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Assessing Canada's 2025 passenger vehicle greenhouse gas standards: Methodology and OMEGA model description

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Background

This paper is part of a series that reports on an analysis done by the ICCT of Canada-specific technology pathways, costs, and benefits of Canada's 2025 passenger vehicle greenhouse gas standards, as finalized in 2014 (Regulations Amending the Passenger Automobile and Light Truck Greenhouse Gas Emission Regulations, 2014). The analysis compares that scenario—that is, the standards in force—to the alternative of following the Trump Administration's proposal to roll back the 2025 U.S. fuel economy and greenhouse gas emissions standards.

The comparison is relevant because Canada's passenger vehicle fuel efficiency regulation is structured in such a way as to tie Canada's standards directly to the U.S. regulation. If Canada rests with the regulatory status quo, its greenhouse gas standards will automatically retreat to whatever level is the final outcome of the U.S. rulemaking process initiated in August 2018.

The ICCT analysis used the U.S. Environmental Protection Agency's Optimization Model for Reducing Emissions of Greenhouse Gases from Automobiles (OMEGA) version 1.4.56, updated most recently to support the technical assessment for the midterm review (U.S. Environmental Protection Agency [EPA], National Highway Traffic Safety Administration [NHTSA], and California Air Resources Board [CARB], 2016a). The model evaluates the relative costs and effectiveness (CO_2 emission reduction) of vehicle technologies and applies them to a defined baseline vehicle fleet to meet a specified CO_2 emissions target.

This analysis applied the OMEGA model to the Canadian baseline fleet[1] to assess the costs and benefits of different regulatory scenarios. This paper describes the methodology and model used in carrying out the analysis.

OMEGA model description

OMEGA was developed by the EPA as a tool to evaluate the impact of the U.S. 2012–2016 greenhouse gas (GHG) regulations for the light-duty vehicle (LDV) fleet. It was used again in the development and assessment of the 2017–2025 standards, and updated in 2016 for the midterm review analysis (EPA, NHTSA, & CARB, 2016a).

The ICCT analysis of the Canadian standards also incorporated ICCT updates as inputs to the OMEGA model. Those updates considered both emerging technologies and improvements in known technologies, which yielded both reduced costs and improved GHG benefits (Lutsey, Meszler, Isenstadt, German, & Miller, 2017). Using both EPA and ICCT cost curves in the OMEGA model allows this analysis to capture a range of outlooks for vehicle and engine design under GHG standards in the 2012–2025 time frame. Each cost curve includes technologies that are applicable to various types of vehicles, as well as their costs, phase-in constraints, and how effective they are at improving efficiencies.

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[1] For a detailed description of the baseline fleet used in this analysis, see the first paper in this series, Posada, Isenstadt, Sharpe, and German (2018).

The OMEGA model combines the technology and cost inputs with the baseline fleet data to project how various manufacturers would apply the available technology to meet increasingly stringent CO_2 emission targets. The result is a description of the technologies that would need to be added to each vehicle platform, along with the resulting costs, to reach the CO_2 targets under various GHG standards.

OMEGA is designed to apply technology in a manner similar to the way that a vehicle manufacturer might make such decisions (EPA, NHTSA, & CARB, 2016b). In general, the model considers the cost of the technology and the degree to which the technology moves the manufacturer toward achieving its fleet-wide CO_2 emission target. Although the model solves an optimization problem to find the lowest compliance cost for each manufacturer, it does not solve the problem for each vehicle. This makes some specific vehicle models overcompliant while others may be undercompliant. As such, it is not necessarily useful to assess the outcomes by vehicle model. Instead, outputs should give a good understanding of the average costs by manufacturer or vehicle type. The model applies technology—subject to phase-in constraints, such as estimated hybrid and electric vehicle (EV) penetration rates—to vehicles until the sales- and activity-weighted emission average complies with the specified standard, or until all the available technologies have been applied. Vehicle activity is used to balance total CO_2 for cars and trucks.[2]

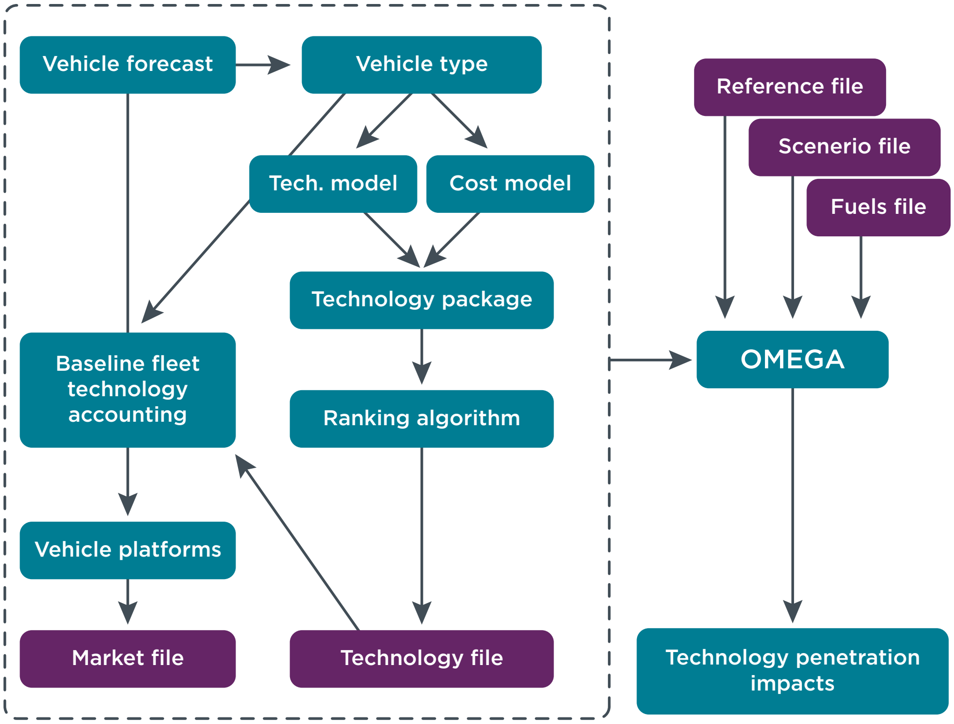

Figure 1. OMEGA model general structure and information flow.
Source: (Posada et al., 2017)

OMEGA FILES

The overall structure of the OMEGA model is summarized in Figure 1. OMEGA includes several components, including a number of preprocessors that assist the user in preparing a baseline vehicle database, creating and ranking technology packages, and calculating the degree to which technology is present on baseline vehicles. OMEGA's core model collates this information and produces estimates of changes in vehicle cost and CO_2 emission level. Based on this output, the technology penetration and costs of the new vehicle mix are calculated via postprocessors.

The OMEGA model uses five basic sets of input data: the vehicle market file, the technology file, the fuels file, the compliance scenario file, and the reference file. Following is a list of model input requirements that were modified in the ICCT analysis for use with the Canadian LDV fleet. Note that the reference file and the fuels file are unchanged for the Canadian fleet.

Vehicle market fleet characterization file

OMEGA requires a detailed baseline fleet, including manufacturer, sales, base CO_2 emissions, footprint, and the extent to which efficiency technologies are already in use. This file is the input that describes the vehicle fleet composition used by the model to estimate costs. This file also contains information on future sales. On a vehicle-by-vehicle basis, the market data worksheet is composed of:

a. Manufacturer

b. Model

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[2] The average lifetime mileage accrual is assumed to be approximately 141,100 miles for passenger cars and 158,200 miles for light trucks (Lawson, 2010).

c. Vehicle type number

d. EPA vehicle class (car or truck)

e. Sales

f. Tailpipe emissions, gCO_2/mi

g. Footprint, ft^2

h. Fuel type

j. Refrigerant type (for air conditioners)

k. Efficiency technology penetration

The last input item, the efficiency technology penetration, contains information on all of the technologies that are already incorporated in the baseline vehicle fleet. This basic set of information allows the model to avoid adding technology to models that are already sold with the technology. It follows that costs are also discounted. As an example, if a vehicle model sold in 2016 already has turbocharging technology, then the cost of that specific technology is removed from the technology package costs for that specific model.

As described in the Canadian vehicle market characterization document (Posada et al., 2018), the original Canadian fleet database lacked information on many of the technologies included in the OMEGA model. Filling in the missing fields was primarily performed by combining several databases, as well as obtaining data from online sources. Sales data for the OMEGA baseline was taken from the original calendar year (CY) 2016 database. Though total sales in Canada have grown somewhat over the past few years, the car/truck market split has remained fairly stable. No projections on future sales growth were made. Instead, current sales volumes (and corresponding car/truck split) were maintained.

The efficiency technology file

The technology file contains costs and efficiency values for each of the technology packages by vehicle type. Technology packages combine a number of individual technologies that reduce CO_2 emissions according to vehicle type. The OMEGA model uses 29 different vehicle types to assign technology packages (EPA, NHTSA, & CARB, 2016b). These vehicle types represent various vehicle categories, including subcompact cars, midsize cars, crossovers, sport utilities (SUVs), and pickups, as well as variants within these categories, such as luxury or sport models, with different performance characteristics. EPA defined a set of criteria to aggregate the application of many dozens of different model offerings across 29 different vehicle types according to their differing engine technology, power, and weight characteristics.

EPA developed a list of 50 fuel-efficiency technology packages that can be applied to each vehicle type. Technology packages and costs are also defined for each of the evaluation years 2021 and 2025, as well as the baseline. In total, the technology file includes 1,099 technology package estimates of cost and fuel economy benefits (EPA, NHTSA, & CARB, 2016b). A detailed description of how these technology packages were defined is available in the appendix of EPA's draft technical assessment (EPA, NHTSA, & CARB, 2016b).

The cost data for most of the technology packages was developed by EPA using vehicle tear-down studies (EPA, NHTSA, & CARB, 2016a). Such studies involve disassembling vehicle systems and components to identify each component part—down to the level of individual nuts and bolts—and then estimating and aggregating the manufacturing costs associated with each component. A list of components was developed and costed using the best, and most credible, available information. Where tear-down cost estimates were not available, information was obtained from parts suppliers and vehicle manufacturers. A detailed description on how individual technology costs were assessed is available in the appendix of EPA's draft technical assessment (EPA, NHTSA & CARB, 2016b).

In addition to developing current cost estimates for fuel economy technologies, EPA also estimated learning factors, which are used to forecast future year costs from developed base year costs, and the current state of development for each potential fuel economy technology. Technologies that are in a more advanced stage of development are assumed to undergo relatively minor cost declines over time, whereas emerging technologies are subject to greater reductions, which are expected to accrue as manufacturers gain design and production experience. Thus, the same technology usually has a lower cost in 2025 than it does in 2021 or 2020.

Efficiency benefits were first determined for each individual technology, then synergies between technologies were evaluated to integrate technologies into the model as technology packages. Estimates of the fuel economy benefits of a given technology were based on detailed vehicle simulation modeling. Such estimates are necessary to define the specific benefits associated with both individual technologies and packages of multiple technologies, and to determine how much technology is required to attain a specific standard. Substituting alternative technologies for one or more of the vehicle components allows for associated fuel economy effects to be isolated. The development of the required physical models is quite demanding, but the resulting impact estimates are quite rigorous.

Although EPA's technology and cost assumptions used as inputs in OMEGA version 1.4.56 were rigorous and comprehensive, delays in obtaining and processing data meant that the latest developments in this fast-changing market were not included. To help evaluate recent technology development and inform the next phase of fuel economy standards in the United States, the ICCT conducted a study of emerging vehicle efficiency technologies and their emission benefits and costs in the 2025–2030 time frame (Lutsey et al., 2017). The analysis was focused on providing an update to the U.S. midterm evaluation regulatory analysis for new 2025 vehicles, as well as estimating the potential and cost of continued improvements through 2030. The analysis starts with the technology inputs and updates the technology cost and benefit inputs according to the latest research on emerging technologies, including cylinder deactivation, hybridization, lightweighting, and electric vehicles. These updates were conducted in cooperation with vehicle suppliers and draw upon peer-reviewed literature, simulation modeling, and auto industry developments.

The ICCT's analysis for the U.S. market indicates that an 8%–10% greater efficiency improvement in internal combustion engines is available by 2025 at no additional cost relative to the improvements reflected in OMEGA's technology data (Lutsey et al., 2017). Continual improvements to technologies such as cylinder deactivation, high-compression Atkinson-cycle engines, lightweighting, and mild hybridization will allow manufacturers to comply with 2025 GHG standards without full hybrids or plug-in vehicles. The analysis also found that the cost of plug-in vehicles is dropping rapidly and that some manufacturers may decide that plug-in vehicles are a more cost-effective solution to meeting the 2025 standards and beyond.

At the same time, technology costs continue to decrease, demonstrating that previous estimates—including those made by EPA—have been too conservative. State-of-the-art engineering studies and emerging technologies from suppliers indicate that by 2025, costs for lightweighting, gasoline direct injection (GDI), and cooled exhaust gas recirculation will be reduced by hundreds of dollars per vehicle, and electric vehicle costs will drop by thousands of dollars per vehicle. Including these latest efficiency developments, the ICCT estimates that compliance costs for the 2025 standards will be 34%–40% lower than projected in the latest U.S. midterm evaluation regulatory analysis (Lutsey et al., 2017).

In modeling Canada's LDV fleet for this analysis, no changes were made to the technology files developed by EPA and ICCT for the U.S. modeling. The Canadian assessment used the same technology file used by EPA in the midterm review as the EPA input, and the ICCT modifications to the EPA inputs were used as the ICCT input. (See Lutsey et al. [2017] for more details on these modifications.) As explained in the first part document to this analysis (Posada, Isenstadt, Sharpe, and German, 2018), the LDV market for Canada and the United States is extremely similar, with vehicle characteristics (average mass, rated power, and others) and CO_2 emissions performance numbers within +/- 2% of each other. Due to the almost complete harmonization of vehicles and fuel-efficiency technologies between the United States and Canada, no changes were made to the original EPA and ICCT estimates of total manufacturing costs and cost reductions by learning in manufacturing to reflect the cost of producing vehicles in Canada.[3]

The U.S. federal government has proposed to roll back the CO_2 emissions standards for model years 2022–2025. California, and the so-called Section 177 U.S. states that have adopted California's vehicle standards in lieu of the federal standards, have made it clear that they do not intend to roll back their separate standards similarly.[4] Combined sales of new light-duty vehicles in Canada, California, and the Section 177 states total approximately 8.1 million, or about 41% of all new LDV sales (totaling 19.8 million) in the United States and Canada (Luria, Baum, & Sharpe, 2018). A market size of 8.1 million vehicles is large enough that costs similar to those in the OMEGA analysis still apply. Furthermore, the market for these efficiency technologies stretches far beyond North America (most other large vehicle markets worldwide are subject to fuel-efficiency standards that approximate the MY 2022–2025 standards in California, the Section 177 states, and Canada), which lends additional credibility to the cost estimates used in the OMEGA model.

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[3] EPA's technology cost analysis includes a consideration for projected cost reductions as an effect of process learning. A detailed study on the cost reductions due to learning in the vehicle technology field can be found in a report by ICF and RTI International under contract for the EPA (EPA, 2016a).

[4] Although states other than California are not permitted to develop their own vehicle emissions standards, Section 177 of the Clean Air Act authorizes states to choose to adopt California's standards in lieu of federal requirements, and 12 states have done so.

In view of the uncertainty that now envelops the passenger vehicle fuel economy and GHG emissions standards in the United States, ICCT's evaluation of the Canadian standards also included a cost estimate of the impact a bifurcated market will have on Canada. The market split assumes that Canada, California, and the Section 177 states retain the GHG 2025 targets after MY 2021, while the rest of the U.S. market remains at GHG 2020 targets. That analysis uses manufacturer cost-learning rates to estimate the impact of such market volume changes.

The GHG compliance scenario file

The scenario file defines regulatory scenarios and targets to be met by each manufacturer. In the scenario file, the user must specify the year, type of compliance target (CO_2 or MPG), and type of compliance function (single-value target, S-shaped target, or piecewise linear). Two scenarios were studied: maintaining GHG 2025 targets for MY 2021–2025 vehicles, and freezing GHG at 2020 targets, beginning with MY 2021. In the first scenario, technology projections and costs were calculated for a Canadian LDV fleet that follows the GHG 2025 standards. The second scenario presents a Canadian LDV fleet that harmonizes with the MY 2021–2025 targets frozen at 2020 levels.

METHODS FOR CONSUMER AND FLEET-WIDE BENEFITS ANALYSIS

Consumer benefits of LDV efficiency technology under both scenarios were evaluated using three distinct measures: payback period, which refers to the number of years it takes for cumulative fuel savings to recover the initial investment in technology; lifetime fuel savings, which reflects the cumulative fuel savings over the lifetime of the vehicle, including those that take place after the investment in technology has been fully recovered; benefit-to-cost ratio, which reflects lifetime fuel savings divided by the investment in vehicle technology, including any changes in maintenance costs, insurance costs, and vehicle taxes over the vehicle's lifetime.

Of the three measures considered, lifetime fuel savings and benefit-to-cost ratio are more complete measures of consumer benefits than the payback period, since these count fuel savings that continue to accrue after the investment is paid back. All three measures are quantified for sensitivity analysis, including those that reflect a range of fuel prices. For the economic valuation of future cash flows, the consumer benefits are estimated using a 3% discount rate, and a 7% discount rate for sensitivity.

ICCT's analysis for Canada applies the same underlying assumptions and methods as the EPA's, except that the ICCT analysis draws from updated vehicle technology assessments and inputs for fuel price, vehicle survival rates, annual mileage driven, and driving externality costs (such as congestion, accidents, noise, and refueling time) that are unique to Canada (Lawson, 2010). These payback methods apply detailed outputs from the OMEGA model for incremental vehicle technology costs and technology uptake time to meet corresponding annual CO_2 targets. They also include projections for the new vehicle fleet, including annual vehicle mileage, retail fuel prices, and electricity prices for electric vehicles.

Fuel prices come from the National Energy Board of Canada (NEB, 2017). The "reference" payback analysis used NEB's Reference case, and NEB's Technology case and its Higher Carbon Price case were also used for sensitivity analyses of fuel savings.

Pre-tax motor gasoline fuel prices per gallon for CY 2025–2035 range from $3.82 to $3.98 for the reference case, $3.94 to $3.98 for the Technology case, and $3.98 to $4.03 for the Higher Carbon Price case. Retail fuel prices were calculated from the pre-tax prices using current fuel tax rates from Natural Resources Canada (NRCan, 2017).

Vehicle survival rates assume vehicle median lifetimes of 12 to 15 years (Lawson, 2010). The annual mileage driven falls with vehicle age, and the average lifetime accrual for MY 2025 vehicles in Canada is estimated to be approximately 227,000 km (141,051 mi) for passenger cars and 254,600 km (158,201 mi) for light trucks (Lawson, 2010). For reference, EPA's analysis of U.S. consumer benefits assumes a lifetime average of approximately 273,600 km (170,007 mi) for passenger cars, and 316,600 km (196,726 mi) for light trucks. Driving externality costs, including the monetary value of congestion, accidents, noise, and refueling time were also adjusted for Canada (Lawson, 2010).

To estimate the fleetwide benefits of the two different GHG standards, the per-vehicle results were agglomerated for all vehicles using total sales. Analysis of the fleetwide effects includes annual and model year lifetime tonnes of CO_2 avoided, as well as the net fuel savings in billions of dollars.

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