United States Environmental Protection Agency

Evaluating the impacts of decarbonization scenarios on nitrogen deposition

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Chesapeake Bay Program Quarterly Meeting
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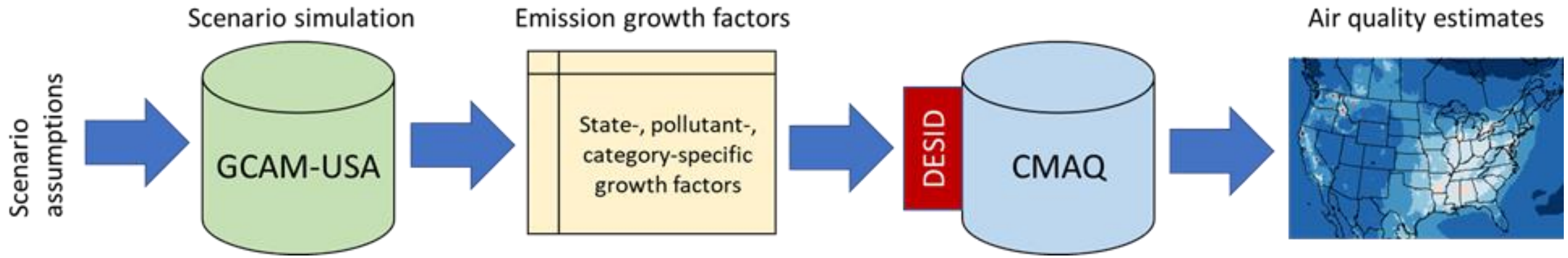
Note: these are DRAFT slides that have not been cleared for dissemination

Modeling Framework

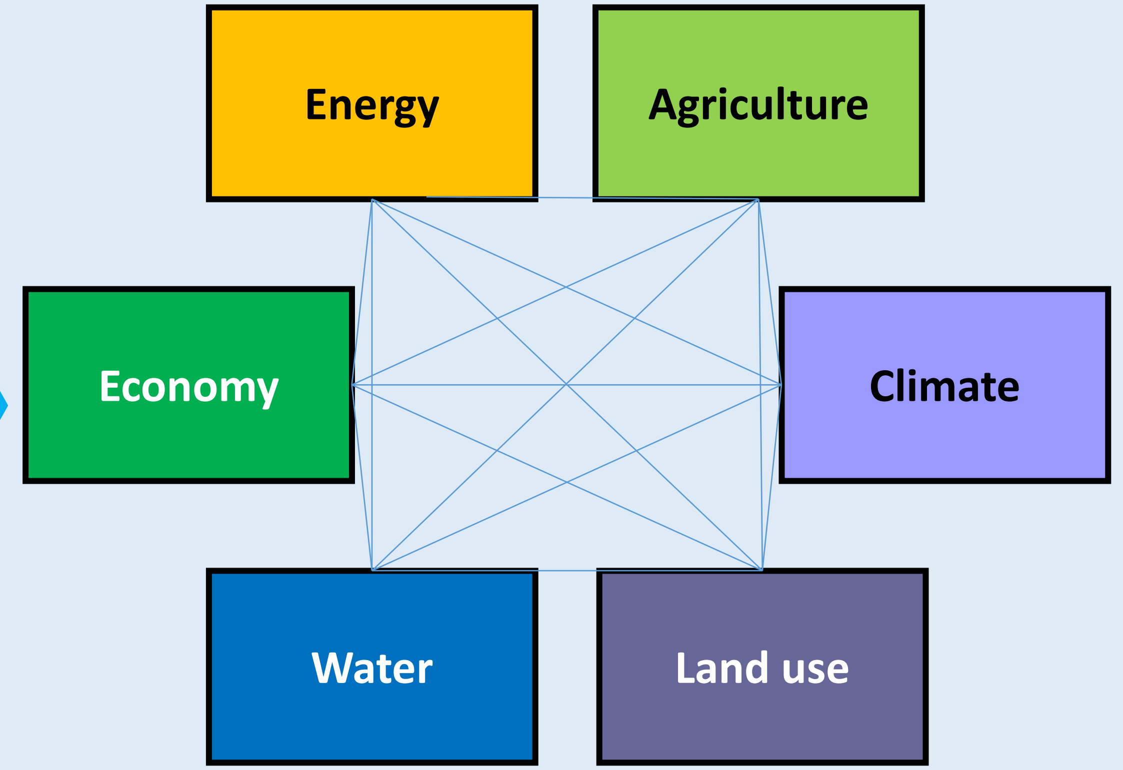


Global Change Analysis Model

Scenario assumptions

- Population growth
- Economic growth
- Resource availability
- Climate change
- Technology development
- Behavior and preferences
- Policies

GCAM



Simulates the co-evolution of these systems through time

End points

Energy
- Technology penetrations
- Fuel use and prices

Economic
- Policy cost
- Cost of energy services
- Land and food prices

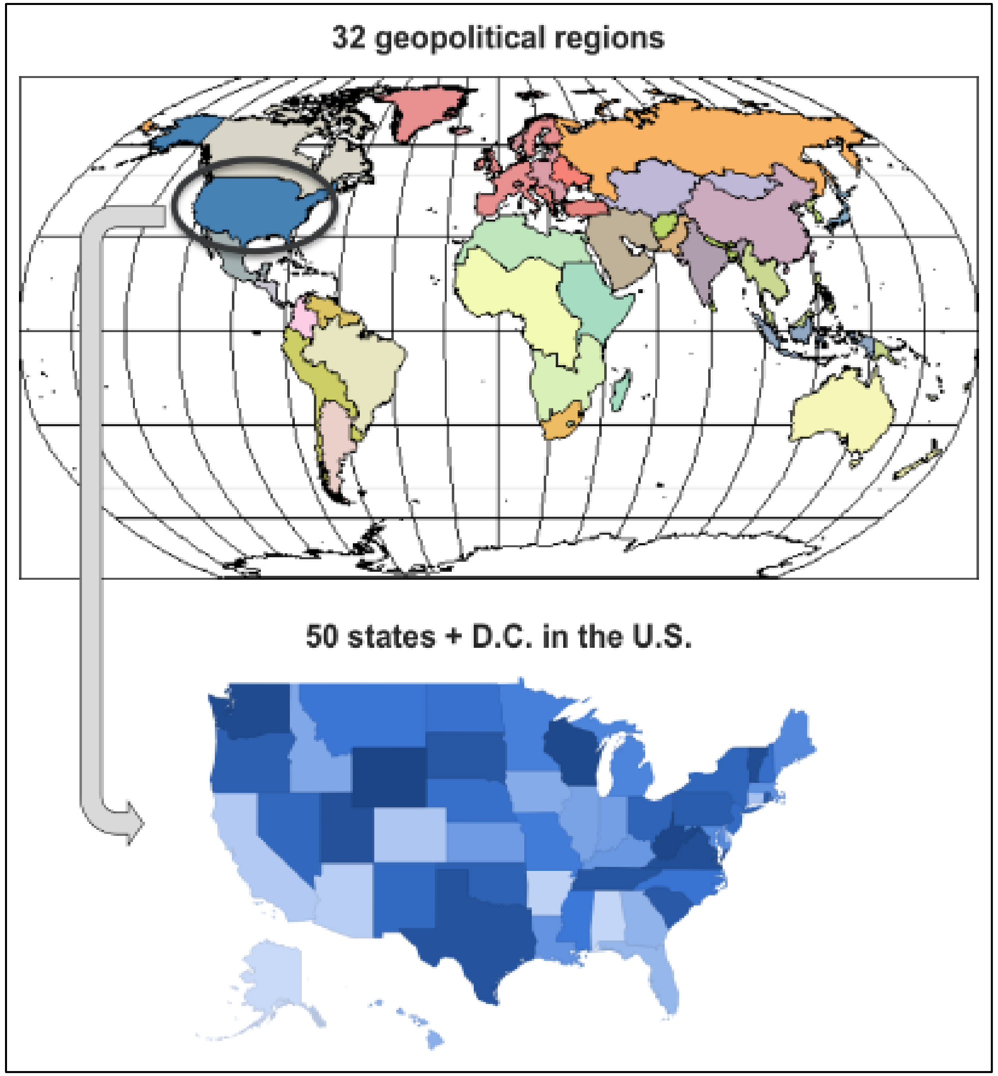
Climate
- GHG emissions
- Global mean temperature

Environmental
- Air pollutant emissions
- Water use
- Health impacts

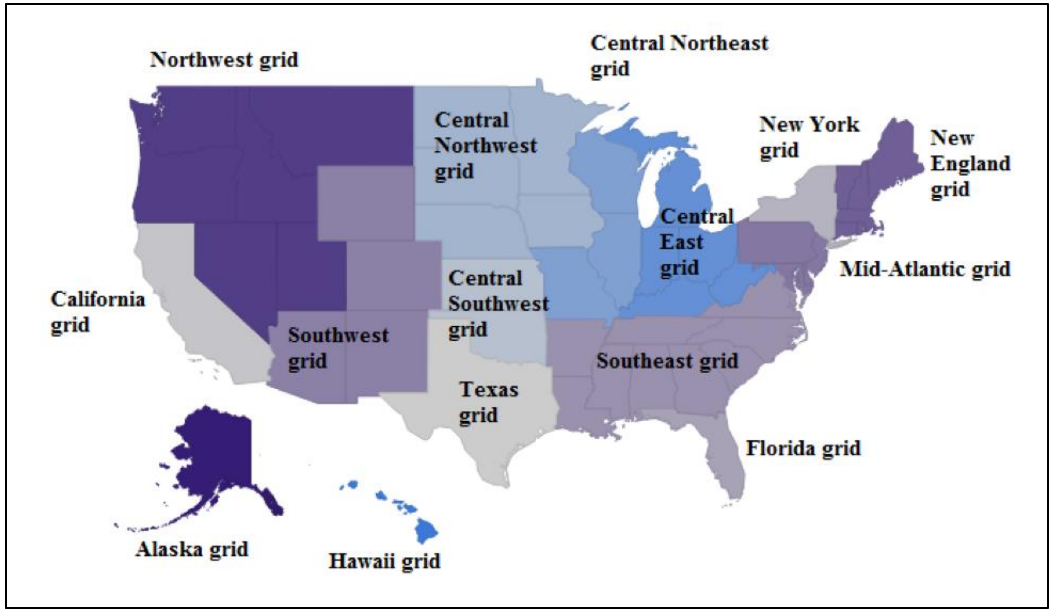
GCAM documentation: http://jgcri.github.io/gcam-doc/

GCAM-USA spatial resolution

Socio-economic and energy regions



Electric grid regions



Land regions and water supply basins

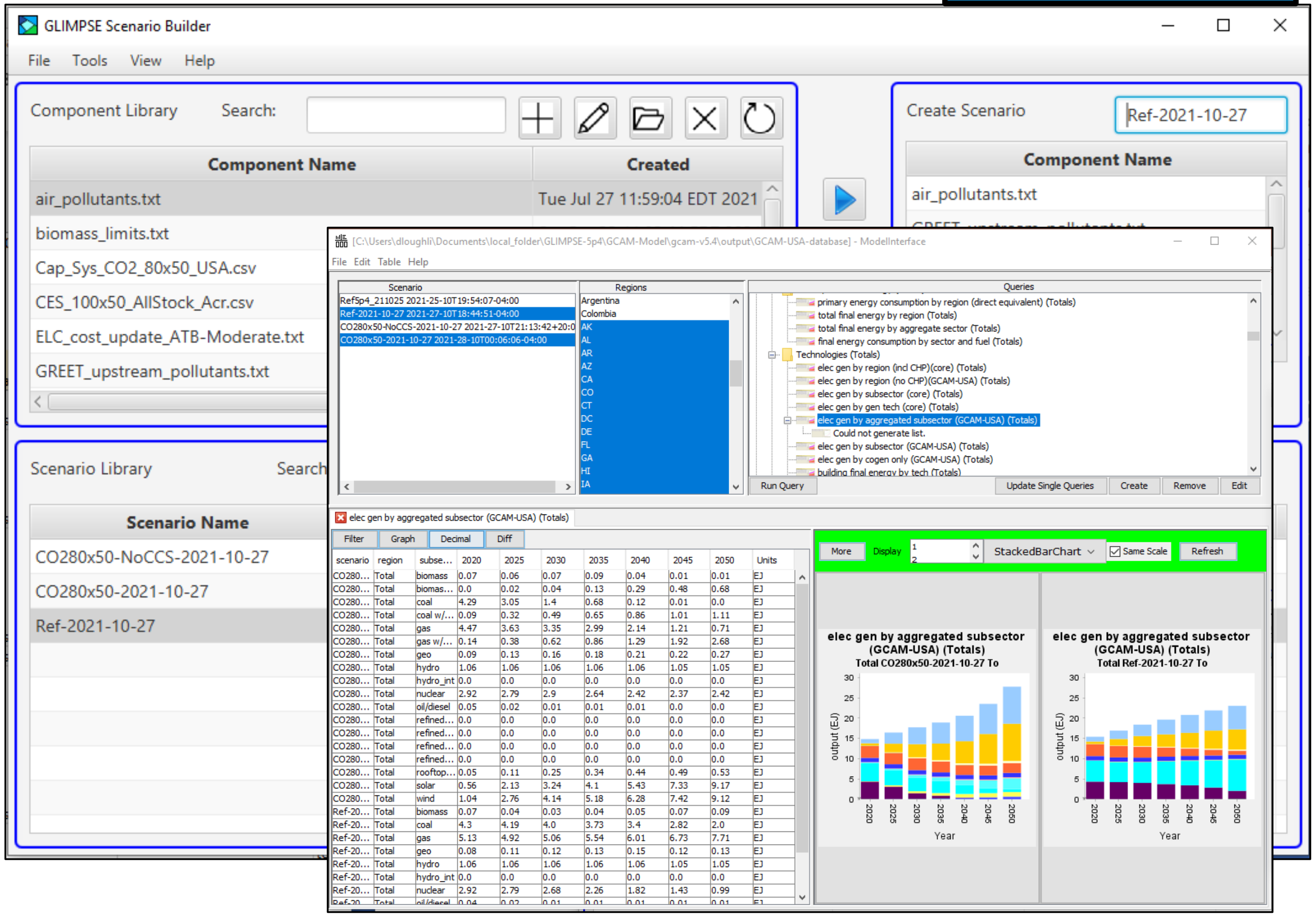
GCAM documentation: http://jgcri.github.io/gcam-doc/

EPA GLIMPSE Project

GLIMPSE: GCAM Long-term Interactive Multi-Pollutant Scenario Evaluator

Decision support system

- GLIMPSE graphical user interface for GCAM
- Supports exploratory analyses
    - Constructing scenarios
    - Managing GCAM execution
    - Visualizing results
- Facilitates policy evaluation
    - Technology market share targets
    - Technology and fuel subsidies or taxes
    - Pollutant taxes and caps
    - Technology availability
- Operational modes
    - Test specific policy or scenario
    - Outline goals; GCAM identifies strategy



https://www.epa.gov/glimpse

Scenario “levers” supported by GLIMPSE

Policy levers

Emissions:

- tax
- reduction target or cap

Technologies:

- subsidy
- market share targets:
  + *Renewable Portfolio Standards*
  + *EV market share targets*
  + *High efficiency technologies*
  + *Biofuels*
- specific output targets
  + *e.g. offshore wind*

Non-policy levers

Fuel prices:

- coal, natural gas, oil, and biomass

Technology attributes:

- *availability*
- cost
- efficiency
- lifetime

Behavior and choice:

- technology preference or bias (via shareweights)

Application

Air pollutant emission co-benefits of deep decarbonization pathways

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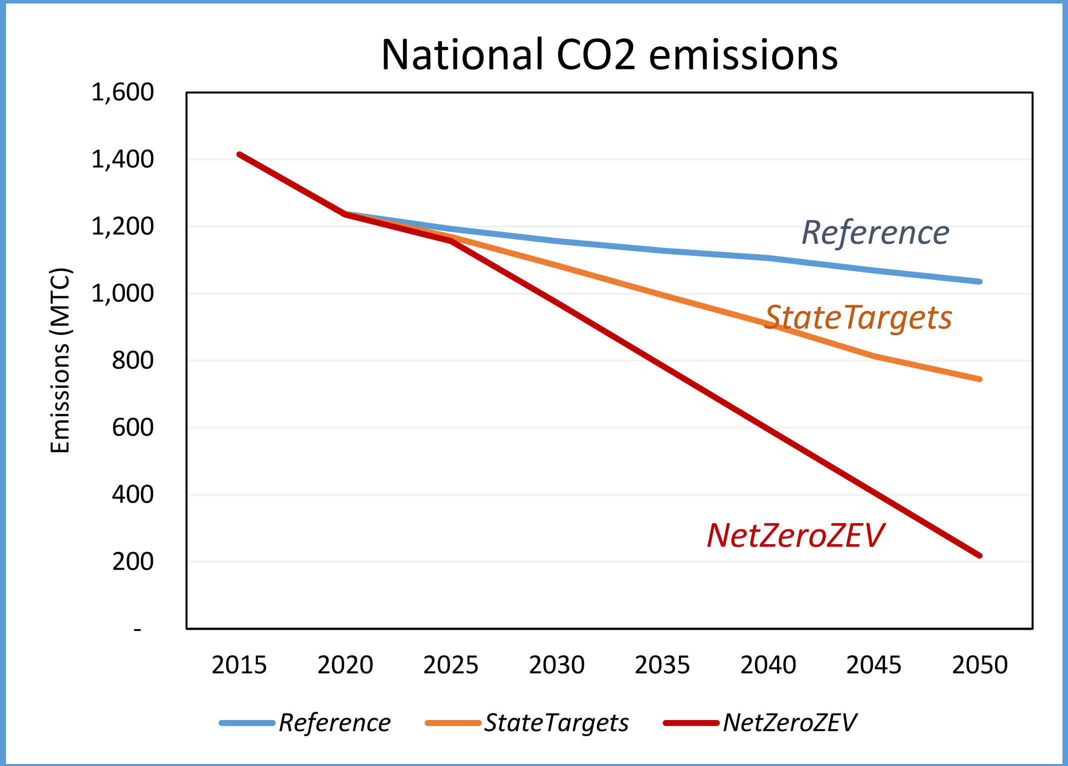
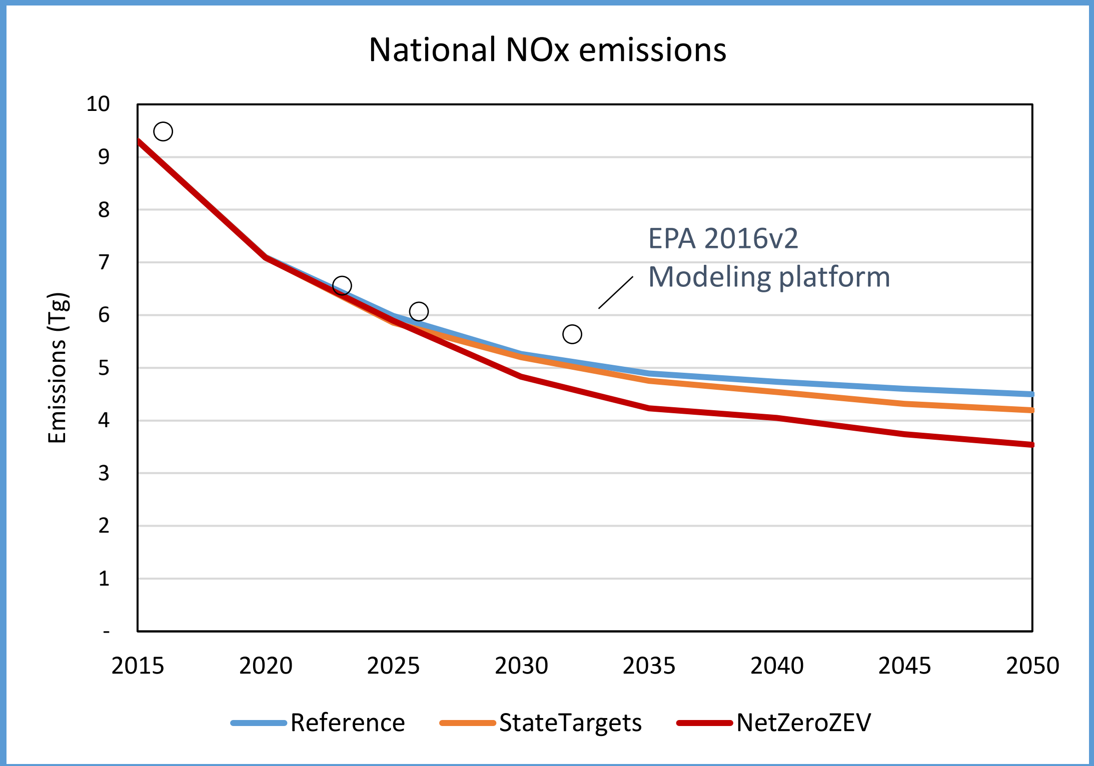
Scenario Design

- *Reference*: A baseline scenario that includes:
  - limited GHG mitigation and no additional air pollutant control requirements
- *StateTargets:* A mitigation scenario that includes:
  - State GHG reduction goals, implemented as regional CO2 targets
  - New CA light-duty electrification targets adopted by Section 177 states
  - Medium- and Heavy-Duty Electrification MOU adopted by signatory states
- *NetZeroZEV*: A mitigation scenario that includes:
  - A national, economy-wide declining CO2 cap reaches Net-Zero by 2050
  - Transportation electrification targets in *StateTargets* adopted nationally

National CO2 and NOx projections from GCAM





	2023	2026	2028	2032	2050
StateTargets	-1.2%	-2.9%	-4.5%	-8.4%	-28%
NetZeroZEV	-1.9%	-5.6%	-11%	-22%	-79%

	2023	2026	2028	2032	2050
StateTargets	-1.2%	-2.0%	-1.8%	-2.2%	-7.0%
NetZeroZEV	-0.9%	-2.7%	-5.3%	-10%	-21%

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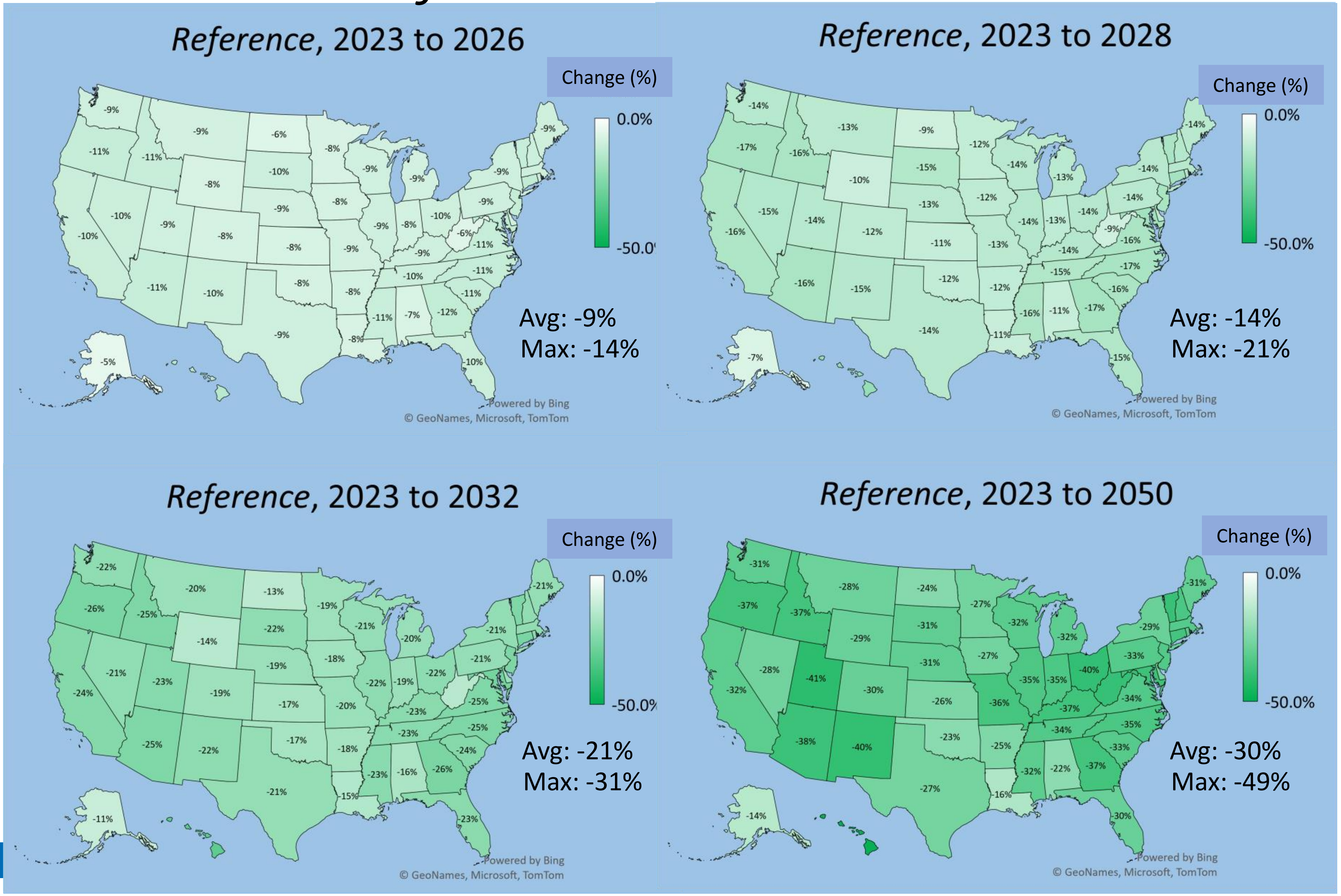
Spatial distribution of NOx reductions in *Reference*



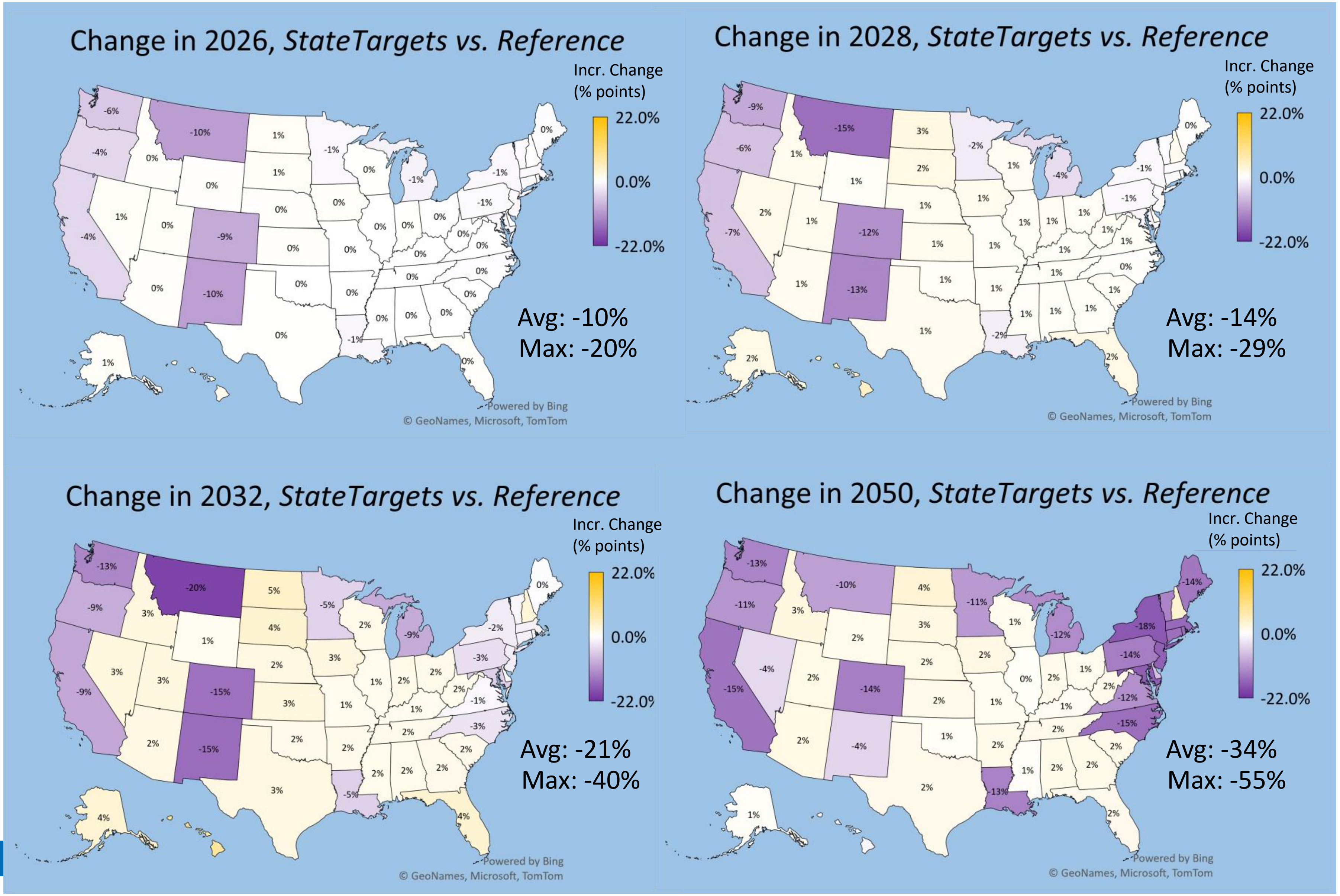
National NOx vs. 2023

Scenario	2026	2028	3032	2050
Reference	-9%	-14%	-21%	-30%

State-level NOx vs. 2023

	2026	2028	2032	2050
NY	-9%	-14%	-21%	-29%
NJ	-11%	-17%	-25%	-34%
PA	-9%	-14%	-21%	-33%
CT	-12%	-17%	-26%	-36%
OH	-10%	-14%	-22%	-40%
WV	-6%	-9%	-14%	-39%
VA	-11%	-16%	-25%	-34%
MD	-12%	-18%	-27%	-38%
MI	-9%	-13%	-20%	-32%
KY	-9%	-14%	-23%	-37%
IN	-8%	-13%	-19%	-35%
Other	-1%	-2%	-3%	-5%
All states	-6.0%	-9.0%	-14%	-20%

Additional NOx reductions from *StateTargets*



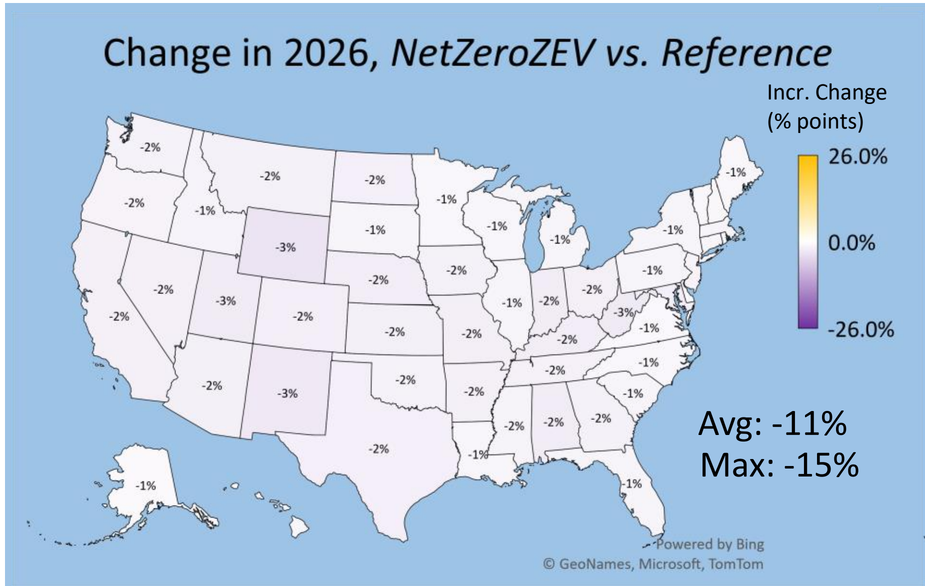
National NOx vs. 2023

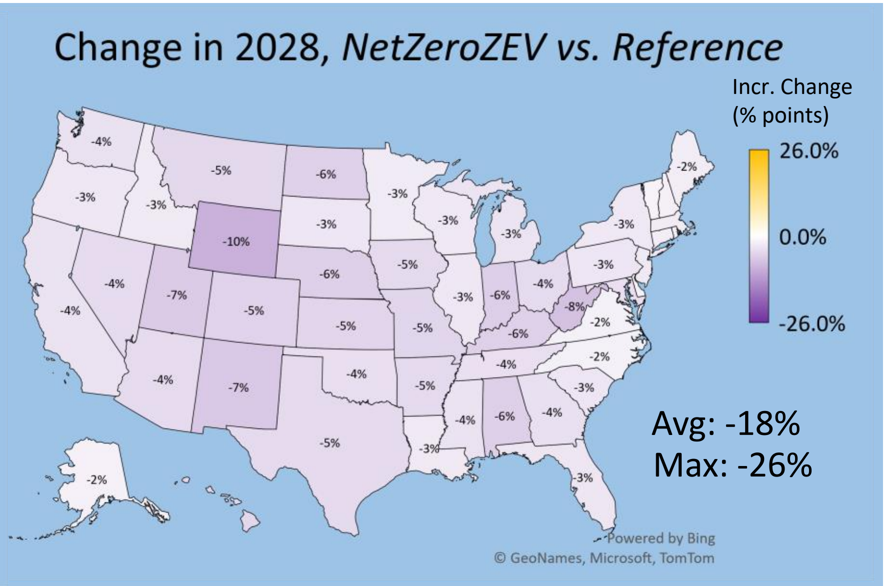
Scenario	2026	2028	3032	2050
Reference	-9%	-14%	-21%	-30%
StateTargets	-10%	-14%	-21%	-34%

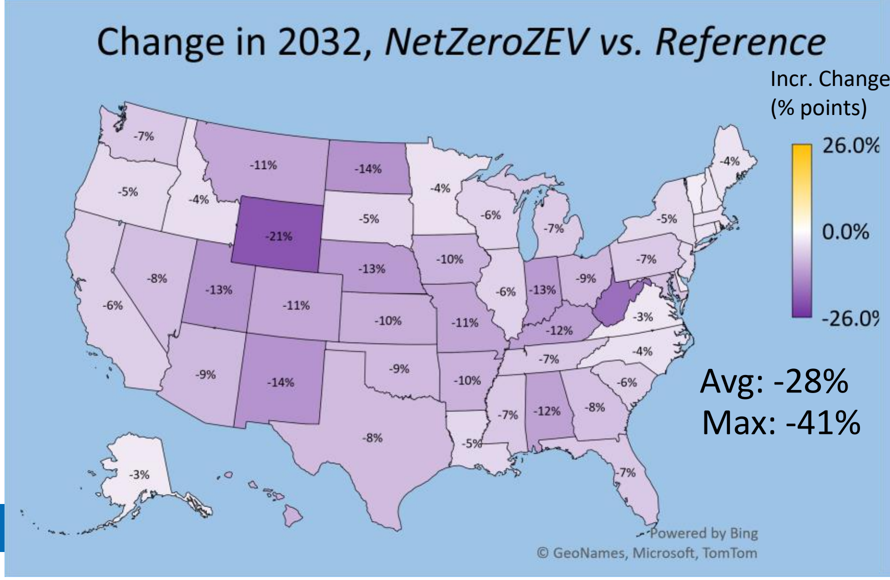
State-level NOx vs. 2023

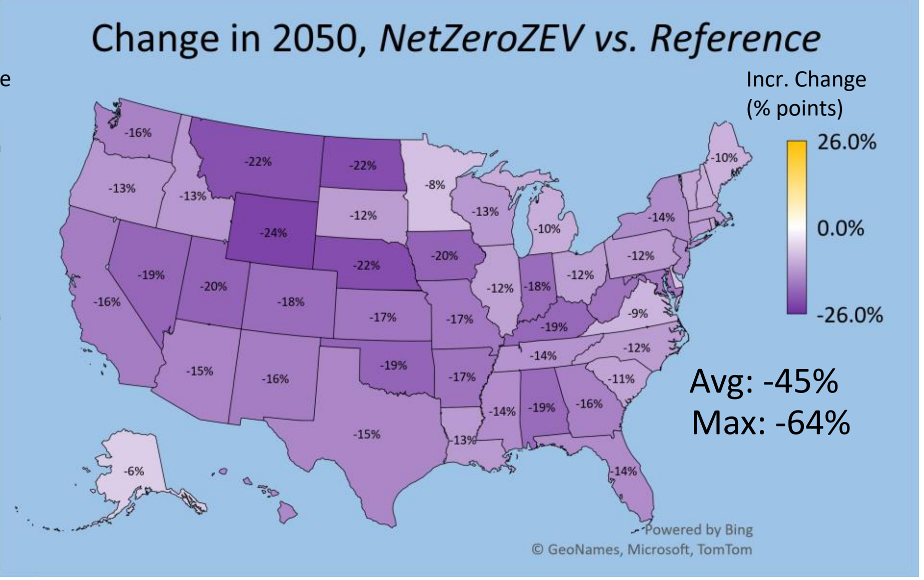
	2026	2028	2032	2050
NY	-10%	-15%	-23%	-47%
NJ	-12%	-17%	-27%	-50%
PA	-10%	-14%	-24%	-47%
CT	-13%	-18%	-27%	-51%
OH	-10%	-14%	-21%	-38%
WV	-6%	-8%	-12%	-38%
VA	-11%	-16%	-25%	-45%
MD	-13%	-19%	-32%	-55%
MI	-10%	-17%	-29%	-44%
KY	-9%	-14%	-21%	-36%
IN	-8%	-12%	-18%	-33%
Other	-1%	-2%	-3%	-5%
Total	-6.4%	-9.3%	-15%	-28%

Additional NOx reductions from *NetZeroZEV*









National NOx vs. 2023

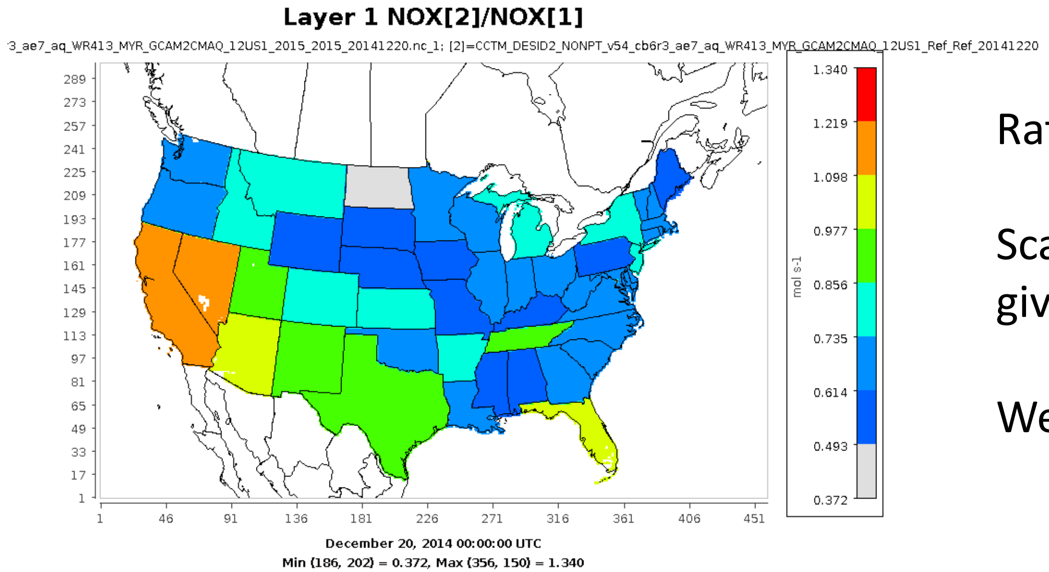
Scenario	2026	2028	3032	2050
Reference	-9%	-14%	-21%	-30%
StateTargets	-10%	-14%	-21%	-34%
NetZeroZEV	-11%	-18%	-28%	-44%

State-level NOx vs. 2023

	2026	2028	2032	2050
NY	-11%	-17%	-26%	-44%
NJ	-13%	-19%	-30%	-48%
PA	-11%	-17%	-27%	-45%
CT	-13%	-20%	-29%	-49%
OH	-12%	-19%	-31%	-52%
WV	-9%	-17%	-32%	-57%
VA	-12%	-18%	-28%	-43%
MD	-14%	-22%	-34%	-54%
MI	-10%	-17%	-27%	-42%
KY	-12%	-20%	-35%	-56%
IN	-11%	-19%	-32%	-53%
Other	-2%	-3%	-4%	-7%
Total	-6.9%	-11%	-17%	-28%

Linking GCAM to CMAQ

- Use CMAQ's Detailed Emissions Scaling, Isolation, and Diagnostics (DESID) module (Murphy et al., Geosci Model Dev 2021)
- Apply regional (state level) and sectoral scaling factors for NOx, SO2, primary PM25, VOCs, and NH3
  - applied to sources modeled by GCAM, i.e., those related to energy system. While GCAM has an ag sector, we are not linking changes in cropland simulated by GCAM to changes in fertilizer application



Ratio of NOx NONPT (area) emissions, Ref2050 to 2015.

Scaling factors follow state boundaries, as specified via instructions given to CMAQ based on GCAM simulations

We are applying scaling factors like this for 11 emissions sectors

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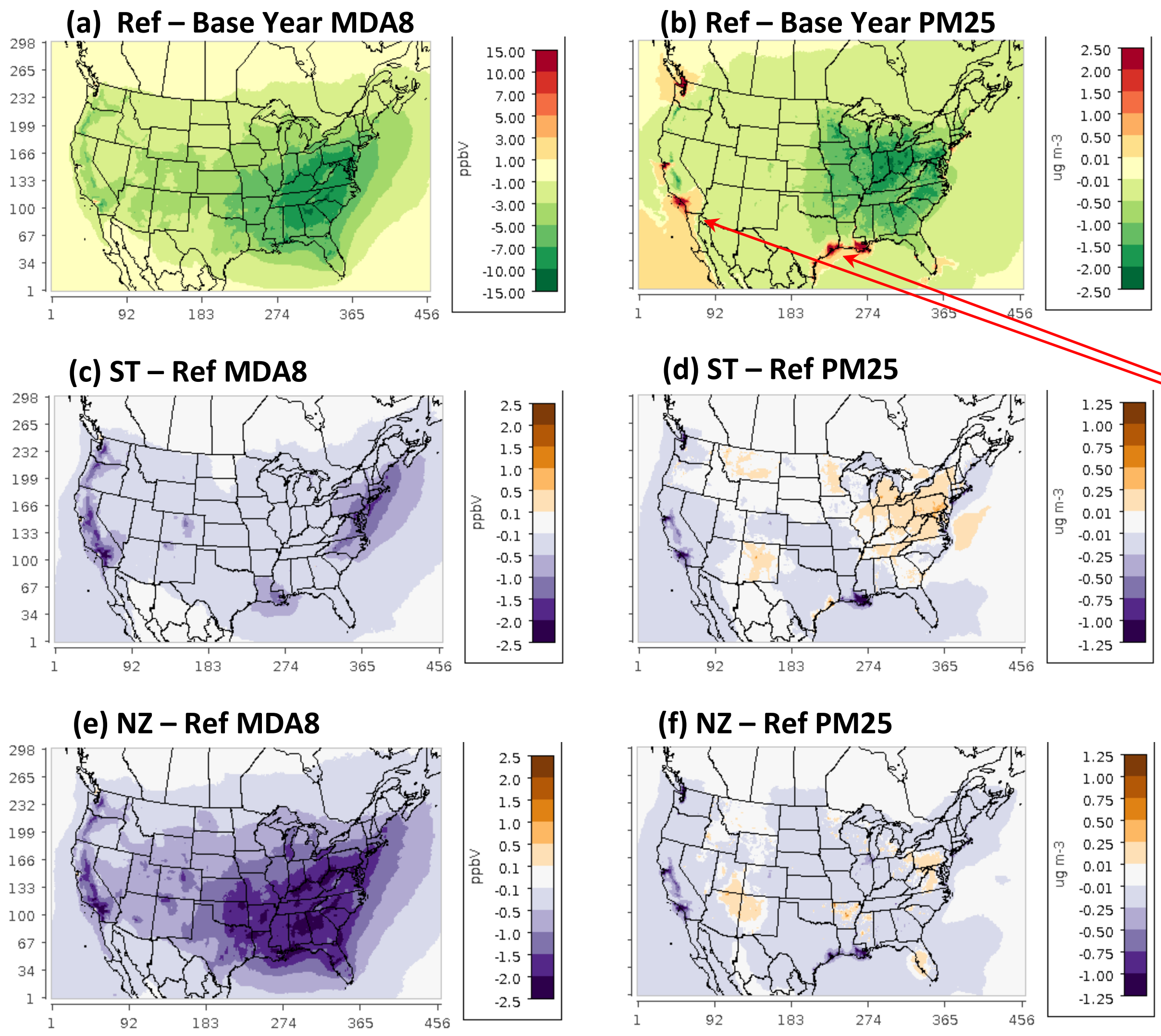
Initial Results (June 2023)

MDA8 May-Sept Avg

$PM_{2.5}$ Annual Avg



Panels a, b: *Reference* – Base Year

Panels c, d: *StateTargets* – *Reference*

Panels e, f: *NetZeroZEV* - *Reference*

Maximum Co-benefit -3.8 ppb

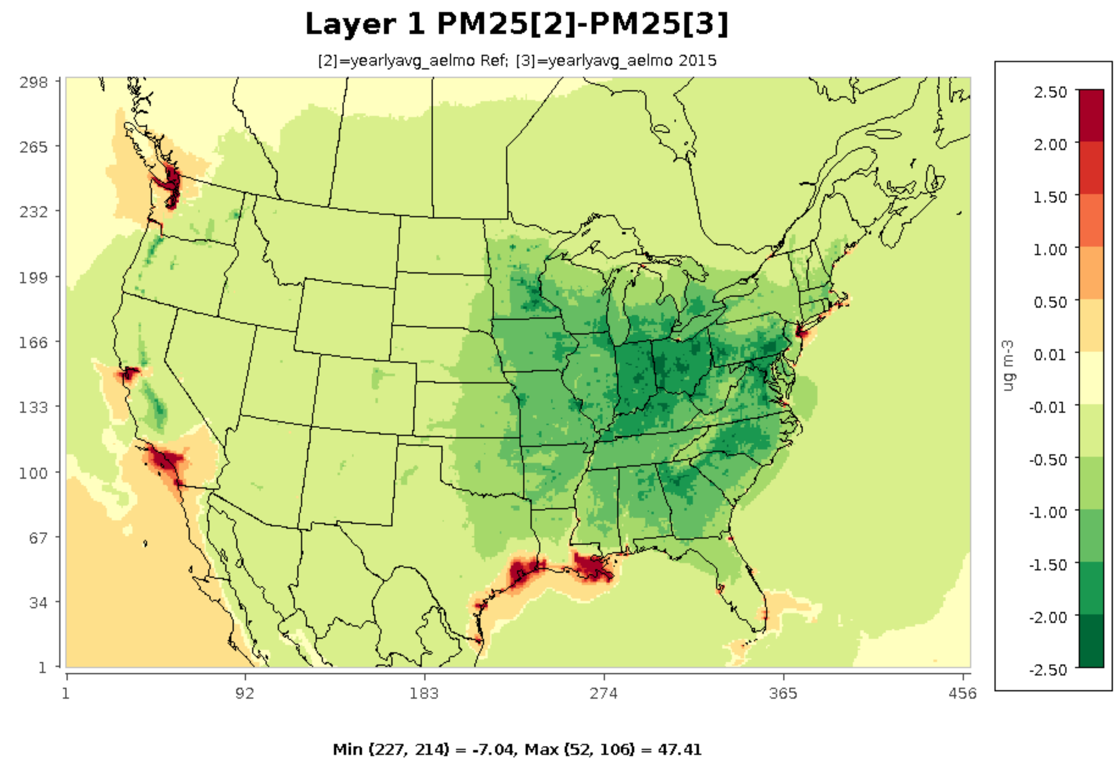
Maximum Co-benefit -14.1 μg/m³

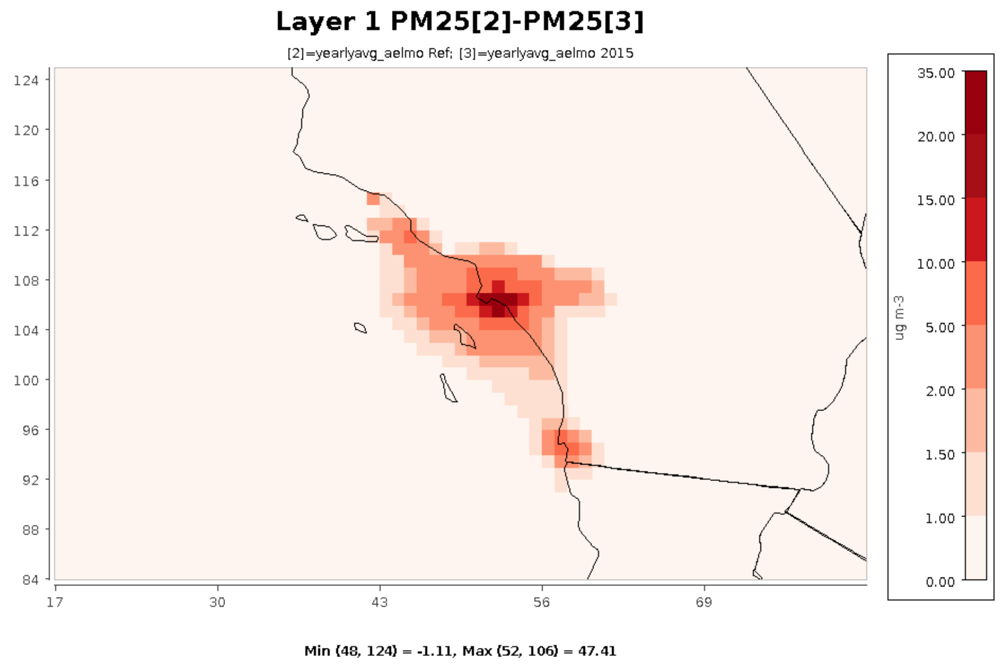
What is causing these increases in PM2.5?

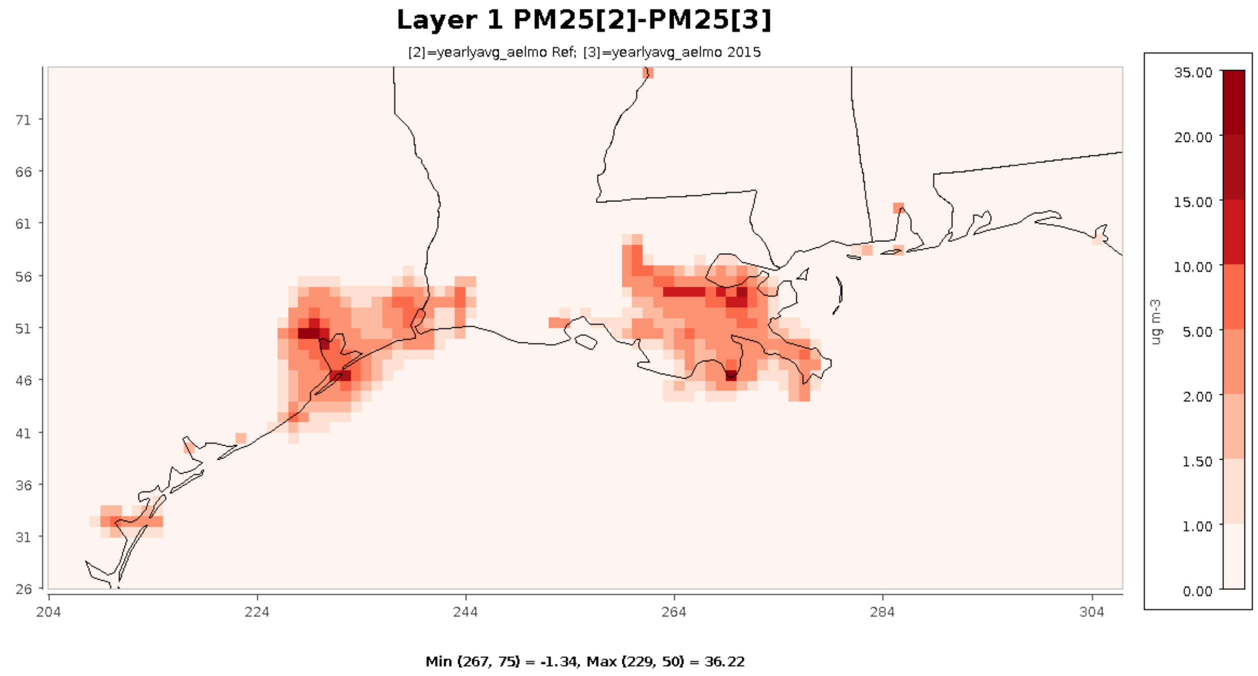
Maximum Co-benefit -4.1 ppb

Maximum Co-benefit -9.0 μg/m³

*MDA8: Maximum Daily 8-Hour Average Ozone







Increases greater than 5-15 ug/m3 extending over urban areas (Seattle, SF, LA, Houston, New Orleans, NYC), max increase over 47 ug/m3 *annual average.*

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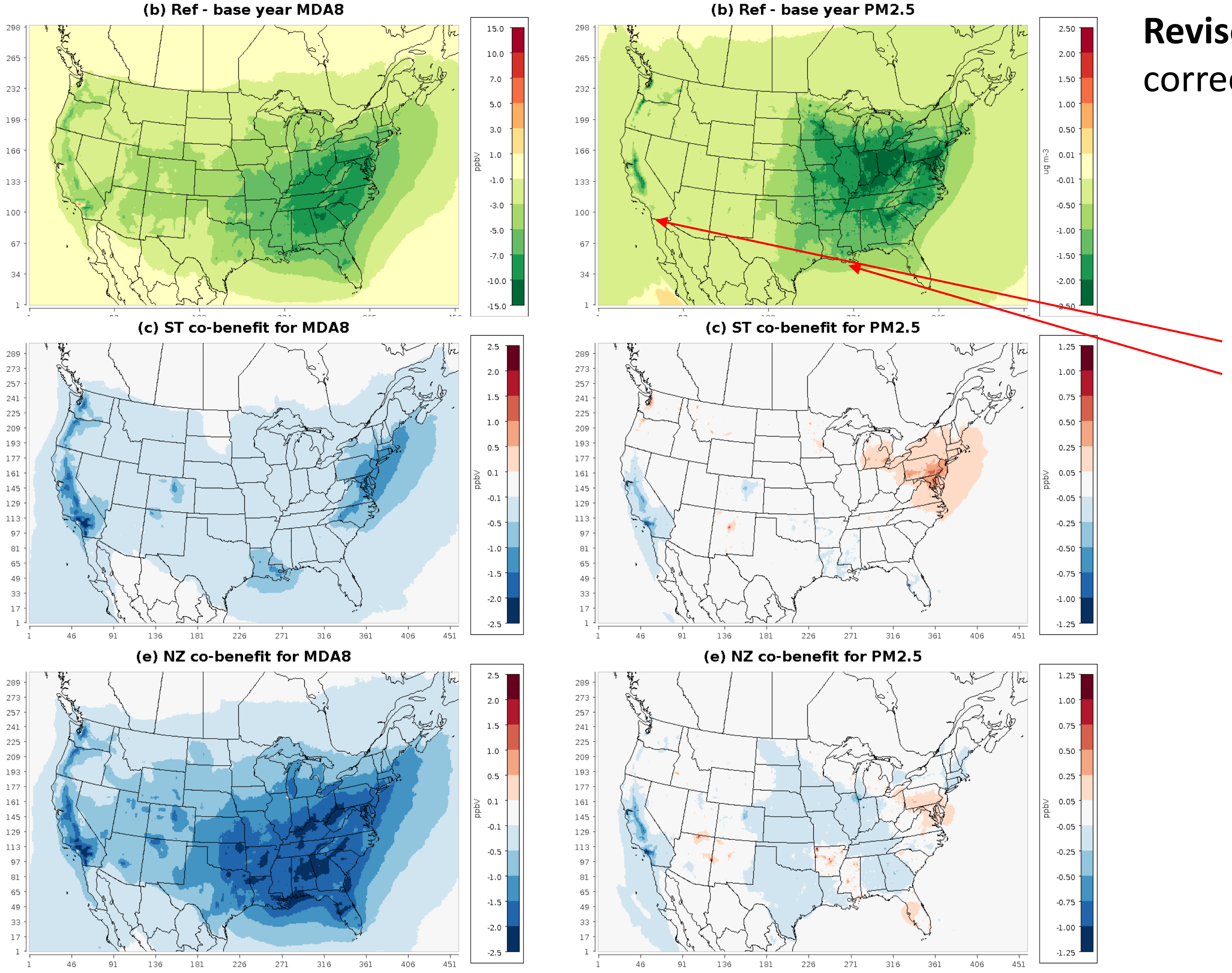
MDA8 May-Sept Avg | $PM_{2.5}$ Annual Avg

Revised results after correcting shipping emissions

Ref – 2015

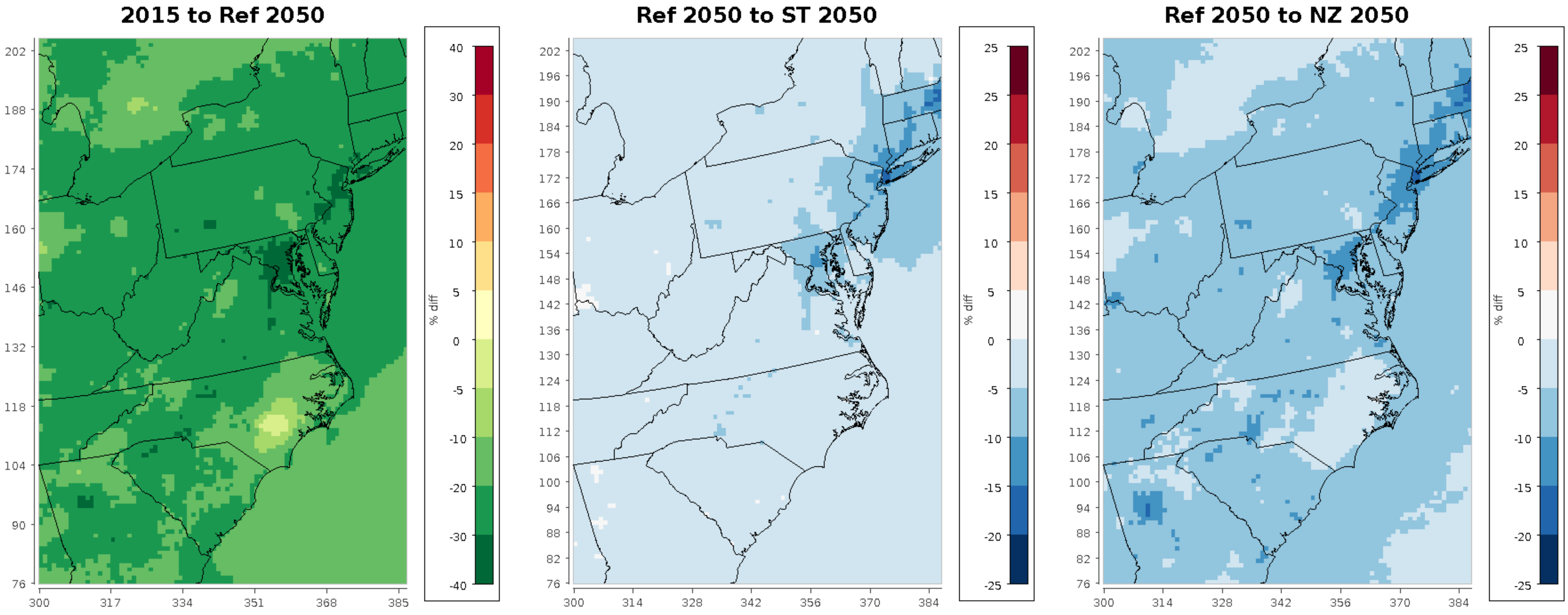
ST – Ref

NZ – Ref



Anomalous increase resolved

Relative Changes in total N Deposition



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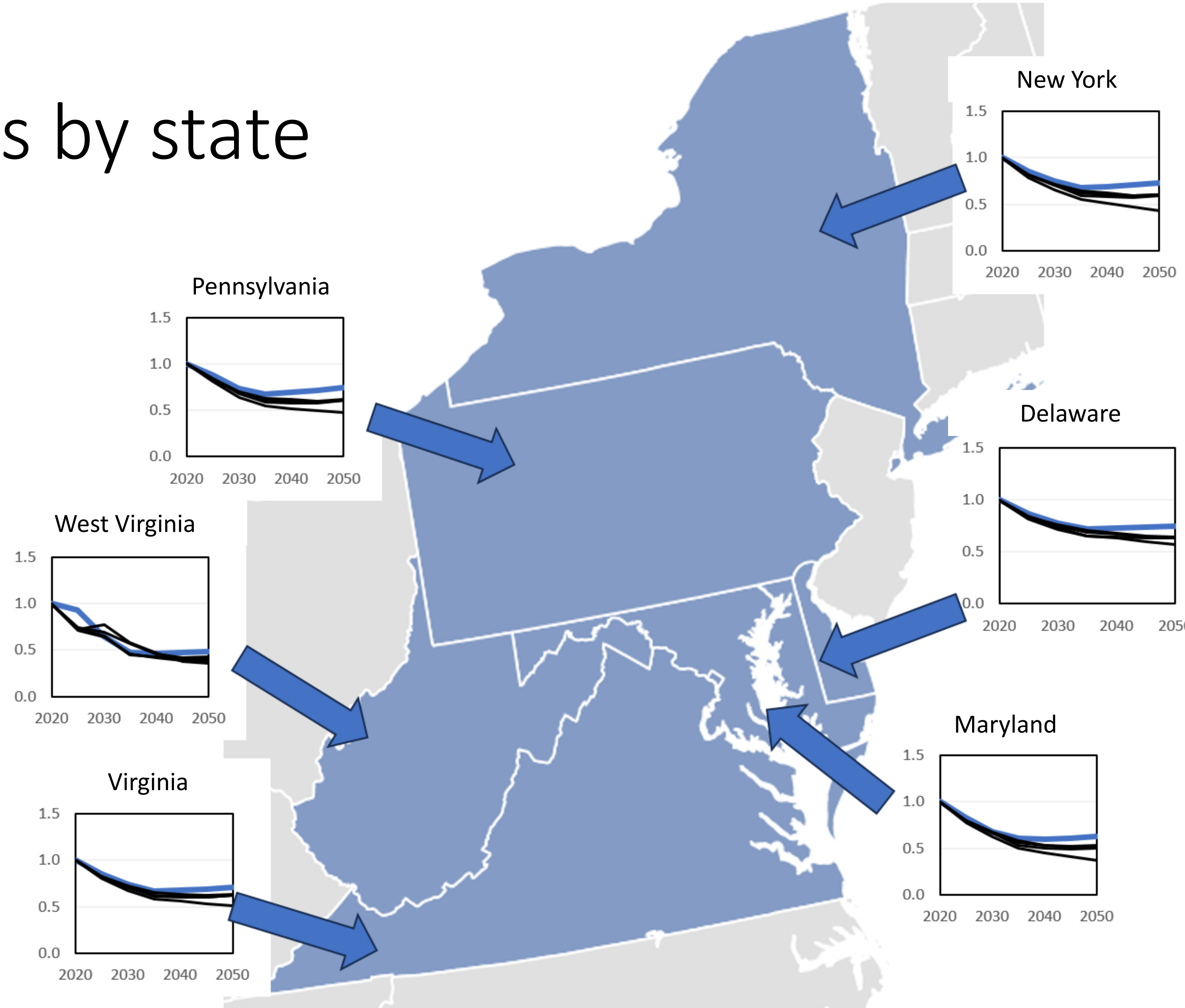
Ongoing Work – New Scenarios (GLIMPSEv1.1/GCAM7.0)

- IRA Scenario
  - Production Tax Credit (PTC) and Investment Tax Credit (ITC)
  - Biofuel, hydrogen (H2), and carbon capture and sequestration (CCS) subsidies
  - Residential and commercial energy efficiency credits
  - High efficiency electric home rebates
  - Passenger and commercial electric vehicle credits
  - Methane reduction program (incl. agricultural)
- Net-Zero Scenario
  - Layers on national Net-Zero CO2 emissions by 2050 target
  - Direct Air Capture (DAC) of CO2 is available
  - Barriers to electric vehicle adoption are addressed 5 years earlier
- Alternative Net-Zero Scenarios with one of the following:
  - Limited role for bio-energy
  - Limited role for nuclear power
  - Increased role for nuclear power
  - No availability of CCS and DAC
  - "Electrify everything" applied to transportation and buildings
- Will use 2035 outputs to scale emissions for CMAQ modeling, with Integrated Source Apportionment Model (CMAQ-ISAM) to estimate sectoral contributions to deposition

NOx emissions by state

Observations:

- NOx emissions tend to decrease for every state and across all scenarios
- Emission vary across NetZero scenarios, but tend to be less than in the IRA scenario

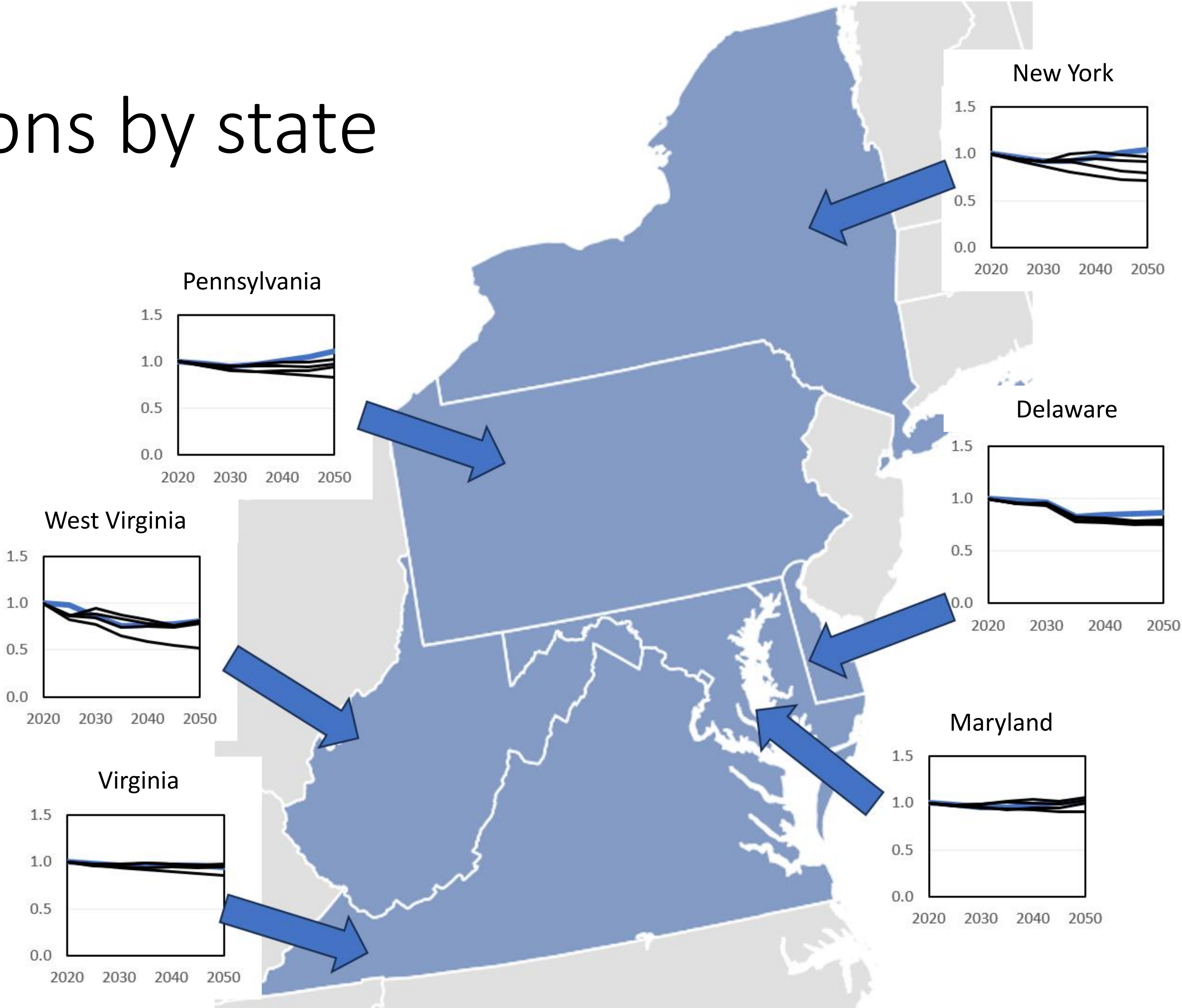


Blue – IRA
Black – NetZero

PM2.5 emissions by state

Observations:

- PM2.5 emission trends vary by state and by scenario



Blue – IRA
Black – NetZero

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NH3 emissions by state

Observations:

- NH3 emission trends vary by state and by scenario
- NetZero scenarios result in reductions, but those reductions vary by scenario

Blue – IRA
Black – NetZero