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# Future in- and out-of-state air pollutant emissions under decarbonization pathways for Massachusetts

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The views expressed in this presentation are those of the authors and do not necessarily represent the views or the policies of the U.S. Environmental Protection Agency or the National Oceanic and Atmospheric Administration

# Tackling Climate Change


"Despite the peril that is already evident, there is promise in the solutions — opportunities to create well-paying union jobs to build a modern and sustainable infrastructure, deliver an equitable, clean energy future, and put the United States on a path to achieve net-zero emissions, economy-wide, by no later than 2050."

-Executive Order on Tackling the Climate Crisis at Home and Abroad

The Regional Greenhouse Gas Initiative
an initiative of Eastern States of the US

TRANSPORTATION & CLIMATE INITIATIVE

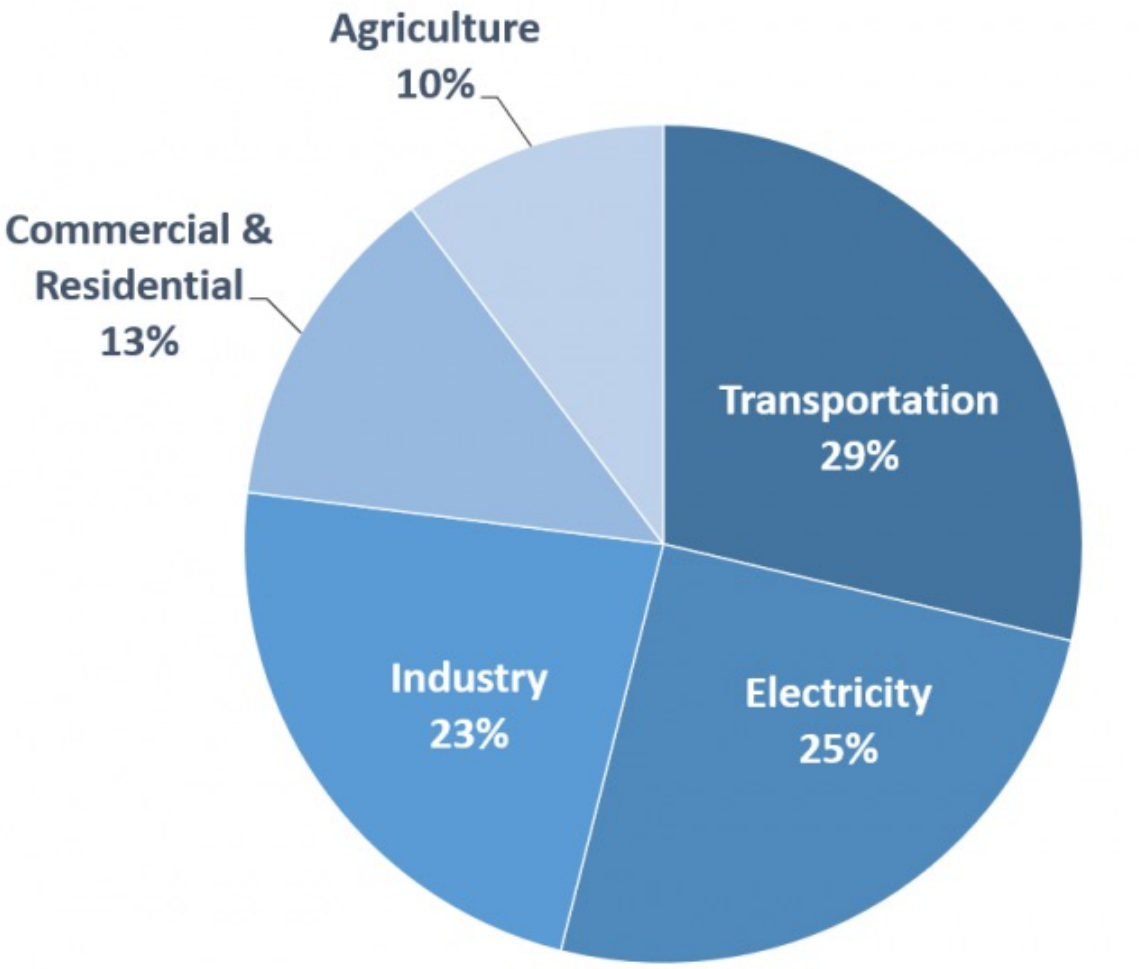
"The climate crisis is a generational challenge that, without decisive action, leaves residents and communities across the state on the front lines. Recognizing the urgency of this crisis, the Baker-Polito Administration listened to the science, and set Massachusetts on an aggressive path to Net Zero greenhouse gas emissions by 2050."

- MA 2050 Decarbonization Roadmap

# Energy Transition is the Key

"The main human activity that emits $CO_2$ is the combustion of fossil fuels (coal, natural gas, and oil) for energy and transportation, although certain industrial processes and land-use changes also emit $CO_2$. "

Total U.S. GHG by Economic Sector in 2019




Source: https://www.epa.gov/ghgemissions/overview-greenhouse-gases

Source: Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990–2019.

# Co-benefits of Decarbonization

## Energy and Air Quality

The energy system is also responsible for a large fraction of U.S. anthropogenic air pollutant emissions.

89% of $NO_x$

70% of $SO_2$

16% of Primary $PM_{2.5}$

There can be substantial air quality co-benefits associated with decarbonization.

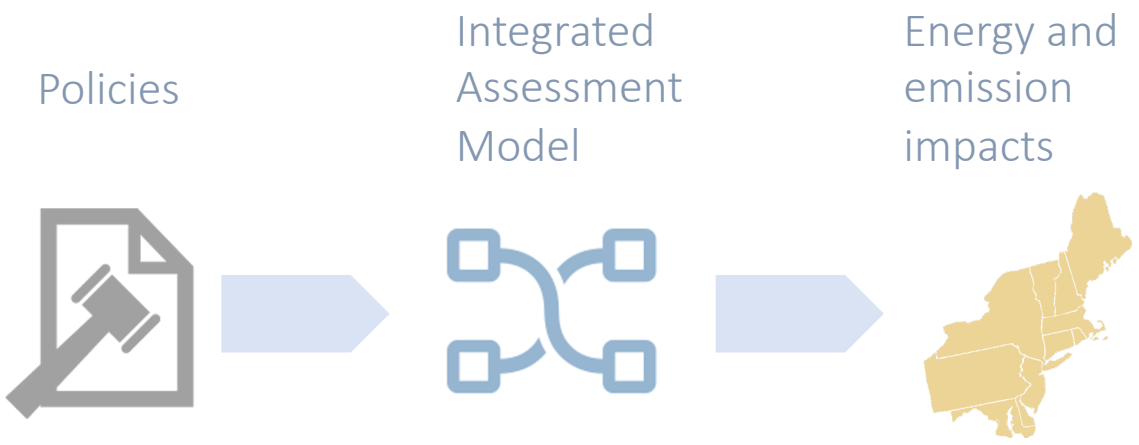
Source: Air Pollutant Emissions Trends Data 2020, National Tier 1 CAPs Trends. https://www.epa.gov/sites/default/files/2021-03/national_tier1_caps.xlsx

## Research Questions

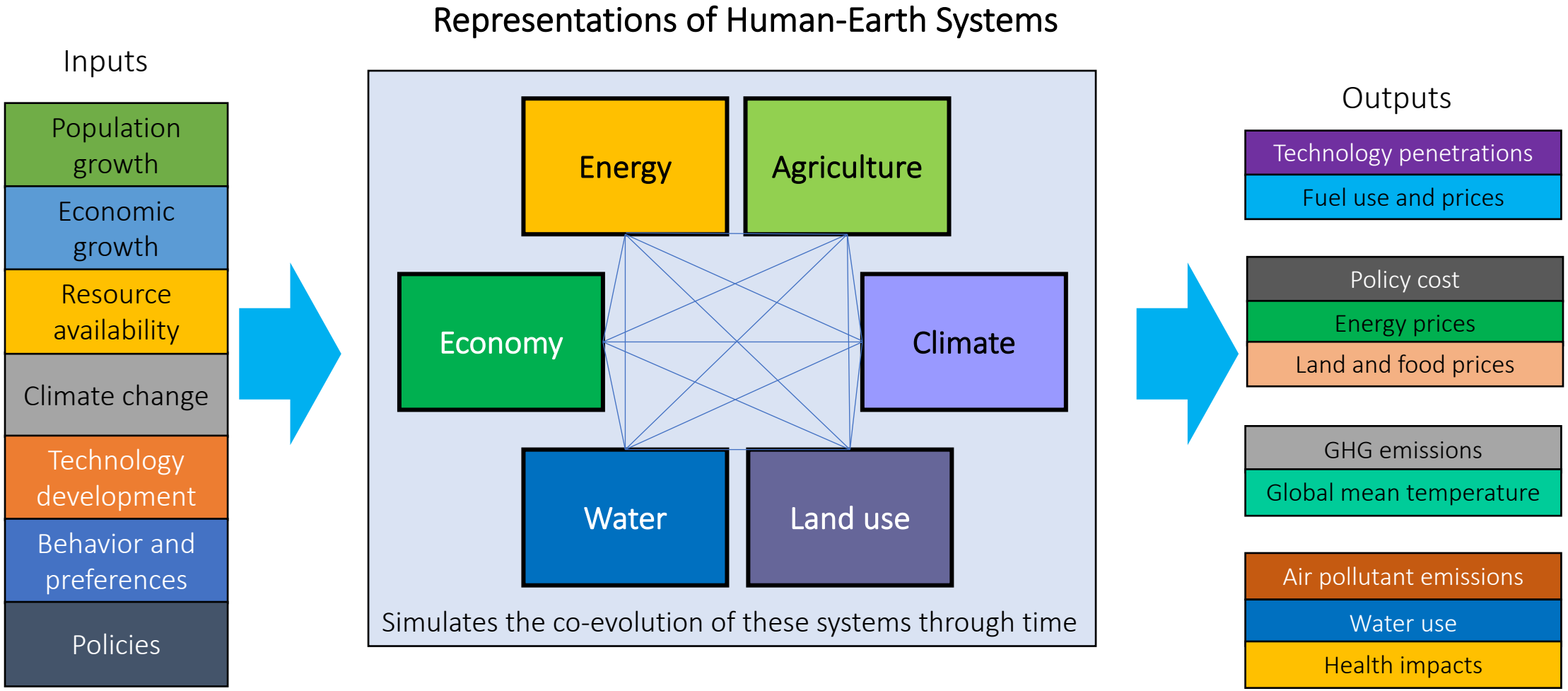
How do regional and state policies work synergistically to achieve emissions targets in the state?

Would Massachusetts' policies result in emission leakage to neighboring states?

## Approach



# The Global Change Analysis Model (GCAM)




Source: U.S. EPA GLIMPSE info session.
https://www.epa.gov/sites/default/files/2018-01/documents/glimpse_fact_sheet_remake_0.pdf

# Economic Choice in GCAM-USA

## Logit Function

$$s_i = \frac{\alpha_i p_i^{\gamma}}{\sum_{j=1}^{N} \alpha_j p_j^{\gamma}}$$

Where:
$s_i$: Sales share of technology i
$p_i$: Price of technology i
$\alpha_i$: Shareweight of technology i

The Shareweight represents preference or bias.

By convention, a Shareweight > 1 will result in greater market share.

A Shareweight of 0 means that the technology cannot be purchased

Source: U.S. EPA GLIMPSE info session.
https://jgcri.github.io/gcam-doc/choice.html

## Example of logit results (assume γ = -8)

| Technologies competing for "large car" market in 2030 | | | |
|---|---|---|---|
| Tech (i) | Price ($p_i$) $/Pass-km | Shareweight ($a_i$) | Sales Share ($s_i$) % |
| Electric | 0.229 | 0.5 | 14 |
| Gasoline | 0.222 | 1 | 35 |
| Hybrid | 0.215 | 1 | 46 |
| Fuel cell | 0.231 | 0.18 | 5 |
| Natural gas | 0.289 | 0.22 | 1 |

Prices represent estimated lifetime averages costs for NY

## Implementing scenarios

We can examine scenarios of increasing electric vehicle market share by decreasing the Shareweights of competing vehicle technologies.

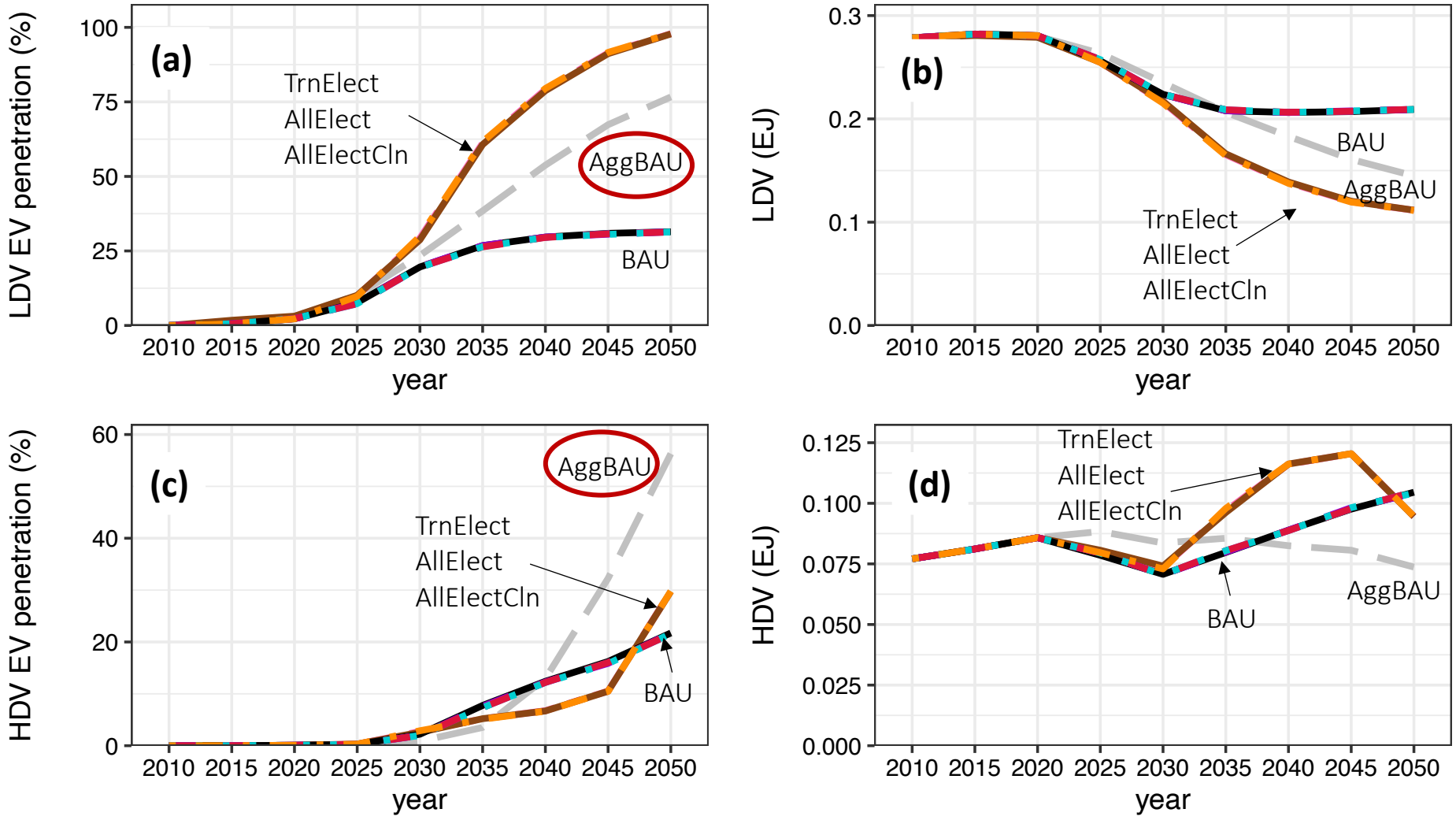
# Scenarios

| Scenario Name | Descriptions |
|---|---|
| Business as Usual (BAU) | Regional: Conservative scenario with on-the-book restrictions and regulations |
| Aggressive Business as Usual (AggBAU) | Regional: Aggressive scenario that includes cost reductions for light duty electric vehicles and the most stringent TCI and RGGI restrictions in which the slopes of carbon caps are extended through 2050 |
| Transportation electrification (TrnElect) | MA only: LDV EV sales share reaches 100% in 2035. HDV EV sales share reaches 100% in 2050 |
| Building electrification (BldElect2025/2030/2035) | MA only: Electric heat pumps sales share reaches 100% by 2025. Alternative versions reach this target by 2030 and 2035, respectively |
| Clean Energy (ClnErg100) | MA only: Electricity generation is increasingly produced by clean energy, reaching 100% in 2050 |
| BAU+TrnElect+BldElect2030 (AllElect) | MA only: Combines the building and transportation electrification scenarios |
| BAU+TrnElect+BldElect2030+ClnErg100 (AllElectCln) | MA only: Combines the building, transportation electrification, and 100% clean energy targets |

# Electrification – Light- and heavy-duty vehicles

LDV

HDV

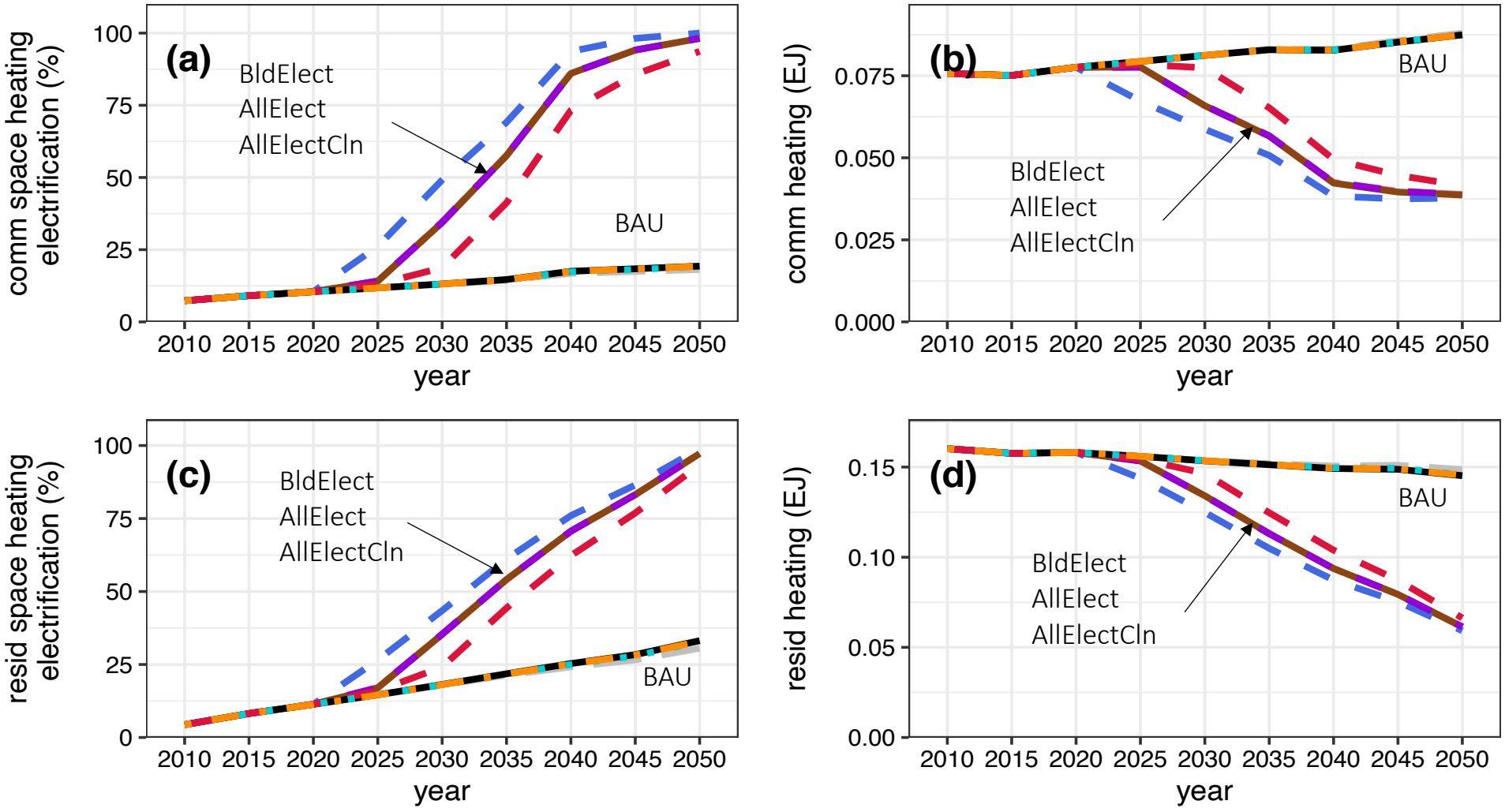



*LDV, light-duty vehicle
*HDV, heavy-duty vehicle
*EJ, Exajoule, $10^{18}$ joules

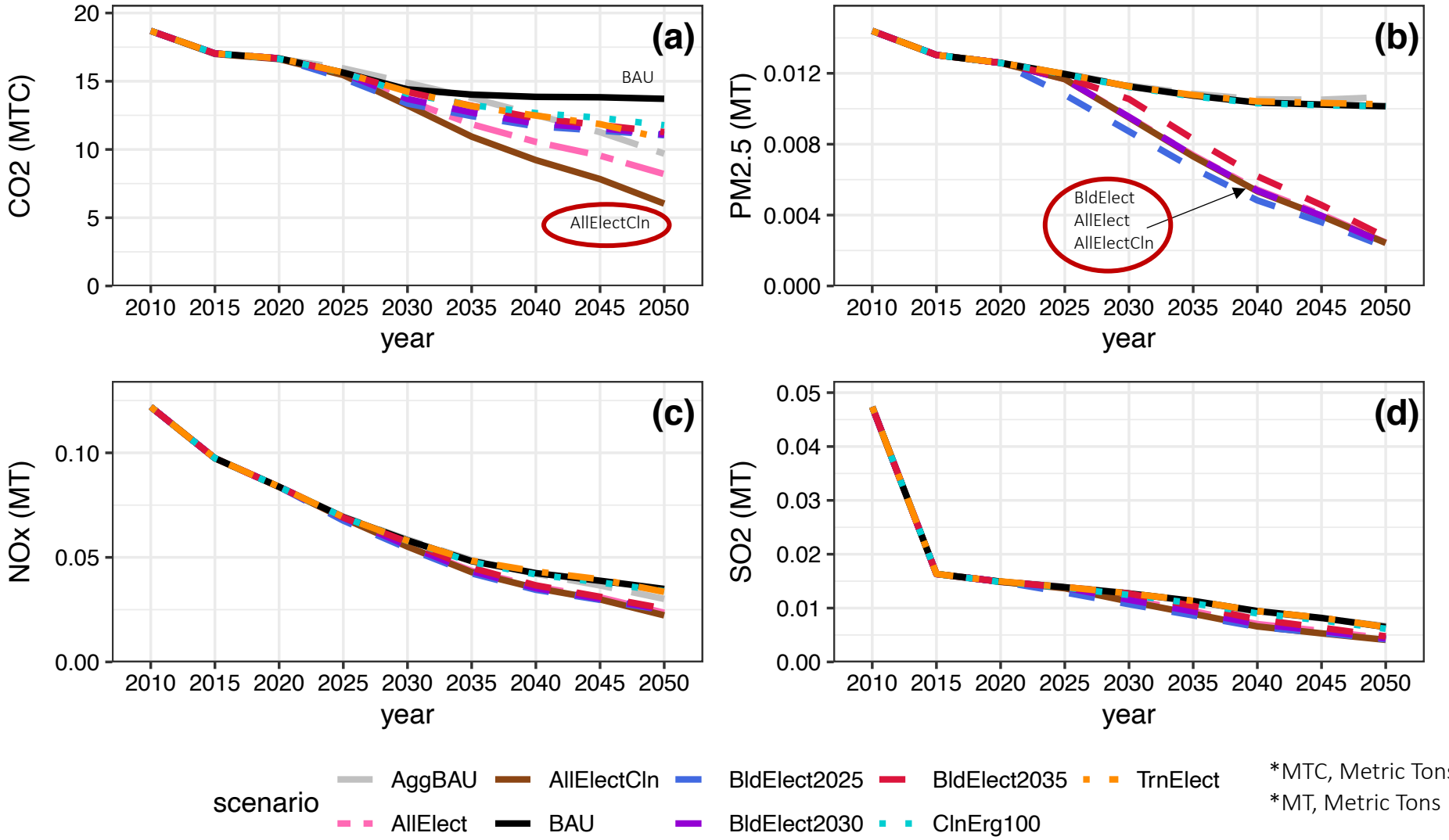
# Electrification – Commercial and Residential heating

Commercial

Residential



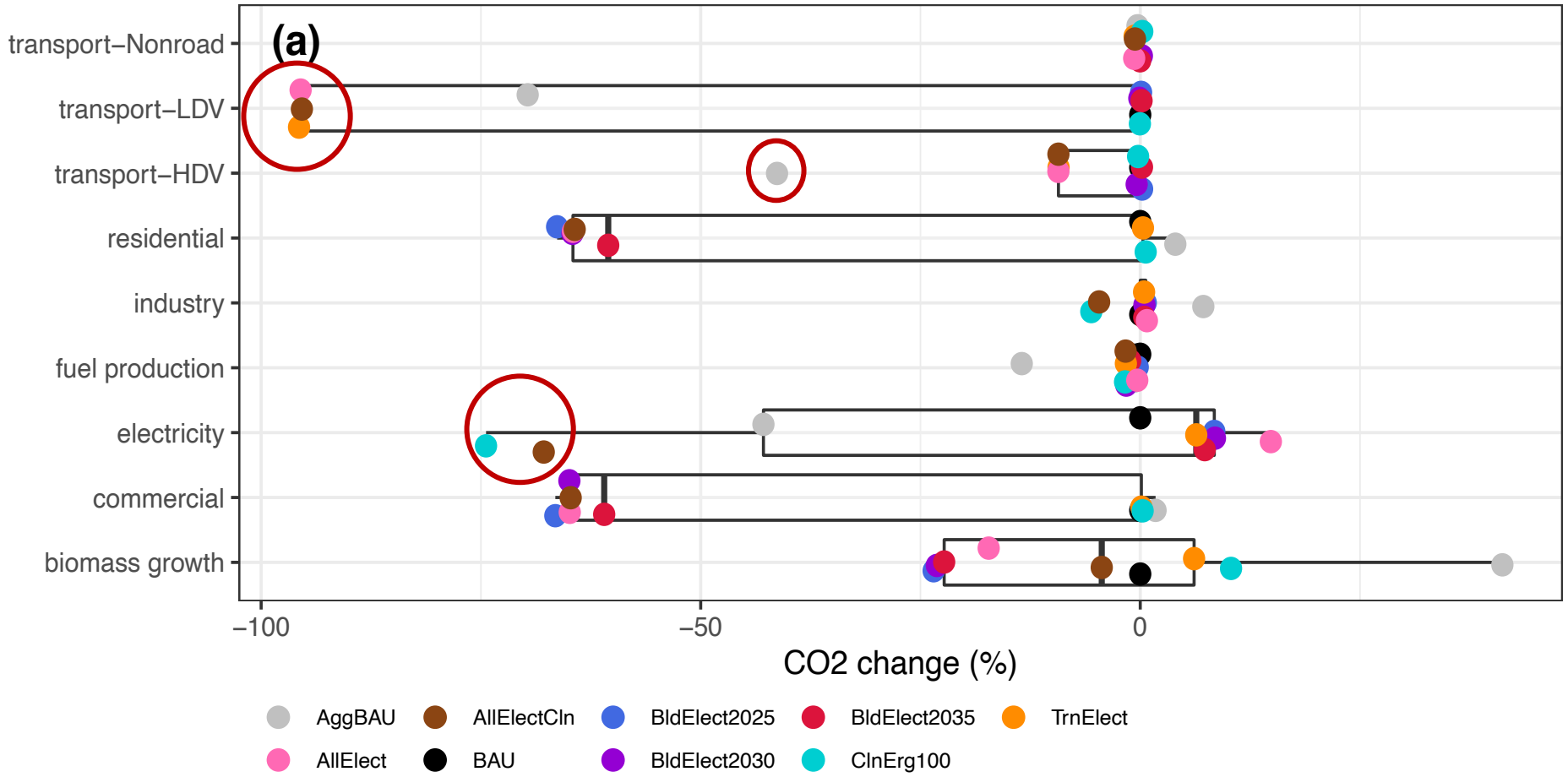
# Emission Implications in Massachusetts




*MTC, Metric Tons Carbon
*MT, Metric Tons

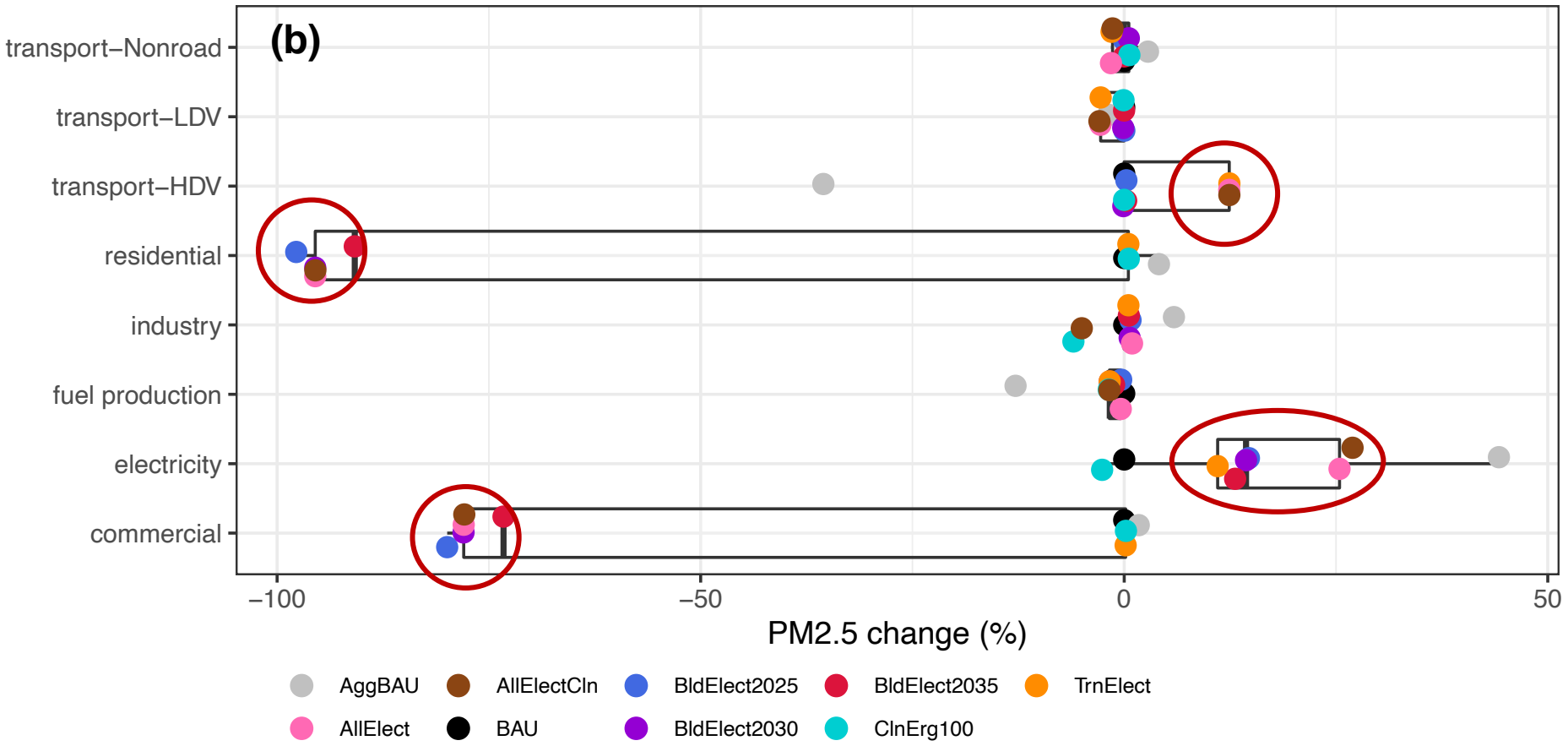
- With the deep decarbonization plans, AllElectCln can achieve 65% of carbon reduction in MA
  - the remaining carbon comes from industry and nonroad sectors
- Building electrification has significant impacts on PM reduction

# Sectoral Contribution to $CO_2$




- LDV, HDV, residential building, commercial building, and electricity sectors show the largest emission changes
- LDV sector contributes more than HDV sector
  - aggressive LDV electrification policy results in high EV penetration rate
- $CO_2$ emissions from the electric sector are only reduced under grid decarbonization scenarios
  - increased demand from building and vehicle electrification

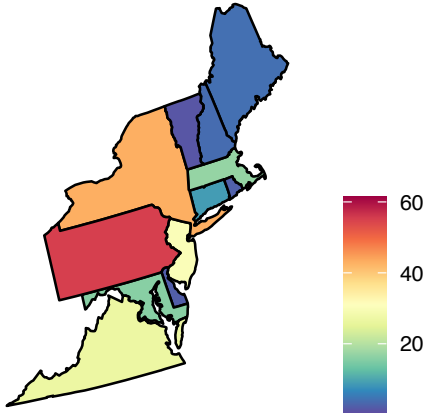
# Sectoral Contribution to $PM_{2.5}$



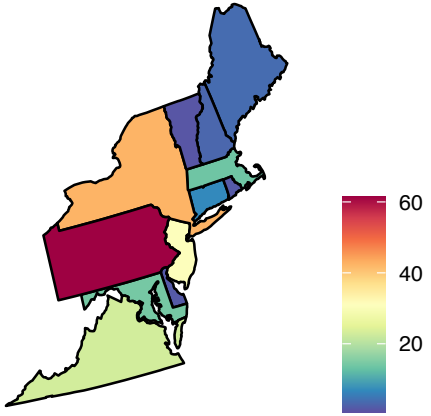

- Residential and commercial buildings have large reductions under the building electrification policies
- Increasing $PM_{2.5}$ emissions from electricity because of increasing electricity demand
  - growing share of biomass-based power generation
- Increases in HDV $PM_{2.5}$ emissions in scenarios with the state-level transportation electrification policy
  - shifts in service demands from other freight modes to HDVs in these scenarios

# Impacts on Neighbor States

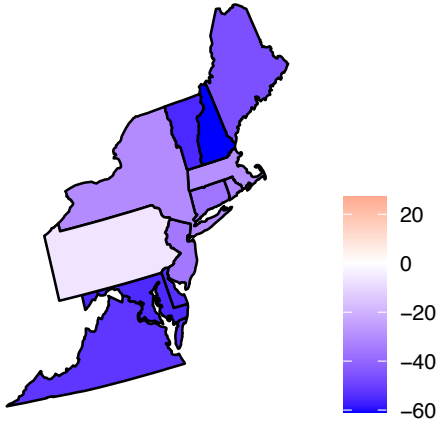
**(a)** 2015 CO2 (MTC) in BAU



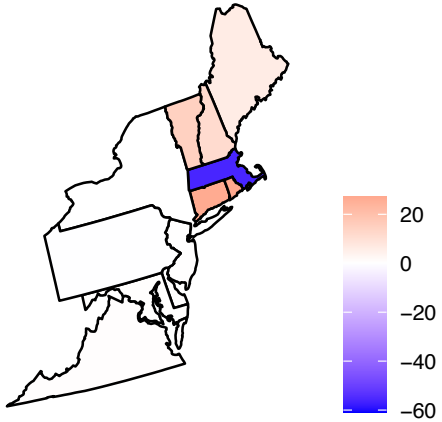

**(b)** 2050 CO2 (MTC) in BAU




**(c)** AggBAU–BAU CO2 change (%) in 2050




**(d)** AllElectCln–BAU CO2 change (%) in 2050




- PA and NY have highest emissions
  - determined by population
- Under the AggBAU scenario with its more ambitious regional policies, all states show carbon reductions, while in the AllElectCln scenario, there are no further reductions compared to the BAU scenario
- AggBAU scenario shows much less emissions reduction compared to the AllElectCln scenario in MA
  - additional state level policies needed to achieve reduction goal
- Neighbor states in the AllElectCln scenario all show increases
  - MA imports electricity results in carbon leakage

# Key Takeaways

- The most aggressive state decarbonization pathway that was examined would achieve only a 65% of reduction in $CO_2$ emissions by 2050, indicating the need for further decarbonization options within the industry and non-road transportation sectors.

- The stated emission reduction targets RGGI and TCI are not sufficient to meet state and regional long-term reduction goals and must be enhanced or supplemented with state-level policies in order to meet aggressive decarbonization targets.

- The air pollution co-benefits under the modeled decarbonization pathways are significant, especially for primary fine particulate matter.

- While policies focusing only on MA are shown to produce in-state reductions of $CO_2$ and air pollutant emissions, a portion of these reductions was countered by emission increases in other states, indicating the need for coordinated planning to prevent leakage.

# Acknowledgement

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# Thanks

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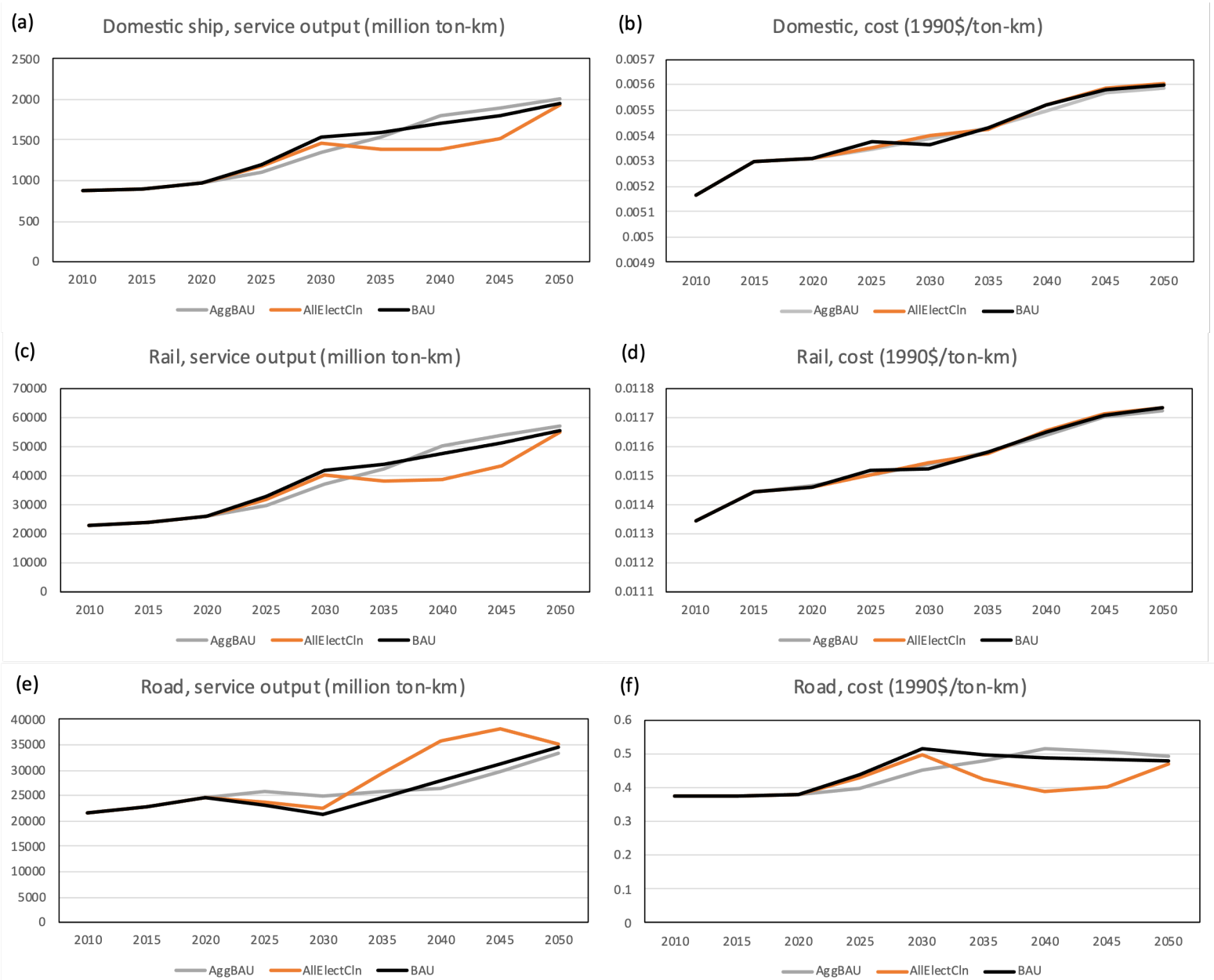
# SI

Service output of domestic ship (a), rail (c), road (e) and cost of domestic ship (b), rail (d), road(f).



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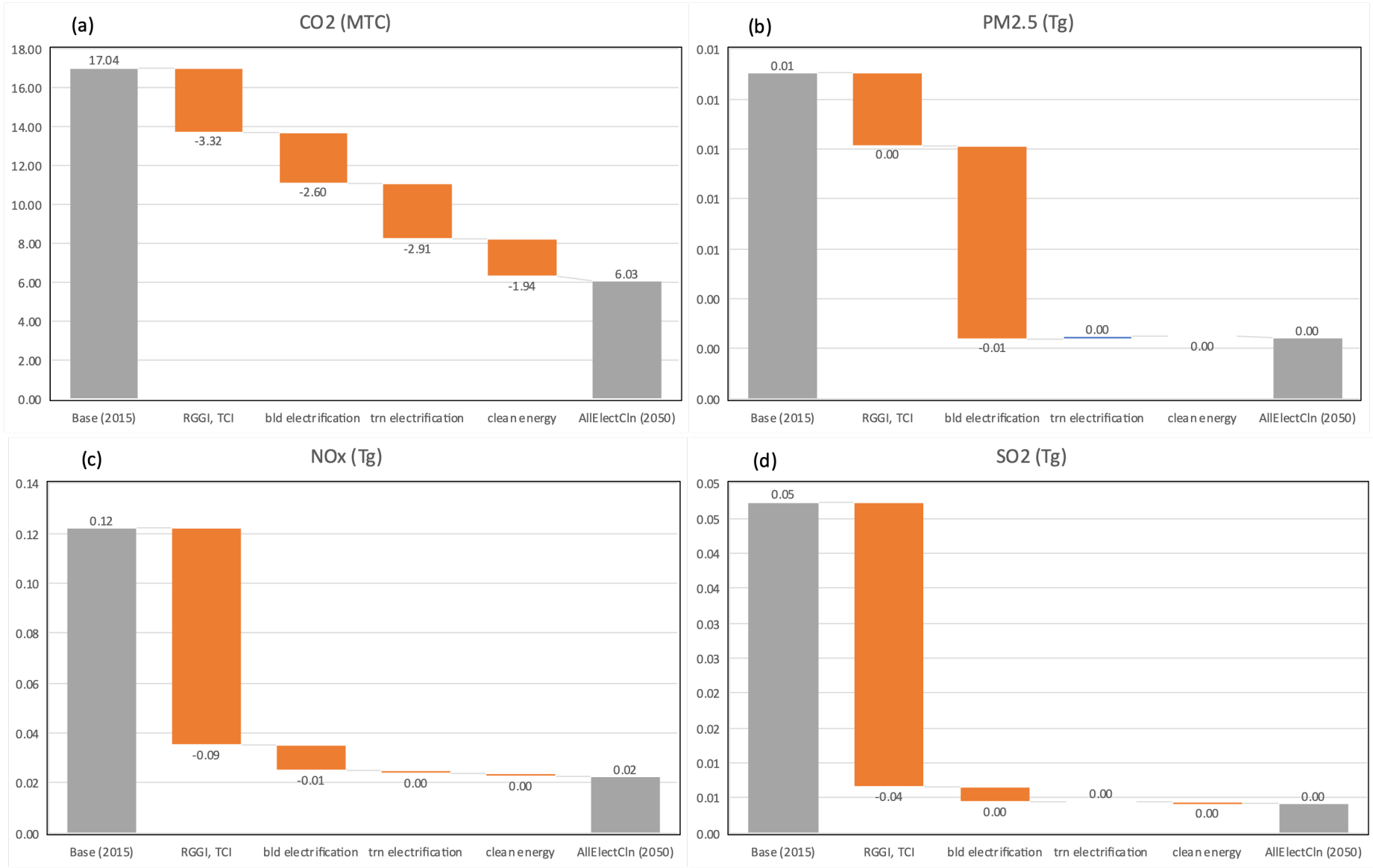


Decomposition analysis of CO2 (a), PM2.5 (b), NOx (c), SO2 (d).