Clearing the Air

How electric vehicles and cleaner trucks can reduce pollution, improve health and save lives in the Greater Toronto and Hamilton Area

STAKEHOLDER REPORT

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Glossary of terms

Commercial vehicles: Short and long-haul vehicles (e.g. trucks used for freight) and light commercial vehicles (e.g. small vans, delivery trucks).

Electric Vehicle (EV): A vehicle powered by electricity which produces no tailpipe emissions.

Greenhouse gas (GHG) emissions: Climate change is caused by the increase in concentrations of greenhouse gases in the atmosphere, which include carbon dioxide (CO_2), methane, nitrous oxide, and other gases.[1] Our modelling took into account vehicle exhaust emissions and upstream emissions from fuel production, but not emissions from vehicle manufacturing or decommissioning.

GTHA: Greater Toronto and Hamilton Area, including Halton, Peel, York and Durham regions, and the cities of Toronto and Hamilton.

Passenger vehicle: A motor vehicle designed to carry people on highways and streets, carrying up to 9 passengers. Includes most cars, and SUVs.

Social benefits: We calculated social benefits using a measure known as the Value of Statistical Life (VSL). This represents how much people are willing to pay to reduce their risk of death. For instance, it can include the wage premium required to attract employees to do dangerous work, or the willingness to pay for improved vehicle safety features. The VSL captures the value of reduced risk of premature death, but does not include health care costs. As vehicle electrification will lead to both health and social benefits, the economic valuation of electrification is even greater than the social benefit amounts calculated for this report.

Traffic-related air pollution (TRAP): Air pollution emitted from on-road vehicles like cars, SUVs, trucks, buses, and motorcycles.

Zero-emissions vehicle (ZEV): A vehicle with the potential to produce no tailpipe emissions, including vehicles powered by electricity and hydrogen.[2]

Introduction

Policies on climate change and air pollution are often considered separately, but are linked with a common goal. Both aim to prevent harmful impacts from polluting emissions released into the air, and ultimately improve human health and well-being. But our reliance on fossil fuel powered transportation in Canada is working against this goal and harming our health.

In many parts of the country, transportation is the most significant source of air pollution. Our vehicles are pumping toxic air pollutants such as nitrogen oxides (NO_x) and fine particulate matter ($PM_{2.5}$) into the atmosphere. Exposure to this traffic-related air pollution (TRAP) is a major contributor to illness and premature death. With 14,600 annual deaths in Canada attributed to air pollution, and about a third of Canadians living in areas with high exposure to traffic-related air pollution, this is a serious public health concern. Transportation is also a significant source of greenhouse gas (GHG) emissions in Canada, second only to the oil and gas sector.[3]

We can build a better transportation system that will achieve both immediate health benefits and a healthier future. A sustainable transportation system needs to include many solutions - ones that get us out of cars and onto public transit, bikes, and walking, solutions like working from home which leads to less travel overall, and solutions that reduce emissions from vehicles on the road. There will always be people who need to use vehicles to move goods or to travel longer distances, or who live in rural and remote areas where private vehicles are their only option. We need solutions that will ensure that these vehicles are cleaner and greener, thereby reducing air pollution-related illness and death, and reducing GHGs that contribute to climate change.

A substantial body of research has focused on electric vehicles and their potential to reduce GHG emissions to fight climate change. But GHGs are not the only emissions coming from tailpipes, even if they've factored more heavily in policy decisions on electrifying vehicles. There are significant health benefits of reducing vehicle emissions of air pollutants like NO_x and $PM_{2.5}$, meaning actions to reduce traffic-related air pollution will save lives today, as well as save future lives from the impacts of climate change.

Governments at all levels are at a defining moment, deciding how much funding and ambition to devote to protecting us from vehicle emissions. They're deciding on electric vehicle strategies, reforming decades-old environmental legislation like the Canadian Environmental Protection Act (CEPA), deciding how many electric vehicle charging stations to build, and how to improve fuel efficiency regulations for cars and trucks.

As they make these crucial decisions, governments must consider the impacts of both air pollution and GHG emissions. Examining these problems in isolation leaves critical information off the table. This report provides evidence to support clean vehicle policies that integrate both health and climate considerations, ensuring all of society has access to the health benefits of cleaner transportation, now and in the future.

Executive Summary

People in the Greater Toronto Hamilton Area (GTHA) use vehicles every day to travel to work, go to school, move goods, and perform many other tasks. This vehicle travel emits air pollution that contributes to illness and premature deaths, and GHG emissions that are responsible for climate change.

In the GTHA, air pollution causes more than 3,000 premature deaths every year[4]. A 2014 report estimated that traffic-related air pollution was responsible for approximately 700 premature deaths and over 2,800 annual hospitalizations due to heart and lung conditions in the GTHA each year with an economic impact of over $4.6 billion per year.[5] Older adults, young children, and people with existing heart or lung conditions or with diabetes, are more susceptible to the harmful impacts of these air pollutants. Those who are active outdoors and people who live near industrial pollution or high traffic corridors have a greater exposure to air pollution.[6] The impacts are also worse for those who contribute the least to traffic-related air pollution, with public transit riders, cyclists, and pedestrians exposed to higher levels of air pollution than drivers of the vehicles that cause the pollution.[7]

There is a substantial body of evidence linking exposure to traffic-related air pollution with a wide range of adverse health outcomes including exacerbation and onset of asthma, cardiovascular illness and death, impaired lung function and lung cancer.[8] This evidence, along with the fact that a significant proportion of the GTHA population lives in close proximity to high traffic corridors,[9] amplifies the need for policies to reduce exposure to traffic-related air pollution (TRAP).

Our research goal for this project was to investigate and understand the impacts of more ambitious action to get cleaner vehicles on the road in communities throughout the GTHA. Researchers at the University of Toronto modelled five different clean vehicle scenarios (plus a base case of current conditions) to compare the health, social and climate change benefits that could result from reducing traffic pollution from cars and SUVs, trucks, and public transit buses.

The scenarios we modelled are as follows:

- Base Case – current emissions (calculated with 2016 data)
- 20 per cent of cars (private passenger vehicles including SUVs) are fully electric (EVs)
- 50 per cent of cars (private passenger vehicles including SUVs) are fully electric (EVs)
- 100 per cent of cars (private passenger vehicles including SUVs) are fully electric (EVs)
- 100 per cent of public transit buses in the GTHA are fully electric
- All trucks (commercial vehicles, delivery vehicles) are replaced with newer, more efficient models meeting at least 2008 technology standards

The modelling reveals that switching to electric cars and SUVs, electric public transit buses, and more efficient trucks will dramatically reduce traffic-related air pollution. This improvement in air quality would lead to cleaner air and health benefits for residents, preventing hundreds of premature deaths and providing billions in social benefits every year.

For example, our modelling shows that a shift to electric cars and SUVs (EVs) in the GTHA would prevent 313 premature deaths per year and provide $2.4 billion per year in social benefits, while newer, cleaner trucks would prevent 275 premature deaths annually and provide $2.1 billion per year in social benefits. Electrifying all public transit buses would prevent 143 premature deaths per year and provide $1.1 billion per year in social benefits.

In a scenario where all cars and SUVs are electric, a single EV replacing a gas-powered car brings $9,850 in social benefits shared by everyone, not just EV buyers. This valuation does not include health care costs, so the true benefits are likely much higher. This justifies significant spending to quickly electrify vehicles on our roads.

The health and social benefits are on top of the climate change benefits that come with reducing nearly 8 mega tonnes of GHG emissions per year, if all cars, SUVs, and public transit buses were electric. This is equivalent to the output of two coal plants,[10] or about half of the reductions needed to meet Ontario's 2030 carbon emissions reduction targets.

As governments take unprecedented action to address the COVID-19 pandemic, improving air quality may minimize the risk of experiencing severe consequences of infectious diseases such as COVID-19 that disproportionately impact those with underlying medical conditions like heart disease, respiratory diseases and cancer. Recent studies on this issue suggest that long-term exposure to air pollution increases the likelihood of experiencing the most severe COVID-19 outcomes.[11,12]

Cleaner vehicles lead to a significantly healthier population, and one that is economically better off. The benefits will be broadly felt by all GTHA residents, but are even greater for those who live closest to major roads and highways and thus experience the greatest residential exposure to traffic-related air pollution. Preventative approaches help to reduce the burden on our healthcare system and create healthier, more equitable communities. In short, the research makes a compelling case for action to improve health outcomes, one we hope policy makers act on quickly and decisively.

To achieve these positive health outcomes we have recommended stronger policies that governments can implement to reduce air pollution and carbon emissions from vehicles. These policies will save lives by improving respiratory and cardiovascular health, and mitigating future climate-related health risks. They include:

Electrifying passenger vehicles:

- **Zero-emission vehicle (ZEV) sales mandates for cars and SUVs:** A ZEV sales mandate requires that automakers ensure a rising percentage of their car sales are electric by specific dates (British Columbia and Quebec currently have them). This places the onus on automakers to ensure that ZEVs are widely available to consumers, and that promotional dollars are behind them.
- **Zero-emission vehicle (ZEV) purchase incentives:** Offering temporary incentives will help make ZEVs more affordable until they drop to a similar up-front price as gas-powered vehicles.
- **Investments in EV charging infrastructure:** Ensuring drivers have access to charging stations is key to accommodating EV growth.
- **Stronger fuel efficiency regulations for cars:** Current federal rules mean that automakers must achieve progressively more stringent annual fleet average GHG emission standards. This encourages them to produce and sell cleaner cars like EVs. Canada's standards are now tied to the U.S., but the U.S. plans to roll back their standards. Canada must maintain our stringent standards to incent increased ZEV deployment and help meet our climate targets.

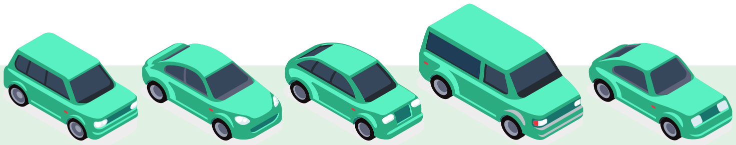
Electrifying public transit buses:

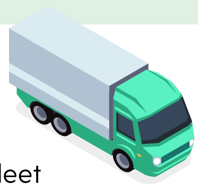
- **Commitments from public transit providers to purchase exclusively electric buses:** Some public transit authorities (for example, Toronto and Montreal) have already committed to bus electrification, and most have begun integrating electric buses.
- **Federal and provincial funding programs to support a transition to electric public transit buses:** The cost of electric buses means that transit providers would need funding support from other governments to achieve full bus electrification. This also presents an opportunity to support Canadian electric bus manufacturers.

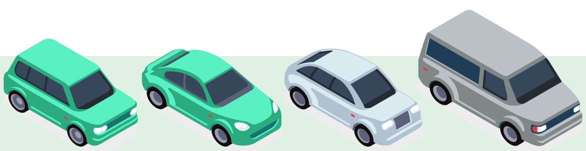
Getting cleaner trucks on the road:

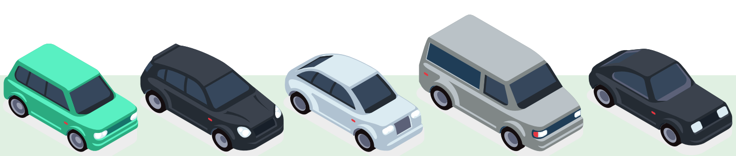
- **Truck scrappage programs:** This program would allow fleet or vehicle owners to “cash in” older, more polluting trucks and get financial help buying newer, more efficient (or electric) trucks which cost more.
- **Low Emission Zones:** In high-pollution areas with dense populations, cities or regions could restrict the most polluting vehicles from entering certain areas. More than 250 cities in the European Union have already adopted such measures, resulting in significant air pollution and GHG reduction benefits for their residents.
- **Maintain stringent fuel efficiency regulations for trucks:** Like fuel efficiency rules for cars, current federal regulations for heavy trucks require increasingly stringent GHG emission standards for new / trucks. The more stringent regulations for trucks are still in play in the U.S., but Canada needs to separate our standards to avoid a similar weakening process to regulations for cars.
- **Green commercial vehicle incentive programs:** Rebates would be available to companies who adopt electric, renewable natural gas, or natural gas-powered trucks, and devices to retrofit existing trucks.

Comparing Vehicle Pollution Scenarios in the GTHA









SOLUTION & HOW WE GET THERE	Health impact: Mortalities prevented/yr	Cost impact: Social benefits/yr	GHG Impact: MTs reduced/yr	**Health Rank**	**GHG Rank**
Cars and SUVs: 100% electric Zero Emissions Vehicle (ZEV) Sales Mandate @ 100%: supported by incentives, charging access and standards	313	2.4 billion	7.6	**1**	**1**
Cleaner Trucks Truck scrappage program, green vehicle incentive program, truck fleet efficiency requirements, Low Emission Zones	275	2.1 billion	0.06	**2**	**5**
Cars and SUVs: 50% electric ZEV Sales Mandate @ 50%: supported by incentives, charging access and standards	157	1.2 billion	3.7	**3**	**2**
Public Transit Buses: 100% electric All GTHA public transit providers with buses commit to 100% bus electrification, supported by funding from province/federal government	143	1.1 billion	0.3	**4**	**4**
Cars and SUVs: 20% electric Current planned passenger vehicle policies from federal, municipal government plans	63	0.5 billion	1.4	**5**	**3**

PART 1: BACKGROUND

Health Impacts of Air Pollution

Air pollution is the largest single environmental risk for health globally, with outdoor air pollution causing the death of 4.2 million people each year (7.6 per cent of all deaths).[13] In Canada, 14,600 deaths per year are attributed to air pollution, and the total annual economic value of health outcomes associated with air pollution is approximately $114 billion.[14]

In the Greater Toronto Hamilton Area (GTHA - Toronto, York, Durham, Peel, Halton & Hamilton) over 3,000 deaths per year are attributed to major air pollutants (according to an analysis conducted by Health Canada in 2019).[15] A 2014 report estimated that traffic-related air pollution was responsible for approximately 700 premature deaths and over 2,800 annual hospitalizations due to heart and lung conditions in the GTHA each year with an economic impact of over $4.6 billion per year.[16]

A wide range of health impacts have been attributed to air pollution including cardiovascular conditions such as angina, heart attack, hypertension and stroke, cardiovascular deaths, respiratory conditions such as asthma, allergies and chronic obstructive pulmonary diseases as well as cancer. Older adults, young children, and people with existing heart or lung conditions or with diabetes, are more susceptible to the harmful impacts of these air pollutants.

Those who are active outdoors and people who live near industrial pollution or high traffic corridors have a greater exposure to air pollution.[17] A substantial body of evidence reveals that the zone within 300 to 500 metres from major roads is the area most affected by traffic emissions.[18] Approximately 32 per cent of the Canadian population live within this zone.[19] Research from the City of Toronto estimated that 42 per cent of premature deaths and 55 per cent of hospitalizations due to air pollution emitted within Toronto's borders were from exposure to traffic-related air pollution.[20]

Health Equity Impacts of Traffic-Related Air Pollution and Climate Change

Inequities exist in exposure to air pollution, just as inequities exist in those suffering the greatest impacts of climate change.[21,22] Canadian research has shown that marginalized socio-economic groups are disproportionately exposed to traffic-related air pollution. Residents who face socio-economic barriers are also likely to be more vulnerable to the impacts of this pollution, as they face other health inequities correlated with socio-economic status.[23]

Several studies have revealed that lower socio-economic status (SES) neighbourhoods are often located in areas with greater exposure to traffic-related air pollution. A Hamilton study found a higher percentage of people living in close proximity to major roadways with higher traffic-related air pollution were from lower SES neighbourhoods.[24] A Toronto study found that lower SES areas in Toronto were more likely to be within 200 metres of a highway than higher SES areas.[25] In addition, a 2017 study by the City of Toronto reported that a large proportion of facilities with populations more vulnerable to air pollution (child-care centres, schools, long-term care homes, seniors residences) were located within close proximity to high traffic corridors.[26] These inequities are exacerbated as residents in lower SES areas are more likely to face other health inequities, making them both more likely to be exposed to air pollution, and more likely to be vulnerable to the effects of the exposure[27].

The examples below demonstrate the amplifying impact of climate change for those experiencing health inequities:[28]

1. **Exposure** refers to the likelihood of someone experiencing a climate related event. Low income neighbourhoods in cities are more likely to be situated in areas more susceptible to climate-related health impacts such as industrial areas, high traffic corridors, flood-prone areas or neighbourhoods lacking adequate greenspace.

2. **Sensitivity** refers to the underlying health conditions that increase the likelihood of someone experiencing an adverse health impact as a result of climate change. People with asthma, other respiratory conditions or heart disease are more sensitive to air pollution and extreme heat.

3. **Adaptive capacity** refers to the ability of individuals or communities to protect themselves from climate change and climate-related events. Marginalized individuals and communities are less likely to have the ability to access air conditioned spaces during an extreme heat event, relocate away from areas of poorer air quality or protect their homes from the impacts of extreme weather events such as flooding or wind storms.

Climate change and air pollution share another inequity: those who are least responsible for creating these problems tend to suffer most from their impacts. For example, Toronto research has shown that those most responsible for generating traffic-related air pollution (drivers) are least exposed, while public transit riders and active commuters like cyclists and pedestrians are most exposed.[29]

The inequitable distribution of climate change impacts is both a local and global issue. Wealthier countries emit far more GHG emissions per capita, while poorer countries emit fewer GHG emissions per capita yet suffer the highest burden from extreme weather, rising sea levels, extreme heat and other impacts of climate change.[30] On a local scale, urban low-income neighbourhoods tend to be located in areas that are more susceptible to climate change impacts, but a 2011 study found that a person in the top income quintile produces nearly 1.8 times more emissions compared to those in the bottom income quintile.[31] This inequity will only worsen if action is not taken to reduce the harmful impacts of climate change and air pollution.

Transportation, Air Pollution and Health

Most air pollution comes from burning fossil fuels, like gasoline, diesel, natural gas, and coal, which are burned by vehicles, refineries and power plants, among other sources. When fuels are burned or combusted, a large number of chemicals are produced and emitted into the air.

While there are many sources of air pollution, the largest sources in Canada by sector include transportation, electricity generation, industry (including the oil and gas industry) and mining, incineration and waste, agriculture, the commercial/residential/industrial sector, and dust.[32] Air pollution can also come from natural sources such as forest fires.

Air pollution is made up of many components. Here is an overview of the main pollutants we've included in our modelling. Some are primary pollutants - emitted directly through vehicle emissions, and others are secondary pollutants - formed in the atmosphere by chemical reactions of primary pollutants.

NITROGEN DIOXIDE (NO_2)

There is strong evidence linking exposure to nitrogen dioxide (NO_2) with premature deaths, respiratory/asthma hospitalizations and asthma-related emergency department visits.[33] Exposure to NO_2 decreases lung function and can exacerbate asthma symptoms. Long-term exposure to even low levels of NO_2 increases the risk of developing breathing problems. People with asthma, airborne allergies and chronic obstructive pulmonary diseases such as bronchitis and emphysema are more sensitive to the health impacts of NO_2.[34] In Ontario, 400 deaths each year are attributed to NO_2 exposure. In the GTHA 243 deaths per year are attributed to NO_2 exposure.[35] The main human-caused sources of NO_2 are transportation, industry and electric power generation.

NITROGEN OXIDES (NO_x)

Nitrogen dioxide (NO_2) and nitric oxide (NO) are referred to as nitrogen oxides (NO_x). NO_x is primarily emitted as NO which rapidly converts to NO_2. While NO_2 itself is a very harmful pollutant, through a series of chemical reactions in the atmosphere, NO and NO_2 contribute to the formation of other harmful pollutants such as ground level ozone (O_3) and fine particulate matter ($PM_{2.5}$). These secondary pollutants are the main components of smog. In Ontario, the transportation sector is the leading source of NO_x, including NO_2, representing 70 per cent of total Ontario's NO_x emissions (35 per cent from road vehicles and 35 per cent from other transportation).[36]

GROUND LEVEL OZONE (O_3)

Exposure to ozone (O_3) has been linked to premature mortality, and a range of health impacts including asthma exacerbation, shortness of breath, decreased lung function, coughing and irritation of the eyes, nose and throat. People with underlying breathing conditions are more sensitive to exposure to O_3.[37]

In Ontario, 1,800 deaths each year are attributed to O_3 exposure. In the GTHA, 752 deaths per year are attributed to exposure to O_3.[38]

Ground level ozone (O_3) is a secondary pollutant, formed when NO_x and Volatile Organic Compounds (VOCs) react in sunlight and stagnant air. As noted above, the main sources of NO_x from human activity are transportation, industry and electric power generation. VOCs from human activity come mainly from gasoline combustion, oil and gas production, residential wood combustion and the evaporation of fuels and solvents.[39] Reductions in NO_x can lead to increases in O_3 (as NO_x have a dual role as O_3 precursors and O_3 quenchers) which offset some of the benefits of NO_x reductions.[40]

FINE PARTICULATE MATTER ($PM_{2.5}$)

Exposure to fine particulate matter of 2.5 microns or less in diameter ($PM_{2.5}$) affects breathing, heart and blood vessel function, and is a major cause of morbidity and mortality associated with cardiovascular disease, respiratory disease and cancers. $PM_{2.5}$ has health impacts even at very low concentrations.[41] $PM_{2.5}$ can lodge deep in the lungs and penetrate the lung barrier entering the blood stream.[42] Populations most susceptible to $PM_{2.5}$ include children with asthma, older adults and people with preexisting heart and lung conditions.[43]

In Ontario, 4,500 deaths each year are attributed to $PM_{2.5}$ exposure. In the GTHA 2,194 deaths per year are attributed to exposure to $PM_{2.5}$.[44]

Transportation or “mobile sources” contribute to ambient $PM_{2.5}$ as both primary pollutants (directly from vehicle tailpipes, tire and brake wear, and road dust) and secondary pollutants (formed from precursor pollutants such as NO_x and volatile organic compounds (VOCs)). It is difficult to quantify the contribution of precursor pollutants to the formation of $PM_{2.5}$ as it is quite variable (30-90 per cent). However, Canadian research reveals that transportation is the second leading contributor to population weighted $PM_{2.5}$ across Canada (16 per cent) following wildfires (17 per cent).[45] [46]

BLACK CARBON

Black carbon is a major component of fine particulate matter and has been linked to both short-term and long-term health impacts including premature mortality and morbidity.[47] It has been linked to cardiovascular and cardiopulmonary deaths and hospital admissions. Studies of health effects associated with black carbon suggest it may be a better indicator of harmful particulate exposure from combustion sources, especially traffic.[48]

In 2018, transportation and mobile equipment were the largest source of black carbon in Canada, accounting for 57 per cent of total emissions. The use of diesel engines was the main source of black carbon emissions.[49]

CARBON DIOXIDE (CO_2)

Carbon dioxide (CO_2) is a GHG, which means it warms the Earth's atmosphere and contributes to climate change. A typical passenger vehicle emits about 4.6 metric tons of carbon dioxide per year.[50] Cars, SUVs, buses and trucks also produce other potent GHG emissions like methane in smaller quantities.

The largest source of GHG emissions in Canada is the oil and gas sector (26 per cent), closely followed by the transportation sector (25 per cent).[51] Although Canada represents approximately 1.6 per cent of global GHG emissions, it is one of the highest per capita emitters of GHGs worldwide.[52]

Canada is warming at twice the global average.[53] The effects of rising temperatures are projected to intensify with increased severity of heat waves, increased drought and wildfire risks, and increased urban flood risks from more intense rainfall. Limiting climate change will only occur if nations around the world, including Canada, drastically and rapidly reduce carbon emissions.[54]

Canadians are already experiencing the health impacts of climate change, and these impacts will increase. They include heat-related illness and death, deteriorating air quality, vector-borne diseases, injury and illness from heavy flooding and other extreme weather events, food insecurity and exacerbation of health inequities. Extended, warmer seasons have contributed to the spread of the tick that transmits Lyme disease, with the reported number of cases in Canada increasing exponentially in recent years.[55] Longer and warmer seasons increase air pollution risk from forest fires, smog and pollen, worsening asthma and other health impacts.

Climate change is expected to double or triple the number of extremely hot days in some parts of Canada in the next 30 years.[56] In the City of Toronto alone, heat contributes to an average of 120 premature deaths each year.[57] The mental health impacts of climate change are also expected to increase as Canadians face escalating climate change risks.[58]

According to the Intergovernmental Panel on Climate Change (IPCC), a number of climate change impacts we are already experiencing could be avoided by limiting global warming to 1.5^{0}C but it requires rapid and far reaching transitions in many sectors including transportation.[59]

Overview of Vehicles on our Roads

Of all the vehicles on Ontario's roads, the vast majority are cars, SUVs, and light trucks. The data below shows which vehicles were on the road in 2016, the base year for our vehicle and population modelling.

ONTARIO'S ON-ROAD VEHICLE MIX (2016) - STATISTICS CANADA[60]

Total on-road vehicles	8,538,070
Light-duty vehicles under 4,500 kgs (cars, SUVs, light trucks)	8,037,343
Heavy-duty vehicles over 4,500 kgs	250,800
Buses (public transit and school buses)	30,043
Motorcycles and mopeds	219,933

The proportion of electric vehicles is small but growing. EVs make up about 0.5 per cent of Canada's 23 million passenger vehicles on the road.[61] In terms of sales, EVs jumped from about 2 per cent in 2019 to about 3.5 per cent of total Canadian passenger vehicle sales.[62]

CLEAN CARS

Most cars on the road today are powered by an internal combustion engine (ICE) which burns gasoline or diesel and releases pollution from the car's tailpipe. Pollution also comes from producing the fuel burned by the vehicle, and from manufacturing or decommissioning these vehicles and their parts, often called "lifecycle" emissions.

A zero-emission vehicle (ZEV) is an umbrella term for a vehicle that has the ability to create no tailpipe pollution. The most common types are battery-electric (EVs) powered by electricity, but ZEVs can also be powered by hydrogen. ZEVs also produce lifecycle emissions and have some environmental impacts, for example, from battery production.

EVs charge up a battery from the electrical grid instead of filling up with fuel. Running on electricity means EVs can be much cleaner than gas-powered cars, particularly in places like Ontario with a grid that produces very few GHG emissions. Recent studies have shown that the vast majority of EVs produce fewer GHG emissions throughout their lifespan than fossil-fuel powered vehicles, even when emissions from producing the lithium-ion batteries and other parts are considered.[63]

Since EVs don't use an internal combustion engine, they have fewer moving parts and usually require less maintenance. This means that the higher sticker price of an EV is often offset by savings on fuel and maintenance.[64] However, less maintenance (and therefore less profit) has reduced the incentive for the auto industry to produce and sell EVs to customers compared to gas cars which yield higher profits.

Plug-in hybrid electric vehicles can be powered by either electricity or gasoline. Their batteries are not as powerful as a full EV, but have the flexibility to fuel up with gas when driving in areas with fewer charging options.

CLEAN TRUCKS

Most large trucks on the road today burn diesel. Older heavy-duty diesel trucks produce a lot more air pollution than newer trucks. Research analyzing air pollution data from multiple sites near roads and highways in Toronto and Vancouver showed that larger, older trucks were a much bigger determining factor in air pollution levels than the number of cars.[65] For example, the data revealed a significant drop in air pollution on the 401 near Toronto on weekends, when car traffic is still very high, but truck traffic is low.

Electric trucks are a promising technology for the future. But electric trucks are not yet manufactured at the scale necessary to make them an affordable option for most commercial trucking fleets. Thus, many policies and programs to reduce truck pollution focus on shifting to newer, more efficient diesel models. Trucks built within the last decade are notably cleaner and less polluting than older trucks, largely due to government regulations requiring better fuel economy and less pollution.

Trucks can also be powered by natural gas blended with renewable natural gas, which emits much less air pollution than diesel trucks in the short and medium-term. However, natural gas is also a fossil fuel which emits air pollution and GHG emissions, and the lifecycle GHG emissions of natural gas vehicles are comparable to diesel vehicles.[66] Electric and hydrogen fuel cell vehicles show much greater long-term potential to reduce emissions, especially as many jurisdictions increase the amount of renewable energy in their electricity mix.

CLEAN PUBLIC TRANSIT BUSES

Public transit buses operate primarily in dense urban environments. Traditional diesel buses therefore emit air pollution where many people are around to breathe it in; for example, pedestrians or cyclists stuck behind diesel buses at rush hour.

People in major Canadian cities may have already boarded an electric bus without even noticing a difference (aside from their lack of engine noise). Toronto, Montreal, Vancouver and many other cities have added fully electric and hybrid electric buses to their fleets, and most plan to add more.[67] York Region, Durham Region,[68] and Oakville[69] have also added electric buses locally. Electric bus technology has progressed to the point where 100 per cent bus electrification is an attainable goal for public transit providers.

Many electric transit buses are also manufactured in Canada. Leading North American electric bus companies like New Flyer Industries and Nova Bus are already providing these buses to Canadian cities,[70] and Newmarket is now home to an electric bus assembly plant.[71] Ramping up production to serve all-electric transit fleets in these cities would provide many more good clean technology jobs for Canadian workers.

PART 2: RESEARCH AND RECOMMENDATIONS

Modelling Results and Impacts

To show the benefits of cleaner vehicles, we've modelled five scenarios to compare the impacts of reducing traffic-related air pollution and GHG emissions from operating cars and SUVs, trucks, and public transit buses. Each scenario explores a hypothetical future: what would the GTHA look like with a specific mix of cleaner vehicles? How would this impact air pollution, public health, and GHG emissions?

The scenarios we modelled are as follows:

- Base Case - current emissions (calculated with 2016 data)
- 100 per cent of cars (private passenger vehicles including SUVs) are fully electric (EVs)
- 50 per cent of cars (private passenger vehicles including SUVs) are fully electric (EVs)
- 20 per cent of cars (private passenger vehicles including SUVs) are fully electric (EVs)
- 100 per cent of public transit buses in the GTHA are fully electric
- All trucks (commercial vehicles) are replaced with newer, more efficient models meeting at least 2008 technology standards

We've modelled scenarios that are feasible with current technology. Although electric passenger vehicles and electric transit buses are already widely available and growing rapidly in use, electric trucks are still in their infancy. As battery and other technologies progress, prices will drop further, making them more feasible for fleet-wide adoption. For this modelling, we've chosen a truck scenario that is based on newer, more efficient vehicles, not truck electrification.

Our modelling used an integrated transportation emissions-air quality tool developed by the Transportation and Air Quality (TRAQ) research group at the University of Toronto. More information on the research methodology is available in the Appendix. Although our scope of work focused on the impacts of switching to cleaner vehicles, exploring the impacts of reducing the total number of vehicles on the road is critical work which is also underway in the region, like York Region's Streetscape Program, investing in sustainable transportation options that promote walking, cycling, public transit use, recreational use and social interaction.[72] Solutions like regional freight planning, expanding work-from-home options, and supporting walking and cycling are critical to cutting vehicle pollution and GHG emissions. Similar to the principle of "Reduce, Reuse, Recycle," the first and most effective solution is always to reduce.

HOW CAN THESE SCENARIOS BECOME REALITY? THROUGH STRONGER GOVERNMENT ACTION

There are many actions governments can take to improve people's health by reducing vehicle pollution. Clean vehicle policies are already being implemented by federal, provincial, and municipal governments in Canada. For example, the federal government now offers electric vehicle purchase incentives of $5,000 to help make the up-front purchase price of these vehicles more affordable.

The federal price on carbon also has a positive impact. Since EVs don't use gasoline, the cost argument for EVs gets better as the price on carbon rises - although in recent months, global fluctuations in gas prices have a significantly bigger impact on gasoline prices than Canada's price on carbon.

However, current government policies are not yet ambitious enough to achieve the massive health benefits illustrated by our modelled scenarios. That's why we've also included recommendations for policies likely to achieve the health outcomes in each scenario. These recommendations reflect currently available data, and are not an exhaustive list of policy options – rather they represent a potential pathway to these outcomes.

Our modelling shows that there is both a health and economic argument for more ambitious policy implementation. The social benefits of reducing traffic-related air pollution and its accompanying health impacts outweigh the costs involved in supporting a transition to cleaner vehicles. For example, governments have been criticized for offering purchase incentives for electric vehicles. However our modelling shows that, in a scenario where all cars and SUVs are electric, a single EV replacing a gas-powered car brings $9,850 in social benefits, justifying significant spending to get more EVs on the road quickly. These benefits are shared by everyone in the GTHA, not just EV owners.

Regulatory actions are even more cost-effective for governments. For example, requiring that automakers sell a certain percentage of EVs or reduce emissions in their overall fleets. These measures would bring health benefits to everyone without directly subsidizing vehicles that may only be accessible to higher-income drivers.

Rather than considering health and climate impacts separately, governments should consider both health and climate benefits when considering clean vehicle policies. This will help all of society access health and economic benefits now and in the future.

SCENARIO DESCRIPTIONS AND POLICY RECOMMENDATIONS

The Base Case - Where is Traffic Pollution Concentrated Now?

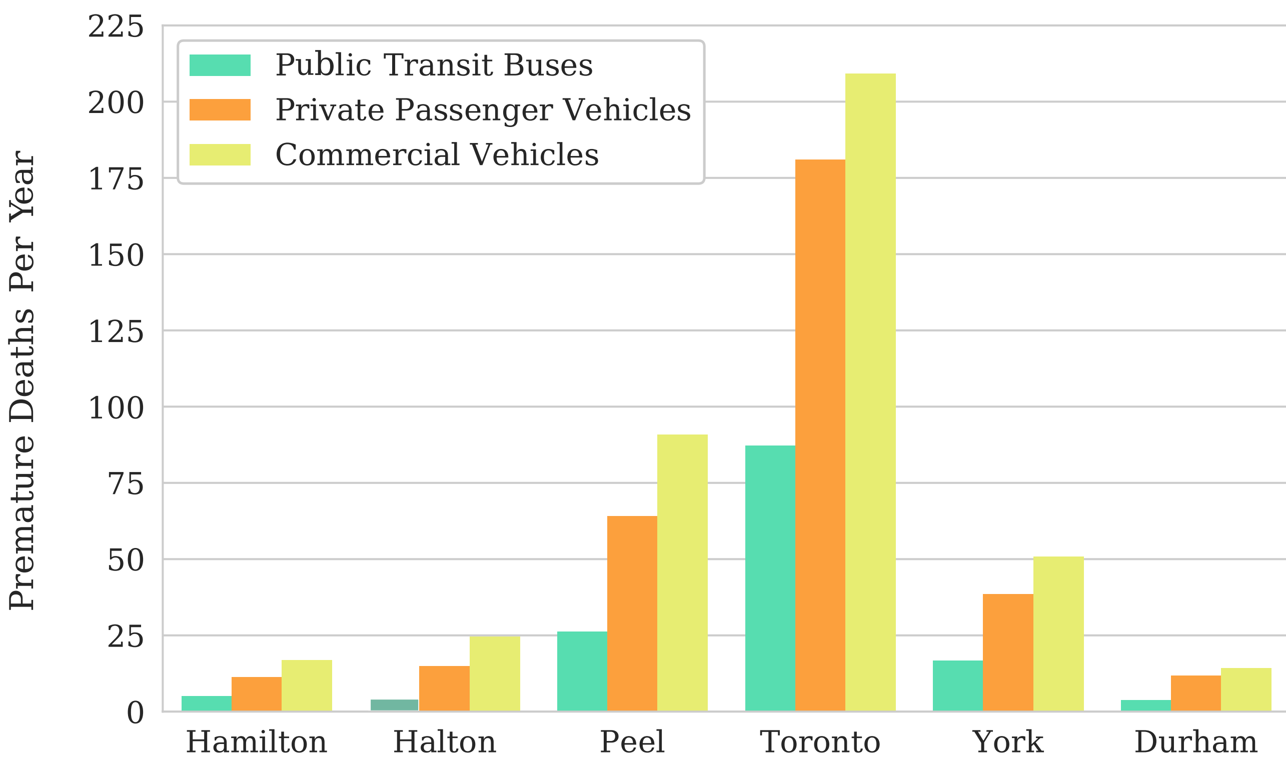
Our base case modelling of air pollution accounts for all anthropogenic and natural sources. For GHGs, we modelled only traffic-related operating and fuel-cycle emissions, which include emissions from nearby power plants.

Simulating power plant pollution allows us to consider the power source used to charge electric vehicles and its impact on air pollution and GHG emissions. Results are based on the current emissions profile of electricity in Ontario, which is relatively low in carbon emissions. However, Ontario's plan to use more natural gas - a fossil fuel - for electricity generation could mean that electricity use will pollute more in the future.

Our base case scenario figures below reveal some important facts:

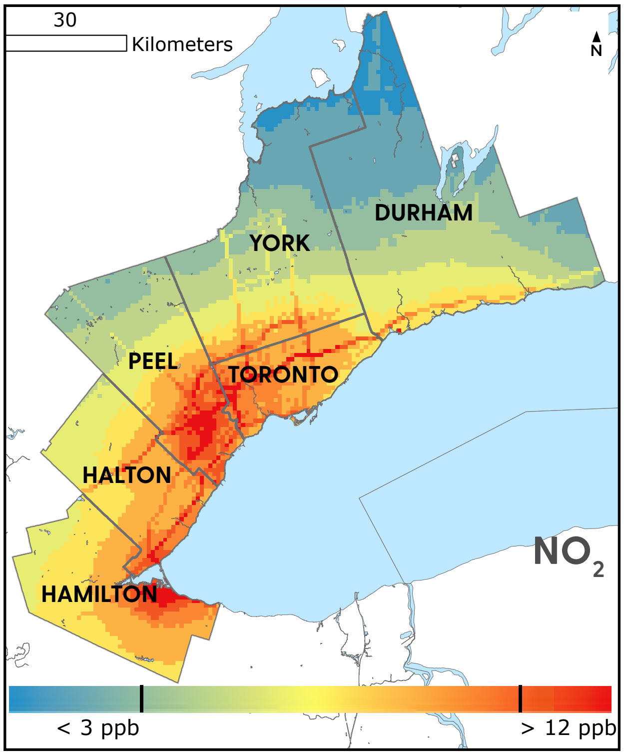
1. **Traffic-related air pollution, from trucks, cars and buses,** is responsible for 872 premature deaths in the GTHA every year.

PREMATURE DEATHS PER YEAR ATTRIBUTED TO TRAFFIC-RELATED AIR POLLUTION BY VEHICLE TYPE AND REGION

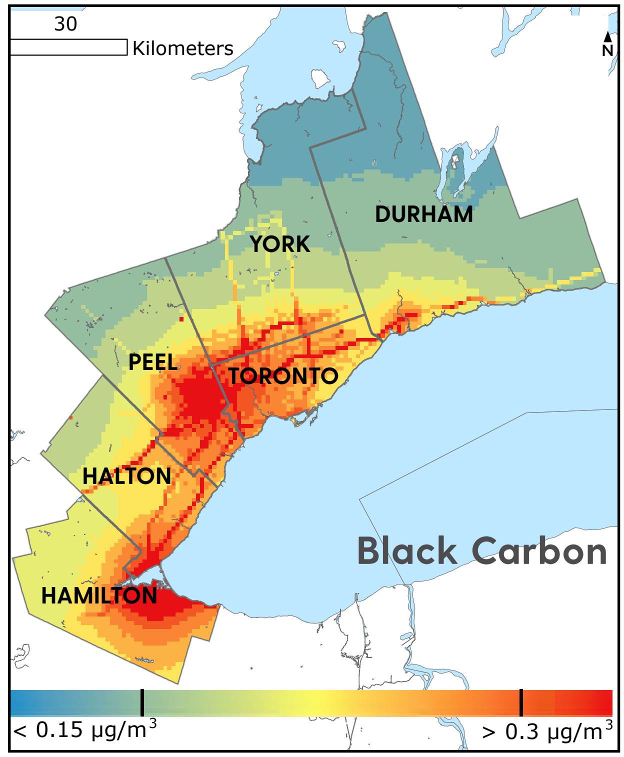


2. **Exposure to air pollution is unevenly distributed throughout the region.** Harmful air pollutants like black carbon and NO_2 are concentrated close to busy roads and highways, and close to hubs of freight movement such as Toronto Pearson airport. From a population exposure perspective, residents of Toronto, York and Peel Region have higher exposures to traffic-related air pollution than residents in Hamilton, Halton or Durham (although in all regions, residents closest to high traffic areas would be exposed to higher levels of air pollution).

NITROGEN DIOXIDE CONCENTRATIONS ON AN AVERAGE DAY

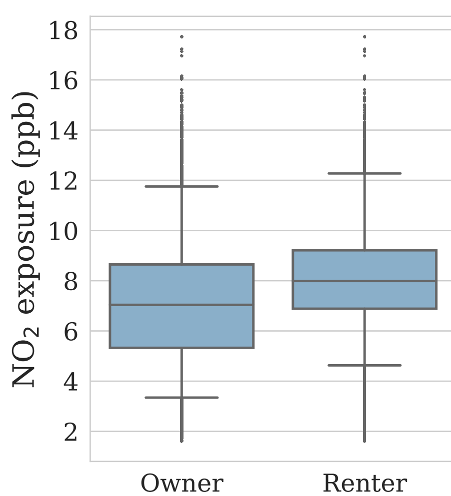


BLACK CARBON CONCENTRATIONS ON AN AVERAGE DAY



The degree of exposure also varied slightly by dwelling type. When we analyzed residential exposure by dwelling in the GTHA, renters were exposed to slightly more traffic-related air pollution than home owners.

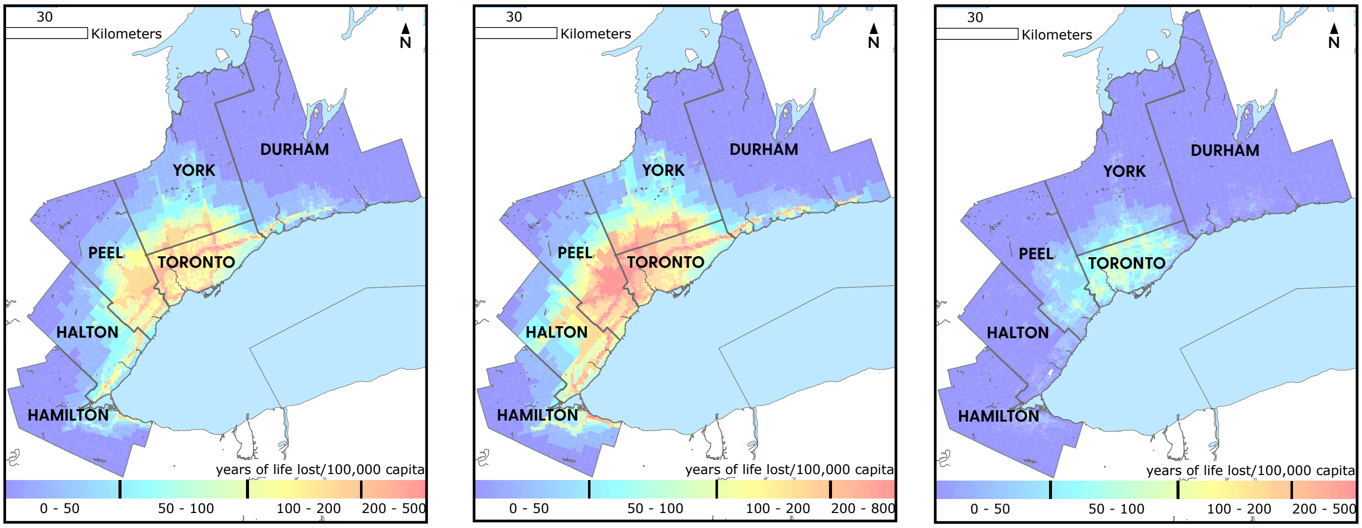
NITROGEN DIOXIDE (NO_2) EXPOSURES IN THE GTHA, OWNER VS RENTER



3. The amount of air pollution created by each vehicle type varies widely

Trucks (commercial vehicles) create a disproportionate amount of air pollution, and are responsible for almost 50 per cent of all traffic-related air pollution mortalities in the GTHA.

ANNUAL NUMBER OF YEARS OF LIFE LOST PER 100,000 INHABITANTS DUE TO TRAFFIC-RELATED EMISSIONS BY VEHICLE TYPE

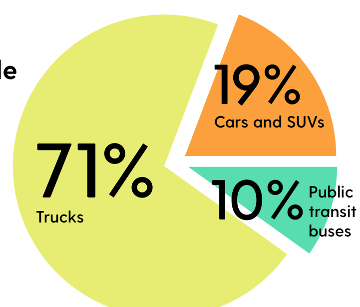


PRIVATE PASSENGER VEHICLES **COMMERCIAL VEHICLES** **PUBLIC TRANSIT BUSES**

Trucks emit proportionately more NO_x and black carbon than cars and SUVs. Our research shows that diesel and gasoline trucks account for 52 per cent of traffic-related NO_x emissions in the GTHA, with cars responsible for 36 per cent and buses at 12 per cent. Trucks are also the primary source of $PM_{2.5}$ emissions from vehicles (including black carbon) at 71 per cent.

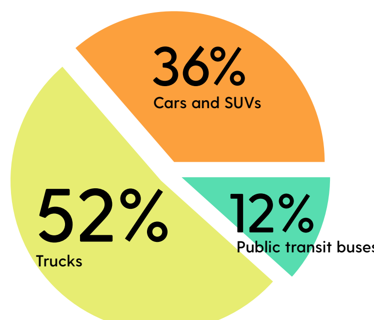
Traffic-related black carbon (BC) emissions by vehicle type in the GTHA

0.54 tonnes BC/day



Traffic-related nitrogen oxides (NO_x) emissions by vehicle type in the GTHA

30 tonnes NO_x/day



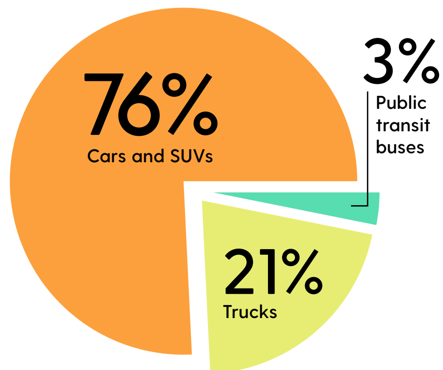
4. The amount of greenhouse gas emissions from each vehicle type varies widely

Cars and SUVs, trucks and buses in the GTHA release about 11 mega tonnes of GHG emissions per year. This is a significant share of the approximately 160 mega tonnes of total annual GHG emissions released in Ontario in recent years.[73]

Cars and SUVs emit 76 per cent of the traffic-related GHG emissions, but proportionately lower amounts of NO_x and black carbon. Public transit buses have a much smaller proportional impact on GHG emissions compared with other vehicle types. This does not indicate that buses are cleaner, just that there are many fewer buses on the roads than trucks or cars.

Traffic-related greenhouse gas (GHG) emissions by vehicle type in the GTHA

34,340
tonnes CO_2 eq./day



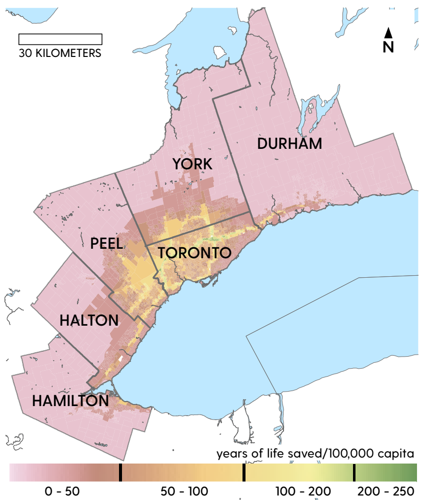
Comparing Clean Vehicle Scenarios

The modelling done by researchers at the University of Toronto shows the health and social benefits and the air pollution and GHG reductions that can be achieved with different mixes of cleaner vehicles on roads and highways in the GTHA. To determine premature deaths prevented, years of life saved, and social benefits we've combined exposure data from all air pollutants simulated except CO_2, which has longer-term health impacts from climate change, such as the impact from heat waves, extreme weather events, and vector-borne diseases.

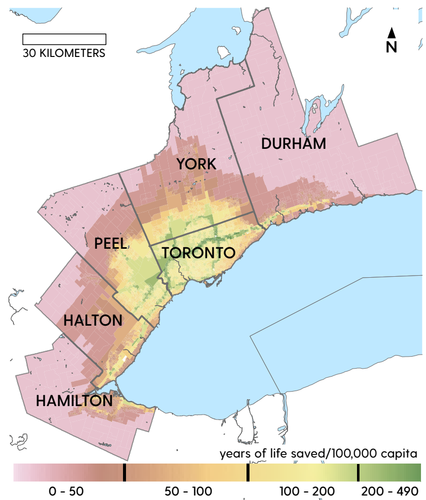
The maps and tables below from the modelling allow us to compare the relative health and social benefits and GHG reductions resulting from all five scenarios.

20% of cars/SUVS are electric

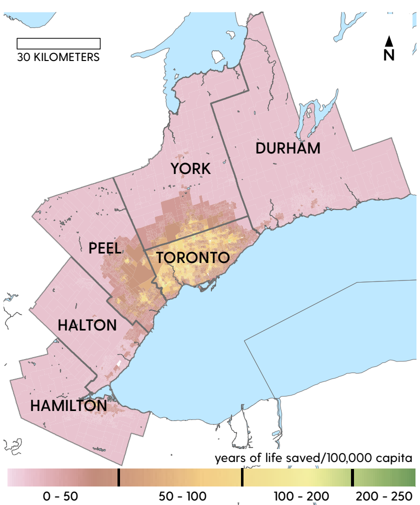
50% of cars/SUVS are electric



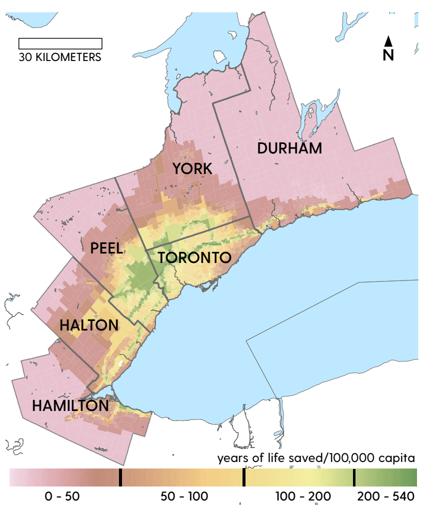
100% of cars/SUVS are electric



100% of public transit buses are electric

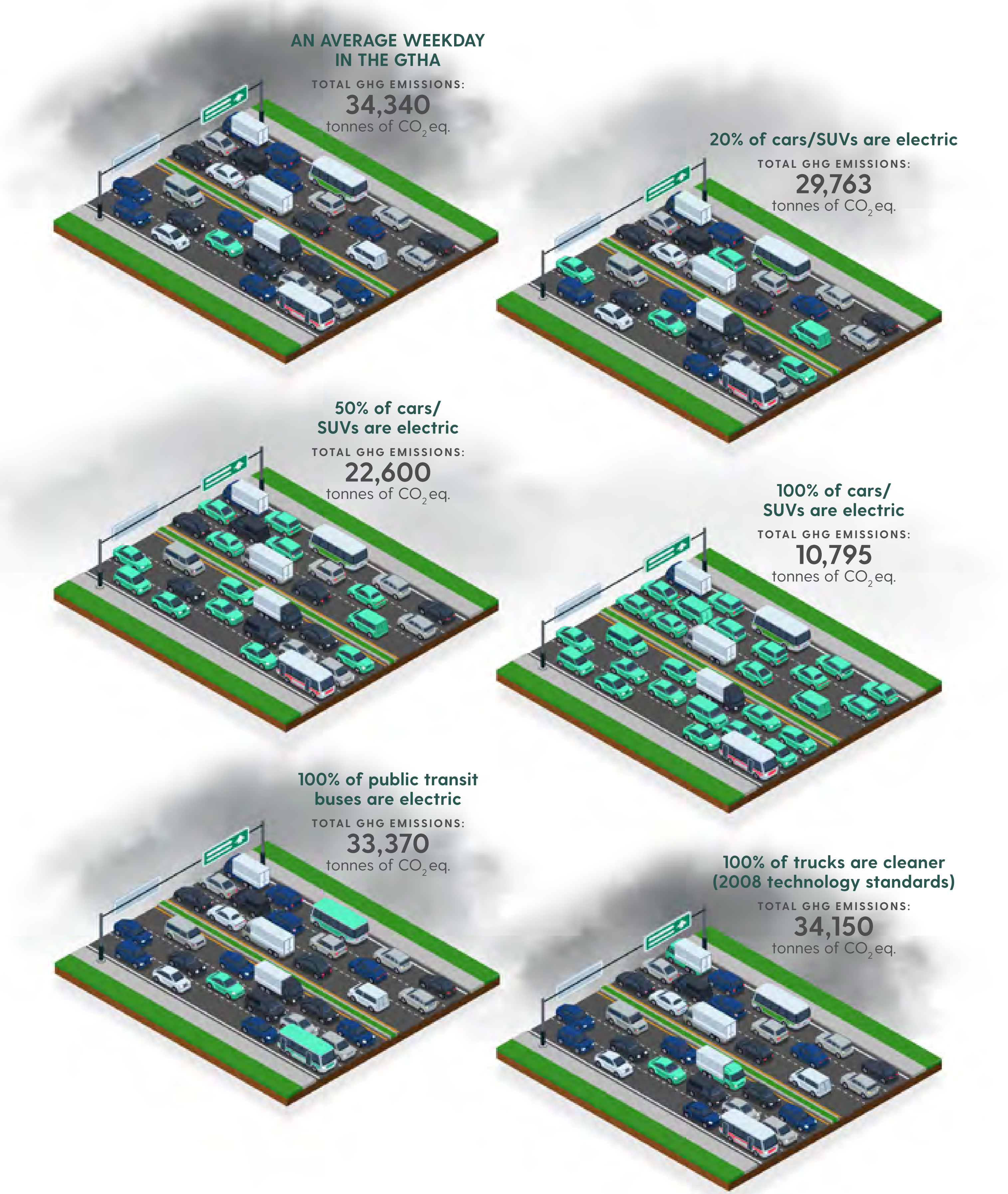


100% of trucks are cleaner (2008 technology standards)

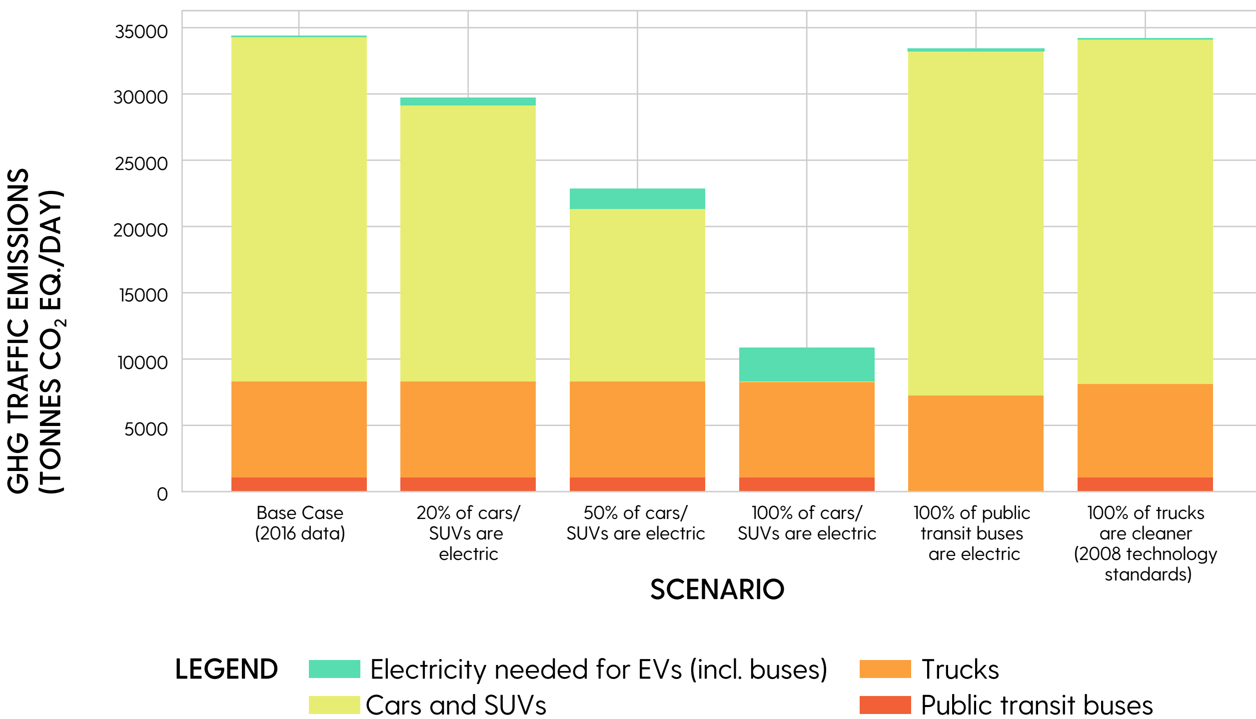


YEARS OF LIFE SAVED IN THE GTHA PER 100,000 INHABITANTS BY MODELLED SCENARIO EVERY YEAR

TRAFFIC-RELATED GREENHOUSE GAS (GHG) EMISSIONS IN THE GTHA UNDER EACH MODELLED SCENARIO



DAILY TRAFFIC-RELATED GREENHOUSE GAS (GHG) EMISSIONS BY VEHICLE TYPE AND MODELLED SCENARIO



Key findings:

1. Of all scenarios modelled, 100 per cent car and SUV electrification achieves the greatest immediate health benefits and air quality improvements overall in the GTHA and the greatest GHG emission reductions.
2. Replacing older trucks with newer, more efficient trucks brings strong immediate health benefits and air quality improvements to many communities in the GTHA, particularly those along 400-series highways where truck traffic is concentrated.
3. Electrifying 100 per cent of public transit buses in the GTHA (including GO and regional public transit) can reduce exposure to air pollution in urban centres like Toronto.
4. Scenarios differ in their relative impacts on reducing air pollution versus reducing GHG emissions. Broadening policy action to make multiple vehicle types cleaner is the best way to balance immediate health benefits from better air quality with long-term benefits of reduced GHG emissions.
5. Existing research in Toronto has revealed that people who are contributing little or no air pollution by walking, cycling or taking public transit, are exposed to more air pollution than those who are causing the pollution by driving gas and diesel vehicles.[74] Vehicle electrification and cleaner trucks, along with reducing the number of vehicles on the road, will help address these unjust inequalities in air pollution exposure.

6. Broad policy action to improve multiple vehicle types (trucks, cars, SUVs, and public transit buses) can improve health across the entire GTHA. Reducing emissions from certain vehicle types benefits some regions in the GTHA more than others. For example, regions with higher truck traffic, such as Peel Region, would benefit proportionally more from cleaner trucks, while Toronto residents would benefit proportionally more than other regions from electrifying buses. Reducing emissions from multiple vehicle types would help distribute health benefits across the regions of the GTHA.

7. Reducing air pollution through the modelled scenarios showed that populations currently exposed to higher air pollution levels would generally experience slightly greater health benefits. Since the biggest reductions in air pollution happen near major roads, people who live closest to major roads benefit most from the cleaner vehicles on these roads. Renters also experienced slightly greater social benefits from reductions in traffic-related air pollution than owners. While we were not able to draw any conclusions from our modelling in terms of socio-economic status, exposure to traffic-related air pollution, and health and health equity impacts, Canadian research has shown that marginalized socio-economic groups are disproportionately exposed to air pollution,[75] and thus would benefit more from reducing that pollution.

8. Government funding to help get cleaner cars and trucks on the road will more than pay for itself in social benefits to GTHA residents. If all cars and SUVs on the road were electric in the GTHA, each electric vehicle that replaces a gas-powered car would bring $9,850 in social benefits.

SCENARIO 1A - 100 PER CENT OF CARS AND SUVS ARE FULLY ELECTRIC (EVS)

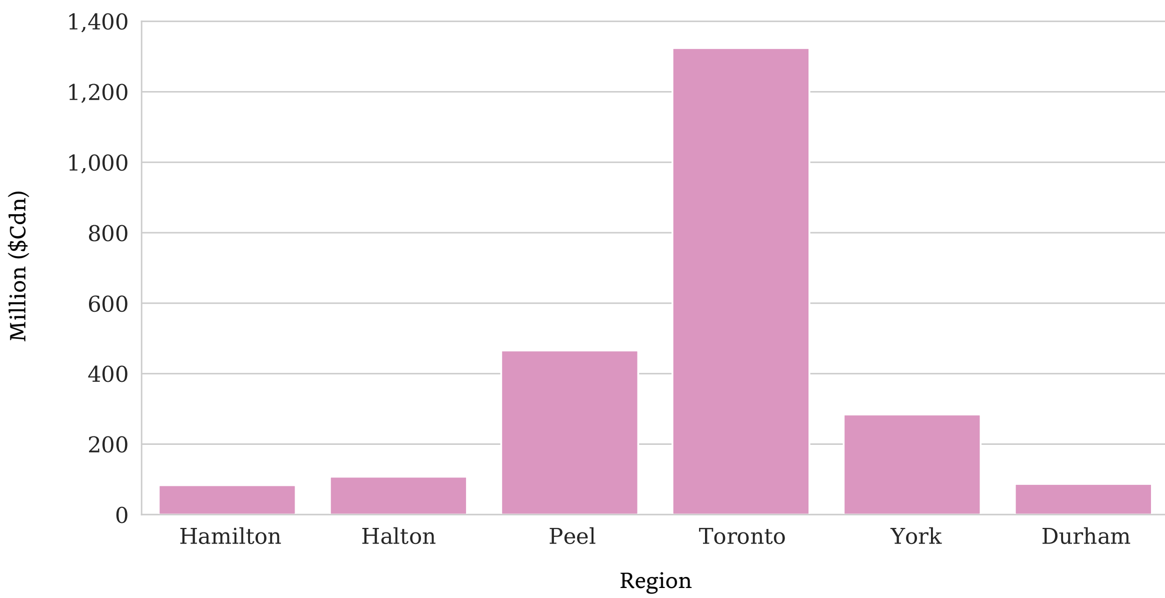
This scenario assumes that 100 per cent of cars and SUVs in the GTHA are fully electric. This scenario produces the greatest health benefits overall to people living and working in the GTHA, and the greatest reductions in GHG emissions. The broad benefits of this scenario justify the higher level of government investment and policy intervention required over the other scenarios. More ambition yields the greatest results across the region.

Our modelling takes into account an increase in electricity use for EV charging, and therefore rise in GHG emissions and air pollution from power plants as a result of greater demand to power vehicles. This is based on the assumption that Ontario's electricity supply mix remains constant, and some of the additional electricity needed is produced by burning natural gas. Even considering the associated increase in GHG emissions from electricity, this scenario still achieves a substantial decrease in GHG emissions.

Key outcomes include:

- 313 premature deaths prevented per year
- $2.4 billion per year in social benefits
- 7.6 mega tonnes annual GHG reductions (68.5 per cent of traffic-related GHG emissions in the GTHA)
- Proportionally greater social benefits for residents in Toronto, Peel and York Region

ANNUAL SOCIAL BENEFITS WITH 100 PER CENT ELECTRIC CARS AND SUVS BY REGION (IN MILLIONS $CDN)



POLICY RECOMMENDATIONS

National Zero Emission Vehicle (ZEV) sales mandate scaling up to 100 per cent, supported by:

- **temporary vehicle purchase incentives**
- **investments in charging infrastructure**
- **increasingly stringent passenger vehicle GHG standards**

A ZEV refers to a vehicle that has the ability to produce no tailpipe emissions, like an electric vehicle (EV) or hydrogen vehicle. A ZEV sales mandate requires that automakers ensure a rising percentage of their light-duty vehicle sales are ZEVs by specific dates. For example, British Columbia currently has a ZEV mandate requiring that automakers meet ZEV sales targets of 10 per cent of light-duty vehicle sales by 2025, 30 per cent by 2030, and 100 per cent by 2040. This is a strong regulatory tool available to federal and provincial governments. It places the onus on automakers to ensure that ZEVs are not only widely available to consumers, but that promotional dollars are behind them to help level the playing field with increasingly popular SUVs and light trucks.

A national ZEV mandate would help avoid the current patchwork of provincial systems where automakers ship ZEVs in much higher volume to provinces with mandates, leaving them harder to find in provinces without a mandate.

This scenario represents the endpoint of a ramped-up ZEV sales mandate, which requires ambition and time. Once in place, automakers would need time to ramp up to 100 per cent ZEV sales from the current level of 3.5 per cent in Canada,[76] since auto manufacturing would have to be substantially shifted.

Stronger accompanying policy actions would encourage quicker uptake, achieving health benefits much more quickly. For example, a 2017 Equiterre report modelled the impacts of a ZEV sales mandate complemented by a temporary ZEV purchase incentives and ambitious charging infrastructure deployment. Their model found that while the mandate required 30 per cent ZEV sales by 2030, uptake estimates with additional measures ranged from 30 to 50 per cent.[77] On the other hand, purchase incentives and charging infrastructure investments acting without an accompanying ZEV sales mandate yielded much lower sales when modelled in the above-mentioned analysis.

These purchase incentives should be temporary, to help make ZEVs more affordable until they drop to a similar purchase price as gas-powered vehicles. ZEVs generally offer better value for money over their lifespan due to savings on maintenance and gasoline, but the sticker price can be a barrier.

Government decisions to fund ZEV purchase incentives (for example, current federal purchase incentives of $5,000) are offset by the social benefits to all of society. For every vehicle that switches from gas to electric in a 100 per cent EV scenario, our modelling shows $9,850 in social benefits in the GTHA.

Governments can also strengthen existing GHG emission standards for passenger vehicles. These rules require automakers to meet progressively more stringent annual fleet average GHG emissions, meaning cars on average release fewer GHG emissions. This encourages them to produce and sell more ZEVs, since they produce no tailpipe emissions and drastically lower the fleet average emissions.

Existing standards are already in place which set a pathway for lower emission vehicles all the way until 2025 in both Canada and the U.S. However, Canada's standards are currently tied to U.S. standards, which are being substantially weakened by the current U.S. government. Canada can make progress towards total electrification of passenger vehicles by continuing to strengthen standards instead of following the U.S. if they weaken theirs.

CASE STUDY: A ZEV MANDATE AT WORK IN QUEBEC

In 2016 the Quebec government passed the ZEV Act, giving it the power to require car manufacturers to sell or lease a minimum number of ZEVs through a system of tradable credits called a ZEV standard. Quebec was the first province in Canada to adopt this kind of program.

The goal of the program is to “spur the automobile market to develop greater numbers of models that rely on increasingly efficient low-carbon technologies.” [78] Put simply, this regulation makes sure that automakers build and ship enough ZEVs for Quebec customers to have access to the ZEVs they want. And the impact has been significant. Not only do automakers prioritize getting more ZEVs to jurisdictions like Quebec and B.C. who have these rules in place, but they also sell many more of them. In 2019, Quebec and B.C. continued to set new ZEV sales records with huge increases, while Ontario fell behind due to the cancellation of purchase incentives in the summer of 2018.[79]

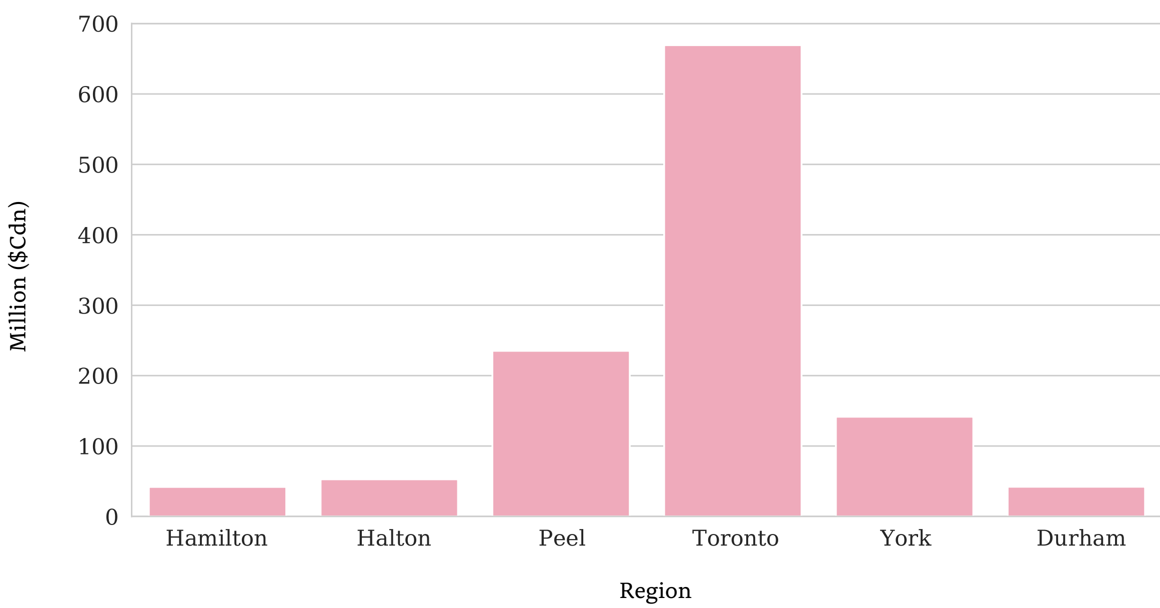
SCENARIO 1B - 50 PER CENT OF CARS AND SUVS ARE FULLY ELECTRIC (EVS)

This scenario assumes that 50 per cent of cars and SUVs in the GTHA are electric. It achieves the second highest GHG emission reduction impacts, but achieves fewer overall health benefits than the truck renewal scenario (See Scenario 3). The distribution of benefits is similar to the full 100 per cent electrification scenario, however the benefits are less pronounced.

Key outcomes include:

- 157 premature deaths prevented per year
- $1.2 billion per year in social benefits
- 3.7 mega tonnes annual GHG reductions
- A proportionally higher benefit to residents in Peel Region, York Region, Toronto

ANNUAL SOCIAL BENEFITS WITH 50 PER CENT ELECTRIC CARS AND SUVS BY REGION (IN MILLIONS $CDN)



POLICY RECOMMENDATIONS:

Zero Emission Vehicle (ZEV) sales mandate scaling up to 50 per cent, supported by:

- **temporary vehicle purchase incentives**
- **investments in charging infrastructure**
- **increasingly stringent passenger vehicle GHG standards**

This scenario can be interpreted as either a snapshot of the halfway point of implementing a 100 per cent ZEV sales mandate, or a less ambitious ZEV sales mandate requiring that automakers ensure 50 per cent of their sales are electric.

While existing ZEV mandates in many jurisdictions aren't aiming to hit 100 per cent ZEV market share until 2040 or later, ambitious accompanying policies like purchase incentives could bring 50 per cent within reach in the next decade, by 2030.[80] Much like the 100 per cent EV scenario, it is unlikely that vehicle purchase incentives, charging infrastructure investments, and fleet GHG standards would achieve the results in this scenario without the regulatory force of a ZEV sales mandate to lead the way.

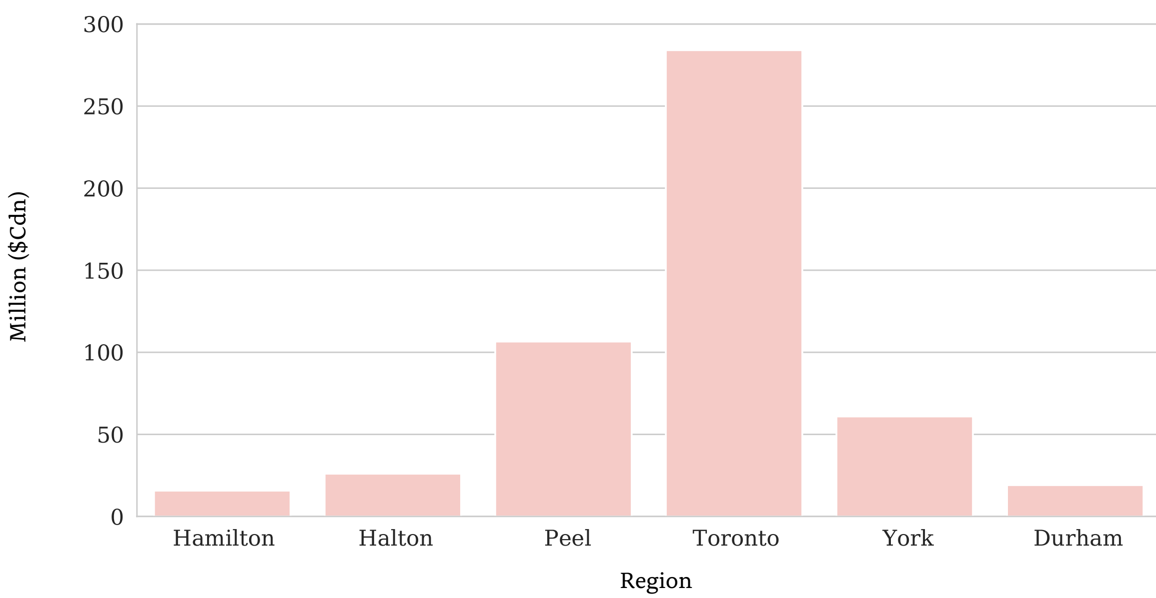
SCENARIO 1C - 20 PER CENT OF CARS AND SUVS ARE FULLY ELECTRIC (EVS)

This scenario shows the estimated impact of the current suite of proposed passenger vehicle electrification policies from all levels of government by 2030, if fully implemented and funded. The relatively weak results from this scenario show that increasing ambition beyond currently planned policies will save lives, accelerate progress towards carbon reduction goals, and leave us economically better off.

Key outcomes include:

- 68 premature deaths prevented per year
- $0.5 billion in social benefits
- 1.4 mega tonnes annual GHG reductions
- A proportionally higher benefit to residents in Peel Region, York Region, Toronto

ANNUAL SOCIAL BENEFITS WITH 50 PER CENT ELECTRIC CARS AND SUVS BY REGION (IN MILLIONS $CDN)



POLICY PATHWAY: ACHIEVING 20 PER CENT EVS IN THE GTHA

POLICY RECOMMENDATIONS

A number of proposed passenger vehicle electrification policies could lead to 20 per cent car electrification by 2030. The City of Toronto set a goal of 20 per cent vehicle electrification by 2030, and the federal government is aiming for 30 per cent of all new car sales to be electric by 2030.

Proposed actions include:

- **The City of Toronto's 2019 Electric Vehicle Strategy, which includes significant investments in charging infrastructure to support a goal of 20 per cent electrification by 2030.[81]**
- **Continued federal government electric vehicle purchase incentives of $5,000 for passenger vehicles.[82]**
- **Continued federal government 100 per cent tax write-off for ZEV for businesses.[83]**
- **Other regional vehicle electrification plans currently in development or announced in regions of Peel, York, Halton, Durham[84], and Hamilton.**

As outlined above, federal, provincial, regional, and local governments have recently announced programs and policies to support electrifying passenger vehicles. These will help to accelerate uptake over and above what would happen without this support, and bring health and social benefits to the GTHA.

However, the potential for much greater health and social benefits from higher-percentage vehicle electrification scenarios shows that governments can and must aim higher. Current ambition moves too slowly to accomplish Canada's GHG emissions reductions targets, leaving all GTHA communities with much higher mortality rates from traffic-related air pollution and burdening our health care system. In addition, provincial programs to support EV adoption were cancelled along with Ontario's cap-and-trade system, causing a drastic decline in EV sales.[85] Ontario's EV program cancellations will negatively impact air quality and public health unless replacement programs of similar ambition are quickly implemented.

SCENARIO 2 : 100 PER CENT OF PUBLIC TRANSIT BUSES ARE ELECTRIC

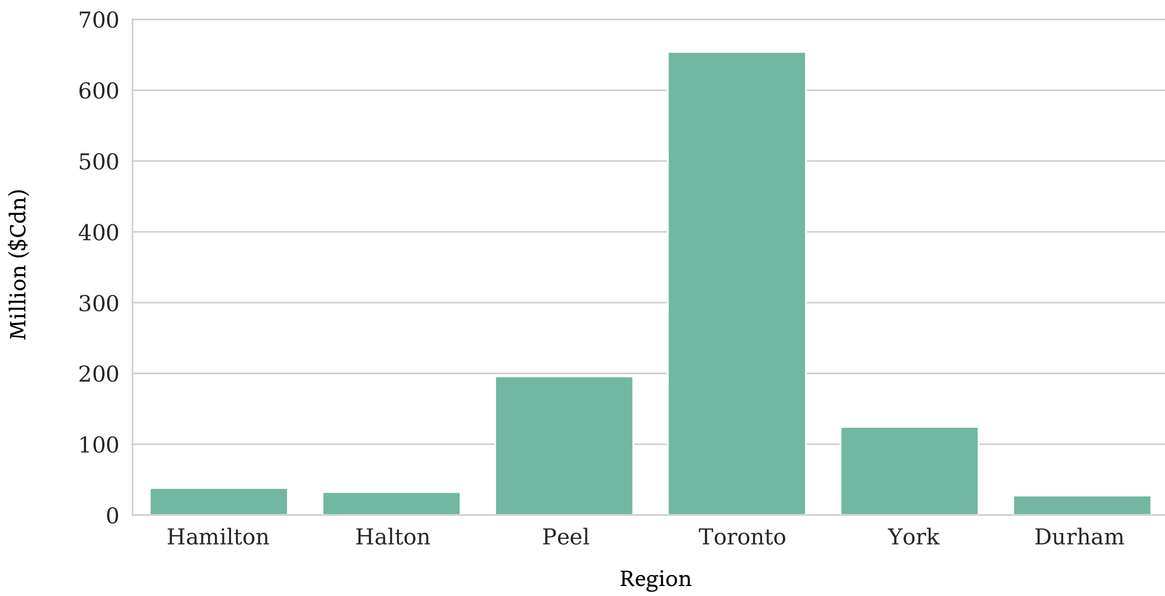
This scenario assumes that all public transit buses in the GTHA are electric (including GO and local transit authorities, excluding school buses).

Public transit buses make up a very small proportion of on-road vehicles, so the GHG reduction benefits are relatively small compared to other scenarios. However, the health and air quality benefits are more significant due to the fact that buses are concentrated on major roads and dense population centres. Reducing their pollution levels reduces exposure to harmful air pollution for more people, particularly in urban centres like Toronto. This means that on a per vehicle basis, the impact of electrifying public transit buses is much greater. Buses also move more people more efficiently, accounting for 32 per cent of total daily passenger kilometres travelled.[86]

Key outcomes include:

- 143 premature deaths prevented per year
- $1.1 billion in social benefits
- 0.3 mega tonnes annual GHG reductions
- Greatest benefit to residents in City of Toronto

ANNUAL SOCIAL BENEFITS WITH 100 PER CENT ELECTRIC PUBLIC TRANSIT BUSES BY REGION (IN MILLIONS $CDN)



POLICY PATHWAY: ACHIEVING 100 PER CENT ELECTRIC TRANSIT BUSES IN THE GTHA

POLICY RECOMMENDATIONS

- **Commitments from public transit providers to purchase exclusively electric buses and retire diesel-powered buses**
- **Federal and provincial funding programs to support a transition to fully electric public transit buses**

Total public transit bus electrification could be achieved with a commitment from municipal and regional transit authorities (Toronto Transit Commission, Hamilton Street Railway, MiWay, GO, York Region Transit, Oakville Transit, Durham Region Transit) to purchase exclusively electric buses, and retire diesel buses at the end of their lifespan, or sooner.

Some public transit authorities have committed to bus electrification goals already, and most have begun integrating electric buses in some capacity. York Region Transit is now implementing a pilot project with federal funding to add new fully electric buses to their fleet, along with overhead charging capacity.[87] The City of Toronto has added fully electric buses to their TTC fleet, and has committed to a 100 per cent zero-emissions bus fleet by 2040.[88]

The cost of fully electric buses means that public transit providers would need funding support from the federal and provincial government to achieve full electrification. This also presents an opportunity to support Canadian manufacturing, since many electric buses are made in Canada. Toronto recently purchased 25 electric buses from New Flyer Industries, a Canadian company and leading bus manufacturer.[89] Expanding electric public transit bus fleets made by Canadian companies would create jobs in a growing clean economy, in addition to bringing health benefits to urban populations.

CASE STUDY: ELECTRIC PUBLIC TRANSIT BUSES IN MONTREAL

Montreal is leading the way when it comes to getting electric buses into their transit fleet quickly. The Société de transport de Montréal made a commitment that all new bus acquisitions will be hybrid or electric by 2025, becoming 100 per cent electric after 2040. To do this, they piloted rapid-charge buses over an 18-month period in 2017 and 2018, and then began purchasing many more buses to suit their needs. During the trial, the electric buses saved over 100 tonnes of CO_2.[90]

SCENARIO 3: TRUCKS ARE CLEANER AND MORE EFFICIENT

This scenario assumes newer technology for all heavy-duty trucks, delivery vehicles, and other commercial vehicles. Older trucks are replaced with newer, more efficient models meeting at least 2008 technology standards. Since older vehicles are the worst offenders when it comes to air quality, and electric trucks are not yet affordable at scale for most commercial vehicle owners, we have modelled a non-electrification option for trucks.

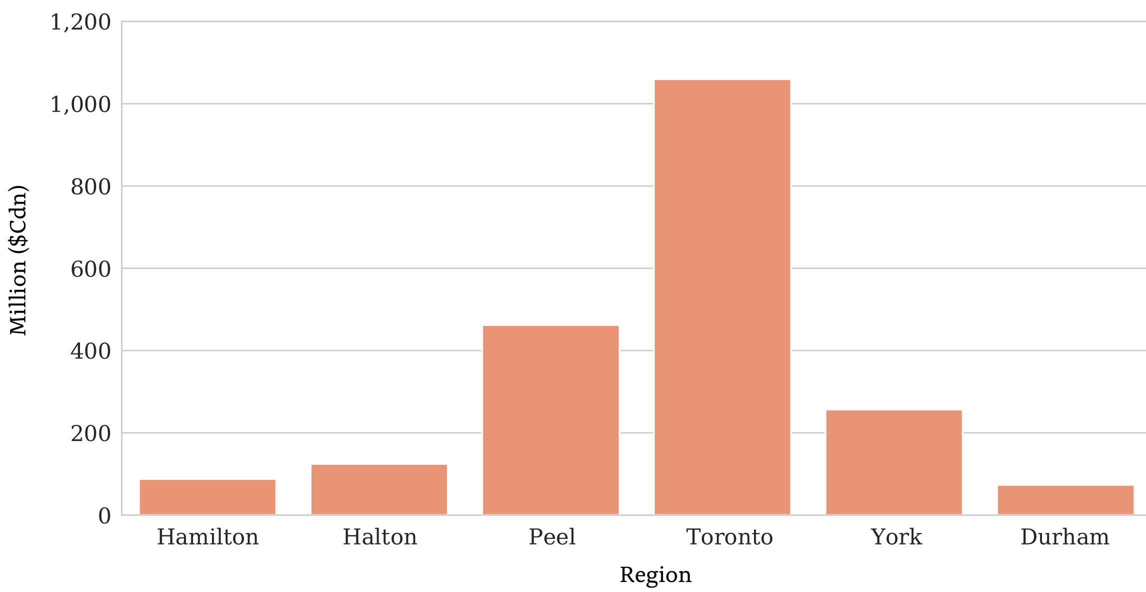
Renewing truck fleets has massive potential to bring immediate health benefits to many communities in the GTHA, particularly those outside of the City of Toronto along 400-series highways where truck traffic is concentrated. Air pollution data from sites near roads and highways in Toronto showed that larger, older trucks had a disproportionate impact on air pollution levels.[91]

This scenario ranked just behind 100 per cent car and SUV electrification in overall health benefits in the GTHA, which shows the impacts of cleaner truck fleets. However, it ranked last in GHG emission reductions, making only a small impact on carbon pollution. This illustrates the need to complement actions supporting cleaner commercial vehicles with strong action to support public transit bus and private passenger vehicle electrification, which can reduce GHG emissions more quickly in the short term.

Key outcomes include:

- 275 premature deaths prevented per year
- $2.1 billion social benefits
- 0.06 mega tonnes annual GHG reductions
- Proportionally greater benefits where truck traffic is most concentrated

ANNUAL SOCIAL BENEFITS WITH 100 PER CENT CLEANER TRUCKS BY REGION (IN MILLIONS $CDN)



POLICY PATHWAY: ACHIEVING TRUCK FLEET RENEWAL IN THE GTHA

POLICY RECOMMENDATIONS

There is a strong correlation between economic growth and trucking activity. This has meant a steep increase in commercial vehicle pollution in Ontario in recent years.[92] Despite a predicted economic recession period sparked by COVID-19, the long term trend is clear: economic and population growth means more demand for goods, and higher demand means increased air pollution and GHG emissions from moving these goods, unless we take substantial action. To successfully decouple economic growth from trucking emissions, we need cleaner trucks on our roads.

To get cleaner trucks on the road, we recommend prioritizing solutions that improve heavy truck fuel efficiency.

Since our modelling focused on the benefits of getting cleaner commercial vehicles on the road, we've excluded policies which reduce numbers of vehicles, kilometres driven or traffic congestion. Instead, we focused on a few solutions which would replace old trucks - the biggest polluters on the road when it comes to health impacts - with cleaner vehicles.

1. Truck scrappage (vehicle replacement) programs

This type of program would allow fleet or vehicle owners to "cash in" older, more polluting trucks and get financial help buying newer, more efficient trucks which cost more. Making electric trucks eligible for support through this program would allow fleets to gradually shift as technology improves and electric trucks come closer to price parity with diesel-powered trucks.

An effective replacement program should only incentivize newer trucks proven to reduce pollution in "real world" operating conditions, and include strong oversight of the destruction and recycling of the replaced vehicles to ensure heavy polluting vehicles stay off the roads.[93]

2. Maintain stringent fuel efficiency/fuel economy standards for trucks

The federal government's Heavy Duty Vehicle and Engine Greenhouse Gas Emission Regulations call for increasingly stringent emission standards for new trucks, much like the regulations in place for cars. Like standards for cars, Canada must take action to divorce its standards from the U.S. to keep them strong.

The economic argument for fuel efficiency is always there. However, with oil prices low, there's less incentive to cut fuel consumption. This makes regulations requiring fuel efficiency even more important in preventing an emissions spike.

3. Green commercial vehicle incentive programs

Ontario's previous Green Commercial Vehicle Program offered rebates to companies aiming to adopt electric or natural gas-powered trucks, and devices to retrofit existing trucks to reduce their emissions, such as aerodynamics retrofits, anti-idling devices, and electric trailer refrigeration. The program was cancelled alongside cap-and-trade, but early results from when the program was in operation showed promising emissions reductions and strong interest from the trucking industry.

Because of the slower turnover rates of large trucks compared to cars, devices and retrofits that help make existing vehicles cleaner are important to consider alongside incentives to purchase new vehicles.

In the long-term, governments will need to consider ways to accelerate the feasibility of truck electrification and other non-fossil energy sources. GHG emissions from commercial vehicles are expected to overtake passenger vehicles by 2030 as populations grow and goods movement grows in tandem.[94] We need a pathway to mass adoption of trucks that don't rely on burning fossil fuels.

4. Low Emission Zones where stricter vehicle emission standards are in place

In high-pollution areas with dense populations, cities or regions could restrict the most polluting vehicles from entering certain areas. The design of these zones is critical to success. Any exemptions and financial support should be aimed at low-income households and businesses, and should include measures to help transition them to cleaner vehicles.

More than 250 cities in the European Union have already implemented such measures. London's Low Emission Zone (LEZ) encourages the most polluting diesel trucks driving into the city to become cleaner. The LEZ covers most of Greater London and is in operation 24 hours a day, every day of the year. It's set to become even stronger later in 2020.[95] Other European cities have also seen strong results - Madrid has seen a 32 per cent decrease in NO_2 emissions from their LEZ.[96]

CASE STUDY: CALIFORNIA'S CARL MOYER PROGRAM

The California State Legislature created the Carl Moyer Program in 1998 - primarily a vehicle replacement (scrappage) program. It initially focused on reducing emissions from large trucks in order to meet air quality standards. It has since expanded to cars and has received strong public support. The program is funded by smog check, tire, and vehicle registration fees.

Large trucks of model year 1990 or older are eligible for vehicle replacement funding. The replacement vehicle must be a much cleaner model year 2007 or later vehicle, though it can be either new or used. These replacement vehicles reduce emissions of $PM_{2.5}$ and NO_x by more than 95 per cent. Local officials can modify the program to achieve maximum cost-effectiveness and meet their needs.

In its first 12 years, the benefits achieved by replacing more than 24,000 vehicles include reducing emissions of O_3 precursor pollutants—primarily NO_x and VOCs — by about 100,000 tons and $PM_{2.5}$ emissions by 6,000 tons.[97]

Conclusion

Strengthening and accelerating policies to electrify vehicles and renew truck fleets will lead to major health benefits for GTHA residents, significant social benefits, improved air quality and major reductions in carbon pollution.

Our modelling shows that cleaner vehicles, depending on their type, have uneven impacts on air pollution and climate change. For example, actions that drastically reduce air pollution from trucks may not significantly reduce GHG emissions. But both are pressing issues across the region, impacting health, society, and future generations.

This analysis highlights the necessity to reduce emissions from all categories of vehicles: cars and SUVs because they are important sources of GHG emissions and responsible for substantial health impacts and social benefits related to air pollution exposure; heavy trucks because they are responsible for more than half of the premature deaths from traffic-related air pollution exposure in the GTHA; and public transit buses because they operate more frequently in densely populated areas.

Seen through the lens of overall health, reducing all vehicle emissions, including GHG, is critical to improving health now and preventing the devastating future health impacts associated with climate change. As policymakers ask how can we reduce GHG emissions from transportation sources, an equally important question to ask is how can we improve population health and address health inequities.

Governments have the tools at hand to create a healthier population in the GTHA. By accelerating policies to electrify cars and buses, and getting newer, cleaner trucks on the road, they can save hundreds of lives per year, realize social benefits, improve air quality and slow the devastating impacts of climate change. These very real benefits are well worth the effort and investment in stronger clean vehicle policies.

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Methodology

The following methodology for the vehicle pollution and health modelling research was provided by the University of Toronto's Transportation and Air Quality Research Group, with input from the project's Vehicle Pollution Advisory Committee.

METHODOLOGY – SUMMARY

We first designed transportation scenarios for the Greater Toronto and Hamilton Area (GTHA), and developed traffic-related greenhouse gas (GHG) and air pollutants emission inventories for each of them. Then, we set up a chemical transport model (CTM) over the region and ran it for the different scenarios. Finally, we assessed the health outcomes and social benefits associated with the changes in population exposure under each scenario. The year of reference is 2016.

DESIGN OF THE STUDY CASES AND SCENARIOS

We've classified on-road vehicles driven in the GTHA into three categories, and included their emissions in our base case simulation: private passenger vehicles (mainly gasoline-fueled), public transit buses (mainly diesel-fueled), and commercial vehicles (mainly diesel-fueled with a small number of gasoline-fueled). Each category includes the following vehicles:

- Private passenger vehicles: private cars and SUVs, excluding taxis
- Public transit buses: public transit buses, including GO buses which travel from one municipality to another
- Commercial vehicles: short and long-haul vehicles (for instance trucks used for freight), which are diesel-fueled, and light commercial vehicles (for instance small vans and delivery trucks), which are mainly gasoline-fueled.

To assess the impact of each vehicle type on air quality in the GTHA we designed three study cases, each removing one type of vehicle: study case 1 - no private household vehicles; study case 2 – no public transit buses; and study case 3 - no commercial vehicles. We then compared the concentrations modeled under each study case with the base case to determine the contribution of each type of vehicle to the air pollution in the region.

Then, we designed five transportation scenarios, which were the outcome of consultations with stakeholders from an advisory committee. This group included public health organizations, sustainable transportation experts, and specialists from various levels of government. These scenarios were designed to evaluate the health and climate benefits of the separate partial or complete renewal of the three fleets of vehicles of the GTHA:

- 20 per cent of private passenger vehicles are fully electric (EVs)
- 50 per cent of private passenger vehicles are fully electric (EVs)
- 100 per cent of private passenger vehicles are fully electric (EVs)
- 100 per cent of public transit buses are fully electric
- All trucks (commercial vehicles, delivery vehicles) older than 8 are replaced with newer, more efficient models meeting at least 2008 technology standards

The two scenarios of partial electrification of the private passenger vehicle fleet were applied to all vehicles, and not necessarily the oldest: the electrification was proportionally distributed among all age bins following the 2016 age distribution.

Under the four scenarios of electrification, the electric vehicles (EVs) and electric buses were considered fueled with electricity produced according to the 2016 Ontario grid mix, which was 9 per cent natural gas, 61 per cent nuclear, 24 per cent hydro, and 6 per cent wind[1].

AIR QUALITY MODELLING

We set-up the chemical transport model (CTM) Polair3D over a large modelling domain encompassing the GTHA. Polair3D is part of a suite of air quality models, Polyphemus, and is developed at the Centre d'Enseignement et de Recherche en Environnement Atmosphérique (CEREA), France. We used the SIREAM-SOAP configuration with the chemical kinetic mechanism CB05[2, 3].

SETTING UP THE MODEL

We set-up the model over three nested domains, noted D1, D2, and D3 in decreasing order of size, with spatial resolutions of 12 km^2, 4 km^2, and 1 km^2, respectively (Figure 1). The domain of interest D3 is slightly larger than the GTHA and is vertically divided into 11 layers, the ground level being comprised between 0 and 20 m. We ran the model successively over D1, D2, and D3 with a temporal resolution of 10 minutes; average hourly concentrations were saved. The model included land-use, meteorology, initial and boundary conditions, as well as natural and anthropogenic emission inventories. Figure 2 summarizes the input data and their sources.

FIGURE 1 MAP OF THE THREE NESTED DOMAINS [4]

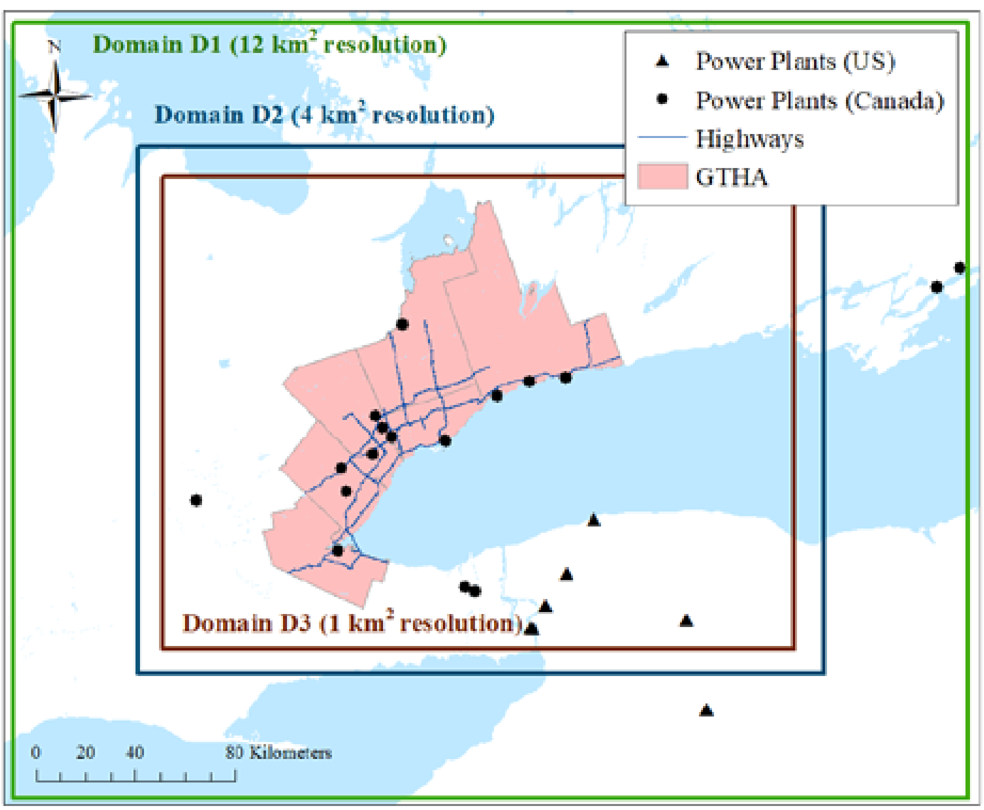
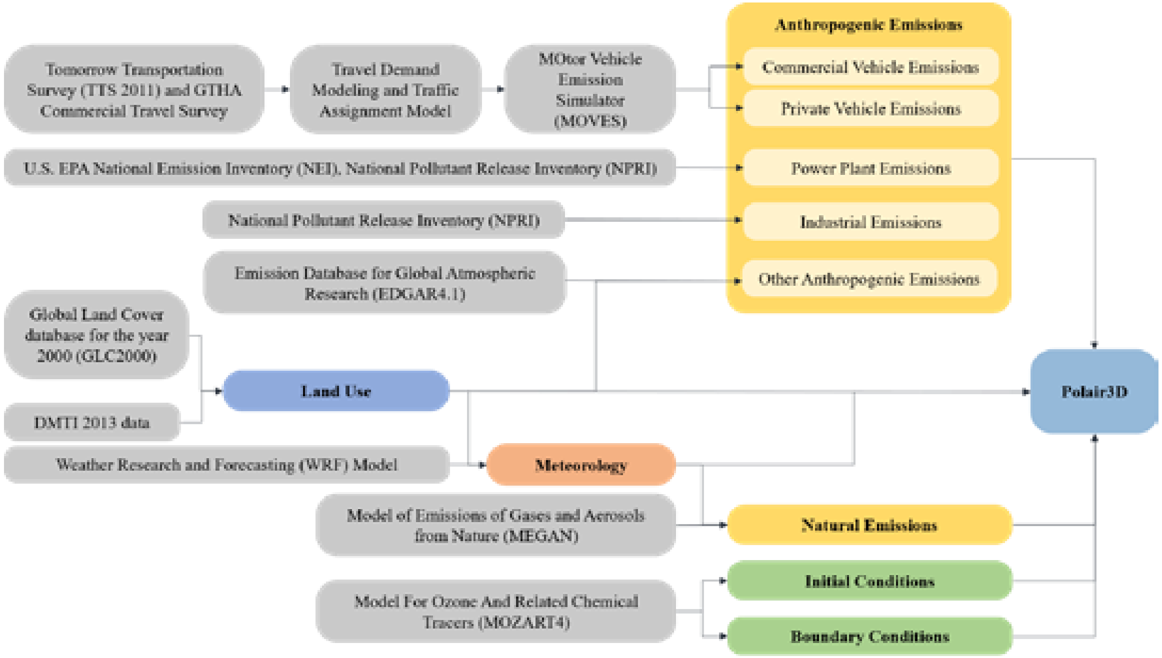


FIGURE 2 DIAGRAM OF THE SETUP OF POLAIR3D[4]



The modeling of air pollutant emissions from traffic and electricity production are detailed in the following paragraphs. The emissions from other anthropogenic sources were determined based on the National Pollutant Release Inventory (NPRI) database for industrial facilities[5], and from EDGAR 4.3.1 database[6] for the agriculture, aviation, shipping, railways, pipelines and off-road transport sectors.

Additionally, we quantified the operating and fuel-cycle GHG emissions from vehicles, which correspond to fuel production and consumption emissions for fossil fuel-powered vehicles, and to electricity production emissions (extraction, transportation and storage of natural gas, generation of nuclear, hydro and wind power) for electric vehicles. We focused solely on operating and fuel cycle GHG emissions rather than on life cycle emissions because considering life cycle emissions would mean calculating the GHG emissions associated with the production of vehicles, which is out of the scope of this study and varies depending on the vehicle in question.

The model was run for two weeks of 2016: 20th to 26th March, and 14th to 20th August, with a one-week spin-up, for each study case and each scenario, and we averaged the output concentrations of the two weeks.

TRAFFIC-RELATED EMISSIONS

We estimated link-level average speeds and volumes of private passenger vehicles and public transit buses using a traffic assignment model set up for the GTHA and based on Transportation Tomorrow Survey (TTS) 2011 data[7]. We assumed private passenger vehicles were all gasoline-fueled, and we divided them between cars and SUVs according to the age and vehicle distribution of Ontario[8]. Public transit buses were assumed to be diesel-fueled, and the fleet age distribution was based on data provided by the Toronto Transit Commission (TTC) and GO Transit, the two most significant transit service providers of the GTHA. Then, using speed-based emission factors derived from the Motor Vehicle Emission Simulator (MOVES)[9], we estimated link-level exhaust emissions of fine and coarse particulate matter ($PM_{2.5}$ and PM_{10}), nitrogen oxides (NO_x), sulfur dioxide (SO_2), ammonia (NH_3), carbon monoxide (CO), and non-methane volatile organic compounds (NMVOC), as well as brake and tire wear emissions of $PM_{2.5}$ and PM_{10}. For EVs and electric buses, we considered the exhaust emissions null. Since EVs and electric buses are heavier, we increased their tire wear $PM_{2.5}$ and PM_{10} emissions by 27 per cent and 18 per cent, respectively[10]; we also decreased their brake $PM_{2.5}$ and PM_{10} emissions by 25 per cent, because EVs and electric buses have a regenerative braking system[11].

Commercial vehicle emissions were derived from the combination of the output of a trip-based model for the GTHA developed by the Freight Transportation Group at the University of Toronto with emissions factors from MOVES[4]. Commercial vehicles were divided between gasoline-fueled light trucks, and diesel-fueled medium and heavy trucks. For the base case, we used the age distribution of commercial vehicles provided by the Canadian Vehicle Survey. Under the scenario with cleaner trucks, we replaced all diesel trucks older than eight years old with newer vehicles. We equally distributed the trucks older than eight (about 40 per cent of the fleet) over the age bins between zero and eight years old, and calculated the new link-based emissions following this new age distribution. The rationale for renewing all trucks older than eight years is that many scrappage programs are designed for vehicles of approximately that age or older[12, 13], and our goal was to assess optimal benefits. The scenario can be considered stringent compared to existing policies, but our goal was to assess optimal benefits.

The operating and fuel-cycle GHG emissions of the three types of fossil fuel powered vehicles were determined following the methodology described by Wang et al.[8]. We estimated the operating GHG emissions using MOVES and the well-to-pump GHG emissions using the fuel-cycle model Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) developed by Argonne National Laboratory[14].

We considered null the operating GHG emissions of EVs and electric buses, and we calculated the fuel-cycle GHG emissions associated with the electricity production using emission factors for each source: for natural gas, the emission factors were specific to each power plant, as detailed in the next paragraph; for the other sources, we used the emission factors developed for Ontario by Mallia et al.[15]: 0 kg CO_2 eq./MWh for hydro, 0.2 kg CO_2 eq./MWh for nuclear, and 0.74 kg CO_2 eq./MWh for wind.

NATURAL GAS POWER PLANT EMISSIONS

There are eight natural gas power plants in Ontario and eight power plants in the U.S within the domains we modeled. For Ontario, we developed the power plant emission factors of $PM_{2.5}$, PM_{10}, NO_x, SO_2, NH_3, CO, and NMVOC using data from the NPRI database[5]; for the U.S., we used data from the U.S. EPA Continuous Emissions Monitoring System (CEMS) and U.S. EPA National Emission Inventory (NEI)[16]. A detailed explanation of how we developed the emission factors specific to each power plant is available in Minet et al.[4]. We assumed that the other significant sources of electricity (nuclear, hydro and wind) did not emit air pollutants in the region.

Under the scenarios of private passenger vehicle electrification, we assumed night-charging of EVs when determining the additional air pollutant emissions of power plants. Using an energy-consumption rate of 23 kWh/100 km for EVs, a worst case scenario representing the average consumption rate of SUVs in Canada[17], as well as a charging efficiency of 89.4 per cent[18] and a 9 per cent electricity grid transmission and distribution line loss[19], we determined the hourly electricity needed by EVs. We attributed 9 per cent of this demand to power plants in Ontario (since 9 per cent of the electricity in Ontario was produced by natural gas power plants in 2016, our base year), and the remaining 91 per cent to the other electricity sources according to the grid mix of Ontario. Using the emission factors of each natural gas power plant, we then established the new emissions of air pollutants and GHG.

Under the scenario of complete deployment of electric buses, we assumed daily-charging of electric public transit buses. This has been shown to be feasible through careful infrastructure optimization[20]. We used an energy consumption rate of 170 kWh/100 km[21] for electric buses and the coefficients for charging efficiency and line losses previously stated to calculate the additional hourly electricity production needed. We allocated 9 per cent of this electricity production to the natural gas power plants of Ontario.

VALIDATION OF THE MODEL

We validated the concentrations of NO_2, O_3 and $PM_{2.5}$ simulated against hourly records at 17 to 19 reference stations in the GTHA during the two weeks chosen (20th to 26th March, and 14th to 20th August). The performance indicators used include bias, which can be positive or negative and quantify the tendency of a model to under- or over-predict the observations, as well as errors, which indicate how a model deviates from the observations[22]. Table 1 provides a description of the performance indicators, as well as the performance goals and criteria used for validation. Results from the validation were generally in alignment with the performance goals and criteria, as presented in Minet et al.[4].

Table 1 Description of the performance indicators and of the goals and criteria for validation of the base case simulation[22, 23]

Performance indicator		Performance goal	Performance criteria
Pearson Correlation Coefficient	$\frac{\sum_N (C_{i,t}-\bar{C})(O_{i,t}-\bar{O})}{\sqrt{\sum_N (C_{i,t}-\bar{C})^2}\sqrt{\sum_N (O_{i,t}-\bar{O})^2}}$ with $\bar{O}=\frac{1}{N}\sum_N O_{i,t}$ and $\bar{C}=\frac{1}{N}\sum_N C_{i,t}$	As high as possible	/
RMSE: Root Mean Square Error ($\mu g/m^3$)	$\sqrt{\frac{1}{N}\sum_N (C_{i,t}-O_{i,t})^2}$	As low as possible	/
MNBE: Mean Normalized Bias Error (%)	$\frac{1}{N}\sum_N \frac{C_{i,t}-O_{i,t}}{O_{i,t}} * 100$	/	≤±15%
MNGE: Mean Normalized Gross Error (%)	$\frac{1}{N}\sum_N \frac{\lvert C_{i,t}-O_{i,t}\rvert}{O_i} * 100$	/	≤±30%
MFB: Mean Fractional Bias (%)	$\frac{2}{N}\sum_N \frac{C_{i,t}-O_{i,t}}{C_{i,t}+O_{i,t}} * 100$	≤±30%	≤±60%
MFE: Mean Fractional Error (%)	$\frac{2}{N}\sum_N \frac{\lvert C_{i,t}-O_{i,t}\rvert}{C_{i,t}+O_{i,t}} * 100$	≤±50%	≤±75%

$O_{i,t}$ and $C_{i,t}$ are the observed and the modeled concentrations at time t and location i, respectively, and N is the total number of time-location pairs.

ASSESSMENT OF HEALTH OUTCOMES AND SOCIAL BENEFITS

The hourly concentrations of NO_2, $PM_{2.5}$, BC and O_3 obtained for each day of the two weeks simulated were averaged for the base case, and for the case studies and scenarios. These pollutants were chosen because the first three are markers of diesel exhaust[24] and O_3 is closely related to NO_2. To assess the population exposure, we used 2016 census data at the dissemination area (DA) level[25]. We first estimated the average concentrations in each DA, and then, using the DA of residence of each inhabitant of the GTHA, we estimated the residential exposure of all inhabitants of the region.

To analyze the health impacts of the different vehicle categories and the scenarios, we adopted a comparative risk assessment (CRA) approach. This approach enables the comparison of the burden of disease associated with the distribution of air pollution exposure under the base case and under the case studies and scenarios. The burdens are converted to the same units: Years of Life Lost (YLL), and number of premature deaths[26].

For each air pollutant of interest (NO_2, O_3, $PM_{2.5}$ and BC) we first identified in the literature a set of appropriate concentration response functions (CRF). A CRF relates a relative risk of mortality or disease (RR), a change in concentration (ΔC), and a coefficient β as in equation (1). Using the four CRFs identified (Table 2), we determined the associated β coefficient.

Then, for each case study and scenario, we calculated the Potential Impact Fraction (PIF), which represents the proportional reduction in air pollution induced-mortality associated with the decrease in exposure. It is calculated using the proportion of the population exposed to each concentration i in the base case (Pi) and in each alternative case (Qi), as shown in equation (2).

Third, we translated the PIF to changes in health impacts by calculating the attributable years of life lost (AYLL) and the attributable number of premature deaths (ANPD) (equation (3)). The AYLL and ANPD represent the number of years saved/number of premature deaths prevented (AYLL/ANPD negative), or the number of years lost/number of premature deaths (AYLL/ANPD positive) under each scenario. To calculate the AYLL and ANPD, YLL and the number of non-accidental deaths (named "Deaths" in equation (4)) for the GTHA population older than 25 years of age were provided by Statistics Canada. Since the correlations between the different pollutants were not considered in the set of CRFs chosen, we used the maximum outcome of one air pollutant, rather than the sum., to determine the final health outcomes of each scenario.

Finally, we estimated the economic value associated with the changes in premature deaths determined for each scenario, referred to as "social benefits" throughout the report. A value of statistical life (VSL) is a metric used to quantify the willingness to pay (WTP) of the population to decrease its risk of mortality. Using the VSL provided by the Canadian Cost-Benefit Analysis Guide[27] for 2004, we considered the inflation to adjust it for 2016 and obtained a value of $7.54 Million (2016CAD$). By multiplying this VSL value with the attributable number of premature deaths calculated for each case study and scenario, we determined the social benefits associated with the changes in exposure.

$$RR=e^{\beta \Delta C} \quad (1)$$

$$PIF=\frac{\sum_{i=1}^{n} P_i RR_i - \sum_{j=1}^{n} Q_j RR_j}{\sum_{i=1}^{n} P_i RR_i} \quad (2)$$

$$AYLL = PIF \times YLL \quad (3)$$

$$ANPD = PIF \times Deaths \quad (4)$$

Table 2 Concentration Response Functions (CRFs)

Pollutant (Source of the Concentration Response Function)	Cause	Relative risk of mortality (RR) associated with a 10 μg/m³ increase
NO_2 [28]	All Causes	1.053 (1.032 - 1.075)
O_3 [29]	Respiratory Disease	1.020 (1.07 - 1.033)
$PM_{2.5}$ [30]	All Causes	1.072 (1.041 - 1.093)
BC [30]	All Causes	1.791 (1.480 - 2.255)

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