


Projecting Land Use and Transportation Impacts on Air Quality in the Upper Midwestern United States (PLUTO)

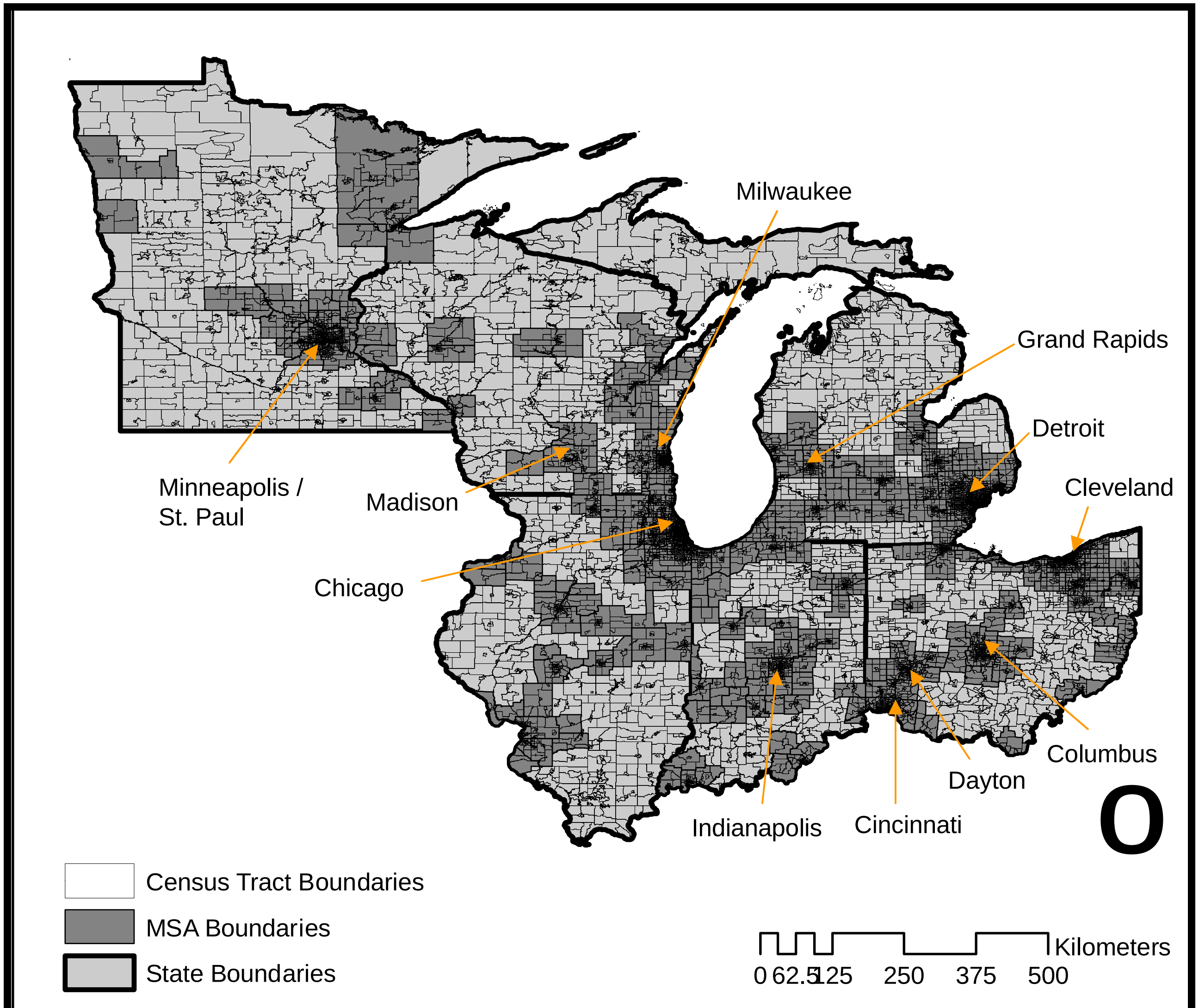
<u>PROJECT TEAM</u>

Brian Stone, Ph.D., City and Regional Planning Program, Georgia Tech
Tracey Holloway, Ph.D., Nelson Institute of Environmental Studies, UW-Madison
Adam Mednick, URPL, UW-Madison
Scott Spak, SAGE, UW-Madison

Overview

- ➢ Research Approach
  - * How to model change in population and vehicle use over the six state region?
- ➢ Results of Scenario Modeling
  - * How would vehicle travel and emissions respond to smart growth policies?
- ➢ Results of Air Quality Modeling
  - * How do urban emissions interact with the Great Lake region?
- ➢ Major Findings and Conclusions
  - * Can smart growth benefit air quality?

Upper Midwest Study Region





Land Use and Technology Change Scenarios

1. Business as Usual: Projection to 2050 of five demographic determinants of travel: population density, employment rate, income, vehicle ownership, and housing population based on historical rates of change between 1970 and 2000

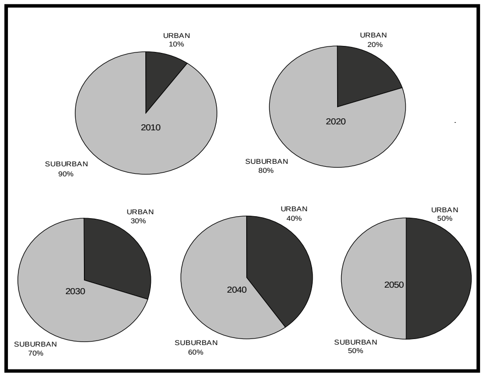
2. Moderate Smart Growth (SG1): Urban share of new population growth based on Portland, Oregon

3. Aggressive Smart Growth (SG2): Urban share of new population growth increases by 10 percentage points per decade

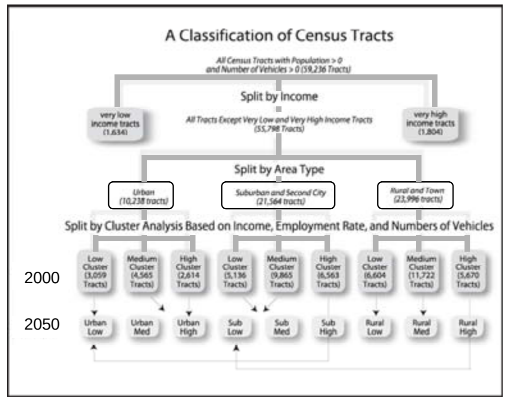
4. Vehicle Fleet Hybridization (HEV): Assumes BAU population growth patterns and full dissemination of conventional hybrid-electric vehicles

Overview of Modeling Components

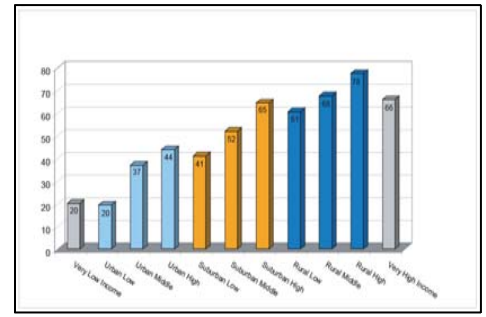
Population Change

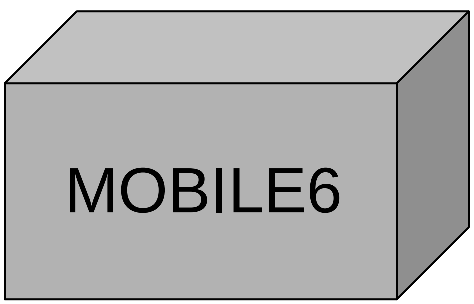


Community Type Designation

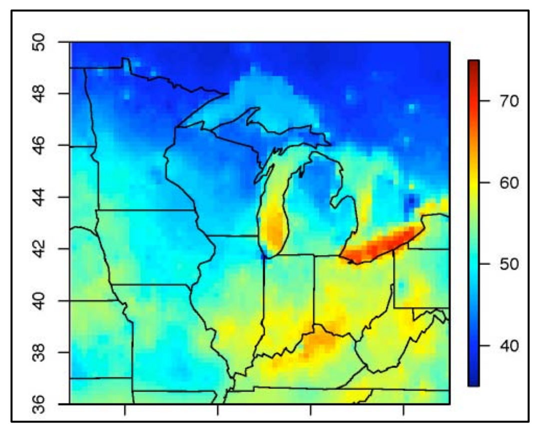


Vehicle Travel Rate Assignment



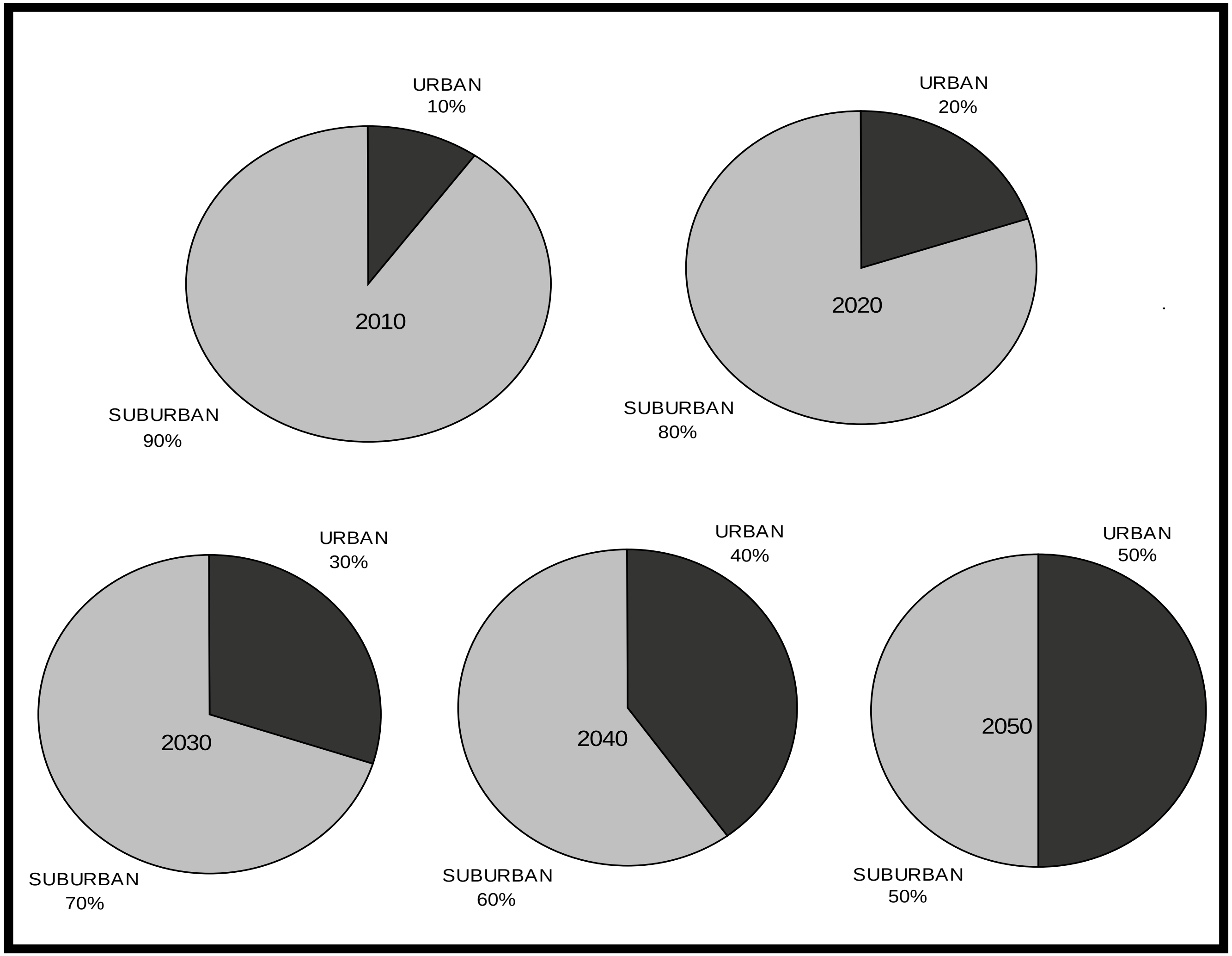


Vehicle Emissions Modeling

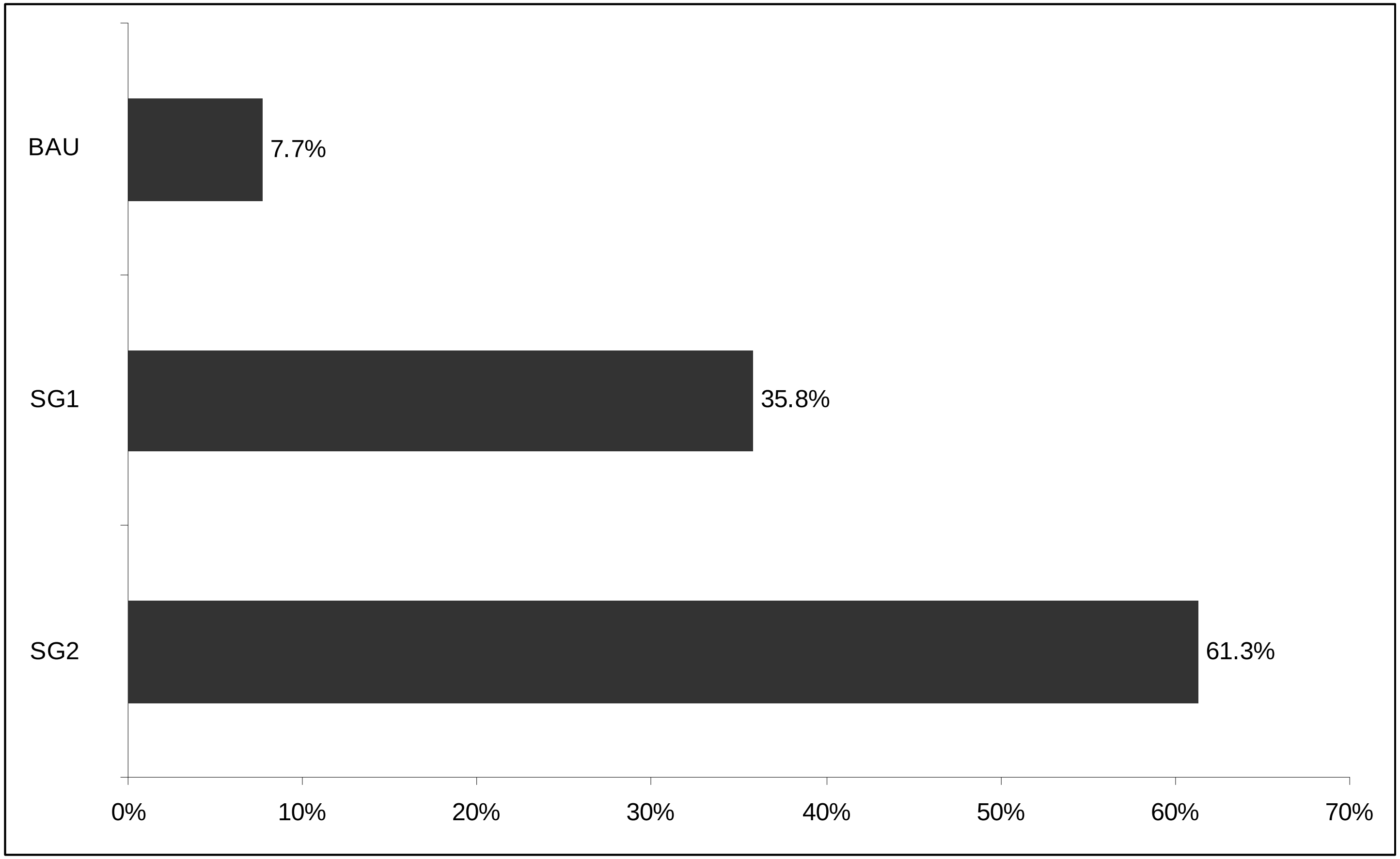


Regional Air Quality Modeling (CMAQ)

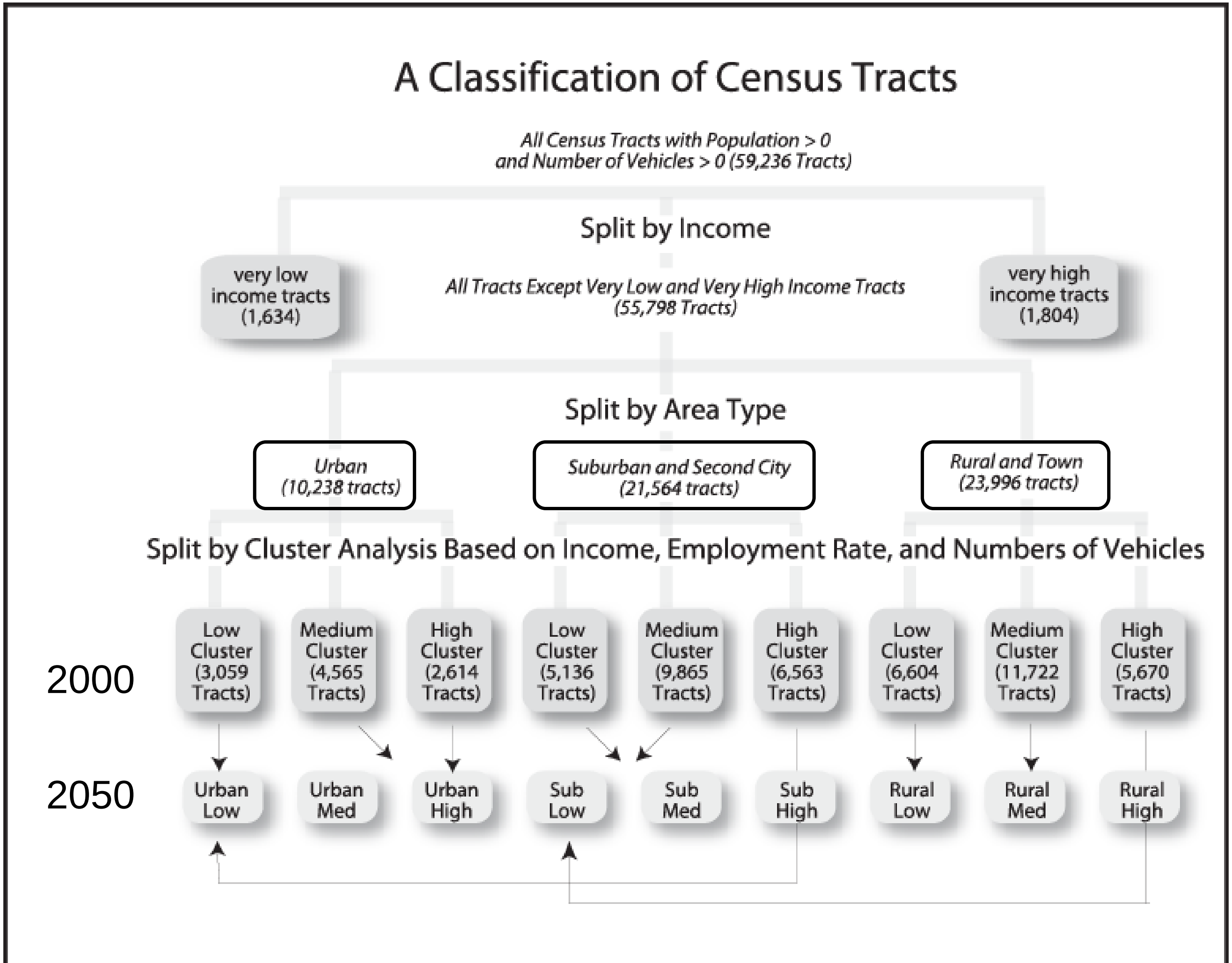
SG2 Scenario: Future Growth Shares based on Fixed Urban Growth Rates (10% / Decade)



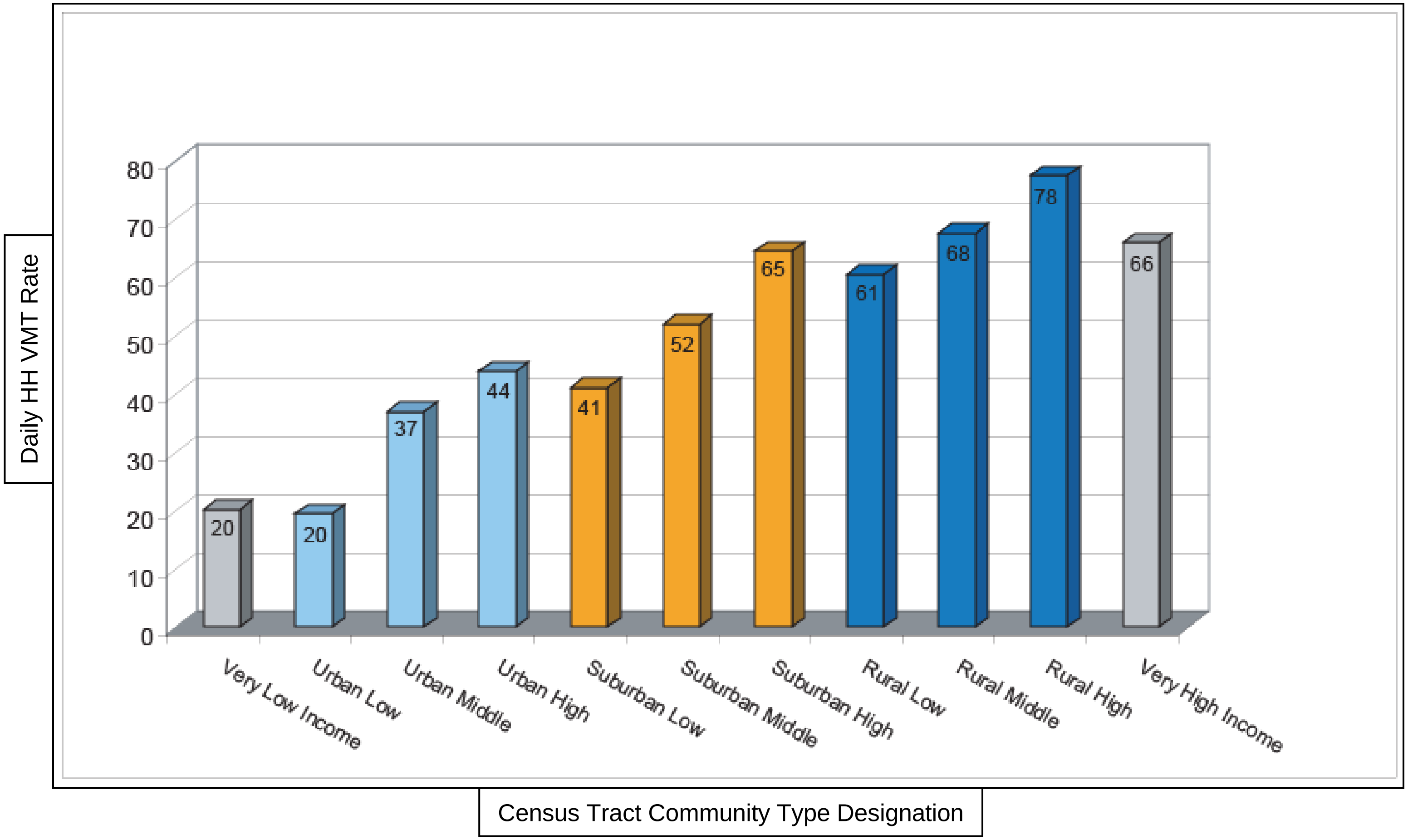
Median Metro Density Change by Scenario: 2000-2050



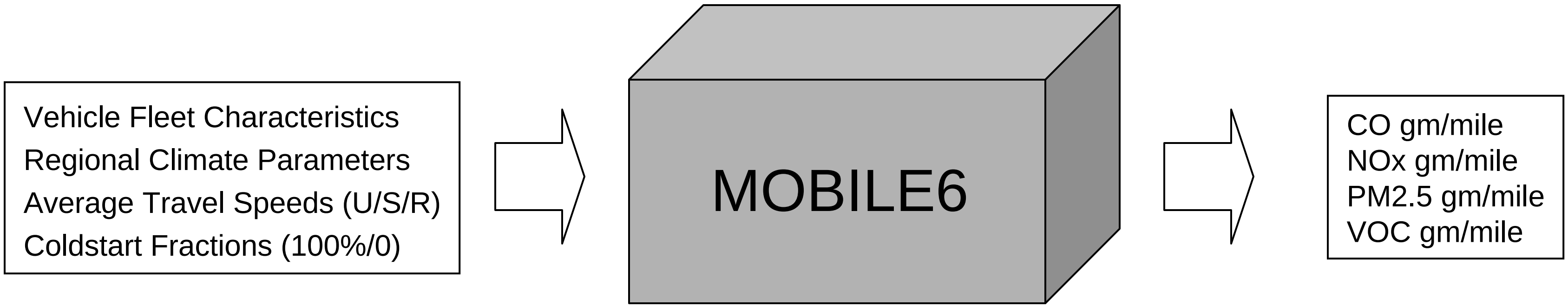
Federal Highway Administration
Community Type Classification Scheme



Household Daily VMT Rates by Community Type

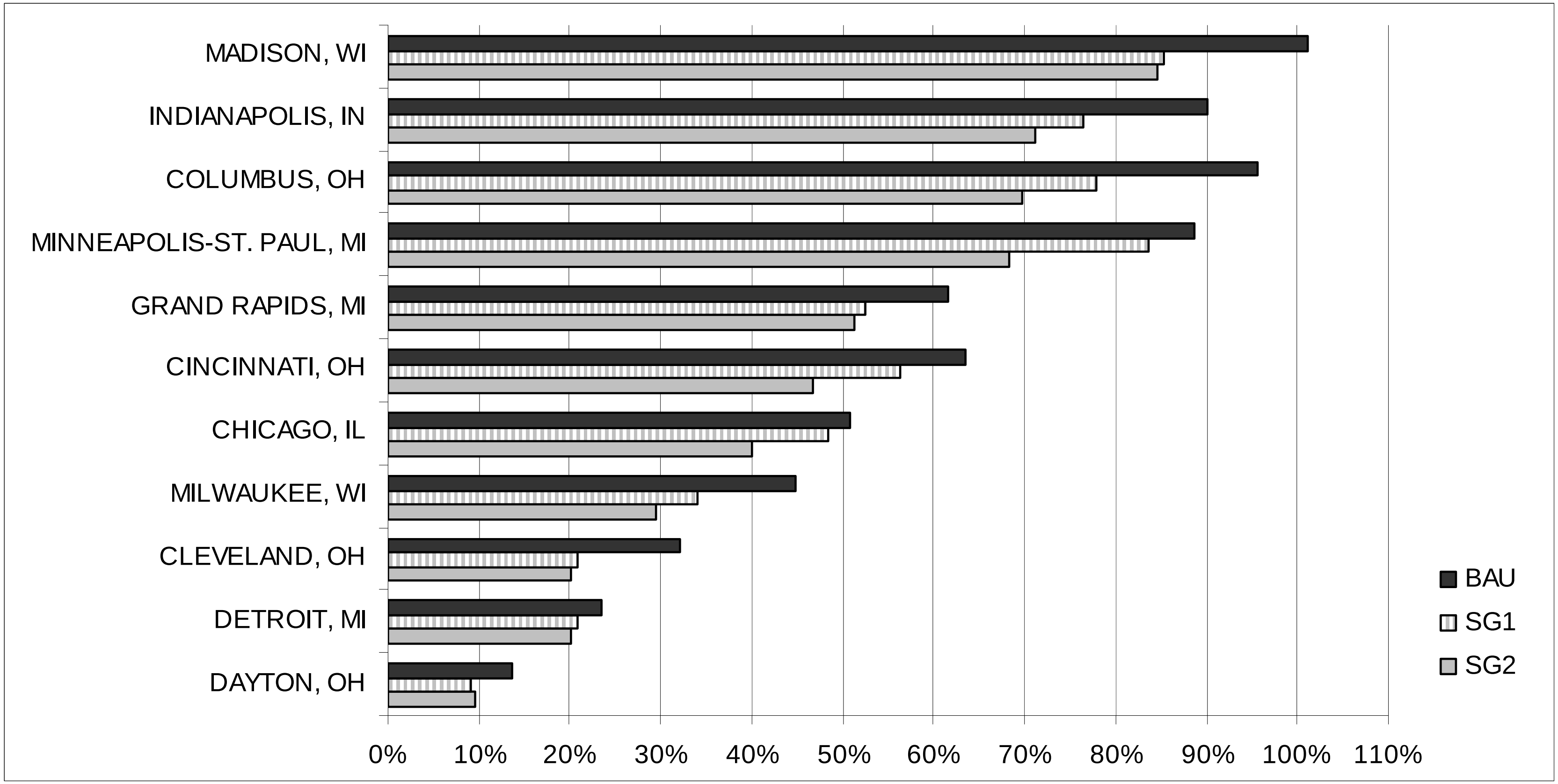


Vehicle Emissions Modeling

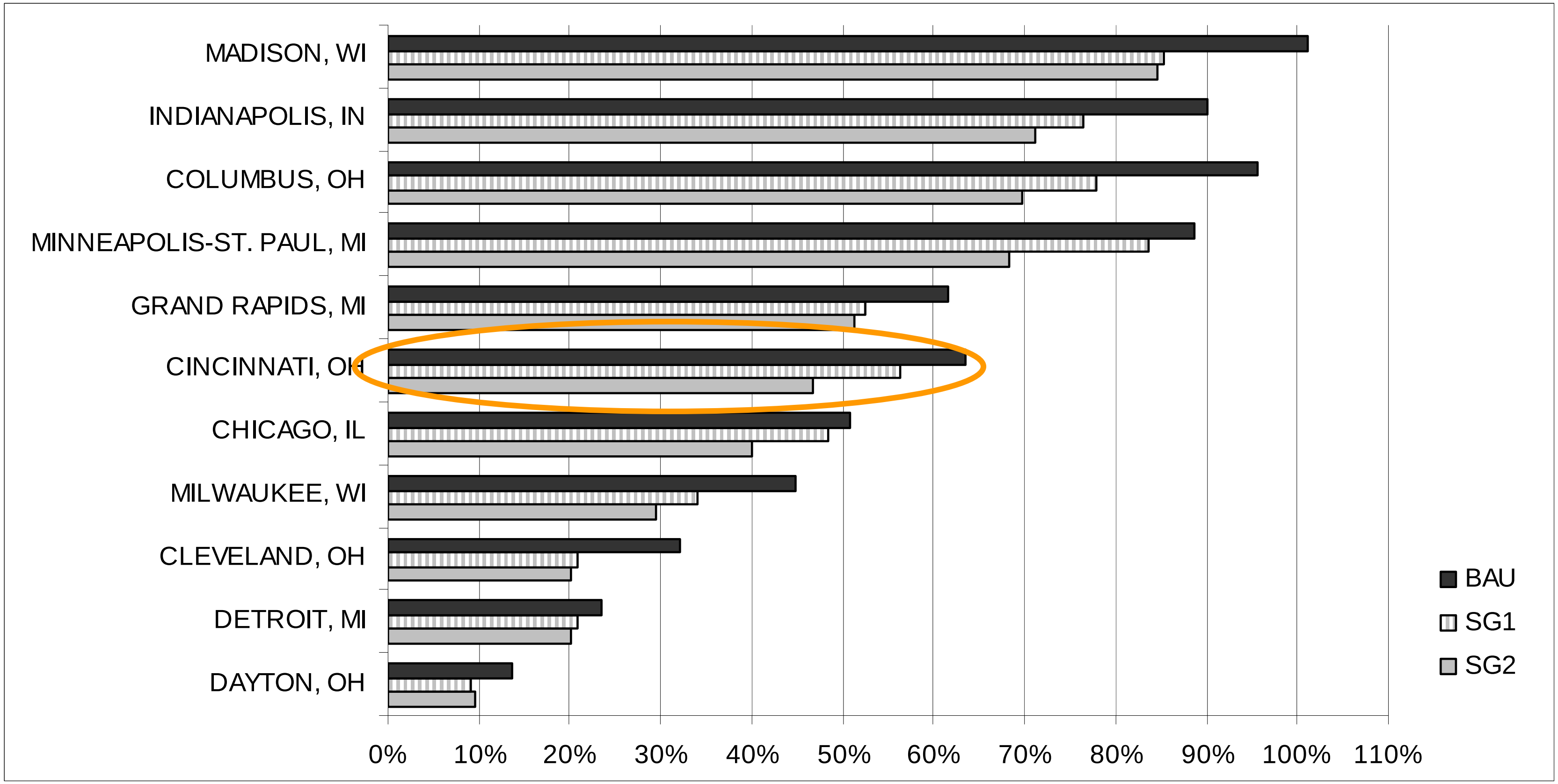


VMT Cluster	Average Speed (MPH)
Rural	29.5
Suburban	23.5
Urban	20.2

Change in Metro VMT since 2000 by Scenario

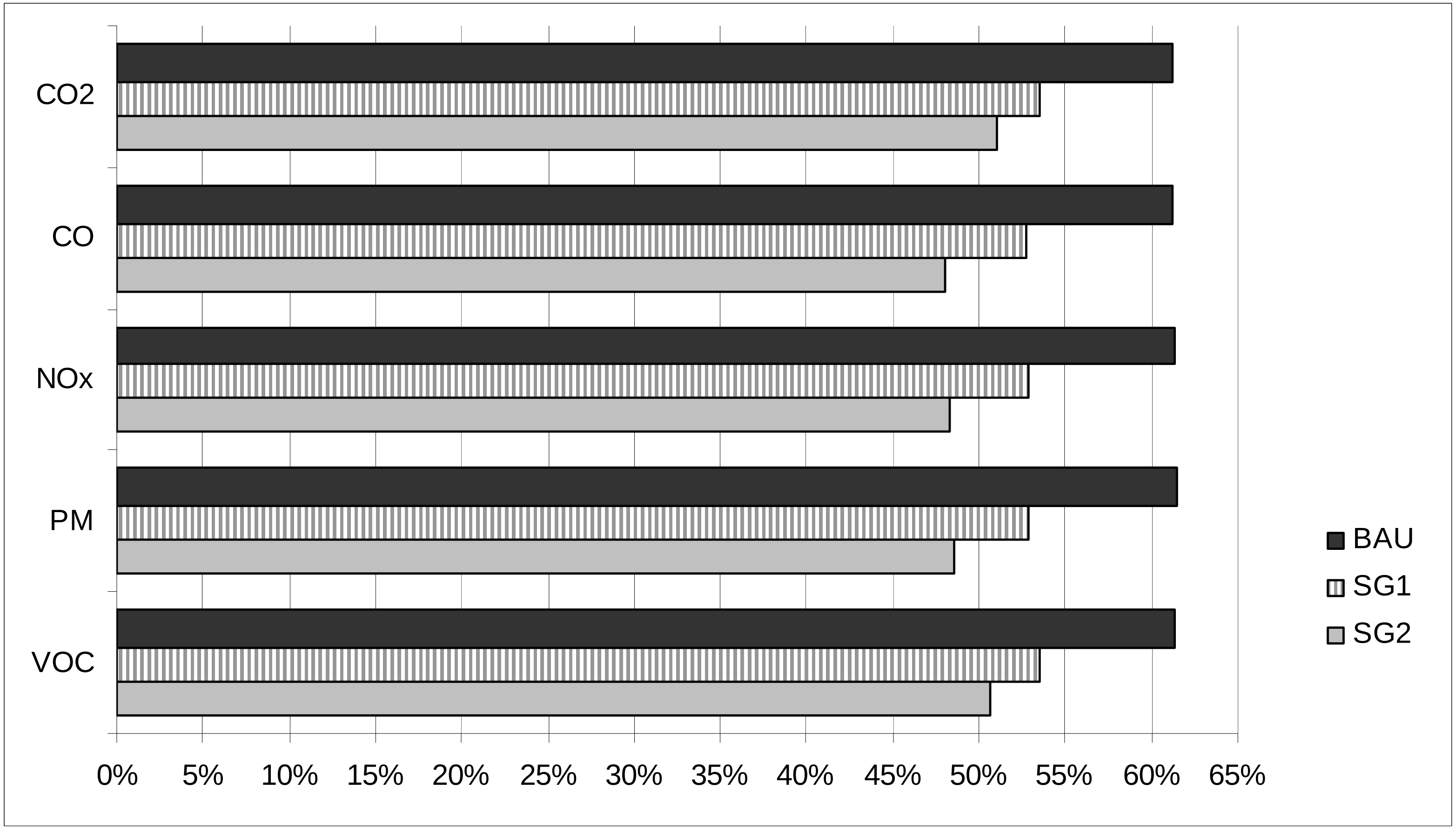


Change in Metro VMT since 2000 by Scenario



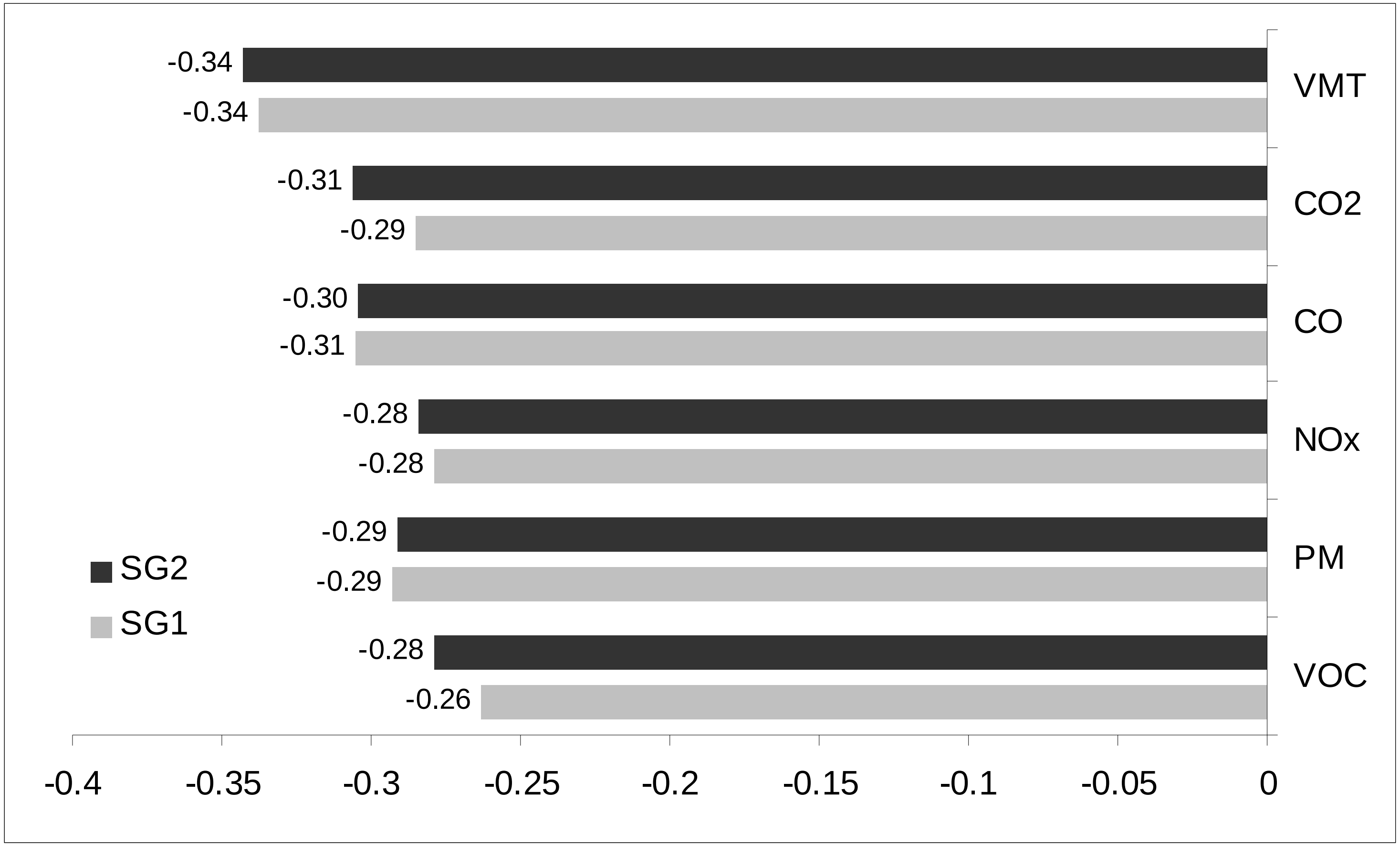
At median, VMT growth under SG2 is 24% lower than BAU

Change in Median Metro Emissions since 2000 by Scenario



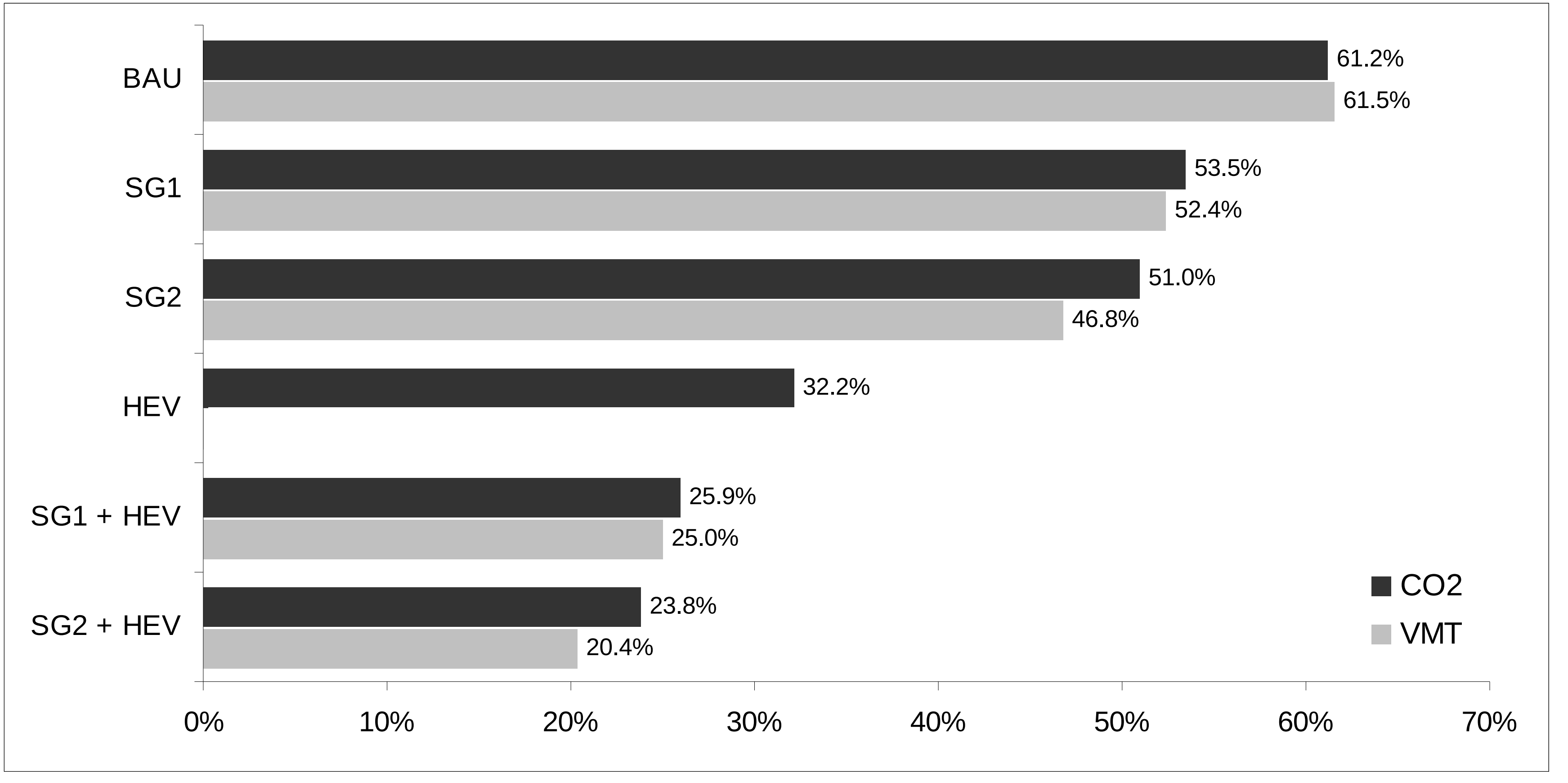
Growth in emissions under SG2 16-20% lower than BAU

Median Metro Elasticities (Density) by Smart Growth Scenario



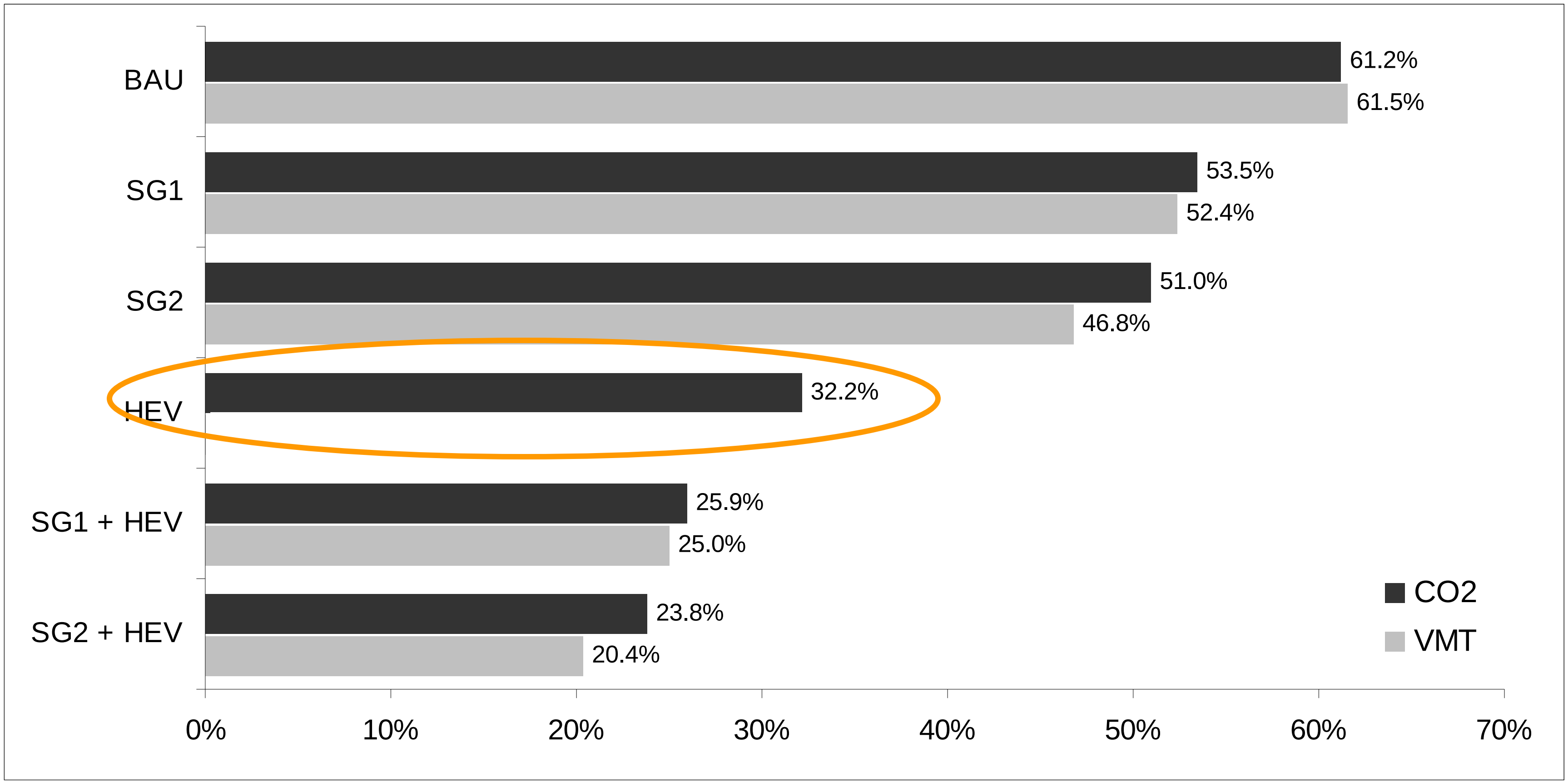
A 10% increase in population density was associated with reductions in VMT and emissions of ~3%

Change in Median Metro VMT and CO_2 since 2000 by Scenario



Combining SG2 with fleet hybridization reduces BAU growth in CO_2 by over 60% for median city

Change in Median Metro VMT and CO_2 since 2000 by Scenario



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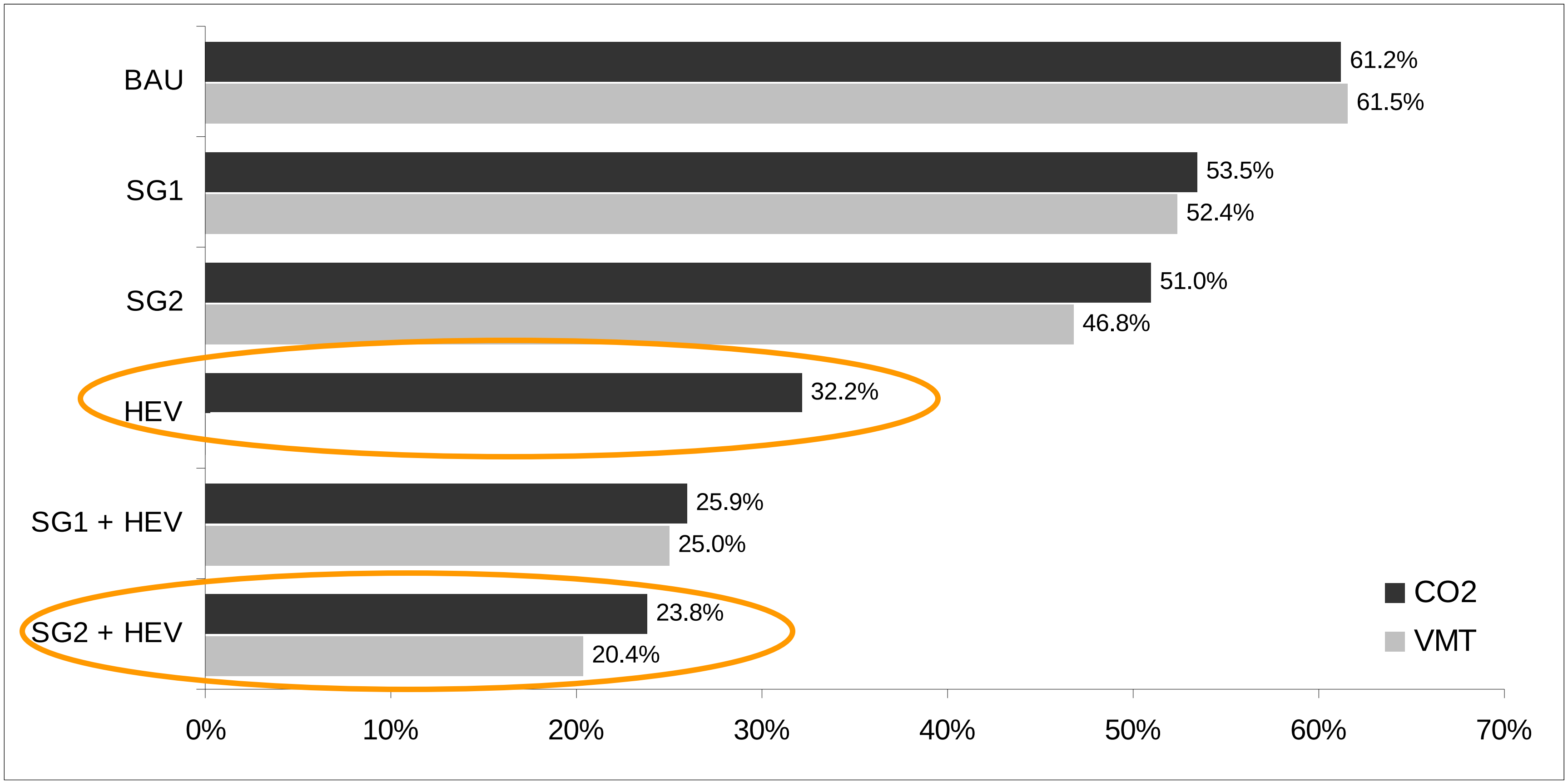
Change in Median Metro VMT and CO_2 since 2000 by Scenario

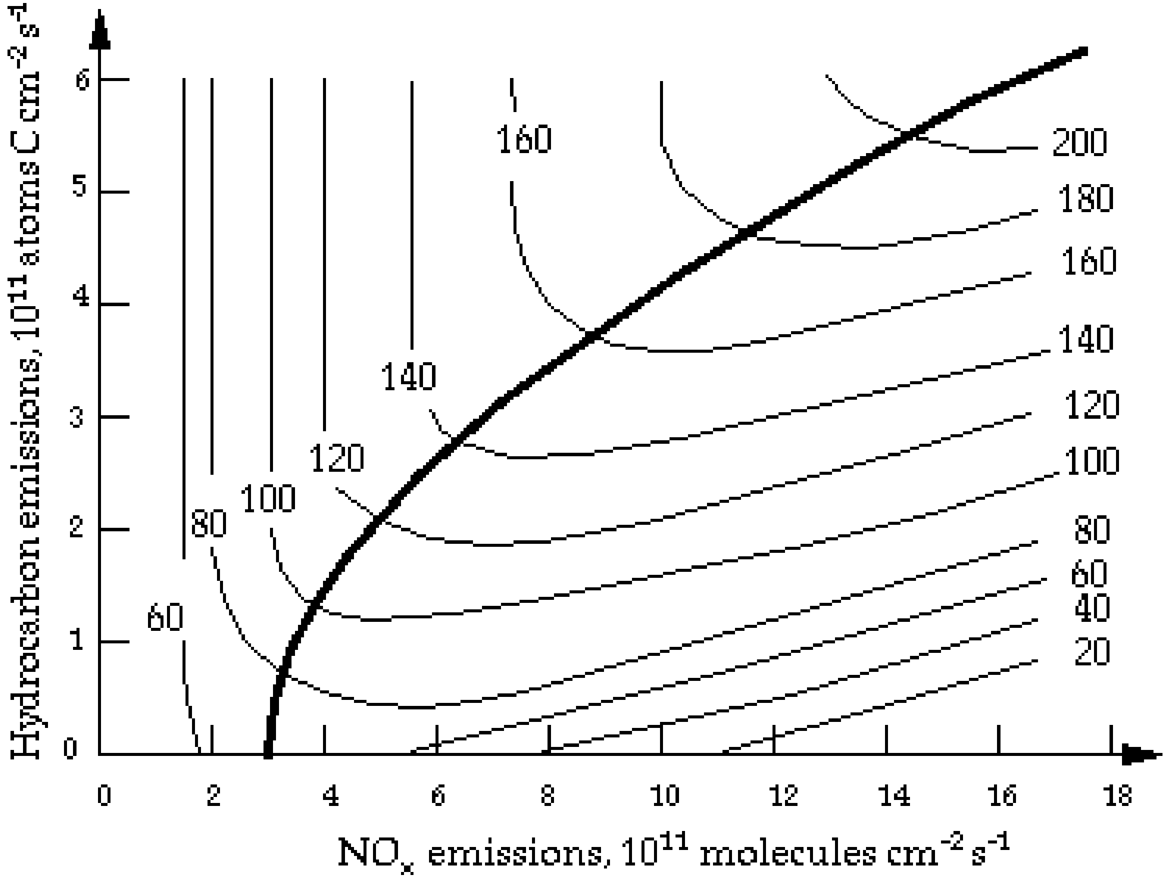


Combining SG2 with fleet hybridization reduces BAU growth in CO_2 by over 60% for median city

Air Quality Modeling Approach

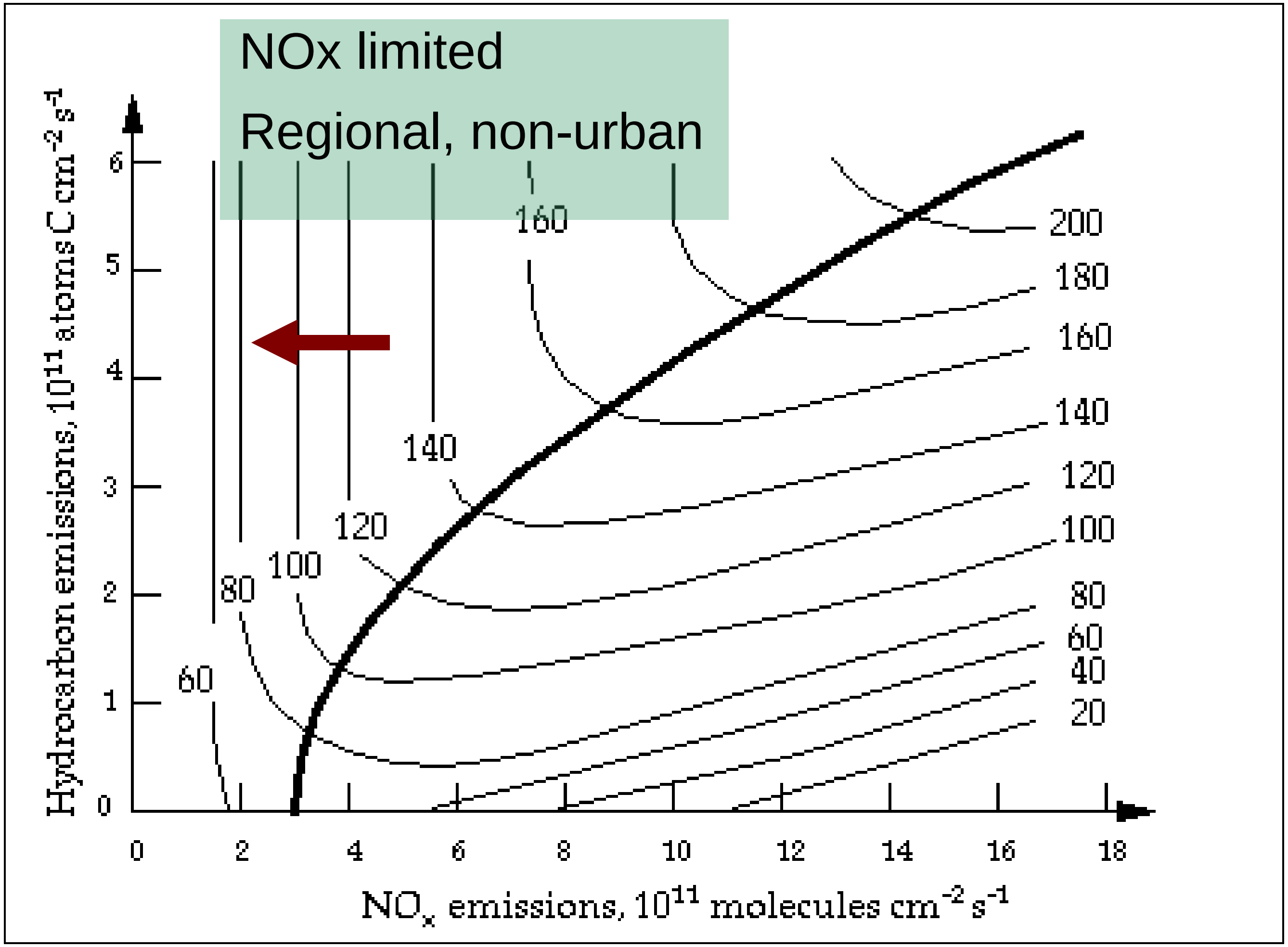
- CMAQ v. 4.6
  - -- CBIV gas-phase chemistry
  - -- RADM aqueous phase chemistry
  - -- ISORROPIA, AERO3, SORGAM SOA
- 36 km x 36 km (MM5 input from LADCO)
- 12 km x 12 km (WRF input, in-house)
- 2001 NEI (from CAIR analysis)

Ozone Isopleth Diagram



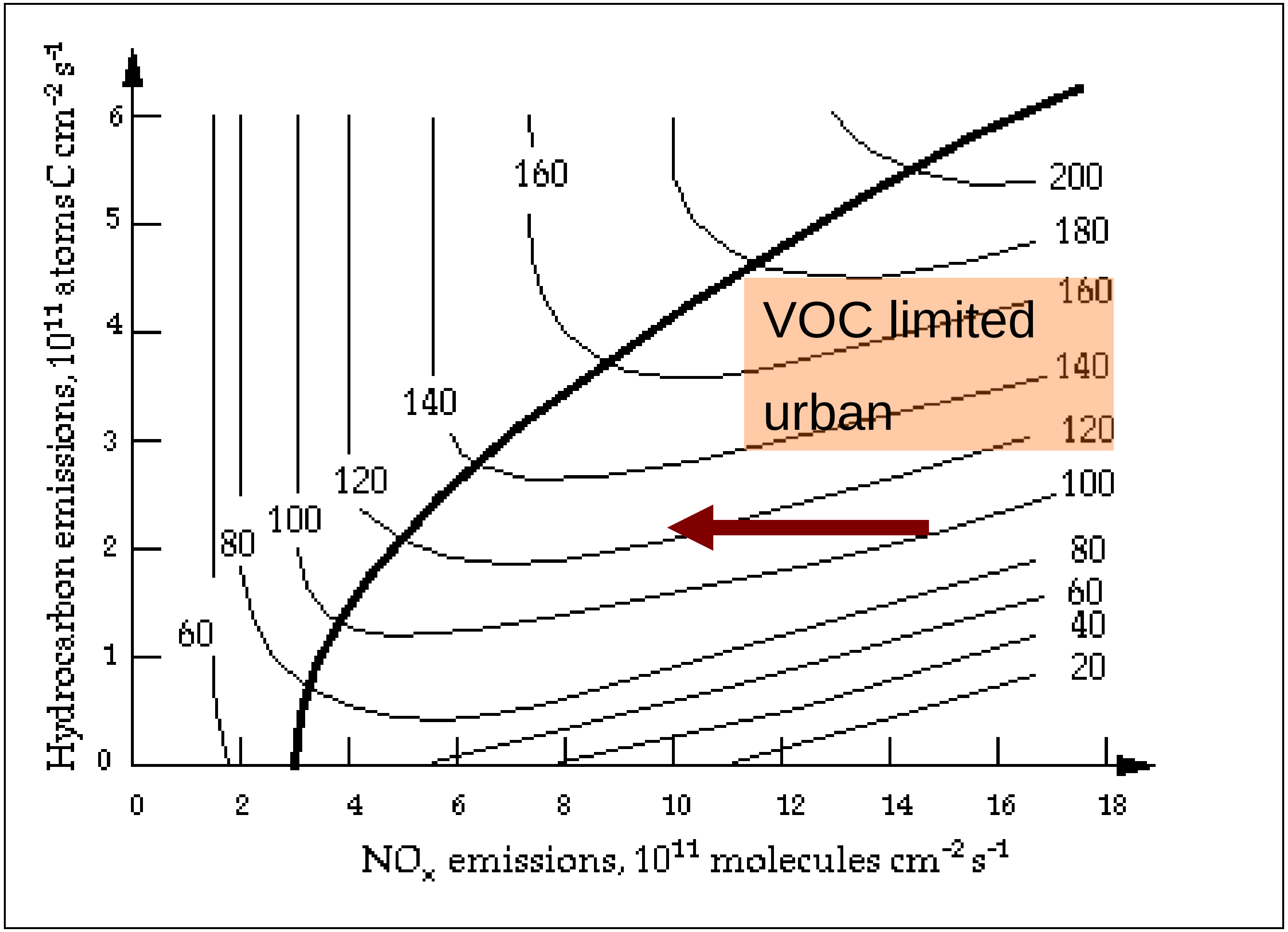
Jacob (1999), adapted from Sillman (1990)

Rural Areas Benefit from NO_x Controls



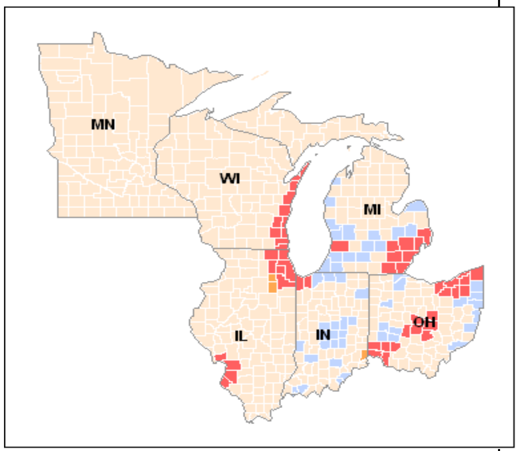
Jacob (1999), adapted from Sillman (1990)

Urban Areas May Experience O_3 *Increases* from NO_x Controls



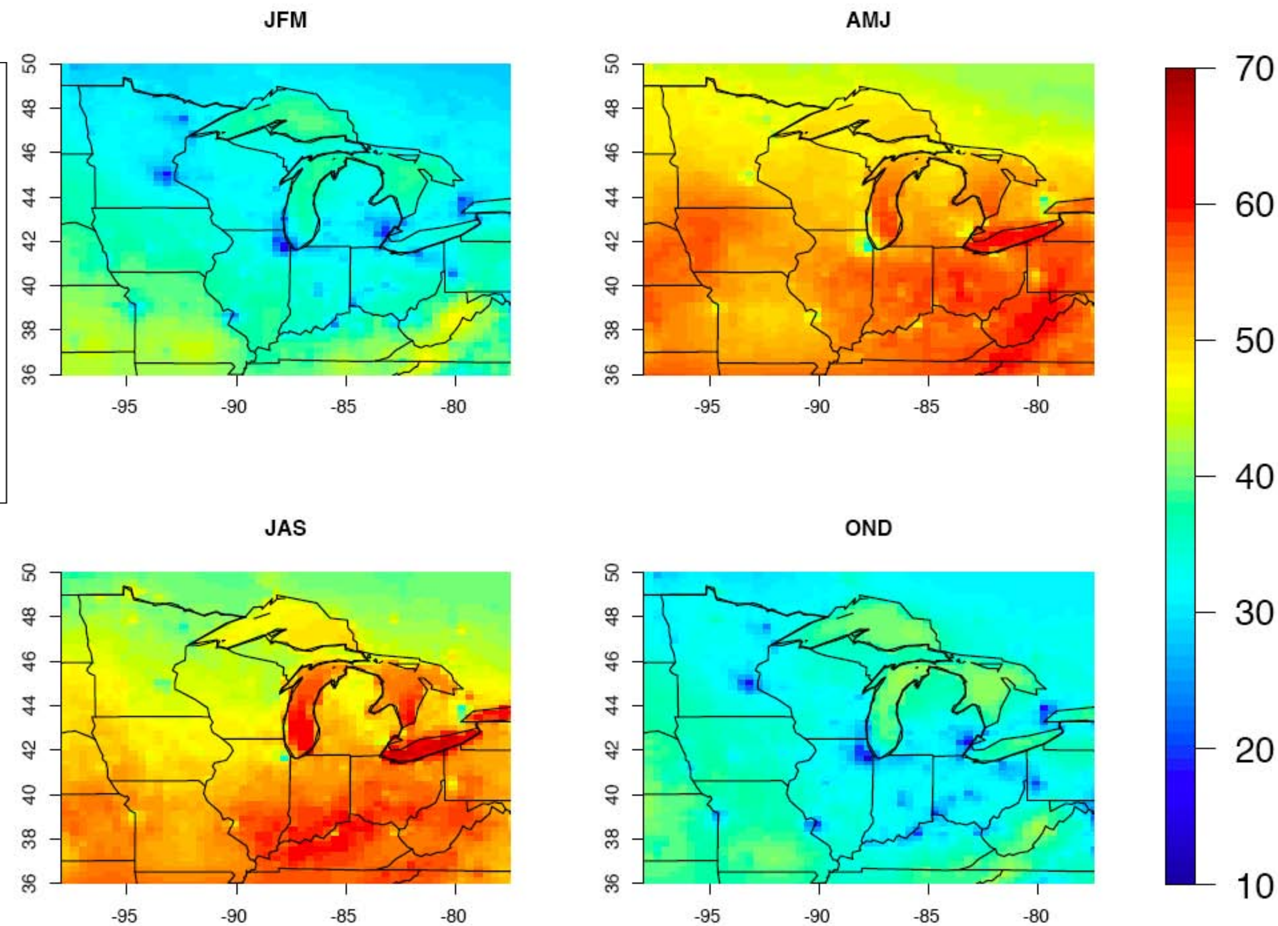
Jacob (1999), adapted from Sillman (1990)

A Unique Air Quality Region



O_3 non-attainment, EPA

Supplemental Figure 2. CMAQ simulated O_3 (ppb) in the lowest model layer, shown for each season: a) JFM; b) AMJ; c) JAS; d) OND.



Spak and Holloway, in review (JGR)



Good Skill for Current Conditions

Figure 1. CMAQ monthly performance for all PM species across the IMPROVE, STN, and CASTNet networks.

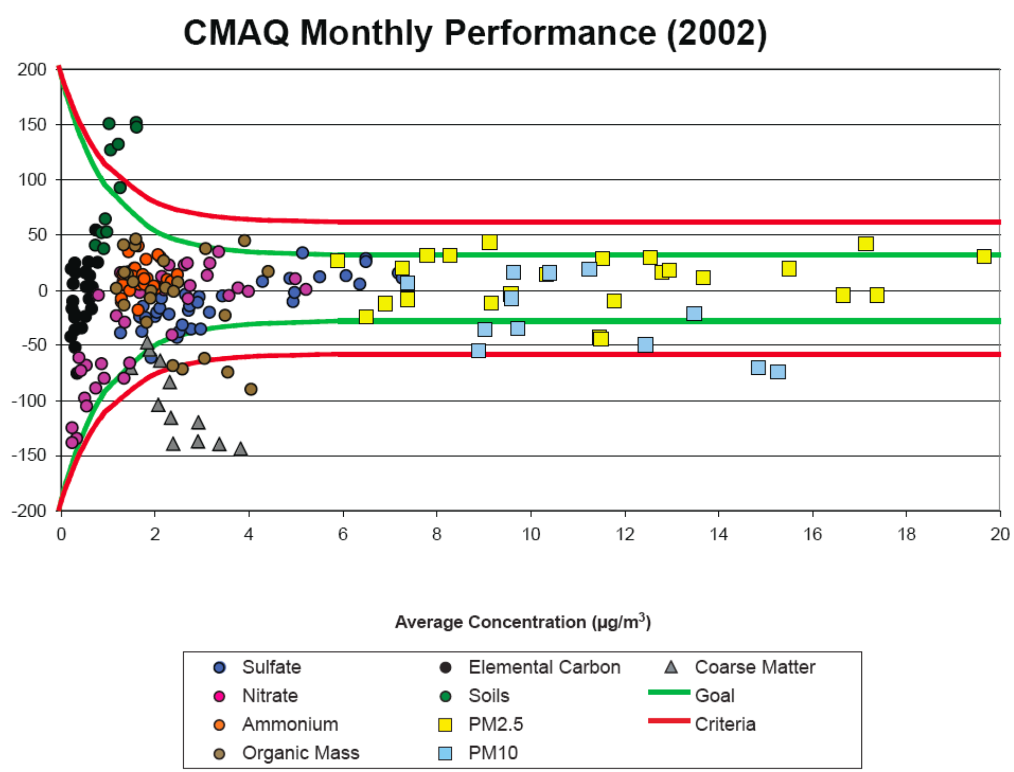
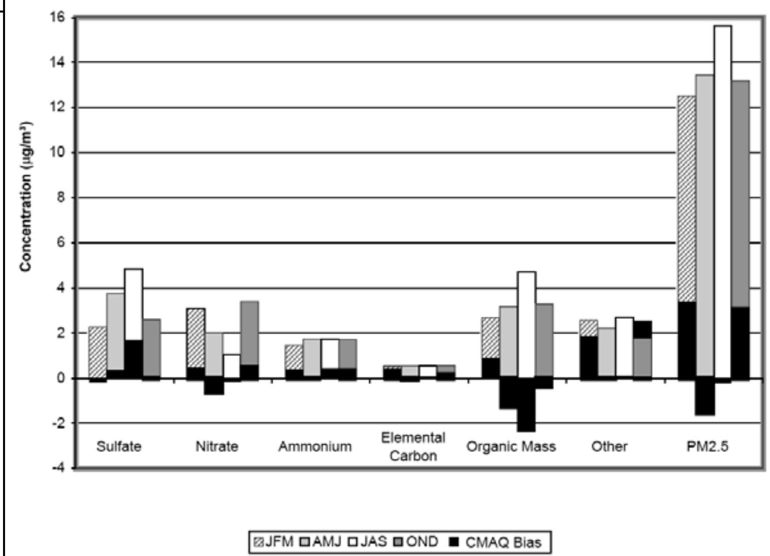
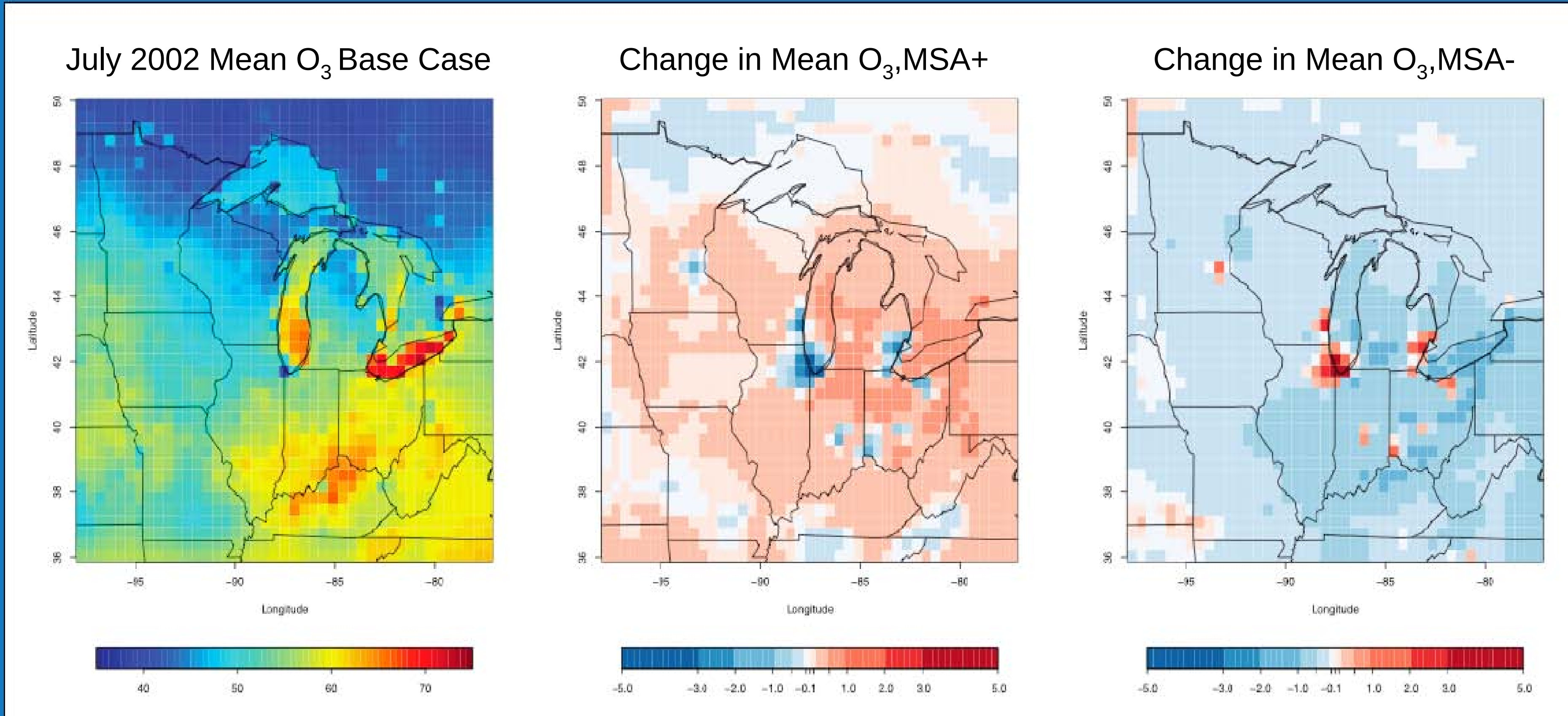


Figure 3. Seasonal average concentrations of PM2.5 and components in μg/m³, as measured at the STN measurement sites in the study region. CMAQ performance is shown as bias relative to these observed values on a seasonal basis.



Spak and Holloway, in review (JGR)



O_3 response to changes in urban emissions is nonlinear

- **Regional impact different from local changes in MSAs**
- **Biggest changes near pop. centers & over southern lakes**

Spak, Holloway, Stone and Mednick, in prep (JGR)

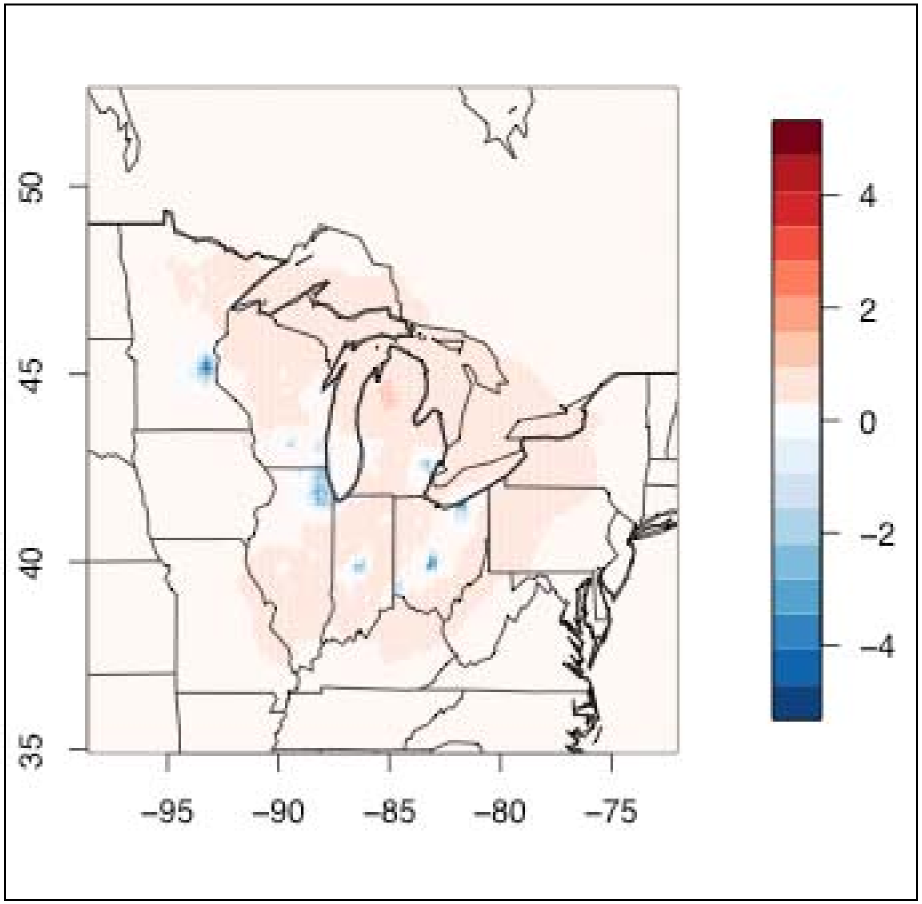
Test Case Simulations: 20% +/-

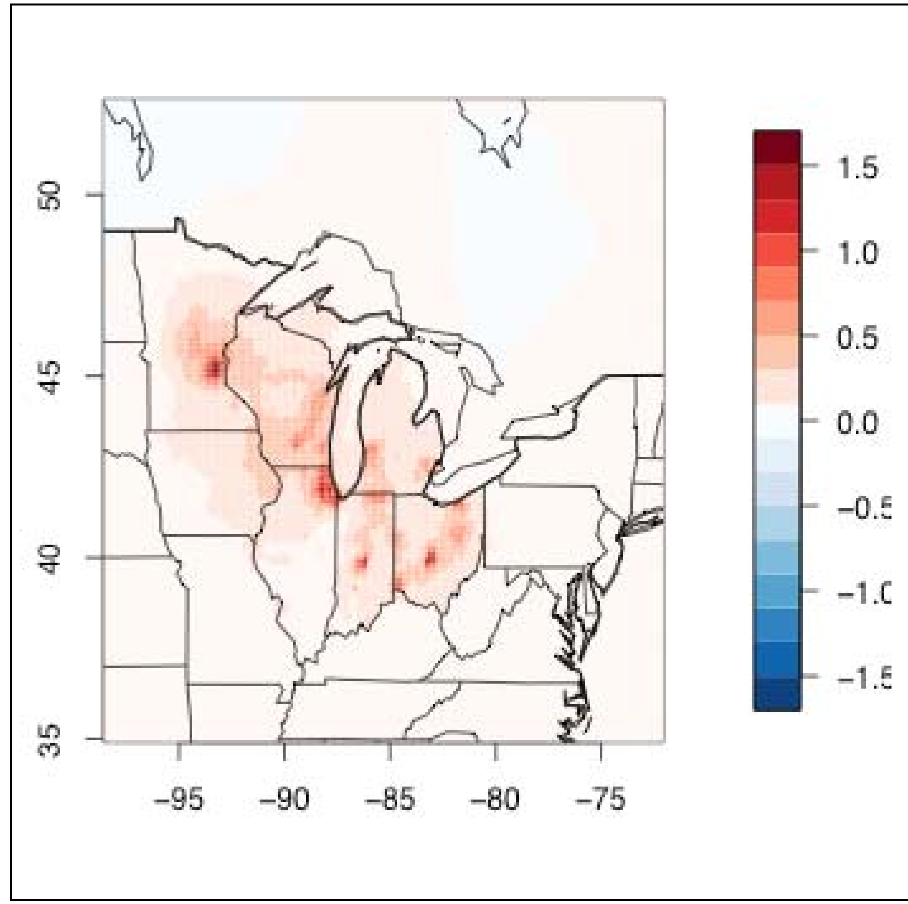


PLUTO Advancements Based on AQ Research

- Well-developed understanding of urban emissions in a regional context, especially impacts on O_3, nitrate aerosol, and SOA
- Confidence in CMAQ performance, awareness of uncertainties
- 36 km not adequate to resolve study focus… 12 km WRF used as input
- VOC-limited urban O_3 regime will complicate impacts of vehicle emissions reductions.

2050 BAU minus 2000

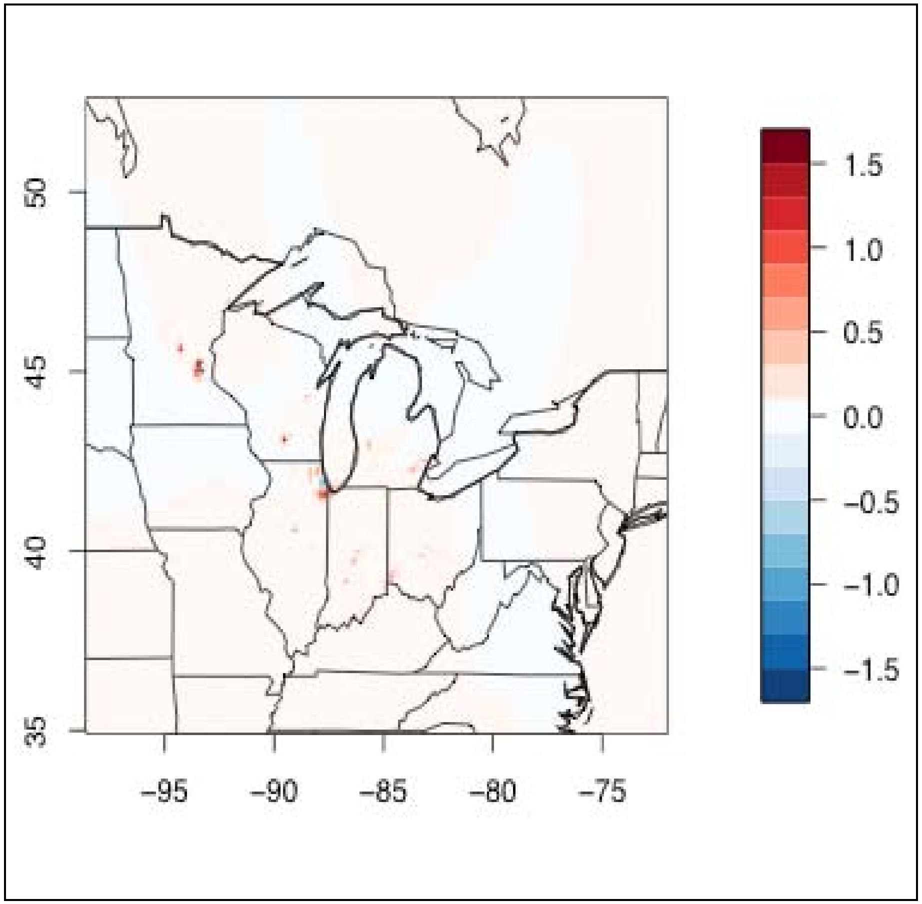




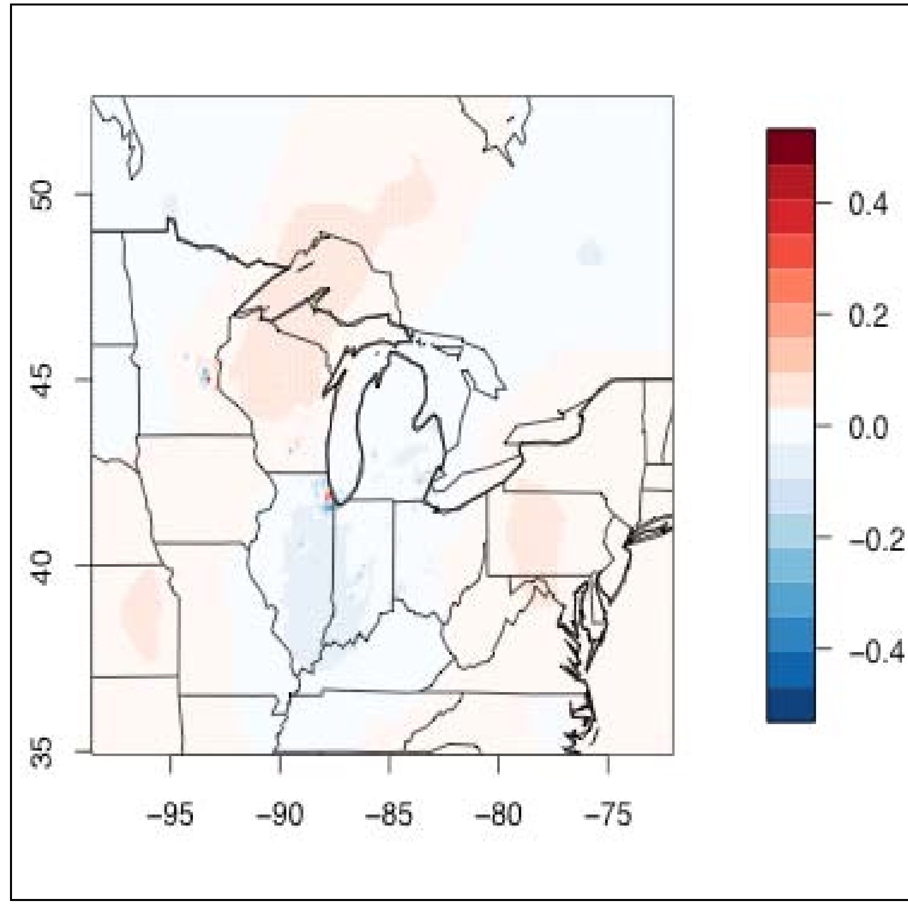
O_3 (ppb)

$PM_{2.5}$ (ug/m^3)

2050 BAU minus
2050 Smart Growth (SG2)



O_3 (ppb)



$PM_{2.5}$ (ug/m^3)



Major Findings

- ❖ Both land use and technology change were found to significantly reduce vehicle travel and emissions over time. A combined SG and HEV scenario was found to offset the expected growth in vehicle travel and emissions by more than 60% in the median city.

- ❖ PLUTO based AQ estimates illustrate the sensitivity of emission inventories and ground-level pollutant concentrations to inventory methodology and local chemical environment, especially urban vs. rural ozone production.

- ❖ Emissions reductions achieved through SG and HEV were found to be associated with mixed effects on $PM_{2.5}$ and O_3 in the most heavily urbanized areas.

Final Stages of PLUTO Analysis

- Evaluate regional distribution of impacts with respect to population

- Evaluate sensitivity of results to key uncertainties
  - -- NOx:VOC ratio as a function of cold-start fraction
  - -- Sensitivity to resolved meteorological processes
  - -- Sensitivity to CMAQ chemical mechanism

- Clarify mechanisms driving results
  - -- Urban vs. Rural O_3 production
  - -- Sensitivity to meteorological parameters (esp. BL)
  - -- Characterize nitrate and SOA, as well as $PM_{2.5}$

Future Directions

- How does the urban heat island - and other climate drivers – affect O_3 sensitivity to NOx and VOCs?
- What planning strategies maximize benefits of urban and regional air quality for O_3 and $PM_{2.5}$?
- How can current air quality analysis tools best inform regional policy-making?