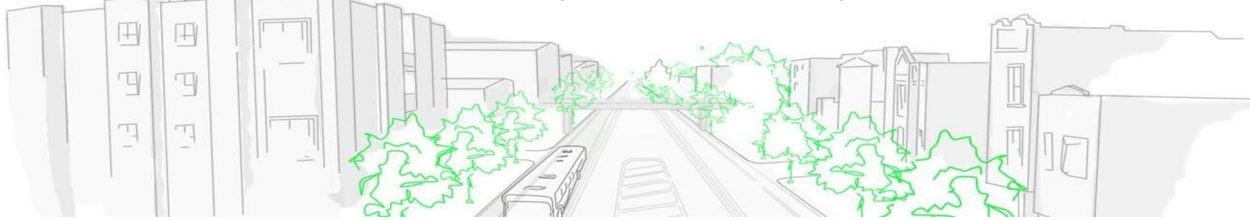
TRAQ

The Transportation & Air Quality Research Group



Anticipating the impacts of transformative transportation technologies on urban sustainability

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Transportation Research Institute

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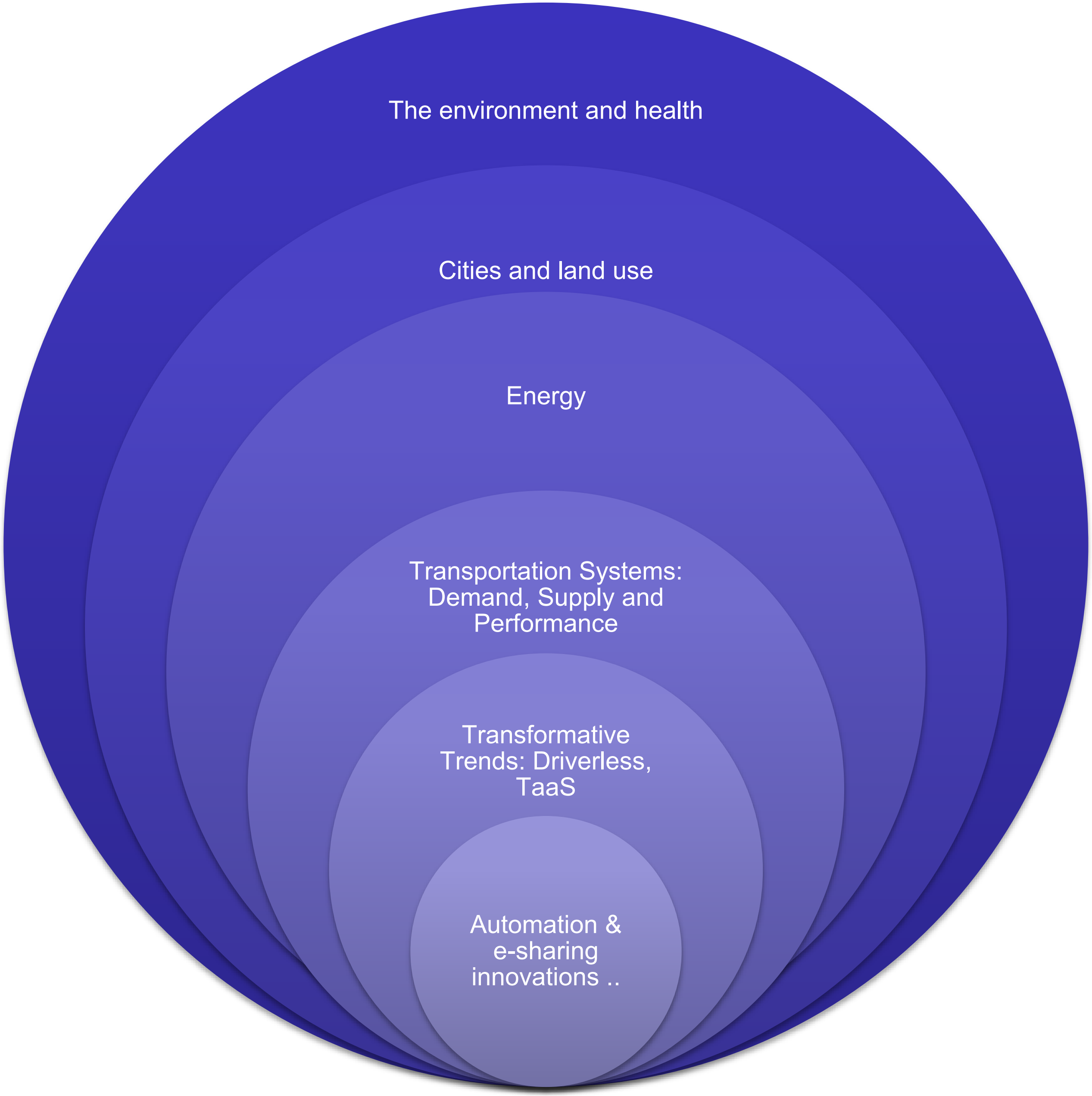
- Witnessing the making of a future of disruptive emergence of “high tech” transportation,
- Transformative technologies are changing transportation faster than we are able to understand, let along predict or manage,
- Bold vision for the future of transportation and cities, but equally high risks and potential for crises,
- **Need to develop quantitative tools to guide the evolution of our cities in the era of disruptive technologies,**
- Empower people and business, protect the environment, harness and maximize potential and minimize risks.

Credits: iCity-CATTS, B. Abdulhai

Societal Ripple Effects



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TaaS = transportation as a service

The Boldest Vision:
Automated, Green, Shared

But if unplanned, will
automation also mean healthy and sustainable?

How green are self-driving cars?

James Phillips
Monday, July 27, 2015 - 1:30am

Shutterstock / Julien Tromeur

Environmental impacts of self-driving cars are evolving as automakers and tech firms get the vehicles closer to market.

WILL SELF-DRIVING CARS REDUCE EMISSIONS?

Posted on April 18, 2018 by Katrina Kazda

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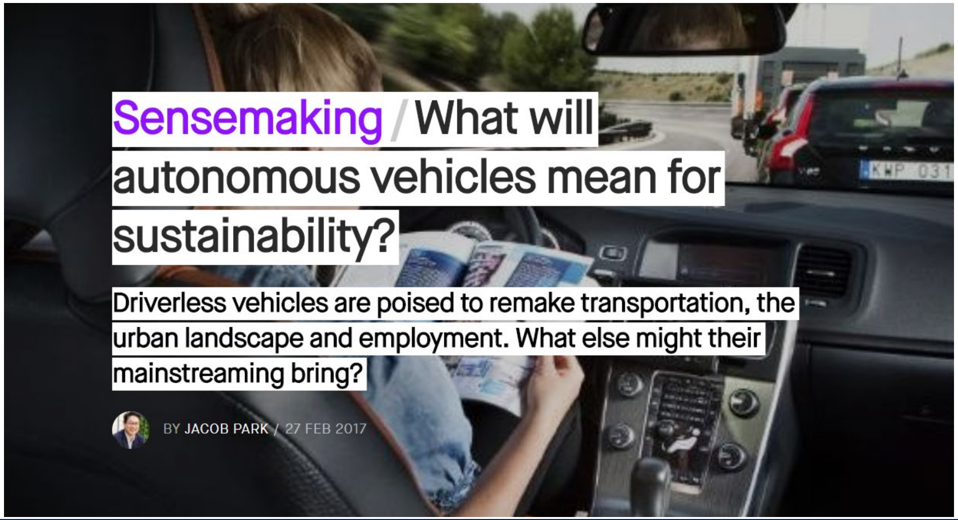
Audi's Aicon Concept autonomous, all-electric car has no steering wheel or pedals with a range of close to 500 miles per charge. Photo: Audi



Sensemaking / What will autonomous vehicles mean for sustainability?

Driverless vehicles are poised to remake transportation, the urban landscape and employment. What else might their mainstreaming bring?

BY JACOB PARK / 27 FEB 2017

ANTICIPATING THE IMPACTS OF CONNECTED AND AUTOMATED VEHICLES ON ENERGY CONSUMPTION, GHG EMISSIONS, AIR POLLUTION

Neighborhood effects

Regional effects

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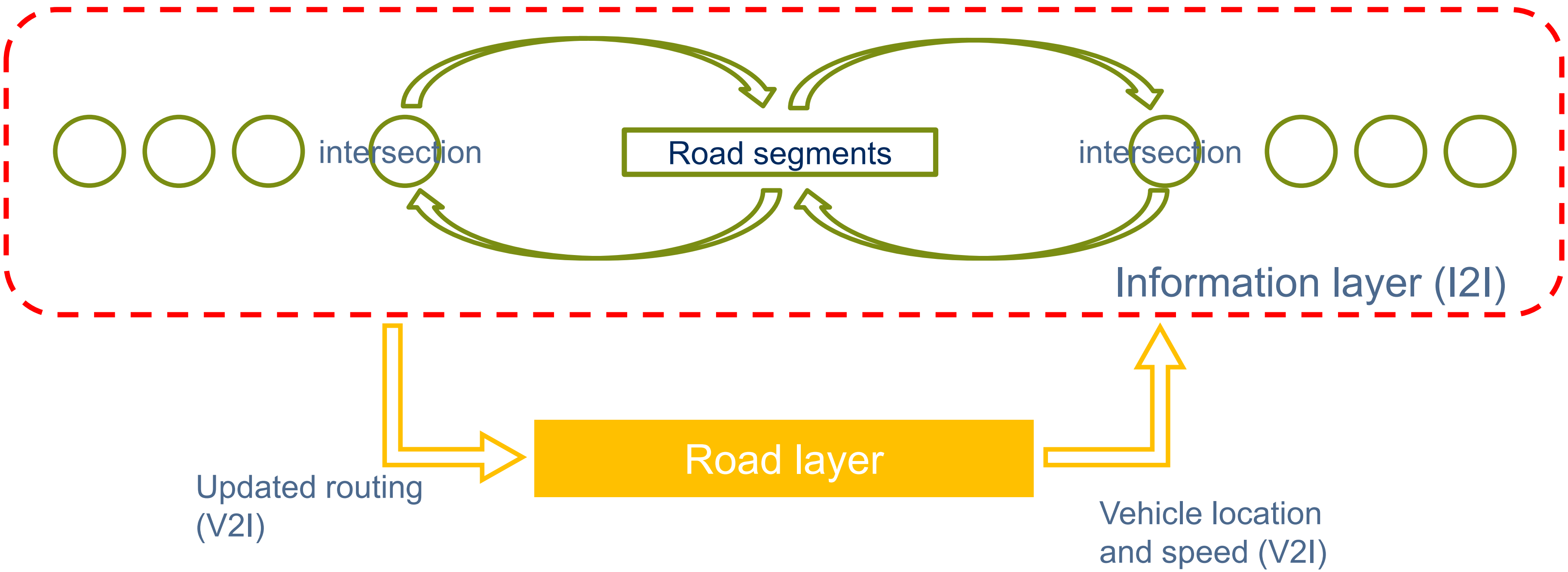
GHG = greenhouse gas

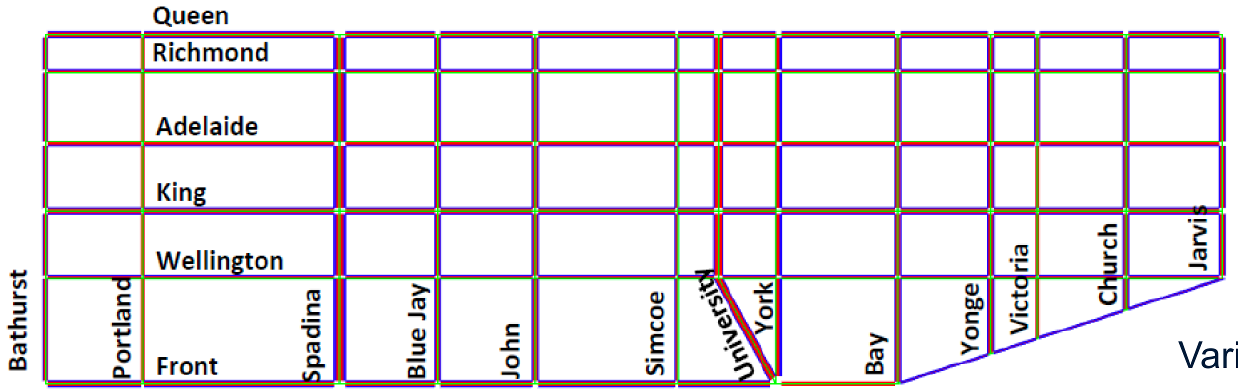
End-to-End (E2E) dynamic routing control with connected and autonomous vehicles (E2ECAV)

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	30% base demand
2	Low	0.05	E2ECAV+HDV	
3	Low	1	E2ECAV	
4	Medium (LOS2)	0	HDV	70% base demand
5	Medium	0.05	E2ECAV+HDV	
6	Medium	1	E2ECAV	
7	High (LOS3)	0	HDV	100% base demand
8	High	0.05	E2ECAV+HDV	
9	High	1	E2ECAV	
10	High	-	AV	

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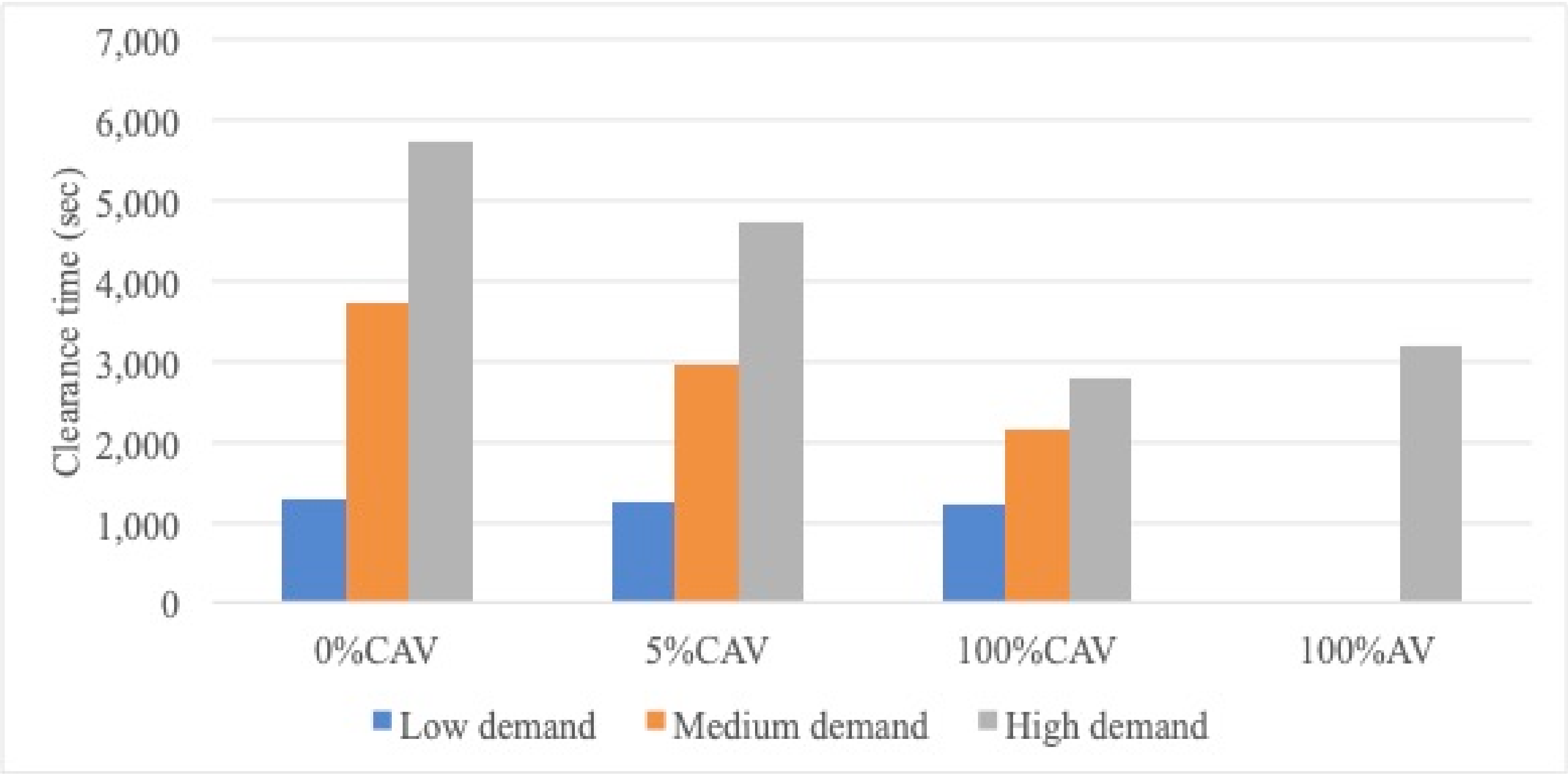
LOS = level of service
HDV = heavy-duty vehicles
E2ECAV = end-to-end connected autonomous vehicles
AV = autonomous vehicles

Traffic throughput increases



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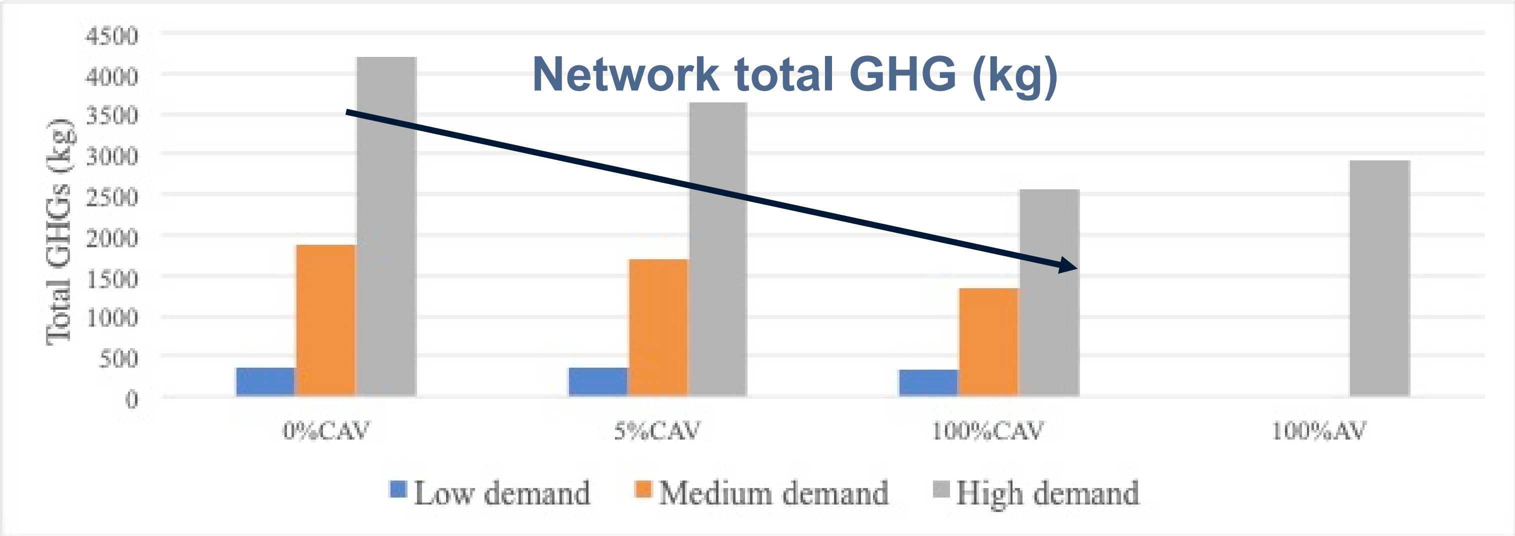
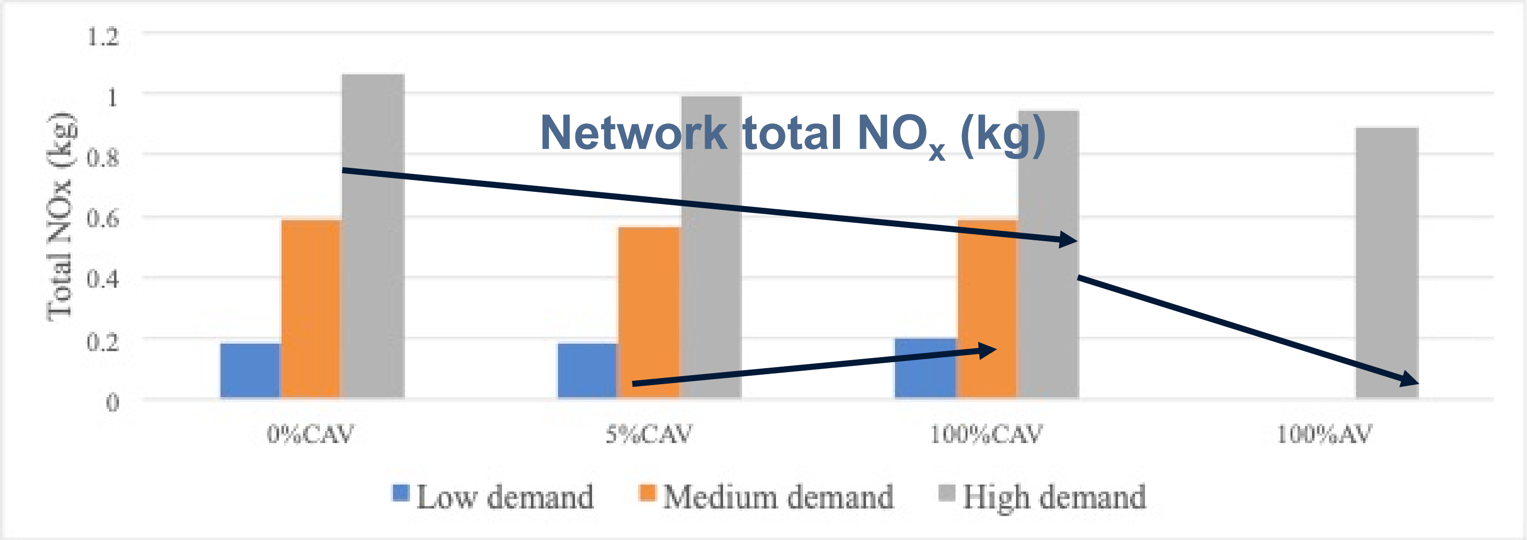
CAV = connected autonomous vehicles
AV = autonomous vehicles

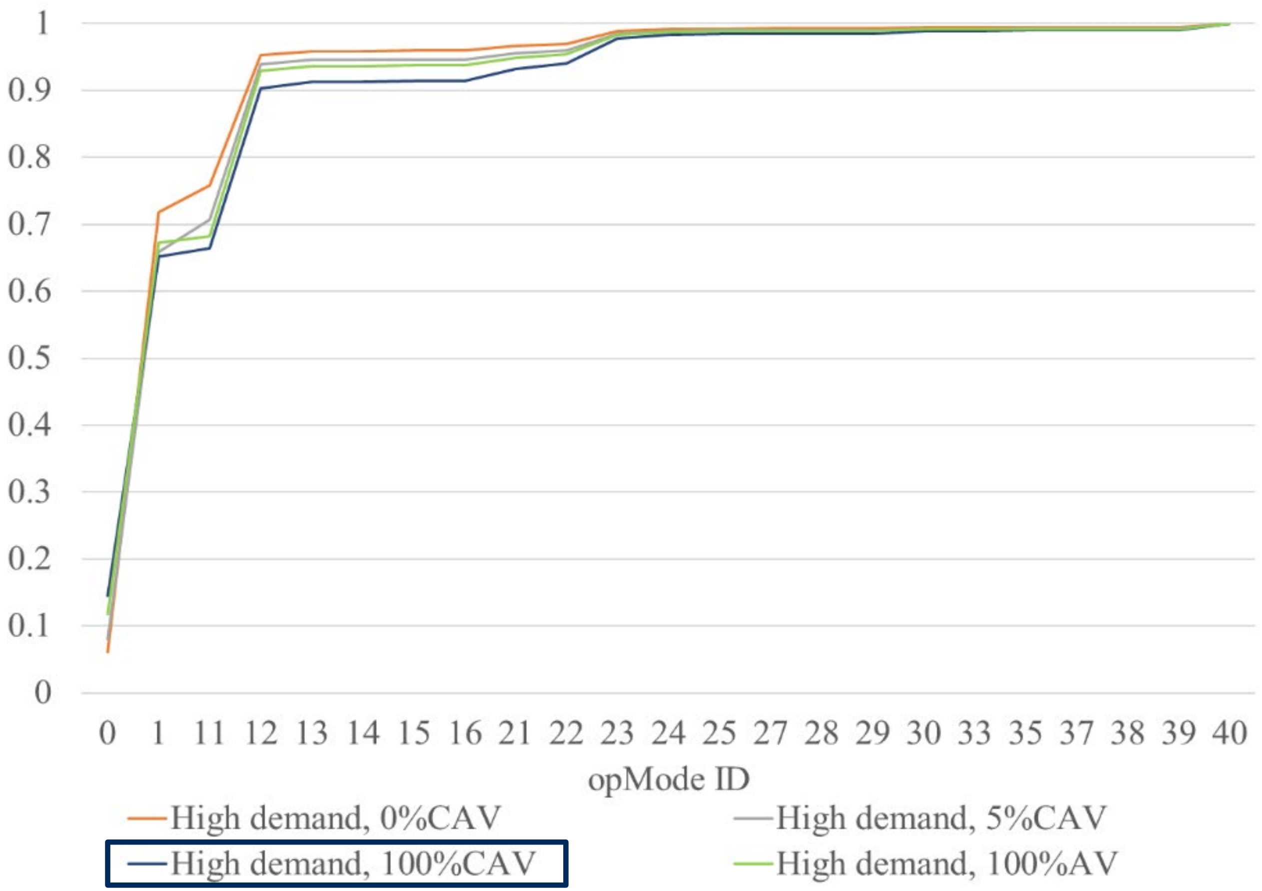
GHG emissions are reduced but reductions in NO_x emissions are minor





GHG = greenhouse gas
NO_x = oxides of nitrogen

Under the E2ECAV scenario, vehicles are spending more time at operating modes associated with higher emission rates



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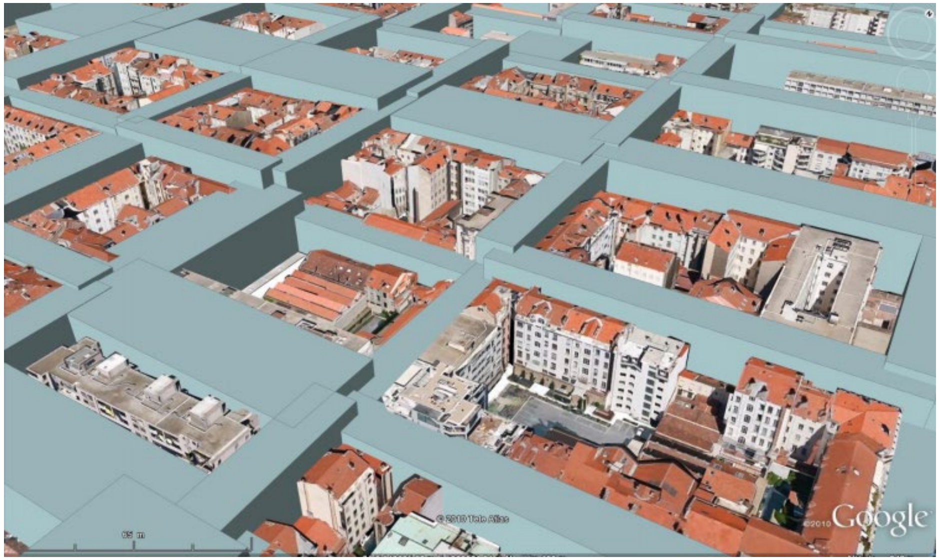
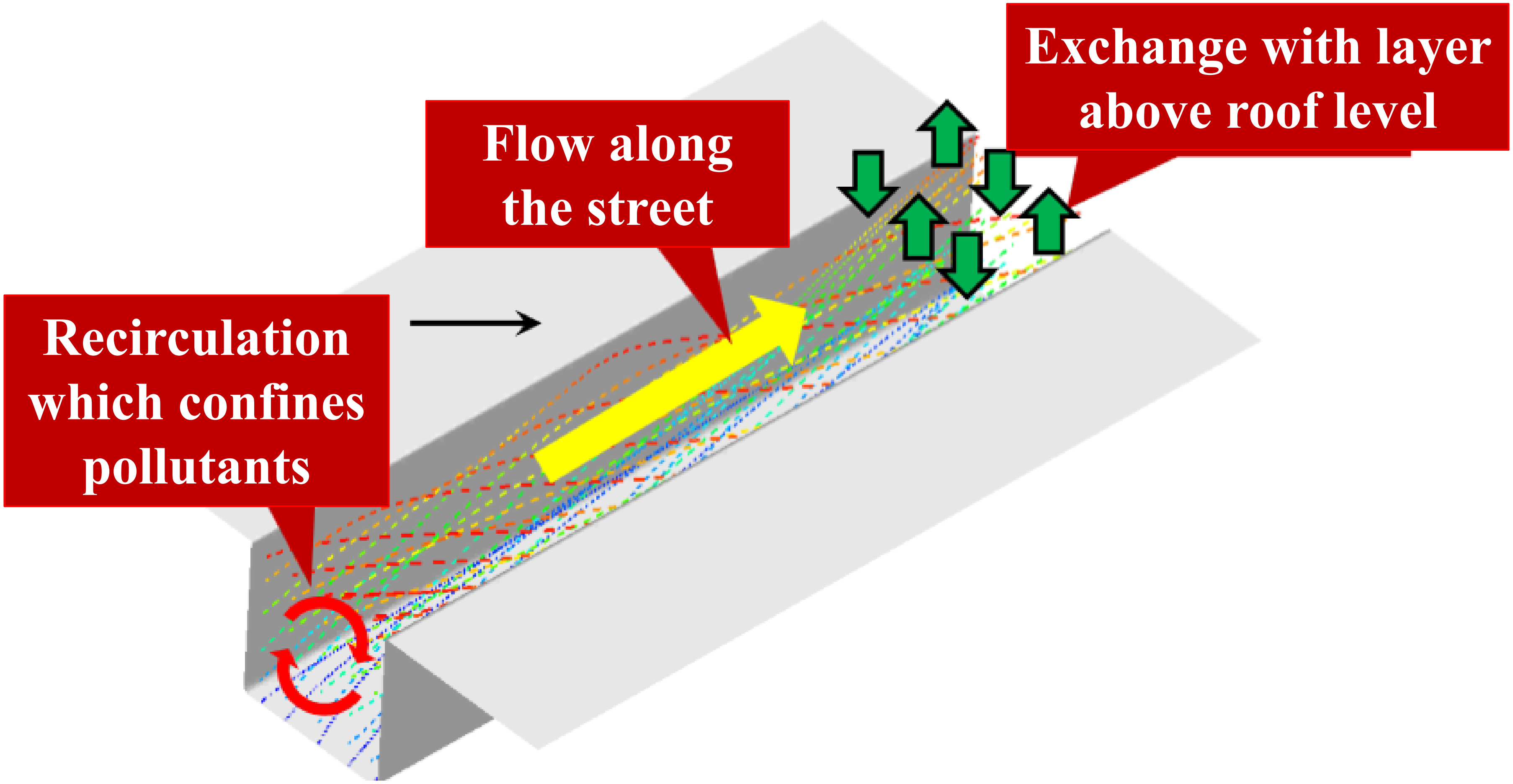
E2ECAV = end-to-end dynamic routing control with connected and autonomous vehicles

Dispersion modeling with a street canyon model: SIRANE

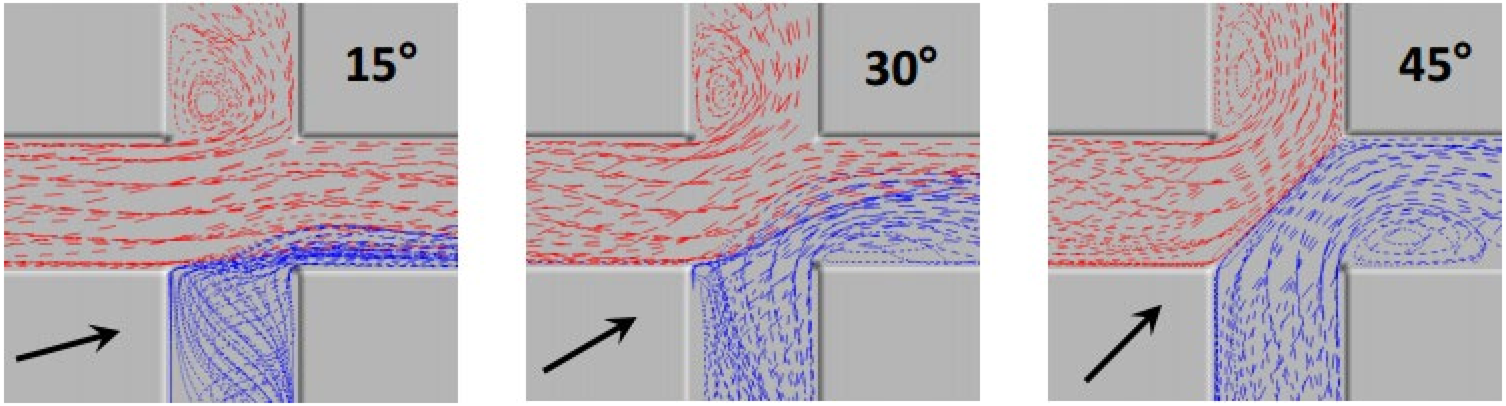


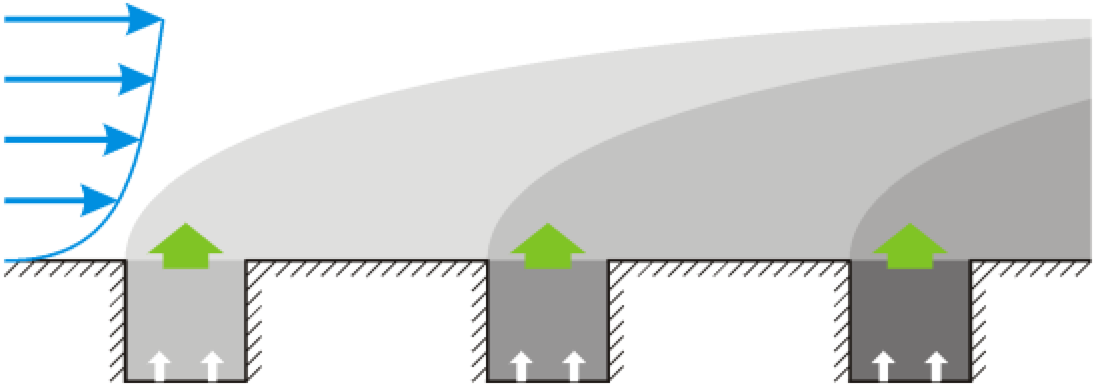
SIRANE



Exchange with layer above roof level
Flow along the street
Recirculation which confines pollutants

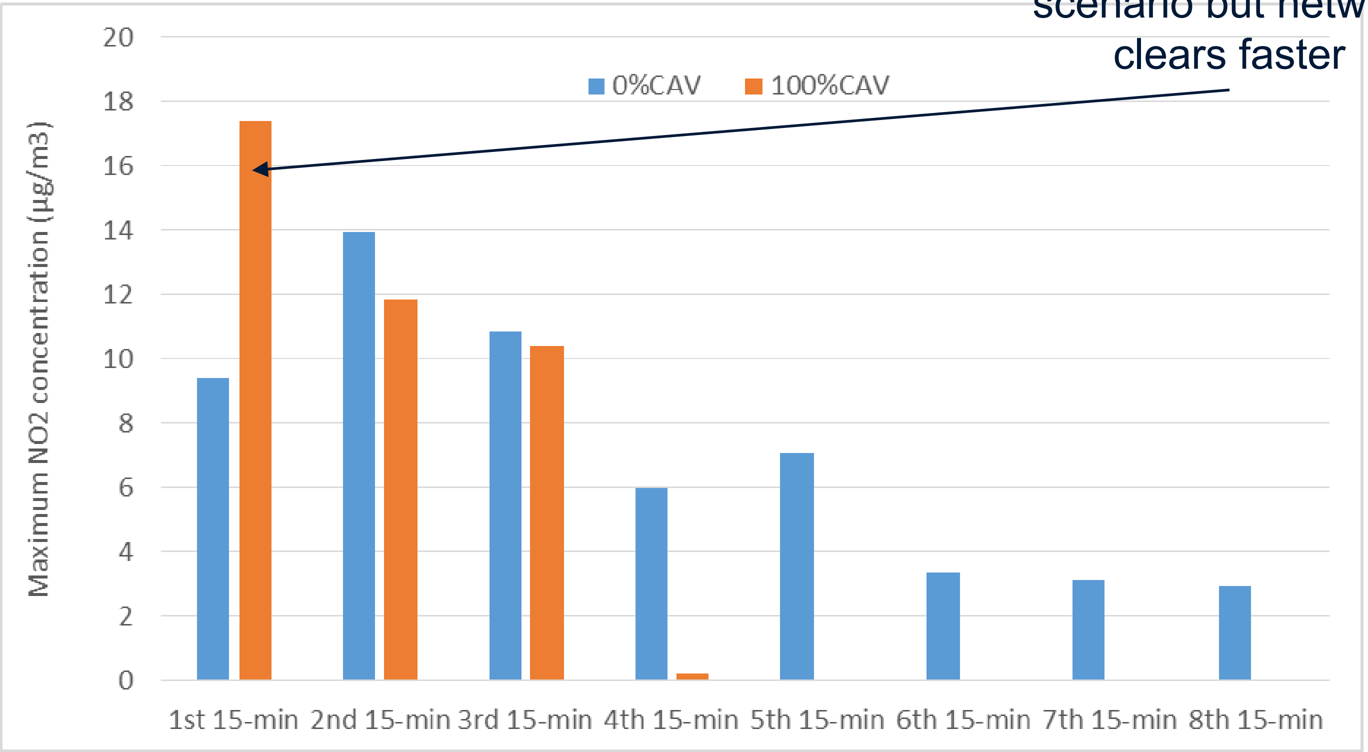
SIRANE





NO_2 concentrations across the network

Higher maxima in CAV scenario but network clears faster



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NO_2 = nitrogen dioxide
CAV = connected autonomous vehicles

Energy consumption under full electric vehicle (EV) environment

- Electric energy consumption model

  Electric power: $P_{electric}(t) = f(v(t), a(t))$

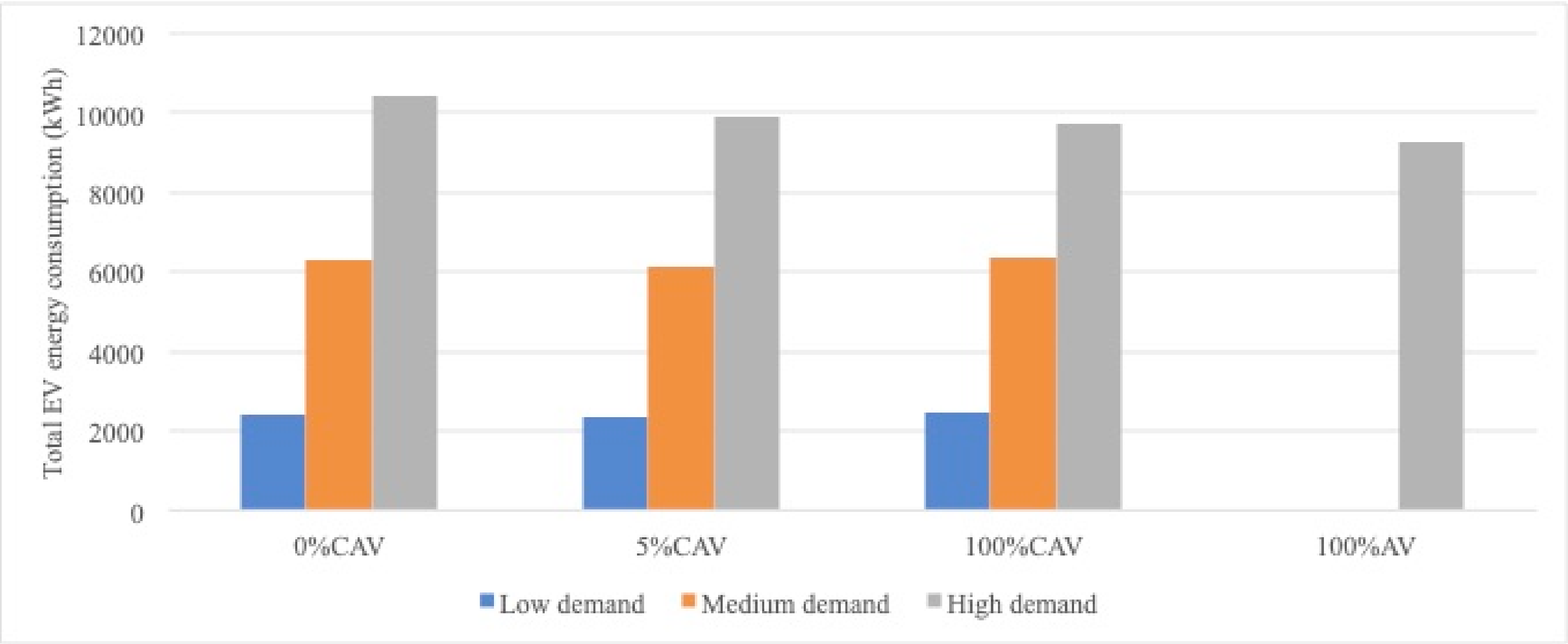
  Electric energy: $E_{electric} = \int P_{electric}(t)\, dt$

- Model calibration is based on the data from Downloadable Dynamometer Data (D3) collected by Argonne National Laboratory(*).

(*) Acknowledgement: The data used for the calibration of electric energy consumption model is from the Downloadable Dynamometer Database and was generated at the Advanced Mobility Technology Laboratory (AMTL) at Argonne National Laboratory under the funding and guidance of the U.S. Department of Energy (DOE).

P = power; *E* = energy;
v = velocity; *a* = acceleration

Energy consumption



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CAV = connected autonomous vehicle
AV = autonomous vehicle
EV = electric vehicle

This analysis does not include latent demand

Automated, electric, or both? Anticipating regional effects

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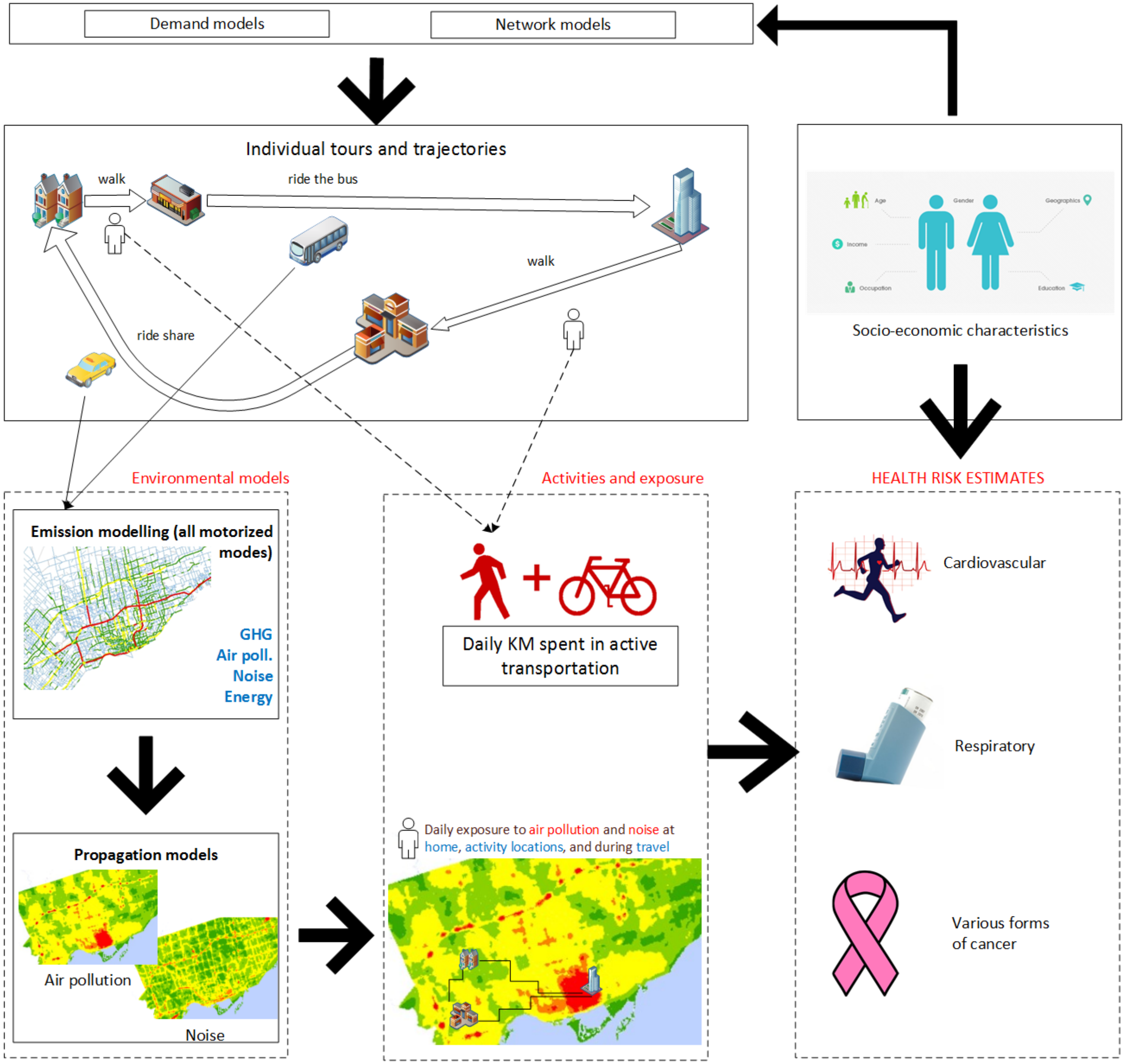
Demand models
Network models
Individual tours and trajectories
walk
ride the bus
walk
ride share
Socio-economic characteristics
Environmental models
Emission modelling (all motorized modes)
GHG
Air poll.
Noise
Energy
Propagation models
Air pollution
Noise
Activities and exposure
Daily KM spent in active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

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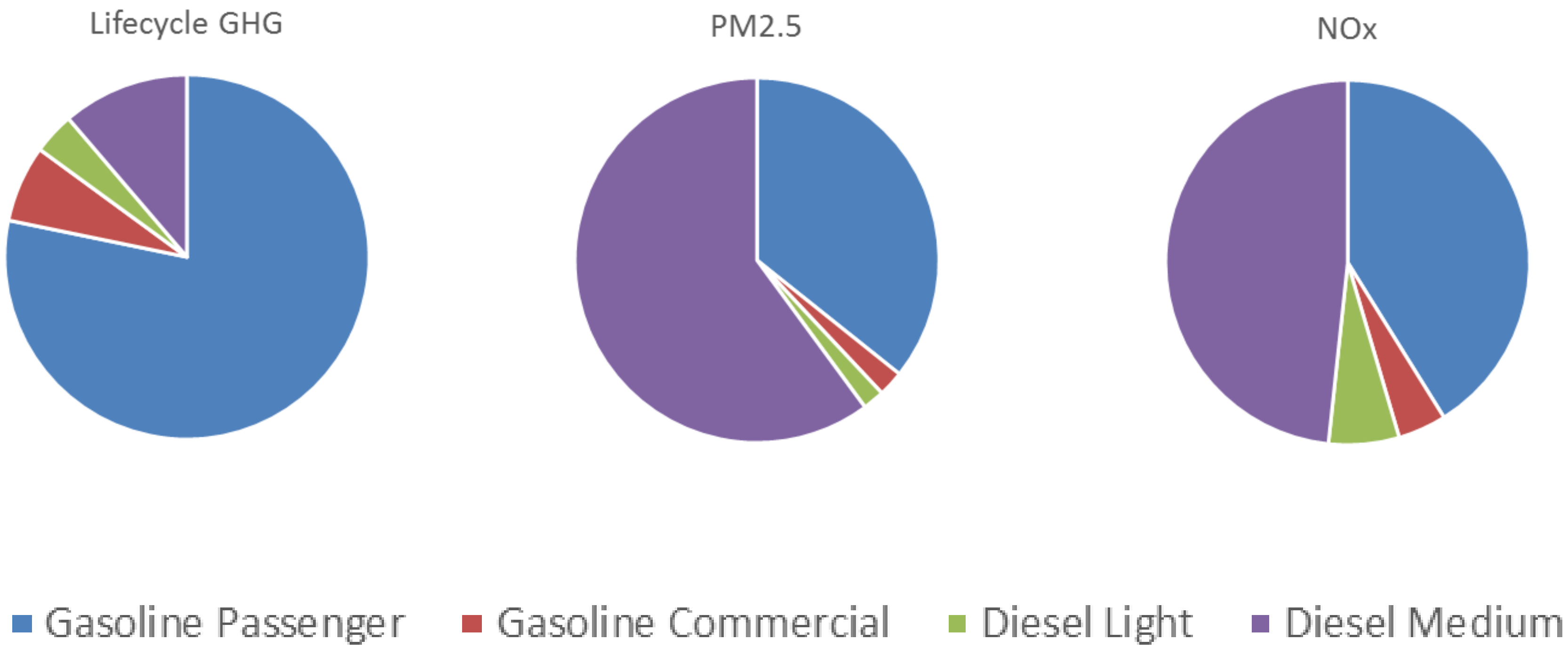
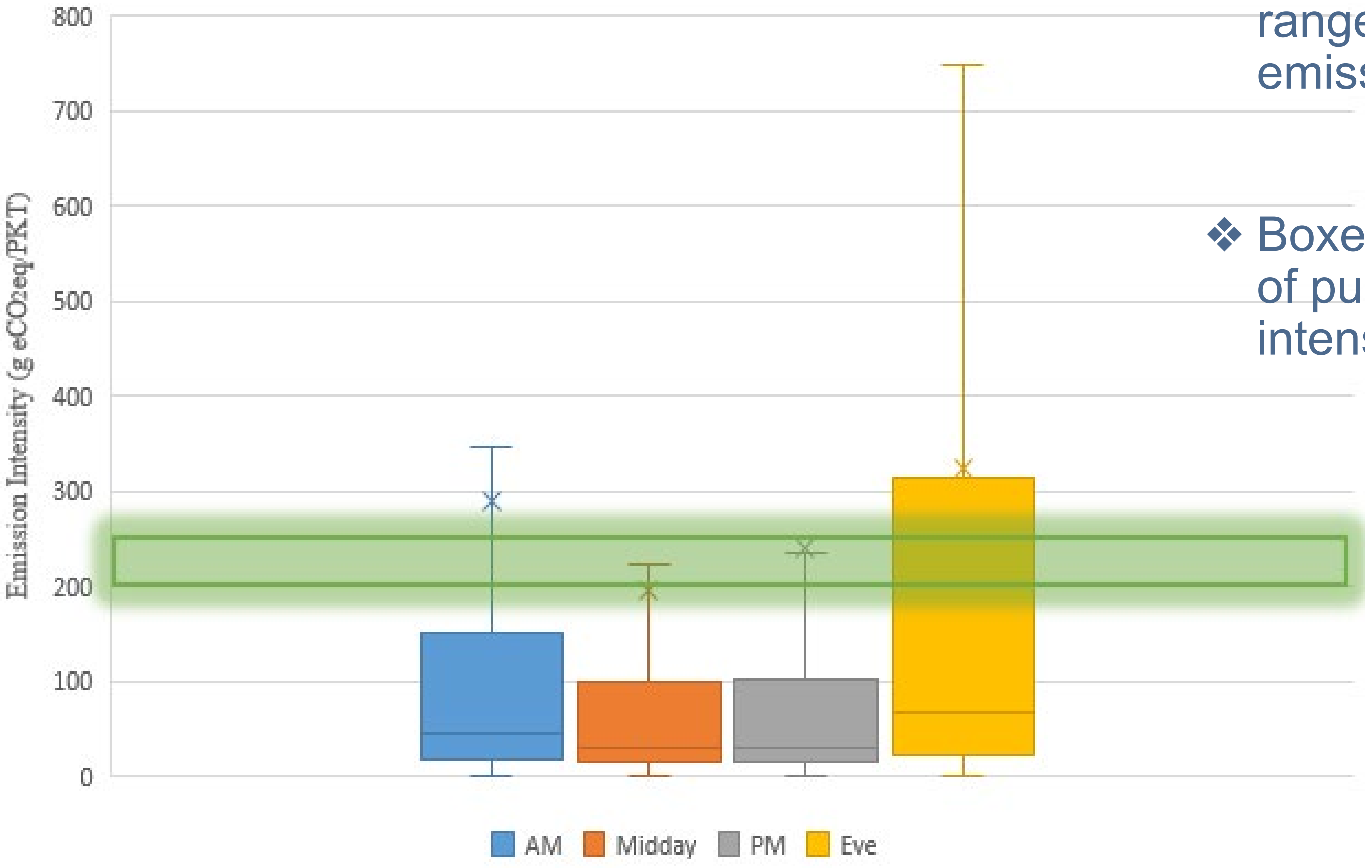
Distribution of transport emissions in the region



GHG = greenhouse gas
$PM_{2.5}$ = fine particulate matter
NO_x = oxides of nitrogen

Comparison with Public Transit



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

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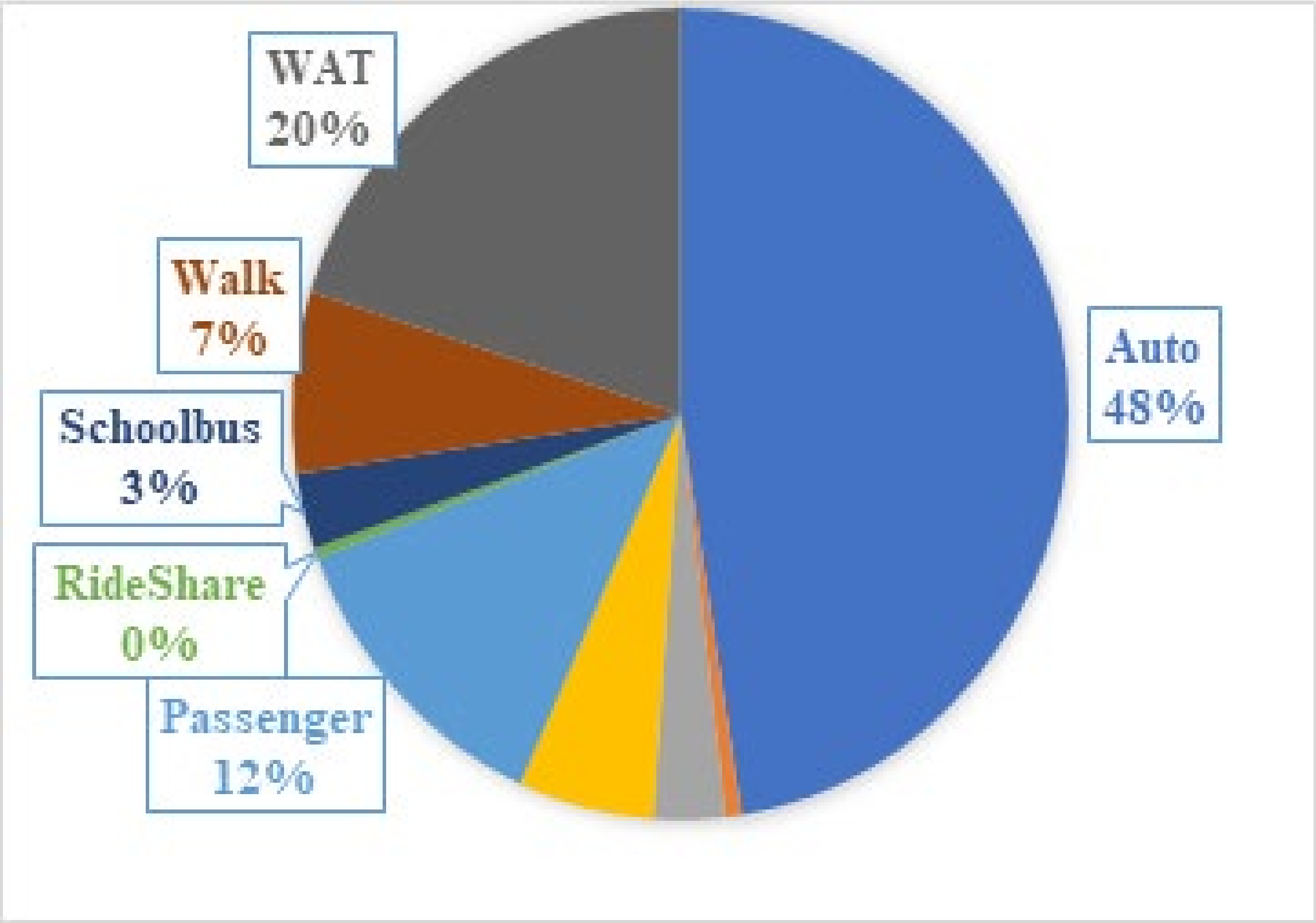
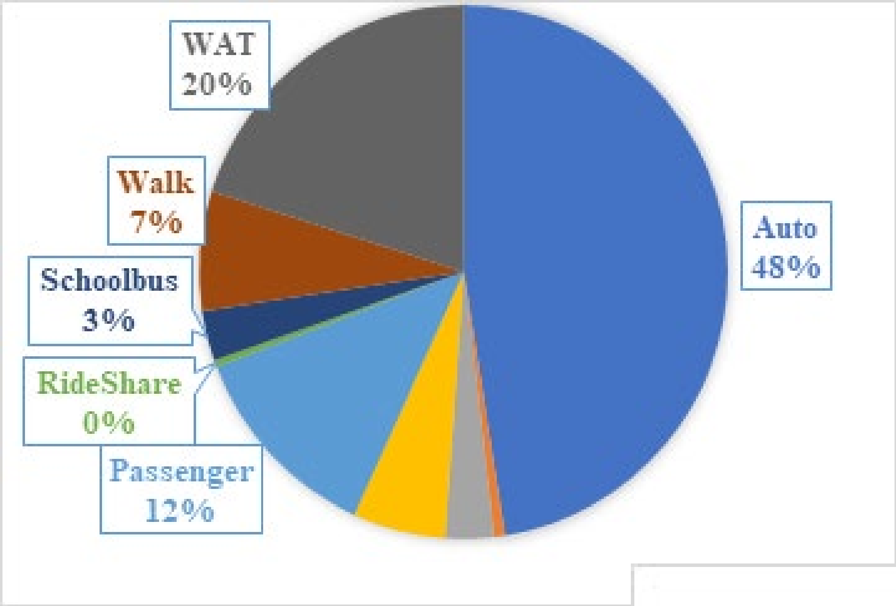
CO_2eq/PKT = carbon dioxide equivalent per passenger kilometer traveled

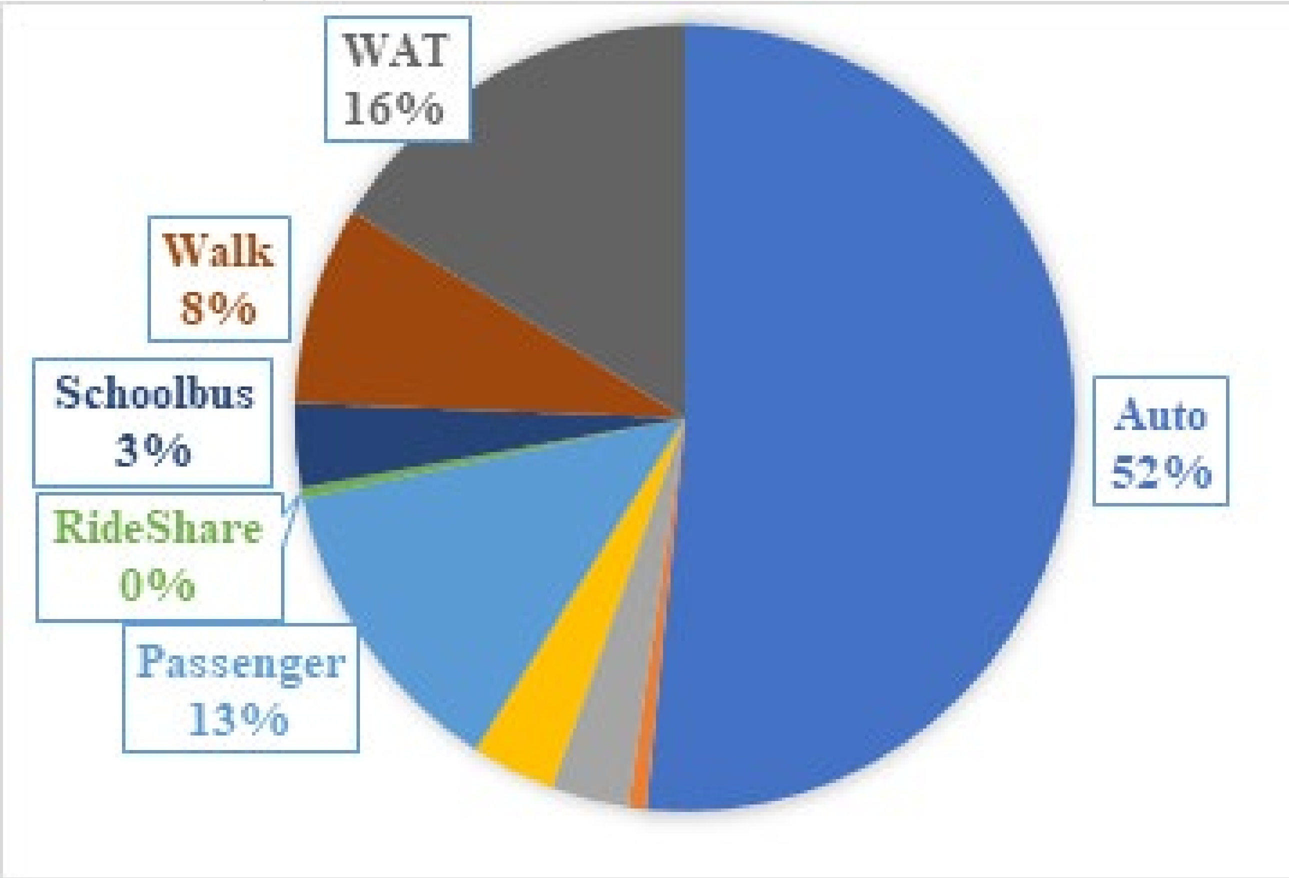
Modal Split – Base Case

WAT: Walk Access Transit



Modal Split – Autonomous vehicle (AV) adoption (15%)





WAT: Walk Access Transit

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Lifecycle GHG emissions of passenger travel if AVs were EVs

The additional electricity needed to support new EVs is supplied by current mix

Scenarios	Efficiency	Fuel Options	Lifecycle Emissions (tonne)	VKT (millions)	Emission Intensity (g CO_2eq/PKT)
A0 (Base Case)	1	Gasoline	36,200	112	282
A1	0.5	Gasoline	37,000	118	273
A2.1		Electric AV Mix1	33,900	118	250
A2.2		Electric AV Mix2	37,200	118	275
A2.3		Electric AV Mix3	34,600	118	255
A2.4		Electric AV Mix4	33,600	118	248
B1	0.9	Gasoline	36,800	116	276
B2.1		Electric AV Mix1	33,700	116	253
B2.2		Electric AV Mix2	36,900	116	277
B2.3		Electric AV Mix3	34,400	116	258
B2.4		Electric AV Mix4	33,500	116	251

The additional electricity needed to support new EVs is supplied by Natural Gas

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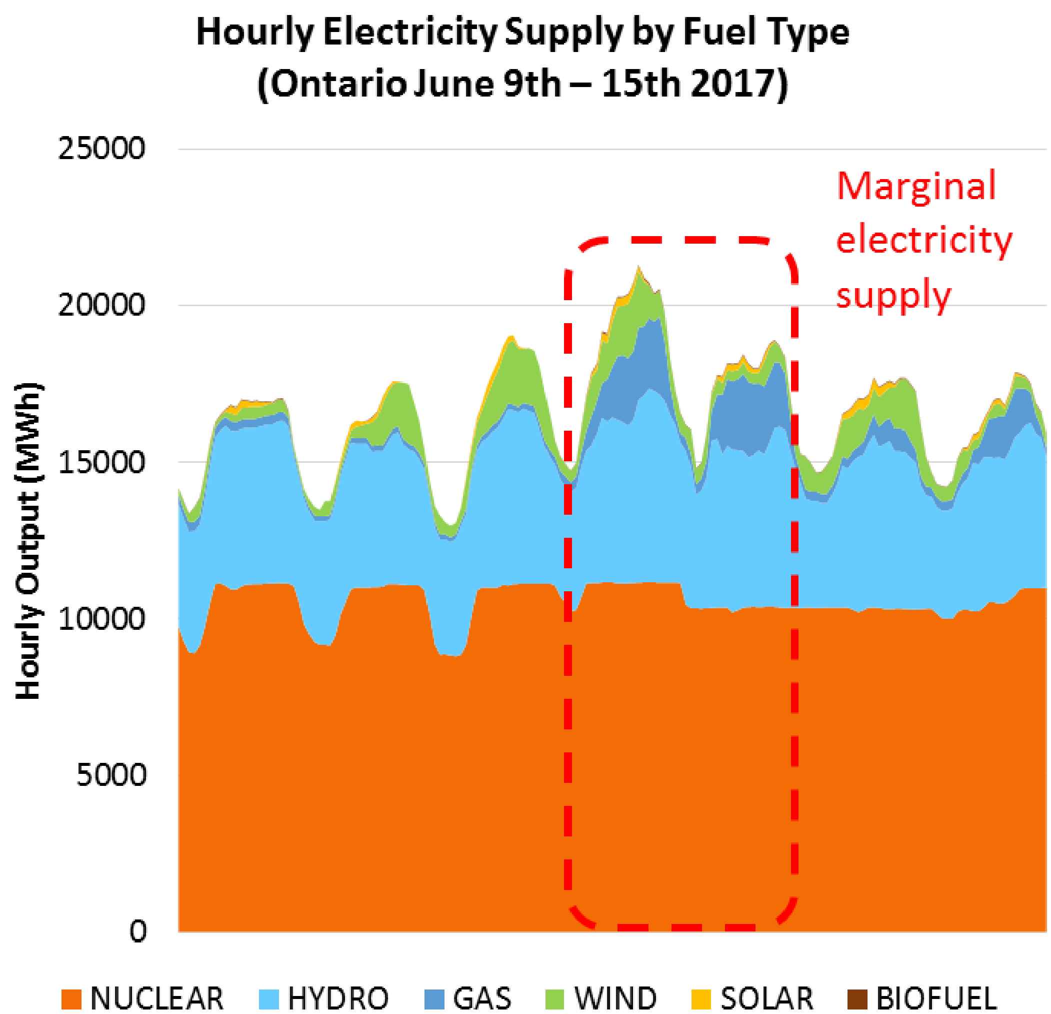
GHG = greenhouse gas; AVs = autonomous vehicles ; EVs = electric vehicles; VKT = vehicle kilometers traveled; CO_2eq/PKT = carbon dioxide equivalent per passenger kilometer traveled

ELECTRIC VEHICLE (EV) CHARGING PATTERNS CAN AFFECT GHG EMISSIONS

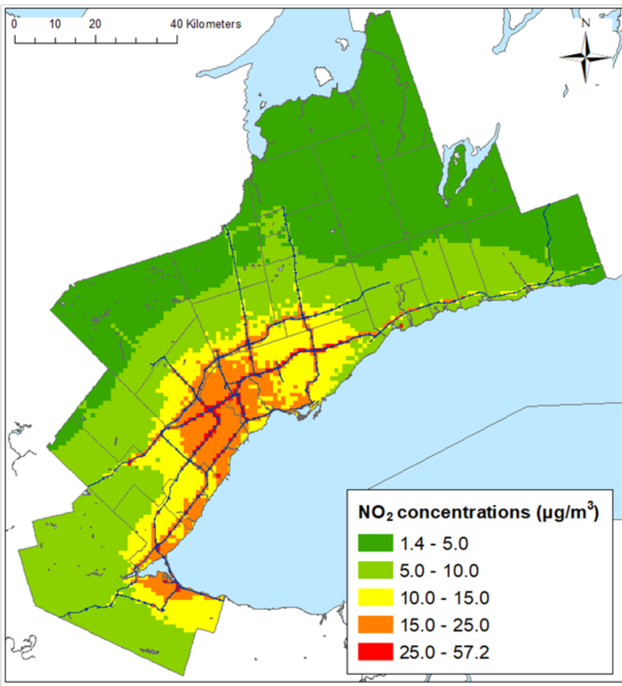
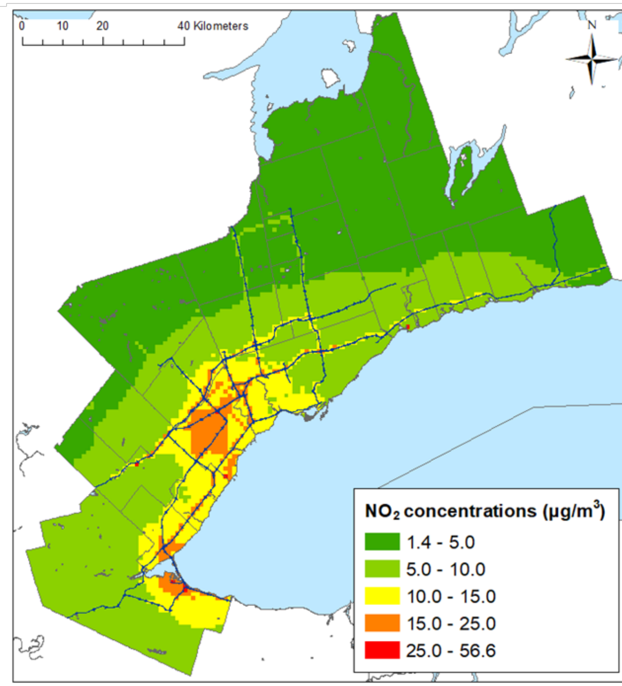
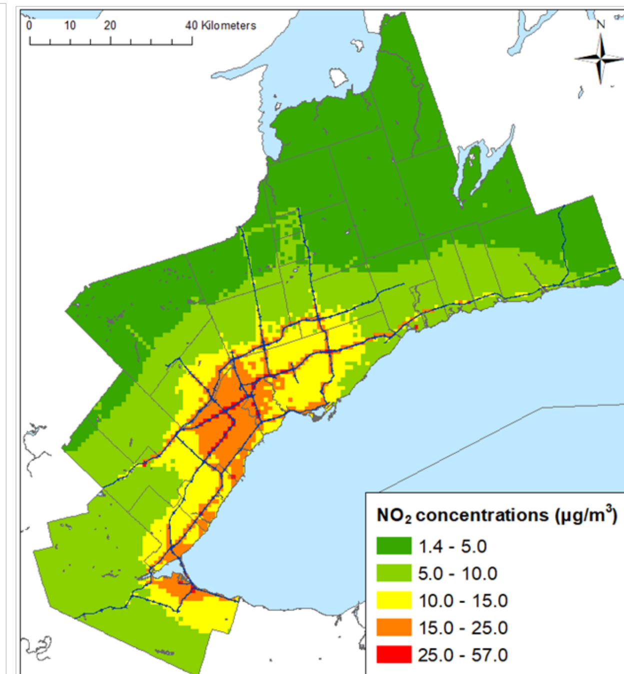
Introducing Marginal Emission Factors (MEF) for electricity production

GHG = greenhouse gas

Marginal Emissions of Electricity Generation



NO_2 concentrations generated by a chemical transport model – assuming all additional electricity production by natural gas

Base Case	100% EV	25% EV
		

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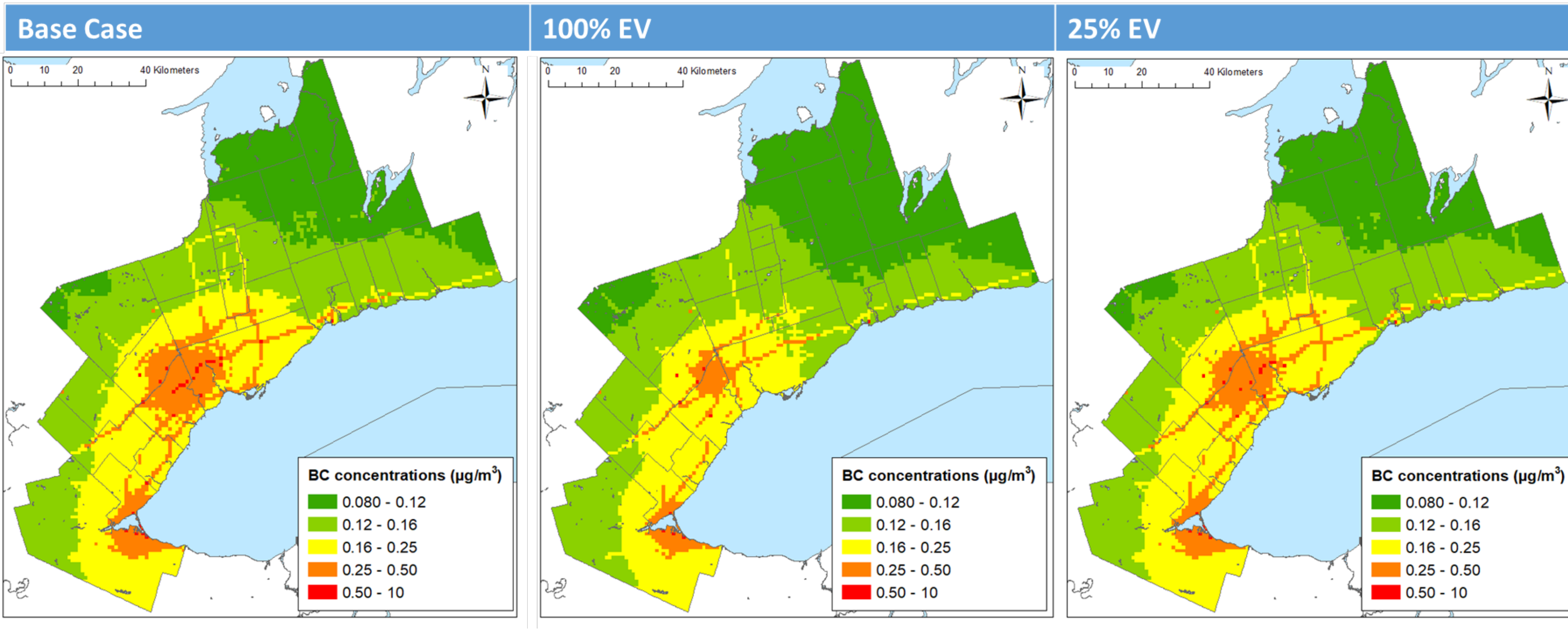
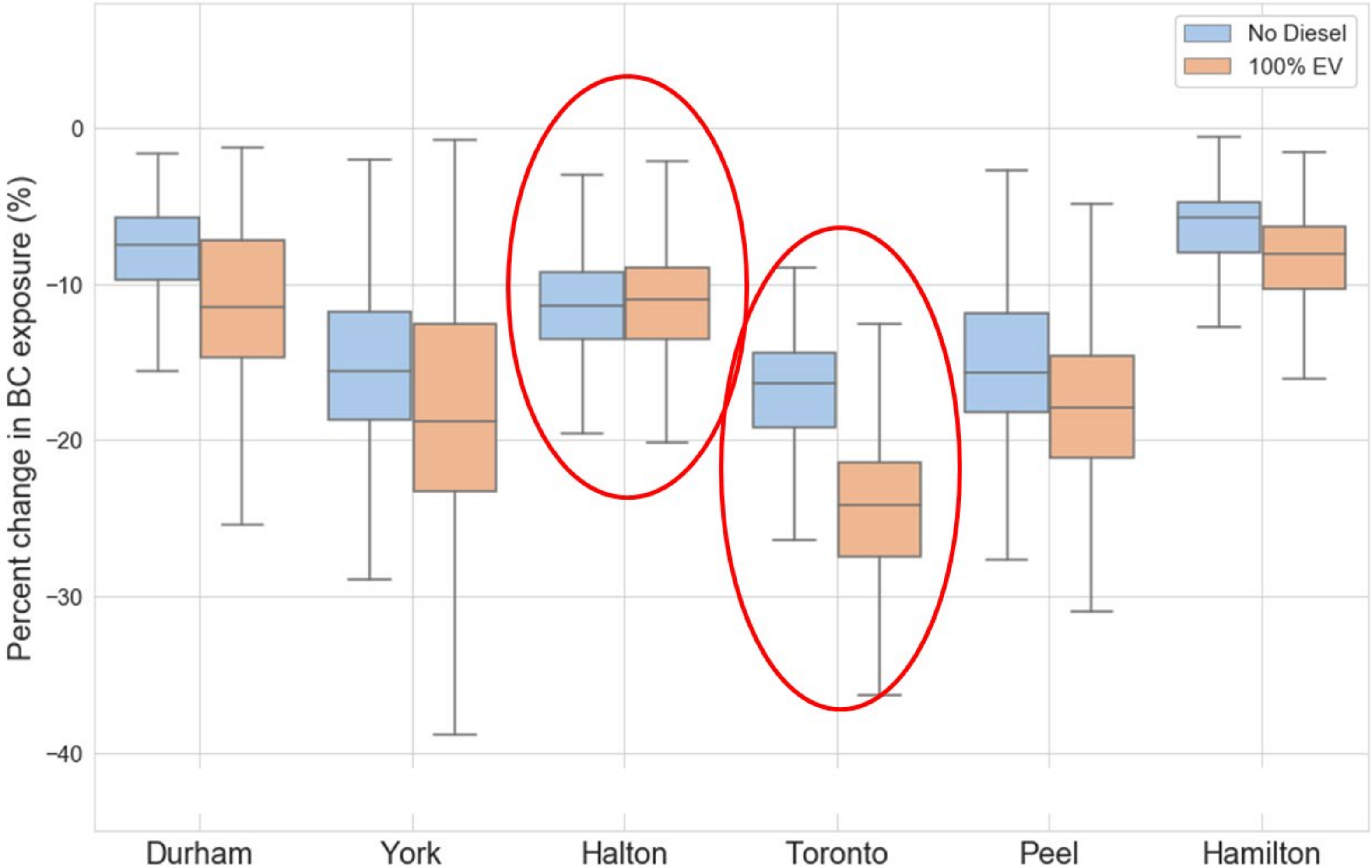
NO_2 = nitrogen dioxide
EV = electric vehicles

Black carbon (BC) concentrations generated by a chemical transport model – assuming all additional electricity production by natural gas



EV = electric vehicles

Comparison with electrification of heavy-duty diesel vehicles – exposure



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BC = black carbon
EV = electric vehicles

Fundamental Dilemma

- Travelers face new choices
- Users will do what is best for them even if detrimental to the system

- Policy makers, planners, operators, engineers and researchers must mind the user but must also mind the system

- **What is our vision for the city we want to live in?**