US EPA ARCHIVE DOCUMENT

Air Pollution, Health and Economic Impacts of Global Change Policy and Future Technologies: An Integrated Model Analysis

Noelle E. Selin

Massachusetts Institute of Technology

Coauthors:
Tammy M. Thompson and Rebecca Saari (MIT), Sebastian Rausch (now ETH)

in partnership with NESCAUM

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Outline

1. Overview: Questions and Modeling Framework
2. Results of two resolution sensitivity studies
3. Co-benefits of climate policies for health impacts
4. Economic modeling of health impacts at US scale
5. Ongoing and future work

Research Questions

- **1) How will technologies and policy choices in response to global change impact air quality, human health and the economy on global to local scales in the next decades?**
- **2) What are the quantified costs and benefits of these different adaptation choices?**

Outcomes

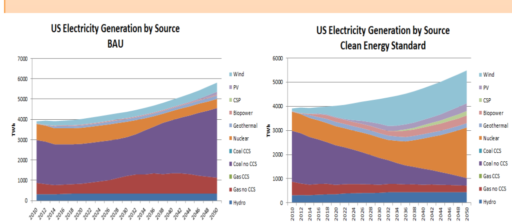
- 1) Developed **modeling capability** to facilitate better understanding of the interplay between human activities, air pollution and regulatory requirements, climate policy, and human health and large-scale economic factors at local to global scales in the next decades.
  - Accounting for uncertainty and variability
- 2) Providing insights to the air quality community **about "win-win," "win-lose" and "lose-lose" strategies for air quality regulation and climate change**, and quantifying potential human health benefits.
  - Coordinate with regional and state-level air quality decision-makers
- 3) Providing insights to the air quality community about the **potential for societal changes, especially collective choices about personal vehicle technologies and fuels, to impact air quality**, and identify potential unintended consequences of these large-scale changes.

1. A Coupled Framework for Policy Analysis

US Economy

USREP Model determines: Policy cost and benefits, economic impacts, distributional effects, co-benefits

Output by Regions and Sectors (Example below: Electricity by fuel)

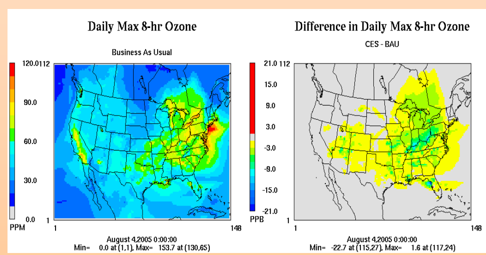


Regional Air Quality

CAMx Model determines: Attainment of standards, ambient levels for exposure

Pollution Concentration: Base Case and Difference due to Policy

(Example: Ozone)

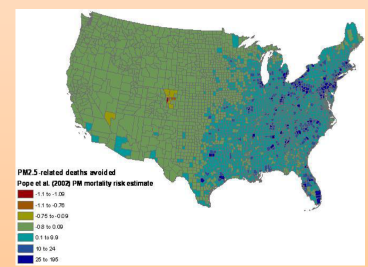


Human Health

Model determines:

Mortality, Morbidity, and Associated Costs

Changes in Exposure Determine Health Response and Economic Valuation



Concentrations, human health impacts and costs are input to USREP

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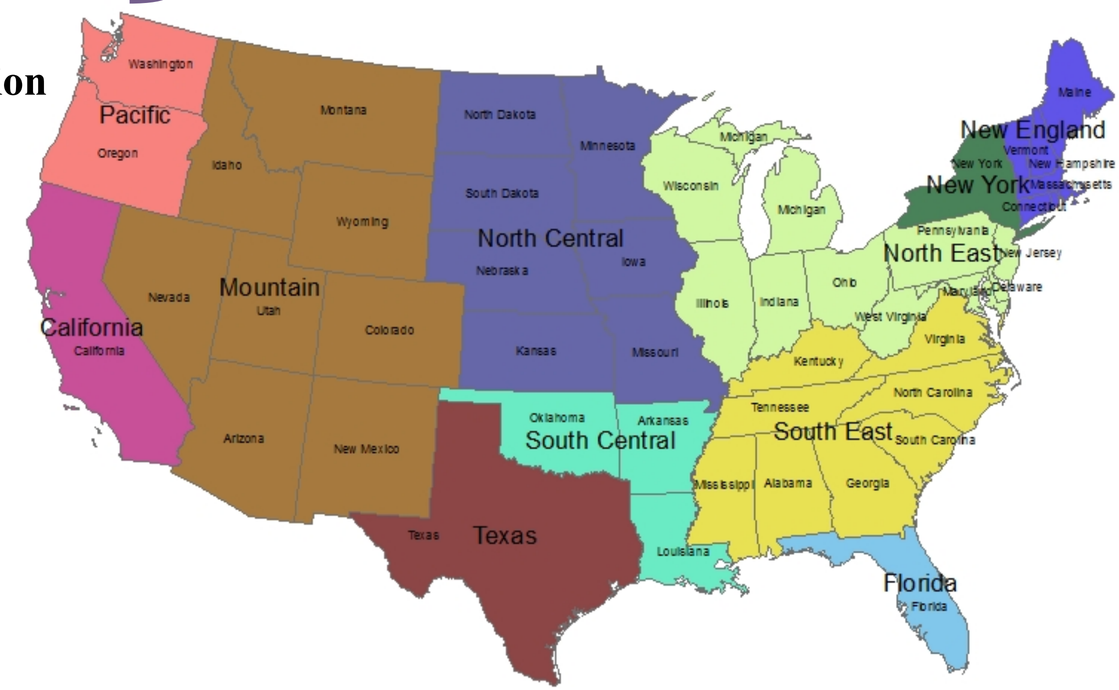
USREP: 17 Sectors and 12 Regions

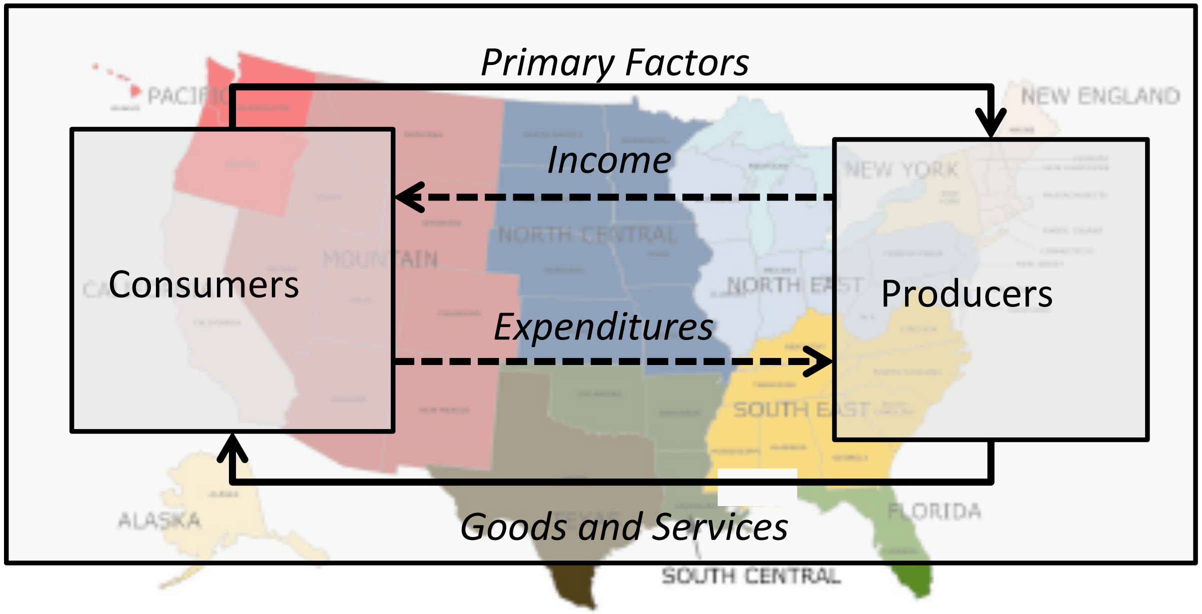
- Electric (ReEDS Model)
- Energy Intensive Industry
- Other Industry

- Coal
- Oil
- Gas

- Private Transportation
- Commercial Transportation
- Agriculture
- Services
- Crude Oil
- Petroleum
- Coal
- Gas



MIT USREP (U.S. Regional Energy Policy) Model



MODEL FEATURES

- Multi-region, multi-sector recursive-dynamic general equilibrium model
- State-level economic (IMPLAN) and energy (EIA) data
- 5 energy and 5 non-energy sectors
- Heterogeneous consumers within regions
- Federal and state government taxes and transfers
- Regional emissions for “Kyoto” greenhouse gases

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USREP Economic Sector/SCC Matching

USREP Economic Sectors

- Electric
- Energy Intensive Industry
- Other Industry

(fuels: Coal, Oil, Gas)

- Private Transportation
- Commercial Transportation
- Agriculture
- Services
- Crude Oil
- Petroleum
- Coal
- Gas

Industry Focused Standard Classification Codes (SCC)

Used in Air Quality Modeling to Identify Source Types

Example: Coal-Fired Power Plants

SCC codes 101001xx, 101002xx, 101003xx, and 101008xx (where x represents any number) are assigned to the USREP electric sector fueled by coal

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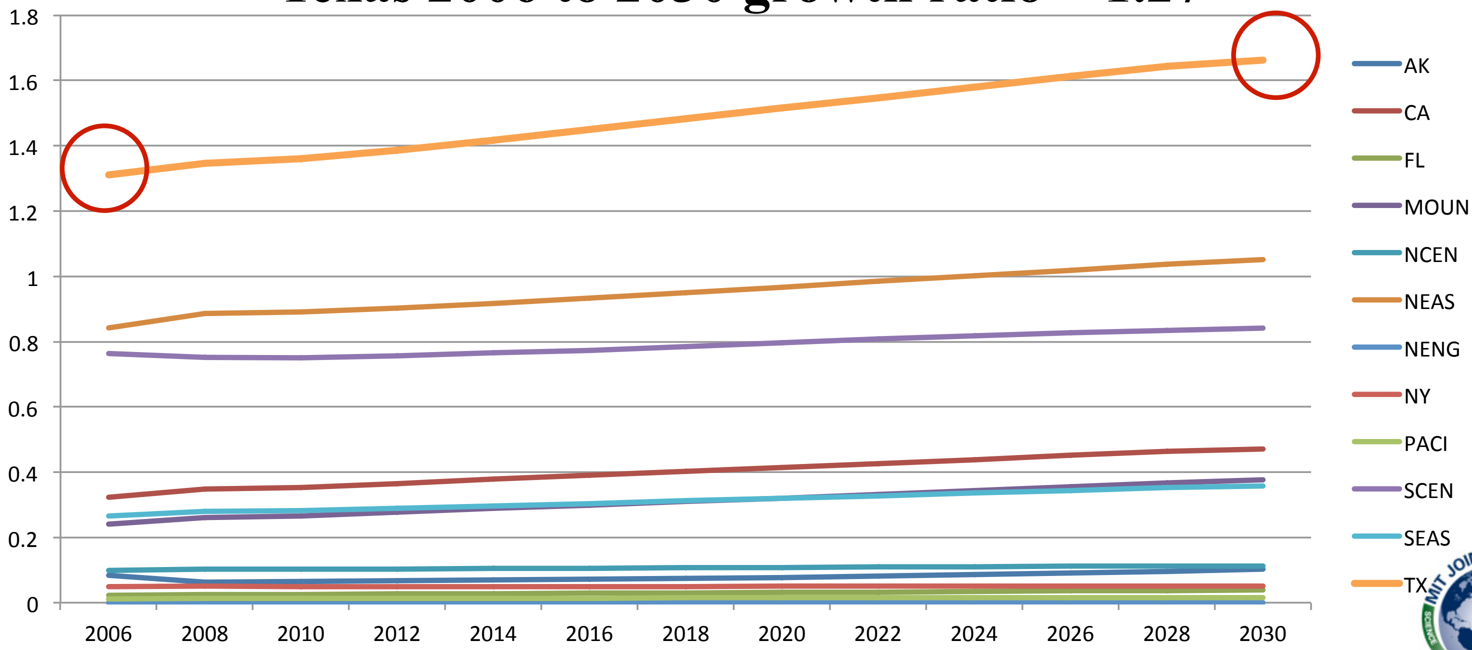
Linking USREP output to Emissions

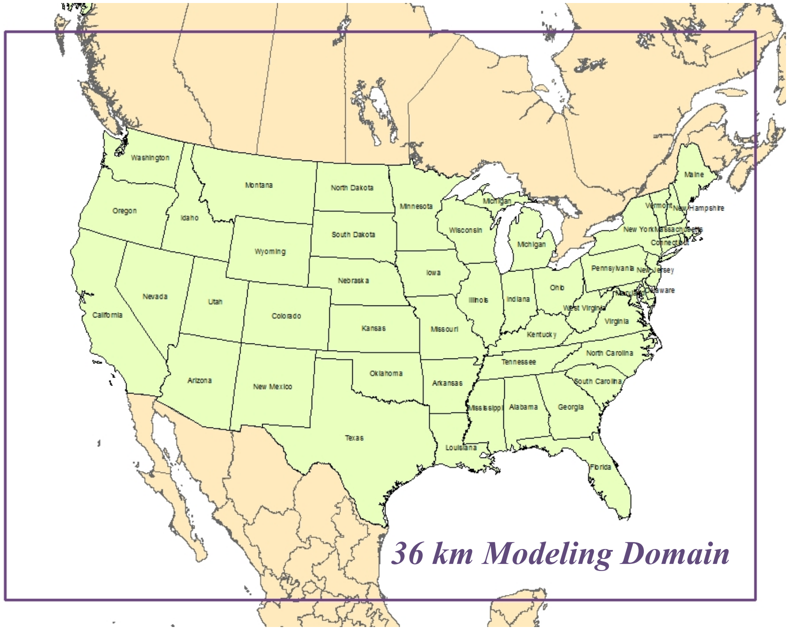
Example: **Energy Intensive Industry fueled by gas**

Texas baseline 2006 fuel input = 1.31 (Quad Btu)
Texas 2030 fuel input = 1.66 (Quad Btu)
Texas 2006 to 2030 growth ratio = 1.27



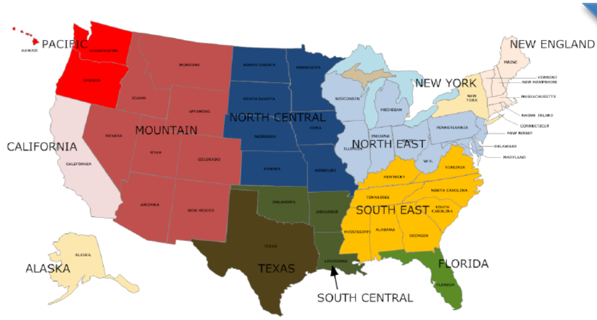
Comprehensive Air quality Model with extensions (CAMx)

- Model the chemical and physical processes that impact pollution production, movement and destruction in the atmosphere
- Year-long modeling episode was developed by the U.S. EPA for CSAPR
  - Basecase (actual) 2005 emissions inventories
  - The meteorological inputs were developed by the U.S.EPA using the Pennsylvania State University/ National Center for Atmospheric Research Mesoscale Model (MM5) and represent conditions as they occurred in 2005



USREP Health Effects

CAMx population-weighted ozone, PM concentrations by region, income group (GIS)



Health impact functions based on BenMAP calculate number of mortalities, morbidities

USREP calculates economic losses to welfare by region, income group (including labor, leisure) due to morbidities and mortalities, taking into account whole economy and feedbacks

Previous studies show that static approaches underestimate impacts of air pollution (Matus et al., GEC, 2012; Nam et al., 2011; Selin et al., 2009)

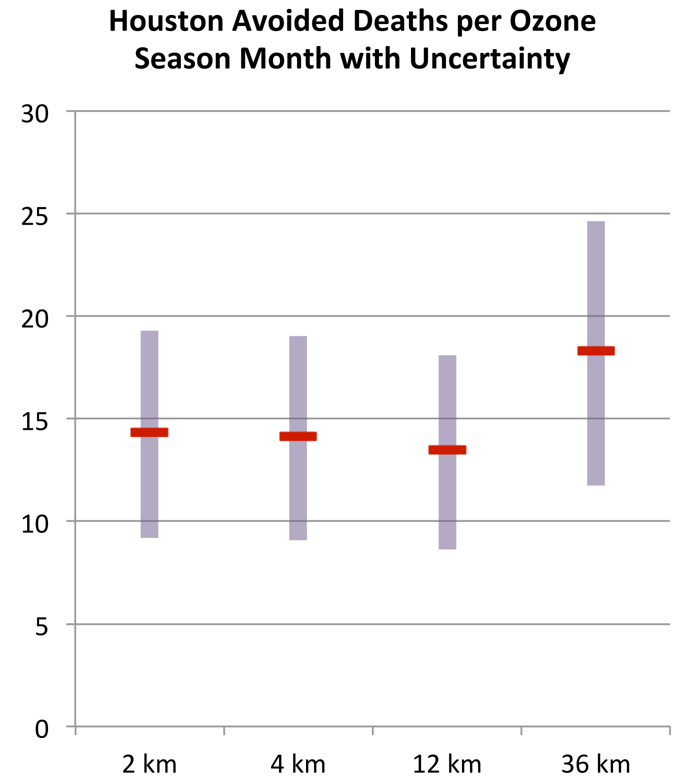
2. Results of two resolution sensitivity studies

Validating the coupled model: we would like to take into account uncertainty and variability. What resolution do we need to model at? Study setup:

1. Conduct air quality modeling with same inputs at multiple resolutions
2. Calculate changes in population-weighted concentrations of ozone and fine Particulate Matter ($PM_{2.5}$)
3. Estimate avoided mortality with 95% confidence interval

Model Resolution Study Part I

- Finding: 36 km Resolution has the potential to over-estimate human health benefits
- Proof of Concept: However, this study only looked at one location, Houston, and one pollutant, Ozone, therefore limited result applicability



Thompson, T.M., N.E. Selin: Influence of air quality model resolution on uncertainty associated with health impacts, *Atmospheric Chemistry and Physics*, 12, 9753-9762, 2012.

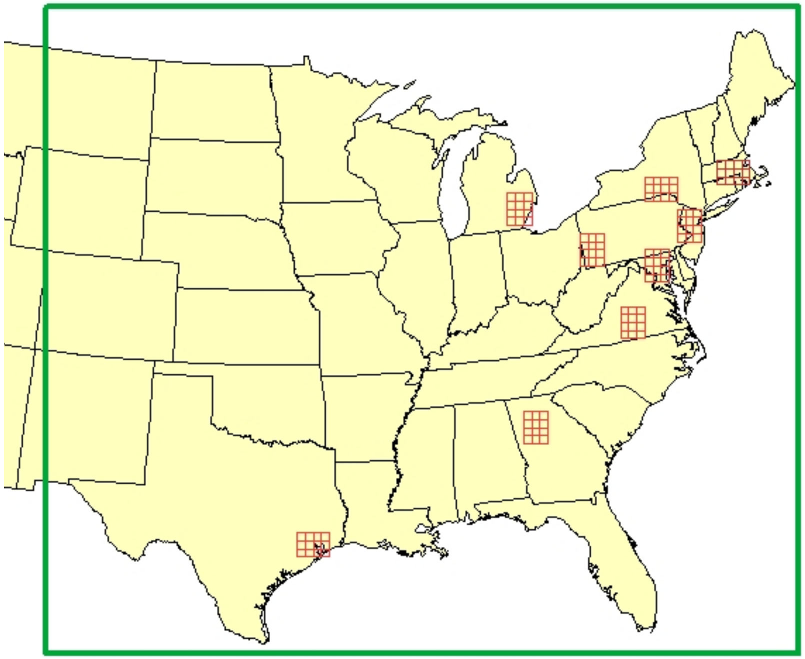
Model Resolution Study part II

1. **Expand analysis to include $PM_{2.5}$**
2. **Model nine regions of the US**
3. **Model a full year**
4. **Utilize BenMAP**

Model Parameters:

- CAMx version 5.3
- SMOKE version 2.7
- Episode Developed by US EPA for evaluation of CSAPR
  - 36 km, 12 km, and 4 km Resolution
  - 2005 Base Case Emissions
  - 2014 Control Case Emissions
  - MM5 developed meteorological inputs representing conditions as they occurred during the full year 2005 (4 km met data is interpolated from 12 km resolution)

Domains Selected for Variability



4 km Regions

Varied Meteorological and Emissions Characteristics:

Coastal/Inland

Rural/Urban

Attainment/Non-Attainment

1. **Houston**
2. **Detroit**
3. **Atlanta**
4. **Washington DC**
5. **New York City**
6. **Boston**
7. **Western Pennsylvania**
8. **Virginia**
9. **New York**

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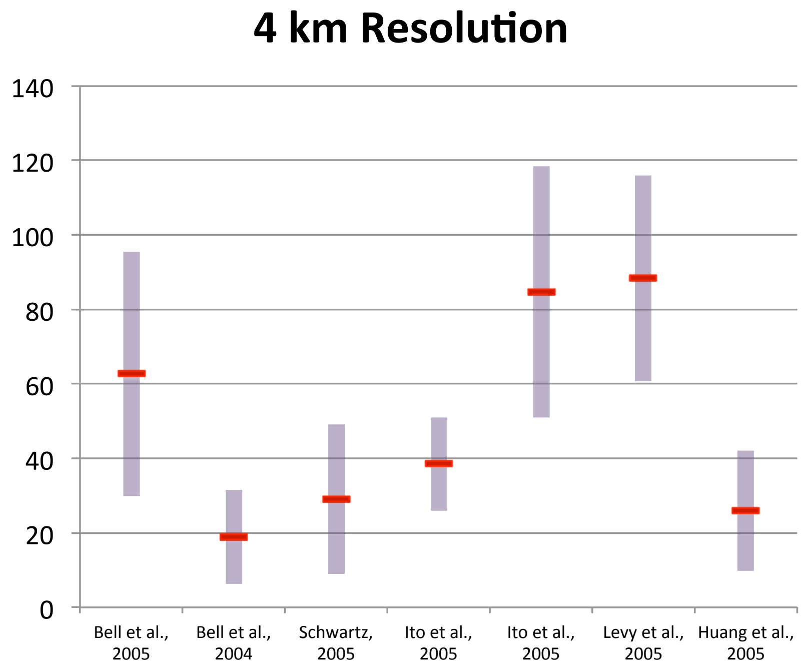
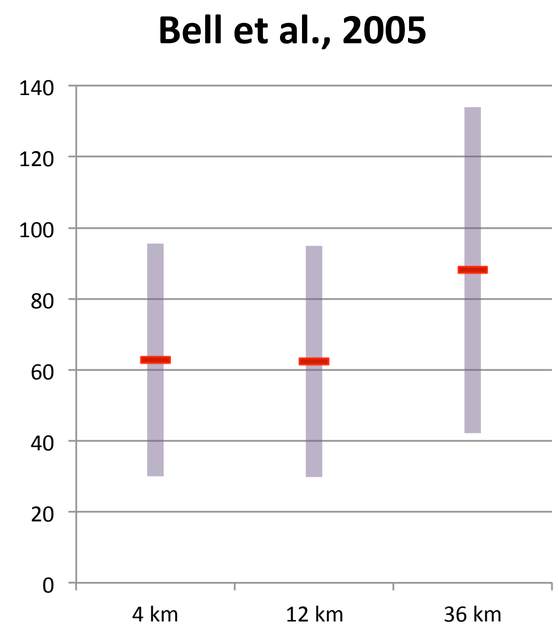
Health Function vs Model Resolution

Ozone season avoided mortalities in Atlanta

- Single resolution, multiple health response functions (left)
- Single health response, multiple resolutions (right)

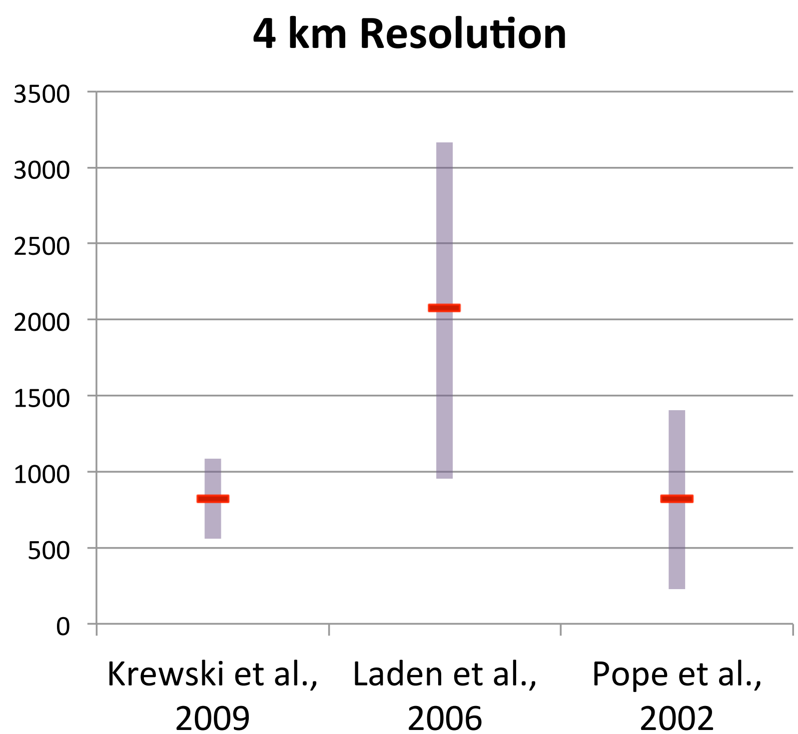


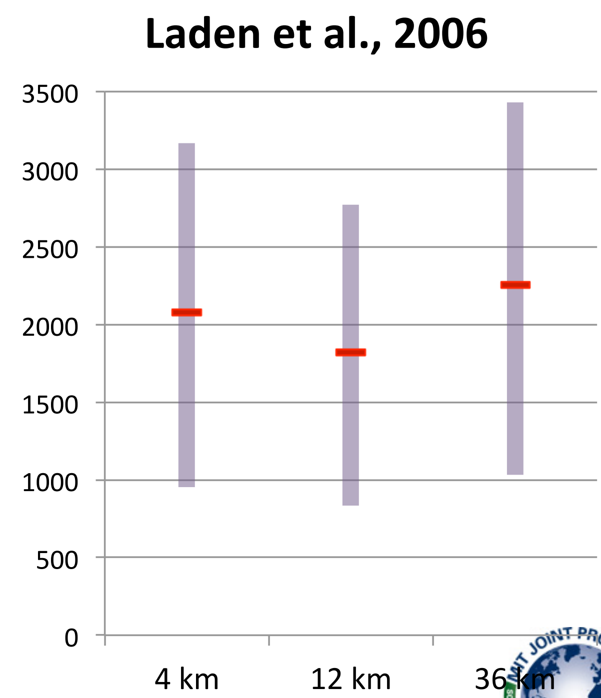


Health Function vs Model Resolution

Annual $PM_{2.5}$ avoided mortalities in Atlanta

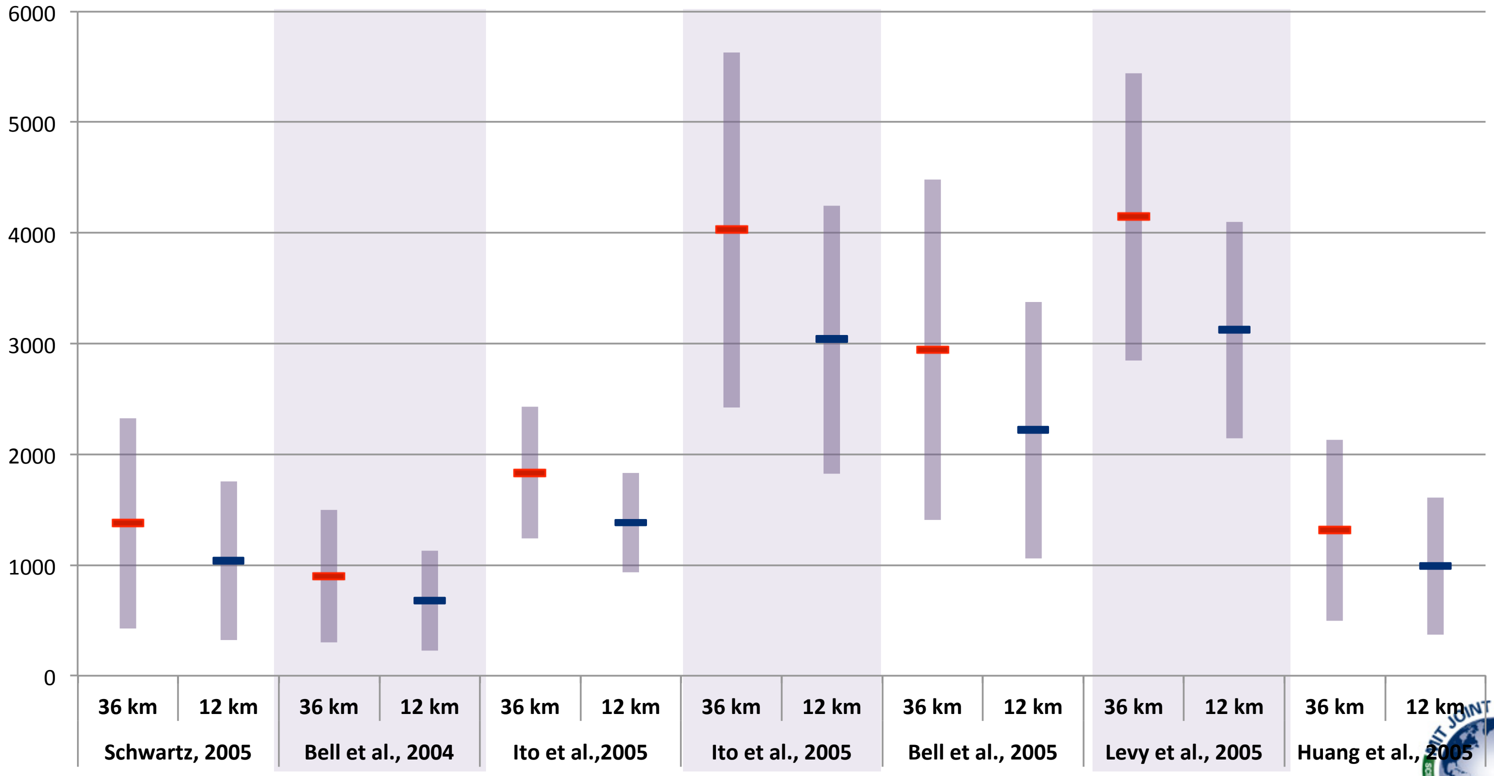
- Single resolution, multiple health response functions (left)
- Single health response, multiple resolutions (right)





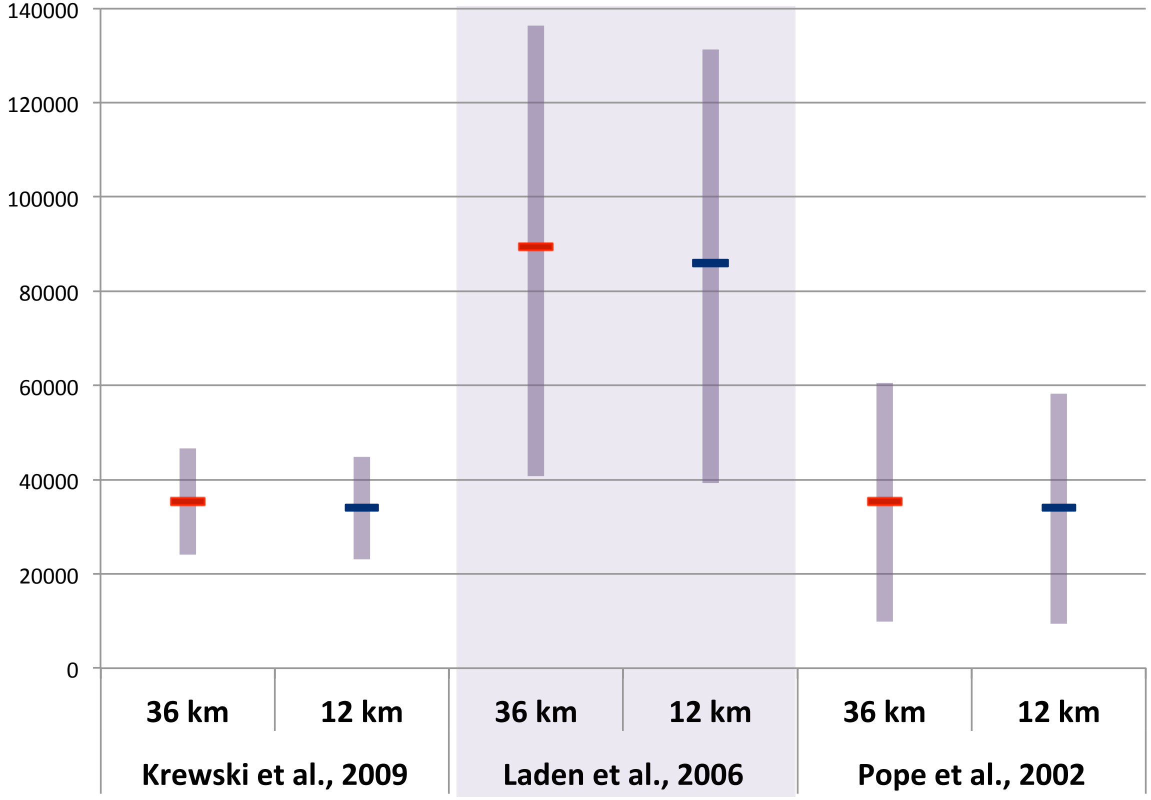
Total Ozone Mortalities Eastern US

Ozone season avoided mortalities in the Eastern US calculated at 36 km (red) and 12 km (blue)



Total PM Mortalities Eastern US

Annual $PM_{2.5}$ avoided mortalities in the Eastern US calculated at 36 km (red) and 12 km (blue)



Main Findings from Part II

Mortality Estimations:

- Ozone is more sensitive to resolution than $PM_{2.5}$
  - Likely due to the larger health impacts associated with $PM_{2.5}$ (therefore larger confidence interval) as well as the mix of primary and secondary species
- Urban areas are more sensitive to resolution than rural areas
  - Population and emissions distributions are more homogenous
- Results are more sensitive to concentration response function selection than model resolution
- **Modeling at <36 km does not improve our bottom-line results**

3. Co-benefits of carbon policy for air pollution health impacts

Semi-coupled approach using USREP+CAMx+BenMAP

1. **Business As Usual** – No carbon policy.

Maintain constant total carbon reduction
(1.1 Billion metric tons in 2030)
across all three policy options

2. **Clean Energy Standard**
3. **Cap and Trade**
4. **Transportation Carbon Cap**

Clean Energy Standard

Assumes 80% “clean energy” in 2035 and a linear progression starting at 42% in 2012.

	% "Clean"
Renewables	100%
Nuclear	100%
Natural Gas with CCS	95%
Coal with CCS	90%
Natural Gas Combined Cycle	50%

- Consistent with Obama’s State of the Union Address in 2011
- 17% (1.1 Billion metric tons) reduction in 2030
- 42% reduction in carbon from electricity sector

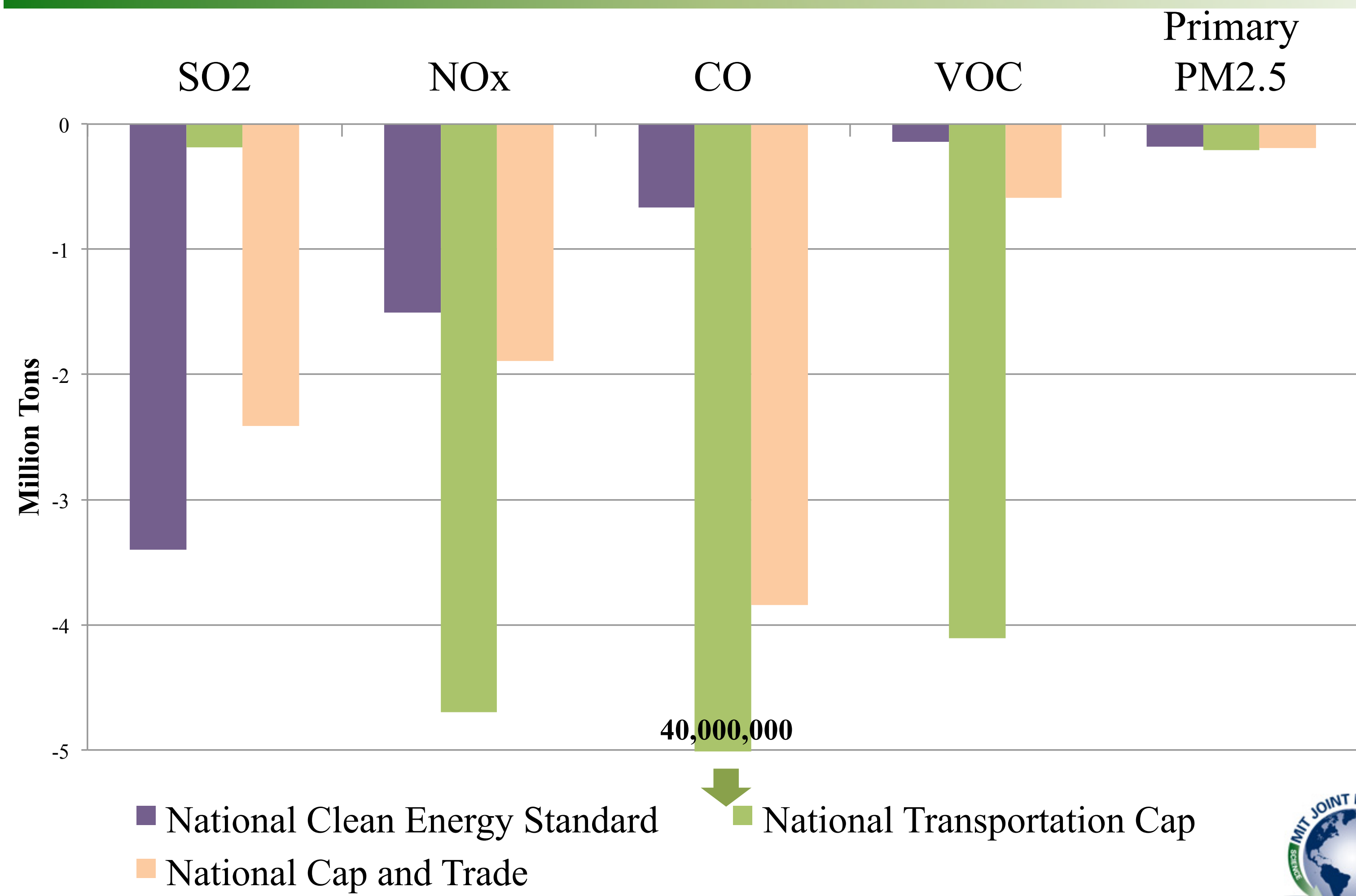
Transportation Carbon Cap

- 17% (1.1 Billion metric tons) reduction in 2030
- Cap applied to private vehicle fleet only
- 67% reduction in carbon from private transportation sector
- More stringent than CAFÉ standards
- Likely to cost more than CES

Cap and Trade

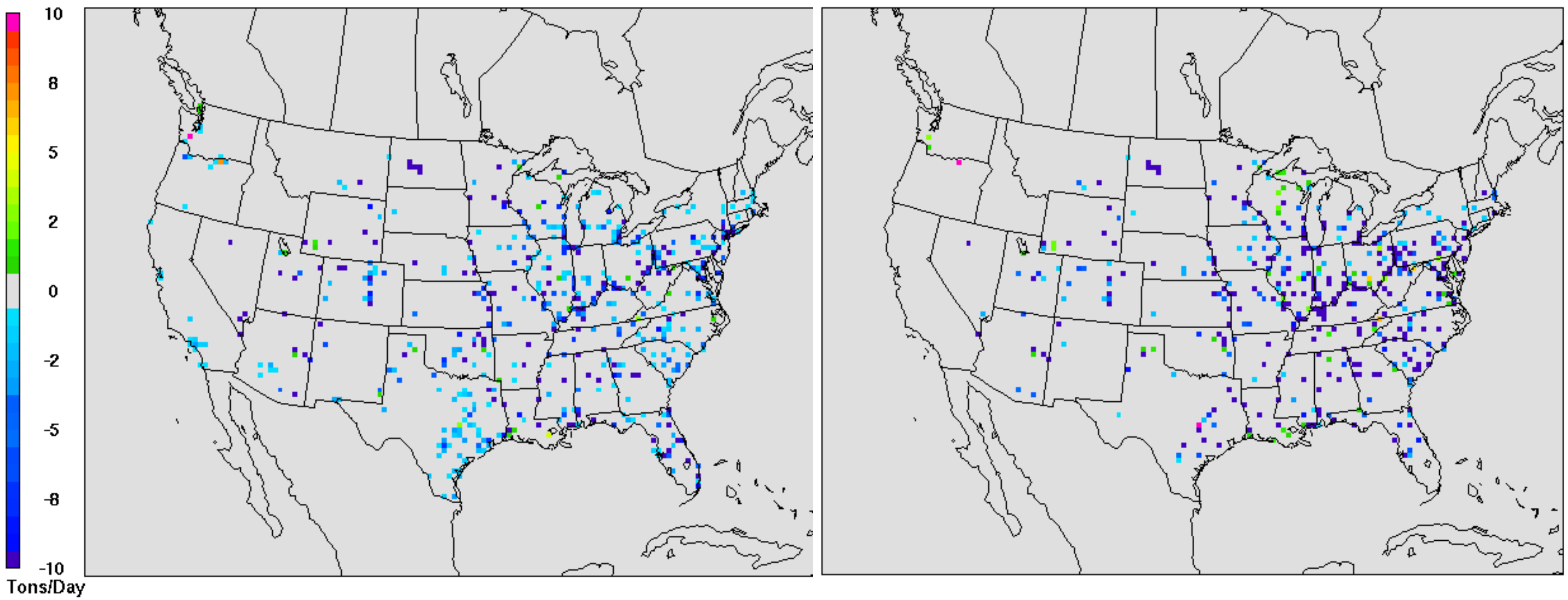
- 17% (1.1 Billion metric tons) reduction in 2030
- Less stringent than Waxman-Markey
- Cap applied to all sectors of the US Economy
- Likely to be cheaper than CES

Annual Emissions Changes due to US Carbon Policies (relative to BAU)



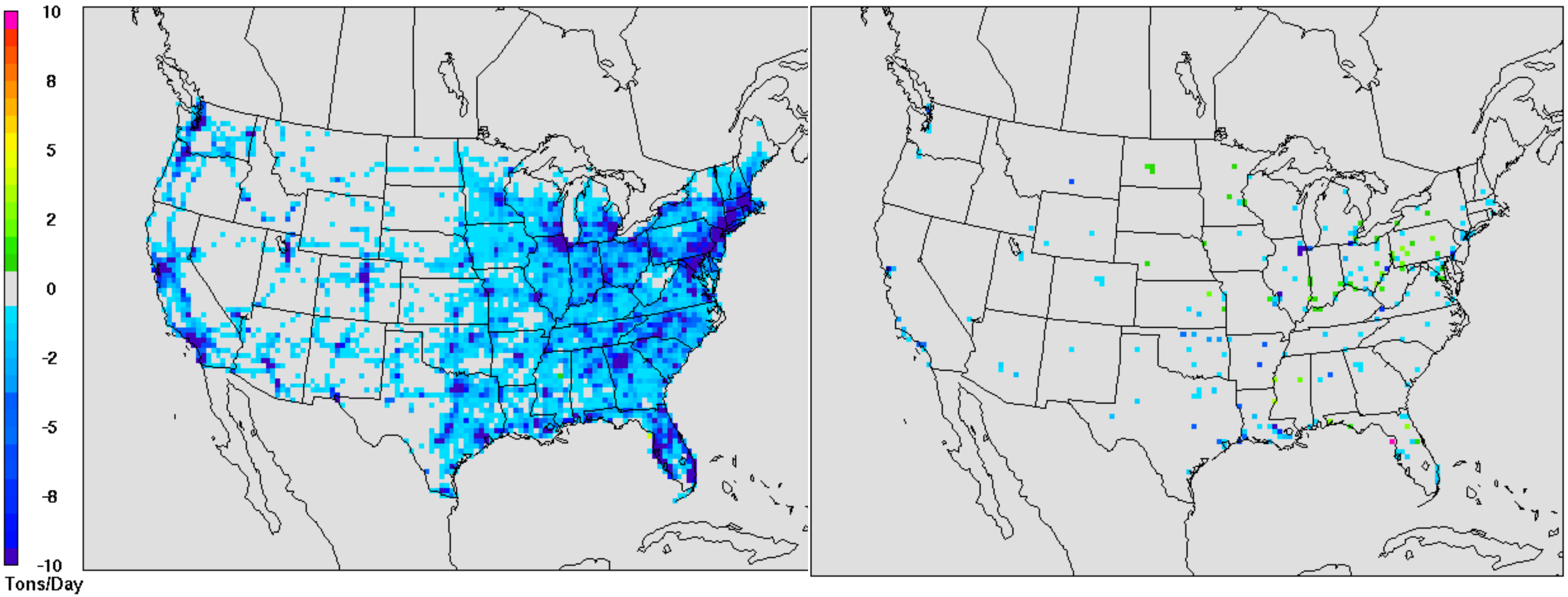
Clean Energy Standard: Impacts Point Sources

NO_x **SO_2**



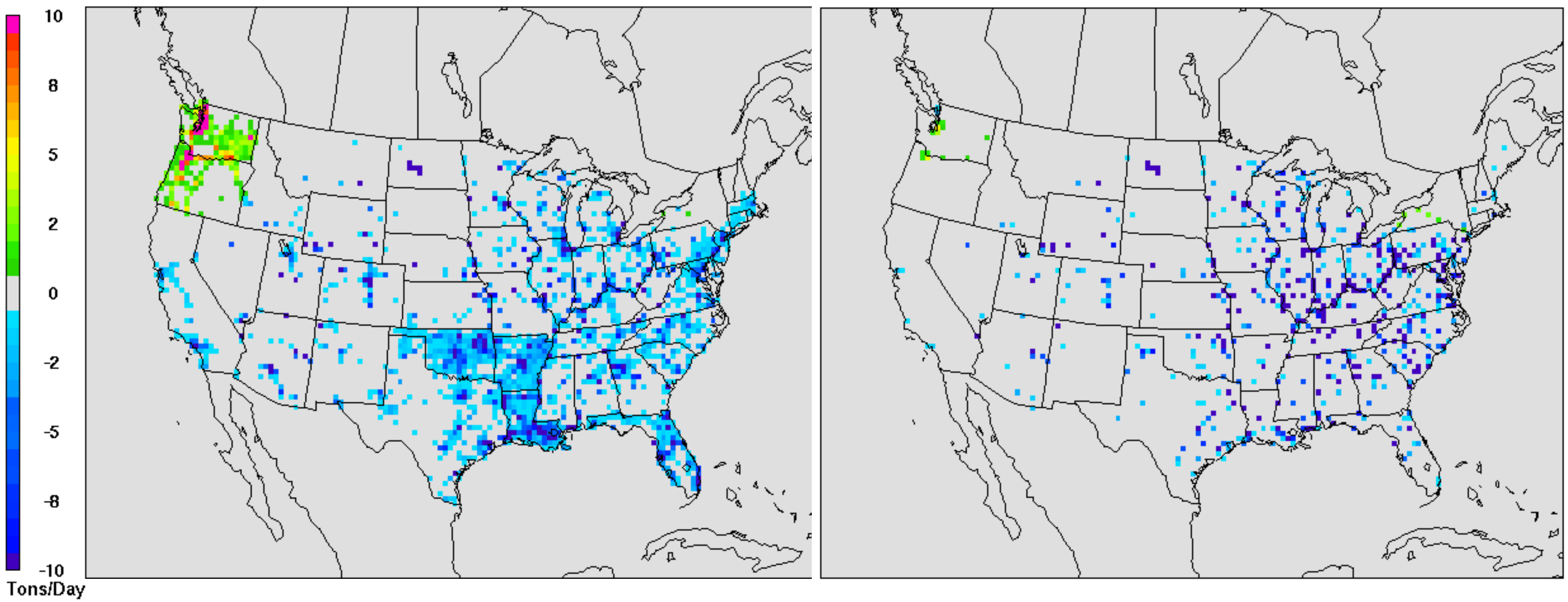
Transportation Cap: Impacts Area Source NO_x

NO_x SO_2



Cap and Trade: Impacts Area and Point Sources

NO_x **SO_2**



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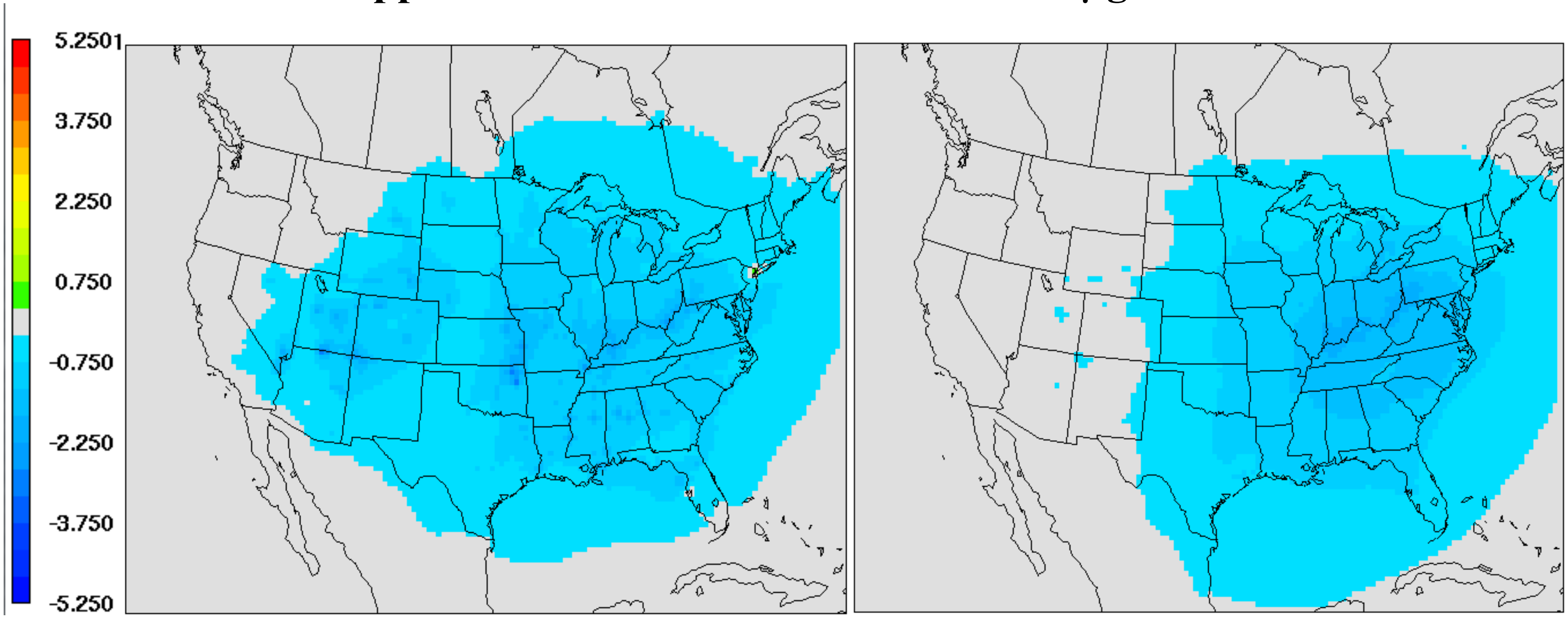
Clean Energy Standard: Widespread Air Quality Improvements

O_3 (ppb)

75 ppb Limit

$PM_{2.5}$ (μg/m^3)

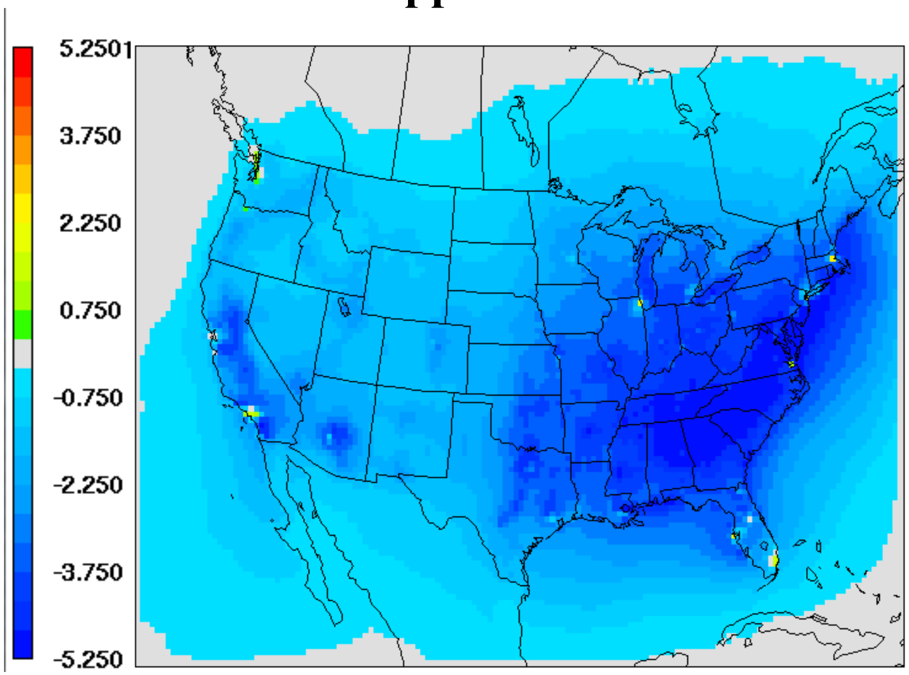
15 μg/m^3 Limit



Transportation Carbon Cap: More influential (positively and negatively) on Ozone

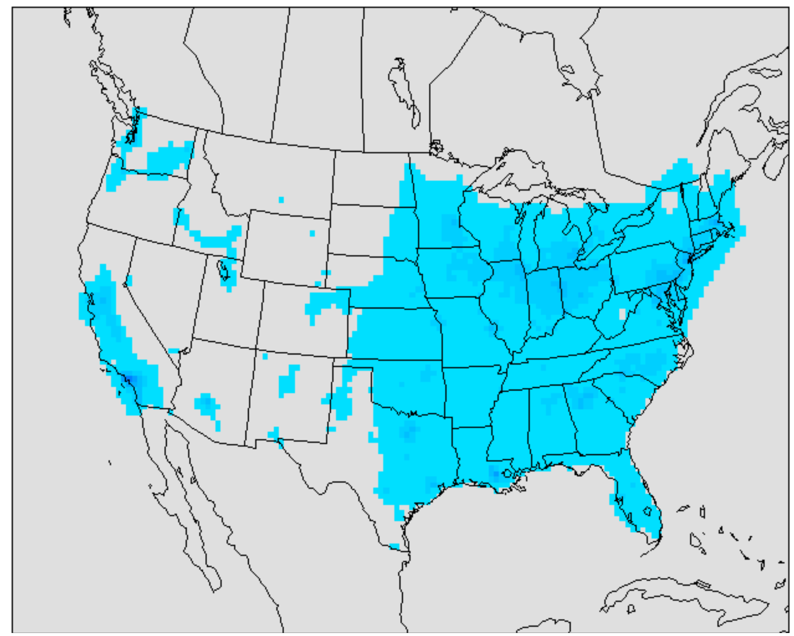
O_3 (ppb)

75 ppb Limit



$PM_{2.5}$ (µg/m^3)

15 µg/m^3 Limit



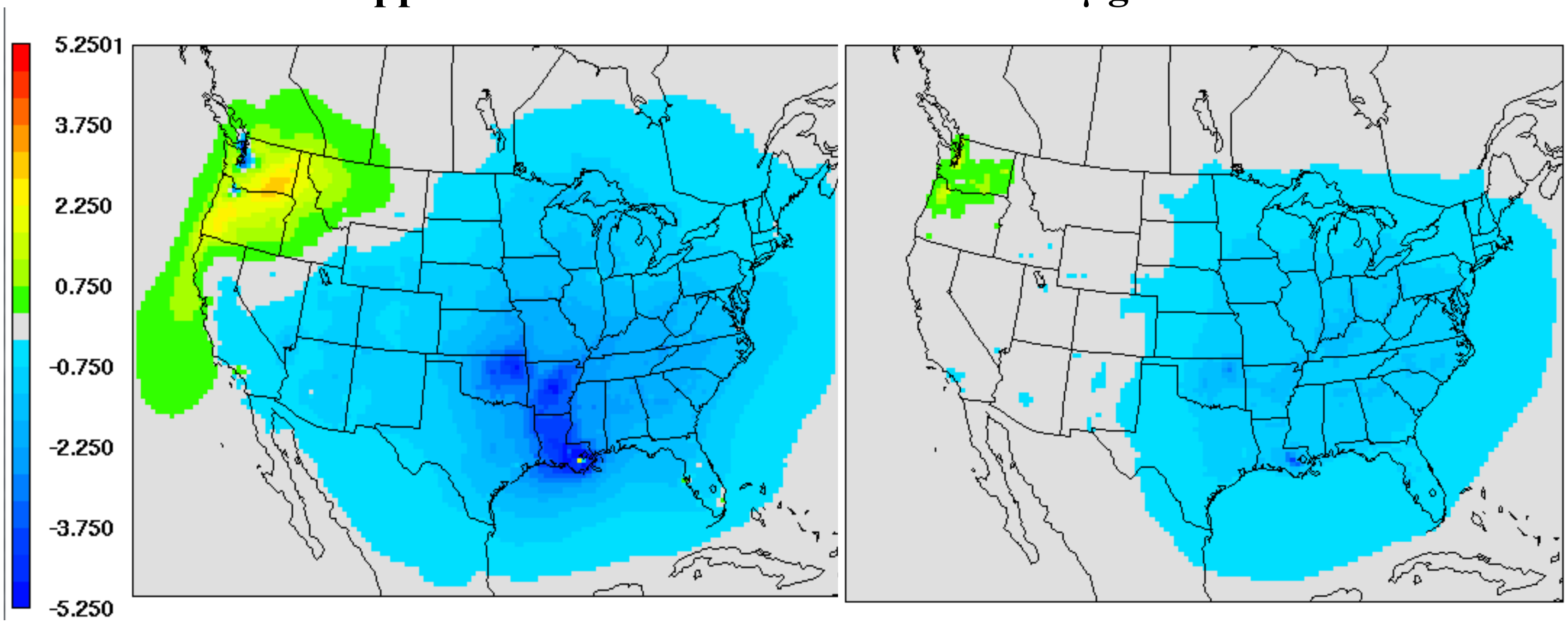
Cap and Trade: Positive and Negative

O_3 (ppb)

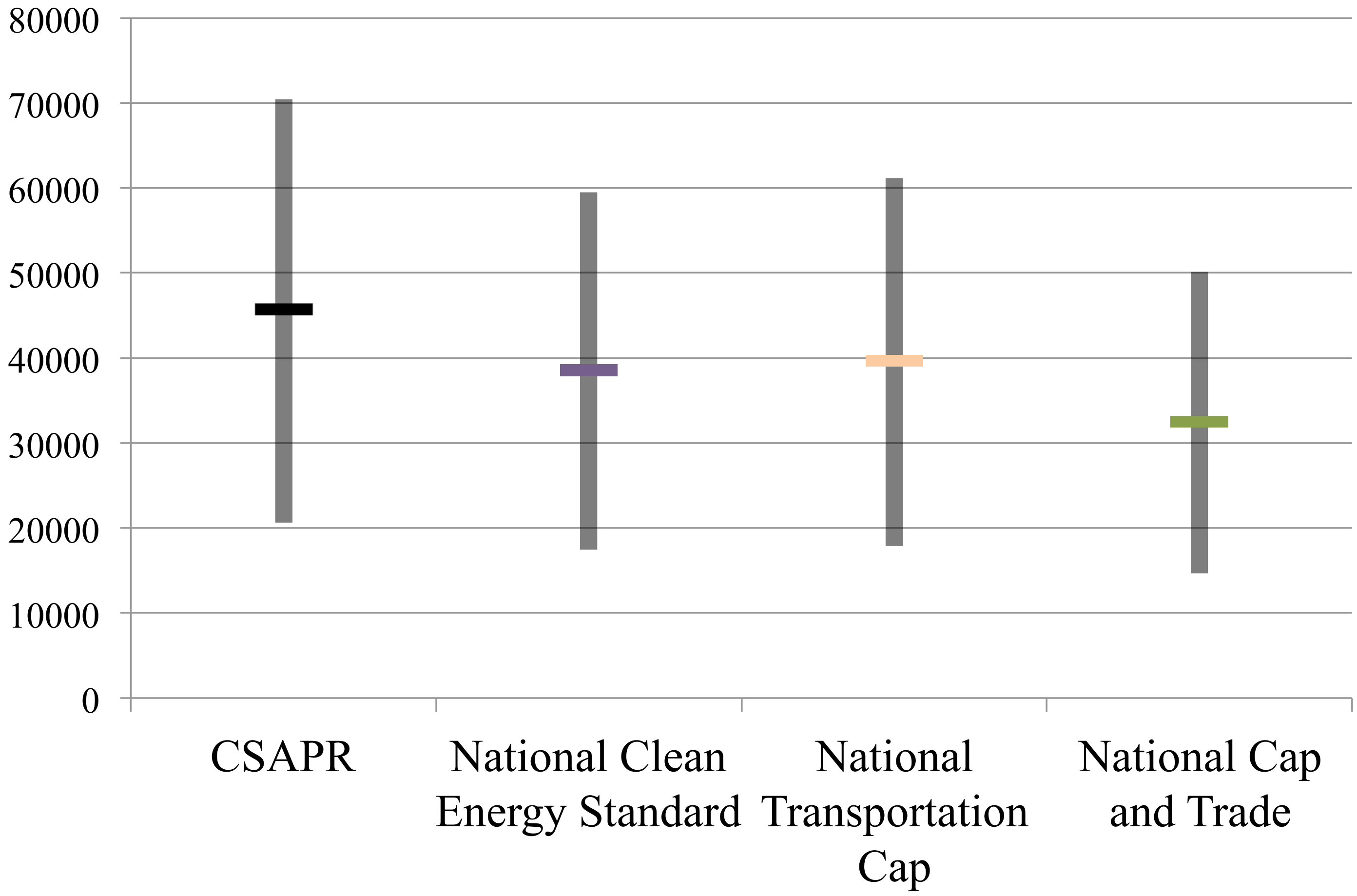
75 ppb Limit

$PM_{2.5}$ (μg/m^3)

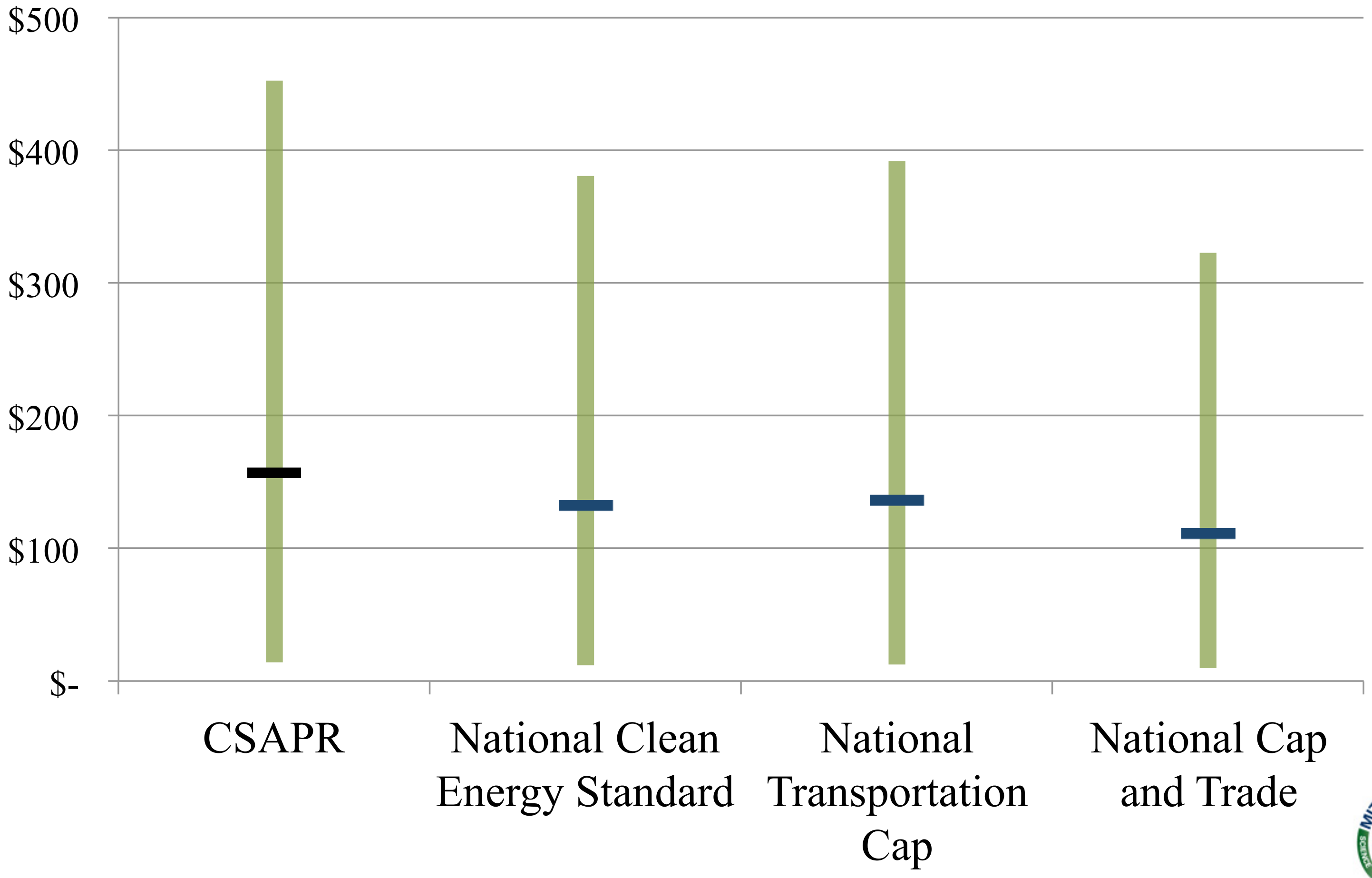
15 μg/m^3 Limit



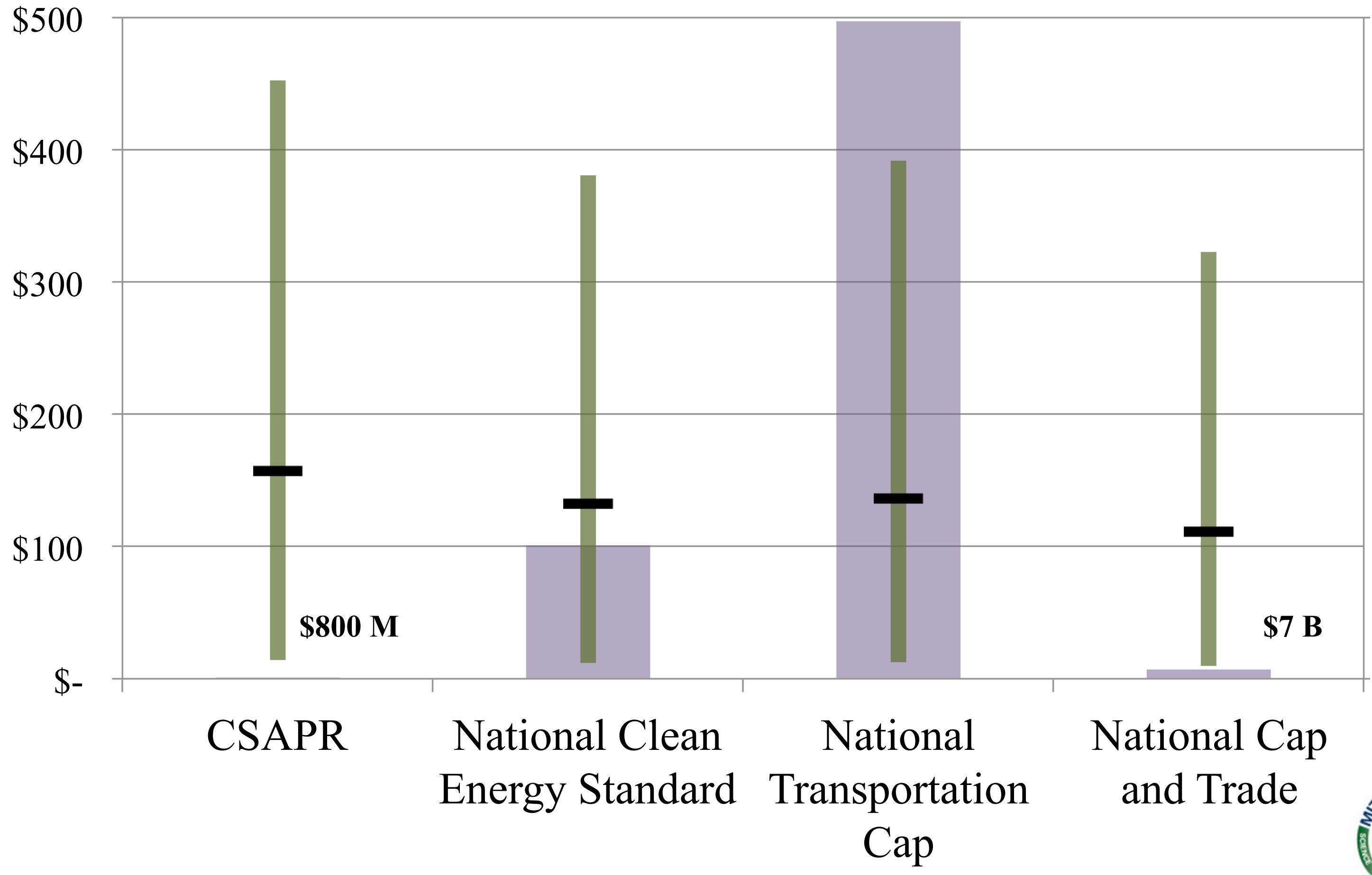
Avoided Annual Mortality due to Policy



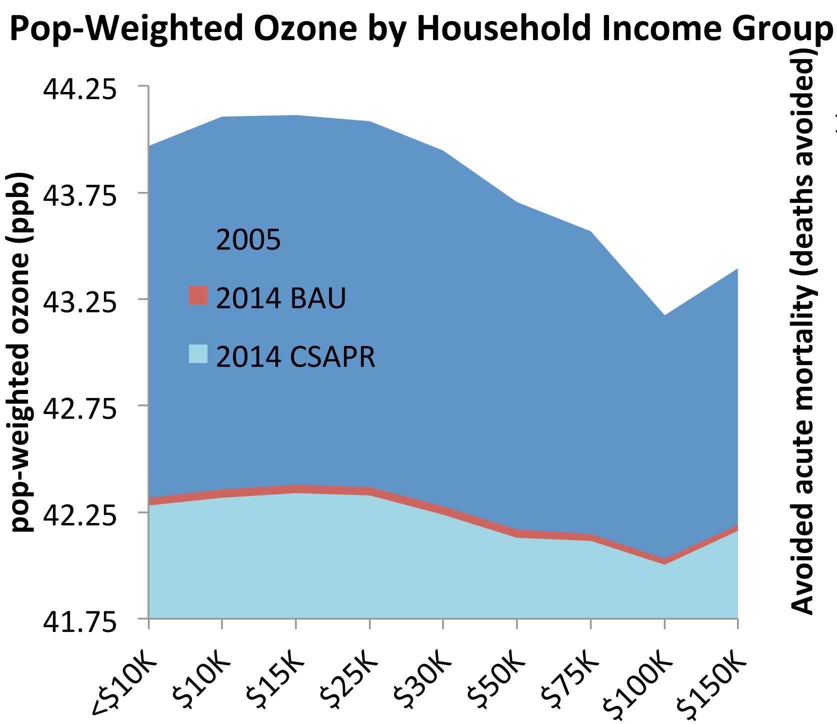
Human Health Benefits in 2030 (in Billion $)

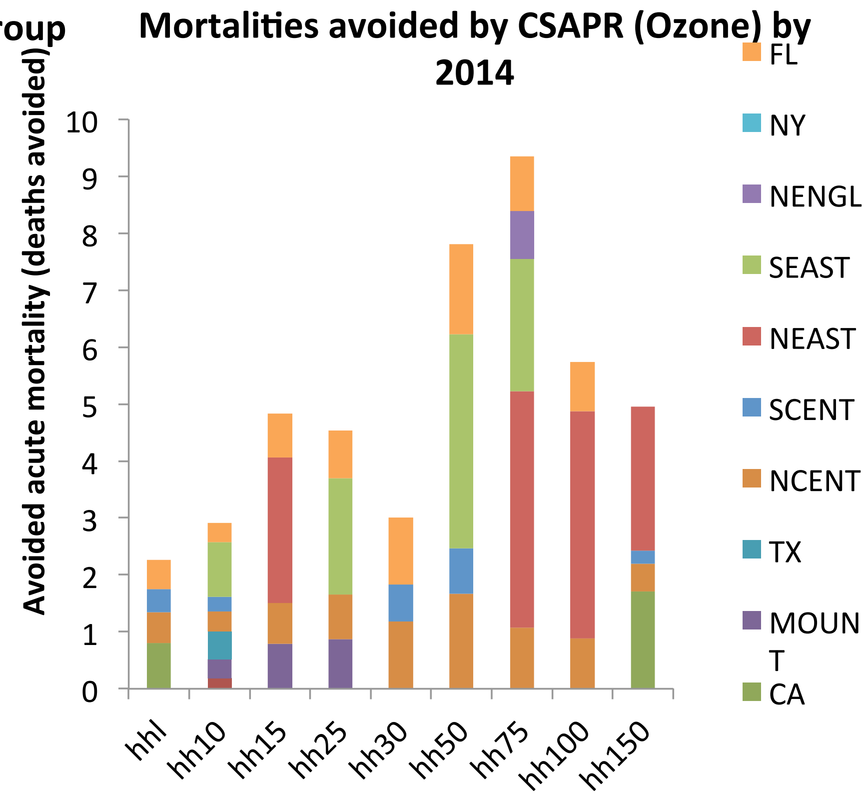


Policy Costs vs Health Benefits (in Billion $)



4. Economic modeling of health impacts at US scale



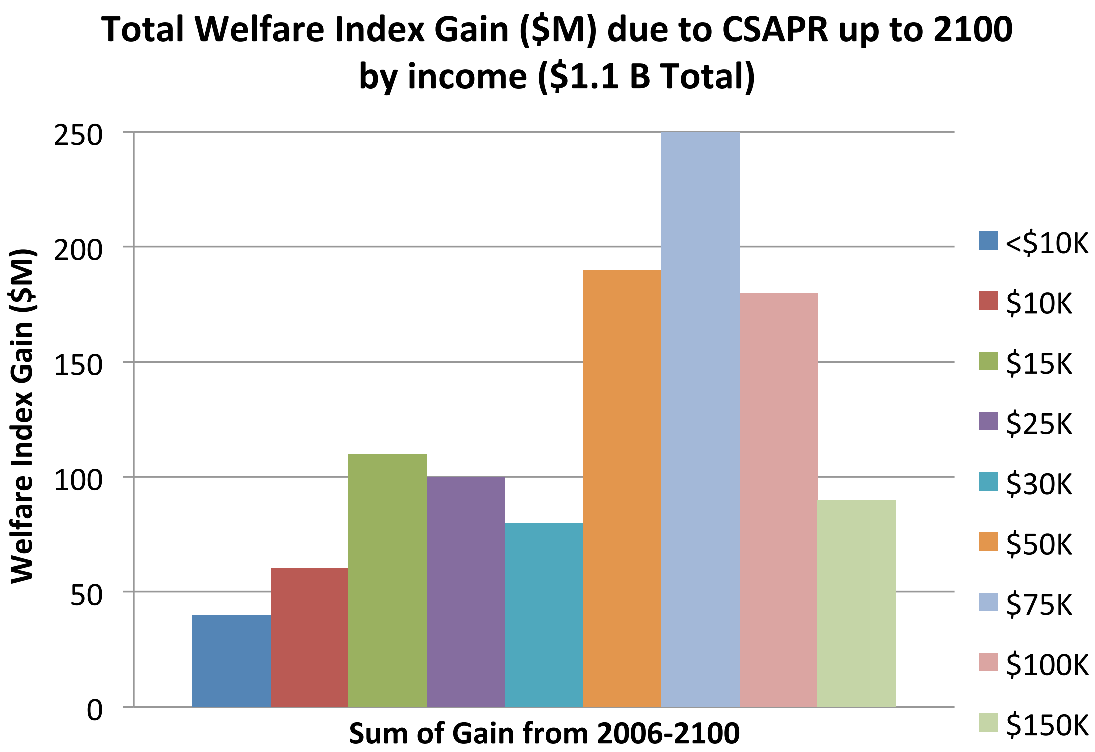


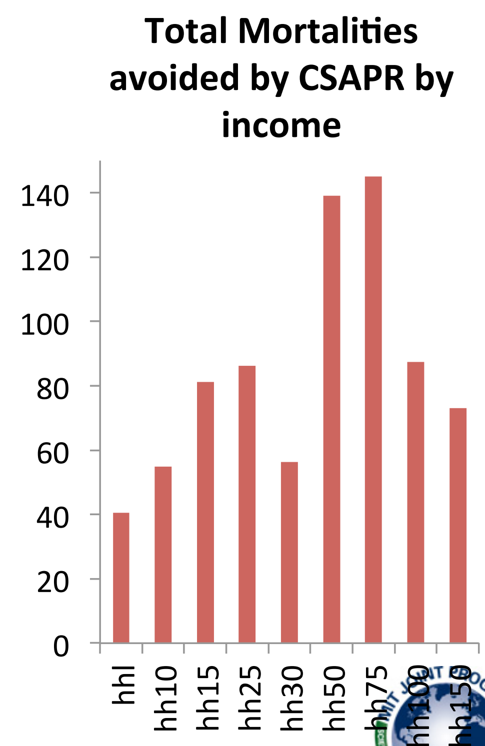
45 deaths estimated from CSAPR

(agrees in magnitude with 27 estimated by EPA)

Welfare Gain by Income

Welfare gain is positive for all income groups, and has a similar income pattern to the mortalities avoided (see figure to the right), suggesting that direct health effects are important. Isolating the indirect effects is work – in-progress.





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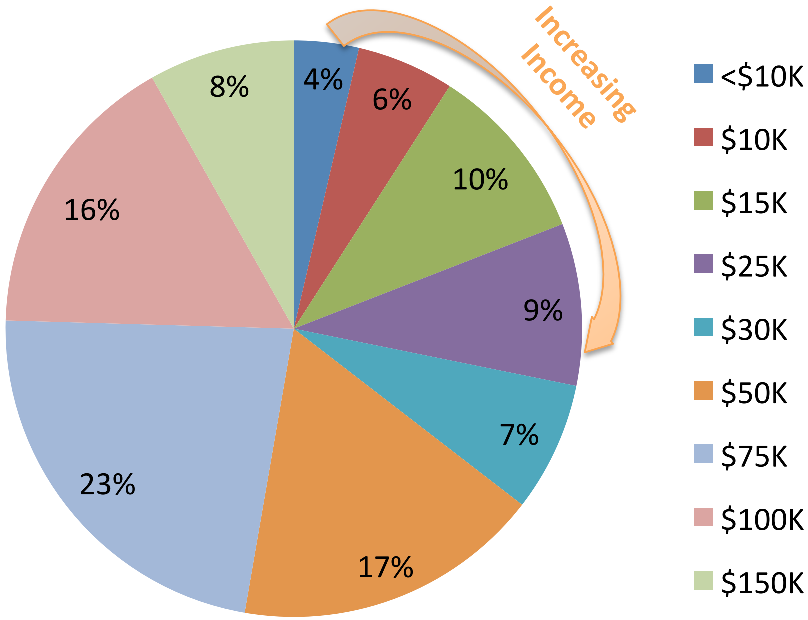
How is welfare gain shared by income?

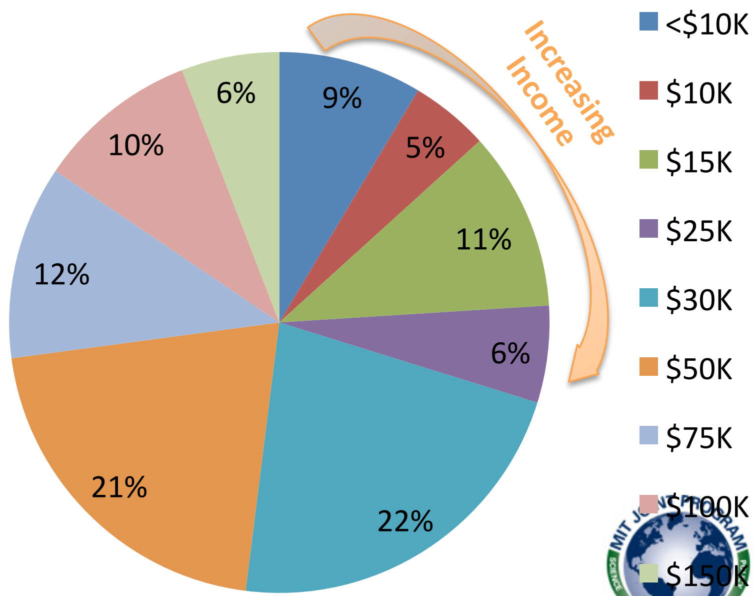
The lowest income groups get the smallest share of the $1.1B “Pie”.

The $30K income group has the largest population (22%) but only gets 7% of the benefit.

Share of Welfare Gain Received due to the CSAPR Policy – by Income Group



Share of Welfare Gain That Would be Received If the Benefits Were Distributed Evenly Per Capita



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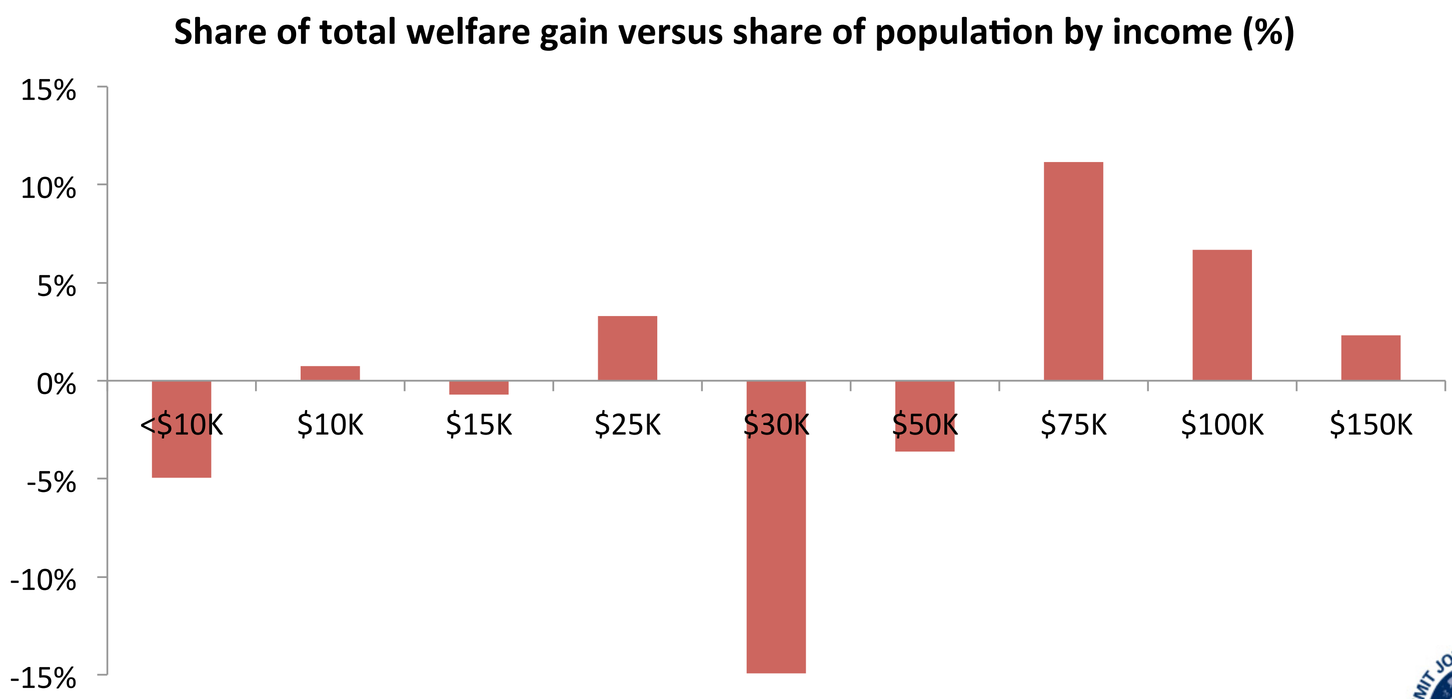
How is welfare shared per capita by income?

Do some groups get less or more than their even share?

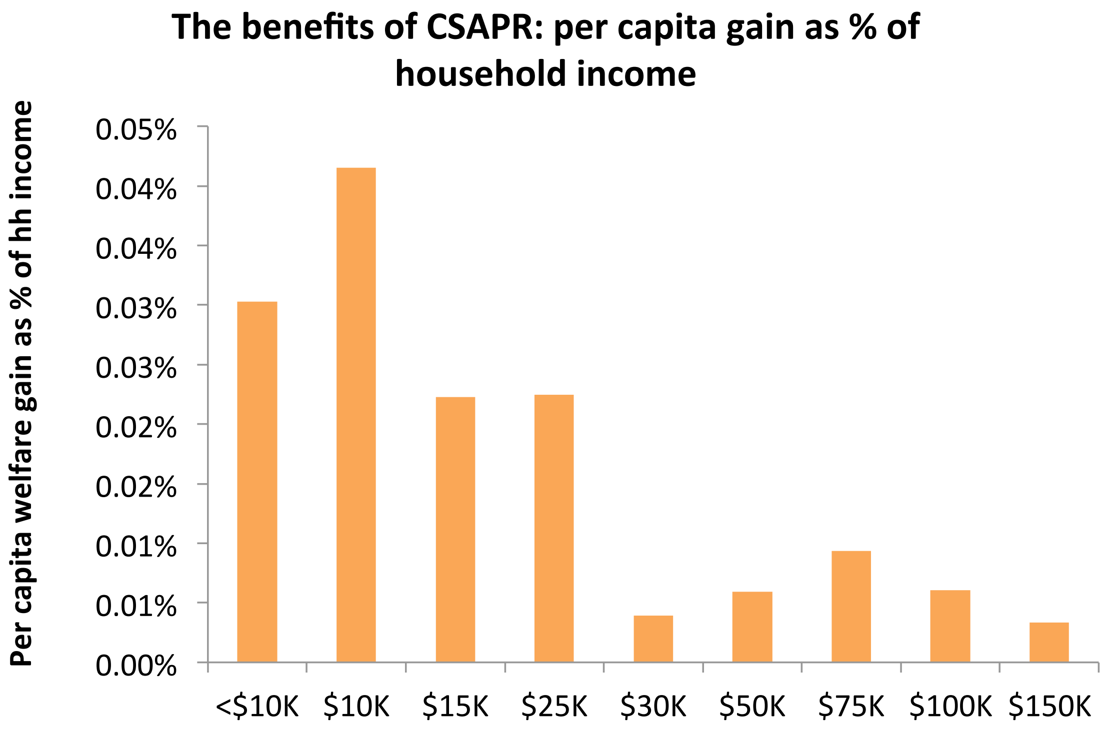
We subtracted the share of share of population from the share of welfare gain.

We can see that the high income groups get a higher per capita share of the gain.



Welfare gain vs. household income

Low income groups gain more as a share of their income. Though they gain less per capita, that gain is more important to them. Thus, the benefits of CSAPR appear progressive.



Future Work

- Regional Policy – Apply all three carbon policies to the North East and New England states
- Evaluate coupled response with our health impacts economic model
- Further discussion with state air pollution regulators organized by NESCAUM (early 2013)

Backup slides

Regional Energy Deployment System (ReEDS) Model

ReEDS has been developed by NREL's Strategic Energy Analysis Center (Short et. al, 2009)

- Capacity expansion & dispatch linear programming model for the continental US electricity sector including transmission & all major generator types
- Minimize total system cost in each 2-year investment period until 2050
  - All constraints (e.g. balance load, reserves, etc.) must be satisfied
- Multi-regional (356 wind/solar resource regions, 134 power control areas)
  - Enables transmission capacity expansion
  - Enables treatment of the variability of wind/solar
- Temporal Resolution
  - 17 time slices in each year
  - Statistical treatment of variability and uncertainty of wind & solar

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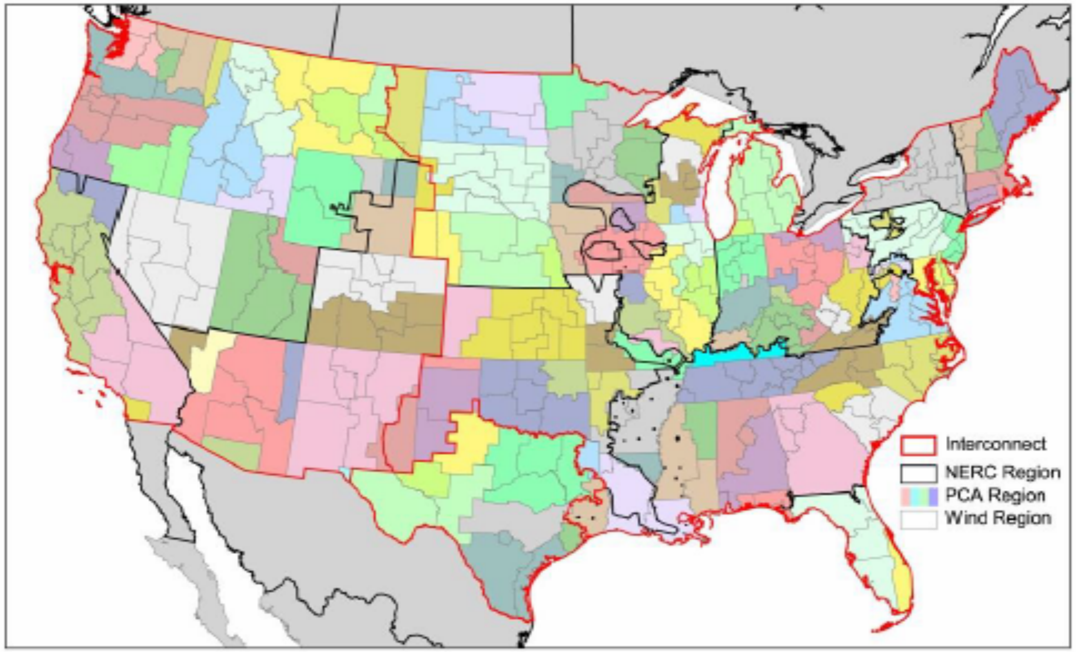
Regional Energy Deployment System (ReEDS) Model



- 356 CSP/Wind resource regions: level at which CSP/Wind capacity expansion occurs and resource limitations are considered
- 134 Power Control Areas (PCA): level at which demand requirements must be satisfied
- 21 RTOs: level at which reserve requirements must be met
- 13 NERC regions: level at which demand and fuel price inputs are provided
- 3 asynchronous interconnects

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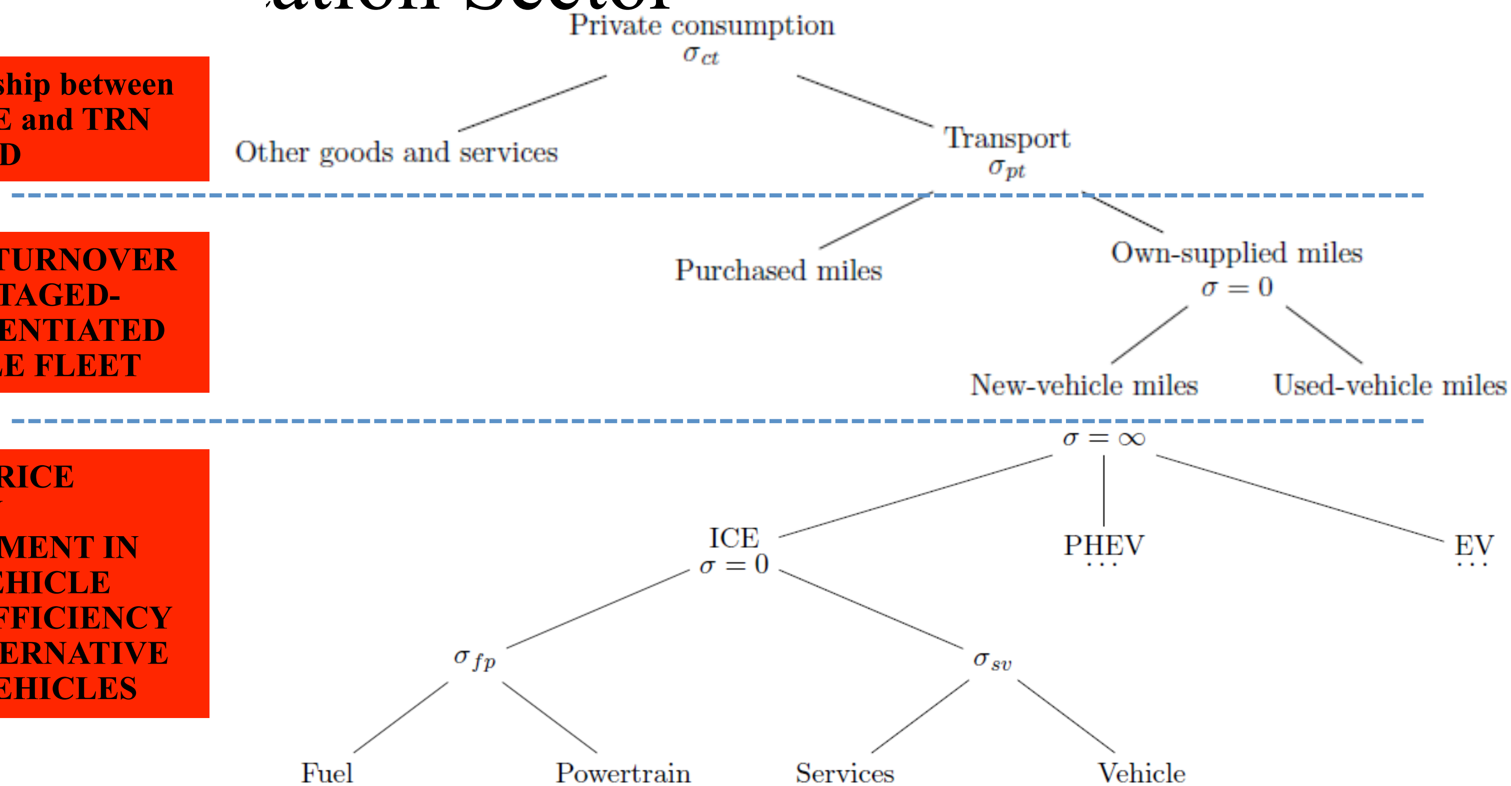
USREP: Overview of Enhanced Transportation Sector

Relationship between INCOME and TRN DEMAND

FLEET TURNOVER and VINTAGED-DIFFERENTIATED VEHICLE FLEET

FUEL-PRICE DRIVEN INVESTMENT IN NEW VEHICLE FUEL EFFICIENCY and ALTERNATIVE FUEL VEHICLES



- TOP-DOWN APPROACH based on nested CES functions incorporating bottom-up cost data.
- CONSTRAINTS ON ADOPTION OF NEW TECHNOLOGY: (1) vehicle stock turnover and (2) fixed costs associated with scaling up production and market penetration.
- SUPPLEMENTAL PHYSICAL ACCOUNTING tracks passenger VMT.

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