EPA United States Environmental Protection Agency

Chesapeake Bay Program
40 years of science, restoration and partnership

Impact of Decarbonization Scenarios on Atmospheric Nitrogen Deposition to the Chesapeake Bay

Jesse Bash, Chris Nolte, Dan Loughlin, Ben Murphy

EPA, Office of Research and Development, Center for Environmental Measurement and Modeling

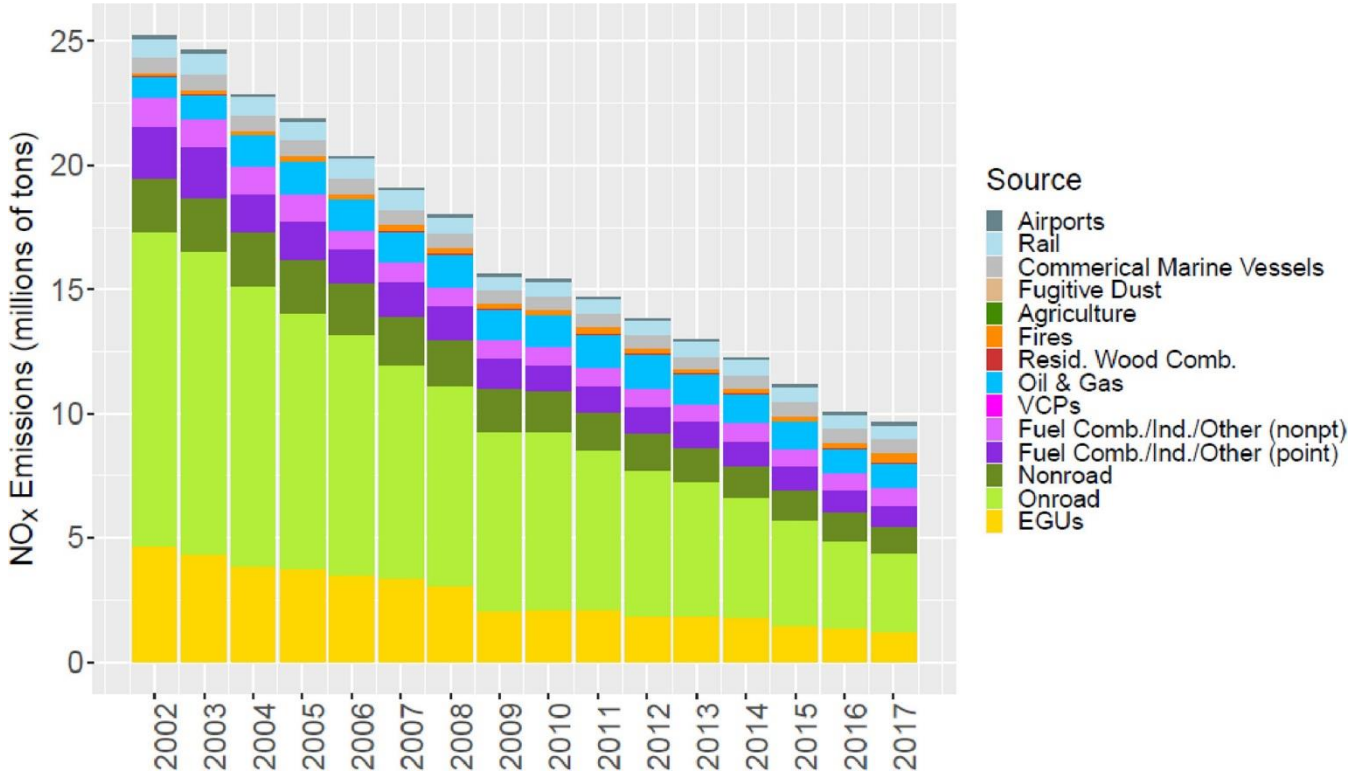
EPA United States Environmental Protection Agency

Model Simulations

- 2002 – 2019 Retrospective CMAQ simulations
  - EPA'S Air QUAlity TimE Series (EQUATES) project
  - CMAQ v5.3.2 simulation for 108 km northern hemisphere and 12 km Conterminous U.S. simulations
  - Emissions based on 2017 NEI methodology
- 2016, 2035, and 2050
  - CMAQ v5.4 with integrated source apportionment
  - Base 2016 emissions scaled to Global Change Analysis Model (GCAM) for future energy scenarios using CMAQ's Detailed Emissions Scaling, Isolation, and Diagnostics (DESID) module

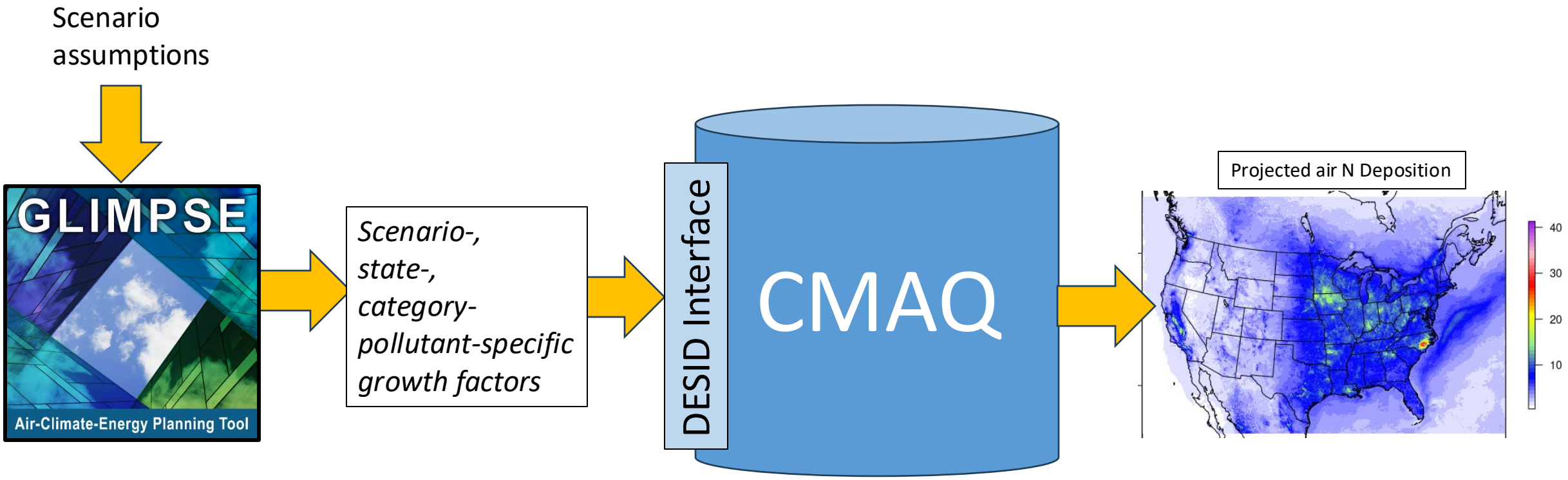
2002 -2019 CMAQ Simulations

- Changes from Phase 6
  - Developed new methodology for emission estimates
    - Foley et al., 2023 https://doi.org/10.1016/j.dib.2023.109022
  - Consistent CMAQ model version for all simulations
    - Benish et al., 2022 https://doi.org/10.5194/acp-22-12749-2022
  - Source apportionment data is available for 2005, 2011, 2016, and 2018
    - de la Paz et al., 2024 https://doi.org/10.5194/acp-24-4949-2024
  - Available land use/high-resolution deposition
    - Hogrefe et al., 2023 https://doi.org/10.5194/acp-23-8119-2023



Foley et al., 2023

Modeling Framework



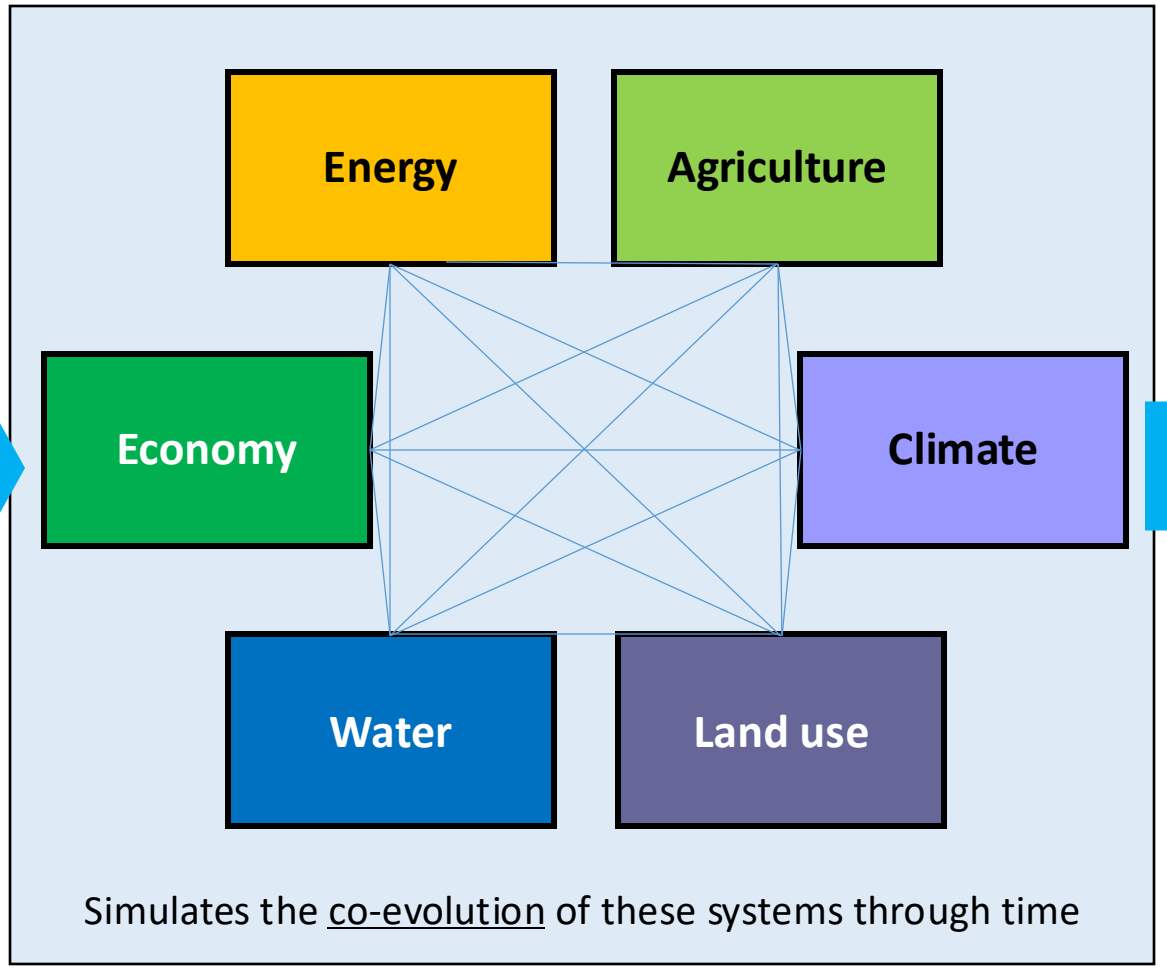
GCAM: Global Change Analysis Model (O'Neil et al., 2017 http://dx.doi.org/10.1016/j.gloenvcha.2015.01.004)
GLIMPSE: GCAM Long-term Interactive Multi-Pollutant Scenario Evaluator (Ou et al., 2023 https://doi.org/10.1016/j.egycc.2023.100117)
DESID: Detailed Emission Scaling, Isolation, and Diagnostics module (Murphy et al., 2021 https://doi.org/10.5194/gmd-14-3407-2021)

Global Change Analysis Model

Scenario assumptions

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

GCAM



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

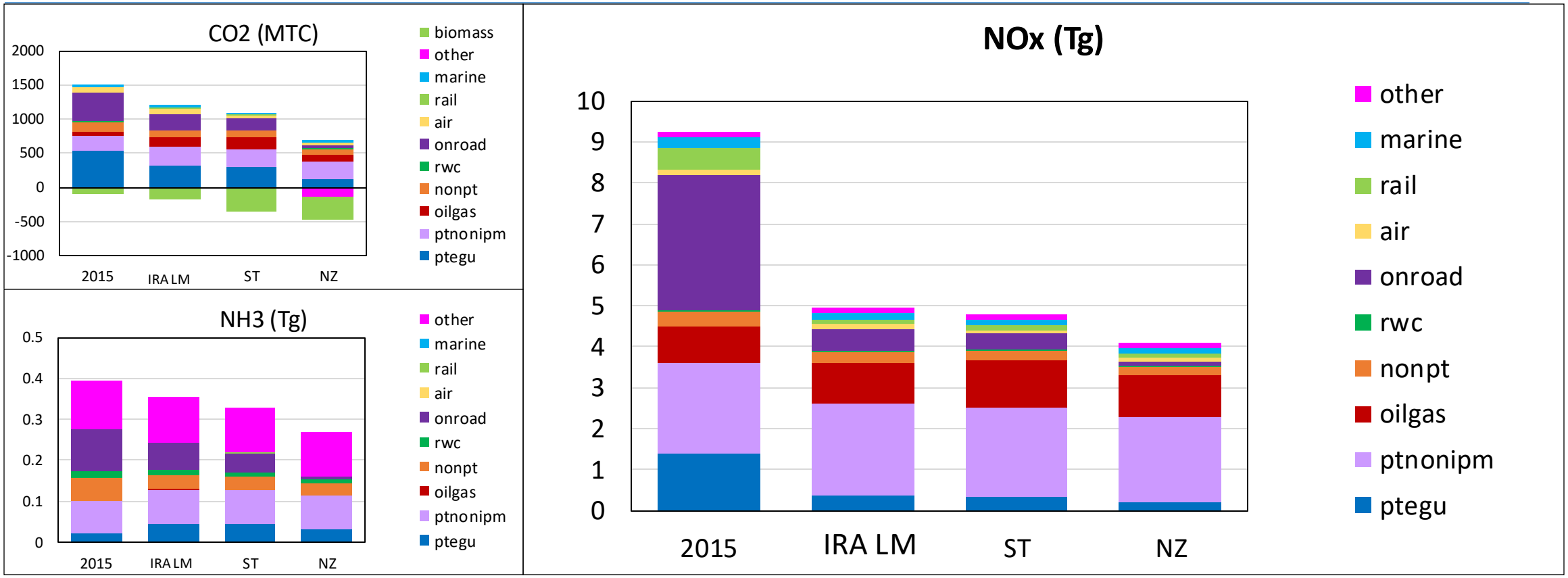
Environmental
- Air pollutant emissions
- Water use
- Health impacts

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

Scenario Design

- *Historical*: 2016 EQUATES emissions
- *IRA LM*: A baseline scenario that includes:
  - limited GHG mitigation
  - Subsidies specified in the Inflation Reduction Act
  - No new air pollutant control requirements
- *StateTargets (ST):* A mitigation scenario base on IRA LM:
  - Adds state GHG reduction targets as regional CO2 caps
- *NetZeroZEV (NZ)*: A mitigation scenario that includes:
  - A national, economy-wide declining CO_2 cap reaches Net-Zero by 2050
  - New CA light-duty electrification targets adopted by all states
  - Memorandum of Understanding on zero-emission medium- and heavy-duty vehicles adopted by all states
- Several NetZeroZEV variants are also explored with alternative assumptions about the roles of renewables, biomass, and carbon capture

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%

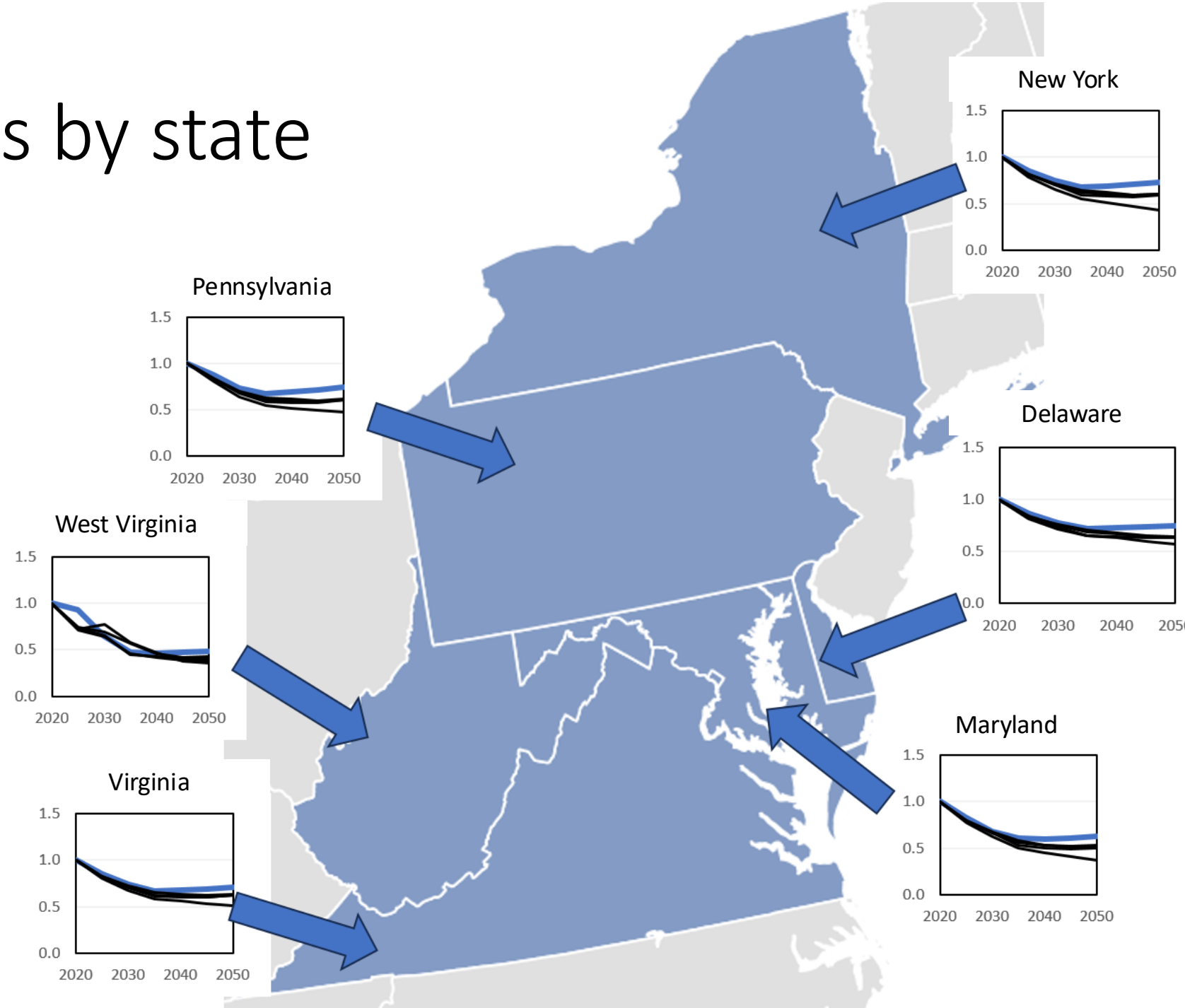
	2023	2026	2028	2032	2050
StateTargets	-1.2%	-2.0%	-1.8%	-2.2%	-7.0%
NetZeroZEV	-0.9%	-2.7%	-5.3%	-10%	-21%

NOx emissions by state

Blue – IRA LM
Black – NetZeroZEV and variants

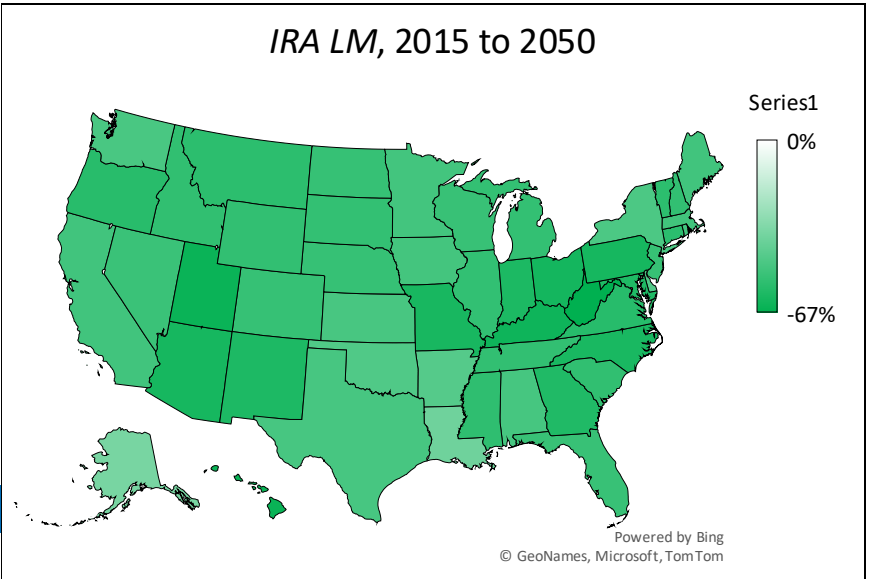
Observations:

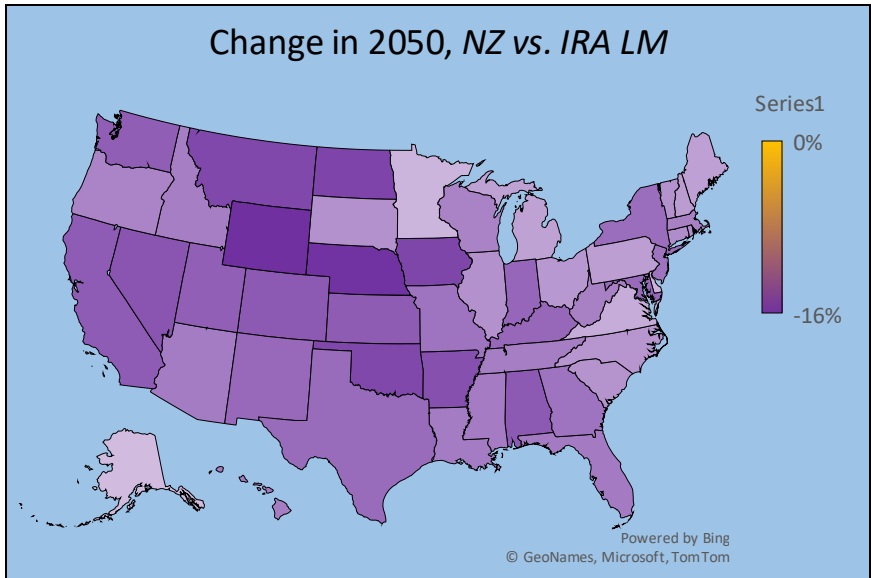
- NOx emissions tend to decrease for every state and across all scenarios
- Emission vary across NetZeroZEV scenarios, but tend to be less than in the IRA scenario



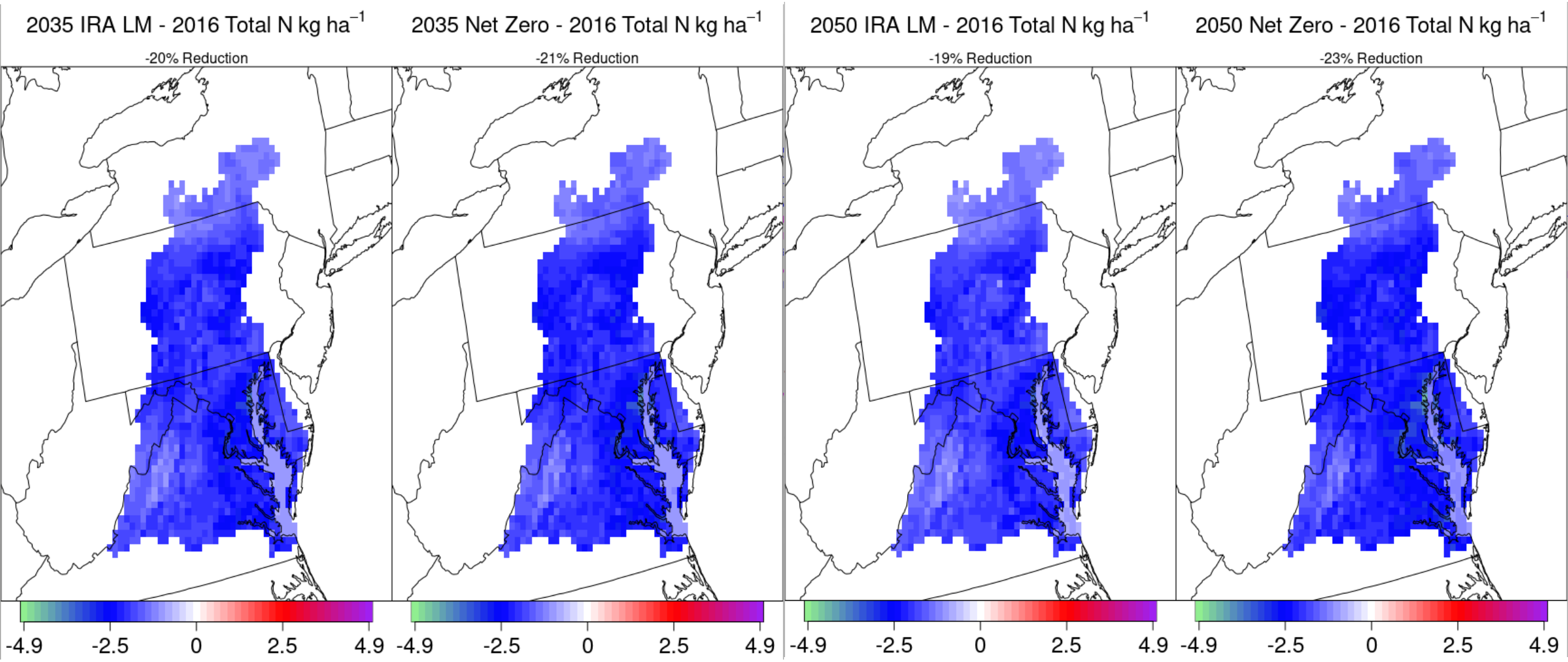
Linking GCAM to CMAQ

- 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

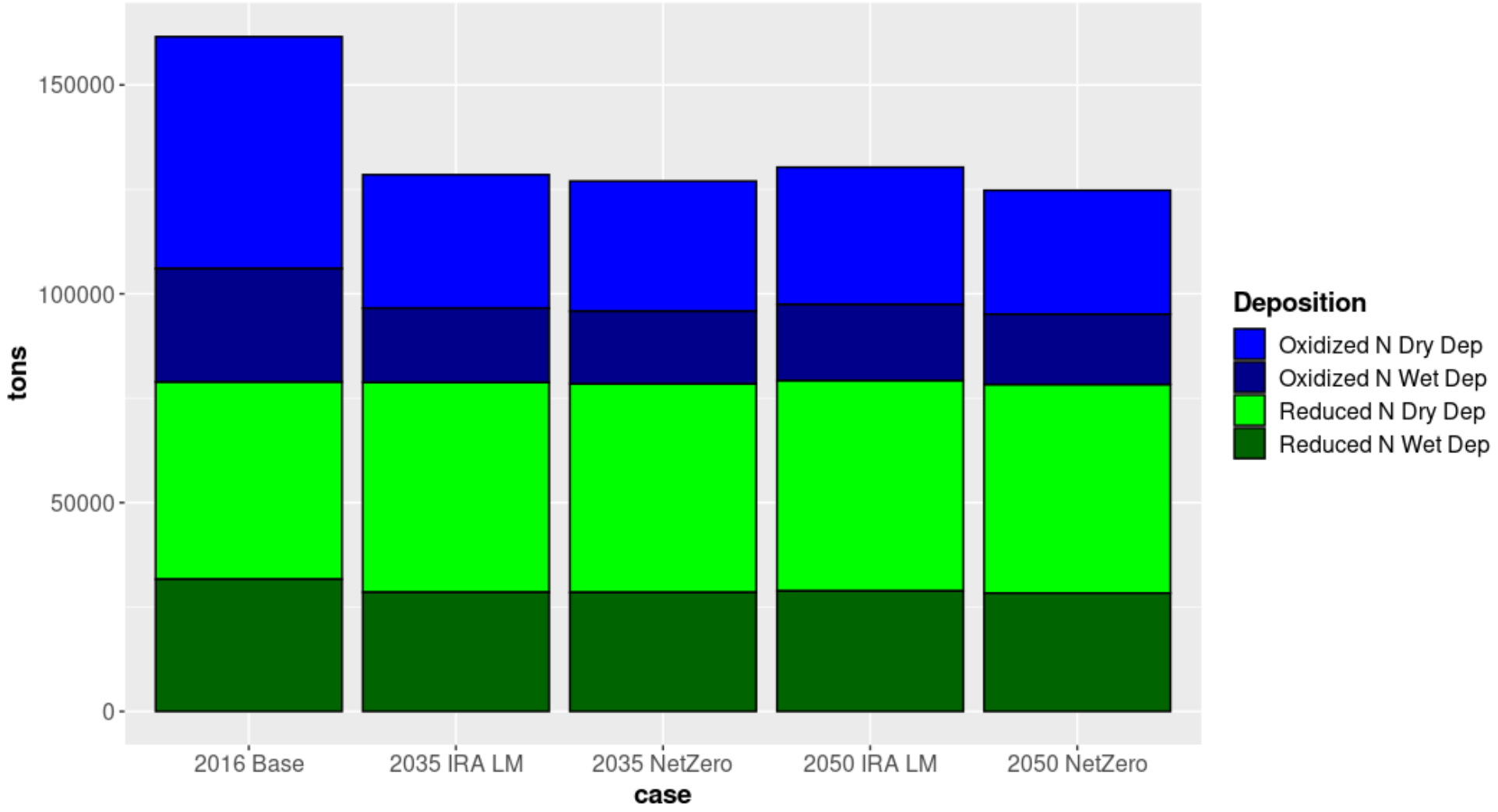




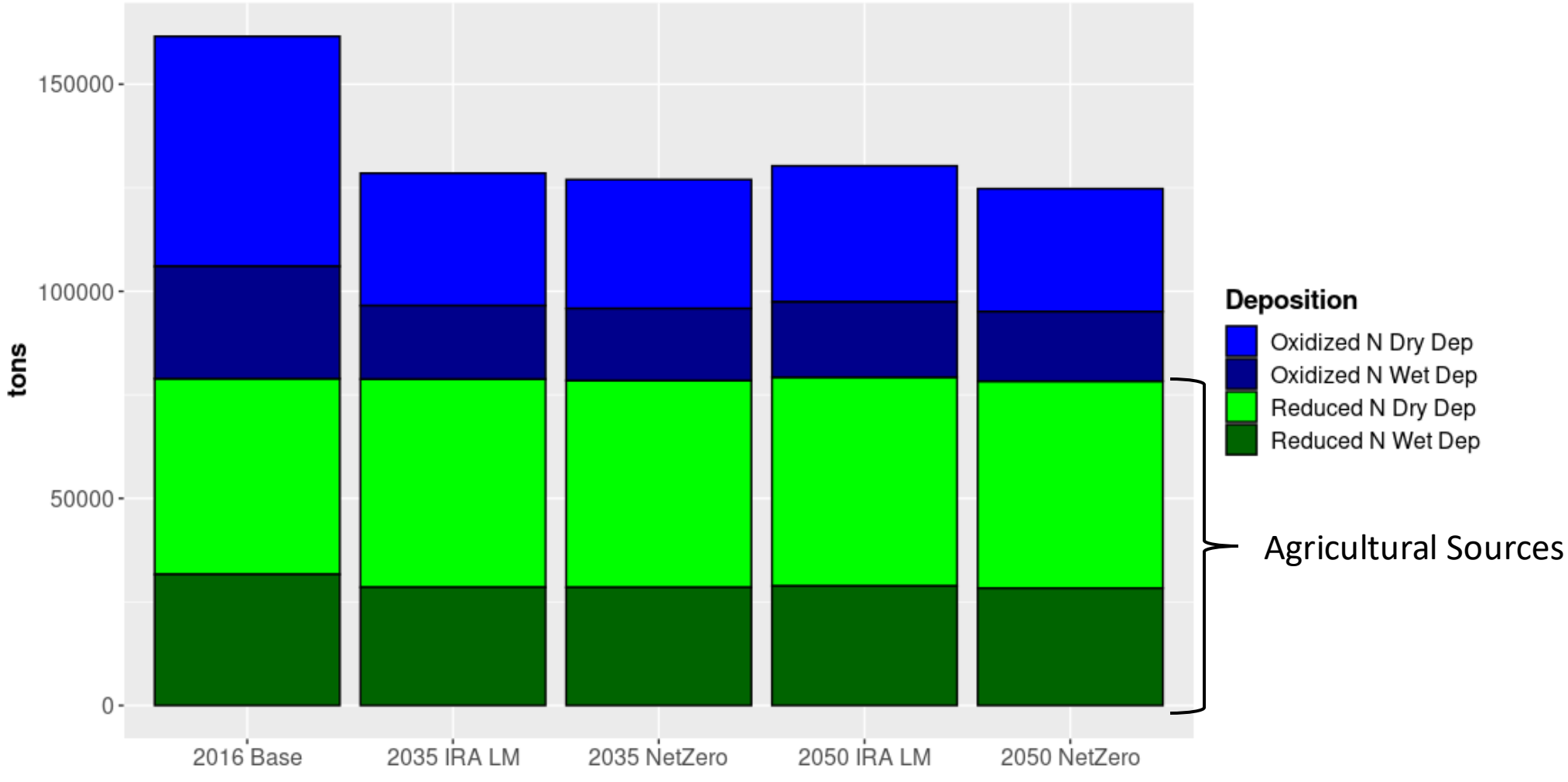
Total N deposition



Nitrogen Deposition by Species



Nitrogen Deposition by Species



Preliminary Results

- CMAQ simulations for 2016 and with projected 2035 emissions for IRA LM and NetZero cases were completed
- 2035 IRA LM case resulted in substantial reductions in total N deposition
  - 21% reduction in total nitrogen deposition to the Chesapeake Bay Watershed
- IRA LM nitrogen deposition increases from 2035 to 2050 by 1% due to growth in the energy sectors and population
- Nitrogen deposition continues to decrease from 2035 to 2050 in the NetZeroZEV cases
- The fraction of nitrogen deposition from agricultural sources increases from 48% in 2016 to over 60% post 2035
  - Most reductions have been focused on regulating combustion sources from energy and transportation sectors