

Preliminary Results – Updated February 25, 2021



**TRECH**  **PROJECT**  
**TRANSPORTATION, EQUITY, CLIMATE & HEALTH**

<https://hsph.me/TRECH>

Image by Eric Spiegel licensed under Creative Commons



**HARVARD T.H. CHAN**  
SCHOOL OF PUBLIC HEALTH

**C-CHANGE**  
CENTER FOR CLIMATE, HEALTH,  
AND THE GLOBAL ENVIRONMENT



**INSTITUTE FOR  
THE ENVIRONMENT**



Columbia University  
MAILMAN SCHOOL  
OF PUBLIC HEALTH

# What is TRECH?



- Multi-university team researching **T**ransportation, **E**quity, **C**limate & **H**ealth.
- Independent analysis of five policy scenarios related to the Transportation & Climate Initiative, or TCI.
- All results reflect what could occur if the 12 Northeast and Mid-Atlantic states and D.C. participate in the Transportation & Climate Initiative program. At this time, three states (MA, CT, and RI) and D.C. have signed a [memorandum of understanding](#) to participate in the TCI program.
- Sharing preliminary results to foster dialogue and to inform policy choices.
- Relied on published peer-reviewed computer models commonly used by EPA, states, and others in regulatory analysis.
- Analysis has been reviewed by our team of 10 experts.
- Analysis is not yet published in a scientific journal, so it is clearly labeled as “preliminary”.
- Scenarios are illustrative, not predictive. Actual health benefits of a TCI program will depend on state participation and actions (such as cap level, investments, and complementary policies).

# What is the Transportation Climate Initiative?

## WHAT

- Regional collaboration that aims to reduce carbon dioxide emissions from on-road vehicles
- Proposed cap and investment structure in states from Maine to Virginia, and D.C.

## HOW

- Cap would apply to on-road diesel and motor gasoline
- The point of regulation would be liquid fuel wholesale suppliers
- Suppliers would need to hold allowances for the CO<sub>2</sub> content of their fuels
- Allowances would be auctioned off annually and decline over time
- Auctions would generate proceeds that are distributed to states for investment

## WHEN

- Proposed program is intended to start in 2023
- The TCI scenario caps reduce CO<sub>2</sub> emissions from on-road vehicles by 20 - 25% from 2022 levels by 2032
- This is equivalent to a 1- 6% reduction between the policy scenarios and reference scenario in 2032
- MOU signed by 3 states and D.C. in December 2020

# Insights from Preliminary Results

1. The estimated health benefits for the five TCI climate mitigation policy scenarios are substantial and are larger than estimated program proceeds, based on this analysis of a subset of total possible benefits.
2. The estimated health benefits of the TCI scenarios analyzed include up to 1,360 deaths avoided, 320 incidences of childhood asthma avoided, and tens of thousands of childhood asthma exacerbations avoided under the top-performing policy scenario in 2032, if all 12 states and D.C. participate in the TCI program.
3. The policy scenario with the largest health benefits is the one with the most ambitious emissions cap (25%) and the largest share of investments dedicated to public transit and active mobility.
4. Under all the policy scenarios examined, health benefits occur in all counties across the region and are concentrated in more populated areas.
5. All the policy scenarios examined modestly reduce inequities in air pollution exposure by race/ethnicity but, even with the reductions estimated under the TCI policy scenarios, people of color would still face higher overall air pollution exposures and more emissions reductions would be needed to address pre-existing inequities.
6. There is a four-fold difference exists in the estimated health benefits across the policy scenarios, underscoring the wide range of possible outcomes and that actual benefits will depend on state participation and state actions.

# Five *Illustrative* TCI Policy Scenarios Defined by States

		Scenario A	Scenario B	Scenario C
		25% CO2 cap	20, 22, 25% CO2 cap	25% CO2 cap
	Electric cars, light trucks and vans	5%	30%	54%
	Low & zero-emission buses and trucks	21%	23%	27%
	Transit expansion and upkeep	35%	18%	-
	Pedestrian and bike safety, ride sharing	16%	14%	10%
	System efficiency	7%	8%	8%
	Indirect/ Other	17%	8%	-

20%, 22% and 25% cap = 1, 3, and 6% carbon dioxide emission reductions, respectively

# TRECH Examines Two Types of Health Benefits

Active Mobility – Biking and Walking



On-road Emission – Air Quality, Equity, Health



These Are a Subset of Total Benefits

# Estimated Health Benefits

## Five Illustrative TCI Scenarios Compared to No-TCI Scenario in 2032

	Scenario A 25% CO <sub>2</sub> Reduction Cap	Scenario B 25% CO <sub>2</sub> Reduction Cap	Scenario C 25% CO <sub>2</sub> Reduction Cap	Scenario B 22% CO <sub>2</sub> Reduction Cap	Scenario B 20% CO <sub>2</sub> Reduction Cap
Estimated deaths avoided (biking, walking, and air quality; central estimate)	1360	1160	840	640	320
Estimated benefits for all health outcomes (billions 2016\$; based on central estimates)	\$13.5	\$11.6	\$8.3	\$6.3	\$3.3
Estimated total annual TCI proceeds in 2032 (billions 2016\$)	\$8.5	\$6.8	\$5.4	\$3.5	\$1.9

PRELIMINARY RESULTS

# Estimated Health Benefits are Larger than TCI Proceeds in 2032

	Scenario A 25% CO <sub>2</sub> Reduction Cap	Scenario B 25% CO <sub>2</sub> Reduction Cap	Scenario C 25% CO <sub>2</sub> Reduction Cap	Scenario B 22% CO <sub>2</sub> Reduction Cap	Scenario B 20% CO <sub>2</sub> Reduction Cap
Estimated deaths avoided (biking, walking, and air quality; central estimate)	1360	1160	840	640	320
Estimated benefits for all health outcomes (billions 2016\$; based on central estimates)	<b>\$13.5</b>	<b>\$11.6</b>	<b>\$8.3</b>	<b>\$6.3</b>	<b>\$3.3</b>
Estimated total annual TCI proceeds in 2032 (billions 2016\$)	<b>\$8.5</b>	<b>\$6.8</b>	<b>\$5.4</b>	<b>\$3.5</b>	<b>\$1.9</b>

PRELIMINARY RESULTS

# The Four-fold Difference in Benefits, Illustrates Large Influence of Policy Decisions

	Scenario A 25% CO <sub>2</sub> Reduction Cap	Scenario B 25% CO <sub>2</sub> Reduction Cap	Scenario C 25% CO <sub>2</sub> Reduction Cap	Scenario B 22% CO <sub>2</sub> Reduction Cap	Scenario B 20% CO <sub>2</sub> Reduction Cap
Estimated deaths avoided (biking, walking, and air quality; central estimate)	1360	1160	840	640	320
Estimated benefits for all health outcomes (billions 2016\$; based on central estimates)	<b>\$13.5</b>	\$11.6	\$8.3	\$6.3	<b>\$3.3</b>
Estimated total annual TCI proceeds in 2032 (billions 2016\$)	\$8.5	\$6.8	\$5.4	\$3.5	\$1.9

PRELIMINARY RESULTS

# Investment Scenario A With the 25% CO<sub>2</sub> Reduction Cap Has the Largest Estimated Health Benefits

	Scenario A 25% CO <sub>2</sub> Reduction Cap	Scenario B 25% CO <sub>2</sub> Reduction Cap	Scenario C 25% CO <sub>2</sub> Reduction Cap	Scenario B 22% CO <sub>2</sub> Reduction Cap	Scenario B 20% CO <sub>2</sub> Reduction Cap
Estimated deaths avoided (biking, walking, and air quality; central estimate)	<b>1360</b>	1160	840	640	320
Estimated benefits for all health outcomes (billions 2016\$; based on central estimates)	<b>\$13.5</b>	\$11.6	\$8.3	\$6.3	\$3.3
Estimated total annual TCI proceeds in 2032 (billions 2016\$)	\$8.5	\$6.8	\$5.4	\$3.5	\$1.9

PRELIMINARY RESULTS

# Active Mobility Health Benefits: Biking & Walking

A photograph of a paved path in a park-like setting. In the foreground, a person in a grey jacket and dark pants is walking away from the camera. To their right, a person wearing a dark jacket, black pants, and a helmet is riding a bicycle away from the camera. In the background, several other people are walking on the path. The path is flanked by green grass and trees with light green foliage, suggesting a spring or early summer setting. The overall scene is bright and clear.

# Estimated Health Benefits from Biking & Walking

Five Illustrative TCI Scenarios Compared to No-TCI Scenario in 2032

	Scenario A 25% CO <sub>2</sub> Reduction Cap	Scenario B 25% CO <sub>2</sub> Reduction Cap	Scenario C 25% CO <sub>2</sub> Reduction Cap	Scenario B 22% CO <sub>2</sub> Reduction Cap	Scenario B 20% CO <sub>2</sub> Reduction Cap
Estimated net deaths avoided from biking and walking in 2032	770	640	420	390	200
Estimated monetized health benefits from biking and walking in 2032 (billions 2016\$)	\$7.4	\$6.1	\$4.1	\$3.8	\$1.9
TCI proceeds invested in biking and walking infrastructure in 2032 (billions 2016\$)*	\$0.64	\$0.51	\$0.28	\$0.26	\$0.13

\*Public transit investments not included. Transit adds walking benefits.  
Raifman et al. 2021. Estimate include a safety in numbers effect.

PRELIMINARY RESULTS

# Central Estimate of Net Deaths Avoided from Biking & Walking by State for Five Illustrative TCI Scenarios Compared to a No-TCI Scenario in 2032

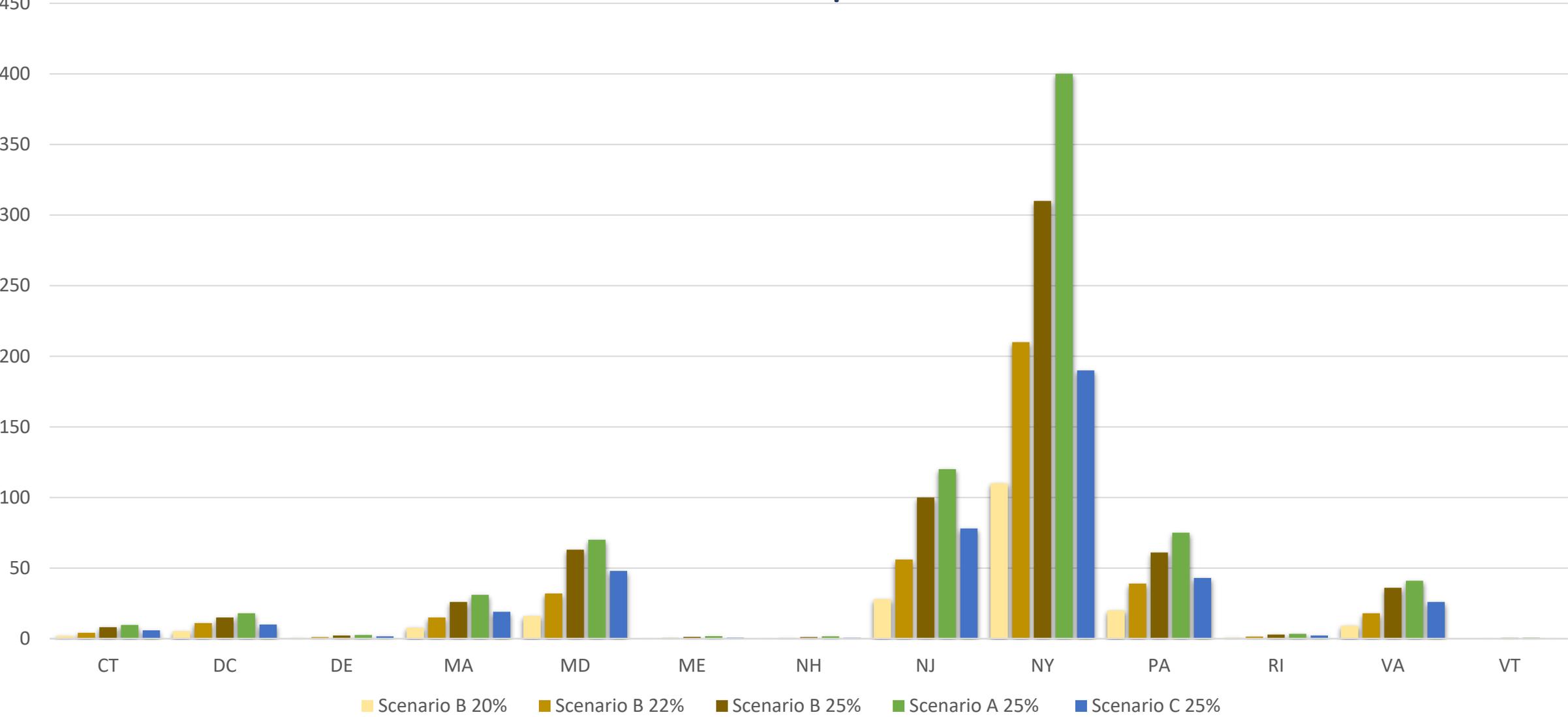


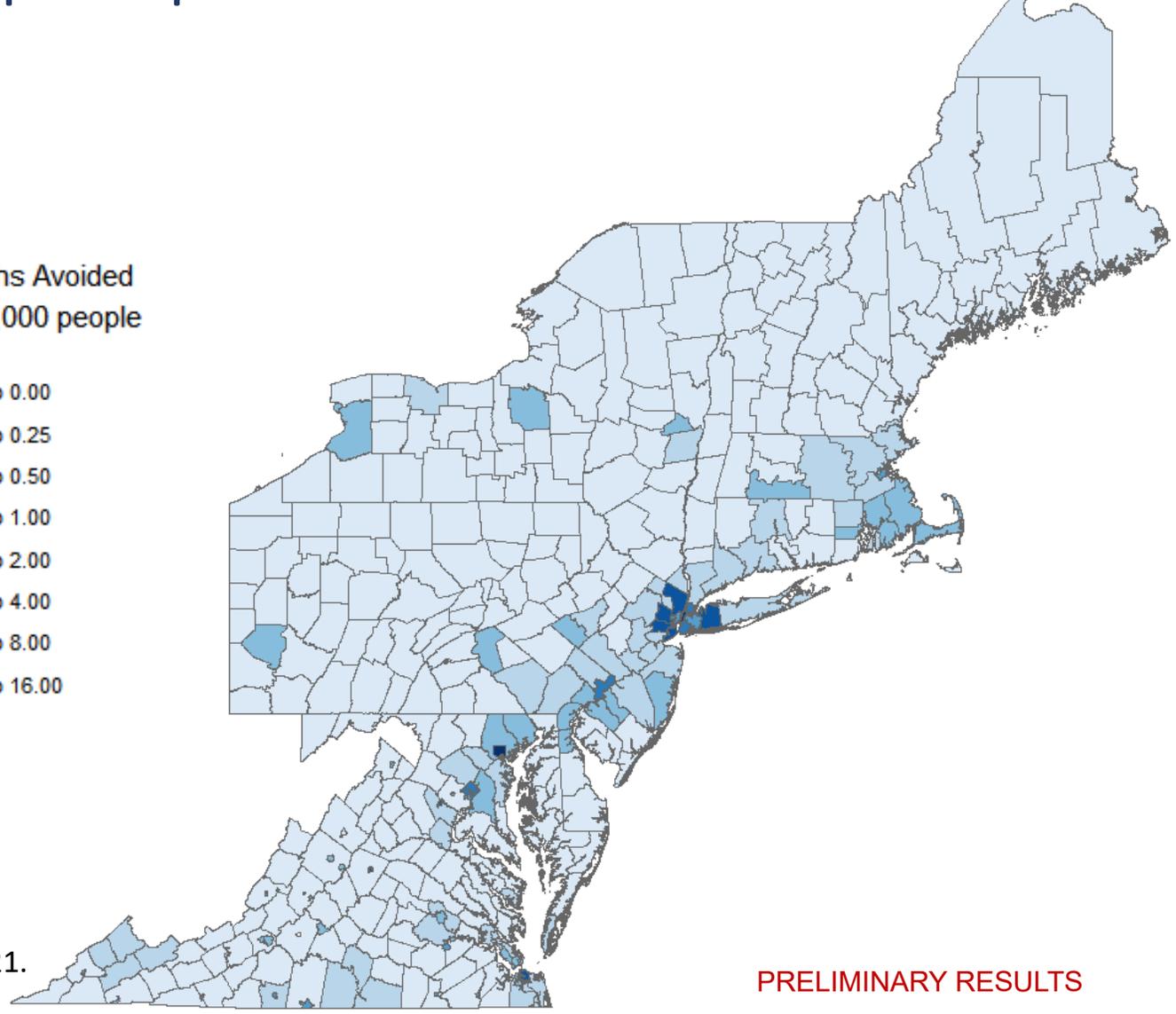
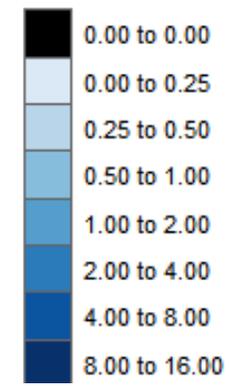
Figure credit: C. Arter. Based on Raifman et al. 2021. Estimates include a safety in numbers effect.

PRELIMINARY RESULTS

# Net Deaths Avoided Per 100,000 People for Scenario B with the 25% CO<sub>2</sub> Reduction Cap Compared to No-TCI Scenario in 2032

Estimated Active Mobility Benefits Occur in All Counties and are Largest in More Populated Areas

Net Deaths Avoided per 100,000 people



Map credit: M. Raifman, P. Kinney. Based on Raifman et al. 2021. Estimates include a safety in numbers effect.

PRELIMINARY RESULTS

# Additional Insights

- Activity benefits from biking and walking are larger than air quality benefits, underscoring the value of having more opportunities for physical activity.
- The top scenario has the largest share of investments dedicated to public transit and biking & pedestrian infrastructure. Shifting from vehicles to other modes of travel has double benefits – increased activity and reduced tailpipe emissions.
- The equity of the distribution of physical activity benefits was not analyzed but is an important policy consideration and a focus of future research.



# On-Road Emissions: Air Quality

# Estimated Air Pollution-related Deaths Attributable to On-road Emissions in the TCI Region, 2016

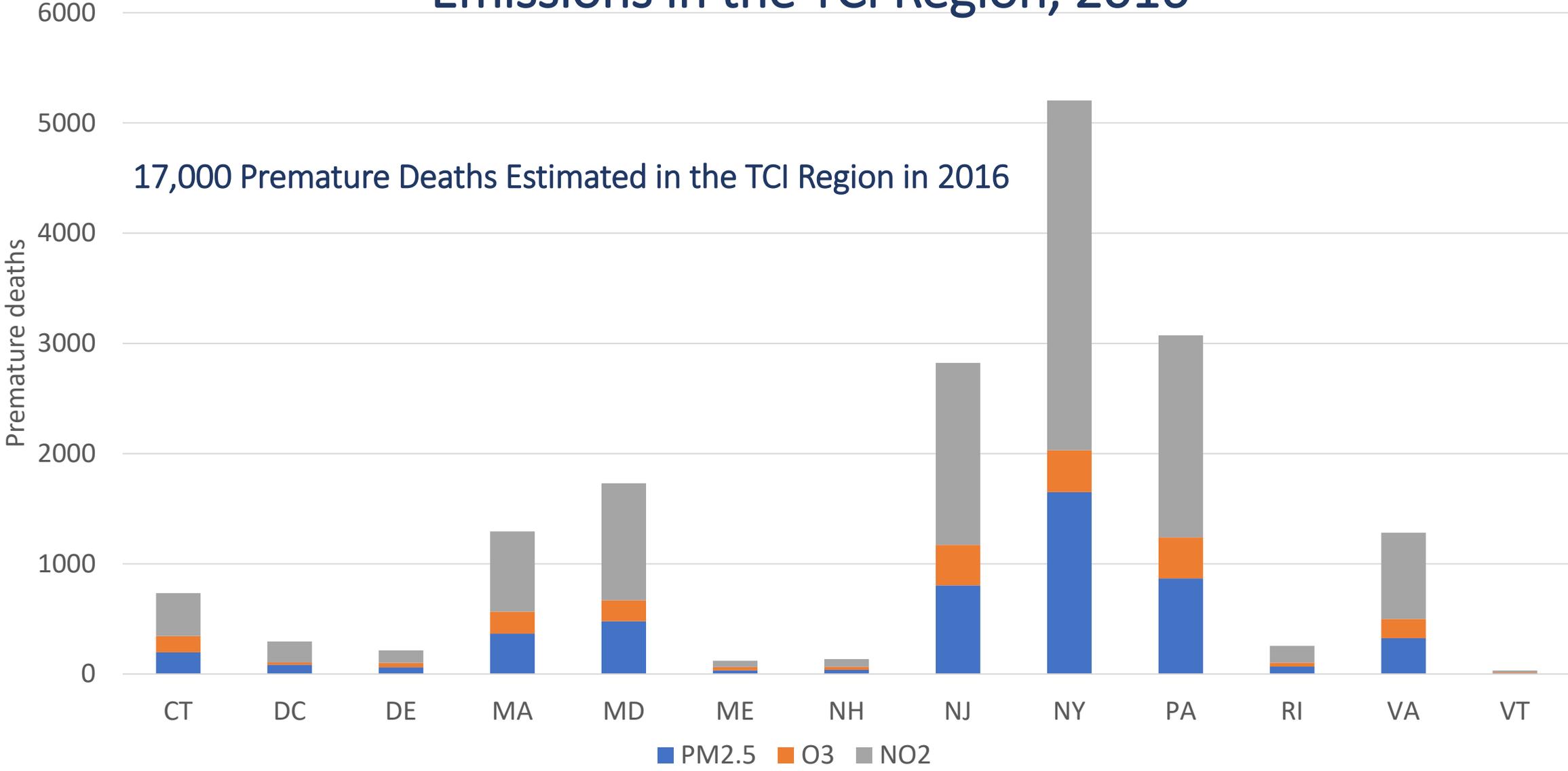
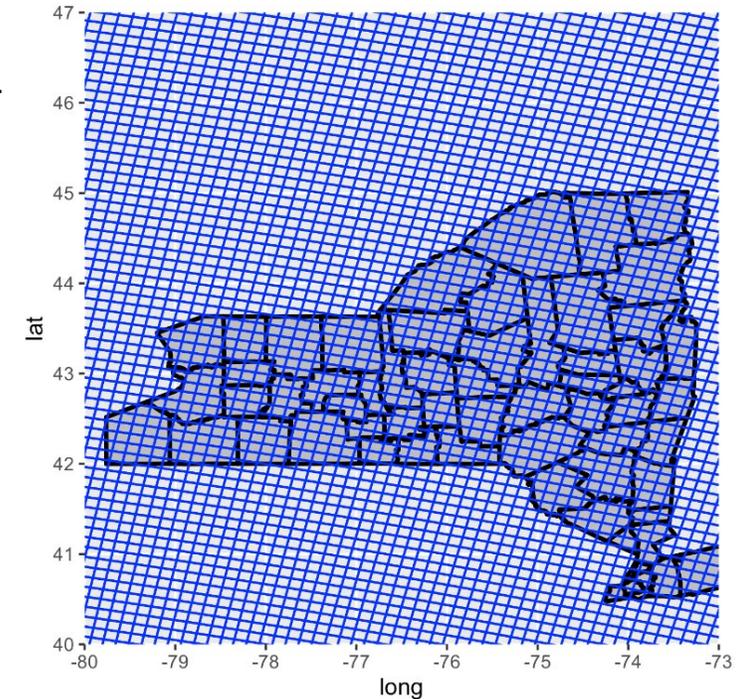


Figure credit: C. Arter, S. Arunachalam. Based on Arunachalam et al. In prep.

PRELIMINARY RESULTS

# Air Quality Modeling Approach

- Analyzed differences in air pollution from changes in on-road emissions between five illustrative TCI policy scenarios and a no-TCI reference scenario for the year 2032.
- The modeling is at a 12x12-kilometer scale which is much smaller than a county scale but larger than a neighborhood scale.
- Scenarios compare outcomes under different TCI policy scenarios. Actual results will depend on the final policy choices, state participation, and investments.



12x12 km air quality modeling grid: Example for New York State

# Change in Air Pollution for Scenario B with 25% CO<sub>2</sub> Reduction Cap Compared to No-TCI Scenario in 2032

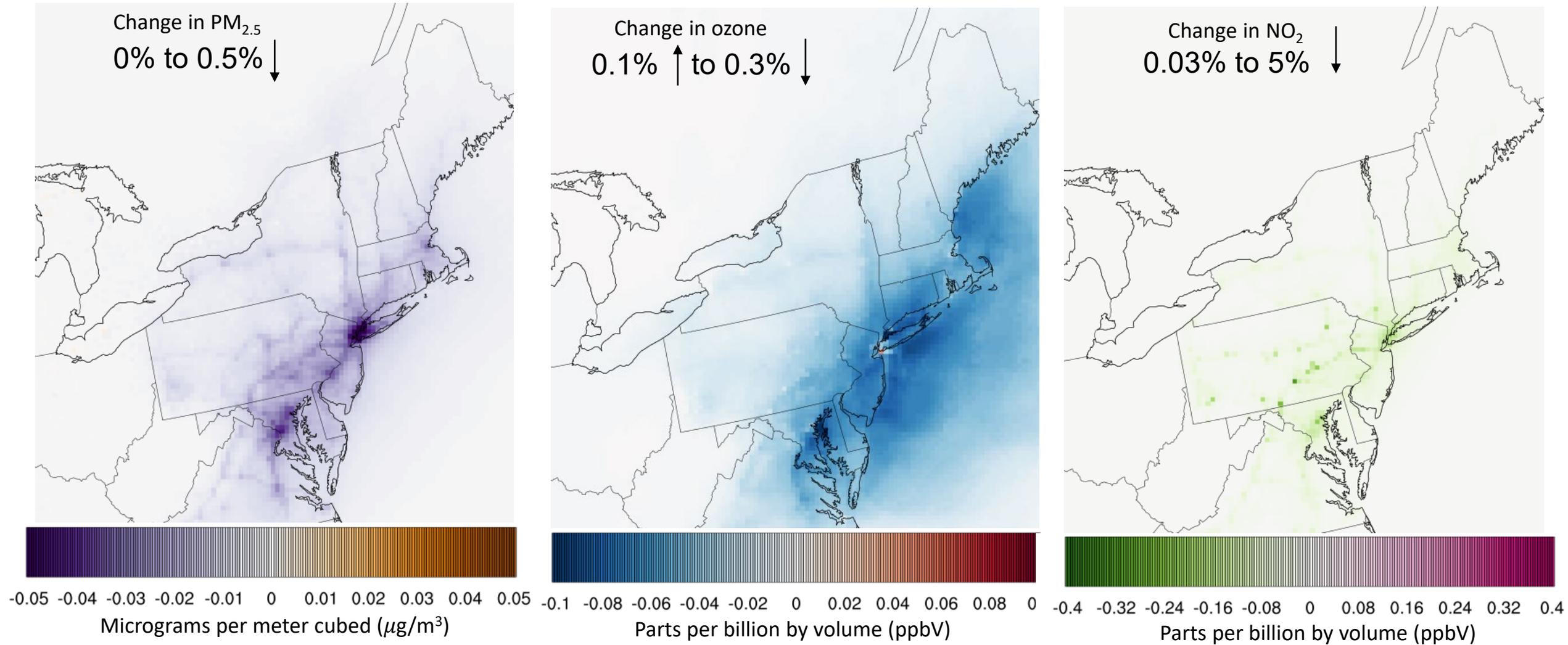


Figure credit: C. Arter, S. Arunachalam. Based on Arunachalam et al. In prep.

PRELIMINARY RESULTS

# Air Pollution Exposure and Health Outcomes

A wide-angle photograph of a busy city street at dusk. The street is lined with tall, multi-story buildings, some with lit windows. In the foreground, a black car is driving from left to right. Pedestrians are crossing the street. A traffic light on the right shows a red light. The sky is a mix of blue and grey, indicating twilight. The overall scene is a typical urban environment with significant traffic and population density.

# Air Pollution Exposure & Health - Preliminary Results

- Under the five illustrative TCI policy scenarios, we estimate a modest reduction in inequality of air pollution exposure by race/ethnicity.
- However, large disparities in air pollution exposures persist by race/ethnicity under the policy scenarios in 2032.
- Equity and health benefits increase as cap stringency increases.
- Equity and health benefits are highest in the scenario with the largest share of investments in public transit, and biking and walking infrastructure.

## Estimated Population-Weighted Exposure to PM<sub>2.5</sub>, NO<sub>2</sub>, and Ozone for Scenario B with a 25% CO<sub>2</sub> Emissions Reduction Cap Compared to the No-TCI Reference Scenario in 2032

	PM <sub>2.5</sub> (µg/m <sub>3</sub> ) in 2032			NO <sub>2</sub> (ppb) in 2032			Ozone (ppb) in 2032		
	No-TCI Reference Scenario	TCI Scenario B 25% GHG Cap	% Decrease	No-TCI Reference Scenario	TCI Scenario B 25% GHG Cap	% Decrease	No-TCI Reference Scenario	TCI Scenario B 25% GHG Cap	% Decrease
Total population	7.94	7.92	0.24	4.48	4.43	1.14	36.34	36.30	0.11
Non-Hispanic White population	7.36	7.34	0.21	3.64	3.60	1.14	36.12	36.08	0.10
Non-Hispanic Black population	9.39	9.37	0.29	6.51	6.44	1.14	37.27	37.23	0.12
Hispanic population	9.90	9.87	0.31	7.42	7.34	1.13	36.75	36.70	0.13
Other populations	9.32	9.29	0.29	6.43	6.35	1.14	36.69	36.64	0.12

Table credit: L. Bucky, J. Levy

PRELIMINARY RESULTS

# Modest Estimated Reductions in the Inequality in Air Pollution Exposure

Estimated PM <sub>2.5</sub> Population-Weighted Exposure (µg/m <sub>3</sub> ) in 2032		
	TCI Scenario B 25% CO <sub>2</sub> Reduction Cap	% Decrease
Total population	7.92	0.24
Non-Hispanic White population	7.34	0.21
Non-Hispanic Black population	9.37	0.29
Hispanic population	9.87	0.31
Other populations	9.29	0.29

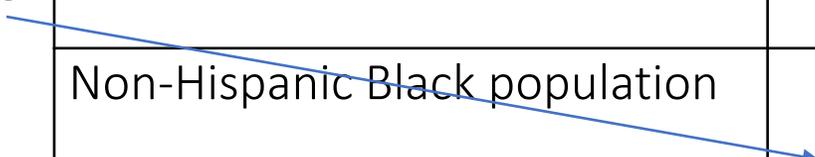
Larger numbers signify larger decreases in exposure and reduced inequality

Example: Estimated Population-Weighted Exposure to PM<sub>2.5</sub> for Scenario B with a 25% CO<sub>2</sub> Emissions Reduction Cap Compared to the No-TCI Reference Scenario in 2032

# People of Color Would Still Face Higher Overall Air Pollution Exposures

Estimated PM <sub>2.5</sub> Population-Weighted Exposure (µg/m <sub>3</sub> ) in 2032		
	TCI Scenario B 25% CO <sub>2</sub> Reduction Cap	% Decrease
Total population	7.92	0.24
Non-Hispanic White population	7.34	0.21
Non-Hispanic Black population	<b>9.37</b>	0.29
Hispanic population	<b>9.87</b>	0.31
Other populations	9.29	0.29

Larger numbers signify higher exposure into the future



Example: Estimated Population-Weighted Exposure to PM<sub>2.5</sub> for Scenario B with a 25% CO<sub>2</sub> Emissions Reduction Cap Compared to the No-TCI Reference Scenario in 2032

# Air Quality-Related Estimated Health Benefits

## Five Illustrative TCI Policy Scenarios Compared to a No-TCI Scenario in 2032

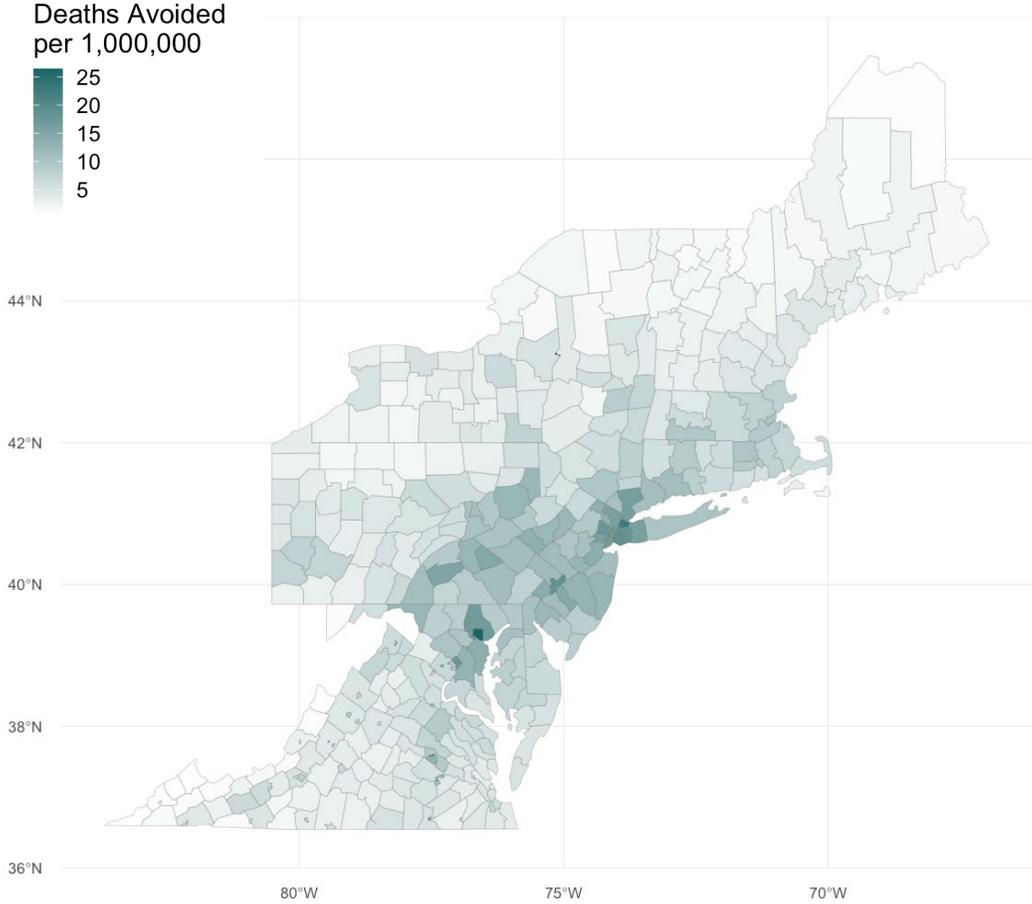
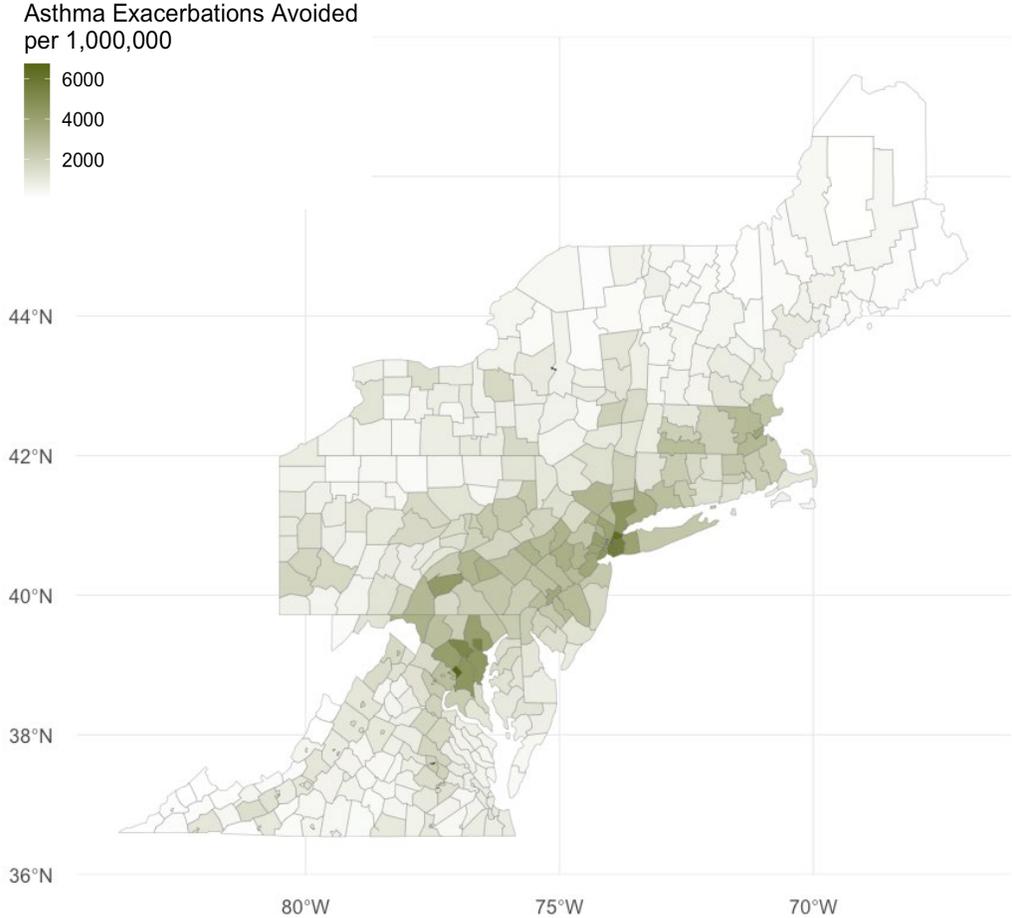
The estimated deaths avoided in this scenario represent about an 8% decrease in estimated deaths from estimated on-road emissions in the TCI region in 2032

	Scenario A 25% CO <sub>2</sub> Reduction Cap	Scenario B 25% CO <sub>2</sub> Reduction Cap	Scenario C 25% CO <sub>2</sub> Reduction Cap	Scenario B 22% CO <sub>2</sub> Reduction Cap	Scenario B 20% CO <sub>2</sub> Reduction Cap
Estimated childhood asthma exacerbations avoided in 2032	56,000	46,000	35,000	22,000	11,000
Estimated deaths avoided in 2032	590	520	420	250	120
Estimated incidences of childhood asthma avoided in 2032	230	200	160	98	48
Total estimated monetized air quality health benefits – all outcomes in 2032 (billions 2016\$)	\$6.1	\$5.4	\$4.3	\$2.6	\$1.3

Table credit: J. Buonocore, F. Perera, A. Berberian et al.

PRELIMINARY RESULTS

# Estimated Childhood Asthma Exacerbations (Ages 5-17) and Premature Deaths Avoided Per Million People for Scenario B with 25% CO<sub>2</sub> Reduction Cap Compared to No-TCI Scenario in 2032



All Counties See Health Benefits from Air Quality Improvements, Largest in More Populated Areas

Map credits: J. Buonocore, F. Perera, A. Berberian et al.

**PRELIMINARY RESULTS**

# Insights from Preliminary Results

1. The estimated health benefits for the five TCI climate mitigation policy scenarios are substantial and are larger than estimated program proceeds, based on this analysis of a subset of total possible benefits.
2. The estimated health benefits of the TCI scenarios analyzed include up to 1,360 deaths avoided, 320 incidences of childhood asthma avoided, and tens of thousands of childhood asthma exacerbations avoided under the top-performing policy scenario in 2032.
3. The policy scenario with the largest health benefits is the one with the most ambitious emissions cap (25%) and the largest share of investments dedicated to public transit and active mobility.
4. Under all the policy scenarios examined, health benefits occur in all counties across the region and are concentrated in more populated areas.
5. All the policy scenarios examined modestly reduce inequities in air pollution exposure by race/ethnicity but, even with the reductions estimated under the TCI policy scenarios, people of color would still face higher overall air pollution exposures and more emissions reductions would be needed to address pre-existing inequities.
6. There is a four-fold difference exists in the estimated health benefits across the policy scenarios, underscoring the wide range of possible outcomes and that actual benefits will depend on state actions.

# TRECH PROJECT

TRANSPORTATION, EQUITY, CLIMATE & HEALTH

- Sarav Arunachalam, PhD, Professor, Institute for the Environment, University of North Carolina at Chapel Hill
- Calvin Arter, PhD student, University of North Carolina at Chapel Hill
- Alique Berberian, MS, Children's Health Center, Columbia Mailman School of Public Health
- Charles Chang, MA, Research Associate, University of North Carolina at Chapel Hill
- Laura Buckley, PhD student, Boston University School of Public Health
- Jonathan Buonocore, ScD, Research Scientist, Harvard C-CHANGE
- Kathy Fallon Lambert, MSc, Senior Advisor, Harvard C-CHANGE
- Patrick Kinney, ScD, Professor, Boston University School of Public Health
- Jon Levy, ScD, Professor and Chair, Boston University School of Public Health
- Frederica Perera, DrPH, PhD, Children's Health Center, Columbia Mailman School of Public Health
- Matthew Raifman, PhD student, Boston University School of Public Health

*The TRECH Project is made possible thanks in part to support from the Barr Foundation*



**HARVARD T.H. CHAN**  
SCHOOL OF PUBLIC HEALTH

**C-CHANGE**  
CENTER FOR CLIMATE, HEALTH,  
AND THE GLOBAL ENVIRONMENT



**INSTITUTE FOR  
THE ENVIRONMENT**



Columbia University  
MAILMAN SCHOOL  
OF PUBLIC HEALTH