WORKING PAPER 2022-22

JUNE 2022

Canada's path to 100% zero-emission light-duty vehicle sales: Regulatory options and greenhouse gas impacts

Authors: Arijit Sen, Anh Bui, Josh Miller

Keywords: Canada, GHG emissions, LDV, passenger cars, light trucks, Quebec, British Columbia, Ontario, CARB, Advanced Clean Cars II, ACC II, EPA, ECCC, net-zero emissions

Introduction

Canada has set economy-wide greenhouse gas (GHG) reduction targets of 40%–45% below 2005 levels by 2030 and net-zero GHG emissions by 2050. Decarbonization of the transport sector is crucial to meeting these targets since the sector accounts for a quarter of Canada's GHG emissions. Light-duty vehicles (LDV), including passenger cars and light trucks, are the largest source of transport GHG emissions in Canada, accounting for close to half of total transport emissions.[1] In December 2021, Environment and Climate Change Canada (ECCC) launched consultations on how it should achieve Canada's targets of at least 50% zero-emission LDV sales by 2030 and 100% by 2035.[2] In March 2022, it announced plans to develop a sales mandate to require at least 20% electric vehicle (EV) sales by 2026 and 60% by 2030.[3]

1 Environment and Climate Change Canada, "National Inventory Report 1990-2019: Greenhouse gas sources and sinks in Canada," (2021), https://publications.gc.ca/collections/collection_2021/eccc/En81-4-1-2019-eng.pdf.

2 Environment and Climate Change Canada, "Government launches consultations on commitment to require all new cars sold in Canada be zero emission by 2035," December 17, 2021, https://www.canada.ca/en/environment-climate-change/news/2021/12/government-launches-consultations-on-commitment-to-require-all-new-cars-sold-in-canada-be-zero-emission-by-2035.html. In Canada, the term ZEV includes plug-in hybrid electric vehicles (PHEV) as well as battery-electric (BEV) and hydrogen fuel cell electric vehicles (FCEV). In this paper, we refer to this grouping that includes PHEVs as "electric vehicles" (EV) and reserve the term "ZEV" for BEVs and FCEVs. This includes referring to "ZEV regulations" as "EV regulations" if the regulation concern allows for PHEVs. For certain Transport Canada documents as well as entities such as the International ZEV Alliance – the ZEV name is retained.

3 Environment and Climate Change Canada, "2030 emissions reduction plan: Canada's Next Steps for Clean Air and a Strong Economy," (2022), https://www.canada.ca/content/dam/eccc/documents/pdf/climate-change/erp/Canada-2030-Emissions-Reduction-Plan-eng.pdf.

Acknowledgments: This study was generously supported by Crux. The authors thank representatives from Transport Canada, Environment Canada, Province of British Columbia, and Province of Quebec for providing helpful supporting information and feedback. The authors would also like to thank all colleagues who contributed to this study, specifically Ben Sharpe and Zifei Yang for helpful reviews. Any errors are the authors' own.

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Alongside Canada's announcements, several policy developments are unfolding in the United States. In December 2021, the U.S. Environmental Protection Agency (EPA) under the Biden administration finalized its LDV GHG emissions standard for model years (MY) 2023 to 2026.[4] The agency was also directed to develop the next phase of GHG targets for MY 2027 to 2030 and achieve at least 50% EV sales by 2030.[5] In California, the California Air Resource Board (CARB) is currently developing its Advanced Clean Cars II (ACC II) regulation.[6] The draft regulation requires 61% EV sales by 2030 and 100% by 2035—the latter consists of at least 80% zero-emission vehicles (ZEVs) and up to 20% plug-in hybrid electric vehicles (PHEVs) with all-electric range of at least 70 miles.[7] The latest revision to CARB's ACC II regulation was published after the technical analysis for this study was completed.[8] In this revision, CARB improves it's 2030 EV sales target to 68% and the required PHEV all-electric range to 73 miles. We estimate that incorporating these assumptions would slightly improve the emissions outcomes of the scenarios, but not significantly alter the overall results and key findings.

Canada has previously committed to align with "the most stringent performance standards in North America post-2025."[9] Yet, because such regulations are still under development by CARB and EPA, Canada's position could have a material impact on the stringency and degree of alignment with these regulatory pathways. In addition to EV sales targets, several other elements of Canada's regulations could influence their overall CO_2 emissions benefits. These include the extent of vehicle efficiency improvements for internal combustion engine (ICE) vehicles and EVs, as well as whether PHEVs are phased out or continue to account for a significant share of EV sales.

In this paper, we evaluate the CO_2 emissions impacts of several possible regulatory pathways to achieving Canada's 100% EV sales target for LDVs by 2035. To do so, we construct four scenarios based on policies under development in Canada, key Canadian provinces (British Columbia, Quebec, and Ontario), the United States, and California. We then pair these policy assumptions with projections of vehicle sales and electricity grid carbon intensity by Canadian province to evaluate the impacts of each scenario on tailpipe and fuel lifecycle CO_2 emissions. We then compare each of these projected LDV CO_2 emission pathways with Canada's GHG targets and conclude with recommendations for Canadian and other North American regulators to consider for the development of post-2025 standards for LDVs.

4 Revised 2023 and Later Model Year Light-Duty Vehicle Greenhouse Gas Emissions Standards, 8 Fed. Reg. 74434 (December 30, 2021), https://www.govinfo.gov/content/pkg/FR-2021-12-30/pdf/2021-27854.pdf.

5 The White House, "Executive Order on Strengthening American Leadership in Clean Cars and Trucks," https://www.whitehouse.gov/briefing-room/presidential-actions/2021/08/05/executive-order-on-strengthening-american-leadership-in-clean-cars-and-trucks/.

6 Advanced Clean Cars II Meetings and Workshops, California Air Resources Board (CARB), accessed April 1, 2022, https://ww2.arb.ca.gov/our-work/programs/advanced-clean-cars-program/advanced-clean-cars-ii-meetings-workshops.

7 California Air Resources Board, "Zero-Emission Vehicle Standards for 2026 and Subsequent Model Year Passenger Cars and Light-Duty Trucks," (2021), https://ww2.arb.ca.gov/sites/default/files/2021-12/draft%20zero%20emission%20vehicle%20regulation%201962.4%20posted.pdf.

8 California Air Resources Board, "Public Hearing to Consider the Proposed Advanced Clean Cars II Regulations - Staff Report: Initial Statement of Reasons," (2022), https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/isor.pdf.

9 Environment and Climate Change Canada, "Government launches consultations on commitment to require all new cars sold in Canada be zero emission by 2035," December 17, 2021, https://www.canada.ca/en/environment-climate-change/news/2021/12/government-launches-consultations-on-commitment-to-require-all-new-cars-sold-in-canada-be-zero-emission-by-2035.html

Methods

The analysis uses ICCT's Roadmap model updated with historical province-level stock and sales data from Statistics Canada, and future stock and sales projections from Transport Canada.[10] We additionally assume that due to COVID-19, vehicle mileage is affected in 2020 and 2021 but returns to the 2019 level from 2022. The policy scenarios are then overlaid to calculate stock turnover, energy consumption, and CO_2 emission impacts for the provinces of British Columbia, Quebec, Ontario, all other provinces (combined as the Rest of Canada), and at the national level.

Scenario overview

We developed four policy scenarios: a Baseline scenario that accounts for the impacts of currently adopted policies and three Alternative scenarios representing possible regulatory pathways to achieve Canada's target of 100% light duty EV sales in 2035.

The **Baseline** scenario accounts for the impacts of adopted policies, including British Columbia's EV regulation and Canada's LDV GHG standards that are aligned with EPA's through 2026. This implies that in terms of fleet emission standards, EPA's and Canada's reduction pathway between 2022 and 2026 are expected to be roughly similar. We also assume that Quebec, which has not finalized its EV regulations, follows the same pathway as British Columbia's and that Canada will eventually meet its International ZEV Alliance commitment of 100% EV sales by 2050 and achieve gradual reductions in electricity grid carbon intensity.[11] The projection for British Columbia and Quebec is slightly more conservative than Transport Canada's EV baseline projections but higher for the Rest of Canada.[12]

Alternative 1 reflects the ambition of ECCC's December 2021 consultation, which is aligned with Biden's goal of 50% EV sales in the United States by 2030. Meanwhile, **Alternative 2** reflects the ambition of ECCC's March 2022 Emissions Reduction Plan, which is roughly aligned with CARB's draft ACC II regulation.[13] **Alternative 3** goes even further than Alternative 2, assuming post-2026 performance standards that further improve LDV efficiency and a phase out of PHEV sales by 2035. Table 1 provides an overview of scenario assumptions at the national level. The assumptions are discussed with greater detail in the next three subsections.

10 ICCT, Roadmap model version 1.8, (2022), https://theicct.github.io/roadmap-doc/versions/v1.8/

11 ZEV Alliance, "International ZEV Alliance Announcement," November 10, 2021, http://www.zevalliance.org/wp-content/uploads/2021/11/izeva-2021-announcement.pdf

12 ZEV sales shares are derived from the BAU-Base scenario of Transport Canada's "Transport Canada internal ZEV BAU model," January 2022 version, which was provided to ICCT by Transport Canada.

13 Environment and Climate Change Canada, "2030 emissions reduction plan: Canada's Next Steps for Clean Air and a Strong Economy," (2022), https://www.canada.ca/content/dam/eccc/documents/pdf/climate-change/erp/Canada-2030-Emissions-Reduction-Plan-eng.pdf

Table 1. Overview of scenario assumptions at the national level

Scenario	EV sales share			PHEV share of EV sales	Post-2026 annual efficiency improvement[a]	Annualized change in national grid carbon intensity 2020–2050
	2025	2030	2035			
Baseline	13%	21%	38%	28%	0	-0.9%
Alternative 1	15%	50%	100%		2.6%	-3%
Alternative 2	19%	61%		20% from 2026	5.4%	
Alternative 3				0% by 2035	8.5%	

[a] Annualized efficiency improvements continue until reaching a 30% reduction compared to the ICE performance needed to meet EPA's LDV GHG 2026 standard.

Electric vehicle sale shares

The pace of EV uptake is a crucial driver of LDV CO_2 emissions. We developed three sets of EV sales share projections: Baseline, Alternative 1, and Alternatives 2 and 3. For each one, we differentiate assumptions for British Columbia, Quebec, and Ontario and the Rest of Canada (Figure 1). We include Ontario with the Rest of Canada since Ontario has not developed its own EV rule, whereas British Columbia and Quebec have such rules.

The Baseline scenario reflects the growth in EV uptake based on provincial and national policies and goals as of April 2022. In 2019, British Columbia enacted the Zero-Emission Vehicle Act that requires a 30% EV sale share by 2030 and 100% by 2040.[14] We assume a linear growth in EV uptake in British Columbia from 2020 to reach the 2030 target, resulting in 20% uptake in 2025. Quebec has been working to amend its EV regulation but it has not yet been adopted. To reflect Quebec's commitment to advance EV regulation, we assume Quebec follows the same ZEV pathway as British Columbia in this scenario. We base the Rest of Canada EV sale share from 2025 to 2030 on Transport Canada's ZEV business-as-usual (BAU) model projection.[15] The national target of 100% EV sales by 2050 reflects Canada's participation in the International ZEV Alliance and its mission to reach 100% EV sales of passenger vehicles no later than 2050.[16]

Alternative 1 builds on the Baseline scenario and considers more stringent EV regulations. In this scenario, British Columbia accelerates its EV uptake to 26% by 2025, 90% by 2030, and 100% by 2035 based on its Roadmap to 2030.[17] In addition, we assume Quebec adopts its EV draft regulation of 65% EV sales by 2030 and 100% by 2035.[18] At the national level, the government achieves its target of 50% EV sales by 2030, similar to the Biden administration's goal in the United States, and 100% by 2035.[19] The 2035 goal in turn affects the EV sales share assumptions for the Rest of Canada.

Alternatives 2 and 3 reflect more ambitious local and national goals. In these scenarios, British Columbia reaches 95% EV sales by 2030, Quebec achieves a slightly higher

14 Government of British Columbia, "Zero-Emission Vehicles Act," (2019), https://www2.gov.bc.ca/gov/content/industry/electricity-alternative-energy/transportation-energies/clean-transportation-policies-programs/zero-emission-vehicles-act

15 ZEV sales projection was from ZEV BAU scenario in Transport Canada's January 2022 modeling version, provided by Transport Canada.

16 ZEV Alliance, "International ZEV Alliance Announcement," November 10, 2021, http://www.zevalliance.org/wp-content/uploads/2021/11/izeva-2021-announcement.pdf

17 Government of British Columbia, "Roadmap to 2030," (2021), https://www2.gov.bc.ca/assets/gov/environment/climate-change/action/cleanbc/cleanbc_roadmap_2030.pdf

18 Government of Quebec, "Draft regulation to amend the Regulation respecting the application for the ZEV Act," (2021), http://www2.publicationsduquebec.gouv.Quebec.ca/dynamicSearch/telecharge.php?type=1&file=105485.pdf

19 Environment and Climate Change Canada, 2030 emissions reduction plan: Canada's Next Steps for Clean Air and a Strong Economy," (2022), https://www.canada.ca/content/dam/eccc/documents/pdf/climate-change/erp/Canada-2030-Emissions-Reduction-Plan-eng.pdf

2025 EV share to catch up with British Columbia, and Quebec reaches a 75% EV sales share by 2030. Canada achieves its interim target of 61% EV sales by 2030, aligning with CARB's draft ACC II regulation. The main differences between Alternative 2 and Alternative 3 are the split between PHEV and BEV sales, and the assumptions for post-2026 GHG standard stringency and required annual ICE efficiency improvements. These differences are further discussed in the next section.

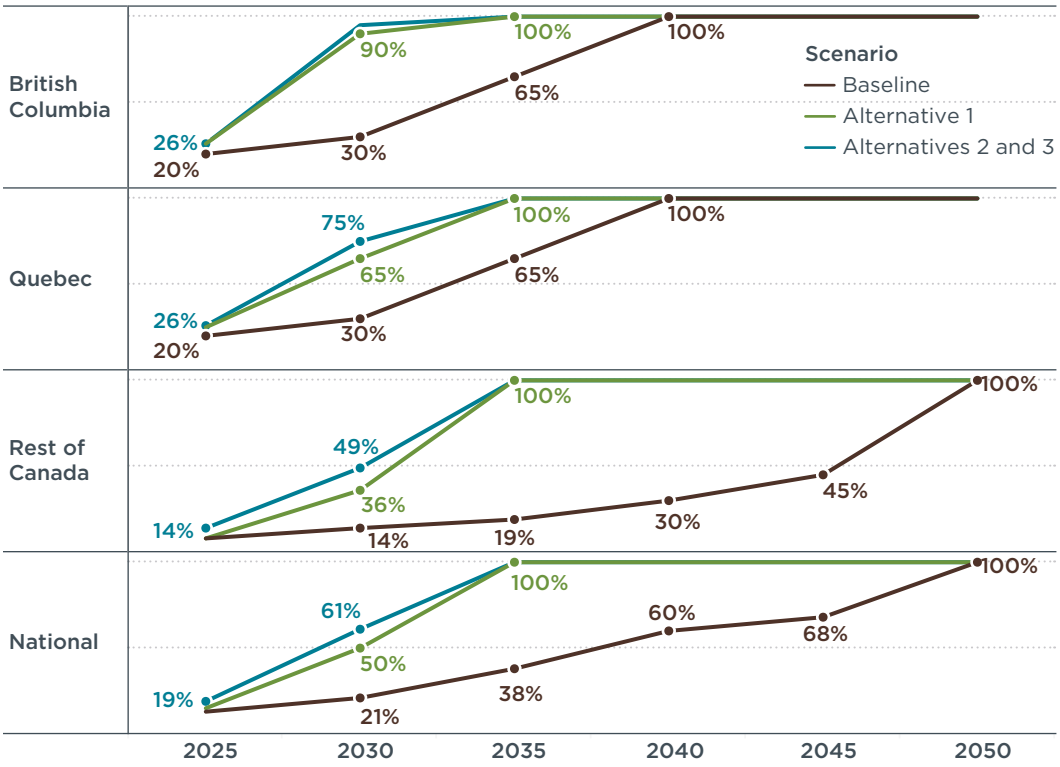

Figure 1. EV sales share assumptions by region and scenario for Canada.

The extent to which PHEVs are phased out or continue to account for a substantial fraction of EV sales has important implications for the progression of CO_2 emissions from LDVs in Canada. Previous ICCT analyses have found that 54% of PHEVs' mileage in North America is powered by electricity while the remainder relies on conventional fuel.[20] PHEVs sold in the United States in 2030 are projected to reduce lifecycle GHG emissions by about 50% compared to average ICE vehicles, whereas BEVs sold in 2030 are projected to reduce lifecycle GHG emissions by 75%.[21] These differences in the lifecycle GHG emissions of BEVs and PHEVs are likely to be greater in Canada since fossil fuel carbon intensity is similar, but Canada's average electricity grid is cleaner than the U.S. average.

PHEVs currently account for a sizeable fraction of Canada's EV market; in 2020, PHEVs made up 28% of total EV sales in Canada. The attractiveness of PHEVs is expected to

20 Patrick Plötz, Cornelius Moll, Yaoming Li, Georg Bieker, and Peter Mock, Real-World Usage of Plug-in Hybrid Electric Vehicles: Fuel Consumption, Electric Driving, and CO2 Emissions, (ICCT: Washington, DC 2020), https://theicct.org/publication/real-world-usage-of-plug-in-hybrid-electric-vehicles-fuel-consumption-electric-driving-and-co2-emissions/.

21 Georg Bieker, A Global Comparison of the Life-Cycle Greenhouse Gas Emissions of Combustion Engine and Electric Passenger Cars, (ICCT: Washington, DC, 2021), https://theicct.org/publication/a-global-comparison-of-the-life-cycle-greenhouse-gas-emissions-of-combustion-engine-and-electric-passenger-cars/.

fall over time as BEVs become increasingly cost-competitive. However, as EV uptake broadens to eventually cover all new LDV sales, it is also possible that certain consumers will prefer the fueling flexibility and greater range of PHEVs. Without policy intervention, there is no guarantee that PHEVs will be phased out completely or even capped at a certain share of EV sales.

Figure 2 shows the assumed split in PHEV and BEV sales shares at the national level in all four scenarios between 2020 and 2035. Post-2035 shares are assumed to be the same as in 2035 and, therefore, are not shown. In the Baseline and Alternative 1 scenarios, absent specific policy interventions, we assume no change in PHEV's share of EV sales.

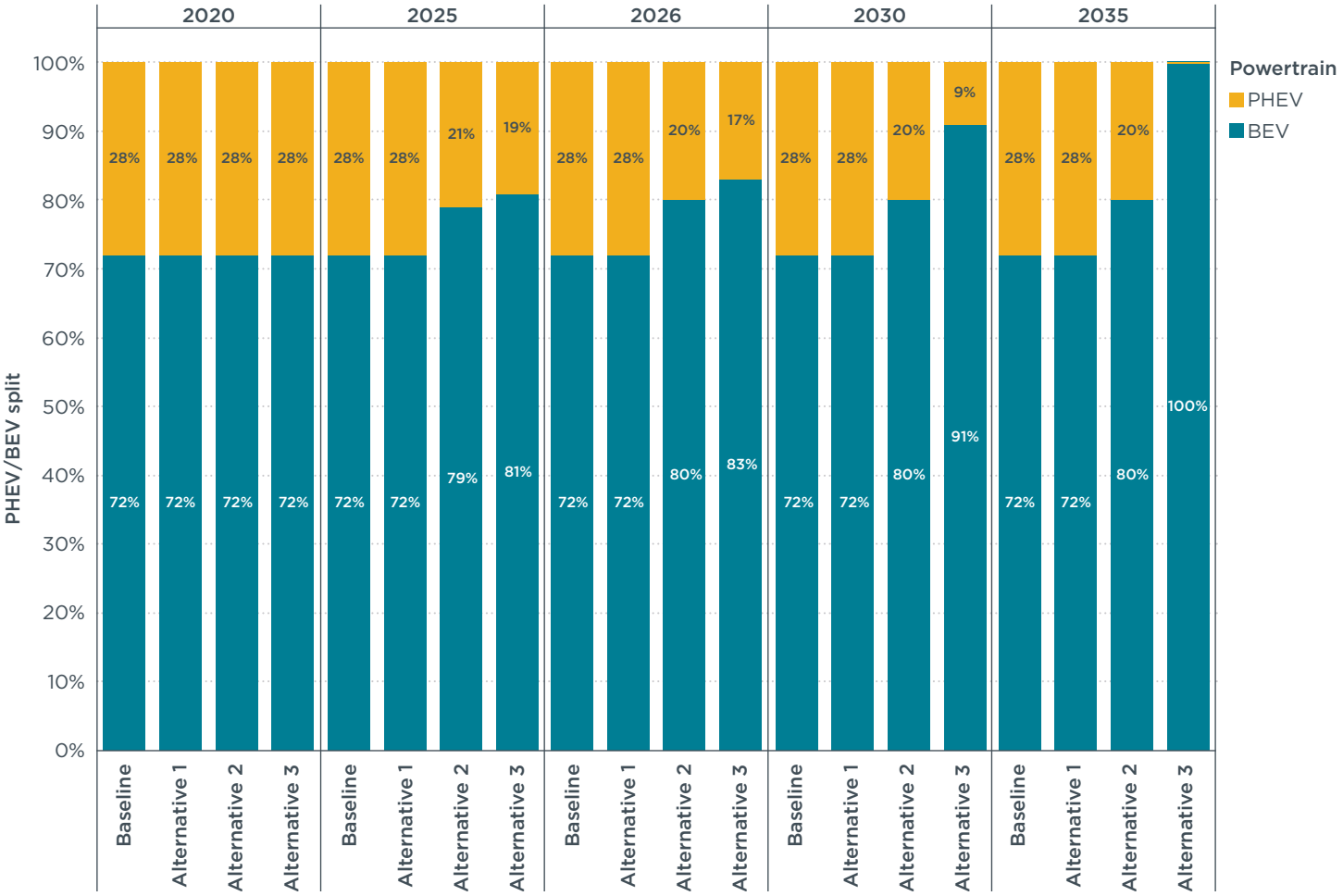

Figure 2. Assumed split in EV sales shares for PHEVs and BEVs by scenario for Canada.

Regulations can be designed to cap or eventually phase out the share of PHEVs to provide greater certainty of LDV GHG emission pathways. In the regulatory impact analysis of the draft ACC II regulation, CARB projects PHEVs will account for 17.3% of EV sales in 2035—or just under CARB's proposed 20% cap.[22] This means that PHEVs would continue to account for a significant share of EV sales in California even as the share

22 California Air Resources Board, "Zero-Emission Vehicle Standards for 2026 and Subsequent Model Year Passenger Cars and Light-Duty Trucks," (2021), https://ww2.arb.ca.gov/sites/default/files/2021-12/draft%20zero%20emission%20vehicle%20regulation%201962.4%20posted.pdf

of ICE vehicles is reduced. We reflect this proposed cap in our Alternative 2 scenario, assuming Canada's EV regulation aligns with CARB's draft ACC II regulation. Although it is possible that PHEVs could account for less than 20% of EV sales in the first three scenarios, we hold the PHEVs share of EV sales constant in the Baseline and Alternative 1 scenarios and at 20% after 2026 in Alternative 2 in order to quantify the GHG benefits of setting a 20% cap on PHEVs' share. In Alternative 3, we assume this cap is tightened over time, leading to a complete phaseout of PHEV sales by 2035. A more detailed breakdown of the PHEV and BEV split by province group (British Columbia, Quebec, and the Rest of Canada) is shown in the Appendix.

Electricity grid carbon intensity

By international measures, Canada's average electricity grid is already relatively clean, yet there is variation among provinces. The extent to which the grid decarbonize over time will impact the well-to-wheel (WTW) emissions of EVs.

Our analysis considers two possible long-term grid carbon intensity pathways developed by the Canada Energy Regulator (CER).[23] Our Baseline scenario assumes grid carbon intensity aligns with CER's Current Policies pathway. This pathway includes gradual improvement in mature technologies and limited uptake of emerging technologies, leading to continued reliance on natural gas for electricity generation. In 2050, the grid carbon intensity in both British Columbia and Quebec is less than 10 grams of CO_2 per kilowatt-hour (gCO_2/kWh), reflecting little change to their relatively clean grids that are primarily hydro powered. Meanwhile, Ontario's grid carbon intensity increases to approximately 40 gCO_2/kWh in 2030 and remains approximately constant until 2050, whereas grid carbon intensity for the Rest of Canada decreases from roughly 280 gCO_2/kWh in 2020 to 160 gCO_2/kWh by 2050 (Figure 3).

Figure 3 shows the two grid carbon intensity pathways in grams per kilowatt-hour (g/kWh) for British Columbia, Quebec, Ontario, and the Rest of Canada from 2019 to 2050.[24] Each of the Alternative scenarios assumes progressive grid decarbonization in line with CER's Net Zero Energy (NZE) pathway. The NZE pathway assumes that stronger domestic climate policy leads to 10%–30% higher demand, depending on the province, due to end-use electrification. By 2050, the grid carbon intensity in British Columbia, Quebec, and the Rest of Canada is 1.3, 1.3, and 4 gCO_2/kWh, respectively, and the grid carbon intensity is 9 gCO_2/kWh in Ontario. In aggregate, national grid carbon intensity reduces from 97 gCO_2/kWh in 2019 to 72 gCO_2/kWh by 2050 under the Current Policies pathway and to 8 gCO_2/kWh by 2050 under the NZE pathway.

23 Canada Energy Regulator, "Canada's Energy Future 2021: Energy supply and demand projections to 2050," (2022), https://open.canada.ca/data/en/dataset/5a6abd9d-d343-41ef-a525-7a1efb686300.

24 The provincial and Rest of Canada Baseline grid emission reduction pathway is based on a combination of data, including electricity generation from Canada Energy Regulator, "Canada's Energy Future 2021: Energy supply and demand projections to 2050," (2022), https://open.canada.ca/data/en/dataset/5a6abd9d-d343-41ef-a525-7a1efb686300, GHG emission from ECCC, "National Inventory Report 1990-2019: Greenhouse gas sources and sinks in Canada," (2021), https://publications.gc.ca/site/eng/9.506002/publication.html and emission factor by generation sources from ICCT's model inventory https://github.com/theicct/roadmap-doc; The Net Zero Emission pathway is based on data from Canada Energy Regulator, "Canada's Energy Future 2021: Energy supply and demand projections to 2050," (2022), https://www.cer-rec.gc.ca/en/data-analysis/canada-energy-future/2021/index.html

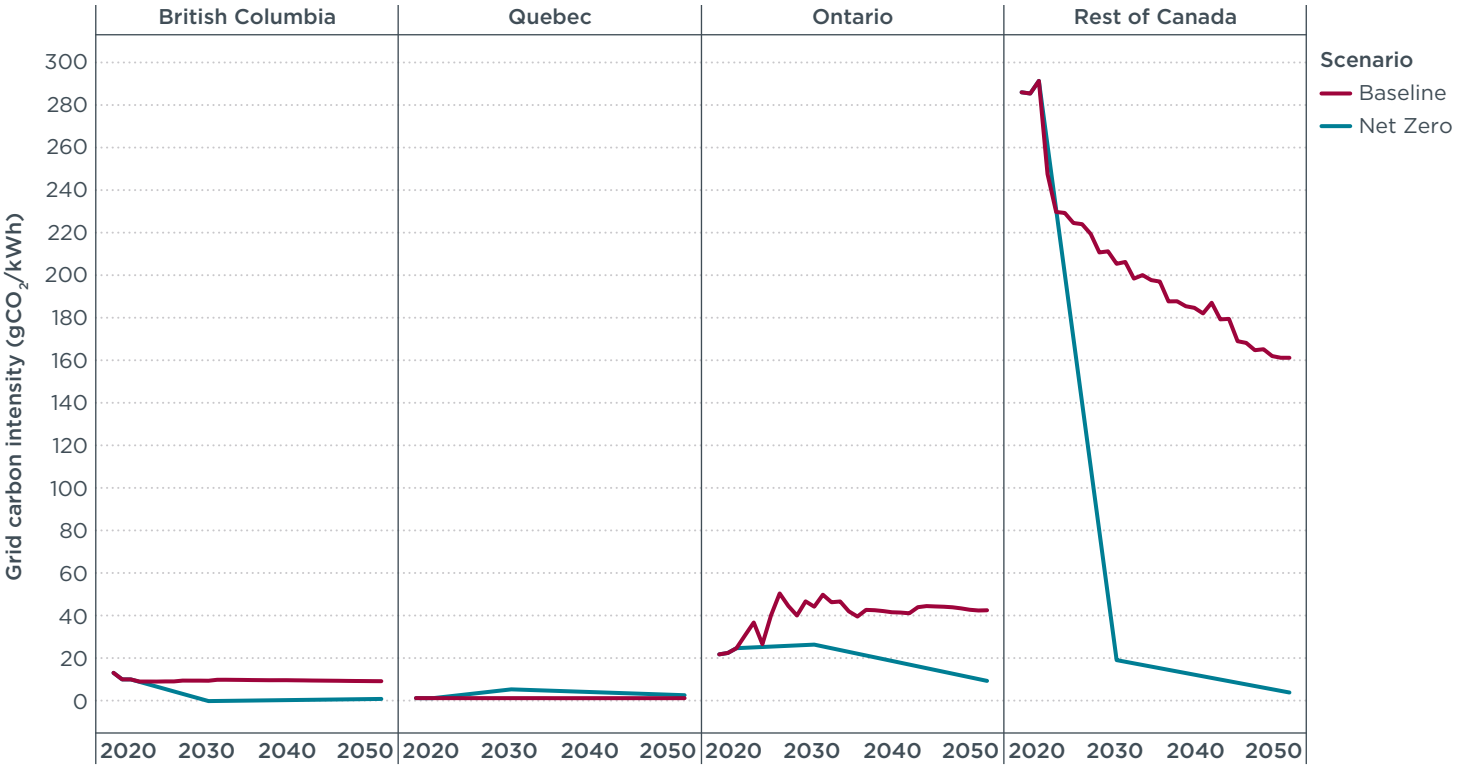

Figure 3. Canada electricity grid carbon intensity from 2020 to 2050 under two grid pathways developed by CER.

ICE and BEV efficiency potential

Canada is expected to remain aligned with EPA's newest LDV GHG standards through 2026.[25] We assume these standards are implemented as-is in all four scenarios. In the Baseline scenario, after accounting for the expected uptake of BEVs and PHEVs, we estimate the energy intensity of ICE vehicles in Canada would need to decline 30% from 2019 to 2026 to meet the MY 2026 GHG standards.[26] In Alternative 1, to achieve the same fleet-level GHG target in 2026, the energy intensity of ICE vehicles would need to decline 25% from 2019 to 2026. In Alternative 2 and Alternative 3, ICE vehicles would need to improve 18%. Among these scenarios, as EV uptake increases, the effective requirements for ICE vehicles become less stringent, since both strategies count toward compliance with the GHG standards.

Even under the Baseline scenario with modest EV uptake, the LDV GHG standards will not exhaust cost-effective ICE efficiency technology potential. For example, EDF consultants used the same version of NHTSA's CAFE model that was used by EPA in its final rule to estimate the costs of further increasing ICE efficiency technology uptake post-2026.[27] They estimate that a further 30% reduction in ICE vehicle fuel consumption is achievable at a cost of $2,780 for cars and $2,450 for light trucks. Under such a

25 8 Fed. Reg. 74434

26 ECCC, "Greenhouse gas emissions performance for the 2019 model year light-duty vehicle fleet: In relation to the Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations under the Canadian Environmental Protection Act, 1999 ," (July 2021), https://www.canada.ca/en/environment-climate-change/services/canadian-environmental-protection-act-registry/greenhouse-gas-emissions-performance-2019.html#tab2.

27 National Highway Traffic Safety Administration, "CAFE Compliance and Effects Modeling System," Accessed March 31, 2022, https://www.nhtsa.gov/corporate-average-fuel-economy/cafe-compliance-and-effects-modeling-system.

scenario, EDF projects that strong hybrids would account for three quarters of ICE vehicle sales.[28]

Previous ICCT studies have indicated that the technology effectiveness assumptions in NHTSA's CAFE model are conservatively low and the costs are conservatively high.[29] In a 2018 analysis, ICCT's estimates of the technology costs to meet EPA MY 2025 standards in Canada were 33% lower than estimated using EPA's technology inputs.[30] If this finding holds for NHTSA's current CAFE model, a further 30% reduction in ICE fuel consumption from MY 2026 could be achievable at a cost of less than $2,000 per vehicle, in line with the benefits estimated by EPA.

In each of our Alternative scenarios, we assume post-2026 GHG standards are tightened to achieve a further 30% improvement in ICE efficiency compared to the MY 2026 ICE energy intensity value projected in the Baseline scenario. Between 2026 and 2030, we assume ICE efficiency improves by 10% in Alternative 1, 20% in Alternative 2, and 30% in Alternative 3. This results in annualized post-2026 energy efficiency improvement rates of 2.6%, 5.4%, and 8.5%, respectively, for the three scenarios. Since in the three alternative scenarios the EV uptake is higher than the Baseline, the ICE energy efficiency value in 2026 is higher as well. This means that, using the annual improvement rates, we find that the 30% improvement from the 2026 Baseline ICE energy efficiency value is achieved by 2043 in Alternative 1, 2036 in Alternative 2, and 2032 in Alternative 3. These improvements are applicable for ICE vehicles as well as the ICE part of PHEVs. We assume that 50% of the PHEV kilometers travelled are using the ICE part of the powertrain, roughly in line with the real-world pattern observed in the United States.[31] In all scenarios, we also assume BEV efficiency improves by 0.65% annually from 2022 to 2035.[32]

GHG targets needed to achieve EV sales and efficiency improvements

The rates of EV uptake modeled in each scenario could be achieved by dedicated EV regulations; however, the modeled ICE vehicle efficiency improvements would require tightening GHG standards post-2026. Assuming no changes to the design of adopted GHG standards through MY 2026, we calculated the GHG targets that would need to be set in 2030 and later to achieve the combination of EV uptake and ICE efficiency improvements modeled in each of the four scenarios.

Table 2 summarizes three key elements in our scenarios: fleet-wide CO_2 compliance targets, EV uptake, and effective targets for ICE vehicles after accounting for EV uptake. Future GHG standards would need to be substantially tightened to phase out ICE vehicles.

28 Environmental Defense Fund, "Letter to California Air Resources Board, Re: EDF Analysis of Impact of Post-2026 GHG Standards on ACCII ICEV Costs," (February 24, 2022), https://www.edf.org/sites/default/files/content/Letter-ARB-EDF-Analysis-Impact-Post-2026-GHG-Standards-ACCII-ICEV-Costs.pdf.

29 Nic Lutsey, Dan Meszler, Aaron Isenstadt, John German, and Josh Miller, Efficiency technology and cost assessment for U.S. 2025-2030 light-duty vehicles, (ICCT: Washington, D.C., 2017) https://theicct.org/wp-content/uploads/2021/06/US-LDV-tech-potential_ICCT_white-paper_22032017.pdf.

30 Francisco Posada, Aaron Isenstadt, Ben Sharpe, and John German, Assessing Canada's 2025 passenger vehicle greenhouse gas standards: benefits analysis, (ICCT: Washington, D.C., 2018), https://theicct.org/publication/assessing-canadas-2025-passenger-vehicle-greenhouse-gas-standards-benefits-analysis/.

31 Patrick Plötz, Cornelius Moll, Yaoming Li, Georg Bieker, and Peter Mock, Real-World Usage of Plug-in Hybrid Electric Vehicles: Fuel Consumption, Electric Driving, and CO_2 Emissions, (ICCT: Washington, DC 2020), https://theicct.org/publication/real-world-usage-of-plug-in-hybrid-electric-vehicles-fuel-consumption-electric-driving-and-co2-emissions/.

32 Nic Lutsley and Michael Nicholas, Update on electric vehicle costs in the United States through 2030, (ICCT: Washington, DC, 2019), https://theicct.org/publication/update-on-electric-vehicle-costs-in-the-united-states-through-2030/.

In the Baseline scenario, assuming no further ICE efficiency improvements after 2026, GHG standards would need to be tightened by 85% from 2026 to 2050 to completely phase out ICE vehicle sales by 2050. In Alternatives 1 and 2, to achieve 100% EV sales in combination with further ICE vehicle and PHEV efficiency improvements, 2035 GHG targets would have to be tightened to 22 and 13 grams of CO_2 per mile (gCO_2/mi), respectively. Under these targets, PHEVs could still account for up to 26% and 18% of EV sales, respectively. In these scenarios, post-2035 improvements in ICE efficiency would only apply to PHEVs since, at that point, ICE vehicle sales have already been phased out. In Alternative 3, tightening GHG targets to 0 gCO_2/mi by 2035 would phase out sales of PHEVs as well as ICE vehicles.

Table 2. GHG targets needed to achieve EV sales and efficiency improvements for all scenarios from 2019 to 2050.

		2019	2022	2026	2030	2035	2040	2050
Baseline	Fleet-wide CO_2 Compliance (gCO_2/mi)	269	243	175	164	137	104	26
	BEV uptake (%)	1.7%	4%	10%	14%	25%	40%	74%
	PHEV uptake (%)	0.8%	2%	4%	5%	10%	15%	26%
	Total EV uptake (%)	2.4%	6%	13%	20%	35%	55%	100%
	Effective Target for ICEs (gCO_2/mi)	283	263	197	197	197	197	197
	Effective Target for ICEs Compared to 2019 (%)	0%	-7%	-30%	-30%	-30%	-30%	-30%
Alternative 1	Fleet-wide CO_2 Compliance (gCO_2/mi)	269	250	183	109	22	19	18
	BEV uptake (%)	1.7%	4%	11%	36%	74%	74%	74%
	PHEV uptake (%)	0.8%	2%	4%	13%	26%	26%	26%
	Total EV uptake (%)	2.4%	6%	16%	50%	100%	100%	100%
	Effective Target for ICEs (gCO_2/mi)	283	269	212	191	167	146	138
	Effective Target for ICEs Compared to 2019 (%)	0%	-5%	-25%	-33%	-41%	-48%	-51%
Alternative 2	Fleet-wide CO_2 Compliance (gCO_2/mi)	269	243	174	83	13	13	13
	BEV uptake (%)	1.7%	7%	22%	49%	81%	81%	81%
	PHEV uptake (%)	0.8%	2%	5%	11%	19%	19%	19%
	Total EV uptake (%)	2.4%	9%	27%	61%	100%	100%	100%
	Effective Target for ICEs (gCO_2/mi)	283	275	230	184	139	138	138
	Effective Target for ICEs Compared to 2019 (%)	0%	-3%	-18%	-35%	-51%	-51%	-51%
Alternative 3	Fleet-wide CO_2 Compliance (gCO_2/mi)	269	243	174	68	0	0	0
	BEV uptake (%)	1.7%	7%	22%	55%	100%	100%	100%
	PHEV uptake (%)	0.8%	2%	4%	5%	0%	0%	0%
	Total EV uptake (%)	2.4%	9%	27%	61%	100%	100%	100%
	Effective Target for ICEs (gCO_2/mi)	283	275	232	162	138	138	138
	Effective Target for ICEs Compared to 2019 (%)	0%	-3%	-18%	-43%	-51%	-51%	-51%

Stock, sales and activity projections

Canada's historical LDV stock data (from 2000 to 2019) and sales data (from 2010 to 2021) were obtained from Statistics Canada.[33] For future projections—2020 to

33 Statistics Canada, "Vehicle registrations, by type of vehicle," (September 2020). https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2310006701; Statistics Canada, "New motor vehicle sales, by type of vehicles," (March 2021). https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2010000201.

2050 for stock and 2022 to 2050 for sales—we used a January 2022 model estimates dataset provided by Transport Canada. Since the 2019 stock and 2021 sales values were different in the Transport Canada dataset, we did not use the absolute projection values from Transport Canada. Instead, the annual growth rate between 2021 and 2050 Transport Canada sales projections and between 2019 and 2050 Transport Canada stock projections were applied to generate projected values consistent with the historical Statistics Canada data as their starting point and the growth rates forecasted by Transport Canada.

Sales growth in Canada is estimated to be 23% between 2021 and 2050, largely driven by British Columbia (24%), Ontario (23%), and Quebec (20%). Model estimates of average vehicle activity per LDV (vehicle-km traveled per vehicle) were calibrated for 2019 to align estimated GHG emissions with ECCC's 2019 GHG data.[34] We then adjusted these estimates for 2020 and 2021 to capture the reduction in activity due to COVID-19. For this, we used data on gasoline sales in 2020 and part of 2021 as proxies for the reductions in vehicle activity compared to 2019 levels—about 15% lower in 2020 and about 8% lower in 2021.[35] From 2022 onwards, average vehicle activity per LDV is assumed to recover to the 2019 value.

Results

EV penetration

Figure 4 shows the LDV stock by powertrain for each scenario and province group. The total LDV stock in Canada is projected to grow 39% from 2020 to 2050, although it slows down after 2035, at which point the stock growth is 33% compared to 2020. There are considerable differences in provincial growth rates between 2020 and 2050: Quebec grows the fastest at 69%, followed by British Columbia at 56% and Ontario at 46%. Like the national stock, the growth rates in these provinces are considerably higher between 2020 and 2035 than between 2035 and 2050. In the Rest of Canada, a slight decrease in total LDV stock (8%) is projected from 2020 to 2050.

In the Baseline scenario, ICE vehicles still account for 36% of the national LDV stock in 2050; however, in the three Alternative scenarios, ICE vehicles account for only a small percentage of the stock by 2050. By 2050, BEVs are projected to reach 46% of total LDV stock in the Baseline scenario, 71% in Alternative 1, 80% in Alternative 2, and 98% in Alternative 3.

At the province level in the Baseline scenario, British Columbia's and Quebec's strong EV policies result in most of the stock being comprised of EVs by 2050 (72% in British Columbia and 59% in Quebec). This is in stark contrast to Ontario, which accounts for approximately 40% of the nationwide LDV fleet, but where only 34% of vehicles are projected to be EVs by 2050. In the Alternative scenarios, the differences in EV uptake are greatest in Ontario and the Rest of Canada, which have not yet adopted strong EV policies but are assumed to reach 100% EV sales by 2035 driven by national regulations.

34 Environment and Climate Change Canada, "Transport sector greenhouse gas emissions, Canada, 1990 to 2019," (October 2021), https://www.canada.ca/en/environment-climate-change/services/environmental-indicators/greenhouse-gas-emissions.html.

35 Statistics Canada, "Sales of fuel used for road motor vehicles, annual," (September 2021), https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=2310006601; Statistics Canada, "Energy Statistics, December 2021," (March 2022), https://www150.statcan.gc.ca/n1/daily-quotidien/220309/dq220309b-eng.htm.

Figure 4. Canada's light-duty vehicle stock from 2020 to 2050 by powertrain for each scenario.

Energy consumption impacts

Figure 5 shows the impacts of each scenario on LDV energy consumption in all regions analyzed. In all scenarios, LDV energy consumption in Canada peaks in 2025. This is primarily driven by the fact that EV sales and significant GHG standard restrictions only start impacting the overall stock after 2025.

In the Baseline scenario, nationwide LDV energy consumption declines 43% from 2025 to 2050. Alternative 3 achieves a reduction of 71% over the same period, which is slightly greater than the reductions in Alternative 2 (68%) and Alternative 1 (67%). The incremental reductions in Alternatives 2 and 3 are mainly driven by their higher proportions of BEVs, which are more energy efficient than PHEVs.

In the Baseline scenario, British Columbia's and Quebec's projected reductions in energy consumption of 52% and 53%, respectively, from 2025 to 2050 are higher than other provinces due to their existing EV policies. In each of the Alternative scenarios, the projected reductions in energy consumption are more similar among provinces due to the convergence of EV sales shares by 2035. In these Alternative scenarios, ICEs account for 14%–24% of LDV energy consumption among provinces by 2050.

Nationally, we project that light-duty EVs in Canada will consume between 61 TWh and 88 TWh of electricity by 2050, depending on the scenario. Based on Canada's Energy Future 2021 estimates, total electricity generation in 2050 is expected to be between 778 TWh and 876 TWh, which means that between 7% and 11% of total electricity generation should be sufficient to meet LDV electricity demand.

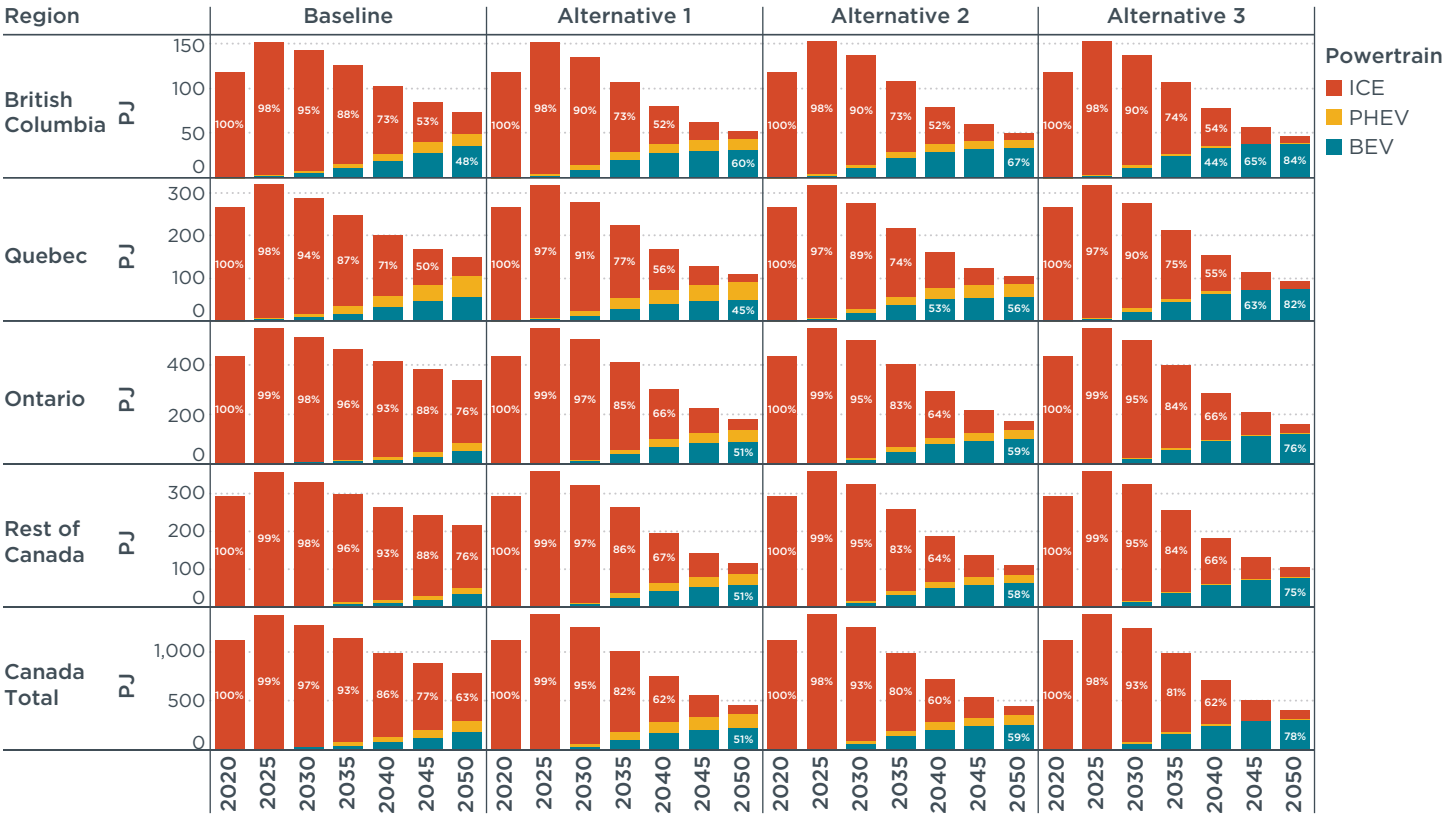

Figure 5. Energy consumption of LDVs in Canada (in Petajoules) from 2020 to 2050 by powertrain and scenario.

Annual CO_2 emissions trajectories

Whether and how Canada meets its 2035 EV target has significant implications for the trajectory of CO_2 emissions from its LDV fleet. In all scenarios, LDV CO_2 emissions are projected to increase until around 2026, reflecting the recovery in vehicle activity after the COVID-19 related slowdown in 2020 and 2021 (Figure 4). Despite differences in EV uptake across scenarios, minimal differences in LDV CO_2 emissions are projected through 2026, since the 2026 LDV GHG standards create a regulatory backstop for fleet average GHG emissions for new vehicles.

Figure 6 summarizes the LDV emission trajectories for both tank-to-wheel (TTW) and well-to-wheel (WTW) CO_2 emissions. In the Baseline scenario, LDV CO_2 emissions are projected to decline 52%–55% from 2021 values by 2050. Projected CO_2 reductions are far more substantial in the Alternative scenarios, achieving TTW CO_2 reductions of 86% in Alternative 1, 88% in Alternative 2, and 93% in Alternative 3. In these scenarios, WTW CO_2 emissions have nearly identical trajectories as TTW CO_2 emissions.

If we consider Canada's 2030 economy-wide GHG reduction target of 40%–45% below 2005 levels and assume LDVs should achieve a similar reduction, their TTW CO_2 emissions should be between 45 million tonnes (Mt) of CO_2 and 50 Mt CO_2 in 2030. Although this benchmark is not met in 2030 under any of these scenarios, Alternative 3 could achieve this benchmark by around 2036—10 years faster than the Baseline scenario.

Considering Canada's net zero GHG target in 2050, LDV CO_2 emissions should be as close to zero as feasible to comply with this target. Of the scenarios we evaluated, only

Alternative 3 gets close to zero in 2050, reaching 8 Mt CO_2 on a WTW basis. In 2050, the key difference between Alternative 3 and Alternative 2 is the complete phaseout of PHEVs by 2035, compared to allowing PHEVs to account for up to 20% of EV sales indefinitely. To further reduce LDV CO_2 emissions to zero in 2050, accelerated fleet renewal will likely be needed along with complete grid decarbonization.

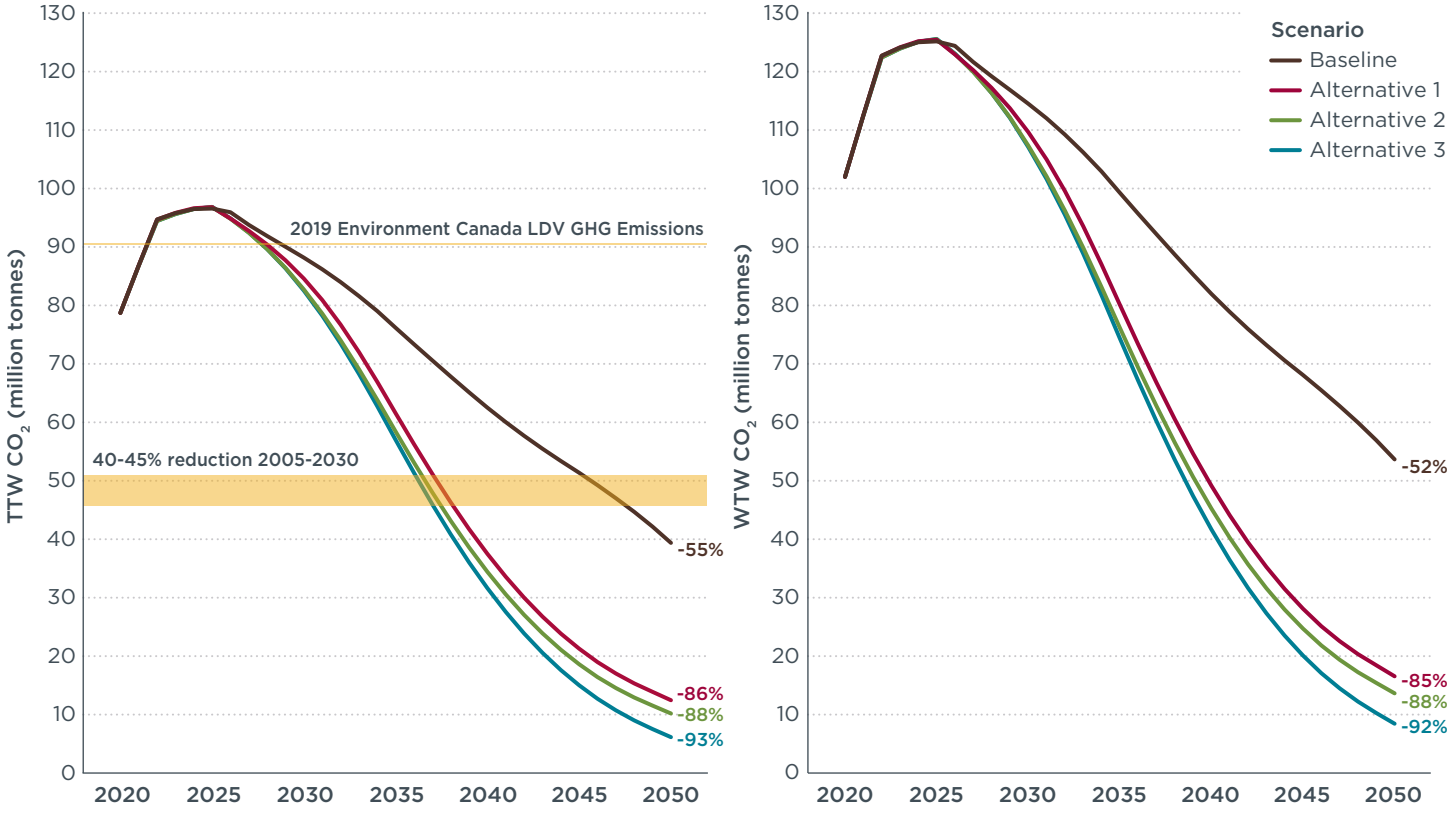

Figure 6. TTW and WTW CO_2 emissions from Canada's LDV fleet between 2020 and 2050. The data labels in 2050 show the percent reduction from 2021 emissions. WTW emissions include TTW emissions and upstream emissions from fuel production, refining, and distribution, as well as electricity generation.

At the provincial level, the disparities in emission reductions in the Baseline scenario reflect the lack of strong EV policies in Ontario and the Rest of Canada (Figure 7). The projected emission reductions in these two regions from 2021 to 2050 are considerably lower (around 40%) than in British Columbia and Quebec (each around 74%). However, in the Alternative scenarios, while Ontario and the Rest of Canada slightly lag behind British Columbia and Quebec, the LDV CO_2 trends are more similar: 85%–88% for Alternative 1, 87%–90% for Alternative 2, and 91%–94% for Alternative 3.

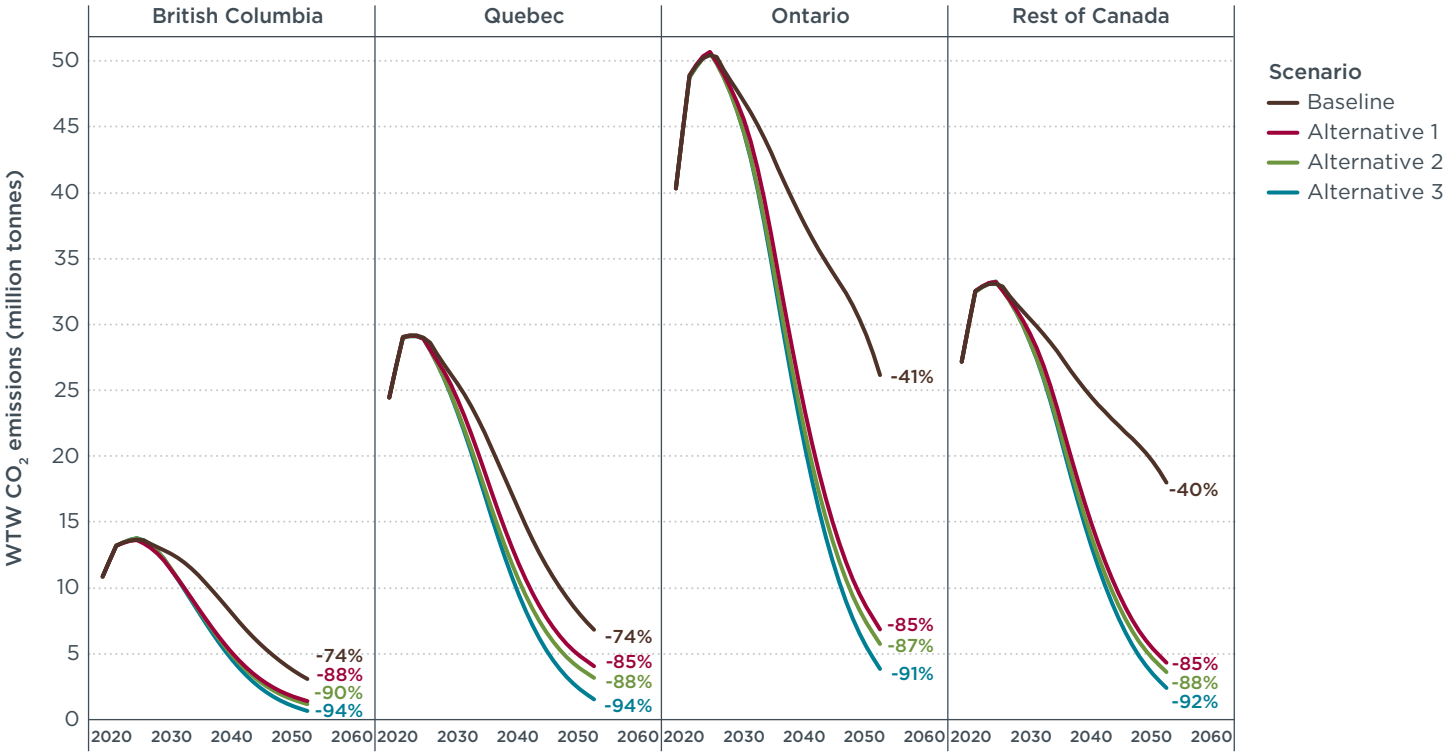

Figure 7. WTW CO_2 emissions from Canada's LDV fleet between 2020 and 2050 by province group. The data labels in 2050 show the percent reduction from 2021 emissions.

Cumulative CO_2 emission reductions

Figure 8 summarizes cumulative LDV CO_2 emissions in the Baseline scenario and reductions in each Alternative scenario from 2027 to 2050. We consider emissions starting from 2027 in order to isolate the impacts of post-2026 regulations. In the Baseline scenario, Canada's LDV fleet is projected to emit nearly 1,600 Mt CO_2 on a TTW basis and 2,130 Mt CO_2 on a WTW basis from 2027 to 2050. Alternative 1 would avoid 28% of these cumulative CO_2 emissions due to increased EV sales, improved ICE efficiency, and reduced grid carbon intensity. Alternative 2 would avoid an additional 60 and 77 Mt CO_2 on a TTW and WTW basis, respectively, compared to Alternative 1, reflecting a 13% increase in benefits compared to Alternative 1. This is primarily driven by a combination of faster EV uptake, the 20% cap on PHEV sales, and tighter ICE efficiency requirements.

Alternative 3 would avoid an additional 51 and 67 Mt CO_2 on a TTW and WTW basis, respectively, compared to Alternative 2, reflecting an additional 11% increase in benefits compared to Alternative 1. In addition to improving ICE efficiency at a faster rate, Alternative 3 is the only scenario which phases out new PHEV sales by 2035. This underlines the importance of provinces and the federal government developing policies that are guaranteed to phase out PHEVs by a certain date, even if BEVs are expected to account for the bulk of EV sales.

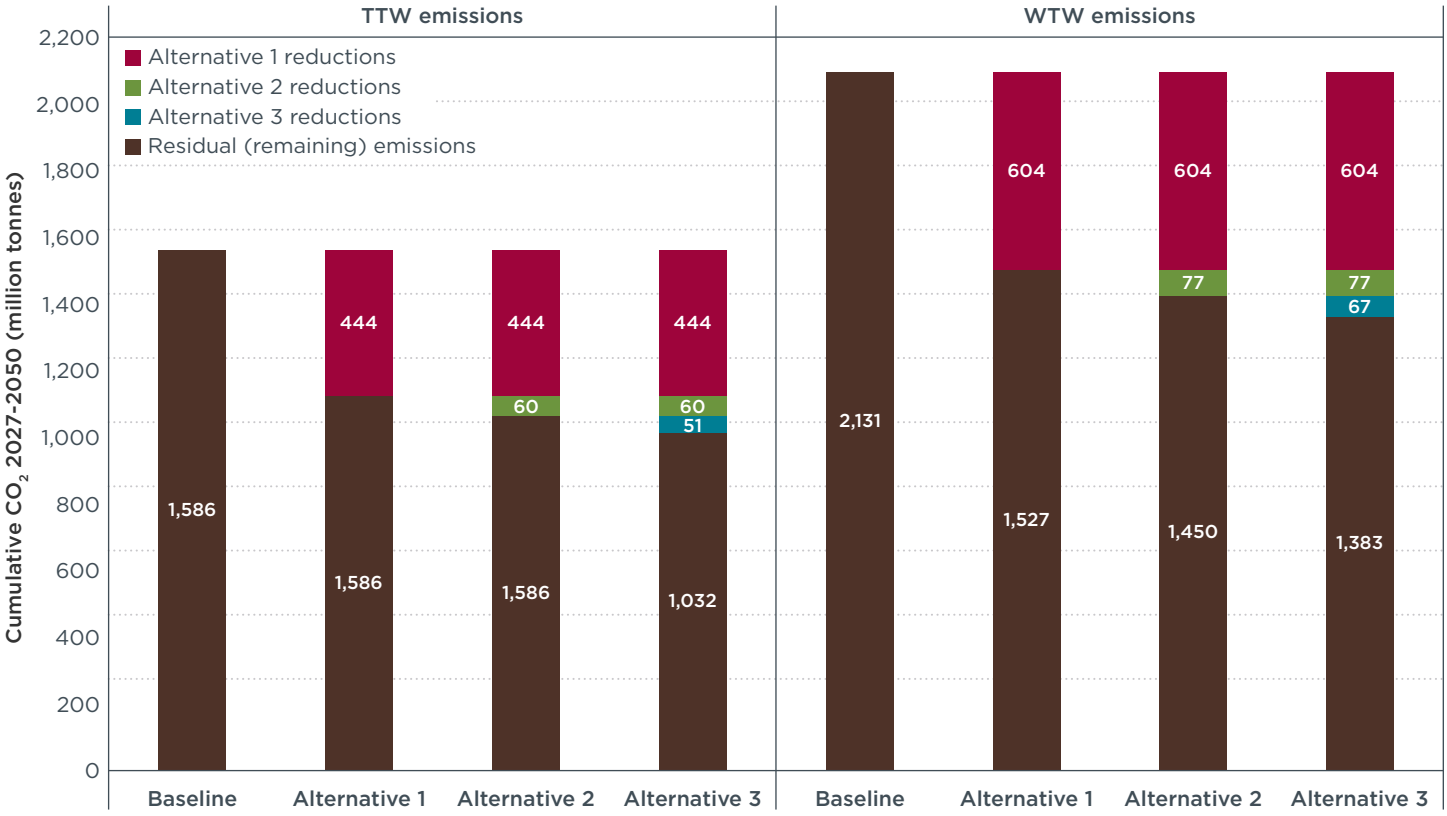

Figure 8. Cumulative TTW and WTW CO_2 emissions from Canada's LDV fleet between 2027 and 2050 and reductions in Alternative scenarios.

Conclusions

Achieving Canada's 100% EV sales target for LDVs by 2035 is crucial to reducing LDV CO_2 emissions in line with Canada's GHG goals. In the near term, federal LDV GHG standards through MY 2026 leave little room to further reduce CO_2 by increasing EV uptake, since increases in EV sales will reduce the effective stringency of the standards for ICE vehicles. Post-2026, however, not all regulatory pathways are equal.

We evaluated three Alternative scenarios to meet Canada's 100% EV sales target for LDVs: Alternative 1, in which Canada achieves 50% EV sales by 2030; Alternative 2, in which Canada achieves 61% EV sales by 2030; and Alternative 3, in which Canada further requires the phase-out of PHEVs by 2035. In each of these scenarios, we also differentiate the assumed rates of ICE efficiency improvement and calculate the GHG standards that would be needed to achieve each combination of EV uptake and ICE improvement.

Although all three Alternative scenarios achieve markedly better outcomes than the Baseline scenario which reflects the impacts of current policies, we find significant differences in the annual CO_2 emission trajectories of these scenarios, their cumulative emission benefits, and the extent to which they are compatible with Canada's 2030 GHG target and 2050 net zero GHG target.

Canada's 2030 economy-wide GHG target requires a 40%–45% reduction from 2005 levels. The most stringent LDV scenario that we modeled (Alternative 3) could achieve a similar level of CO_2 reduction by 2036—10 years faster than in the Baseline scenario.

The differences among Alternative scenarios become more clear when looking out to 2050. Considering Canada's 2050 target of net zero GHG emissions, the only scenario that comes very close to achieving that target is Alternative 3 (-93% from 2021), which completely phases out PHEV sales by 2035. Alternative 2, which caps PHEVs at 20% of EV sales, would achieve an 88% reduction from 2021 to 2050.

Canada should also consider strategies to minimize cumulative LDV CO_2 emissions between now and reaching net zero. One such strategy is aligning with CARB's expected regulatory pathway (Alternative 2), which calls for faster adoption of EVs by 2030 and caps the share of PHEVs in EV sales. This scenario would increase cumulative emission benefits by 13% from 2027 to 2050 compared to the benefits of aligning with likely EPA action (Alternative 1). Canadian regulators should also consider developing more stringent 2030 GHG standards that achieve significant improvements to ICE vehicles as well as high EV uptake. The benefits of tightening GHG standards to varying degrees are reflected in our Alternative scenarios 1, 2, and 3. Finally, regulators should consider phasing out PHEV sales no later than 2035 to maintain a chance at reaching net zero LDV CO_2 emissions by 2050. Doing so would increase cumulative emission benefits by a further 11% (Alternative 3) in addition to the incremental benefits of Alternative 2. Lastly, to eliminate residual CO_2 emissions from ICE vehicles in 2050, regulators could also consider strategies to accelerate fleet turnover and fully decarbonize the electricity grid.

Appendix

The tables below specifies the data behind some of the figures and assumptions that were provided in the main text. These include detailed BEV/PHEV split assumptions by province and scenario at five-year intervals, annual projected LDV sales and stock by province, annual EV sales shares assumptions by province and scenario, annual projected electricity consumption by EVs by province and scenario, and annual projected CO_2 emissions by province and scenario.

Table A1. Scenario assumptions for the share of new light-duty EV sales by powertrain (PHEV and BEV) in British Columbia, Quebec, and the Rest of Canada from 2020 to 2035.

			2020	2025	2026	2030	2035
British Columbia	**Baseline**	PHEV	21%	21%	21%	21%	21%
		BEV	79%	79%	79%	79%	79%
	Alternative 1	PHEV	21%	21%	21%	21%	21%
		BEV	79%	79%	79%	79%	79%
	Alternative 2	PHEV	21%	16%	15%	15%	15%
		BEV	79%	84%	85%	85%	85%
	Alternative 3	PHEV	21%	14%	12%	7%	0%
		BEV	79%	86%	88%	93%	100%
Quebec	**Baseline**	PHEV	35%	35%	35%	35%	35%
		BEV	65%	65%	65%	65%	65%
	Alternative 1	PHEV	35%	35%	35%	35%	35%
		BEV	65%	65%	65%	65%	65%
	Alternative 2	PHEV	35%	26%	25%	25%	25%
		BEV	65%	74%	75%	75%	75%
	Alternative 3	PHEV	35%	23%	21%	12%	0%
		BEV	65%	77%	79%	88%	100%
Rest of Canada	**Baseline**	PHEV	24%	24%	24%	24%	24%
		BEV	76%	76%	76%	76%	76%
	Alternative 1	PHEV	24%	24%	24%	24%	24%
		BEV	76%	76%	76%	76%	76%
	Alternative 2	PHEV	24%	18%	17%	17%	17%
		BEV	76%	82%	83%	83%	83%
	Alternative 3	PHEV	24%	16%	15%	8%	0%
		BEV	76%	84%	85%	92%	100%

Table A2. Projected LDV sales volume by province and nationwide

Year	British Columbia	Quebec	Ontario	Rest of Canada	Canada
2020	175,662	370,108	638,824	373,964	1,558,558
2021	185,038	381,027	622,048	381,973	1,570,086
2022	188,104	384,134	631,614	389,544	1,593,396
2023	204,001	415,820	684,822	422,777	1,727,420
2024	215,922	438,686	724,506	448,037	1,827,151
2025	220,845	448,545	741,000	458,316	1,868,706
2026	222,993	451,799	747,956	463,209	1,885,957
2027	224,177	452,109	751,445	466,486	1,894,217
2028	225,204	452,657	754,540	469,216	1,901,617
2029	225,904	453,530	756,764	470,883	1,907,081
2030	226,159	453,529	757,499	471,612	1,908,799
2031	226,321	454,304	758,149	471,784	1,910,558
2032	226,286	453,010	757,745	472,177	1,909,218
2033	225,705	451,060	755,620	471,276	1,903,661
2034	226,471	452,873	758,254	472,768	1,910,366
2035	226,516	453,104	758,433	472,807	1,910,860
2036	226,211	452,610	757,433	472,117	1,908,371
2037	226,247	452,825	757,597	472,144	1,908,813
2038	226,478	453,489	758,416	472,546	1,910,929
2039	226,550	453,505	758,623	472,744	1,911,422
2040	226,434	453,472	758,277	472,423	1,910,606
2041	226,854	454,451	759,719	473,249	1,914,273
2042	227,578	455,882	762,137	474,763	1,920,360
2043	227,495	455,652	761,849	474,618	1,919,614
2044	227,903	456,289	763,172	475,539	1,922,903
2045	229,142	458,401	767,237	478,268	1,933,048
2046	229,615	459,347	768,819	479,253	1,937,034
2047	230,002	459,959	770,082	480,131	1,940,174
2048	230,322	460,404	771,105	480,874	1,942,705
2049	230,178	459,761	770,537	480,707	1,941,183
2050	229,903	458,885	769,544	480,261	1,938,593

Table A3. EV sales shares by province and nationwide

Scenario	Year	British Columbia	Quebec	Ontario	Rest of Canada	Canada
Baseline	2020	8%	7%	1%	1%	3%
Baseline	2021	11%	11%	2%	2%	5%
Baseline	2022	13%	13%	2%	2%	7%
Baseline	2023	15%	15%	3%	3%	8%
Baseline	2024	17%	17%	5%	5%	10%
Baseline	2025	20%	20%	8%	8%	13%
Baseline	2026	21%	21%	9%	9%	14%
Baseline	2027	24%	24%	9%	9%	15%
Baseline	2028	26%	26%	10%	10%	16%
Baseline	2029	28%	28%	12%	12%	18%
Baseline	2030	30%	30%	14%	14%	21%
Baseline	2031	37%	37%	15%	15%	24%
Baseline	2032	44%	44%	15%	15%	27%
Baseline	2033	51%	51%	16%	16%	31%
Baseline	2034	58%	58%	17%	17%	34%
Baseline	2035	65%	65%	19%	19%	38%
Baseline	2036	72%	72%	21%	21%	42%
Baseline	2037	79%	79%	23%	23%	46%
Baseline	2038	86%	86%	25%	25%	51%
Baseline	2039	93%	93%	28%	28%	55%
Baseline	2040	100%	100%	30%	30%	60%
Baseline	2041	100%	100%	33%	33%	61%
Baseline	2042	100%	100%	36%	36%	63%
Baseline	2043	100%	100%	39%	39%	64%
Baseline	2044	100%	100%	42%	42%	66%
Baseline	2045	100%	100%	45%	45%	68%
Baseline	2046	100%	100%	55%	55%	74%
Baseline	2047	100%	100%	64%	64%	79%
Baseline	2048	100%	100%	74%	74%	85%
Baseline	2049	100%	100%	86%	86%	92%
Baseline	2050	100%	100%	100%	100%	100%
Alternative 1	2020	8%	7%	1%	1%	3%
Alternative 1	2021	12%	11%	2%	2%	6%
Alternative 1	2022	15%	14%	2%	2%	7%
Alternative 1	2023	19%	18%	3%	3%	9%
Alternative 1	2024	22%	21%	5%	5%	12%
Alternative 1	2025	26%	25%	8%	8%	15%
Alternative 1	2026	32%	28%	9%	9%	17%
Alternative 1	2027	40%	32%	16%	16%	24%
Alternative 1	2028	55%	35%	24%	24%	31%
Alternative 1	2029	72%	50%	31%	31%	41%

Scenario	Year	British Columbia	Quebec	Ontario	Rest of Canada	Canada
Alternative 1	2030	90%	65%	36%	36%	50%
Alternative 1	2031	92%	72%	49%	49%	61%
Alternative 1	2032	94%	79%	62%	62%	71%
Alternative 1	2033	96%	86%	75%	75%	81%
Alternative 1	2034	98%	93%	87%	87%	90%
Alternative 1	2035	100%	100%	100%	100%	100%
Alternative 1	2036	100%	100%	100%	100%	100%
Alternative 1	2037	100%	100%	100%	100%	100%
Alternative 1	2038	100%	100%	100%	100%	100%
Alternative 1	2039	100%	100%	100%	100%	100%
Alternative 1	2040	100%	100%	100%	100%	100%
Alternative 1	2041	100%	100%	100%	100%	100%
Alternative 1	2042	100%	100%	100%	100%	100%
Alternative 1	2043	100%	100%	100%	100%	100%
Alternative 1	2044	100%	100%	100%	100%	100%
Alternative 1	2045	100%	100%	100%	100%	100%
Alternative 1	2046	100%	100%	100%	100%	100%
Alternative 1	2047	100%	100%	100%	100%	100%
Alternative 1	2048	100%	100%	100%	100%	100%
Alternative 1	2049	100%	100%	100%	100%	100%
Alternative 1	2050	100%	100%	100%	100%	100%
Alternatives 2 and 3	2020	8%	7%	1%	1%	3%
Alternatives 2 and 3	2021	12%	11%	4%	4%	7%
Alternatives 2 and 3	2022	15%	14%	7%	7%	10%
Alternatives 2 and 3	2023	19%	18%	9%	9%	13%
Alternatives 2 and 3	2024	22%	21%	12%	12%	16%
Alternatives 2 and 3	2025	26%	26%	14%	14%	19%
Alternatives 2 and 3	2026	35%	35%	22%	22%	28%
Alternatives 2 and 3	2027	44%	44%	31%	31%	36%
Alternatives 2 and 3	2028	60%	55%	37%	37%	45%
Alternatives 2 and 3	2029	77%	65%	43%	43%	54%
Alternatives 2 and 3	2030	95%	75%	49%	49%	61%
Alternatives 2 and 3	2031	96%	80%	59%	59%	70%
Alternatives 2 and 3	2032	97%	85%	69%	69%	77%

Scenario	Year	British Columbia	Quebec	Ontario	Rest of Canada	Canada
Alternatives 2 and 3	2033	98%	90%	80%	80%	85%
Alternatives 2 and 3	2034	99%	95%	90%	90%	92%
Alternatives 2 and 3	2035	100%	100%	100%	100%	100%
Alternatives 2 and 3	2036	100%	100%	100%	100%	100%
Alternatives 2 and 3	2037	100%	100%	100%	100%	100%
Alternatives 2 and 3	2038	100%	100%	100%	100%	100%
Alternatives 2 and 3	2039	100%	100%	100%	100%	100%
Alternatives 2 and 3	2040	100%	100%	100%	100%	100%
Alternatives 2 and 3	2041	100%	100%	100%	100%	100%
Alternatives 2 and 3	2042	100%	100%	100%	100%	100%
Alternatives 2 and 3	2043	100%	100%	100%	100%	100%
Alternatives 2 and 3	2044	100%	100%	100%	100%	100%
Alternatives 2 and 3	2045	100%	100%	100%	100%	100%
Alternatives 2 and 3	2046	100%	100%	100%	100%	100%
Alternatives 2 and 3	2047	100%	100%	100%	100%	100%
Alternatives 2 and 3	2048	100%	100%	100%	100%	100%
Alternatives 2 and 3	2049	100%	100%	100%	100%	100%
Alternatives 2 and 3	2050	100%	100%	100%	100%	100%

Table A4. Projected LDV stock by province and nationwide

Year	British Columbia	Quebec	Ontario	Rest of Canada	Canada
2020	2,507,650	5,786,362	9,301,444	6,090,737	23,686,193
2021	2,600,352	5,929,778	9,580,686	6,234,884	24,345,700
2022	2,685,643	6,050,944	9,830,994	6,361,887	24,929,468
2023	2,776,893	6,180,857	10,097,975	6,499,320	25,555,045
2024	2,870,599	6,312,237	10,369,474	6,640,828	26,193,138
2025	2,960,204	6,434,305	10,624,021	6,773,255	26,791,785
2026	3,043,348	6,542,703	10,854,110	6,892,587	27,332,748
2027	3,119,657	6,637,239	11,059,215	6,999,171	27,815,282
2028	3,189,467	6,720,460	11,241,954	7,095,010	28,246,891
2029	3,253,232	6,795,420	11,405,238	7,181,987	28,635,877
2030	3,311,215	6,863,493	11,550,355	7,261,489	28,986,552
2031	3,364,190	6,927,234	11,679,608	7,334,730	29,305,762
2032	3,412,627	6,985,882	11,794,928	7,403,567	29,597,004
2033	3,457,435	7,042,193	11,901,021	7,469,238	29,869,887
2034	3,500,676	7,101,148	12,005,990	7,535,015	30,142,829
2035	3,537,941	7,153,048	12,094,201	7,587,656	30,372,846
2036	3,571,582	7,201,715	12,173,688	7,633,872	30,580,857
2037	3,603,338	7,250,391	12,250,774	7,678,924	30,783,427
2038	3,632,954	7,297,603	12,323,940	7,721,799	30,976,296
2039	3,660,269	7,342,304	12,392,298	7,762,221	31,157,092
2040	3,685,643	7,385,193	12,457,109	7,801,303	31,329,248
2041	3,708,356	7,424,232	12,515,127	7,835,850	31,483,565
2042	3,728,751	7,460,316	12,567,897	7,866,163	31,623,127
2043	3,746,563	7,493,186	12,615,112	7,892,053	31,746,914
2044	3,762,437	7,523,525	12,657,766	7,914,714	31,858,442
2045	3,777,241	7,552,424	12,696,345	7,936,467	31,962,477
2046	3,790,187	7,577,673	12,728,605	7,957,795	32,054,260
2047	3,801,395	7,599,002	12,755,329	7,979,035	32,134,761
2048	3,810,830	7,617,696	12,778,654	7,997,439	32,204,619
2049	3,819,092	7,633,472	12,798,086	8,014,010	32,264,660
2050	3,826,843	7,646,040	12,813,889	8,029,644	32,316,416

Table A5. Projected LDV electricity consumption in TWh by province and nationwide

Scenario	Year	BC	Ontario	Quebec	Rest of Canada	Canada
Baseline	2020	0.0	0.0	0.0	0.0	0.0
Baseline	2021	0.3	0.3	0.3	0.0	0.8
Baseline	2022	0.3	0.3	0.6	0.0	1.1
Baseline	2023	0.3	0.3	0.8	0.3	1.7
Baseline	2024	0.6	0.6	1.1	0.3	2.5
Baseline	2025	0.6	0.6	1.4	0.3	2.8
Baseline	2026	0.8	0.8	1.7	0.6	3.9
Baseline	2027	1.1	1.1	1.9	0.8	5.0
Baseline	2028	1.1	1.4	2.2	0.8	5.6
Baseline	2029	1.4	1.7	2.8	1.1	6.9
Baseline	2030	1.7	1.9	3.1	1.4	8.1
Baseline	2031	1.9	2.5	3.6	1.4	9.4
Baseline	2032	2.2	2.8	4.2	1.7	10.8
Baseline	2033	2.8	3.1	5.0	1.9	12.8
Baseline	2034	3.1	3.6	5.8	2.2	14.7
Baseline	2035	3.6	3.9	6.7	2.5	16.7
Baseline	2036	3.9	4.4	7.5	2.8	18.6
Baseline	2037	4.4	4.7	8.3	3.1	20.6
Baseline	2038	5.0	5.3	9.4	3.3	23.1
Baseline	2039	5.6	5.8	10.6	3.6	25.6
Baseline	2040	6.1	6.4	11.7	4.2	28.3
Baseline	2041	6.7	7.2	12.8	4.4	31.1
Baseline	2042	7.2	7.8	13.6	5.0	33.6
Baseline	2043	7.8	8.6	14.7	5.3	36.4
Baseline	2044	8.3	9.4	15.8	5.8	39.4
Baseline	2045	8.9	10.3	16.7	6.4	42.2
Baseline	2046	9.4	11.4	17.5	7.2	45.6
Baseline	2047	10.0	12.5	18.3	8.1	48.9
Baseline	2048	10.3	14.2	19.2	8.9	52.5
Baseline	2049	10.8	16.1	20.0	10.0	56.9
Baseline	2050	11.1	18.1	20.8	11.4	61.4
Alternative 1	2020	0.0	0.0	0.0	0.0	0.0
Alternative 1	2021	0.3	0.3	0.3	0.0	0.8
Alternative 1	2022	0.3	0.3	0.6	0.0	1.1
Alternative 1	2023	0.3	0.3	0.8	0.3	1.7
Alternative 1	2024	0.6	0.6	1.1	0.3	2.5
Alternative 1	2025	0.8	0.6	1.4	0.3	3.1
Alternative 1	2026	1.1	0.8	1.9	0.6	4.4
Alternative 1	2027	1.4	1.4	2.5	0.8	6.1
Alternative 1	2028	1.7	1.9	2.8	1.4	7.8
Alternative 1	2029	2.2	2.8	3.6	1.7	10.3

Scenario	Year	BC	Ontario	Quebec	Rest of Canada	Canada
Alternative 1	2030	3.1	3.9	4.7	2.5	14.2
Alternative 1	2031	3.9	5.0	5.6	3.3	17.8
Alternative 1	2032	4.4	6.7	6.7	4.2	21.9
Alternative 1	2033	5.3	8.6	7.8	5.3	26.9
Alternative 1	2034	5.8	10.6	9.2	6.7	32.2
Alternative 1	2035	6.4	13.1	10.3	8.3	38.1
Alternative 1	2036	6.9	15.3	11.4	9.7	43.3
Alternative 1	2037	7.5	17.2	12.5	10.8	48.1
Alternative 1	2038	8.1	19.2	13.3	12.2	52.8
Alternative 1	2039	8.3	20.8	14.2	13.3	56.7
Alternative 1	2040	8.6	22.5	14.7	14.2	60.0
Alternative 1	2041	8.9	23.9	15.3	15.0	63.1
Alternative 1	2042	9.2	25.0	15.8	15.8	65.8
Alternative 1	2043	9.2	26.1	16.1	16.4	67.8
Alternative 1	2044	9.4	26.9	16.7	16.9	70.0
Alternative 1	2045	9.4	27.8	16.9	17.5	71.7
Alternative 1	2046	9.4	28.3	16.9	17.8	72.5
Alternative 1	2047	9.7	28.9	17.2	18.3	74.2
Alternative 1	2048	9.7	29.7	17.5	18.9	75.8
Alternative 1	2049	10.0	30.3	17.8	19.2	77.2
Alternative 1	2050	9.7	30.6	17.8	19.4	77.5
Alternative 2	2020	0.0	0.0	0.0	0.0	0.0
Alternative 2	2021	0.3	0.3	0.3	0.0	0.8
Alternative 2	2022	0.3	0.3	0.6	0.3	1.4
Alternative 2	2023	0.3	0.6	0.8	0.3	1.9
Alternative 2	2024	0.6	0.8	1.4	0.6	3.3
Alternative 2	2025	0.8	1.4	1.7	0.8	4.7
Alternative 2	2026	1.1	1.9	2.5	1.1	6.7
Alternative 2	2027	1.4	2.8	3.1	1.7	8.9
Alternative 2	2028	1.9	3.6	4.2	2.2	11.9
Alternative 2	2029	2.5	5.0	5.0	3.1	15.6
Alternative 2	2030	3.3	6.1	6.4	3.9	19.7
Alternative 2	2031	4.2	7.8	7.5	5.0	24.4
Alternative 2	2032	4.7	9.7	8.6	6.1	29.2
Alternative 2	2033	5.6	11.7	10.0	7.2	34.4
Alternative 2	2034	6.1	13.6	11.1	8.6	39.4
Alternative 2	2035	6.9	16.1	12.2	10.3	45.6
Alternative 2	2036	7.5	18.3	13.3	11.4	50.6
Alternative 2	2037	7.8	20.3	14.4	12.8	55.3
Alternative 2	2038	8.3	21.9	15.3	13.9	59.4
Alternative 2	2039	8.6	23.6	15.8	15.0	63.1
Alternative 2	2040	8.9	25.0	16.7	15.8	66.4

Scenario	Year	BC	Ontario	Quebec	Rest of Canada	Canada
Alternative 2	2041	9.2	26.4	16.9	16.7	69.2
Alternative 2	2042	9.4	27.2	17.5	17.2	71.4
Alternative 2	2043	9.7	28.3	17.8	17.8	73.6
Alternative 2	2044	9.7	28.9	18.1	18.3	75.0
Alternative 2	2045	9.7	29.7	18.3	18.6	76.4
Alternative 2	2046	10.0	30.3	18.3	19.2	77.8
Alternative 2	2047	10.0	30.8	18.6	19.4	78.9
Alternative 2	2048	10.0	31.4	18.9	19.7	80.0
Alternative 2	2049	10.3	31.9	19.2	20.3	81.7
Alternative 2	2050	10.3	31.9	19.2	20.3	81.7
Alternative 3	2020	0.0	0.0	0.0	0.0	0.0
Alternative 3	2021	0.3	0.3	0.3	0.0	0.8
Alternative 3	2022	0.3	0.3	0.6	0.3	1.4
Alternative 3	2023	0.3	0.6	0.8	0.3	1.9
Alternative 3	2024	0.6	0.8	1.4	0.6	3.3
Alternative 3	2025	0.8	1.4	1.9	0.8	5.0
Alternative 3	2026	1.1	1.9	2.5	1.1	6.7
Alternative 3	2027	1.4	2.8	3.3	1.7	9.2
Alternative 3	2028	1.9	3.9	4.2	2.2	12.2
Alternative 3	2029	2.5	5.0	5.3	3.1	15.8
Alternative 3	2030	3.3	6.4	6.4	3.9	20.0
Alternative 3	2031	4.2	8.1	7.8	5.0	25.0
Alternative 3	2032	5.0	10.0	9.2	6.4	30.6
Alternative 3	2033	5.6	11.9	10.3	7.5	35.3
Alternative 3	2034	6.4	14.4	11.7	9.2	41.7
Alternative 3	2035	6.9	16.9	13.1	10.6	47.5
Alternative 3	2036	7.8	19.2	14.4	12.2	53.6
Alternative 3	2037	8.3	21.4	15.6	13.6	58.9
Alternative 3	2038	8.6	23.3	16.4	14.7	63.1
Alternative 3	2039	9.2	25.0	17.2	15.8	67.2
Alternative 3	2040	9.4	26.7	18.1	16.9	71.1
Alternative 3	2041	9.7	28.1	18.6	17.8	74.2
Alternative 3	2042	10.0	29.2	19.2	18.3	76.7
Alternative 3	2043	10.3	30.3	19.4	19.2	79.2
Alternative 3	2044	10.3	31.1	20.0	19.7	81.1
Alternative 3	2045	10.3	31.7	20.3	20.0	82.2
Alternative 3	2046	10.6	32.2	20.3	20.6	83.6
Alternative 3	2047	10.6	33.1	20.6	20.8	85.0
Alternative 3	2048	10.8	33.6	20.8	21.4	86.7
Alternative 3	2049	10.8	34.4	21.1	21.7	88.1
Alternative 3	2050	10.8	34.4	21.1	21.7	88.1

Table A6. Projected WTW CO_2 emissions (in million tonnes) by province

Scenario	Year	British Columbia	Quebec	Ontario	Rest of Canada	Canada
Baseline	2020	10.89	24.48	40.36	27.2	102.93
Baseline	2021	12.09	26.85	44.69	29.93	113.56
Baseline	2022	13.26	29.09	48.94	32.57	123.86
Baseline	2023	13.47	29.2	49.68	32.89	125.24
Baseline	2024	13.63	29.21	50.24	33.1	126.18
Baseline	2025	13.7	29.03	50.48	33.12	126.33
Baseline	2026	13.65	28.64	50.34	32.91	125.54
Baseline	2027	13.38	27.79	49.39	32.2	122.76
Baseline	2028	13.13	27.01	48.57	31.58	120.29
Baseline	2029	12.89	26.27	47.78	31.02	117.96
Baseline	2030	12.63	25.53	46.96	30.45	115.57
Baseline	2031	12.32	24.73	46.12	29.89	113.06
Baseline	2032	11.94	23.83	45.19	29.28	110.24
Baseline	2033	11.51	22.84	44.17	28.66	107.18
Baseline	2034	11.01	21.79	43.09	27.99	103.88
Baseline	2035	10.45	20.63	41.88	27.24	100.2
Baseline	2036	9.88	19.46	40.76	26.5	96.6
Baseline	2037	9.29	18.3	39.66	25.81	93.06
Baseline	2038	8.68	17.12	38.59	25.14	89.53
Baseline	2039	8.07	15.94	37.57	24.52	86.1
Baseline	2040	7.45	14.77	36.6	23.93	82.75
Baseline	2041	6.87	13.68	35.69	23.4	79.64
Baseline	2042	6.33	12.67	34.84	22.85	76.69
Baseline	2043	5.82	11.73	34.02	22.36	73.93
Baseline	2044	5.34	10.87	33.22	21.83	71.26
Baseline	2045	4.9	10.06	32.42	21.37	68.75
Baseline	2046	4.49	9.32	31.48	20.83	66.12
Baseline	2047	4.1	8.62	30.41	20.27	63.4
Baseline	2048	3.74	7.98	29.21	19.62	60.55
Baseline	2049	3.41	7.39	27.81	18.88	57.49
Baseline	2050	3.12	6.86	26.19	18.03	54.2
Alternative 1	2020	10.89	24.48	40.36	27.2	102.93
Alternative 1	2021	12.08	26.85	44.69	29.93	113.55
Alternative 1	2022	13.24	29.07	48.94	32.58	123.83
Alternative 1	2023	13.45	29.18	49.75	32.93	125.31
Alternative 1	2024	13.6	29.16	50.39	33.19	126.34
Alternative 1	2025	13.66	28.96	50.72	33.25	126.59
Alternative 1	2026	13.42	28.12	49.93	32.6	124.07
Alternative 1	2027	13.08	27.29	49.05	31.92	121.34
Alternative 1	2028	12.65	26.47	48.03	31.15	118.3
Alternative 1	2029	12.1	25.49	46.89	30.31	114.79

Scenario	Year	British Columbia	Quebec	Ontario	Rest of Canada	Canada
Alternative 1	2030	11.43	24.34	45.58	29.34	110.69
Alternative 1	2031	10.73	23.09	43.92	28.23	105.97
Alternative 1	2032	10	21.74	41.88	26.9	100.52
Alternative 1	2033	9.25	20.3	39.52	25.37	94.44
Alternative 1	2034	8.5	18.81	36.87	23.66	87.84
Alternative 1	2035	7.76	17.29	34.02	21.82	80.89
Alternative 1	2036	7.03	15.82	31.21	20	74.06
Alternative 1	2037	6.34	14.41	28.47	18.23	67.45
Alternative 1	2038	5.69	13.07	25.85	16.53	61.14
Alternative 1	2039	5.08	11.82	23.35	14.92	55.17
Alternative 1	2040	4.52	10.68	21.03	13.43	49.66
Alternative 1	2041	4.01	9.62	18.87	12.04	44.54
Alternative 1	2042	3.56	8.66	16.89	10.77	39.88
Alternative 1	2043	3.15	7.81	15.09	9.6	35.65
Alternative 1	2044	2.79	7.04	13.46	8.54	31.83
Alternative 1	2045	2.48	6.37	12	7.59	28.44
Alternative 1	2046	2.2	5.77	10.68	6.75	25.4
Alternative 1	2047	1.97	5.27	9.56	6.04	22.84
Alternative 1	2048	1.77	4.83	8.57	5.42	20.59
Alternative 1	2049	1.6	4.47	7.72	4.88	18.67
Alternative 1	2050	1.44	4.09	6.89	4.36	16.78
Alternative 2	2020	10.89	24.48	40.36	27.2	102.93
Alternative 2	2021	12.08	26.84	44.65	29.91	113.48
Alternative 2	2022	13.23	29.02	48.79	32.5	123.54
Alternative 2	2023	13.48	29.14	49.59	32.86	125.07
Alternative 2	2024	13.68	29.14	50.26	33.15	126.23
Alternative 2	2025	13.8	28.96	50.67	33.27	126.7
Alternative 2	2026	13.63	28.07	49.82	32.61	124.13
Alternative 2	2027	13.3	27.08	48.82	31.84	121.04
Alternative 2	2028	12.84	25.99	47.63	30.95	117.41
Alternative 2	2029	12.25	24.79	46.24	29.93	113.21
Alternative 2	2030	11.51	23.47	44.63	28.74	108.35
Alternative 2	2031	10.76	22.09	42.73	27.47	103.05
Alternative 2	2032	9.99	20.63	40.5	26.02	97.14
Alternative 2	2033	9.2	19.12	38.01	24.4	90.73
Alternative 2	2034	8.42	17.58	35.29	22.65	83.94
Alternative 2	2035	7.66	16.04	32.42	20.8	76.92
Alternative 2	2036	6.91	14.56	29.59	18.97	70.03
Alternative 2	2037	6.2	13.15	26.86	17.2	63.41
Alternative 2	2038	5.53	11.82	24.24	15.51	57.1
Alternative 2	2039	4.91	10.58	21.77	13.92	51.18
Alternative 2	2040	4.33	9.46	19.48	12.44	45.71

Scenario	Year	British Columbia	Quebec	Ontario	Rest of Canada	Canada
Alternative 2	2041	3.81	8.43	17.35	11.08	40.67
Alternative 2	2042	3.34	7.51	15.41	9.83	36.09
Alternative 2	2043	2.93	6.69	13.66	8.69	31.97
Alternative 2	2044	2.56	5.96	12.08	7.66	28.26
Alternative 2	2045	2.25	5.33	10.67	6.75	25
Alternative 2	2046	1.97	4.77	9.41	5.94	22.09
Alternative 2	2047	1.74	4.3	8.33	5.26	19.63
Alternative 2	2048	1.54	3.89	7.39	4.66	17.48
Alternative 2	2049	1.37	3.55	6.57	4.14	15.63
Alternative 2	2050	1.21	3.2	5.78	3.64	13.83
Alternative 3	2020	10.89	24.48	40.36	27.2	102.93
Alternative 3	2021	12.08	26.84	44.65	29.91	113.48
Alternative 3	2022	13.23	29.02	48.78	32.5	123.53
Alternative 3	2023	13.48	29.14	49.59	32.87	125.08
Alternative 3	2024	13.68	29.14	50.27	33.16	126.25
Alternative 3	2025	13.81	28.95	50.69	33.29	126.74
Alternative 3	2026	13.64	28.07	49.87	32.63	124.21
Alternative 3	2027	13.31	27.07	48.86	31.87	121.11
Alternative 3	2028	12.84	25.95	47.66	30.98	117.43
Alternative 3	2029	12.23	24.71	46.24	29.93	113.11
Alternative 3	2030	11.47	23.33	44.59	28.71	108.1
Alternative 3	2031	10.69	21.88	42.62	27.4	102.59
Alternative 3	2032	9.89	20.33	40.31	25.89	96.42
Alternative 3	2033	9.07	18.72	37.71	24.21	89.71
Alternative 3	2034	8.25	17.06	34.85	22.37	82.53
Alternative 3	2035	7.45	15.4	31.82	20.42	75.09
Alternative 3	2036	6.66	13.79	28.85	18.49	67.79
Alternative 3	2037	5.92	12.26	25.97	16.63	60.78
Alternative 3	2038	5.21	10.83	23.22	14.86	54.12
Alternative 3	2039	4.56	9.5	20.63	13.19	47.88
Alternative 3	2040	3.96	8.29	18.22	11.65	42.12
Alternative 3	2041	3.41	7.18	16	10.22	36.81
Alternative 3	2042	2.92	6.19	13.97	8.91	31.99
Alternative 3	2043	2.49	5.31	12.13	7.72	27.65
Alternative 3	2044	2.11	4.54	10.49	6.65	23.79
Alternative 3	2045	1.78	3.86	9.01	5.69	20.34
Alternative 3	2046	1.49	3.27	7.7	4.85	17.31
Alternative 3	2047	1.25	2.75	6.56	4.13	14.69
Alternative 3	2048	1.04	2.31	5.56	3.5	12.41
Alternative 3	2049	0.86	1.93	4.7	2.95	10.44
Alternative 3	2050	0.69	1.57	3.88	2.44	8.58

Table A7. Projected TTW CO_2 emissions (in million tonnes) by province

Scenario	Year	British Columbia	Quebec	Ontario	Rest of Canada	Canada
Baseline	2020	8.2	18.43	30.38	20.47	77.49
Baseline	2021	9.1	20.22	33.65	22.52	85.48
Baseline	2022	9.98	21.9	36.84	24.5	93.22
Baseline	2023	10.14	21.99	37.41	24.74	94.28
Baseline	2024	10.26	22	37.83	24.88	94.97
Baseline	2025	10.31	21.87	38	24.87	95.05
Baseline	2026	10.28	21.57	37.88	24.7	94.42
Baseline	2027	10.07	20.93	37.16	24.14	92.3
Baseline	2028	9.88	20.34	36.54	23.66	90.43
Baseline	2029	9.7	19.78	35.94	23.2	88.62
Baseline	2030	9.5	19.23	35.31	22.74	86.79
Baseline	2031	9.27	18.63	34.66	22.28	84.83
Baseline	2032	8.98	17.95	33.94	21.8	82.68
Baseline	2033	8.65	17.21	33.17	21.29	80.32
Baseline	2034	8.28	16.41	32.35	20.76	77.8
Baseline	2035	7.85	15.53	31.44	20.16	74.98
Baseline	2036	7.41	14.66	30.57	19.58	72.22
Baseline	2037	6.97	13.78	29.73	19.02	69.49
Baseline	2038	6.51	12.89	28.91	18.48	66.79
Baseline	2039	6.04	12	28.12	17.97	64.13
Baseline	2040	5.57	11.12	27.38	17.48	61.55
Baseline	2041	5.13	10.3	26.67	17.02	59.11
Baseline	2042	4.71	9.53	26	16.57	56.81
Baseline	2043	4.33	8.83	25.35	16.14	54.64
Baseline	2044	3.97	8.17	24.72	15.72	52.58
Baseline	2045	3.63	7.57	24.09	15.3	50.59
Baseline	2046	3.31	7	23.35	14.83	48.5
Baseline	2047	3.02	6.48	22.51	14.3	46.31
Baseline	2048	2.75	6	21.56	13.71	44.02
Baseline	2049	2.5	5.55	20.45	13.02	41.52
Baseline	2050	2.27	5.15	19.16	12.21	38.8
Alternative 1	2020	8.2	18.43	30.38	20.47	77.49
Alternative 1	2021	9.09	20.22	33.65	22.52	85.47
Alternative 1	2022	9.96	21.89	36.84	24.5	93.19
Alternative 1	2023	10.12	21.97	37.46	24.77	94.32
Alternative 1	2024	10.24	21.96	37.94	24.96	95.1
Alternative 1	2025	10.29	21.81	38.19	24.99	95.28
Alternative 1	2026	10.1	21.17	37.59	24.5	93.36
Alternative 1	2027	9.85	20.55	36.92	23.97	91.3
Alternative 1	2028	9.53	19.93	36.14	23.39	88.99
Alternative 1	2029	9.12	19.19	35.26	22.76	86.34

Scenario	Year	British Columbia	Quebec	Ontario	Rest of Canada	Canada
Alternative 1	2030	8.61	18.32	34.26	22.07	83.26
Alternative 1	2031	8.08	17.37	32.99	21.22	79.67
Alternative 1	2032	7.53	16.35	31.43	20.21	75.53
Alternative 1	2033	6.97	15.27	29.62	19.04	70.9
Alternative 1	2034	6.4	14.14	27.6	17.75	65.89
Alternative 1	2035	5.84	12.99	25.42	16.35	60.6
Alternative 1	2036	5.3	11.88	23.27	14.96	55.41
Alternative 1	2037	4.78	10.81	21.19	13.62	50.4
Alternative 1	2038	4.28	9.81	19.19	12.34	45.62
Alternative 1	2039	3.82	8.86	17.3	11.12	41.12
Alternative 1	2040	3.4	8	15.55	10	36.95
Alternative 1	2041	3.02	7.2	13.92	8.96	33.1
Alternative 1	2042	2.68	6.48	12.42	7.99	29.58
Alternative 1	2043	2.37	5.84	11.07	7.12	26.4
Alternative 1	2044	2.1	5.26	9.85	6.33	23.54
Alternative 1	2045	1.86	4.76	8.76	5.62	21
Alternative 1	2046	1.65	4.31	7.78	5	18.74
Alternative 1	2047	1.48	3.93	6.94	4.47	16.82
Alternative 1	2048	1.33	3.6	6.21	4.01	15.16
Alternative 1	2049	1.2	3.33	5.59	3.61	13.73
Alternative 1	2050	1.08	3.05	4.98	3.23	12.33
Alternative 2	2020	8.2	18.43	30.38	20.47	77.49
Alternative 2	2021	9.09	20.21	33.61	22.49	85.41
Alternative 2	2022	9.96	21.85	36.72	24.43	92.97
Alternative 2	2023	10.15	21.95	37.33	24.69	94.12
Alternative 2	2024	10.3	21.95	37.83	24.89	94.97
Alternative 2	2025	10.39	21.8	38.14	24.96	95.3
Alternative 2	2026	10.26	21.14	37.49	24.44	93.33
Alternative 2	2027	10.02	20.39	36.72	23.85	90.97
Alternative 2	2028	9.67	19.56	35.8	23.18	88.22
Alternative 2	2029	9.22	18.66	34.74	22.44	85.06
Alternative 2	2030	8.67	17.66	33.5	21.59	81.43
Alternative 2	2031	8.11	16.61	32.04	20.63	77.39
Alternative 2	2032	7.52	15.51	30.34	19.52	72.89
Alternative 2	2033	6.93	14.37	28.43	18.29	68.02
Alternative 2	2034	6.34	13.2	26.35	16.96	62.86
Alternative 2	2035	5.77	12.04	24.16	15.55	57.52
Alternative 2	2036	5.21	10.92	22.01	14.16	52.3
Alternative 2	2037	4.67	9.86	19.93	12.83	47.28
Alternative 2	2038	4.17	8.86	17.94	11.55	42.52
Alternative 2	2039	3.69	7.93	16.07	10.35	38.04
Alternative 2	2040	3.26	7.08	14.34	9.24	33.92

Scenario	Year	British Columbia	Quebec	Ontario	Rest of Canada	Canada
Alternative 2	2041	2.87	6.3	12.74	8.22	30.13
Alternative 2	2042	2.52	5.61	11.28	7.28	26.68
Alternative 2	2043	2.2	4.99	9.97	6.42	23.59
Alternative 2	2044	1.93	4.45	8.79	5.66	20.82
Alternative 2	2045	1.69	3.97	7.74	4.98	18.38
Alternative 2	2046	1.48	3.55	6.81	4.38	16.22
Alternative 2	2047	1.3	3.2	6	3.87	14.38
Alternative 2	2048	1.15	2.89	5.31	3.43	12.78
Alternative 2	2049	1.02	2.63	4.71	3.05	11.42
Alternative 2	2050	0.9	2.38	4.13	2.69	10.09
Alternative 3	2020	8.2	18.43	30.38	20.47	77.49
Alternative 3	2021	9.09	20.21	33.61	22.49	85.41
Alternative 3	2022	9.96	21.85	36.72	24.43	92.96
Alternative 3	2023	10.15	21.94	37.33	24.69	94.12
Alternative 3	2024	10.3	21.94	37.84	24.89	94.98
Alternative 3	2025	10.4	21.8	38.15	24.97	95.33
Alternative 3	2026	10.27	21.14	37.52	24.46	93.39
Alternative 3	2027	10.02	20.38	36.75	23.87	91.02
Alternative 3	2028	9.67	19.53	35.83	23.19	88.22
Alternative 3	2029	9.21	18.59	34.74	22.43	84.98
Alternative 3	2030	8.64	17.55	33.46	21.57	81.23
Alternative 3	2031	8.05	16.45	31.95	20.57	77.03
Alternative 3	2032	7.45	15.28	30.19	19.42	72.34
Alternative 3	2033	6.83	14.06	28.19	18.14	67.23
Alternative 3	2034	6.21	12.81	26.01	16.75	61.79
Alternative 3	2035	5.61	11.55	23.7	15.26	56.12
Alternative 3	2036	5.02	10.34	21.43	13.8	50.59
Alternative 3	2037	4.45	9.19	19.24	12.39	45.28
Alternative 3	2038	3.92	8.11	17.16	11.05	40.24
Alternative 3	2039	3.43	7.1	15.19	9.79	35.52
Alternative 3	2040	2.98	6.19	13.38	8.63	31.17
Alternative 3	2041	2.57	5.36	11.7	7.56	27.18
Alternative 3	2042	2.2	4.61	10.17	6.58	23.56
Alternative 3	2043	1.87	3.95	8.8	5.69	20.3
Alternative 3	2044	1.58	3.37	7.57	4.89	17.4
Alternative 3	2045	1.34	2.86	6.47	4.17	14.84
Alternative 3	2046	1.12	2.41	5.49	3.55	12.57
Alternative 3	2047	0.93	2.03	4.65	3.02	10.63
Alternative 3	2048	0.77	1.69	3.91	2.55	8.93
Alternative 3	2049	0.64	1.41	3.28	2.15	7.47
Alternative 3	2050	0.51	1.14	2.68	1.77	6.11

Table A8. Projected cumulative TTW and WTW CO_2 emissions (in million tonnes) by province from 2027–2050

Region	Scenario	TTW CO_2	WTW CO_2
British Columbia	Baseline	150.30	200.76
British Columbia	Alternative 1	112.27	149.12
British Columbia	Alternative 2	110.32	146.54
British Columbia	Alternative 3	105.04	139.55
Ontario	Baseline	689.09	921.61
Ontario	Alternative 1	473.68	635.39
Ontario	Alternative 2	449.85	604.85
Ontario	Alternative 3	431.94	581.57
Quebec	Baseline	305.03	405.19
Quebec	Alternative 1	251.24	334.55
Quebec	Alternative 2	232.62	310.01
Quebec	Alternative 3	215.96	288.03
Rest of Canada	Baseline	441.37	603.65
Rest of Canada	Alternative 1	305.15	407.81
Rest of Canada	Alternative 2	290.11	388.49
Rest of Canada	Alternative 3	278.80	373.68
Canada	Baseline	1585.80	2131.21
Canada	Alternative 1	1142.34	1526.87
Canada	Alternative 2	1082.90	1449.88
Canada	Alternative 3	1031.75	1382.83