Canadian Passenger Vehicle Scrappage Policy Analysis

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Executive Summary

To support the reduction of CO_2 emissions from the Canadian automotive fleet, while stimulating automotive sales; vehicle scrappage programs options are examined. New vehicle purchase scenarios as replacements for higher CO_2 emitting scrapped vehicles are explored. The scrapped vehicle is assumed to be a 15-year-old average light-duty vehicle (passenger car or light truck) corresponding to a 2005 model year (MY). With an assumption of a 25-year vehicle lifespan, the time frame of analysis is 2021 to 2030, representing the 10 years remaining life of the scrapped vehicle. A new vehicle is assumed to drive 20,000 km per year each year throughout the 2021 – 2030 timeframe. It is also assumed that the scrapped vehicle would have also driven 20,000 km/year in this timeframe had the vehicle remained on the road.

The analysis looks at various scenarios for what types of new vehicles are eligible to be purchased as part of the scrappage program. In Scenario 1, incentive funds can be applied towards an electric vehicle (EV) or plug-in-electric vehicle (PHEV) only. In Scenario 2 consumers can direct program funds towards an EV, PHEV or an internal combustion engine vehicle (ICEV), provided that the ICEV CO_2 emissions are below a certain threshold. In Scenario 3, funds can be used for an EV, PHEV or ICEV purchase; however, for an ICEV to be eligible for incentive funding, it must be 30% more fuel efficient than that of the scrapped vehicle. Finally, a fourth scenario that is a variant of Scenario 1 ("Scenario 1A") was analyzed to consider a situation in which program incentive funds are offered only towards the purchase of an EV.

The analysis was performed on a per-vehicle basis to quantify the net CO_2 removed under each scenario for a single vehicle scrapped and replaced by a new vehicle. The emissions of the scrapped vehicle is assumed to be that of an average 2005 model year (MY). The new vehicle exhibits characteristics as per the 4 scenarios described. Each scenario is compared against a baseline that represents a scrappage program in which there are no restrictions on the new vehicle purchase, and it is therefore assumed that in this base case the new vehicle will exhibit characteristics of an average 2020 vehicle. The scrapped vehicle will also be 2005 MY vehicle under the baseline scenario.

Table 1: Key Assumptions

Input Variable	Assumption	Comments
All Scenarios & Baseline		
Scrapped vehicle age/MY	15 years old/ MY 2005 for all scenarios	
Vehicle lifespan	25 years	
Timeframe of study	10 years; 2021-2030	Represents the 10 years of residual life of the scrapped vehicle
Kilometers driven per year	20,000 km	Assumes no degradation in annual km over vehicle lifetime. Per-vehicle activity is assumed to be 20,000 km/year
CO_2 emissions rate of scrapped vehicle	Average MY 2005 emissions at 269 g CO_2/km	Derivation described below
New Vehicle Scenario Assumptions		
New Vehicle	MY 2020 for all scenarios with a unique average g CO_2/km value calculated for each scenario.	
Scenario 1 new vehicle CO_2 emissions rate	56.7 g CO_2/km	Derivation described in Annex 1
Scenario 2 new vehicle CO_2 emissions rate	94.7 g CO_2/km	Derivation described in Annex 1
Scenario 3 new vehicle CO_2 emissions rate	101.4 g CO_2/km	Derivation described in Annex 1
Scenario 1A new vehicle CO_2 emissions rate	29.9 g CO_2/km	Emissions of average MY 2020 EV
Baseline	230.7 g CO_2/km	Emissions of average MY 2020 vehicle

Input Variable	Assumption	Comments
Other Assumptions:		
Electricity grid carbon intensity for 2019 EV analysis	15.7 g CO_2/km	Weighted average based on 2019 EV registrations in Canada and provincial grid carbon intensities
Electricity grid carbon intensity for 2021 – 2030 analysis	169.5 g CO2/km	Weighted average based on all provincial vehicle registrations in 2019 across Canada and respective provincial grid carbon intensities
Conversion of L/100km to g CO_2/kg	2,348 g CO2/Liter gasoline	From the EPA specified 8,887 g CO_2/ gallon gasoline. This value is used in all cases throughout paper to covert fuel consumption figures to emissions except where diesel vehicles are segmented out. In this case, the value of 10,180 g CO_2/ gallon diesel equal to 2,689 g CO2/liter diesel is used.
All dollar ($) figures in CAD unless otherwise specified		

Table 2 below illustrates the net CO_2 reduction over the 10-year timeframe on a per-vehicle basis for the 4 scenarios as well as the base case. The scrapped vehicle is assumed to be identical in each of the four scenarios, so the avoided CO_2 emissions are equal in all cases. The CO_2 added under each scenario is the distinguishing factor that varies across each scenario (values in red). The CO_2 added over the 10-year timeframe includes the CO_2 emissions due to early production of the respective vehicle. In comparison to the baseline, each scenario displays an overall benefit in terms of additional CO_2 removed. The EV-only scenario (Scenario 1A) demonstrates a more than 10-fold improvement compared to the baseline.

Table 2: Summary of Results

	BASELINE	Scenario 1	Scenario 1A	Scenario 2	Scenario 3
Tonnes CO_2 **Removed** from Scrapped Vehicle	53.8	53.8	53.8	53.8	53.8
Tonnes CO_2 **Added** from New Vehicle (including early production impact)	49.4	13.6	8.0	21.1	22.4
Net Tonnes CO_2 Emission **Reduction**	**4.3**	**40.2**	**45.7**	**32.7**	**31.3**
Incremental Tonnes Removed vs Baseline		**35.9**	**41.4**	**28.3**	**27.0**
% improvement to Baseline		**827%**	**954%**	**653%**	**622%**

While clearly an environmental benefit, the economic benefit of generating additional EV sales will be skewed towards dealers that sell electric vehicles; and ultimately OEMs that produce these electric vehicles, along with the respective manufacturing locations. With policy and investment attraction initiatives to draw more EV manufacturing to Canada, these initiatives could indirectly benefit from scrappage policies designed to encourage increased local EV demand.

The analysis is on a per vehicle basis and does not consider the total number of incremental vehicles that incentives will yield. An EV-only option would likely result in fewer incremental new vehicles than if ICEVs are permitted – most certainly if per-vehicle incentive funding is equal for EVs and ICEVs. Traditional impediments to EV consumer adoption continue to exist. While EV driving ranges continue to improve, corresponding government initiatives to expand the charging infrastructure and increase charging locations will make EVs more attractive to an increasing number of consumers.

Finally, the benefits of EVs with respect to CO_2 emissions is directly dependent on the mix of feedstocks feeding the electricity grid. Thus, corresponding policies to promote clean energy generation sources will reduce the carbon intensity of the grid and improve the effectiveness of introducing more EVs to the fleet.

Introduction

At the onset of the COVID 19 pandemic and the ensuing demand shock across the global economy, the automotive sector in Canada has been impacted significantly. In the month of March as lockdowns went into effect, Canadian new vehicle sales exhibited significant declines.

An opportunity exists to both stimulate the economy through new car sales, while also implementing environmentally prudent measures aimed at reducing carbon emissions. Encouraging new purchases of fuel-efficient low CO_2 emitting vehicles; contingent upon the removal older higher CO_2 emitting vehicles; will serve to drive a net reduction of this key greenhouse gas from the environment, while stimulating new vehicle sales.

This paper will assess the outcome of various scrappage scenarios to support recommendations for a scrappage policy. Prior scrappage programs will be summarized; as well as more recent initiatives, and proposed initiatives in the wake COVID 19. The current state of the Canadian auto market will be examined with an analysis on 2019 sales data, identifying key trends and determining the average CO_2 emissions of these 2019 vehicles. Average CO_2 emissions of prior year model years are sourced from multiple data sources. With the model year mix of the Canadian fleet, an average vehicle age, and average g CO_2/km of all Canadian registered vehicles is determined.

Four scrappage scenarios are examined and compared to a baseline. Each scenario assesses the impact of replacing a scrapped vehicle with a new vehicle. The permitted new vehicle or choice of vehicle in each scenario is restricted and differs across each scenario. A fleet model is developed to determine the net tonnes CO_2 removed in each of the 4 scenarios as well as in a baseline scenario. All vehicles are assumed to have a 25-year lifespan and assumed to be driven 20,000 km/year. The scrapped vehicle is assumed to be 2005 model year (MY) vehicle, and at 15 years old, to have 10 years of useful life remaining. With this assumption the time period of the study is from 2021-2030 inclusive representing the years the scrapped vehicle would have remained on the road, but instead is replaced by the new vehicle under each scenario. The study is for a current one time scrappage program's impact on this timeframe, and does not consider any impact of future scrappage initiatives that may occur in subsequent year during this timeframe. In closing the outcomes of the 4 scenarios are analyzed and discussed and compared against the baseline scenario. Items of consideration are raised, and policy recommendations are presented.

Scrappage Schemes

Scrappage programs incentivize owners of older vehicles to retire, or scrap, their vehicle. Removing these older polluting vehicles from to road, as opposed to selling them on the secondary market as a used car prevents emissions from being released into the environment. As such it is pertinent that such older high emitting vehicle actually be removed from circulation, and a scrappage program can facilitate this.

Programs are often conditional upon the purchase of a new vehicle and coupled with additional incentives towards the purchase of a new fuel-efficient/low CO_2 emitting vehicles as a replacement vehicle. Such situations can serve the dual purpose of a favorable environmental impact by inducing a net decrease in CO_2 emissions, and an economic impact of stimulating auto sales.

Incentives can however include other options designed to discourage the purchase of a new vehicle all together, while still prompting the removal of an older polluting vehicle. Such incentives can include transit passes, discounts on bikes, and car share service memberships. In these cases, although the net CO_2 removal will be significantly higher and therefore more environmentally beneficial, it would not provide economic stimulus to the automotive sector through new vehicle sales.

Canadian Scrappage Programs

There have been previous scrappage and incentive programs in Canada, most notably the national program known as *Retire Your Ride*. Other programs include various provincial programs, key amongst them the current BC's Scrap It program; which is also the oldest and longest running program in the country; and the current Ontario Plug'n Drive program which incentivizes purchases of used electric vehicles, recently adding a scrappage component to the program.

Retire your Ride

Retire your Ride was a nationwide scrappage program, also known as the *National Vehicle Scrappage Program*. The 2007 Federal Budget targeted investments in clean air, greenhouse gas reduction and overall climate change mitigation; and the removal of older polluting vehicles from the road was specifically cited as a measure to achieve the clean air objective.[1]

The program was launched in January 2009 targeting the removal of vehicles from the 1995 model year and earlier. These vehicles were higher polluting as emissions standards were tightened in 1996. It was estimated that as of 2007 there were approximately 4.6 million 1995 model year or earlier vehicles on Canada's roads which were said to be 19 times more polluting than 2004 model year vehicles; the year in which emissions standards were again tightened.[2] These 1995 or earlier model year vehicles were therefore targeted to remove and scrap.

Environment Canada operated the program and partnered with the Non-Profit, *Clean Air Foundation*[i]. The cash incentive for scrapping an old vehicle was $300. The main goal of the program was the removal of high polluting vehicles from the road, with a secondary objective of greenhouse gas emission reduction through the promotion of sustainable transportation adoption, and vehicle recycling best practices. As such the program did not solely focus on generating new vehicles sales. In addition to rebates on new vehicles, incentives also included transit passes, discounts on bicycles and e-bikes, and memberships in car sharing programs. The program ended in March 2011, and from the period of Jan 2009 to March 2011 a total of 138,600 vehicles were removed from the road. An additional benefit of the program was greater awareness and compliance with environmentally safe recycling practices abiding by the Automotive Recyclers of Canada code.[3]

Prior programs had existed at a national level such as Car Heaven, which although had received operational support from Environment Canada, was not federally funded.[4] This program targeted functioning and non-functioning vehicles, the latter of which were not at the time emitting CO_2 while in a dormant state[5]. Car Heaven was also run by the Clean Air Foundation and as such served to provide

[i] Currently *Summerhill Impact*

insights and lessons learned when designing the Retire Your Ride program. At the termination of the Retire Your Ride program the Clean Air Foundation opted to relaunch the Car Heaven program.

Scrap It (BC)

As the first scrappage program in Canada, BC's *Scrap-It* program is a provincial initiative which has scrapped 49,747 vehicles from April 1996 to Aug 2020[6]. Scrapped vehicles must be registered in the name of the applicant, must be delivered intact without any parts removed, and must be a gasoline, diesel natural gas or propane vehicle in order to claim an EV purchase incentive. The vehicle purchase incentives are towards the purchase of new or used EVs. No incentives are offered towards PHEVs or ICEV vehicles.[ii]

For qualifying new EVs[iii] a $6000 rebate is offered, and a $3000 rebate is offered towards qualifying used EVs[iv]. Other incentive choices include BC Transit passes (an $880 value), rebates of $1,050 towards an electric bike, car share credits of $500, cash rebates of $200 and, $100 rebates for non-qualifying scrapped vehicles. Perks also include free home charging kits. The program has recently announced an expansion into Alberta attempting to mimic the favorable results in BC[7].

Plug'n Drive (Ontario)

The Ontario *Plug'n Drive* program launched in April 2019 offering incentives of $1000 only towards the purchase *used* EVs or PHEV). A scrappage incentive component was added in Feb 2020. This enhancement to the programs offers an additional $1000 to scrap an old gasoline powered vehicle. The program is run by the non-profit 'Plug n Drive', is privately funded by the M.H. Brigham Foundation, and operates in collaboration with the Clean Air Partnership[v]

Global Scrappage Schemes

United States:

A 2009 program commonly known as 'Cash for Clunkers' or the Car Allowance Rebate System (CARS) program was introduced in the aftermath of the global financial crisis. The $3 billion program was launched in July 2009 and offered $3500- $4500 for trade-in vehicles of 18mpg or less[8]. The program came to an end in August 2009 with 685,000 vehicles scrapped. Scrapped vehicles averaged 15.8 mpg with the new vehicle replacement averaging 24 mpg.[9]

There has been consideration of another such automotive stimulus program. In the fall of 2019, a Senate proposal 'Clean Cars for America' suggested a $454 Billion plan to increase the affordability of EVs, PHEVs and HEV vehicles, improve the accessibility of charging infrastructure, and promote US based manufacturing of clean vehicles[10]. The objective of the plan is to remove 63 million gasoline powered vehicles from US roads over 10 years. This plan and has been embraced by Presidential Candidate Joe Biden as part of his clean energy and infrastructure vision[11].

[ii] https://scrapit.ca/faqsinfo/programpolicies/

[iii] A qualifying new or used vehicle is defined as "A car, truck, van or other motor vehicle with an electric engine/motor that is highway capable and has 4 wheels" (https://scrapit.ca/qualifyingevs/)

[iv] https://scrapit.ca/evincentivechoices/

[v] https://www.plugndrive.ca/canadas-only-privately-funded-electric-vehicle-incentive-is-helping-car-buyers-make-the-switch/

France

France introduced a scrappage scheme in the wake of the global financial crises offering €1,000 to scrap old higher polluting vehicles. An increase in new vehicle sales in 2009 was evident and thought to be attributable to this program[12].

In May 2020, during the initial COVID 19 lockdown in France, the Macron government announced an €8 Billion support package which included subsidies for the purchase of electric cars, and funds for scrapping older vehicles[13]. Of the €8 Billion package €1.3 Billion was set aside for EV subsidies to increase the existing €6,000 incentive to €7,000 and offer up to €5,000 for a scrapped vehicle[14]. A consumer could therefore receive up to €12,000 toward the purchase of an electric vehicle.[15] The plan also supports research on self driving and hydrogen powered vehicles, and aims to promoting local manufacturing of clean vehicles[16]. The program, which was intended to remove 200,000 vehicles from French roads, reached this threshold within 2 months[17].

In June 2020, light vehicle sales did in fact increase by 2.4% yoy and forecasted sales for full year 2020 were revised upwards from 1.82 million(-32% yoy) to 2.17 million (-19% yoy) [18]. With the 200,000 vehicle threshold met, a new plan was announced and implemented August 3rd[19]. This subsequent program was structured to better benefit lower income earners with a tiered incentive approach on scrapped vehicles; inversely corresponding to a participant's income. New BEV & PHEV Vehicle incentives remained unchanged[20]. Scrapped vehicle incentive funds are received for gasoline vehicles registered before 2006 and diesel vehicles before 2011[21].

Current State of Canada's Auto Market

2019 Light Vehicle sales in Canada totaled 1,930,120 according to data provided by DesRosiers Automotive Consultants (DesRosiers). Sales peaked in 2017 at 2,036,647 with a steady upward trend from the trough of 2009 in the aftermath of the global financial crisis. From 2010 to 2017 sales grew at a compound annual growth rate (CAGR) of 3.9%. Since 2017 however there has been a downward trajectory to 2019[22]. In 2020, January and February sales exhibited modest yoy gains at +0.8% & +1.7% respectively, before the COVID-19 induced lockdown decline began in March; driving sales down 48.5% yoy. April exhibited a 74.5% decline while May, June and July came in a - 47.2%, -21.5% and -10.5% yoy respectively. While a partial rebound has been evident in May through July, year to date (YTD) sales are down 32%.[23] Full year estimates point to a 22% decline in 2020 with 1.51 million units anticipated to be sold; the lowest annual sales since 2009.[vi]

[vi] Internal estimate based on Jan-July 2020 actual sales data from Statistics Canada. August through December sales are based on an August yoy growth estimate of -9% from Scotiabank Economics which was applied to August through September 2019 to arrive at an estimated 1.51million vehicles for 2020 representing a 22% yoy decline on the 2019 DesRosiers sales figure.
Statistics Canada sales data from Table 20-10-0001-01 New motor vehicle sales (https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2010000101, accessed Sept 19, 2020).
Scotiabank data from: Young, Rebekah. *Canadian and US Vehicle Sales (August 2020): Auto News Flash*. Sept 1, 2020, https://www.scotiabank.com/ca/en/about/economics/economics-publications/post.other-publications.autos.auto-news-flash.september-1--2020.html

Table 3: Year to Date 2020 Canadian New Vehicle Sales

2020 YTD	Jan-20	Feb-20	Mar-20	Apr-20	May-20	Jun-20	Jul-20	YTD July 2020	Full Year 2020 Estimate
Monthly Sales	**112,845**	**126,224**	**96,147**	**47,168**	**109,173**	**149,079**	**158,678**	**799,314**	**1,508,672**
year-over-year %	**0.8%**	**1.7%**	**-48.45%**	**-74.6%**	**-47.2%**	**-21.5%**	**-10.5%**	**-32.4%**	**-21.8%**

Source: Statistics Canada: New motor vehicle sales (Passenger Cars & Trucks) Table: 20-10-0001-01

In Table 4 below are the sales by OEM for 2019 with a comparison to 2016; both datasets of which are based on DesRosiers sales data. A slight drop in sales of -0.9% is evident across these subject years on either side of the 2017 peak noted above. More notable however is the shift in market share, with the North American OEMs Ford and GM, as well as Fiat Chrysler Automotive (FCA) exhibiting a declining share; while Toyota and Volkswagen made notable market share gains. Perhaps the most compelling metric is the growth of Tesla sales in this 3-year span, from under 2500 vehicles in 2016 to 18,850 vehicle sales in 2019; a 671% increase and a respectable 1% 2019 market share for a solely EV manufacturer. The EV segment as a whole grew 626% from 2016 to 2019, representing 2% of the new vehicle sales market in 2019 with 35,305 EV units sold.

Table 4: Sales by OEM 2019 vs 2016

OEM	Units Sold CY 2019	2019 CY Market Share	Units Sold CY 2016	2016 CY Market Share	Change in Market Share	Change Units Sold 2019 vs 2016	%Change
FORD	**283,268**	**14.7%**	300,769	15.4%	-0.8%	(17,501)	-5.8%
GM	**256,789**	**13.3%**	267,339	13.7%	-0.4%	(10,550)	-3.9%
TOYOTA	**237,091**	**12.3%**	217,659	11.2%	1.1%	19,432	8.9%
FCA	**224,174**	**11.6%**	278,223	14.3%	-2.7%	(54,049)	-19.4%
KIA/HYUNDAI	**211,431**	**11.0%**	209,839	10.8%	0.2%	1,592	0.8%
HONDA	**188,828**	**9.8%**	186,668	9.6%	0.2%	2,160	1.2%
NISSAN	**134,729**	**7.0%**	133,926	6.9%	0.1%	803	0.6%
VOLKSWAGEN	**111,856**	**5.8%**	97,862	5.0%	0.8%	13,994	14.3%
MAZDA	**66,421**	**3.4%**	69,210	3.6%	-0.1%	(2,789)	-4.0%
SUBARU	**57,524**	**3.0%**	50,190	2.6%	0.4%	7,334	14.6%
MERCEDES-BENZ	**46,090**	**2.4%**	48,320	2.5%	-0.1%	(2,230)	-4.6%
BMW	**42,792**	**2.2%**	44,714	2.3%	-0.1%	(1,922)	-4.3%
MITSUBISHI	**25,535**	**1.3%**	22,292	1.1%	0.2%	3,243	14.5%
TESLA	**18,850**	**1.0%**	2,442	0.1%	0.9%	16,408	671.9%
JLR	**13,927**	**0.7%**	12,174	0.6%	0.1%	1,753	14.4%
VOLVO	**10,155**	**0.5%**	6,103	0.3%	0.2%	4,052	66.4%
FERRARI	**333**	**0.0%**	199	0.0%	0.0%	134	67.3%
MCLAREN AUTOMOTIVE	**209**	**0.0%**	108	0.0%	0.0%	101	93.5%
ASTON MARTIN	**108**	**0.0%**	53	0.0%	0.0%	55	103.8%
LOTUS	**10**	**0.0%**	0	0.0%	0.0%	10	
TOTAL	**1,930,120**	**100.0%**	**1,948,090**	**100.0%**	**0.0%**	**(17,970)**	**-0.9%**

Source: DesRosiers Automotive

Figure 1 below illustrates the sales-weighted OEM average CO_2 emissions in gCO_2/km, as well as the overall Canada fleet average. The 2019 Canadian average CO_2 emissions per vehicle on a g CO_2/km basis is estimated at 231 g CO_2/km.[vii] Consumers must be encouraged to purchase low CO_2 emitting vehicles from the available models to bring down this average. In 2019 CO_2 emissions from vehicles purchased ranged from 2.4 g CO_2/km (Hyundai Ioniq EV) to 510 g CO_2/km (Lamborghini Aventador). Thus, increasing demand of low emitting vehicles will serve to lower the average g CO_2/km of the Canadian fleet. This favourable effect will carry through during the lifetime of the vehicle on the road.

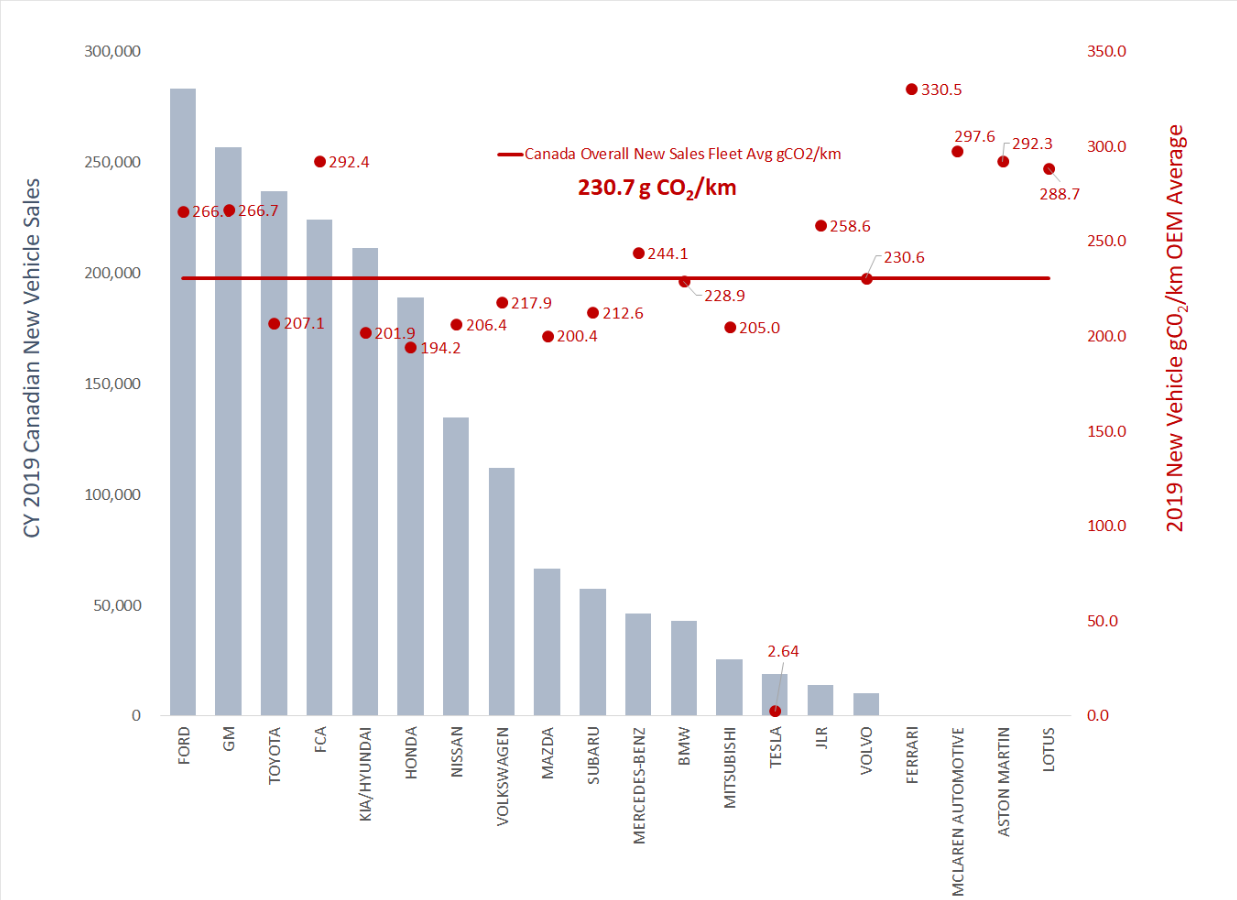
[vii] Based on DesRosiers Automotive 2019 Sales Data and fuel consumption by vehicle line

Electric vehicles have zero tailpipe emissions and the CO_2 footprint is limited to emissions from the electricity grid's power generation source from which the EV is charged. Therefore, electric vehicles within OEM fleets do indirectly generate CO_2 emissions as power drawn when charging from the grid does result in some CO_2 emissions. The power grid's CO_2 intensity from electricity generation by province was considered (in g CO_2/kWh) and examined. When looking at historic data, such as the case in Figure 2 for 2019, the weighted average CO_2/kWh output was calculated based on 2019 *EV* registrations in each province[24]. The bulk of 2019 EVs registrations were in Ontario, Quebec, and BC; all three of which have low CO_2 intensity grids (at 40, 1.2 and 12.9 g CO_2/kWh respectively) [25]. This weighted average figure is 15.66 g CO_2/kWh and represents the CO_2 emitted per kWh drawn from the grid when a 2019 vehicle was charged. To determine the CO_2 emissions by vehicle line, each 2019 electric vehicle's energy consumption figure in kWh/100 km[viii] was multiplied by this 15.66 g CO_2/kWh figure to arrive at a unique emission figure in gCO_2/km for a given EV model sold in 2019. As such the figure for Tesla for example, a pure EV OEM with an average of 2.64gCO_2/km, reflects this estimation.

It is worth noting that when looking at electricity grid data for all provinces, the CO_2 emissions vary from a low of 1.2 gCO_2/kWh in Quebec to 790 gCO_2/kWh in Alberta[26]. If a weighted average were based on all registered vehicles (EV or otherwise, less than 4500kg); this weighted average Canada wide grid CO_2 output would be 169.5 gCO_2/kWh[27]. This is the figure used in a forward-looking analysis to be elaborated on below.

[viii] Calculated from the L/100km equivalent provided by the DesRosiers data and multiplying by 8.9 kWh/L gasoline; the energy equivalent of 1 liter of gasoline; Natural Resources Canada, https://www.nrcan.gc.ca/energy/efficiency/energy-efficiency-transportation-and-alternative-fuels/choosing-right-vehicle/tips-buying-fuel-efficient-vehicle/energuide-vehicles/energuide-label-battery-electric-vehicles/21379

Figure 1: 2019 Sales by OEM and Fleet Average CO_2 emissions (gCO_2/km)



Evident in Figure 2 and 3 below is the increased prevalence of Light Truck sales relative to Passenger Cars between 2016 and 2019. This has indeed been a trend from as far back as 2010 with trucks representing 55% of sales units in 2010, 67% in 2016 and 76% in 2019[28]. When examining Figure 3 in more detail, it is notable that with the exception of FCA, all OEMs that produce trucks experienced an increase in Light Truck sales between 2016 and 2019.

Figure 2: 2016 & 2019 Car-Truck Sales Split by OEM

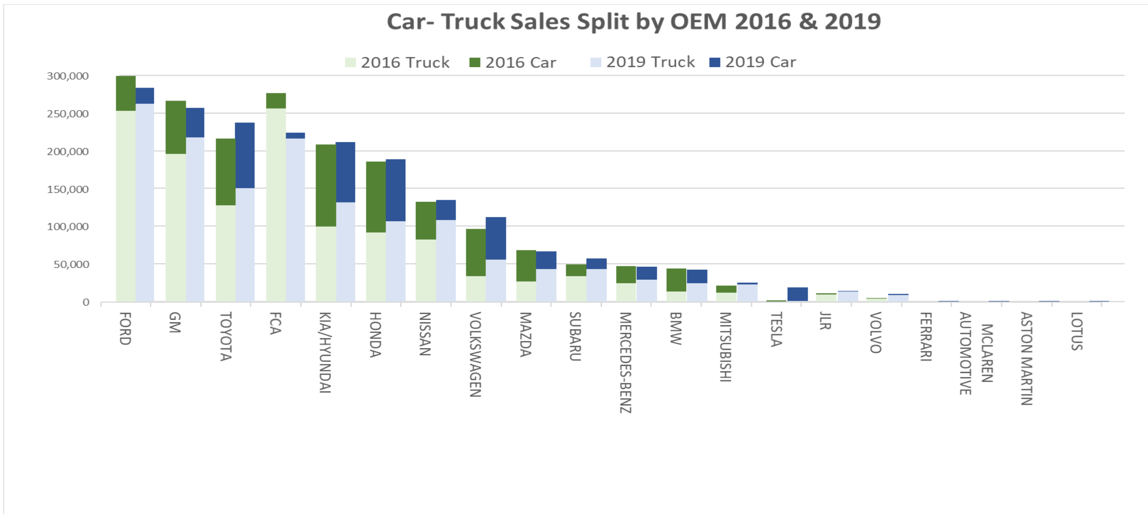
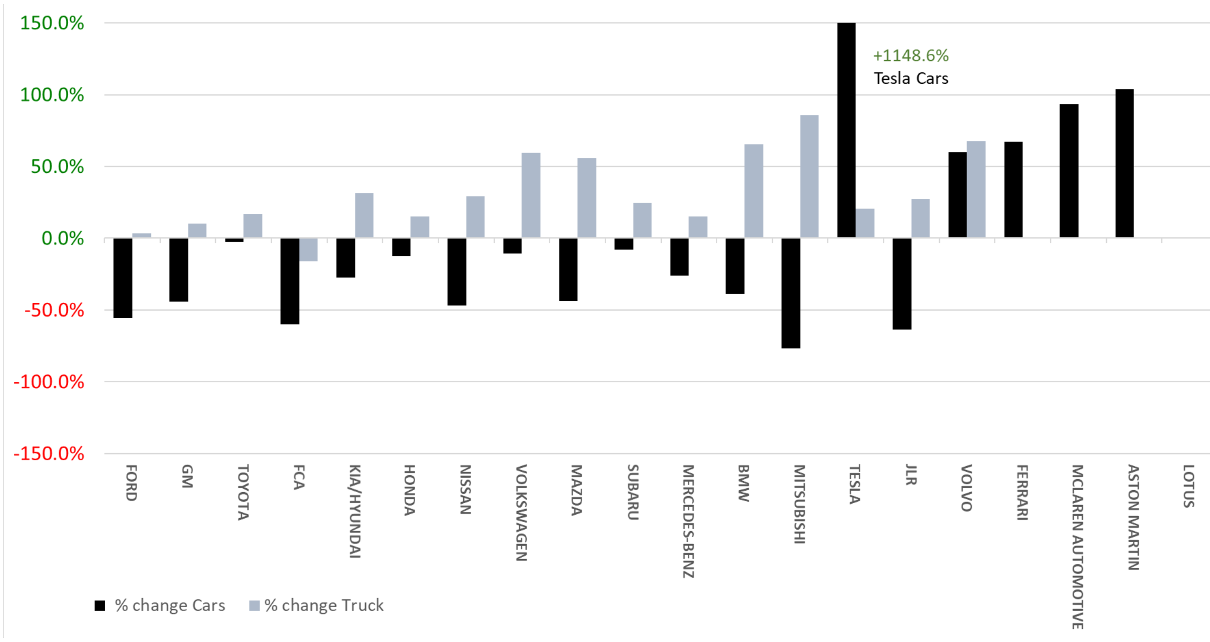
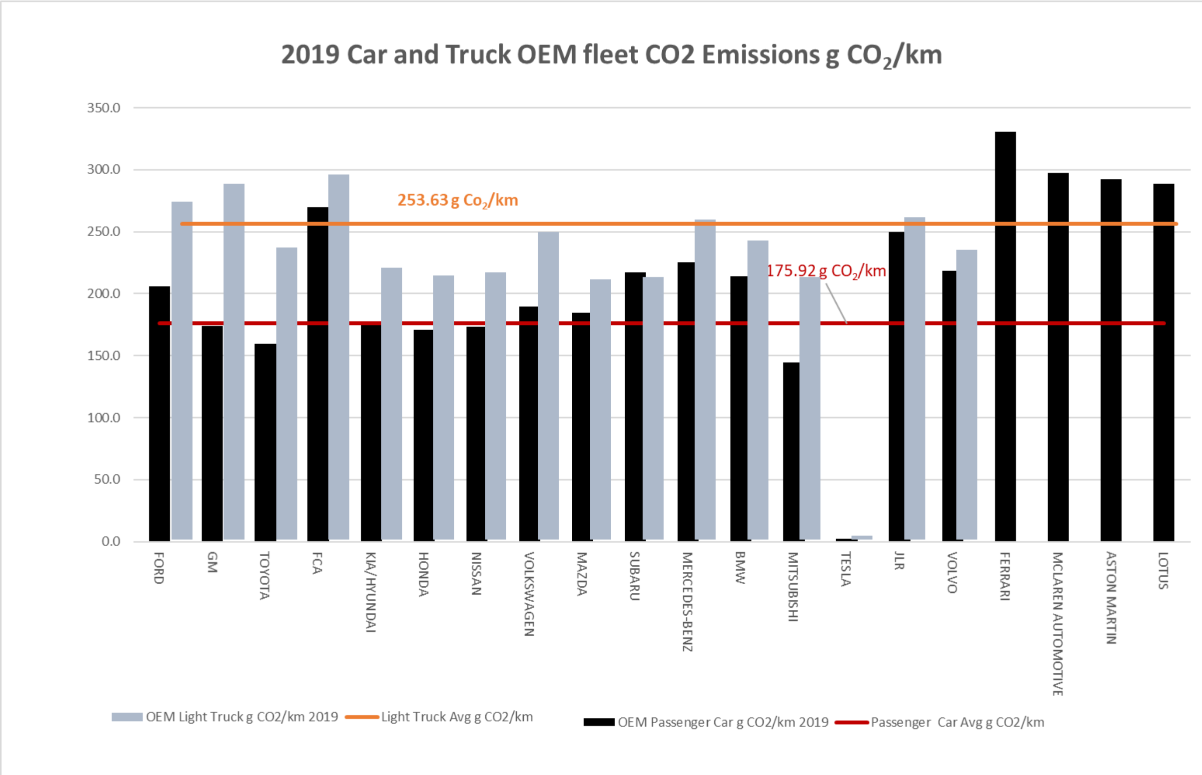


Figure 3 2016 to 2019 Car and Truck growth



In Figure 4 below, the Passenger Car and Light Truck subcategories are segmented to show their CO_2 emissions per km on a weighted average basis for each OEM, as well as a Canada fleet average. The higher emissions values for trucks amongst OEMs is evident with the exception of Subaru. The spread is also evident in the Canada wide figures at 253.6 g CO_2/km for Light Trucks and 175.9 g CO_2/km for Passenger Cars.

Figure 4 Emissions in g CO_2/km for Passenger Cars and Trucks by OEM and Canada Fleet Average



Fleet Model

Emissions by Model Year

The CO_2 emissions by model year for MY 1995 to 2020 was obtained from various sources. Estimates of either the average Canada wide fuel consumption, or CO_2 emissions for a given model year were sourced. Fuel consumption data was converted from L/100km to g CO_2/km using 2348 g CO_2/ Liter for gasoline vehicle lines or 2689 g CO2/Liter diesel vehicle lines.[ix]

For 1995 through 2010, the CO_2 emissions by model year was calculated based on fleet average fuel consumption data for Canadian vehicles in L/100km as per Transport Policy.net for both Passenger Cars and Light Duty Trucks (less than 8501lbs).[29] This fuel consumption data is based on the US Federal Test Procedure (FTP) which uses a 2-cycle testing process. As such this data was adjusted upward by a factor of 25%[x] to arrive at real world emissions levels for vehicles of these respective model years.

Model year 2011 to 2017 data was from an IEA 2019 Fuel Economy in Major Markets report which included data on Canada on a g CO_2/km basis[30]. This data was as per the Worldwide Harmonised Light Vehicle Test Procedure (WLTP). WLTP is deemed to be more representative of real world driving as it

[ix] Based on the EPA specified 8,887 g CO_2/ gallon gasoline or 10,180 g CO_2/ gallon diesel converted to metric. Where L/100km data was sourced, the gasoline and diesel conversion constants were applied in proportion to the % diesel in fleet within a model year (with the residual taken at the gasoline conversion constant). This diesel percentage was drawn from DesRosiers's vehicle registration data by model year.

[x] Based on US EPA real world adjustment factor: ICCT whitepaper: Mock, Peter et al. From Laboratory to Road International, A Comparison of Official and Real-World Consumption and CO_2 Values for Passenger Cars in Europe, The United States, China, and Japan, Nov 2017

examines 4 driving profiles described as "low, medium, high and extra high", each of which contains acceleration, braking and hard stop components[xi]. Therefore, WLTP measures are taken to be representative of real-world driving, and therefore a real-world multiple was not applied.

For model year 2018, data for tailpipe emissions from the 2018 Environment and Climate Change Canada (ECCC) report for the overall fleet average tailpipe emissions was used, sourcing both passenger vehicle and light truck data.[31] A weighted average was determined based on the split of passenger vehicle and light truck sales in 2018 as per Statistics Canada Sales data[32]. To adjust for real world conditions this figure was adjusted upwards by 25% similar to the 1995 to 2010 data.

DesRosiers sales data for 2019, was used to determine an average 2019 g CO_2/km emissions value as described above, and also serves as a proxy for 2020. The 2019 data set was broken out into a greater level of detail with fuel consumption data in L/100km available by vehicle line and fuel source/powertrain. This data was therefore analyzed in more granular detail. With diesel powered vehicles for example (representing 1.94 % of 2019 vehicle sales), the diesel specific multiplier of 2689 g CO_2/Liter diesel was applied to these vehicle lines when converting data from L/100km to g CO_2/km. In the case of EVs, the fuel consumption equivalent was first converted to a kWh/100 km by using the conversion factor of 8.9 kWh/L gasoline. In order to determine a g CO_2/km value for each electric vehicle line, a *forward-looking* estimate of a Canada wide electricity grid carbon intensity figure of 169.5 g CO_2/kWh was used. This Canada wide figure is used as an electric vehicle purchase could happen in any province under a national program

Table 5: 2019 actual and 2020 estimated CO_2 fleet emissions in g CO_2/km by Fuel Type or Powertrain

Gasoline	Diesel	EV	PHEV	HEV	Canada Fleet Avg
237.2	272.1	29.9	104.3	134.0	230.7

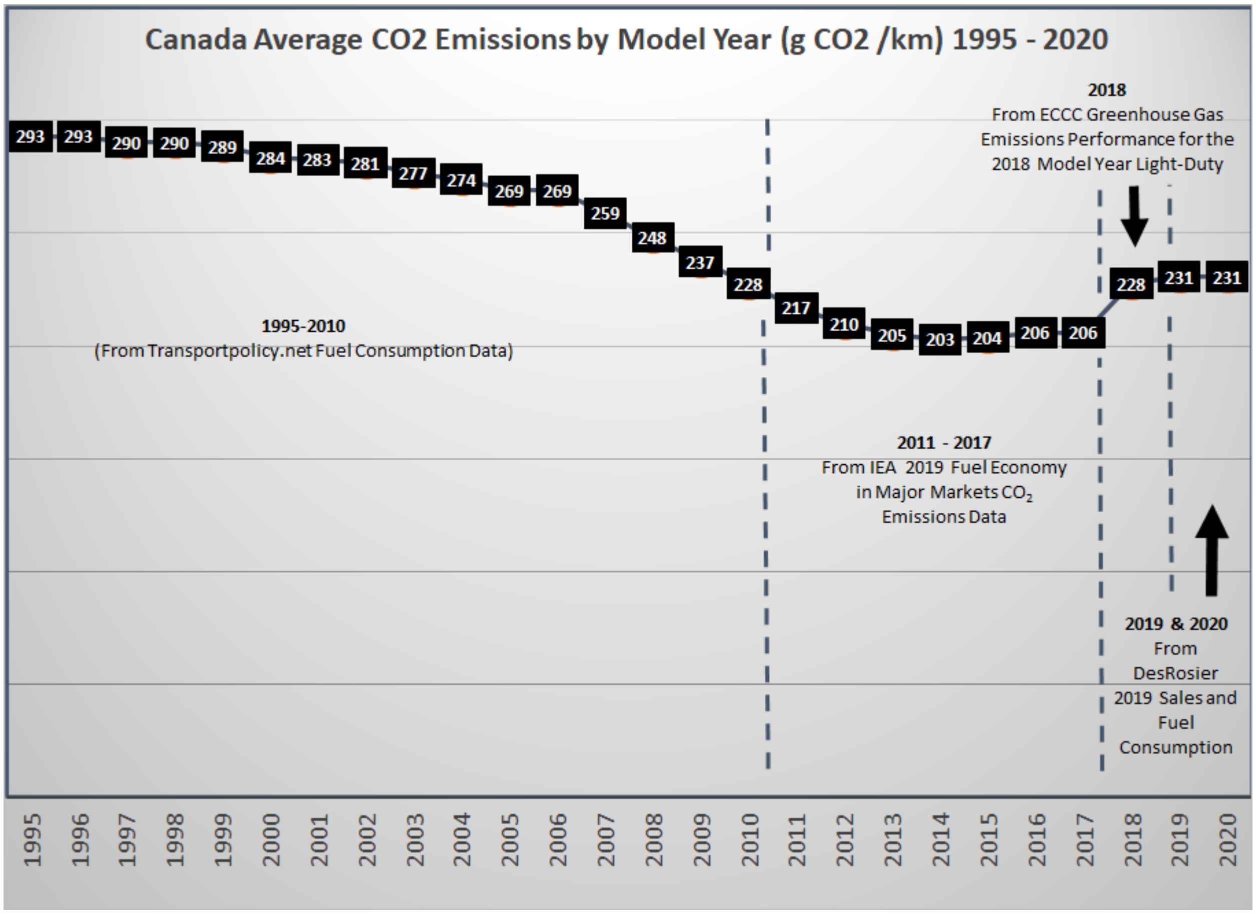
With regards to PHEV vehicles the L/100km figures in the 2019 sales data was based on an estimation of usage in battery mode and gasoline mode. PHEV vehicles have 2 fuel consumption figures; one for battery mode (in equivalent liters /100km by applying 8.9 kWh/L to the a kWh/100km figure) and one for gasoline mode. The battery range in kilometers was used as the basis of the weighting applied to determine an average. For example, for a vehicle with a battery range of 32km, a weighting of 32 % would be applied to the battery fuel consumption figure and 68% to the gasoline fuel consumption figure. This battery mode percentage was capped at 80%. Further when converting the L/100km figure to a CO_2/km figure, the gasoline multiplier of 2348 gCO_2/L was applied. While appropriate for the gasoline portion it represents an overstatement of the electricity portion, implying 263 g CO_2/kWh (2348 gCO_2/L gasoline divided by 8.9 kWh/ L gasoline); in other words implying the vehicle battery charging occurs from a hypothetical gasoline powered electricity grid emitting 263 g CO_2/kWh.[xii]

The estimated emissions figures for the 1995 through 2020 model years in g CO_2/km is summarized below in Figure 5

[xi] https://www.wltpfacts.eu/what-is-wltp-how-will-it-work/

[xii] Hybrid Electric Vehicles (HEV) were also converted from L/100km using the gasoline vehicle multiplier of 2348 gCO_2/L and similar to the case of PHEVs also overstates the CO_2 emissions from the type of vehicle. In this case no consideration was made for the percentage battery usage vs gasoline usage as was the case for the PHEV estimate. HEVs represented 2% of sales in 2019

Figure 5: Real World Estimates of CO2 emission for Model Years 1995 - 2020



Model Year Mix

Using an additional data set from DesRosiers of vehicle registrations by model year[xiii] , the proportion of vehicles by model year was used to determine the average age of the Canadian fleet at 9.9 years. Along with this CO_2 emissions per kilometer of the fleet was on average estimated at 235.4 gCO_2/km.

Scenario Development

Four scenarios were developed to determine i) the removal of CO_2 emissions by scrapping an older vehicle early and ii) emissions added by purchasing a new vehicle. The new vehicle is assumed to be a 2020 model year and deemed to have the same characteristics as that of a 2019 vehicle which was analyzed in detail above. Therefore, as with a 2019 vehicle a 2020 vehicle on average is assumed to emit 230.7 g CO_2/km as illustrated in Figure 5 above. Further this data is segmented into subsets as per Table 5 with 2020 EVs emitting on average 29.9 g CO_2/km; PHEV emitting on average 104.3 g CO_2/km and ICEVs on average emitting 237.2 g CO_2/km (assumed to be gasoline powered vehicle). Hybrid Electric Vehicles (HEV) are omitted from this analysis as they are not considered in the new vehicle purchase scenarios discussed below.

[xiii] DesRosiers data for the distribution of vehicle populations by model year is through July 2019.

A scrapped vehicle is assumed to be a 2005 vehicle with the assumption that a scrapped vehicle would be at least 15 years old. Other key input assumptions were that a vehicle lifespan is 25 years and the average kilometers driven per year at 20,000km/year for each year in the 2021 to 2030 timeframe. With an estimated maximum lifespan of 25 years, there is 10 years of remaining life. It is assumed the driver of a new vehicle purchase begins driving in 2021 so the 10-year period of assessing the removal of emissions from the scrapped vehicle and the added emissions from the new vehicle is 2021 to 2030 inclusive.

Under scenario 1 the scrapping of a vehicle would result in incentives towards only an EV or PHEV vehicle. Under scenario 2 an ICEV vehicle purchase would be permitted, however at no more than half the funding that would be received towards a new EV/PHEV purchase. Should an ICEV vehicle purchase be opted for, the vehicles would be required to have a fuel consumption figure of no more than 8 L/100km; and should a vehicle be below 7 L/100km, a higher premium would be received than that of a vehicle with fuel consumption ranging from 7.1 L/100km to 8 L/100km. Under scenario 3, similar to scenario 2, both PHEV/EV purchases and ICEV would be permitted, however should an ICEV vehicle be purchased it must be at least 30% more fuel efficient than that of the scrapped vehicle. An additional scenario 1A is also examined to consider a situation when the new vehicle purchase must be an EV without the option to purchase a PHEV as in scenario 1.

The emissions of the 15-year-old, 2005 model year scrapped vehicle in all 4 scenarios was estimated at 269 g CO_2/km as per the analysis above and illustrated in Figure 5.

Scenario 1

At an average of 20,000 km/yr and 269 g CO_2/km emitted over the 2021 to 2030 period **53.8 tonnes of CO2 is deemed to be removed** from the atmosphere by retiring this vehicle 10 years early (5.38 tonnes/yr over 10 years).

To this value the forecasted emissions from the new vehicle purchase was added along with a pro-rated CO_2 output from the early production of the vehicle; 10 years earlier than otherwise.[xiv] The new vehicle in the case of scenario 1 would be either an electric vehicle (EV) or a Plug in Hybrid Electric Vehicle (PHEV). It is assumed that the new vehicle uptake would be in the same proportion as demonstrated by 2019 sales, which was at a 64% to 36% ratio for EV to PHEV purchase respectively. Correspondingly with unique values of EV and PHEV g CO_2/km emissions in Table 3 above; a weighted average emissions figure was applied to the new vehicle at 56.7 gCO_2/km.[xv] This represents on average what a new vehicle replacing the scrapped vehicle would emit per kilometer driven. At 20,000 km/yr this yields an addition of 11.4 tonnes (1.14 tonnes a year over 10 years). The impact of early production adds an additional 2.2tonnes (also at a EV/PHEV weighted avg) for a total of **13.6 tonnes added** from the new vehicle over the 10 year period. This is a ***net carbon reduction of approximately 40.2 tonnes over the 10 years timeframe under this scenario and associated assumptions***.

Scenario 1 A

To build upon Scenario 1 above a more stringent Scenario 1A was developed. In this scenario the new vehicle purchase must be an EV. With the same assumptions on the scrapped vehicle, the net impact of

[xiv] The impact of early production is calculated by using data from Bieker and Mock (2020) for CO_2 emissions emitted during manufacturing of and ICEV, EV and PHEV vehicle as well as the kWh from battery production in the case of EVs and PHEV (converted to CO_2 emissions). Source: https://theicct.org/publications/vehicle-replacement-programs-covid-19-may2020
[xv] See Annex 1 for full calculations of all new car emission estimates for all scenarios.

scrapping a 2005 model year vehicle and replacing with a 2020 EV is ***45.7 tonnes of CO2 removed*** over the 10-year 2021 to 2030 timeframe.

Scenario 2

Scenario 2 took the same approach with the same assumption on the scrapped vehicle. With regards to the new vehicle purchase it was assumed with the incentive doubled on the purchase of an EV/PHEV the uptake would also be double and thus at a 2:1 ratio (66% of consumers would opt for the EV/PHEV option and 34% would opt for the ICEV option). This weighting was applied in determining the weighted average CO_2 emission figure of a new vehicle under this scenario. Further, with a higher premium on ICEV vehicles with fuel consumption of 7 L/100km or lower; than those 7.1L/100km – 8L/100km (taken as 7.5 L/100km), it is assumed this 34% for an ICEV uptake is split 22% and 12% respectively (also at a 2:1 ratio). Thus, the weighted average CO_2 emissions figure of a new vehicle in scenario 2 was calculated as 94.7 g CO_2/km for a total CO_2 emissions of 18.9 tonnes CO_2 added over 10 years (1.89 tonnes/yr over 10 years). With the early production factor added for an additional 2.1 tonnes, this results in a total of **21.1 tonnes added** from the new vehicle over the 10-year period. With **53.8 tonnes of CO_2 removed from the scrapped vehicle** this results in a ***net carbon reduction of approximately 32.7 tonnes***

Scenario 3

Scenario 3 is similar to scenario 2 with the option of an EV/PHEV purchase or an ICEV purchase; with a lower incentive applied to in the case an ICEV new vehicle is opted for. In this case however it is required that the ICEV purchase is at least 30% more fuel efficient than that of the scrapped vehicle. With the 2005 model year scrapped vehicle as per scenario 1 & 2 deemed to emit 269 gCO_2/km; equivalent to 11.39 L/100km; a vehicle that is 30% more fuel efficient would have a fuel consumption value that is at most 7.97 L/100km. This equates to CO_2 emissions of 188 gCO_2/km[xvi]. Again, with an assumption of a 2:1 uptake split of new purchases towards an EV or PHEV versus the ICEV vehicle (66 % EV/PHEV and 34% ICEV), on average a new vehicle would have a CO_2 emissions figure of 101.4 g CO_2/km. Therefore, the CO_2 emitted over the 10-year span would be 20.3 tonnes added before early production and **22.4 tonnes added after accounting for early production.** With the removal of CO_2 from the Scrapped vehicle at 53.8 tonnes the ***net reduction would be 31.3 tonnes***

A comparison of scenarios 1-3 compared to scenario 1A is below in tonnes per vehicle over 10-year timeframe is illustrated below in Table 6.

Table 6: Comparison of Scenarios

	Scenario 1	Scenario 1A	Scenario 2	Scenario 3
Tonnes CO_2 **Removed** from Scrapped Vehicle	53.8	53.8	53.8	53.8
Tonnes CO_2 **Added** from New Vehicle (including early production impact)	13.6	8.0	21.1	22.4
Net Tonnes CO_2 Emission **Reduction**	**40.2**	**45.7**	**32.7**	**31.3**
vs Scenario 1A	**5.53**		**13.08**	**14.41**
% underperformance to Scenario 1A	**-12%**		**-29%**	**-31%**

Baseline Comparison

The above scenarios were all compared against a baseline which assumes no restrictions on the new vehicle purchase. As such a new vehicle would be assumed to be an average 2020 vehicle which is estimated to emit 230.7 g CO_2/km. The scrapped vehicle assumption remains the same at a 2005 MY vehicle. Table 7 below is a comparison of the average CO_2 emissions of a given new vehicle under the 4 scenarios compared to the baseline.

Table 7: CO_2 emissions of new vehicle in each scenarios versus Baseline

	BASELINE (average 2020 vehicle)	Scenario 1	Scenario 1A	Scenario 2	Scenario 3
g CO_2/km	230.7	56.7	29.9	94.7	101.4
g CO2/km vs Baseline		-174.0	-200.8	-136.0	-129.3
vs Baseline Vehicle		**-75%**	**-87%**	**-59%**	**-56%**

Below in Table 8 are the results the scenarios versus the baseline case.

Table 8: Summary of Results = Table 1

	BASELINE	Scenario 1	Scenario 1A	Scenario 2	Scenario 3
Tonnes CO_2 **Removed** from Scrapped Vehicle	53.8	53.8	53.8	53.8	53.8
Tonnes CO_2 **Added** from New Vehicle (including early production impact)	49.4	13.6	8.0	21.1	22.4
Net Tonnes CO_2 Emission **Reduction**	**4.3**	**40.2**	**45.7**	**32.7**	**31.3**
Incremental Tonnes Removed vs Baseline		**35.9**	**41.4**	**28.3**	**27.0**
% improvement to Baseline		**827%**	**954%**	**653%**	**622%**

It is evident and with no surprise that mandating a new vehicle purchase be an EV as Scenario 1A, yields the best outcome in terms of net CO_2 removed from the environment over a given timeframe. The greater than 10-fold improvement however is quite compelling with more than 40 additional tonnes of CO_2 removed from the environment per vehicle over a 10-year timeframe (greater than 4 tonnes per year, per vehicle)

The total CO_2 removed is a function of the assumed model year of the scrapped vehicle, the lifespan of the vehicle, and the average number of kilometers driven per year; which in turn determines the remaining life of the scrapped vehicle and the emissions prevented by scrapping the vehicle. Also determined by the assumptions is the CO_2 expected to be emitted by the new vehicle over this timeframe. These variables however are held constant across all three scenarios so the improvement of Scenario 1A vs the other scenarios will remain under different input assumptions.

Annex 1: Calculation of new vehicle emission values

Scenario 1 New Vehicle emissions	56.7 g CO_2/km
Scenario 2 New Vehicle emissions	94.7 g CO_2/km
Scenario 3 New Vehicle emissions	101.4 g CO_2/km
Scenario 1A New Vehicle emissions	29.89 g CO_2/km
Baseline:	230.7 CO_2/km; 2020 Canadian fleet average estimate

Scenario 1:

EV or PHEV permitted as new vehicle

- With 2019 EV and PHEV Sales at 35,305 units and 20,261 respectively; a 64% 36% split
- 2019 EVs average to 29.9 g CO2/km
- 2019 PHEVs average to 104.3 g CO2/km

➢ Weighted Average emissions for a given vehicle in Scenario 1:

(64%*29.9) + (36%*104.3)= **56.7 g CO_2/km**

Scenario 2:

EV or PHEV receives double the incentive of an ICEV less than 8.0 L/100km. Within the ICEV a higher level of funding would be applied for the purchase of a vehicle 7.0 L/100km of lower versus an vehicle 7.1 L/100km to 8.0 L/100km

- It is assumed that with double the funding towards the purchase of an EV or PHEV that twice as many consumers would opt for this choice over an ICEV
  - Therefore 66% of consumers would opt for a EV or PHEV
  - Amongst the remining 34%, it is assumed that vehicles 7.0 L/100km or lower will receive twice the funding of a vehicle between 7.1 L/100km and 8.0 L/100km (a figure of 7.5 L/100km is chosen as representative of this range)
  - It is therefore assume that of the remaining 22% of consumers will opt for a vehicle with fuel consumption of 7.0 L/100km and 12 % will opt for a vehicle of 7.5 L/100km
    - 7.0L/100km vehicle option = 7/100 x 2348 g CO_2/L gasoline = **164.36 g CO_2/km**
    - 7.5 L/100km vehicle option = 7.5/100 v 2348 g CO_2/L gasoline = **176.08 g CO_2/km**
    - EV /PHEV option: as calculated in scenario 1 = **56.7 g CO_2/km**

➢ Weighted Average emissions for a given new vehicle in Scenario 2:

(66%* 56.7 g CO_2/km) + (22% * 164.36) + (12%* 176.08) = **94.70 g CO_2/km**

Scenario 3:

EV or PHEV receives double the incentive of an ICEV. The ICEV must be at least 30% more fuel efficient than the scrapped vehicle

- ICEV Vehicle calculation:
  - Scrapped vehicle: 2005 MY vehicle fuel efficiency 11.4 L/100km = 268.8 g CO_2/km
  - 30% fuel efficiency improvement = 7.97 L/100km = 187.1 g CO_2/km

ICEV Vehicle = **187.1 g CO_2/km**
EV /PHEV option: as calculated in scenario 1 = **56.7 g CO_2/km**

With funding double for the EV/PHEV option it is also assumed that twice as many consumers will opt for this option over the ICEV.

- Weighted Average emissions of a given vehicle in scenario 3:

  (66%* 56.7g CO_2/km) + (34% * 187.1 g CO_2/km) = **101.4 gCO_2/km**

Scenario 1 A

New vehicle must be an EV

- Emissions of a given vehicle in Scenario 1A: **29.9 g CO_2/km**

Baseline

No restrictions on New Vehicle

- Emissions of an average 2020 vehicle: **230.7 g CO_2/km**

References

[1]Department of Finance Canada; Budget 2007; https://www.budget.gc.ca/2007/plan/bpc3-eng.html
[2] Environment and Climate Change Canada; Evaluation of the National Vehicle Scrappage Program; July 12, 2011; https://www.ec.gc.ca/ae-ve/default.asp?lang=En&n=CD4EC913-1&printfullpage=true#wsDA566A19 ; Section 2.1
[3] Evaluation of the National Vehicle Scrappage Program; Environment and Climate Change Canada; July 12 , 2011; https://www.ec.gc.ca/ae-ve/default.asp?lang=En&n=CD4EC913-1&printfullpage=true#wsDA566A19; Executive Summary
[4] Evaluation of the National Vehicle Scrappage Program; Environment and Climate Change Canada; July 12 , 2011; https://www.ec.gc.ca/ae-ve/default.asp?lang=En&n=CD4EC913-1&printfullpage=true#wsDA566A19
[5] Evaluation of the National Vehicle Scrappage Program; Environment and Climate Change Canada; July 12 , 2011; https://www.ec.gc.ca/ae-ve/default.asp?lang=En&n=CD4EC913-1&printfullpage=true#wsDA566A19; Section 4.1
[6] https://scrapit.ca/; Aug 30,2020
[7] Program offering cash rebates to scrap heavy polluting vehicles comes to Alberta; rdnewsNOW, Sept 1, 2020; https://rdnewsnow.com/2020/09/01/program-offering-cash-rebates-to-scrap-heavy-polluting-vehicles-comes-to-alberta/
[8] Valdes-Dapena, Peter. "Cash for Clunkers ending." CNN Money. 21, August 2009. money.cnn.com/2009/08/20/autos/cash_for_clunkers_end/
[9] Office of Energy Efficiency & Renewable Energy. *Fact #587: September, 2009 Cash for Clunkers Program – Fuel Economy Improvement*; https://www.energy.gov/eere/vehicles/fact-587-september-7-2009-cash-clunkers-program-fuel-economy-improvement
[10] Clean Cars for America; https://www.democrats.senate.gov/imo/media/doc/Clean%20Cars%20for%20America%20-%201pg%20summary.pdf
[11] Joselow, Maxine. E&E News, *Why Biden's car plan might not be a 'clunker'*; August 4, 2020; https://www.eenews.net/stories/1063680019
[12]Daneshkhu, Scheherazade. ; Financial Times, *French car sales surge on scrappage scheme*, December 29, 2009; https://www.ft.com/content/c37ca570-f475-11de-9cba-00144feab49a
[13] *Carmakers should emerge greener from the crisis*; Editorial Board, Financial Times; May 26,2020 https://www.ft.com/content/96ae2d26-9f4f-11ea-b65d-489c67b0d85d
[14] MacRae, Calum. *France moves first to bolster the automotive sector*; Just-Auto.com; May 29 2020; https://www.just-auto.com/comment/france-moves-first-to-bolster-the-automotive-sector_id195801.aspx
[15] Sigal, Peter. *France to help auto Sector with measures worth $8.8B*; Automotive News Europe, May 26, 2020; https://europe.autonews.com/automakers/france-help-auto-sector-measures-worth-88b
[16] Mallet, Victor. *Emmanuel Macron injects €8bn to fuel French car industry revival*; Financial Times; May 26, 2020, https://www.ft.com/content/8e84e13b-d02f-4d90-839d-f99c3a0c1d95
[17] French coronavirus recovery incentive scheme replaced after cap reached; Autovista Group, July 28, 2020; https://autovistagroup.com/news-and-insights/french-coronavirus-recovery-incentive-scheme-replaced-after-cap-reached
[18] France is reshaping its car scrapping program; FR24 News, July 30 2020; https://www.fr24news.com/a/2020/07/france-is-reshaping-its-car-scrapping-program-automotive-industry-analysis.html
[19] France is reshaping its car scrapping program; FR24 News, July 30 2020; https://www.fr24news.com/a/2020/07/france-is-reshaping-its-car-scrapping-program-automotive-industry-analysis.html
[20] France is reshaping its car scrapping program; FR24 News, July 30 2020; https://www.fr24news.com/a/2020/07/france-is-reshaping-its-car-scrapping-program-automotive-industry-analysis.html
[21] France is reshaping its car scrapping program; FR24 News, July 30 2020; https://www.fr24news.com/a/2020/07/france-is-reshaping-its-car-scrapping-program-automotive-industry-analysis.html
[22] Statistics Canada. Table 20-10-0002-01 New motor vehicle sales, by type of vehicle; https://doi.org/10.25318/2010000201-eng; accessed Sept 13, 2020
[23] Statistics Canada. Table 20-10-0001-01 New motor vehicle sales; https://doi.org/10.25318/2010000101-eng; accessed Sept 19, 2020
[24] Statistics Canada. Table 20-10-0021-01 New motor vehicle registrations; https://doi.org/10.25318/2010002101-eng; accessed Sept 13, 2020
[25] Canada Renewable Power Landscape 2017 – Energy Markets Analysis; Canadian Energy Regulator; Figure 4 (Greenhouse gas intensity of electricity generation by province and territory); https://www.cer-rec.gc.ca/nrg/sttstc/lctrct/rprt/2017cndrnwblpwr/ghgmssn-eng.html?=undefined&wbdisable=true#:~:text=In%202015%2C%20Canada%20emitted%20722,are%20non%2Demitting%20when%20generating

[26] Canada Renewable Power Landscape 2017 – Energy Markets Analysis; Canadian Energy Regulator; Figure 4 (Greenhouse gas intensity of electricity generation by province and territory); https://www.cer-rec.gc.ca/nrg/sttstc/lctrct/rprt/2017cndrnwblpwr/ghgmssn-eng.html?=undefined&wbdisable=true#:~:text=In%202015%2C%20Canada%20emitted%20722,are%20non%2Demitting%20when%20generating

[27] 2018 Registrations: StatsCan 2018; Statistics Canada. Table 23-10-0067-01 Vehicle registrations, by type of vehicle

[28] Passenger Car vs Light Truck Sales: Statistics Canada. Table 20-10-0002-01 New motor vehicle sales, by type of vehicle; https://doi.org/10.25318/2010000201-eng; accessed Sept 13, 2020

[29] Canada: Light-Duty: Fuel Consumption and GHG; TransportPolicy.net; https://www.transportpolicy.net/standard/canada-light-duty-fuel-consumption-and-ghg/

[30] International Energy Agency (IEA), 2019, (Fuel Economy in Major Car Markets: Technology and Policy Drivers 2005-2017). Licence: Creative Commons Attribution CC BY-NC-ND 3.0 IGO for all parts of the work except chapters 4 and Annex B, and International Energy Agency (IEA)/International Council on Clean Transportation (ICCT), 2019, (Fuel Economy in Major Car Markets: Technology and Policy Drivers 2005-2017). Licence: Creative Commons Attribution CC BY-NC-ND 3.0 IGO for chapters 4 and Annex B of the work.

[31] Environment and Climate Change Canada: *Greenhouse Gas Emissions Performance for the 2018 Model Year Light Duty Vehicle Fleet*; Table 22 & Table 23

[32] Statistics Canada. Table 20-10-0002-01 New motor vehicle sales, by type of vehicle; https://doi.org/10.25318/2010000201-eng; accessed Sept 21, 2020