennsylvania-Jersey-Maryland (PJM) market, using 2025 projected demands and generation mix
  - Unretired existing units
  - Year 2025 ozone season, with detail on ozone episode Aug. 7-9, 2025
- Assumptions:
  - Future capacity mixture
    - Screening curve analyses using NEMS data, subject to existing units
    - Impose generation proportions in LP siting & dispatch model
      - Like Short Run Model: considers NO_x future cap, transmission network (Kirchhoff's Voltage and Current Laws)
  - Hypothetical electricity demand
    - Higher increment in peak period and lower in off peak period with an average of 5%
  - Thermal plant efficiency and capacity losses (as in short run)

2025 Load Duration Curve

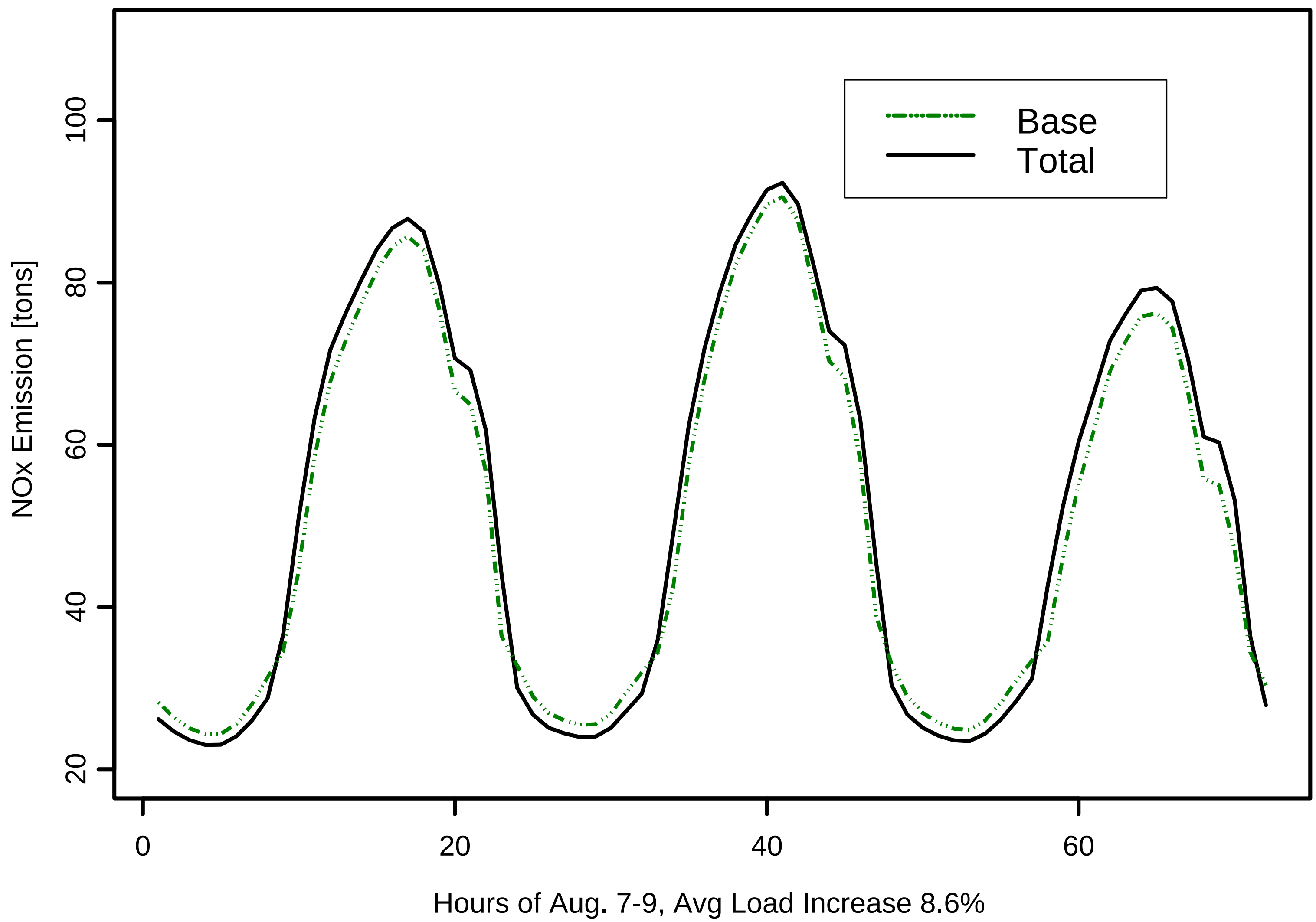


Simulation Summary

- Load blocks:
  - Hourly simulation of Aug. 7-9
  - Ten-period approximation for remainder of season
  - Ten-period approximation for nonozone season
- Results for entire ozone season:
  - 5.4% increase in average demand in ozone season
  - No change in total NO_x (due to cap)
  - Fuel cost increases:
    - 5.7% due to load increase alone
    - 5.8% total, including efficiency losses


Three-day Episode Load
Load [GW]
90
80
70
60
50
40
30
0
20
40
60
Hours of Aug. 7-9, Avg Load Increase 8.6%
2F Load
Normal Load

Three-day Episode NO_x Emission Profile



Next Steps - Regional Air Pollution Modeling

- Incorporation of synthetic met observations into MM5 (within Models-3) and produce future load scenarios
- Execute climate change-driven scenarios to produce ozone concentration field
- Estimate health impact based on epidemiological dose-response relationships