



WWF

REPORT

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Greenhouse Gas Reduction Potential of Electric Vehicles: 2025 Outlook Report

WWF CLIMATE CHANGE AND ENERGY PROGRAM



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WWF's mission is to stop the degradation of the planet's natural environment and to build a future in which humans live in harmony with nature by: conserving the world's biological diversity, ensuring that the use of renewable natural resources is sustainable; and promoting the reduction of pollution and wasteful consumption.

EXECUTIVE SUMMARY

This report analyzes the potential contribution of plug-in hybrid electric vehicles and battery electric vehicles in greenhouse gas (GHG)

emissions reduction over the next decade in Canada. It provides an approximation of carbon emissions savings under unhurried, moderate, and aggressive electric vehicle (EV) market penetration scenarios.

In order to calculate the potential GHG emissions reduction of EVs, WWF-Canada developed a simulation model that takes into account different variables, such as average kilometres travelled, annual light-duty vehicle sales, annual vehicle retirement rate, electricity generation mix of different provinces, and three scenarios for EV sales growth. Under each scenario, an appropriate percentage of GHG emissions from gasoline combustion is replaced by associated GHG emissions from EV electricity usage. All scenarios follow the same exponential growth pattern that hybrid electric vehicles have experienced in North America since 2001. Under the first two scenarios, a relatively low exponential growth of 15 and 25 per cent is assumed. Predictably, these unhurried and moderate sales growth models for EVs over the next 13 years will make a very limited contribution to GHG reduction, compared with all other decision variables for sustainable transportation.

The more aggressive scenario of 35 per cent exponential growth and 12,000 vehicles on the road by the end of 2012 would be able to reduce 1.3 and 6.7 mega tonnes carbon dioxide equivalent (Mt CO₂-eq) per year by 2020 and 2025, respectively.

The electricity generation mixes of different provinces have a significant effect on the magnitude of GHG reductions. For example, emission reduction potential in British Columbia, where the electricity is generated from renewable sources, would be greater than emission cuts in Alberta, where coal is the predominant. In all cases, the GHG emissions reductions increase as the amount of renewable energy in generation mix increases. For example, if Canada were to phase out all coal power plants by 2025, the actual amount of CO₂-eq cuts from EVs in 2025, in the aggressive growth scenario, could increase up to 8.8 Mt.

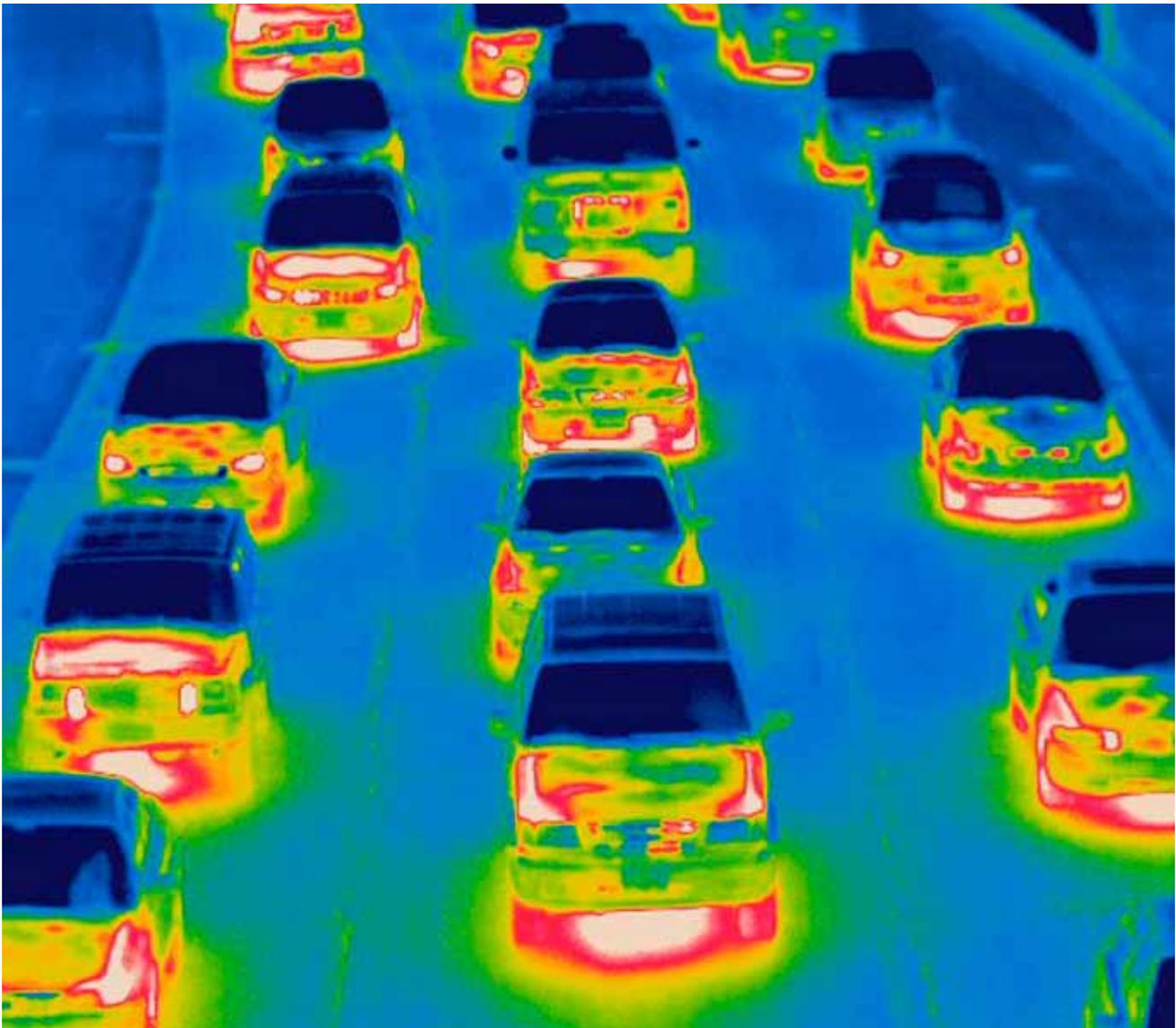
As a result of exponential growth starting from a very small initial number of EVs on the road, all models show that the short-term GHG reduction benefits from EVs are low, but once EVs reach significant penetration, the impact becomes highly significant.

The reductions in greenhouse gas emissions increase as the amount of renewable energy in generation mix increases.

The results demonstrate that electric vehicles can be a powerful long-term contributor to GHG emissions reduction.

In order to compare the role of EVs to other policy options for sustainable transportation, this model calculates the potential reductions from improving Corporate Average Fuel Economy (CAFE) standards and annual one per cent reduction of kilometres travelled (due to shifts in driving behaviour or investments in public transit).

The results demonstrate that EVs can be a powerful long-term contributor to GHG emissions reductions, but should be coupled with other strategies, especially to help meet short- and medium-term emissions reduction targets.



NATIONAL GEOGRAPHIC STOCK / TYRONE TURNER / WWF

According to the U.S. Department of Energy, even when a gasoline engine is operating at maximum thermal efficiency, 70-72% of the total energy released is lost as heat, without being turned into useful work.¹

INTRODUCTION

According to the 2009 national GHG inventory report issued by Environment Canada, road

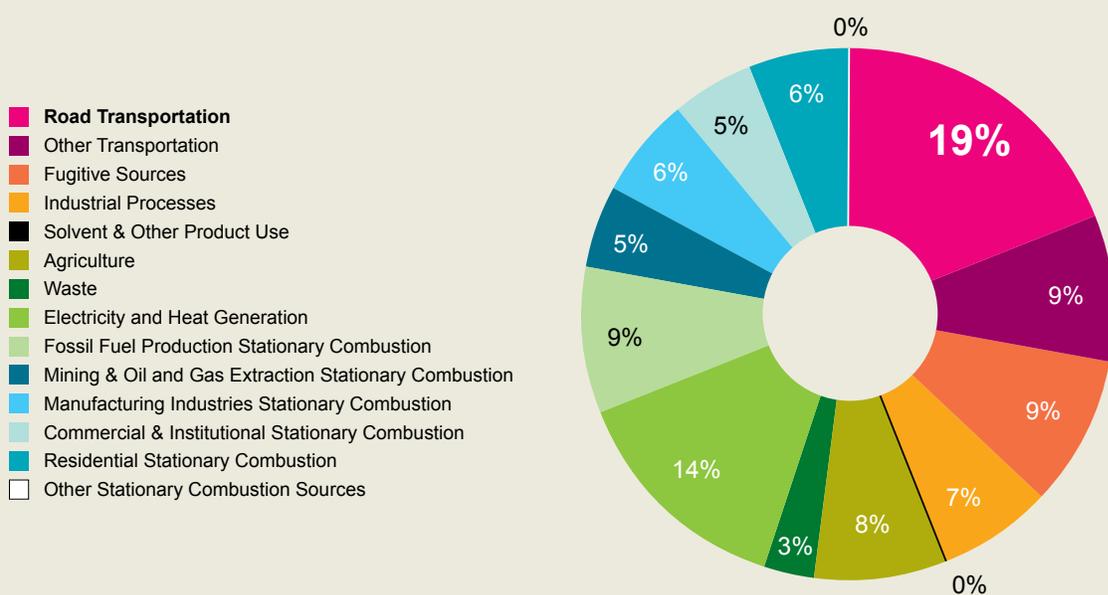
transportation is the single-most significant contributor to carbon emissions in Canada, accounting for 19 per cent of the country's total GHG emissions. Additionally, road transport emissions have increased by 35 per cent since 1990, second only to GHG emissions growth from the Canadian oil sands industry (Figure 1).

Tackling the emissions from this sector will require a set of actions under two main strategies: (a) reduce the amount of GHGs emitted per kilometre travelled (“decarbonize” transportation), and (b) reduce the kilometres travelled by vehicles.

The current dominance of private transportation confirms that any effective strategy to reduce GHGs from the transportation sector must include efforts to decarbonize private transportation, in addition to reducing kilometres travelled. Removing carbon from road commuting can be attained by expanding public transit, increasing fuel economy of vehicles, improving fuel quality, and substituting EVs for internal combustion engines.

Road transportation's GHG emissions have increased by 35 per cent since 1990.

Figure 1. GHG emissions breakdown by sector



SOURCE: NATIONAL INVENTORY REPORT 1990-2009: GREENHOUSE GAS SOURCES AND SINKS IN CANADA

No single sustainable transportation initiative will achieve the necessary emissions reductions. For example, transportation needs in dense urban areas may be met with good urban design, investments in public transit, and behavioural shifts to other modes such as walking and biking. In less dense areas, it may be neither technically feasible nor desirable to invest only in a public transit network, as transit networks running under minimum utilization levels emit more carbon per passenger than a single-occupancy private automobile.

Electrified transportation, including both public transit and electric vehicles, is a particularly important solution for sustainable mobility for a number of reasons, including helping manage the impact of increasing fuel prices and as a GHG emissions reduction tool. The GHG emissions reduction potential of electrified transportation is influenced heavily by how the electricity is generated, with more significant reductions in jurisdictions with less reliance on fossil fuels.

WWF-Canada, as part of its sustainable transportation campaign, developed an in-house simulation model to estimate the potential contribution of electric vehicles to GHG emissions reduction, taking into account different market penetration scenarios and electricity generation mixes in different provinces.



MICHAEL BUCKLEY / WWF-CANADA

ELECTRIC VEHICLES

Electric vehicles transform stored electric energy into motion. EVs are generally more efficient compared with internal combustion engine (ICE) vehicles. Electric motors convert 75 per cent of the chemical energy from the batteries to power the wheels, while ICEs only convert 20 per cent of the energy stored in gasoline.² The range of an EV is the maximum distance that it can travel before needing recharging and is determined by the size and energy intensity of the batteries. Some EVs derive all their power from battery packs and are called battery electric vehicles (BEVs). Other EVs are hybrid electric vehicles with batteries that can be charged externally, but with an ICE that drives the electric motor once battery power is depleted; these are plug-in hybrid electric vehicles (PHEVs).

BEVs emit no tailpipe pollutants; however, the actual amount of emissions created per kilometre driven depends on the electricity generation mix of the grid from which the battery is charged. For example, electricity from nuclear, hydro, solar, or wind-powered plants emits very low amounts of air pollutants. However, in order to accurately assess the emissions profile of a vehicle, it is essential to assess and compare the life cycle from manufacturing to disposal, or even 100 years after disposal.

Life Cycle Assessment of Electric Vehicles

Life cycle GHG emissions assessments of EVs evaluate the emissions associated with manufacturing, usage, and disposal of EVs and compare them with those of conventional vehicles. According to the *Journal of Environmental Science and Technology*,³ GHGs associated with lithium-ion battery materials and production account for only two to five per cent of life cycle emissions from PHEVs. As shown in this study, PHEVs reduce GHG emissions by 32 per cent per kilometre driven compared with conventional combustion engine vehicles, but have small reductions compared with traditional hybrid vehicles under the current U.S. electricity mix, which is heavily dependent on coal (with an average GHG intensity of 615 g CO₂-eq/kWh). Certainly, the most important factor in comparing the life cycle GHG impact of EVs is electricity generation mix. The potential role of electrified transportation in GHG reduction magnifies as we move toward less GHG-intense electricity generation mixes. According

to Environment Canada's *2009 National GHG Inventory Report*, the average electricity generation GHG intensity of Canada is 180 g CO₂-eq/kWh, while the electricity generation GHG intensity in provinces such as Alberta and Nova Scotia is much higher. In all cases, an EV charged by the existing provincial grid would produce less GHG emissions per kilometre driven than a similar ICE vehicle under the current fuel economy average, and this improves considerably as low carbon sources of electricity generation are increased.

GHGs associated with lithium-ion battery materials and production account for only two to five per cent of life cycle emissions from PHEVs.



ISTOCK / WWF-CANADA

CANADIAN MARKET

As EVs are an emerging technology, their growth rate is difficult to predict, and there are markedly different EV sales-growth projections

by different consulting and market research firms. Table 1 shows the U.S. EV market share projections by Deloitte,⁴ Boston Consulting Group (BCG),⁵ and Deutsche Bank⁶ under different scenarios. Most growth projections are based on different consumer purchase prices, different EV ranges, and global oil price. For instance, the conservative growth scenario of Deloitte refers to high EV purchase price (US\$ 45,000), low range capability of EVs (100 miles/full charge), and low gas price (US\$ 3/gallon).

Since 2001, hybrid vehicle market share growth in North America followed an exponential pattern, with an average growth of 46 per cent.

Table 1. EV market-growth projections in United States by different firms and institutes

	Deloitte	BCG	Deutsche Bank
2020 Outlook	Conservative (1.9%)	Slowdown (1%)	7%
	Probable (3.1%)	Steady pace (4.8%)	
	Aggressive (5.6%)	Acceleration (10%)	

This report does not focus on analyzing the rationale behind each introduced scenario. Rather, it tries to evaluate the potential contribution of EVs in reducing GHGs. For that reason, three different market share growth scenarios are introduced and the role of EVs examined under each scenario.

Electric Vehicle Scenarios

The report introduces three different market growth scenarios:

1. Unhurried market growth (business as usual)
2. Moderate market growth
3. Aggressive market growth

Moderate exponential growth of 25 per cent post-2012 will result in capturing 3.9 per cent market share by the end of 2020.

According to a number of studies,⁷ it is fair to assume that EVs would follow more or less the same growth pattern that hybrid vehicles experienced over the past decade in the North American market. Since 2001, hybrid vehicle market share growth has followed an exponential pattern with an average growth of 46 per cent. WWF-Canada has assumed that the growth of EVs in Canada will more or less mirror the growth of EVs in the United States.

Unhurried market growth (business as usual)

The “business as usual” scenario assumes a very limited number of EVs on the road over the next decade. It represents very limited success of EVs in the North American marketplace. Under this scenario, it is assumed automakers will only put 4,000 EVs on Canadian roads by the end of 2012, followed by 15 per cent exponential market growth, resulting in EVs capturing only 0.7 per cent of 2020 market share. Not surprisingly, the extremely small market share of EVs would not have considerable GHG emissions reductions over that time frame, or even in the following five to 10 years.

Moderate market growth

This scenario refers to moderate market share growth of PHEVs and BEVs. This scenario assumes automakers will be able to sell 8,000 EVs by the end of 2012. Moderate exponential growth of 25 per cent post-2012 will result in capturing 3.9 per cent market share by the end of 2020. The moderate EV market share would have emissions reductions higher than the first scenario.

Aggressive market growth

In the “aggressive market growth” scenario, the model assumes an ambitious 12,000 EVs on the Canadian roads by the end of 2012 and 35 per cent growth in market share (equal to North American hybrid vehicle market share growth since 2001). Under this scenario, EVs would be able to capture 10.4 per cent of year model sales in 2020 (Table 2). Predictably, the GHG emissions reduction benefit of this option would be higher than the other scenarios.

Table 2. Description of three different introduced scenarios			
	EVs on the road by 2012	Market Growth Rate	2020 market share
Unhurried (BAU)	4,000	15%	0.7%
Moderate	8,000	25%	3.9%
Aggressive	12,000	35%	10.4%

Plug-in hybrid EVs are expected to use 40-60% less petroleum than conventional vehicles.

Simulation

WWF-Canada's model of the effect of EVs on GHG emissions takes into consideration different factors, such as vehicle sales growth, EV market share growth, average fuel economy of year models and vehicles on the road, average distance travelled, annual vehicle retirement rate, and electricity generation mixes in different provinces.

It is also important to make a distinction between PHEVs and BEVs, in terms of GHG emissions. In PHEVs, the gasoline engine kicks in when the battery runs out of charge. So, many factors such as battery range, driving habits and daily commuting distance determine the gasoline consumption and associated GHG emissions. According to some research,⁸ PHEVs are expected to use 40 to 60 per cent less petroleum than conventional vehicles. In accordance with studies published by some consulting management firms, such as McKinsey and Company,⁹ PHEVs are predicted to be the preferred drive train, at least in the short term.

In order to estimate the potential GHG emissions reduction contribution of EVs, the model assumes average kilometres travelled by passenger cars, based on data from the *Annual Canadian Vehicle Survey* report. By replacing the gasoline consumption of a small proportion of the vehicles on the road with the appropriate electricity usage of PHEVs and BEVs and calculating the associated GHG emissions of electricity generation, WWF-Canada estimated the annual potential emissions reductions.

Since the growth pattern of EV market share is assumed to be exponential, the initial prediction for the number of EVs on the road in 2012 vastly influences the number of electrified vehicles in 2020 and beyond. Therefore, the number of EVs on the road at the end of the first simulation year is an essential assumption of this model.



EDWARD PARKER / WWF-CANADA

As expected, the GHG emission reduction potential of EVs increases as the amount of low carbon energy in the electricity generation mix increases in each province.

Simulation Results

Scenario 1

Assuming automakers will be able to put only 4,000 PHEVs and BEVs on the road by the end of 2012, analysis shows unhurried growth of EVs over the next decade will result in potential reduction of 100,000 tonnes of CO₂-equivalent emissions by 2020, and 300,000 tonnes by 2025. This marginal reduction would be the same as taking 116,000 cars off the road by 2025.

Scenario 2

This moderate scenario assumes 8,000 EVs on the road by 2012 and moderate exponential growth of 25 per cent over the next decade will result in capturing 3.9 per cent of new vehicle year model sales of Canada in 2020. Under this scenario, the total cumulative number of EVs on the road would be able to save 500,000 tonnes of CO₂-equivalent emissions by 2020, and 1.6 million tonnes by 2025. This reduction would be similar to taking 620,000 cars off the road by 2025.

Scenario 3

This aggressive scenario assumes that automakers can sell 12,000 EVs to the Canadian market by the end of 2012. Assuming the ambitious growth of 35 per cent over the next 10 to 15 years, PHEVs and BEVs would be able to potentially reduce 1.3 million tonnes of CO₂-equivalent emissions by 2020, and 6.7 million tonnes only five years thereafter. This reduction would have the same impact as taking 2.6 million cars off the road by 2025.

Table 3 summarizes the 2020 potential GHG emissions reduction of EVs under different scenarios and electricity generation mixes.

Table 3. Potential GHG emissions reduction of EVs under different growth scenarios and electricity generation mixes				
	GHG emissions reduction under existing generation mix (Mt)		GHG emissions reduction under no coal generation mix (Mt)	
	2020	2025	2020	2025
Unhurried	0.1	0.3	0.2	0.4
Moderate	0.5	1.6	0.6	2.1
Aggressive	1.3	6.7	1.7	8.8

In order to get a better sense of how EVs compare with other GHG reduction strategies and policy options, this report also compares the potential contribution of improving CAFE standards, reducing kilometre travelled by vehicles, and increasing use of EVs (scenario 3; Figure 2 and Figure 3).

CAFE standards improvements are assumed to be in line with Canadian fuel economy regulations until 2016 and proposed U.S. fuel economy from 2016 to 2025. In terms of reducing kilometres travelled by vehicles, the model assumes an average of one per cent reduction in annual average kilometre travelled by Canadian vehicles. This reduction will come from different policy tools and options, such as investing and expanding public transit, behavioural changes practices and increasing fuel taxes.

Figure 2. Potential GHG emissions applying two policy variables and reducing vehicle-km travelled – Light-Duty Vehicles (2020)

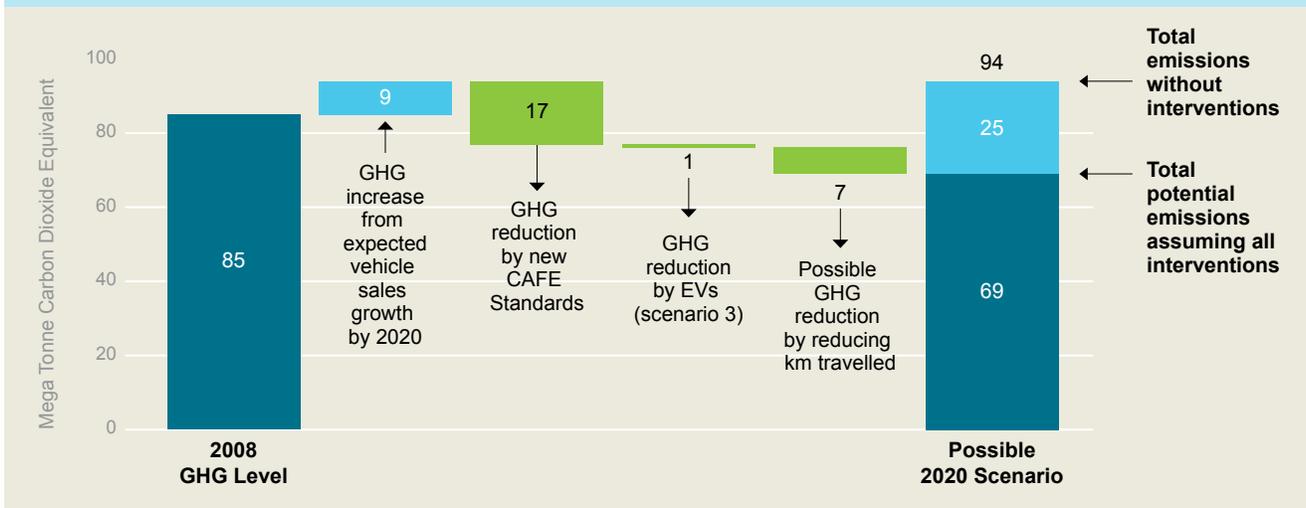
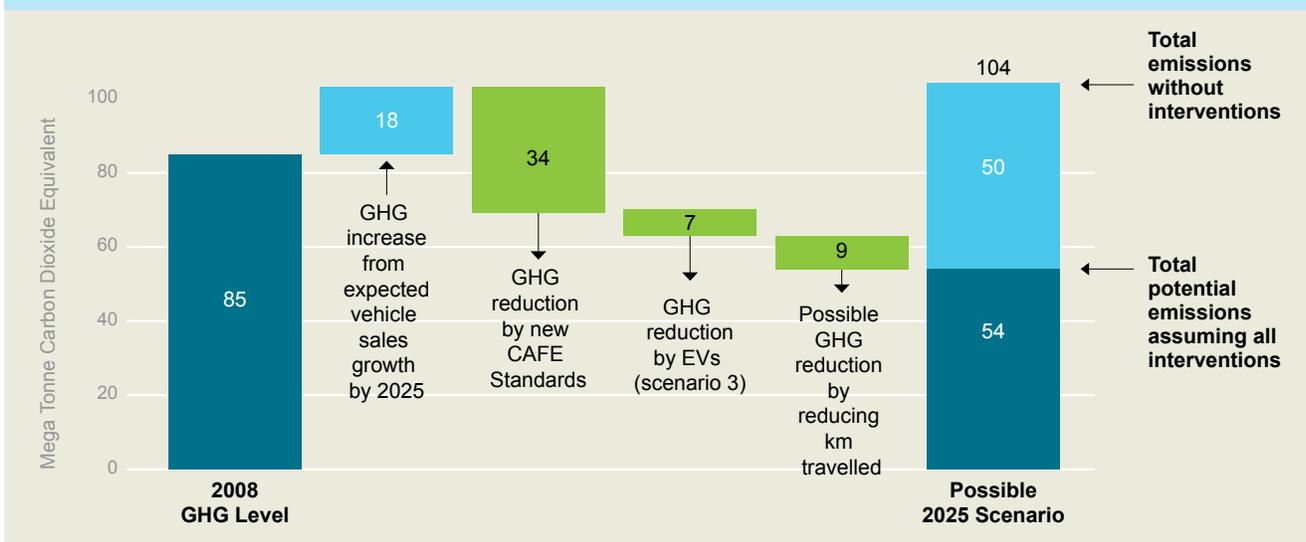


Figure 3. Potential GHG emissions applying two policy variables and reducing vehicle-km travelled – Light-Duty Vehicles (2025)



CONCLUSION

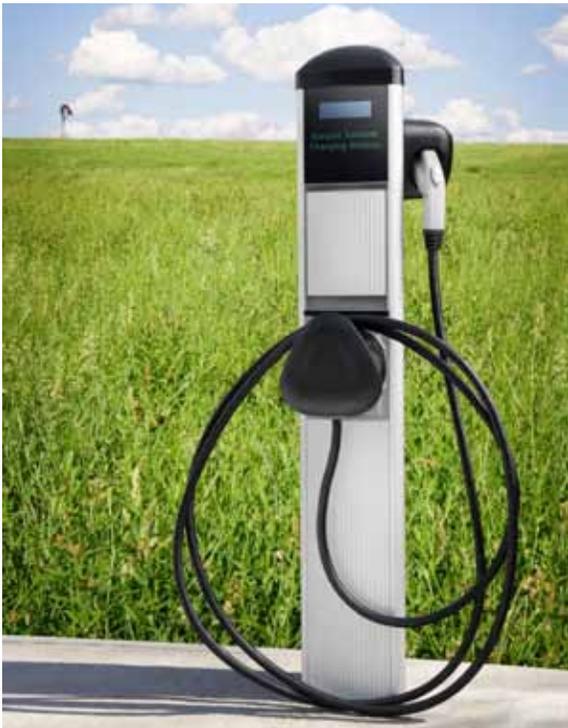
Road transportation is the greatest contributor to GHG emissions in Canada, and the second-highest growth source of emissions in the

country. As such, it must be addressed as part of any successful strategy to significantly reduce Canada's GHG emissions. There are two key strategies to reduce emissions from this sector: reducing vehicle kilometres travelled and decarbonizing the transportation (i.e., increasing the use of EVs). There is no single comprehensive solution for sustainable mobility; rather a set of tools and options, deployed in concert, can help Canada reduce its emissions from road transport.

This report analyzed the potential contribution of electric vehicles in reducing GHG emissions by decarbonizing the transportation. Many respected consulting management and financial market research companies have already introduced different growth scenarios for EVs in North America based on global oil price, battery technology advancement, purchasing price, and availability of charging

infrastructure. This report introduced three different growth scenarios (unhurried, moderate, and aggressive) but does not study the likelihood or enabling conditions necessary for each scenario. By developing a road transportation GHG simulation model, WWF-Canada focuses on the potential role of EVs in emissions reduction, under different scenarios.

As illustrated by this report, even under existing electricity generation mixes and fuel economy standards, electric vehicles would reduce emissions in all provinces, compared with ICE vehicles. However, due to the low initial market penetration, EVs are not an effective solution to meet short-term GHG emissions reduction targets. As market penetration increases, EVs could become a critical—perhaps essential—component to Canada's long-term emissions reduction strategy.



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ENDNOTES

- 1 <http://www.fueleconomy.gov/feg/atv.shtml>
- 2 *Energy Efficiency and Renewable Energies*, US Department of Energy, <http://www.fueleconomy.gov/feg/evtech.shtml>.
- 3 Samaras and Meisterling (2007), “Life Cycle Assessment of Greenhouse Gas Emissions from Plug-in Hybrid Vehicles: Implications for Policy”, *Journal of Environ. Sci. Technol.* 2008, 42, 3170–3176.
- 4 *Gaining Traction: A Customer View of Electric Vehicles Mass Adoption in the US Automotive Market*, Deloitte, 2010.
- 5 *The Comeback of Electric Vehicles?*, Boston Consulting Group, 2009.
- 6 *Electric Cars: Plugged In*, Global Market Research Report, Deutsche Bank, 2008.
- 7 John Shamus Cunningham, “An Analysis of Battery Electric Vehicle Production Projections”, Master Thesis, e Department of Mechanical Engineering, MIT, 2009.
- 8 *Well-to-Wheels Energy Use and Greenhouse Gas Emissions Analysis of Plug-in Hybrid Electric Vehicles*, Center for Transportation Research Energy Systems Division, Argonne National Laboratory, Feb 2009.
- 9 *Electric Vehicles in Megacities – Shanghai Charges Up*, McKinsey & Company Report, 2010.

Transportation by the Numbers

19

Road transportation is the single-most significant contributor to greenhouse gas emissions in Canada, accounting for 19 per cent of total emissions in 2009

35

Road transportation emissions have increased by 35 per cent since 1990, second only to greenhouse gas emissions growth from the Canadian oil sands industry



60

Plug-in hybrid electric vehicles are expected to use 40 to 60 per cent less petroleum than conventional gasoline vehicles

180

The greenhouse gas emissions intensity of electricity generation in Canada averaged 180 grams of CO_2 -eq per kWh generated in 2009 – far less emissions than the average 615 grams in the United States



Why we are here.

We are creating solutions to the most serious conservation challenges facing our planet, helping people and nature thrive.

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