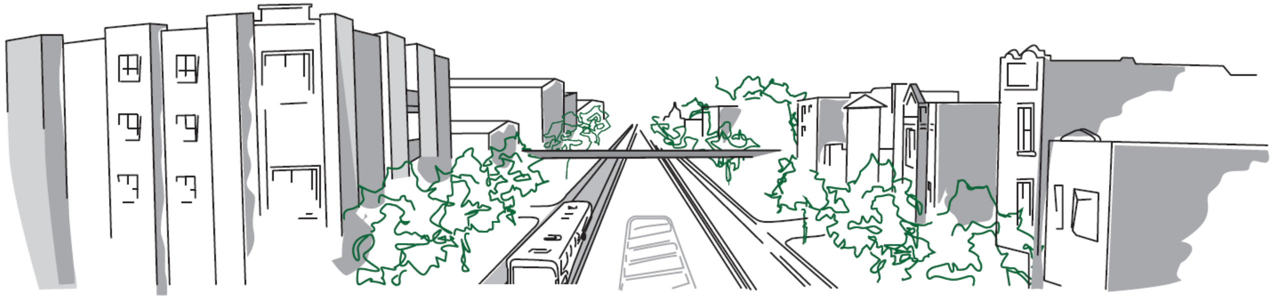
University of Toronto
Transportation and Air Quality Research Group (TRAQ)



Climate, health, and equity in the context of new transportation technologies

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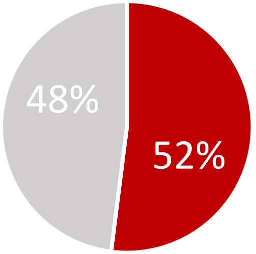
FACULTY OF APPLIED SCIENCE & ENGINEERING
Transportation Research Institute

UTTRI

Urban transportation plays an important role in climate change and has significant health impacts

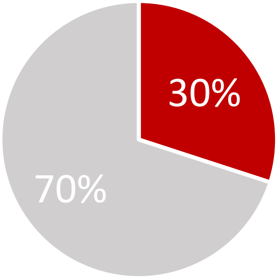
NO_x,
CO,
VOC,
PM

Canada
NO_x Emissions



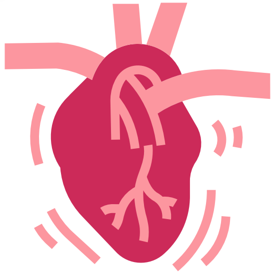
Transportation and mobile equipment

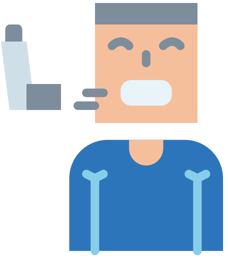
U.S. and Canada
GHG Emissions



Transportation

Criteria Air Contaminants





- Stroke
- Lung cancer
- Respiratory and cardiovascular diseases

$

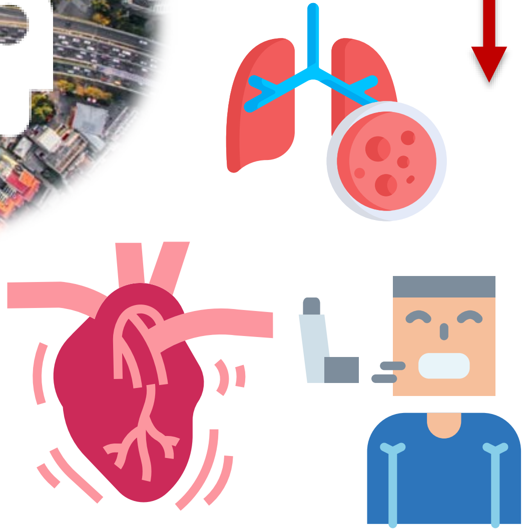
What are the climate, health and economic impacts of Electric Vehicle (EV) deployment?

Canada
NO_x Emissions

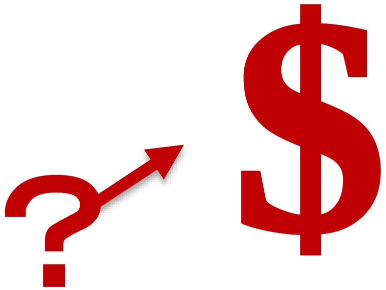
Transportation and mobile equipment

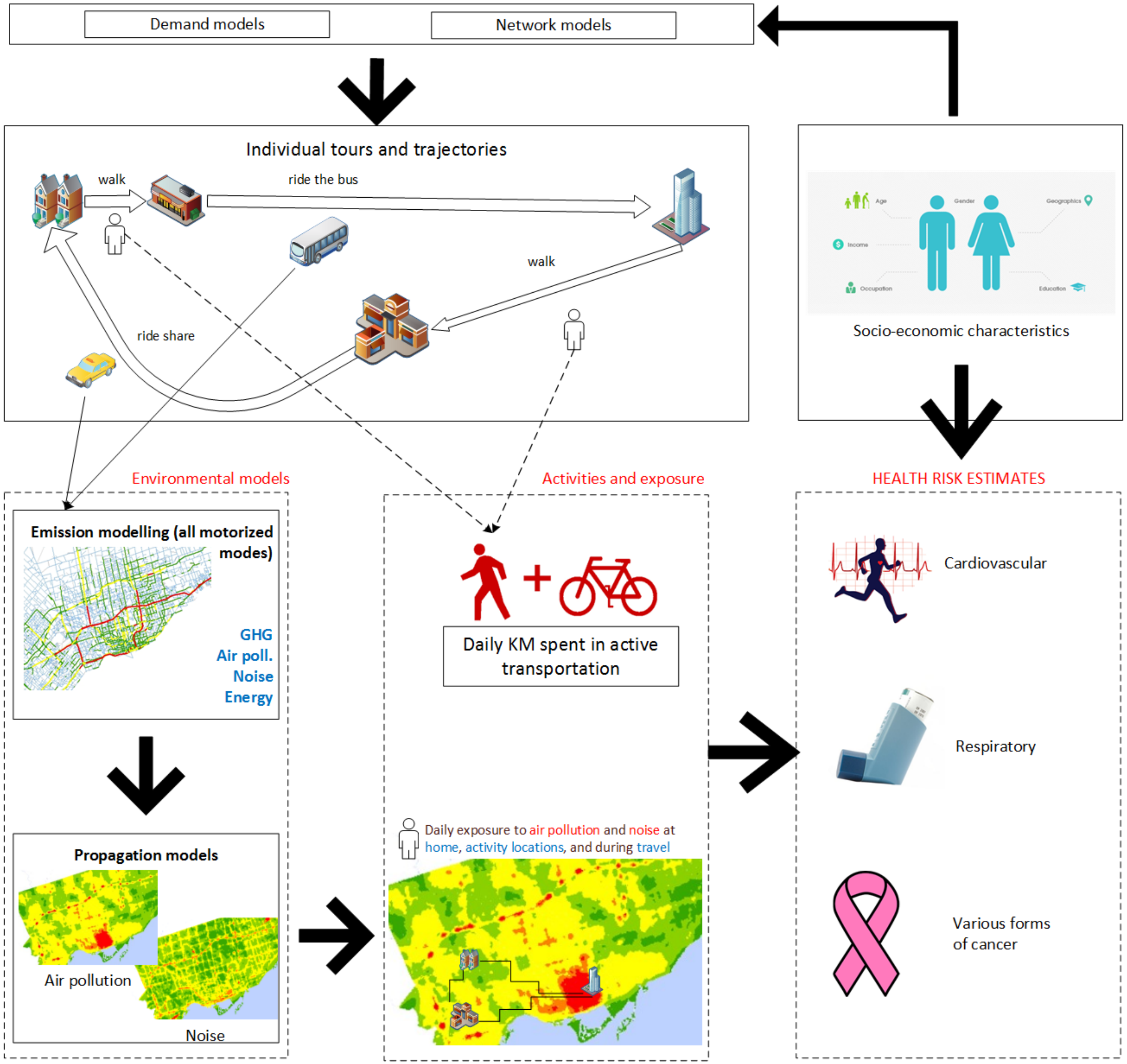
U.S. and Canada
GHG Emissions

Transportation



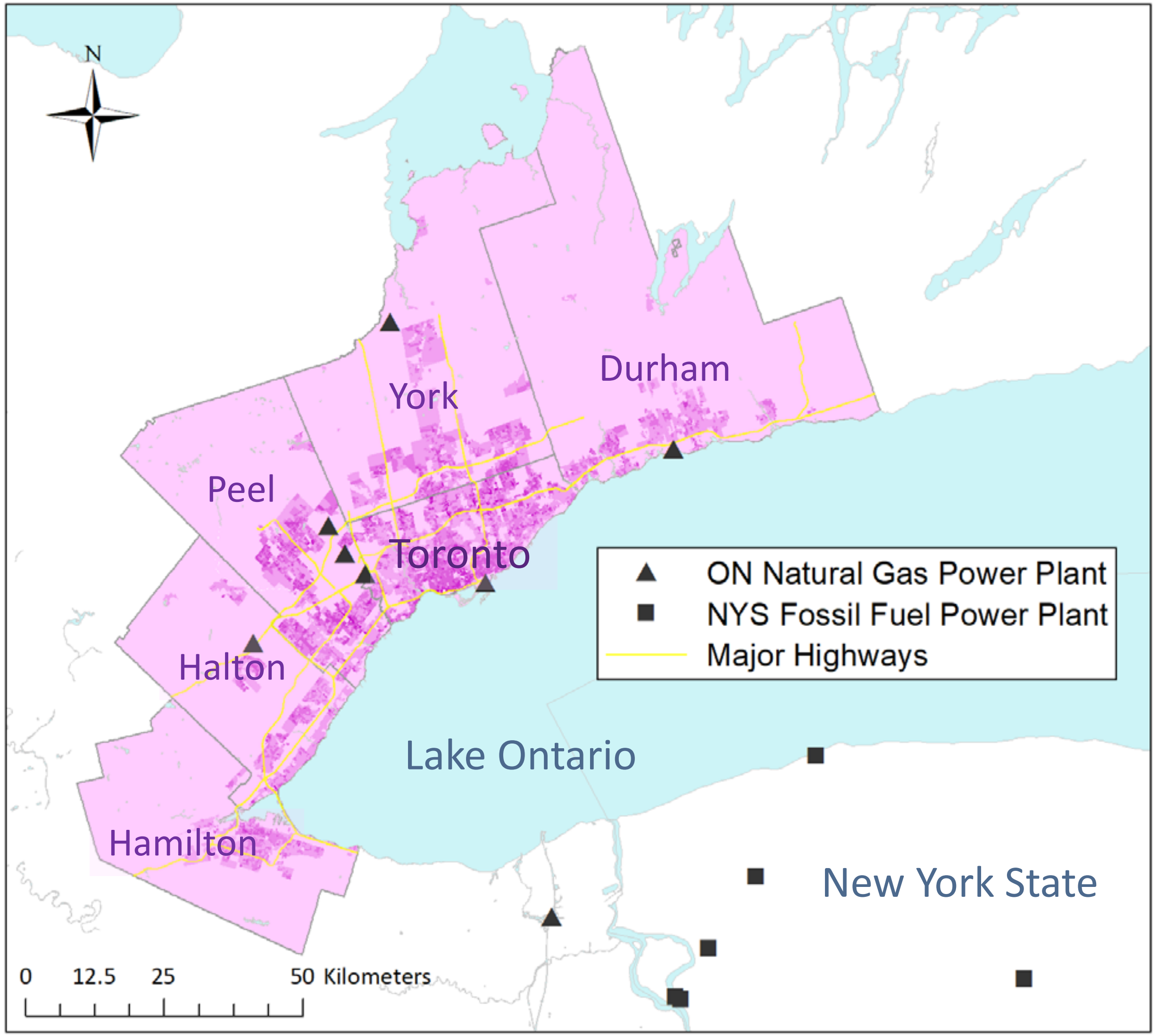
- Stroke
- Lung cancer
- Respiratory and cardiovascular diseases



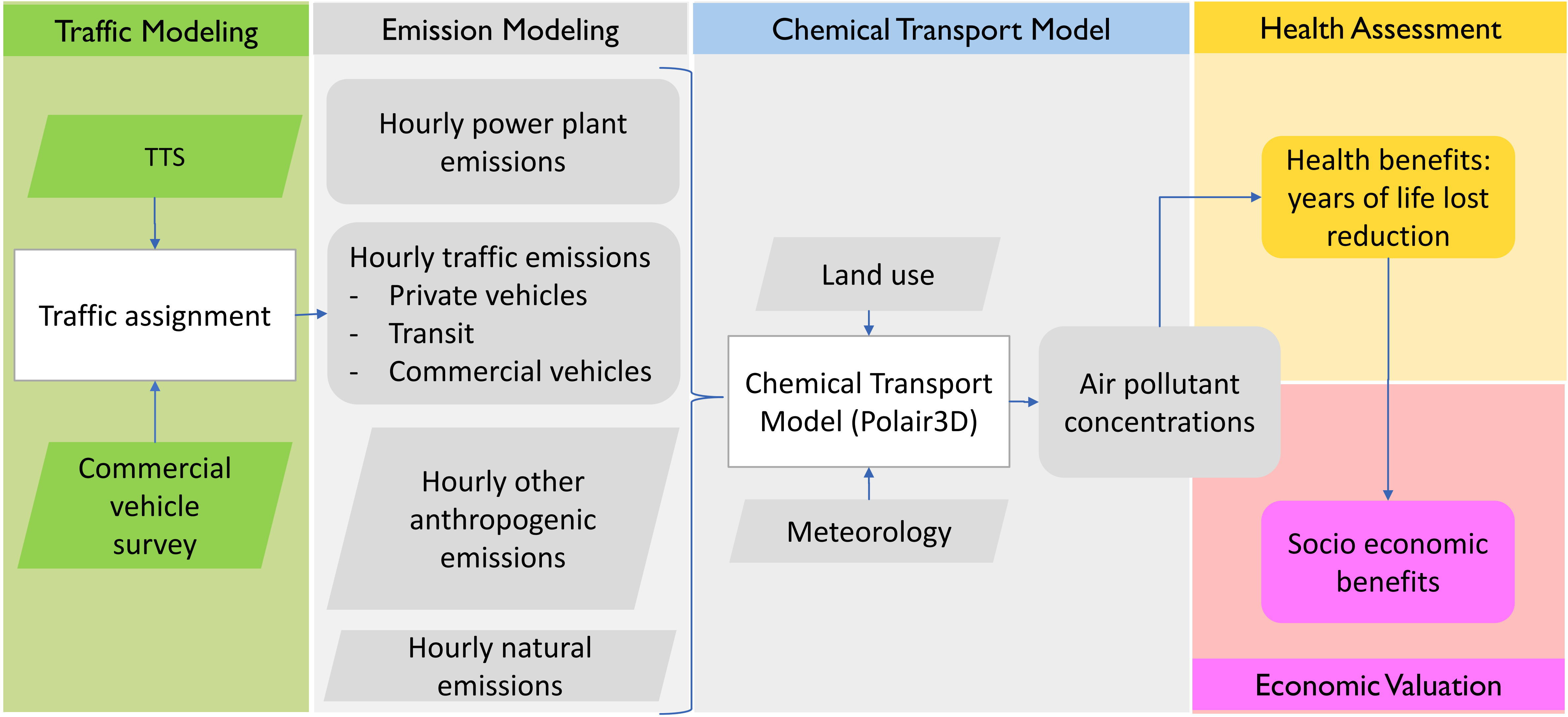


Demand models
Network models
Individual tours and trajectories
walk
ride the bus
walk
ride share
Socio-economic characteristics
Environmental models
Activities and exposure
HEALTH RISK ESTIMATES
Emission modelling (all motorized modes)
GHG
Air poll.
Noise
Energy
Daily KM spent in active transportation
Cardiovascular
Respiratory
Propagation models
Air pollution
Noise
Daily exposure to air pollution and noise at home, activity locations, and during travel
Various forms of cancer

Study Area - The Greater Toronto and Hamilton Area (GTHA)



Overview of the modeling framework



Three case studies

1) Impacts of vehicle electrification

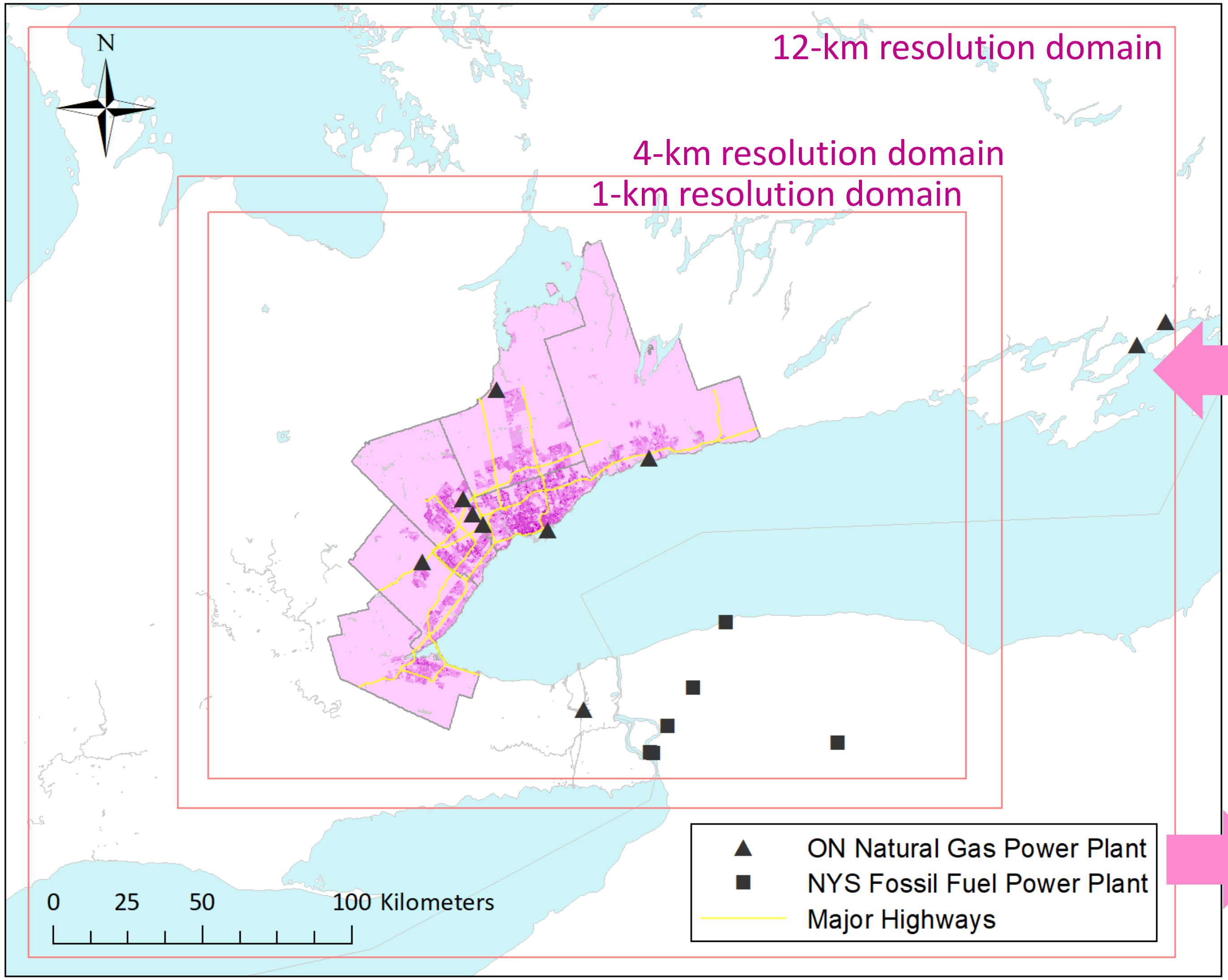
2) Potential for greening freight movements

3) Impacts of CAVs on air quality and exposure

Neighborhood effects

Regional effects

The chemical transport model in Polair3D



Polair3D: The chemical transport model of Polyphemus with a **high spatial** (1×1 km^2) and **temporal** (1 hour) resolution

Input: Hourly emissions of seven criteria air contaminants (CACs) - PM_{10}, $PM_{2.5}$, NH_3, NO_x, CO, VOC, and SO_2.

- Point source emissions from power plants and industries
- Link-based traffic emissions
- Other anthropogenic emissions, biogenic emissions

Output: Hourly concentrations of $PM_{2.5}$, NO_2, O_3, BC for each 1 by 1 km cell

Health outcomes

Approach: Comparative risk assessment (CRA)

Procedure:

1. Identified concentration response functions (CRFs), which define the relationship between exposure and increased risk of disease

Concentration Response Functions (CRFs)

Source	Pollutant	Cause	RR (10µg/m³)
Crouse et al. 2012	$PM_{2.5}$	All Causes	1.100 (1.050 - 1.150)
Crouse et al. 2015	NO_2	All Causes	1.053 (1.032 - 1.075)
Jerrett et al. 2009	O_3	Respiratory Disease	1.020 (1.007 - 1.033)
Janssen et al. 2011	BC	All Causes	1.791 (1.480 - 2.255)
			Max

Health outcomes

Approach: Comparative risk assessment (CRA)

Procedure:

1. Identified concentration response functions (CRFs), which define the relationship between exposure and increased risk of disease
2. Estimate the Years of Life Lost (YLL)

Economic valuation of health impacts

The economic benefits are evaluated based on:

Unit: 2016CAD$

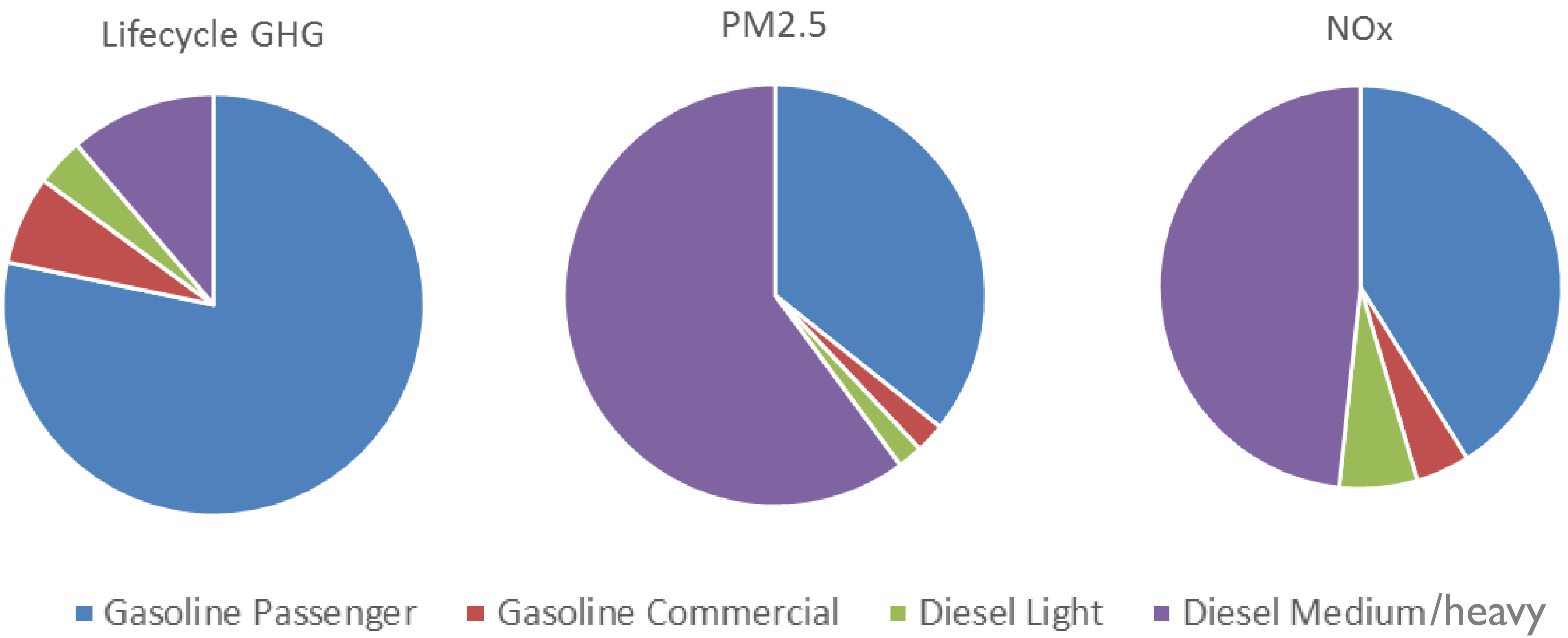
- **Health impacts due to changes in air pollution exposure:** use the Value of Statistical Life Year (VSLY)
  - The Value of a Statistical Life (VSL) is interpreted as a measure of the benefit individuals receive from enhancements to their health and safety
  - The VSLY accounts for life expectancy
  - **VSLY** used: $324,000

Results

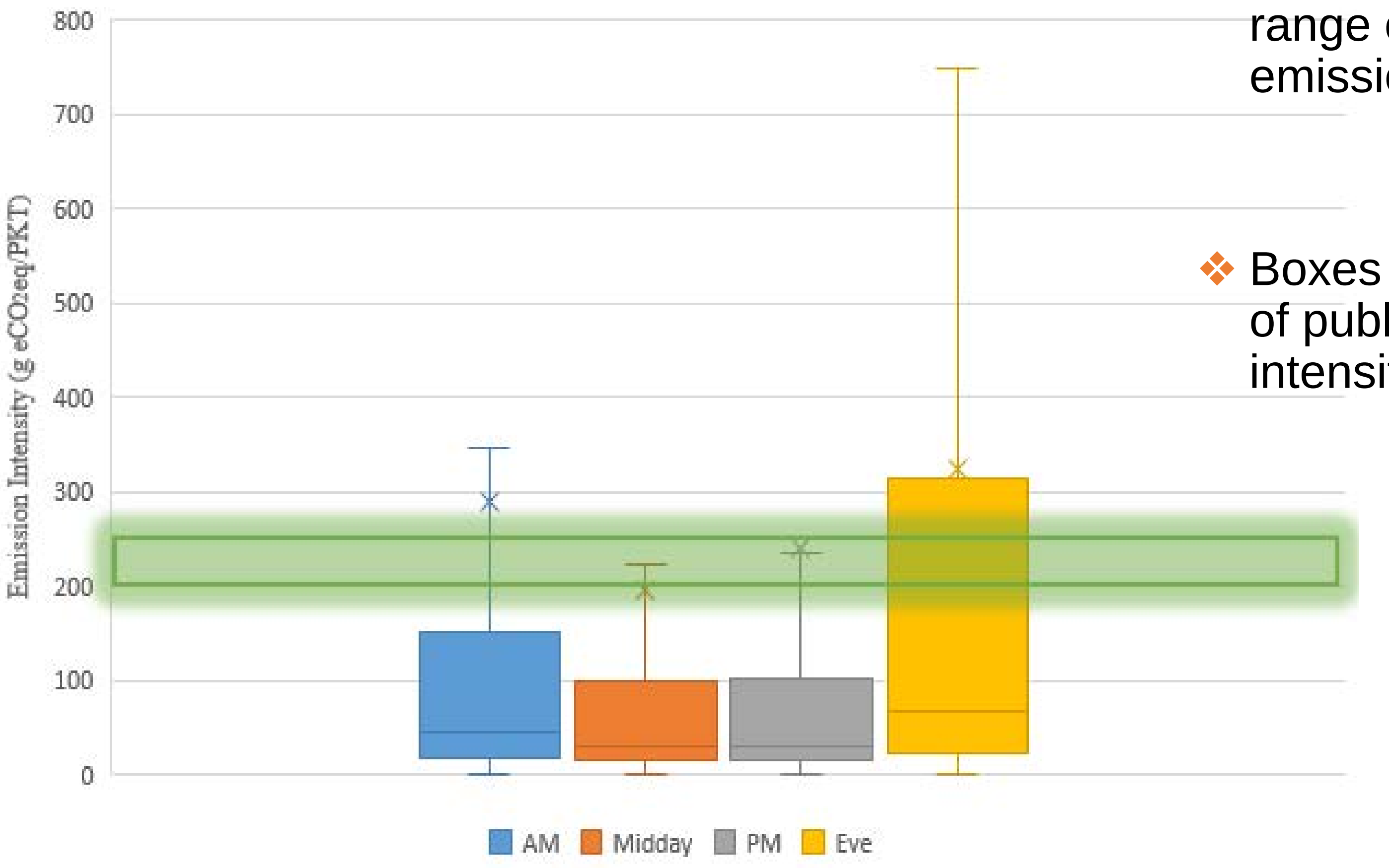
THE BURDEN OF METROPOLITAN TRANSPORTATION EMISSIONS

PASSENGER VEHICLES, PUBLIC TRANSIT, FREIGHT

Distribution of transport emissions in the GTHA

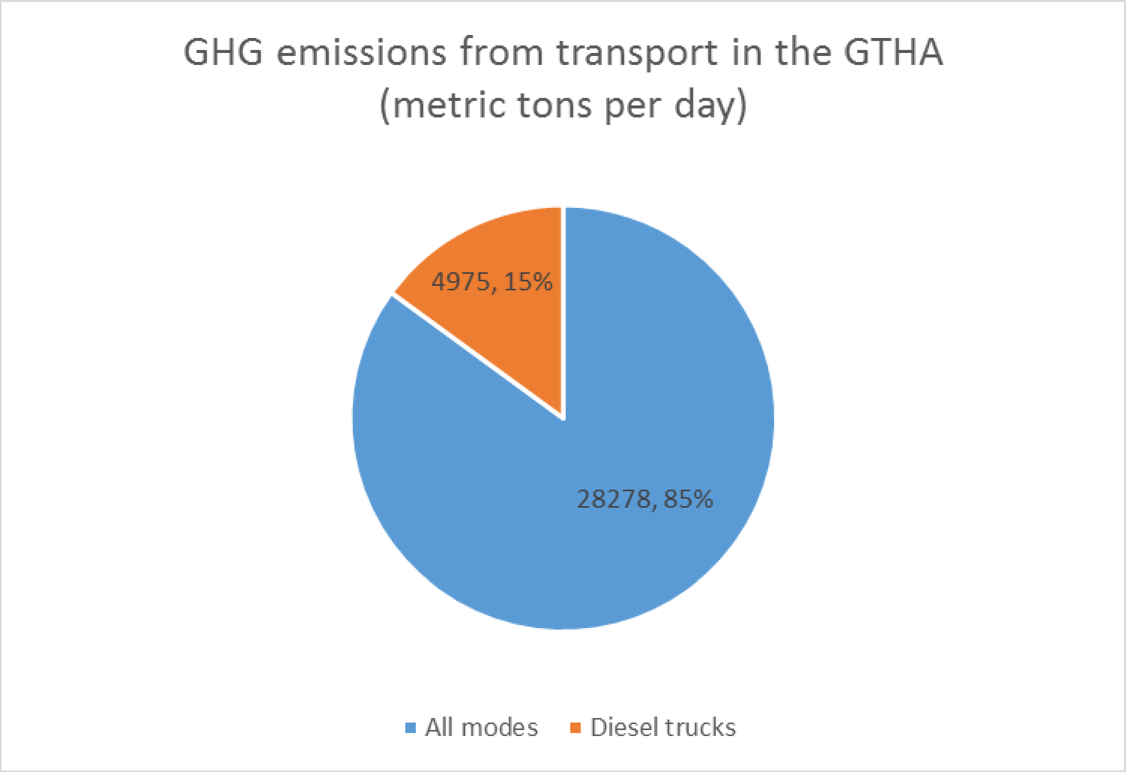


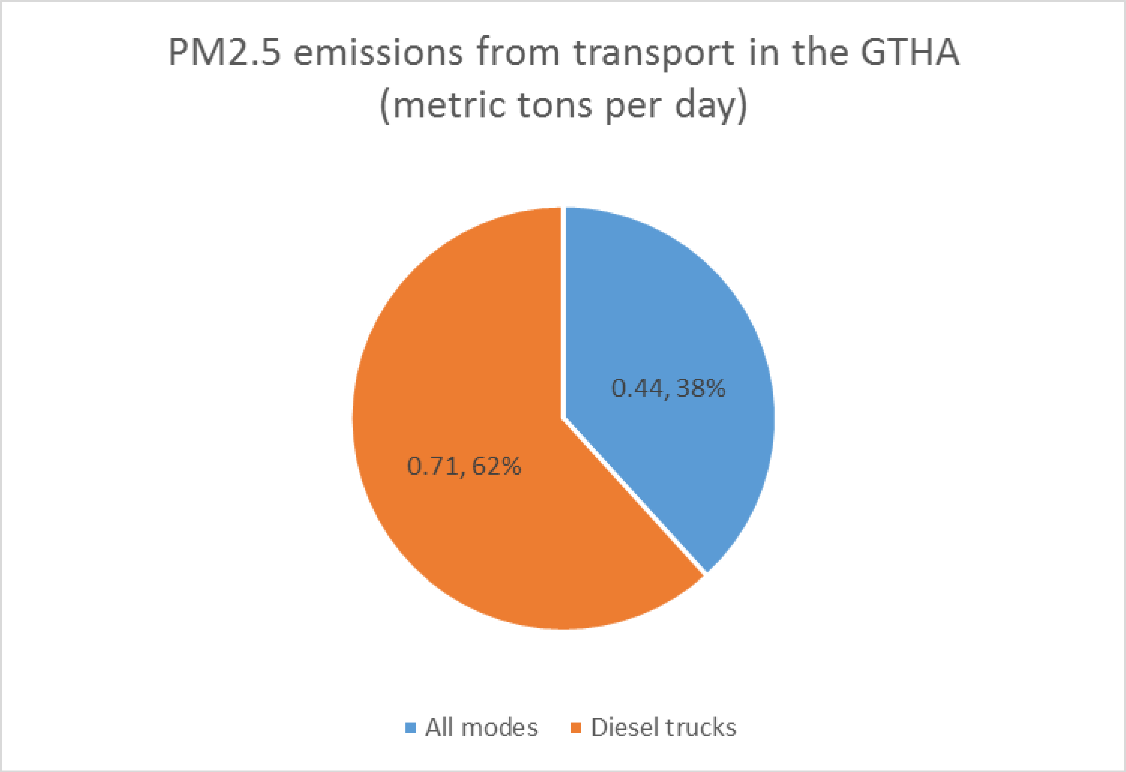
While sharing 4% of the total GHG emissions, public transit serves up to 32% of daily total PKT



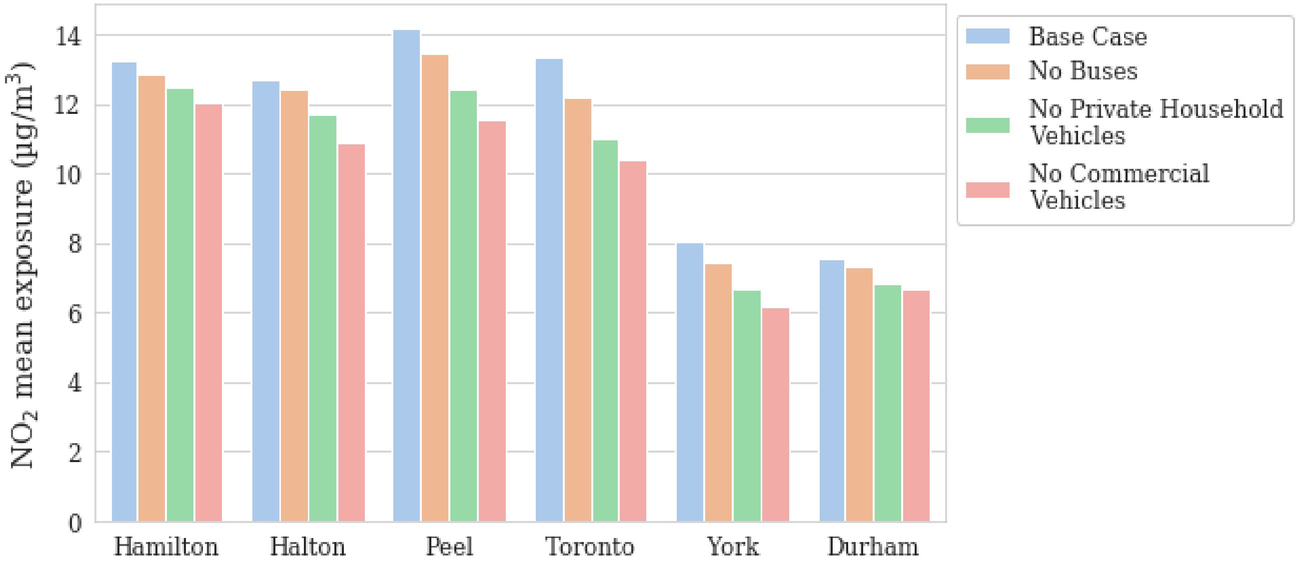
- Green bar illustrates the range of private vehicle emission intensities
- Boxes illustrate the ranges of public transit emission intensities

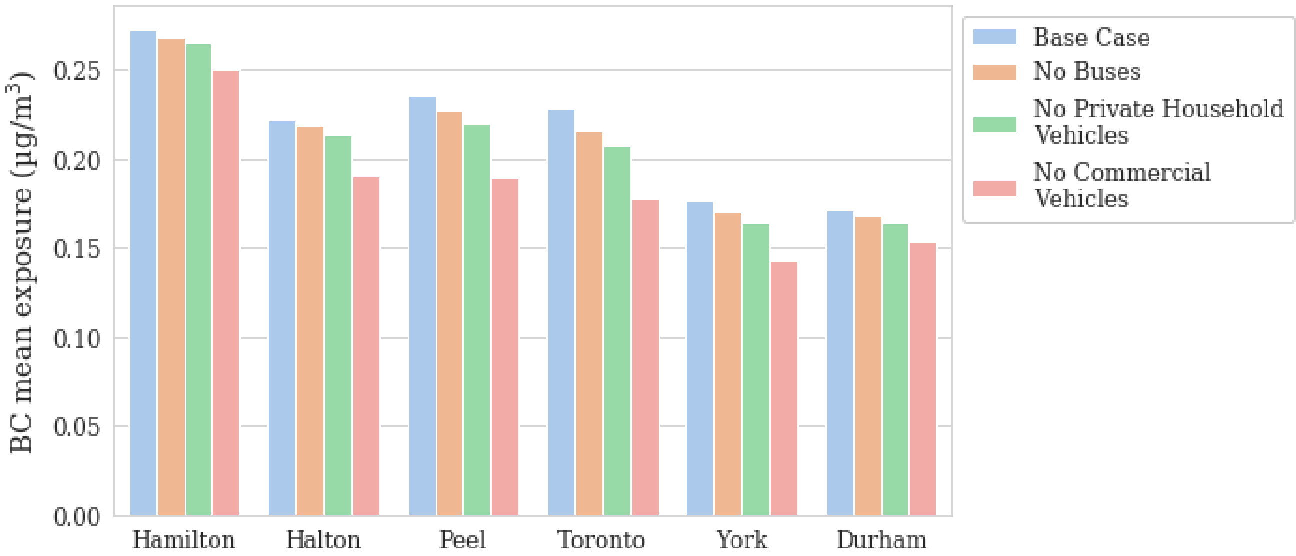
Diesel contributes disproportionately to the emissions of air pollutants



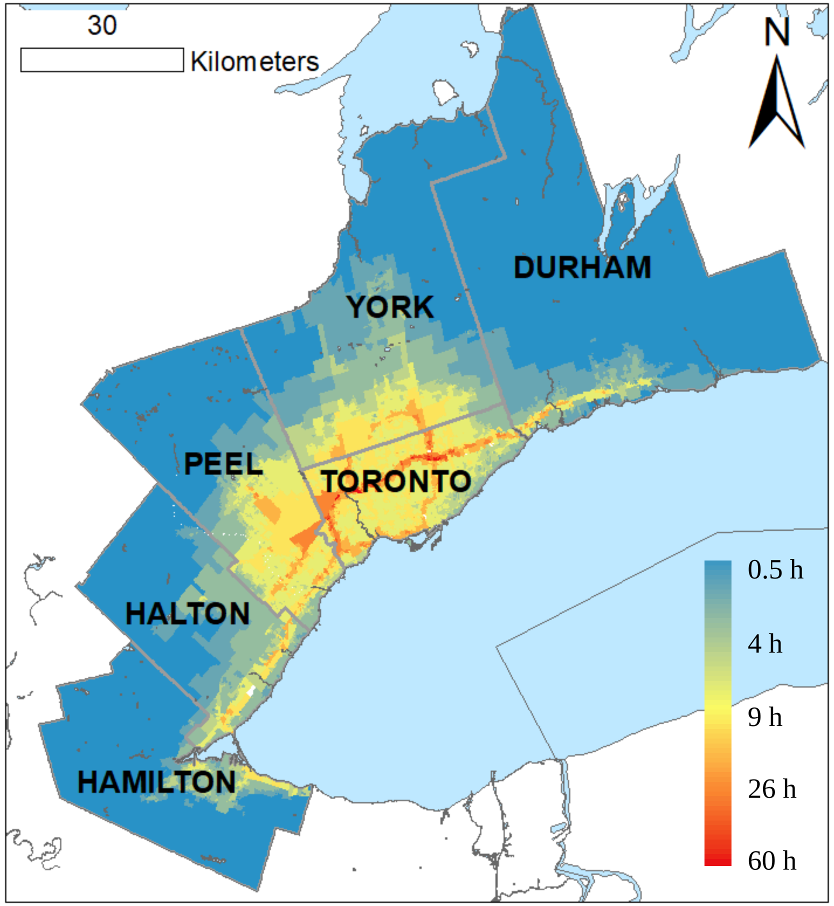


Air pollutant concentrations (NO_2 and Black Carbon)

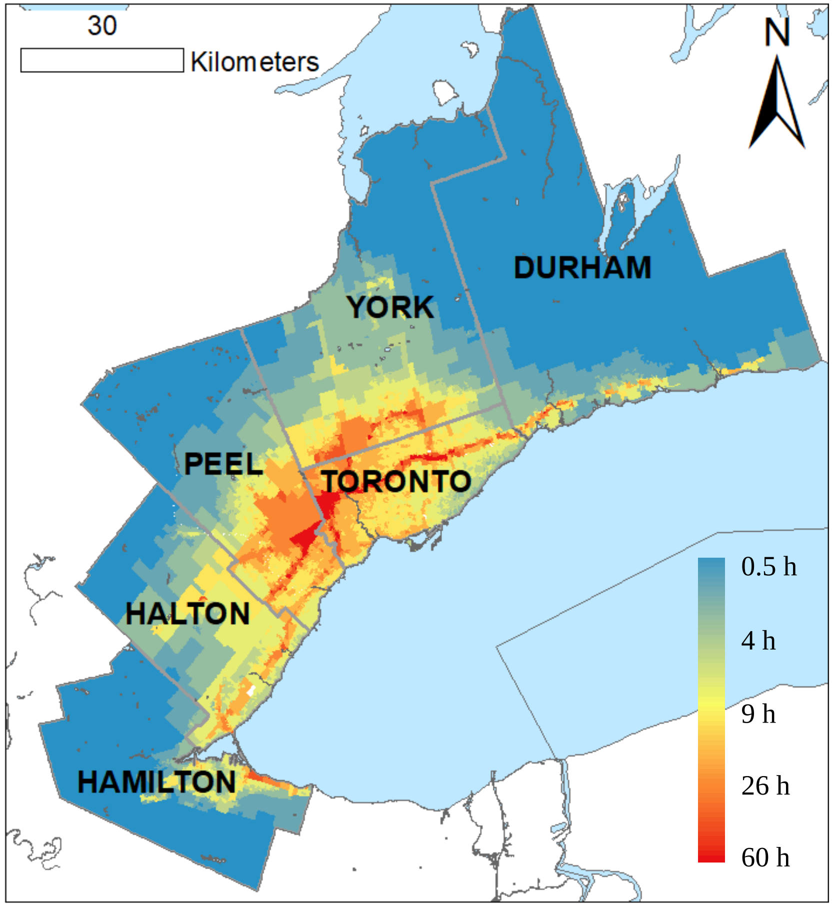




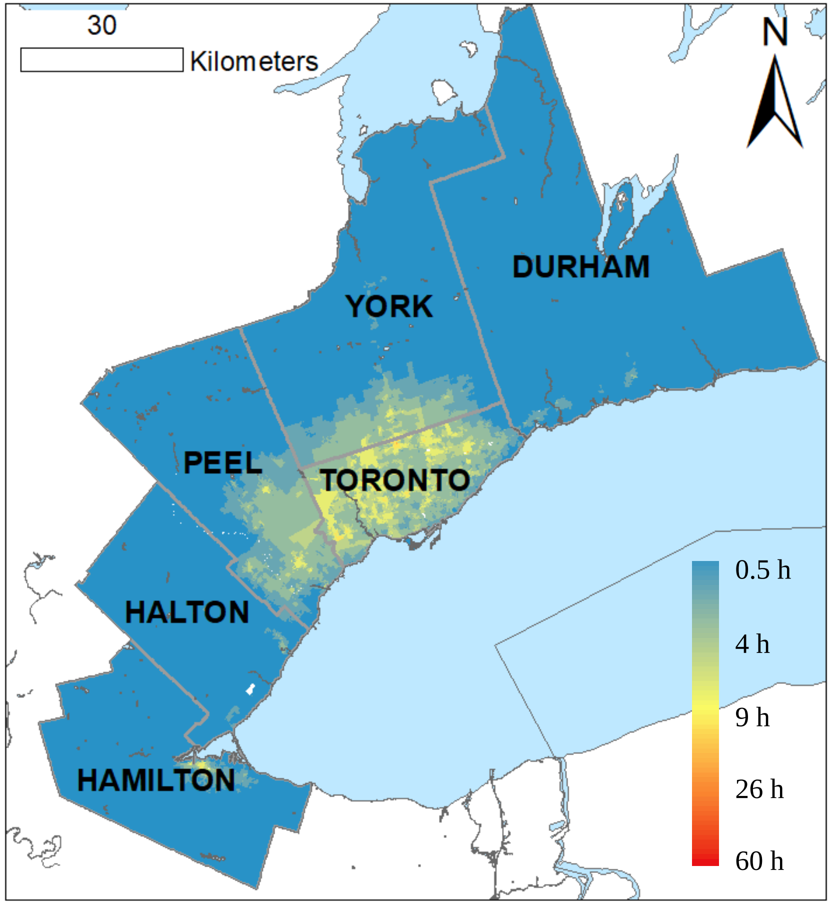
Hours of life lost per capita per year due to the different modes



Burden of Private Household Vehicles

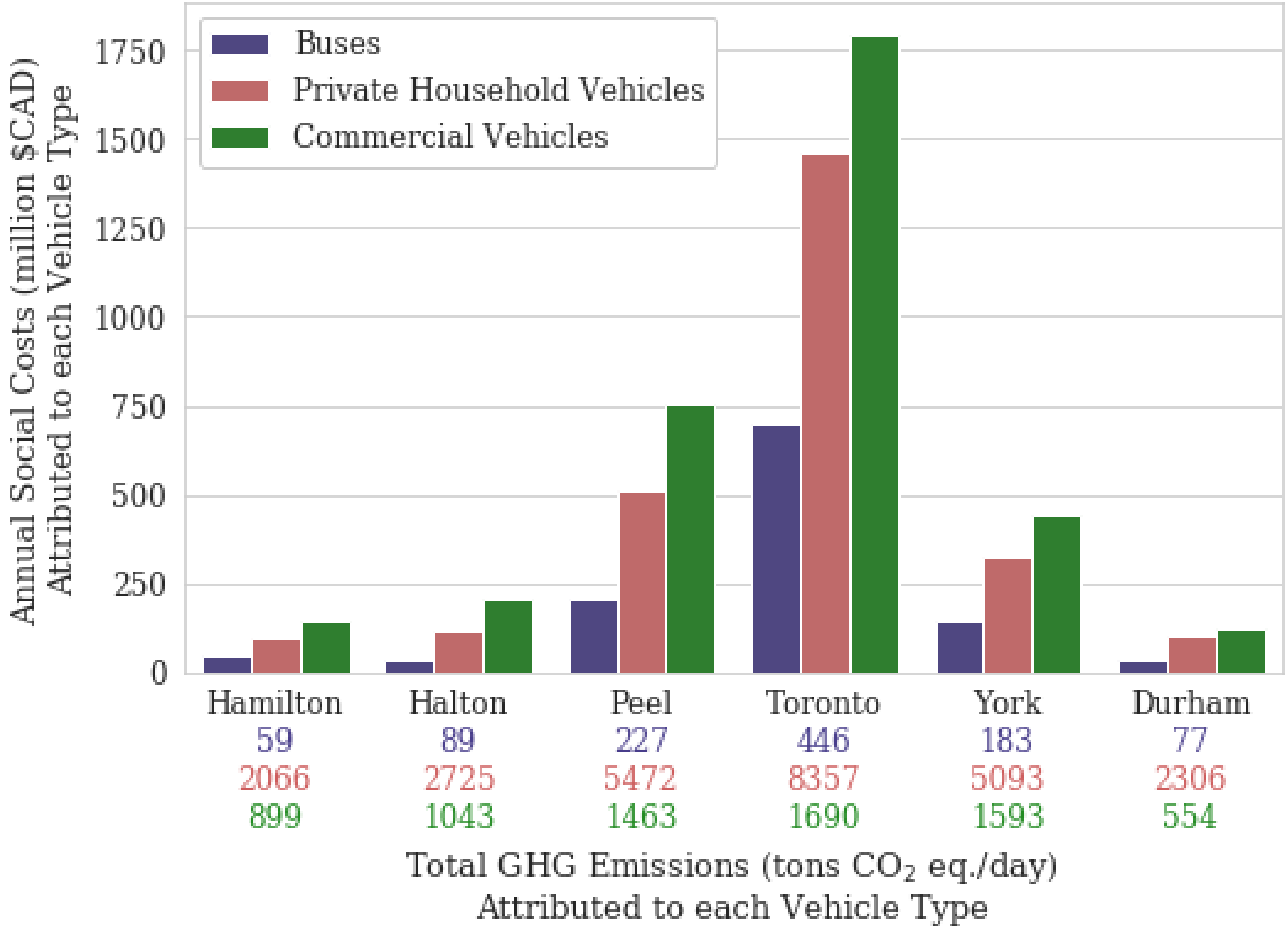


Burden of Commercial Vehicles



Burden of Buses

Health vs climate burden of each mode



THE HEALTH AND CLIMATE IMPACTS OF

ELECTRIC VEHICLES

Two EV Penetration rates - 25% & 100%

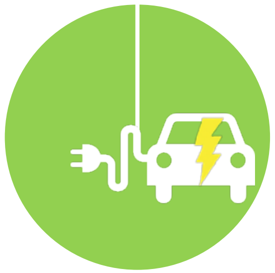
Base case

100% Internal combustion engine vehicles (ICEVs)

1)

25% Electric vehicles (EVs)

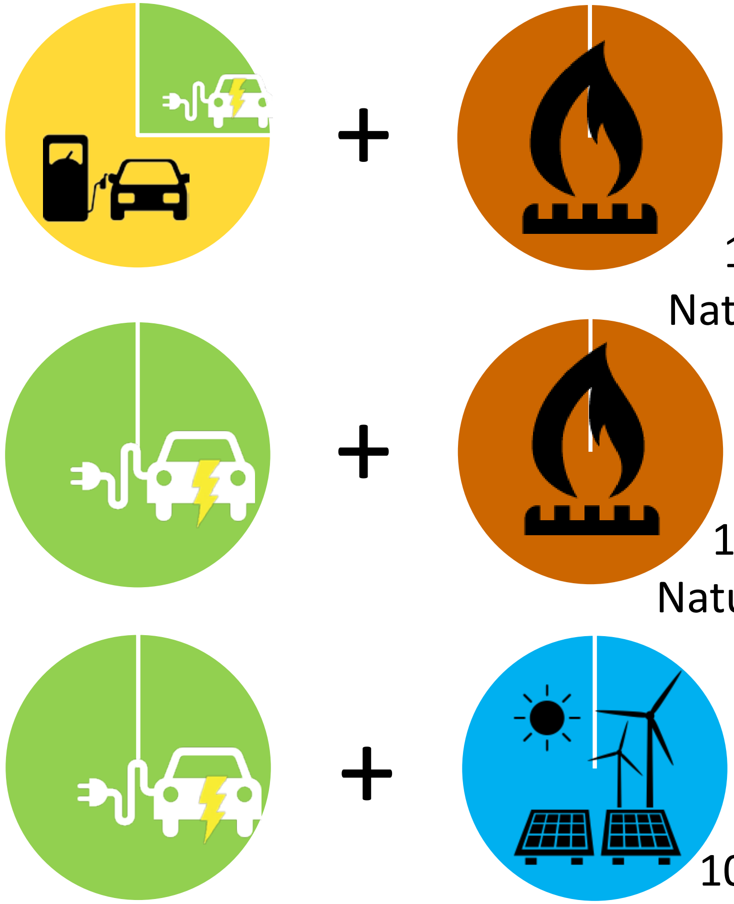
2)

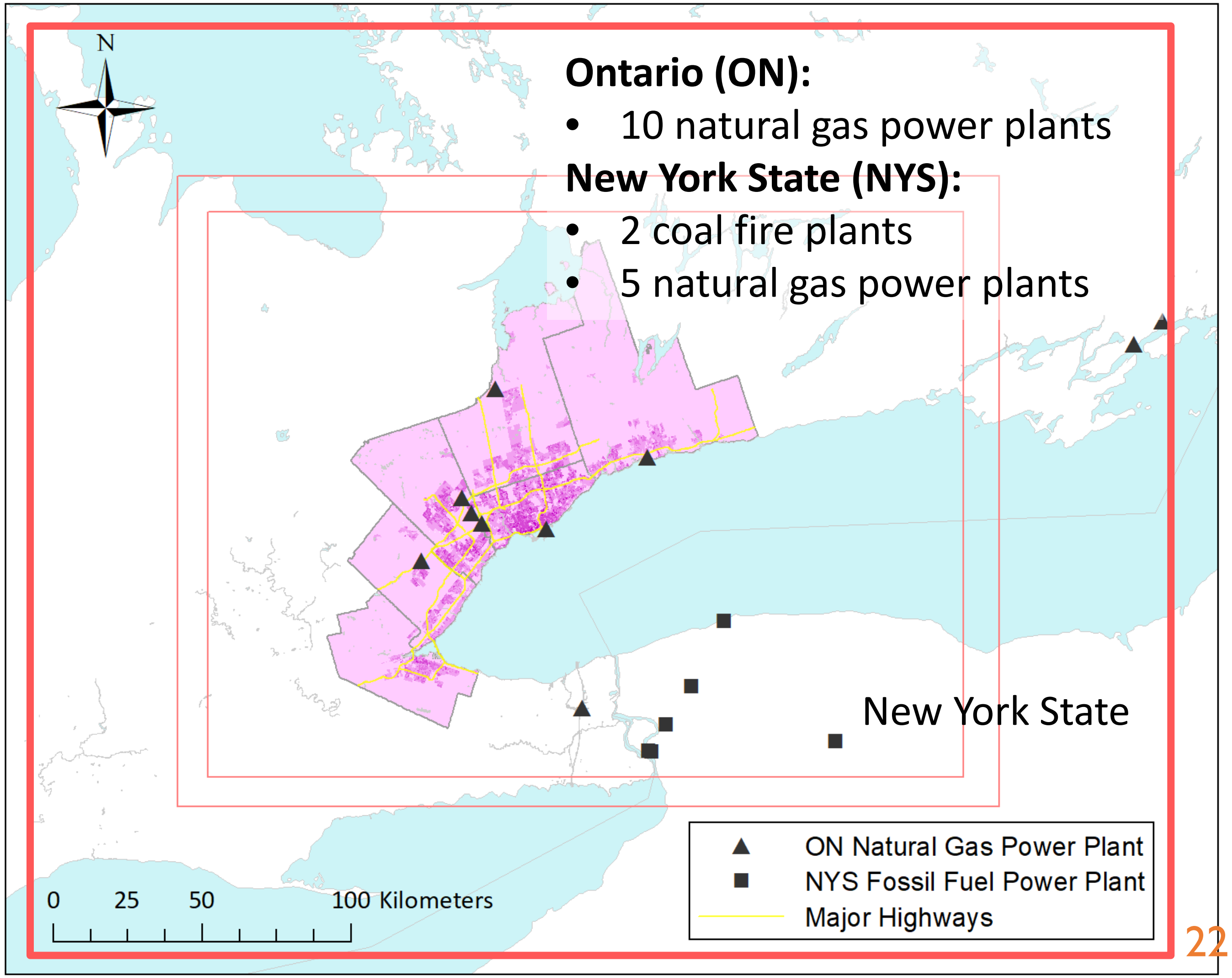


100% Electric vehicles (EVs)

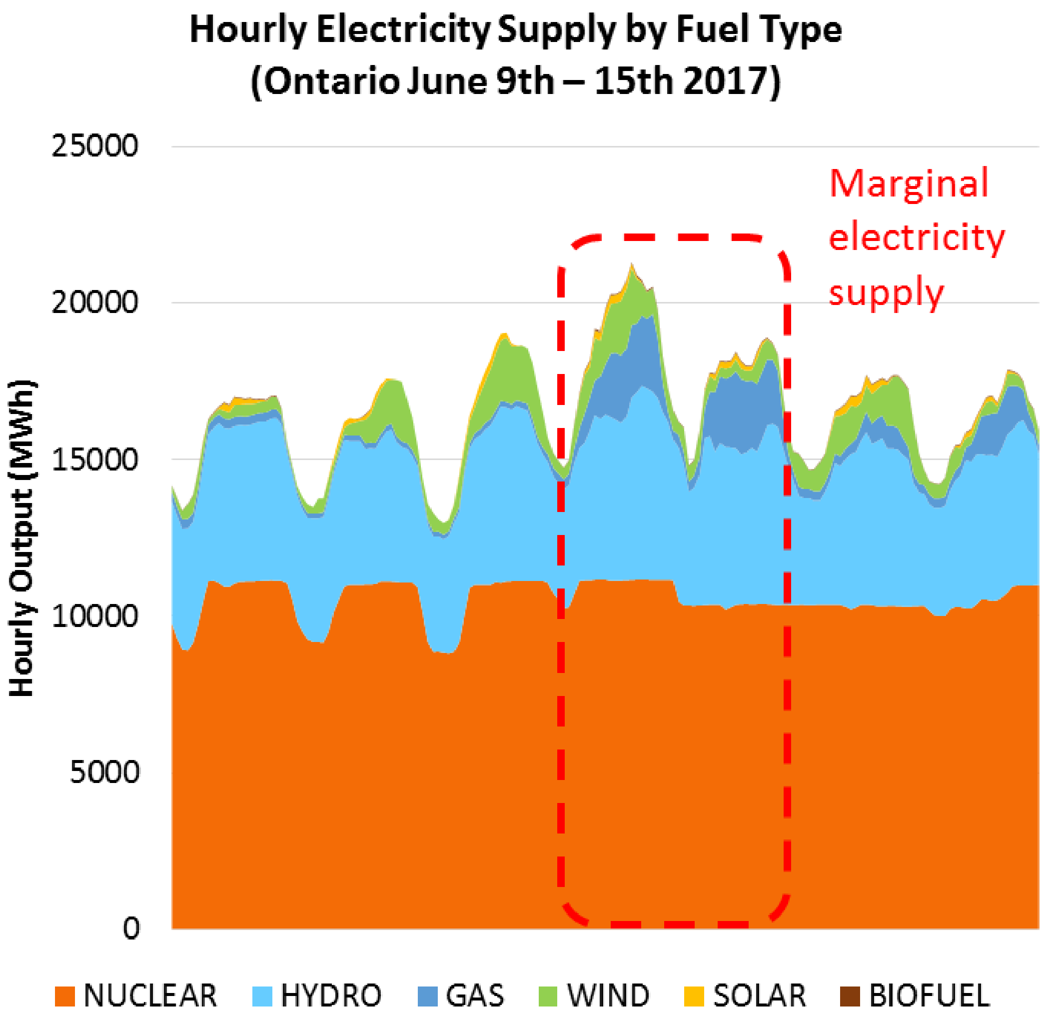
Electricity Generation Mix – Bounding scenarios

	EV Penetration		Energy source for EV charging
1)		+	100% Natural gas
2)		+	100% Natural gas
3)		+	100% Renewable





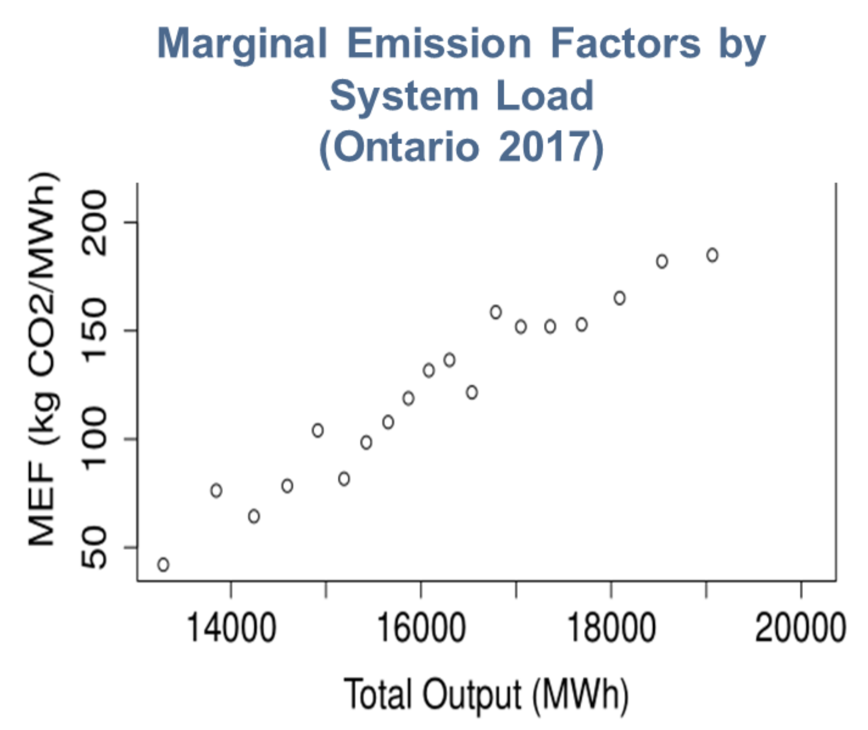
Marginal Emissions of Electricity Generation

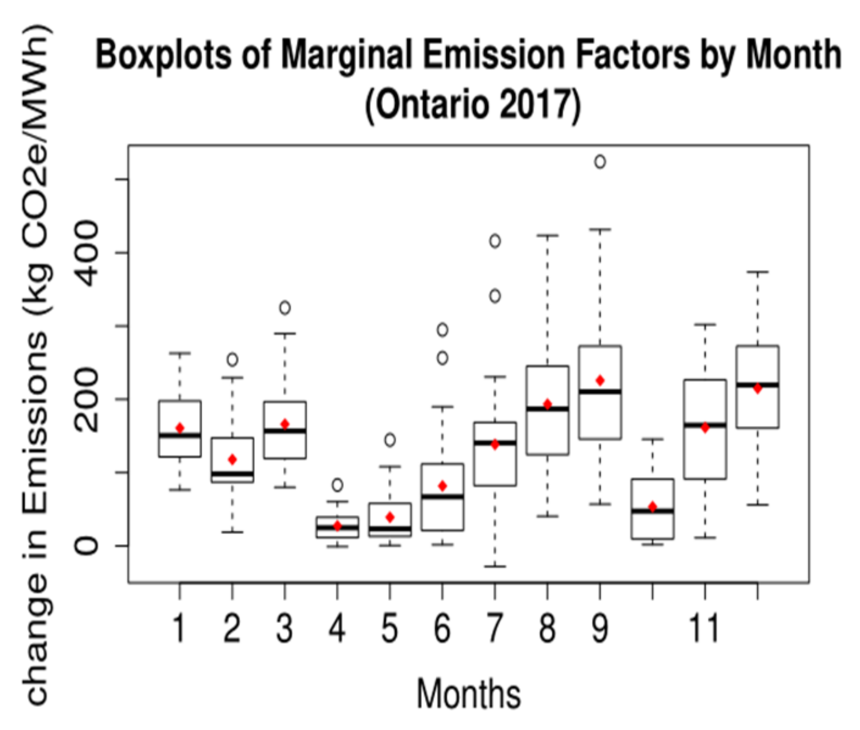


Marginal Emissions of Electricity Generation

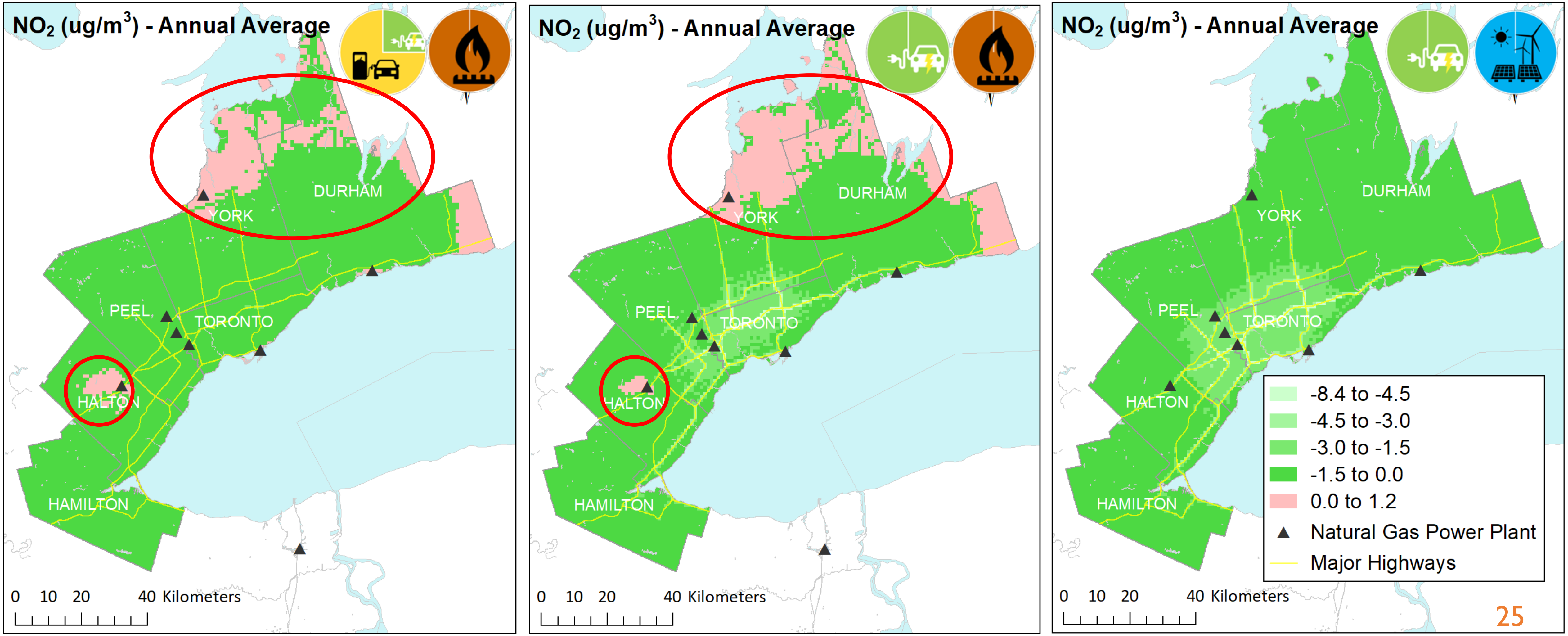
MEF

$$\Delta E = \beta_0 + \underbrace{(\beta_{0*} + \beta_{1*}G + \beta_{2*}\Delta G)}_{\text{MEF}} D_{Month} D_{\Delta G} \Delta G$$

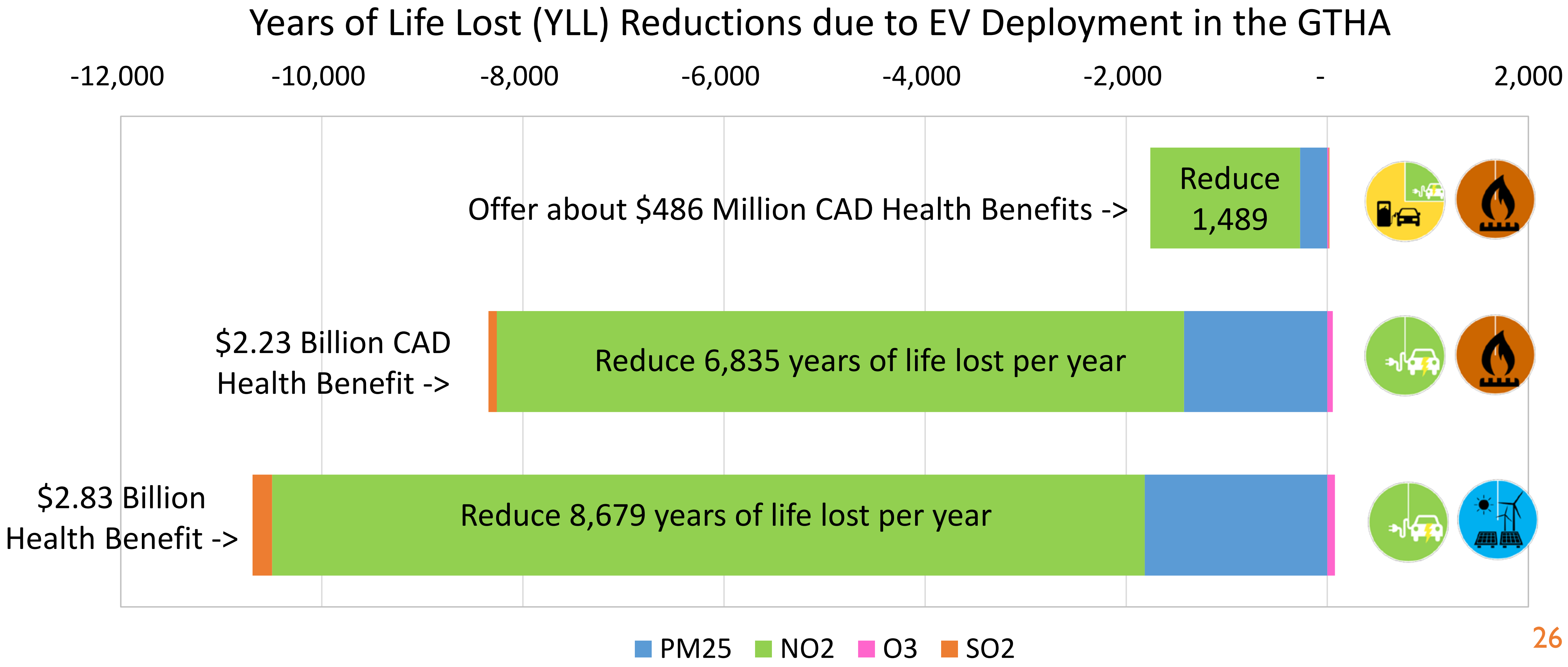




Changes in NO_2 Concentration – comparing to base case:
Overall reduction; but increase can be observed close to natural gas plants

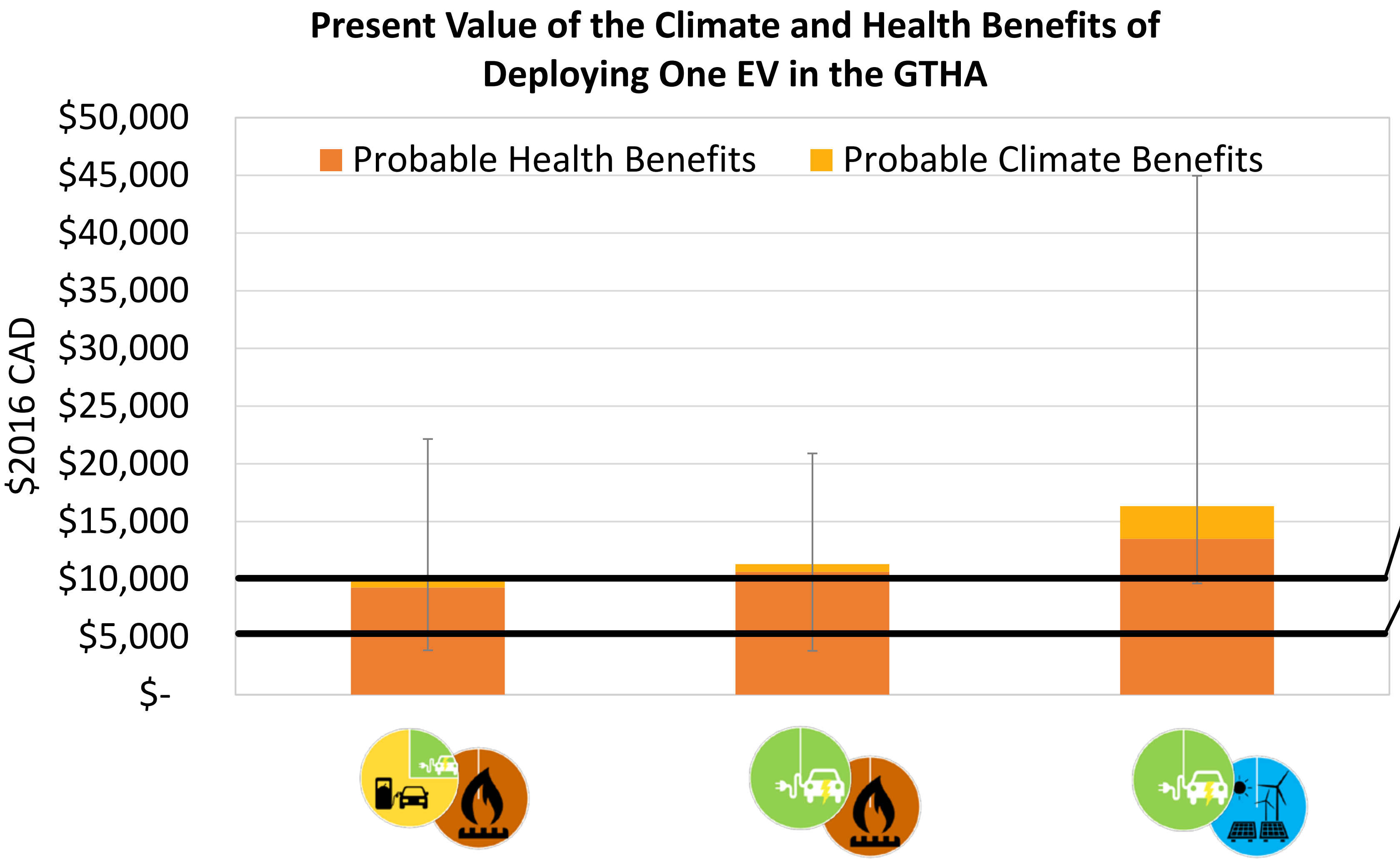


Health Impact Assessment:
100% EV deployment can save more than $2 Billion Health Sector Spending



Economic Valuation

Social economic benefit can be much higher than the EV incentive program

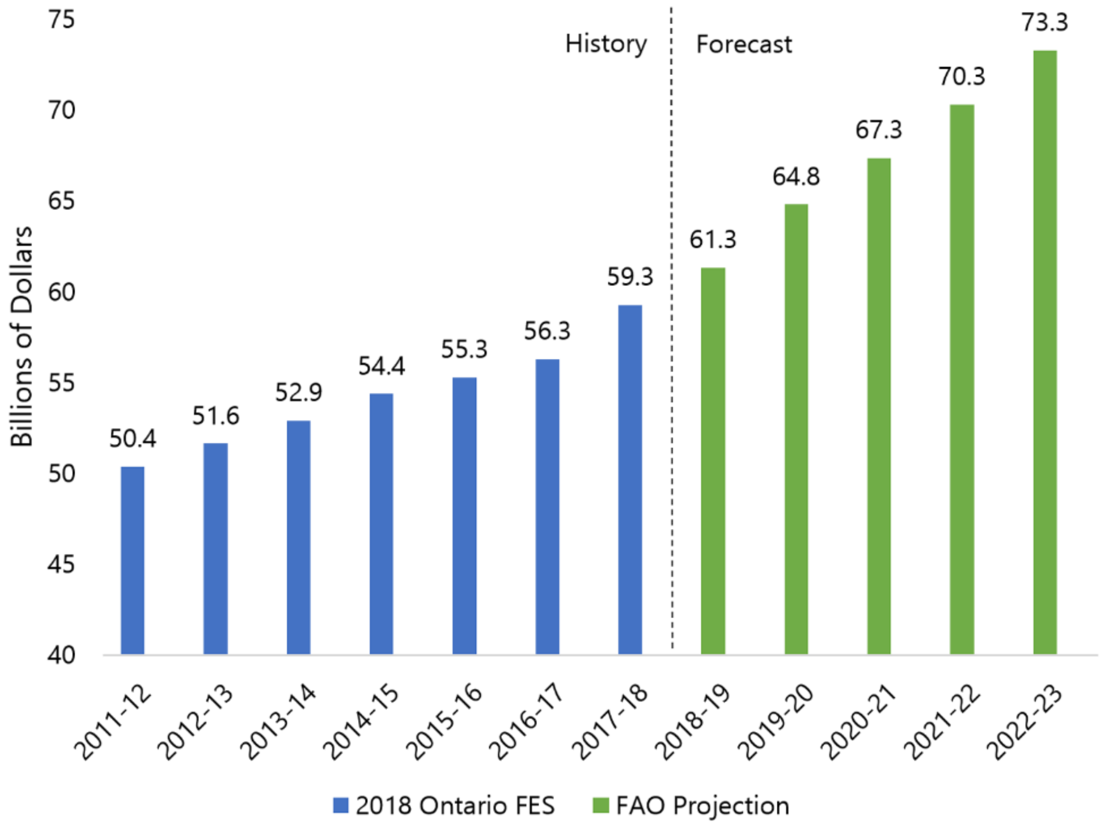


EV Incentives ($CAD):

- Cancelled Ontario Incentive: ~ $10,000
- Canada federal incentive: $5,000

Health sector spending in the GTHA by 2022-23: about **$34.44 Billion CAD**

FAO status quo health sector spending projection ($ billions)



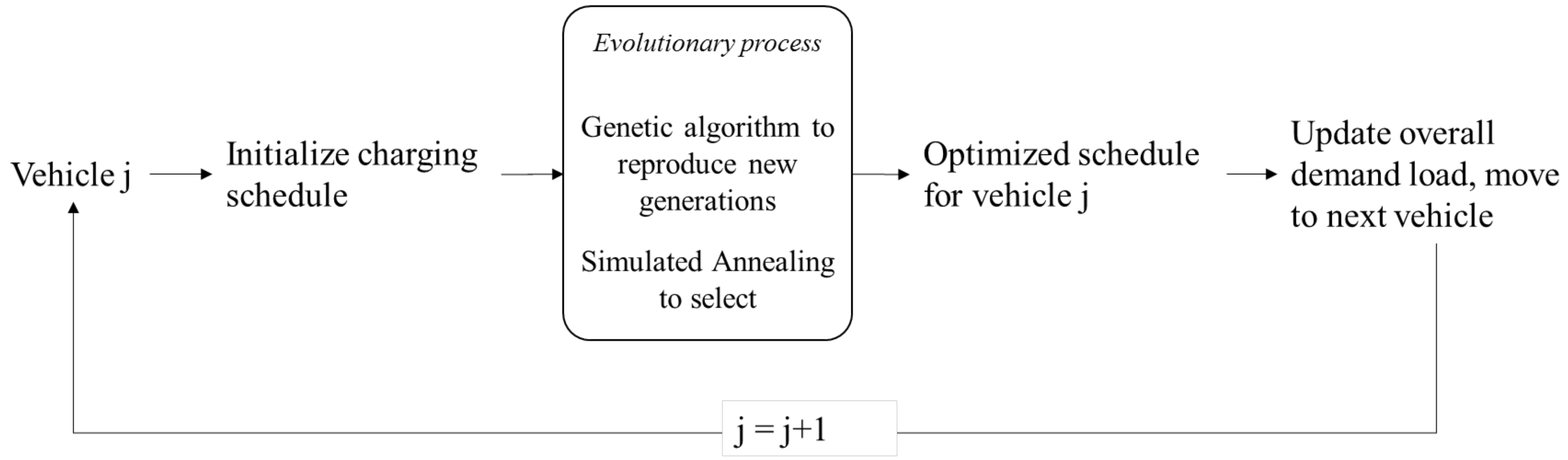
Optimizing EV charging to reduce GHG emissions

The GHG emission intensity of EV charging varies during the day due to the electricity mix (more natural gas during peak periods)

We developed a model that calculates marginal GHG emission factors

Based on travel survey data (TTS), we developed an optimization to identify, for each trip, the time and location of charging that would lead to the lowest system-wide GHG emissions

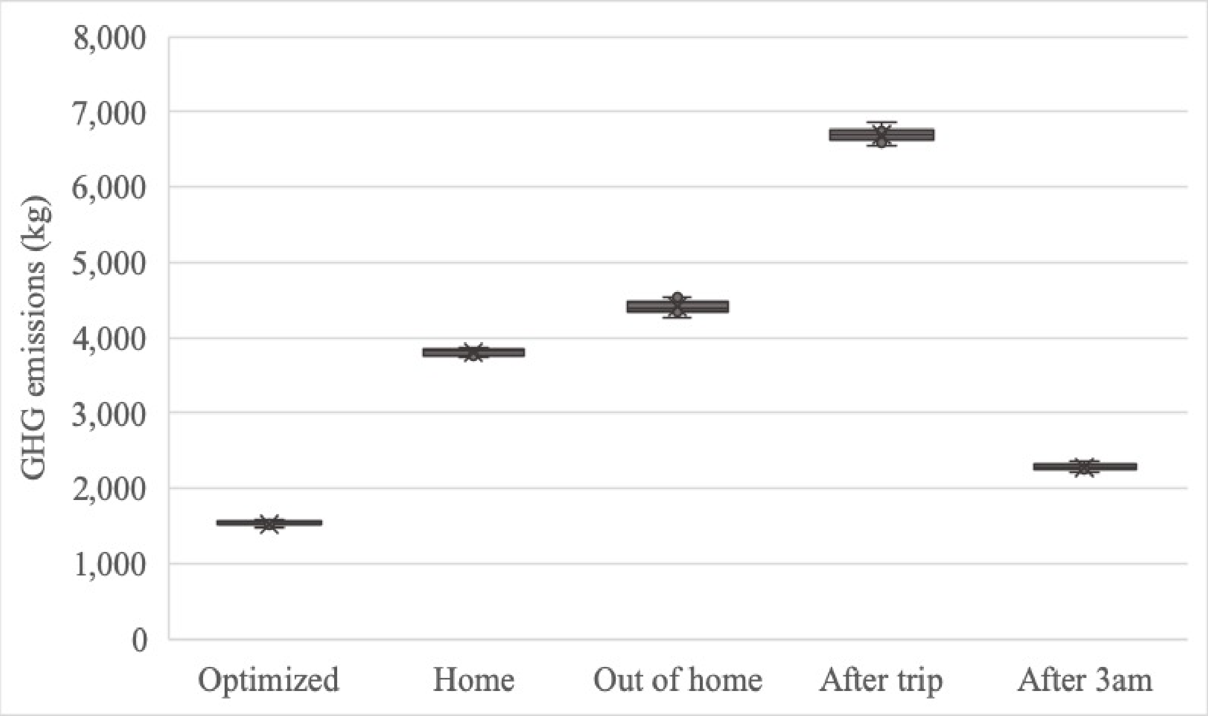
Heuristic optimization



Optimizing EV charging to reduce GHG emissions

Compared to scenarios where everyone charges at home or at work/shopping, the optimized charging scheme achieves the lowest system-wide GHG emissions

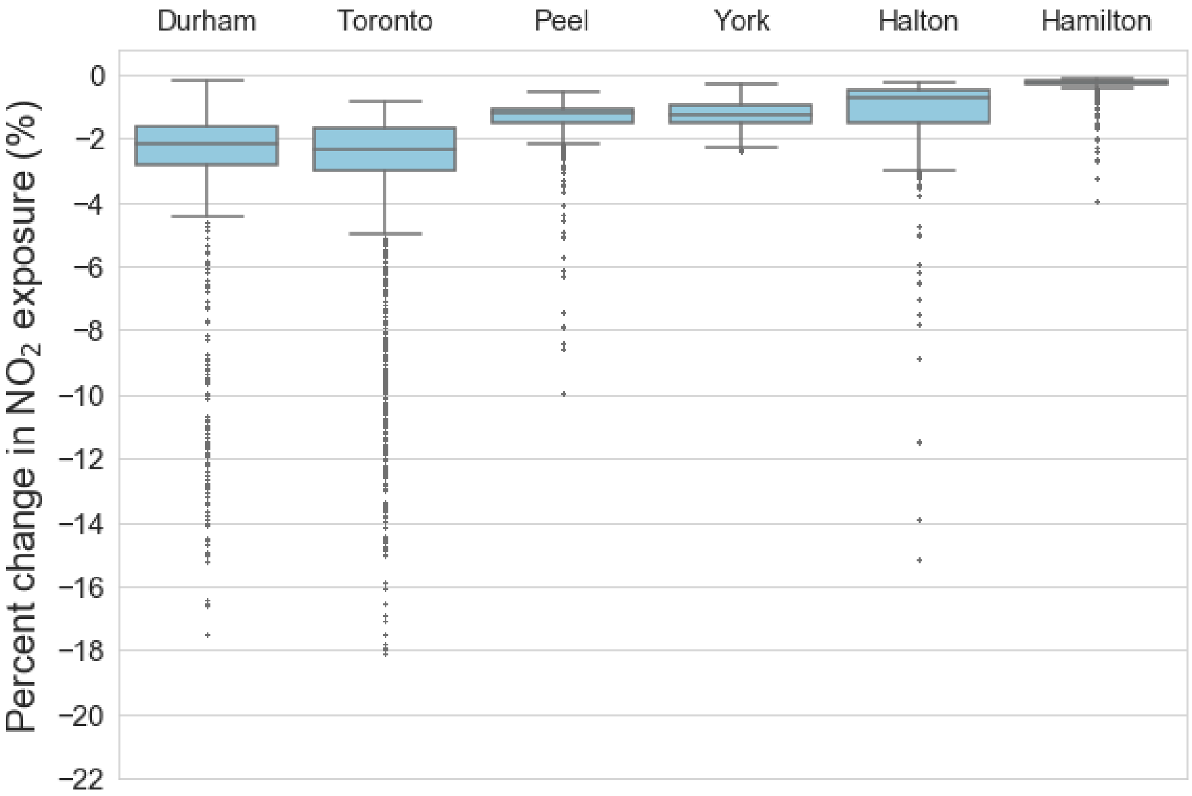
The optimal charging scheme performs better than the scenario where everyone charges at night

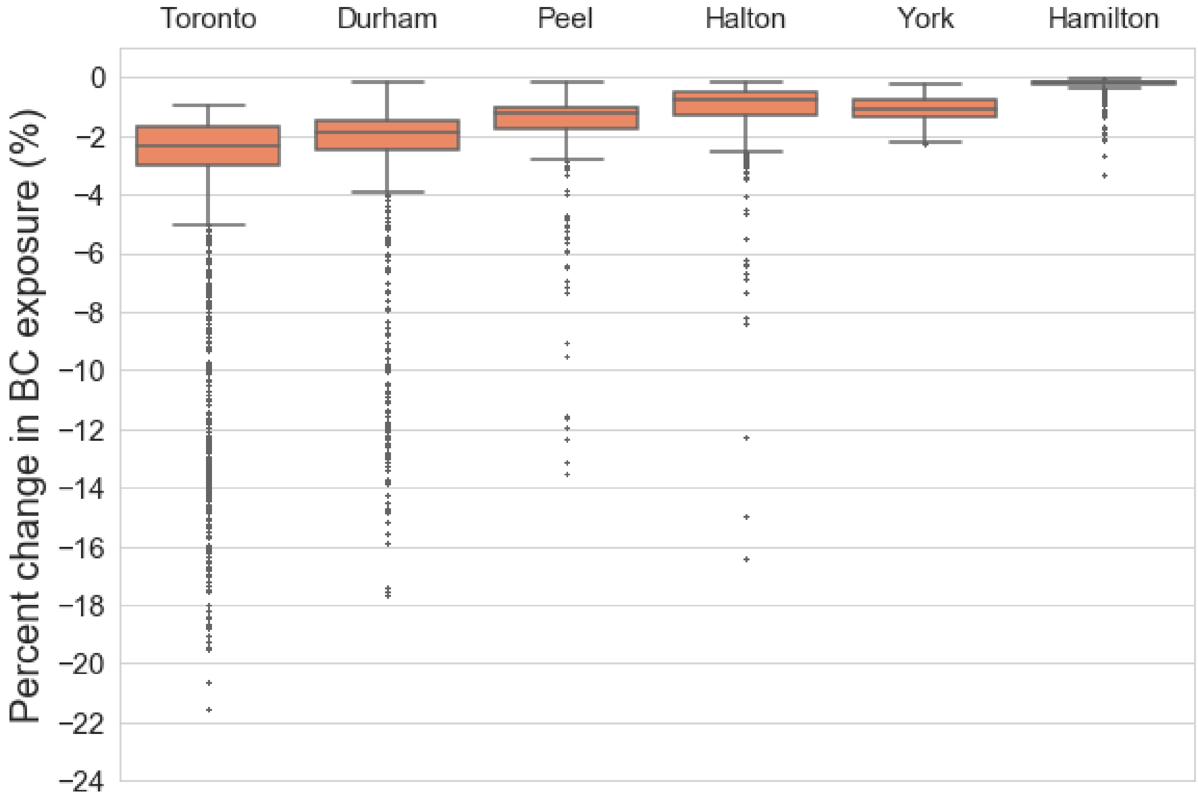


THE HEALTH AND CLIMATE IMPACTS OF

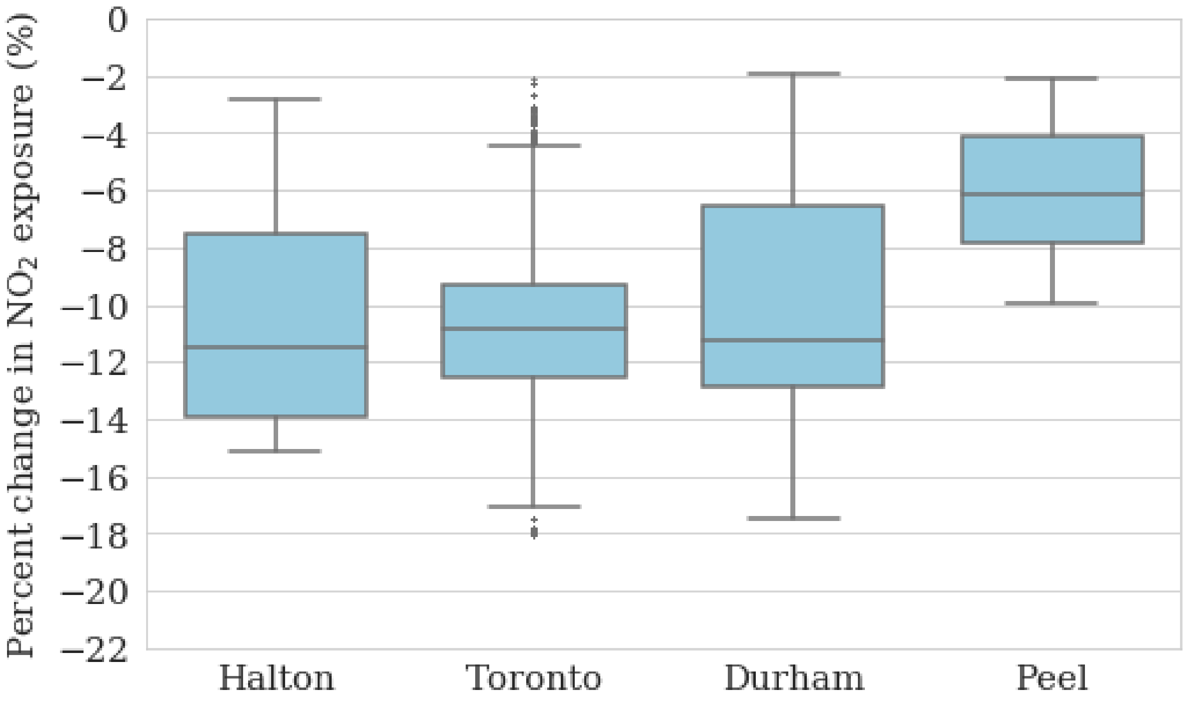
GREENING FREIGHT MOVEMENTS

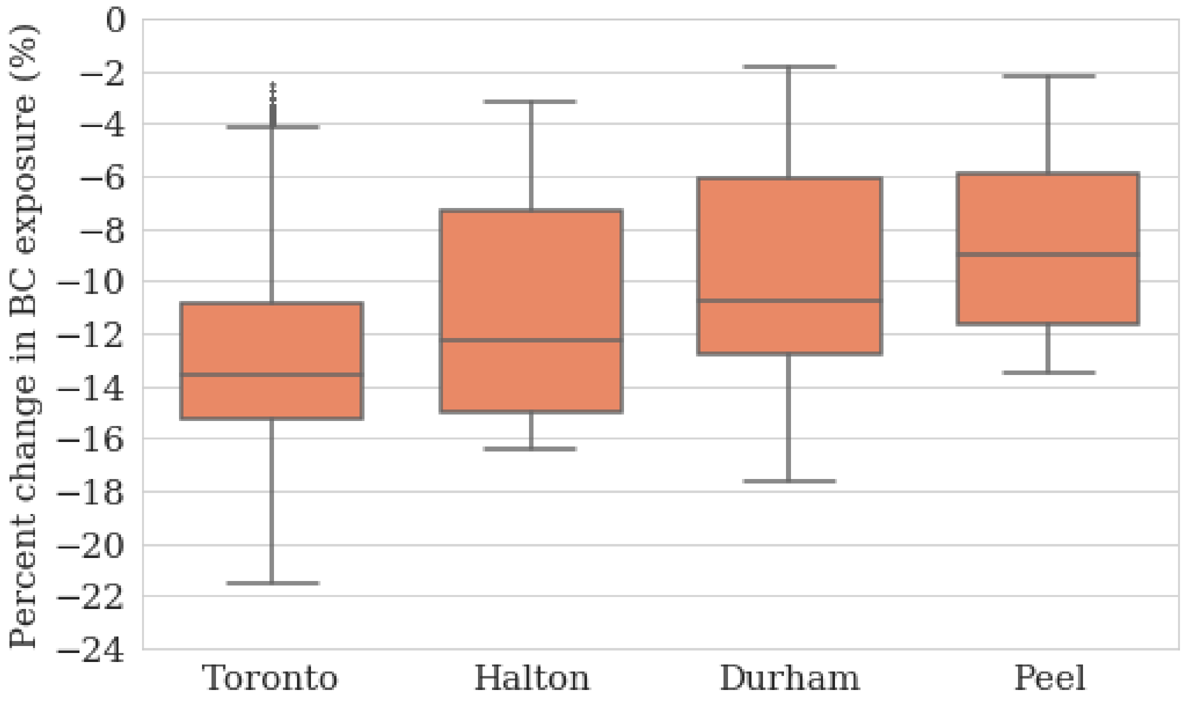
Percent change in the population exposure to NO_2 and BC in the case with less diesel emissions on Highway 401



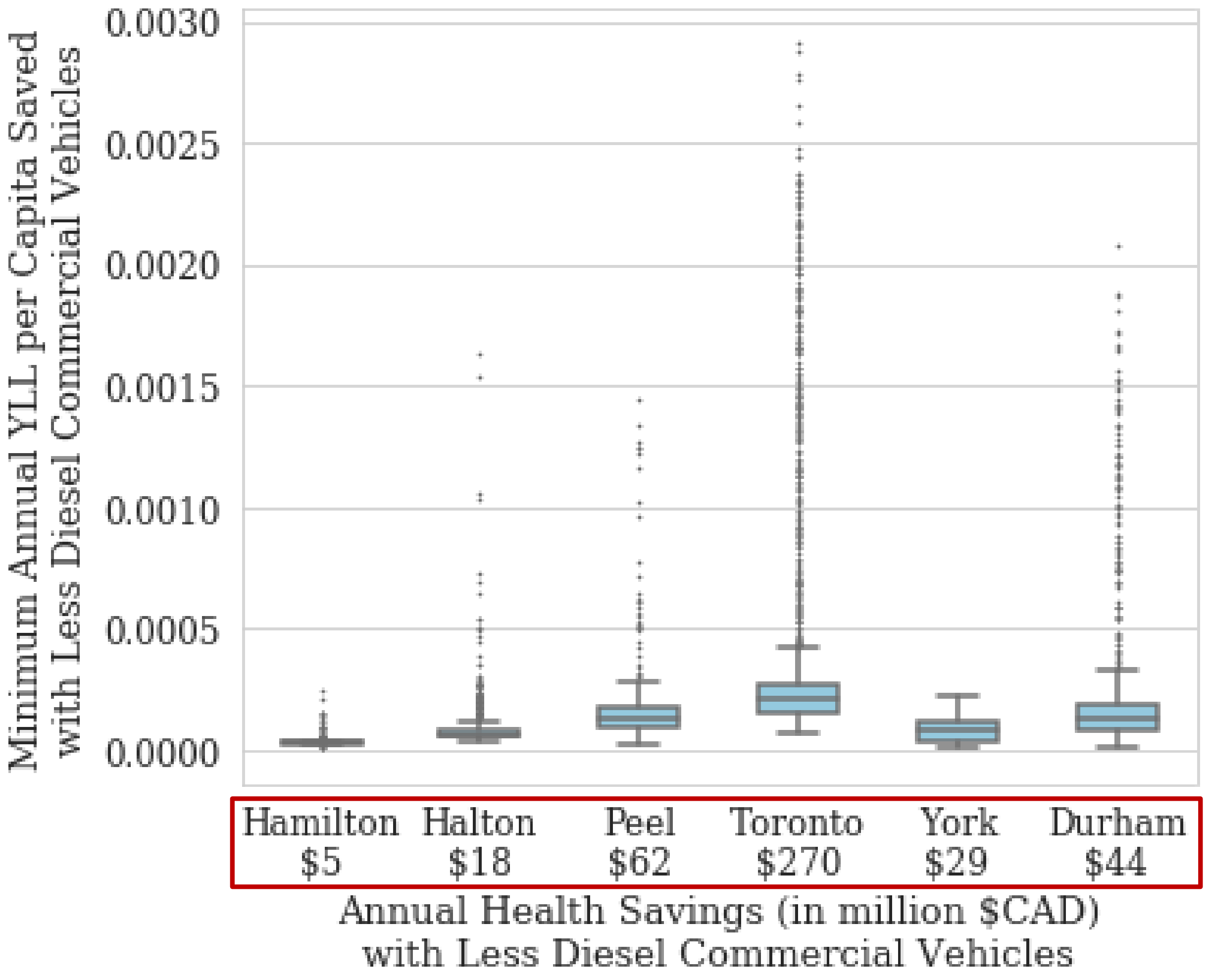


Percent change in the population exposure to NO_2 and BC in the case with less diesel emissions on Highway 401 for population living within 500m of Highway 401





Assessment of the Health Outcomes, under the lower freeway-sourced emissions case



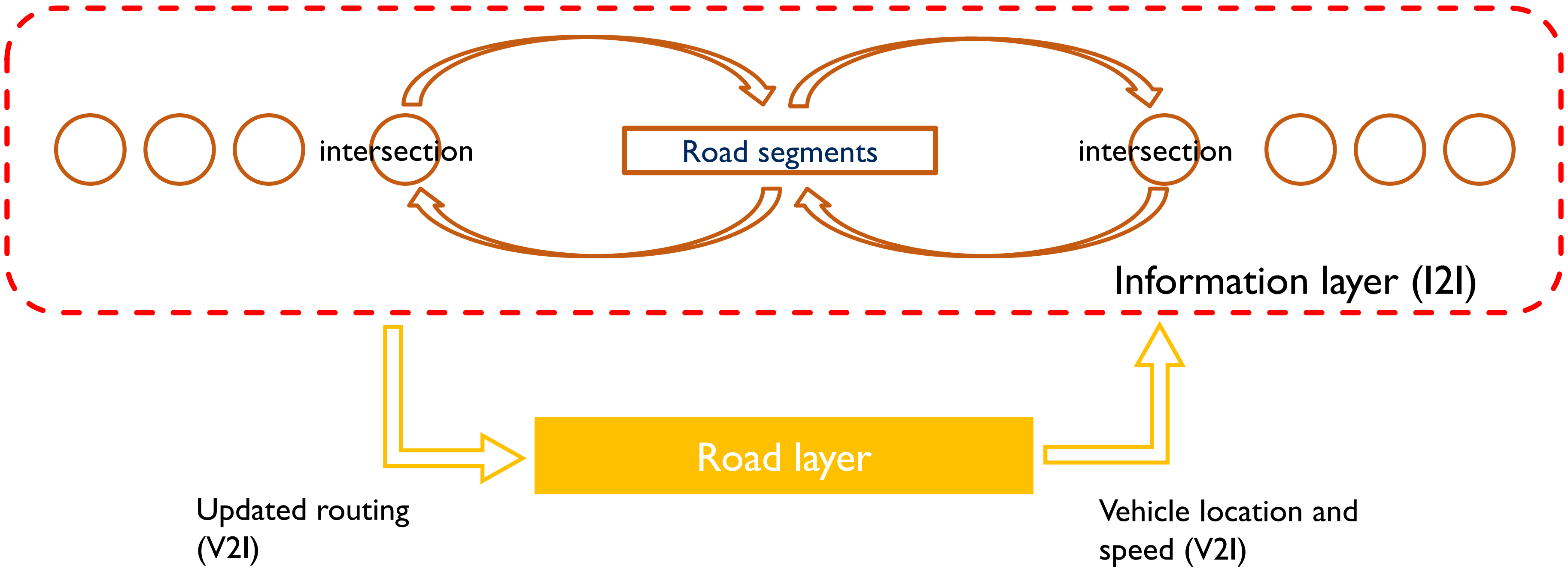
Health savings are higher for regions with higher populations

But this analysis also shows that even small reductions in freeway sourced emissions can achieve large benefits

END-TO-END (E2E) DYNAMIC ROUTING CONTROL WITH CONNECTED AND AUTONOMOUS VEHICLES (E2ECAV)

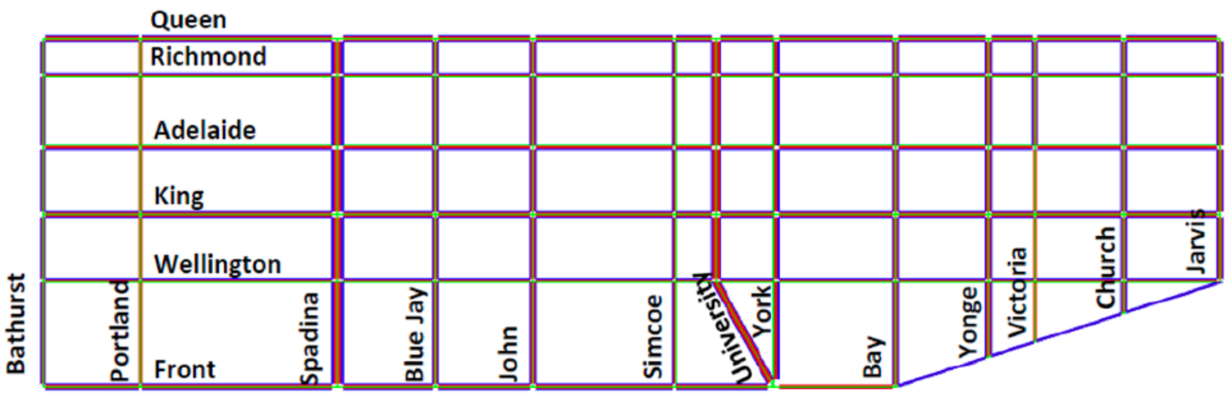
GHG AND AIR POLLUTION

End-to-end distributed control on autonomous vehicles (E2ECAV)



- Up to date real time traffic information
- Single integrated view of the network
- Responsive to changes
- Objective: Maximize capacity & minimize travel time

Application in downtown Toronto



Various scenarios for congestion and penetration of connected and automated vehicles

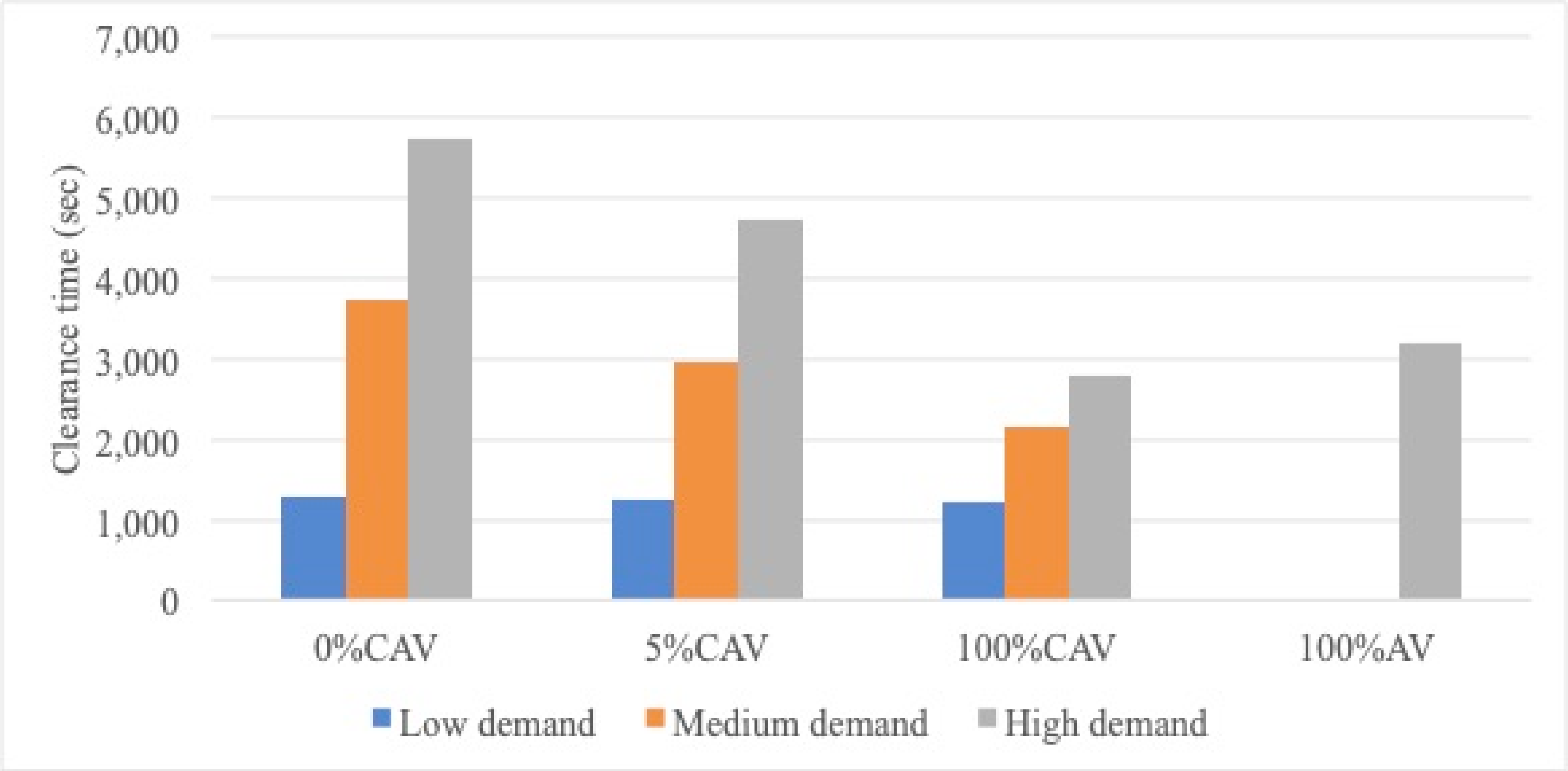
Scenario ID	Network demand level	E2ECAV market penetration rate (MPR)	on-road vehicle type
1	Low (LOS1)	0	HDV
2	Low	0.05	E2ECAV+HDV
3	Low	1	E2ECAV
4	Medium (LOS2)	0	HDV
5	Medium	0.05	E2ECAV+HDV
6	Medium	1	E2ECAV
7	High (LOS3)	0	HDV
8	High	0.05	E2ECAV+HDV
9	High	1	E2ECAV
10	High	-	AV

30% base demand (scenarios 1–3)

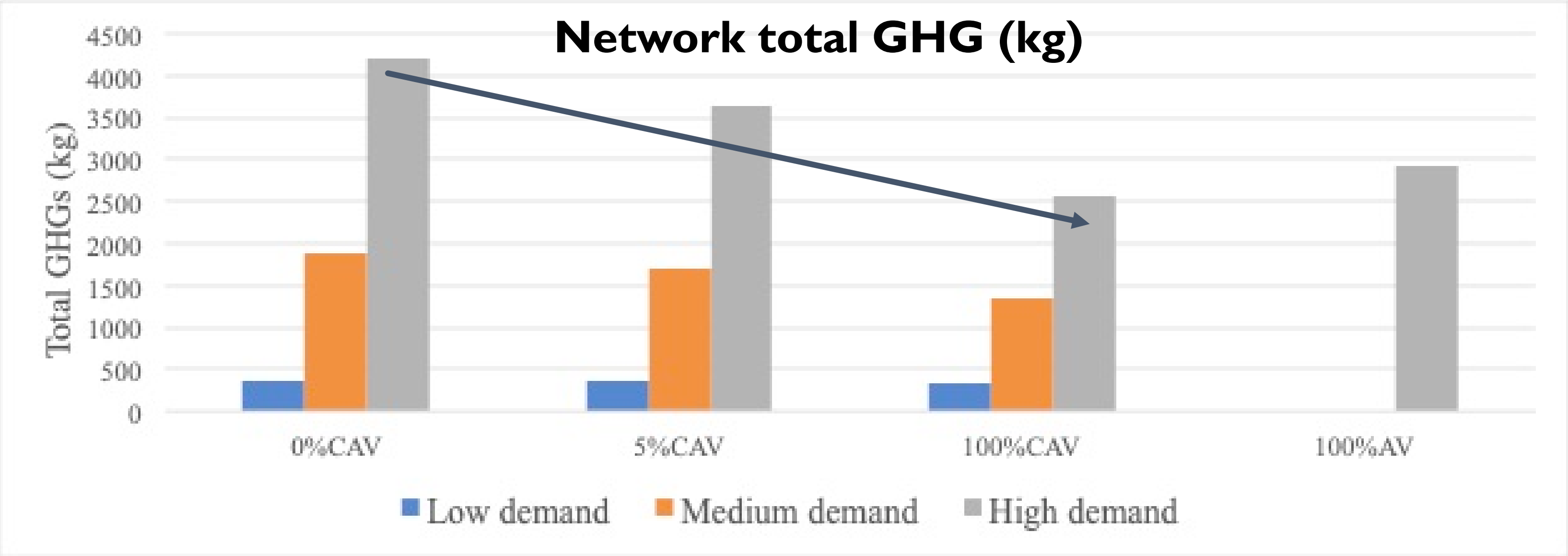
70% base demand (scenarios 4–6)

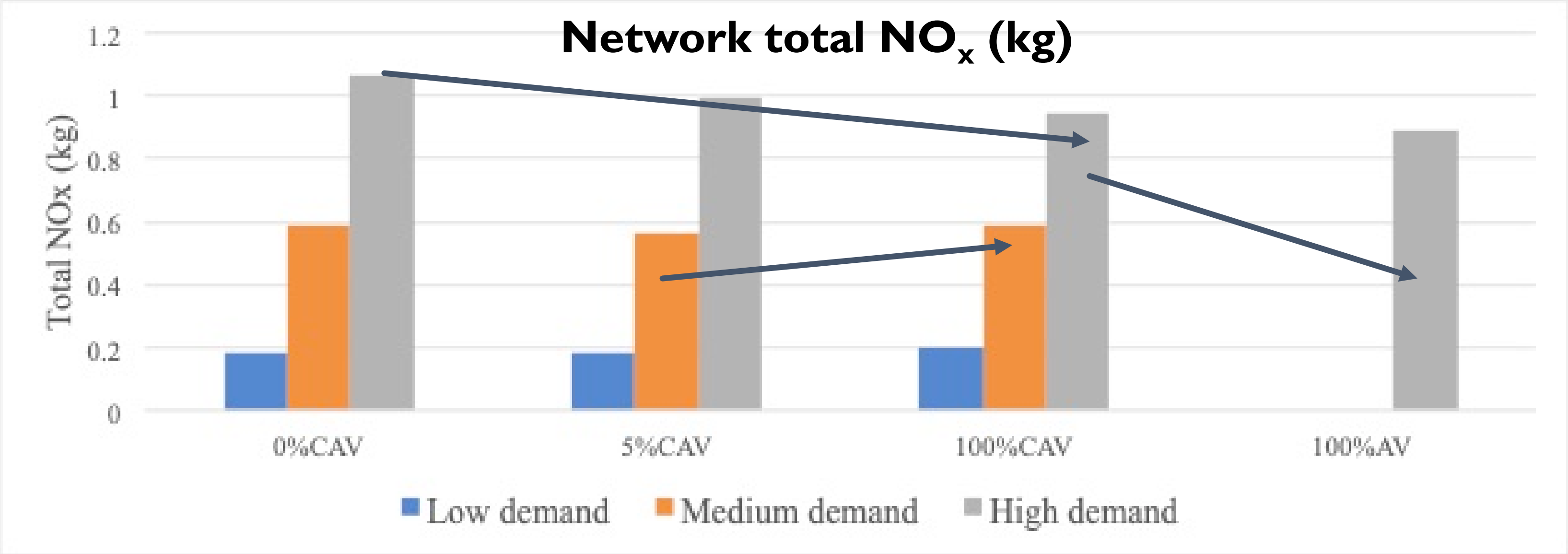
100% base demand (scenarios 7–10)

Traffic throughput increases

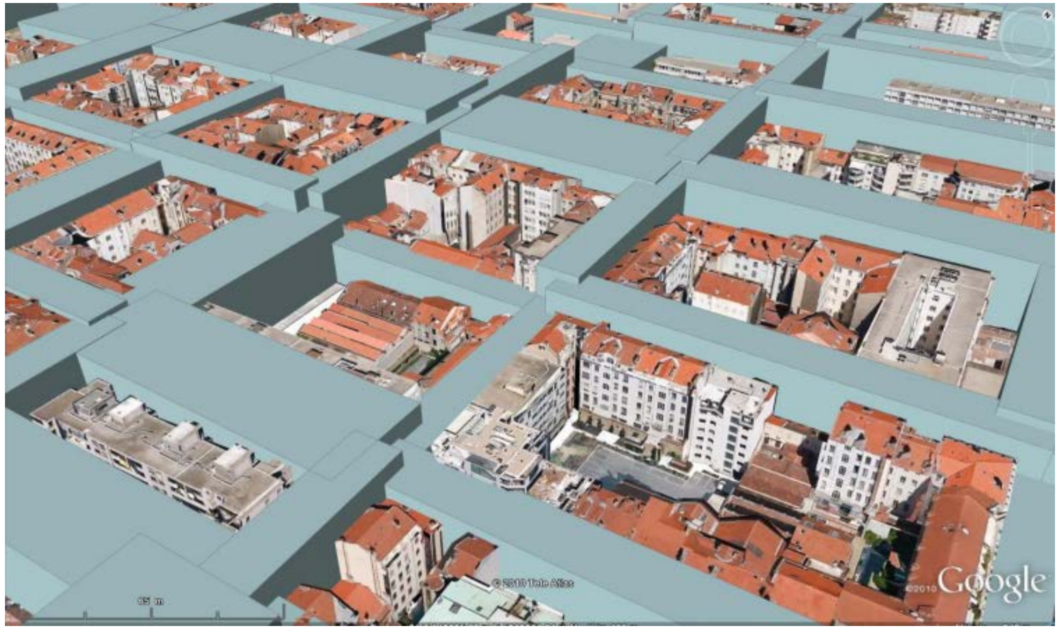


GHG emissions are reduced but reductions in NO_x emissions are minor

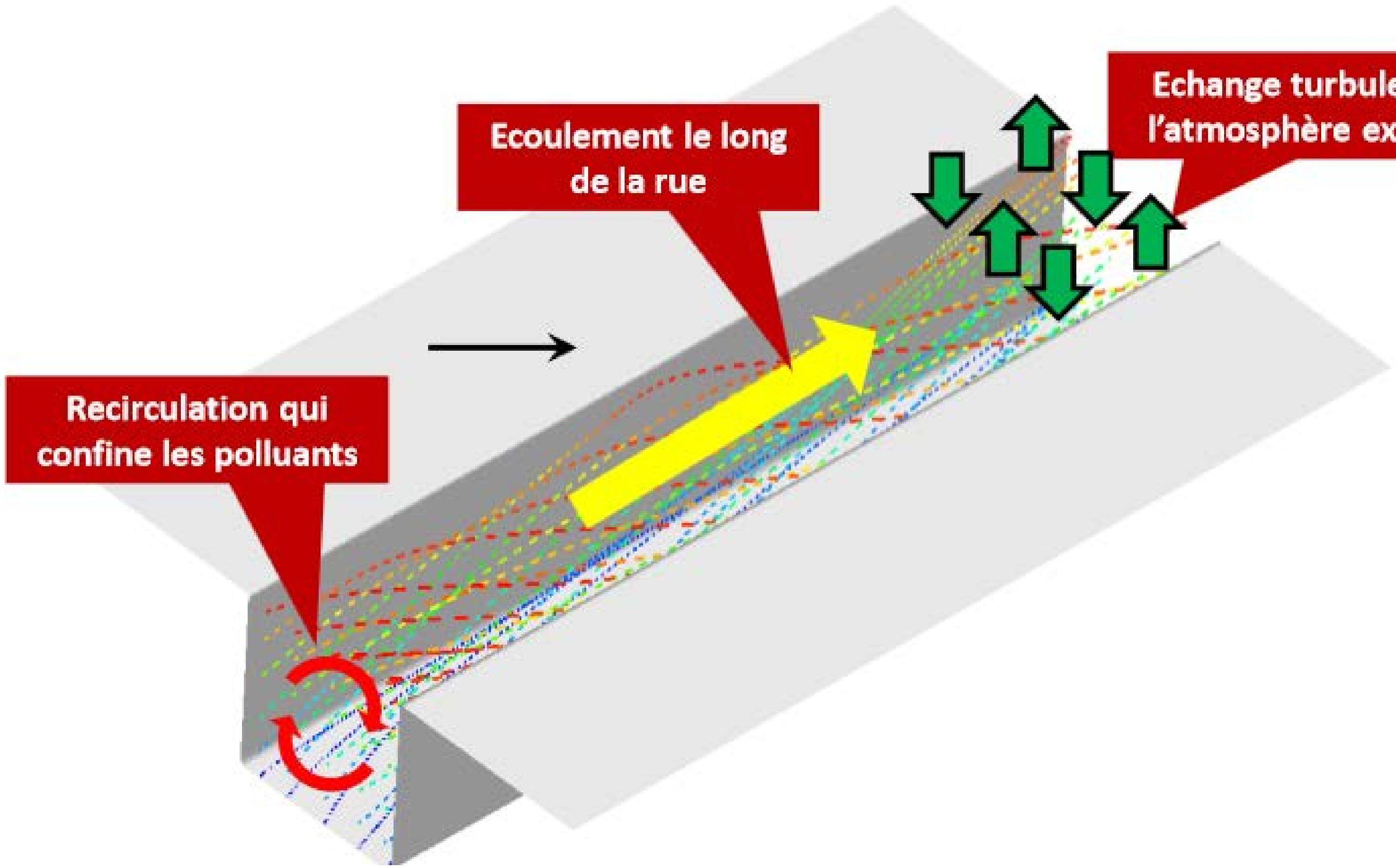


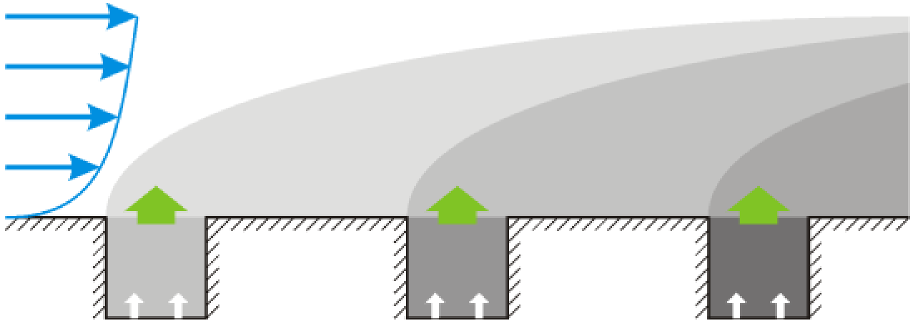


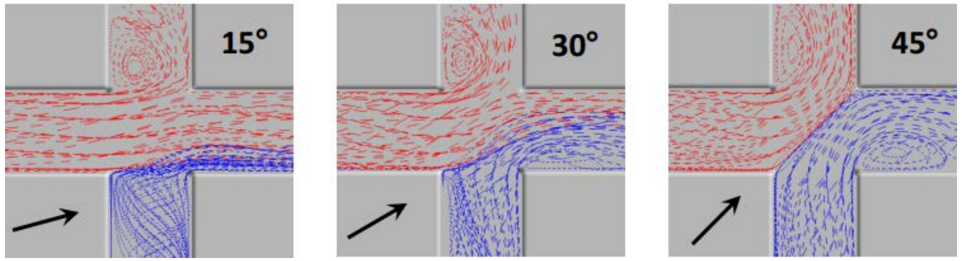
Dispersion modelling with a street canyon model: SIRANE



SIRANE

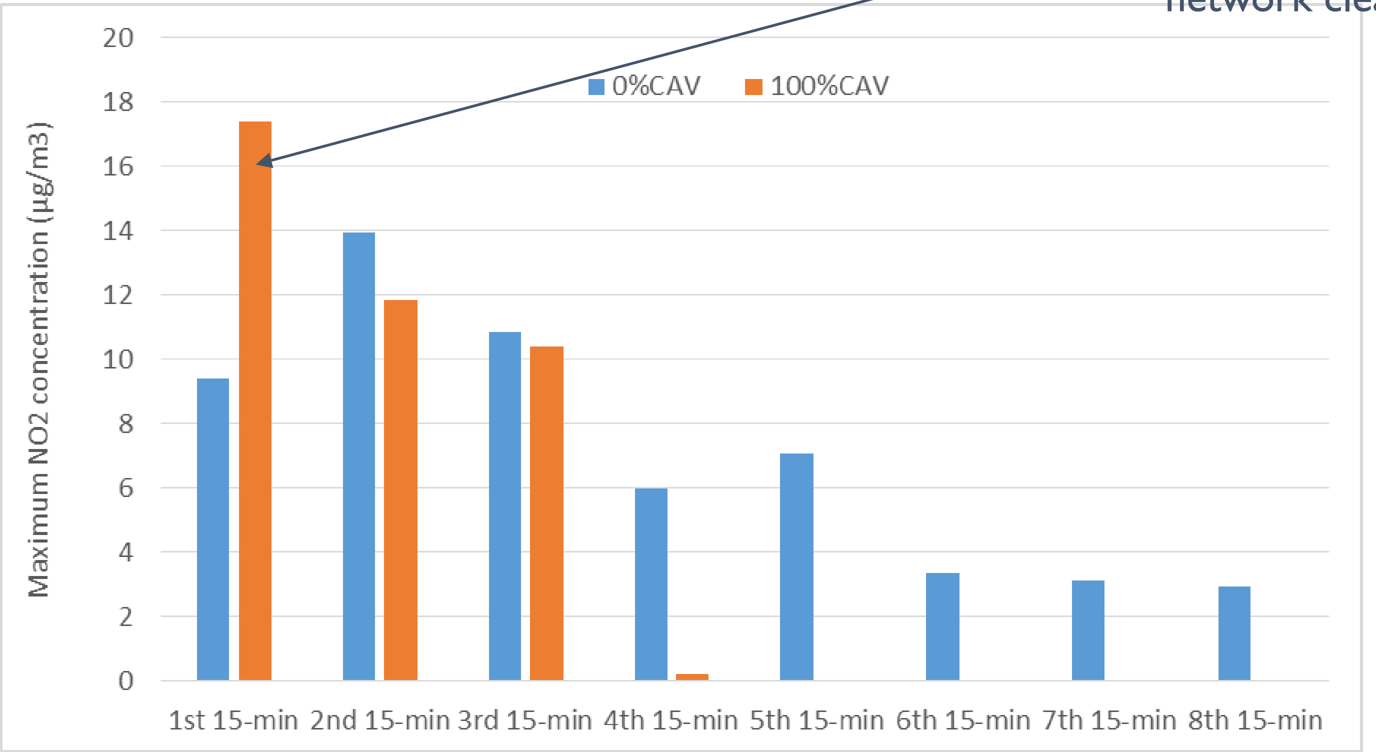

Ecoulement le long de la rue
Echange turbulent avec l'atmosphère extérieure
Recirculation qui confine les polluants




15°
30°
45°

NO_2 concentrations across the network

Higher maxima in CAV scenario but network clears faster



AIR POLLUTION CONTINUES TO BE ASSOCIATED WITH HEALTH EFFECTS EVEN AT THE LOW LEVELS THAT CHARACTERIZE CANADIAN CITIES

ELSEVIER
Health & Place
Volume 34, July 2015, Pages 287–295

Spatial analysis of exposure to traffic-related air pollution at birth and childhood atopic asthma in Toronto, Ontario

K. Shankardass[a, b], M. Jerrett[c], S.D. Dell[d, e], R. Foty[f], D. Stieb[g]

Journal of Toxicology and Environmental Health, Part A: Current Issues
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/uteh20

The Association Between Chronic Exposure to Traffic-Related Air Pollution and Ischemic Heart Disease

Bernardo S. Beckerman [a], Michael Jerrett [a], Murray Finkelstein [b], Pavlos Kanaroglou [c],

ELSEVIER
Environment International
Volume 74, January 2015, Pages 240–248

Exposure to traffic-related air pollution and the risk of developing breast cancer among women in eight Canadian provinces: A case–control study

Perry Hystad[a], Paul J. Villeneuve[b], Mark S. Goldberg[c, d], Dan L. Crouse[e], Kenneth Johnson[f], the

Postmenopausal Breast Cancer Is Associated with Exposure Traffic-Related Air Pollution in Montreal, Canada: A Case-Control Study

Crouse, Dan L; Goldberg, Mark S; Ross, Nancy A; Chen, Hong; Labrèche, France. **Environmental Health Perspectives** 118.11 (Nov 2010): 1578-83.

ELSEVIER
Environmental Research
Volume 115, May 2012, Pages 18–25

Neurobehavioral effects of exposure to traffic-related air pollution and transportation noise in primary schoolchildren ☆ ☆☆

Elise van Kempen[a], Paul Fischer[a], Nicole Janssen[a], Danny Houthuijs[a], Irene van Kamp[a], Stephen Stansfeld[b], Flemming Cassee[a]

Traffic-related air pollution and prostate cancer risk: a case–control study in Montreal, Canada

Marie-Élise Parent[1], Mark S Goldberg[2,3], Dan L Crouse[4], Nancy A Ross[5], Hong Chen[6], Marie-France Valois[2,3], Alexandre Liautaud[7]