Light Duty Vehicle
Fuel Economy and Greenhouse Gas Emissions

Measurement and Reporting Procedures
in Canada and the U.S.

Final Report

Prepared for:

BRITISH COLUMBIA
The Best Place on Earth

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Table of Contents

List of Tables

List of Figures

1.0 Introduction

This report presents information requested by the British Columbia Ministry of Environment on specific issues related to fuel economy[1] and greenhouse gas (GHG) emissions testing and reporting procedures for light duty motor vehicles in Canada in the United States. Both Canada and the U.S. administer fuel economy programs for light duty motor vehicles. At this time, there are no specific *federal* requirements related to either the measurement or reporting of motor vehicle GHG emissions in the U.S.[2] Although Canada also has no current long term requirements for motor vehicle GHG reductions, the country is currently administering a near term voluntary agreement with the automotive industry, calling for a roughly 6 percent reduction in GHG emissions from light duty vehicles by model year 2010 (5.3 million tonnes of 2010 reductions relative to a 90.51 million tonne 2010 baseline). In the U.S., the Environmental Protection Agency (EPA) is currently evaluating whether or not it is appropriate to regulate greenhouse gas emissions under the U.S. Clean Air Act, but no specific requirements are currently proposed.[3]

Formal regulatory action on vehicle GHG emissions has, however, been undertaken at the state level in the U.S. In 2004 and 2005, California adopted the first-ever GHG emission standards for light duty vehicles,[4] and 17 other U.S. states have subsequently adopted the same rules under authority granted in the U.S. Clean Air Act (42 U.S.C. 7507). Additionally, both Quebec and British Columbia are in the process of adopting the California standards (or their equivalent). This report is a component of the British Columbia adoption process. California has won a series of judicial challenges to their standards, but the standards (scheduled to take effect with model year 2009 in California) are currently unenforceable in the U.S. due to the EPA's refusal to grant California an implementation waiver, as required under the federal Clean Air Act (42 U.S.C. 7507). California is currently suing the U.S. federal government over their refusal to grant the waiver.

As mentioned, both Canada and the U.S. currently administer fuel economy programs for light duty vehicles. The U.S. program was established under the Energy Policy and Conservation Act

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[1] As used in this report, the terminology fuel economy is intended to represent both of the generally accepted terms fuel economy (distance per unit fuel volume consumed) and fuel consumption (fuel volume consumed per unit distance travelled). As one is simply the inverse of the other, both are simultaneously determined using a single test method. The use of one term over the other is simply a matter of preference (regulatory or otherwise), although fuel consumption is a more direct measure of the differential fuel use of multiple vehicles. In those few instances where report discussion is applicable to only one of the metrics, the distinction will be contextually obvious.

[2] There are emissions testing requirements that include some greenhouse gas emissions species, namely carbon dioxide and methane, but these requirements have not been adopted for purposes of greenhouse gas emissions control and thus are not structured on a greenhouse gas basis. For example, they do not require testing of all vehicle-related greenhouse gas emission species (e.g., nitrous oxide), do not account for differences in global warming potential, and do not require any assessment of greenhouse gas emissions per se.

[3] See U.S. EPA, "Regulating Greenhouse Gas Emissions Under the Clean Air Act," Advanced Notice of Proposed Rulemaking, Federal Register, Volume 73, Number 147, Page 44354, July 30, 2008.

[4] See California Environmental Protection Agency, Air Resources Board, "Staff Report: Initial Statement of Reasons for Proposed Rulemaking, Public Hearing to Consider Adoption of Regulations to Control Greenhouse Gas Emissions from Motor Vehicles," August 6, 2004 (and subsequent materials).

of 1975 in response to the 1973 OAPEC (Organization of Arab Petroleum Exporting Countries) oil embargo. Under the U.S. program, vehicle manufacturers must meet so-called Corporate Average Fuel Economy (CAFE) standards, expressed in units of miles per U.S. gallon. The first U.S. standards took effect with the 1978 model year and generally increased in stringency through about 1985. Passenger car standards have remained essentially unchanged since that time, although a current U.S. regulatory proposal would significantly increase the stringency of passenger car fuel economy standards beginning in model year 2011. Light duty truck standards increased modestly between the 1985 and 1995 model years and are currently in the process of a more significant increase that began in model year 2005. As with passenger cars, a current U.S. regulatory proposal would significantly increase the stringency of light truck fuel economy standards beginning in model year 2011.

Canada first established a fuel economy program in 1976, when a voluntary Company Average Fuel Consumption (CAFC) goal, equivalent in stringency to the corresponding U.S. CAFE standard, was implemented beginning with the 1978 vehicle model year. Fuel consumption is the inverse of fuel economy, so it is relatively straightforward to convert CAFE standards to CAFC targets and vice versa.[5] CAFC targets are expressed in units of liters per 100 kilometers. In 1982, the Canadian Parliament passed the Motor Vehicle Fuel Consumption Standards Act (MVFCSA), providing Canadian regulators with the authority to establish mandatory fuel economy standards. Because vehicle manufacturers agreed to voluntarily comply with the requirements of the act, the MVSFCA was not proclaimed (i.e., its provisions were not put into statutory effect) until very recently (in 2007, and associated regulations are still under development). Instead, voluntary targets, equivalent in stringency to corresponding U.S. fuel economy standards, continue to be set under the CAFC program. Table 1 presents a summary of the U.S. and Canadian fuel economy standards.

As mentioned above, Canada entered into a Memorandum of Understanding (MOU) with the automotive industry in 2005, which called for a voluntary effort to reduce GHG emissions from light duty vehicles by roughly 6 percent by model year 2010 (5.3 million tonnes of 2010 reductions relative to a 90.51 million tonne 2010 baseline). Although GHG reductions can be achieved by measures other than improvements in fuel economy, it is expected that most manufacturers will rely on fuel economy improvements in their efforts to achieve the targeted reductions.

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[5] It is perhaps important to recognize that fuel consumption is a more appropriate "averaging metric" than fuel economy. In short, the average fuel economy of two (or more) vehicles travelling equal distances does not equal the average of their individual fuel economies. Such a calculation will always overestimate the actual average fuel economy, except in the limited case where the vehicles are operated under conditions of gasoline rationing. Since vehicles are designed with similar useful lives, an assumption of similar lifetime mileages is appropriate. While it may take one vehicle temporally longer to attain its useful life, the total amount of fuel consumed over that lifetime is a function of mileage, not time. Thus, averaging fuel economy values is generally not appropriate. To properly calculate an average fuel economy value, individual fuel economy values should first be inverted to reflect fuel consumption (consumption per unit distance) and then averaged. The resulting average fuel consumption value should then be inverted to reflect the correct average fuel economy value. This is recognized and addressed in the U.S. CAFE program, where although CAFE data are expressed in terms of fuel economy, all associated "averaging" calculations are performed in terms of fuel consumption and converted back into fuel economy equivalents.

Table 1. Canadian and U.S. Fuel Economy Standards

Vehicle Model Year(s)	Passenger Cars			Light Duty Trucks		
	U.S. CAFE Standard (mpg)	U.S. Standard in liters per 100 km	Canada CAFC Target (lit/100km)	U.S. CAFE Standard (mpg)	U.S. Standard as liters per 100 km	Canada CAFC Target (lit/100km)
1978	18.0	13.1	13.1			
1979	19.0	12.4	12.4			
1980	20.0	11.8	11.8			
1981	22.0	10.7	10.7			
1982	24.0	9.8	9.8	17.5	13.4	
1983	26.0	9.0	9.0	19.0	12.4	
1984	27.0	8.7	8.7	20.0	11.8	
1985	27.5	8.6	8.6	19.5	12.1	
1986	26.0	9.0	8.6	20.0	11.8	
1987	26.0	9.0	8.6	20.5	11.5	
1988	26.0	9.0	8.6	20.5	11.5	
1989	26.5	8.9	8.6	20.5	11.5	
1990	27.5	8.6	8.6	20.0	11.8	11.8
1991-1992	27.5	8.6	8.6	20.2	11.6	11.6
1993	27.5	8.6	8.6	20.4	11.5	11.5
1994	27.5	8.6	8.6	20.5	11.5	11.5
1995	27.5	8.6	8.6	20.6	11.4	11.4
1996-2004	27.5	8.6	8.6	20.7	11.4	11.4
2005	27.5	8.6	8.6	21.0	11.2	11.2
2006	27.5	8.6	8.6	21.6	10.9	10.9
2007	27.5	8.6	8.6	22.2	10.6	10.6
2008	27.5	8.6	8.6	22.5	*10.5*	10.5
2009	27.5	8.6	8.6	23.1	*10.2*	10.2
2010	27.5	8.6		23.5	*10.0*	
2011	*31.2*	*7.5*		*25.0*	*9.4*	
2012	*32.8*	*7.2*		*26.4*	*8.9*	
2013	*34.0*	*6.9*		*27.8*	*8.5*	
2014	*34.8*	*6.8*		*28.2*	*8.3*	
2015	*35.7*	*6.6*		*28.6*	*8.2*	

Notes: (1) The U.S. standards converted to units of liters per 100 kilometers (the units employed in the Canadian CAFC program) are expressed to the nearest tenth to facilitate comparison with the Canadian program.

(2) Light duty truck standards were in place in the U.S. in model years 1979-1981, but they varied by truck type and so are not presented here.

(3) U.S. passenger car standards for model years 1986-1989 were reduced from 27.5 mpg in response to petitions from vehicle manufacturers facing significant penalties for noncompliance (gasoline prices had declined and sales of smaller cars were declining in response).

(4) For model years 2008-2010, there are optional U.S. light duty truck standards that are a function of vehicle footprint (vehicle wheelbase times track width), so that actual CAFE standards for manufacturers that comply based on the optional allowance depend on actual production characteristics in the applicable year.

(5) U.S. passenger car and light truck standards for model years 2011-2015 are a function of vehicle footprint and thus dependent on the actual production characteristics of vehicles in those years. The tabulated values are not official standards, but estimates of expected CAFE levels, as developed by the U.S. National Highway Traffic Safety Administration in their CAFE rulemaking materials for model years 2011-2015. For passenger cars, there are minimum standards of 28.7, 30.2, 31.3, 32.0, and 32.9 mpg for model years 2011-2015 respectively (regardless of actual fleet characteristics), but there are no corresponding minimum standards for light duty trucks.

(6) Under the Energy Independence and Security Act of 2007, the U.S. has established a statutory fuel economy target for model year 2020 of 35 mpg for cars and light trucks combined.

Following the development of the GHG MOU, Canada (in October of 2006) announced its intention to bolster their existing voluntary CAFC and GHG agreements by implementing mandatory light duty vehicle fuel efficiency standards. As the first step in this process, the MVFCSA was proclaimed on November 2, 2007 (i.e., its provisions were put into statutory effect). Current plans call for the development of national fuel efficiency standards to be put into effect in model year 2011, following the expiration of the current GHG MOU. As stated by Transport Canada, Canada "has decided to use regulation over voluntary agreements, as it provides a greater degree of certainty, predictability and accountability."[6]

It is perhaps important to reiterate that current fuel economy requirements in both Canada and the U.S. apply only to light duty vehicles. In this context, light duty motor vehicles are motor vehicles with a gross vehicle weight rating of 8,500 pounds (3,855.6 kilograms) or less. Heavier vehicles are generally not subject to current fuel economy requirements. This same weight cutoff generally defines the applicability of California's GHG emission standards for vehicles, although the California program also includes "medium duty passenger vehicles" -- which are vehicles with a gross vehicle weight rating 8,501-10,000 pounds that are designed primarily for the transportation of people. This requires vehicle manufacturers to ensure that passenger vans, large sport utility vehicles, and short-bed pickup trucks with gross vehicle weights above 8,500 pounds (e.g., Hummer H2, Chevrolet Suburban 2500, GMC Yukon XL 2500) do not avoid the standards applicable to light duty passenger vehicles. Current proposed revisions to the U.S. fuel economy requirements would extend the program to cover these same medium duty passenger vehicles beginning with vehicle model year 2011.

Readers of this report should recognize that the covered topics are intended to respond to specific questions posed by the British Columbia Ministry of Environment. The report is not intended to be a comprehensive reference on statutory or regulatory requirements in Canada or the U.S., but it is structured to provide a robust discussion of issues important to the Ministry of Environment. Effort has been expended to provide an appropriate context for each topic and it is expected that readers will be able to fully understand the included discussion and associated nuances without prior background knowledge on either the Canadian or U.S. programs. Nevertheless, appropriate alternative or supplemental resources should be referenced as appropriate. This report is not a surrogate for formal statutory, regulatory, or other related materials.

2.0 Fuel Economy Test Procedures

The basic test procedure used to determine the *regulatory* fuel economy[7] value of a light duty motor vehicle is composed of two specific components -- a standardized dynamometer test designed to estimate the rate of fuel consumed during city-type driving and a standardized

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[6] Transport Canada, http://www.tc.gc.ca/programs/environment/fuelpgm/prog/page3.htm, website discussion of the Canadian fuel consumption program as posted on September 19, 2008.

[7] Unless other wise specified, the *regulatory* fuel economy is that fuel economy calculation used to determine compliance with existing fuel economy standards and/or calculate manufacturer-specific average fuel economy. This is distinguished from alternative fuel economy information that may be provided to consumers in the form of fuel economy labels on vehicles or in fuel economy literature prepared by regulatory agencies. These latter data generally reflect reduced fuel economy relative to the data used for regulatory compliance purposes, as they include several onroad "adjustments" that are not included in the regulatory compliance determination.

dynamometer test designed to estimate the rate of fuel consumed during highway-type driving. Canada and the United States administer identical standardized tests in an identical fashion. Thus, an identical vehicle sold in both countries should have an identical fuel economy rating over the standardized test procedures of each country.

The standardized city test includes both exhaust and evaporative emissions testing, but fuel economy measurement relies only on the exhaust portions of the test. Thus, the evaporative emissions test procedures are ignored in this report.

The standardized city test is most accurately referred to as the Federal Test Procedure (FTP). It is, however, sometimes referred to as the FTP-75 (with the 75 indicating the year 1975 and intended to distinguish the current test from an earlier 1972 version) or the EPA-75. The dynamometer driving cycle[8] used during the FTP is built from a shorter standardized driving cycle named the Urban Dynamometer Driving Schedule (UDDS), which itself is sometimes known as the LA-4 (since it is based on the operating characteristics of a 1960s-era vehicle driven over a route designated as road route number 4 in Los Angeles, California), the FTP-72, or simply the city driving cycle. Each of these terms has a specific meaning, but they are also sometimes used interchangeably to refer to part or all of the FTP.

The FTP cycle is specifically defined in Title 40 of the U.S. Code of Federal Regulations §86.135 (40 CFR 86.135) and consists of one complete execution of the 1,369 second UDDS as defined in 40 CFR Part 86, Appendix I(a), followed by a 10 minute engine-off period, followed by a repetition of the first 505 seconds of the UDDS. The engine-on portion of the FTP is split into three components. The first 505 seconds of the UDDS, which immediately follow a "cold" start of the vehicle (an engine start that follows a 12-36 hour period of engine-off), are referred to as the cold start portion, or Bag 1 of the test.[9] The final 864 seconds of the UDDS, which immediately follow the Bag 1 portion, are referred to as the hot stabilized portion, or Bag 2 of the test (and represent operations following engine warm-up and stabilization). Following Bag 2, the vehicle engine is shut-off for 10 minutes, after which the third portion of the test is run. This portion, referred to as the "hot" start portion, or Bag 3, consists of a repetition of the first 505 seconds of the UDDS. Figure 1 provides a graphic depiction of the engine-on periods of the FTP, while Table 2 presents a number of descriptive cycle statistics.

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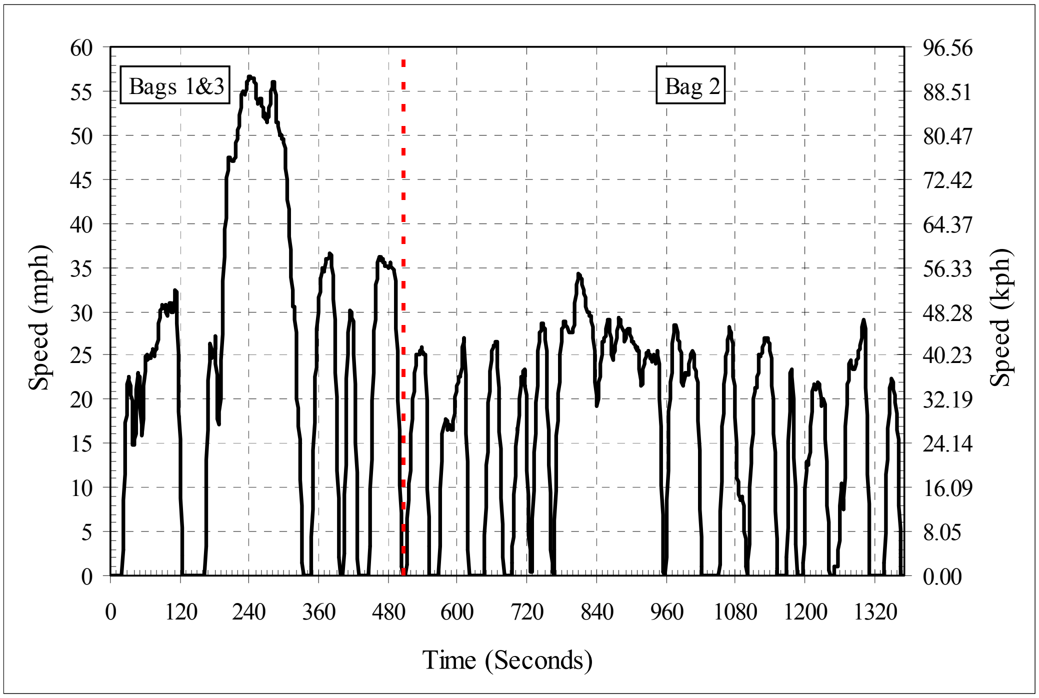
[8] All standardized vehicle testing is performed on a dynamometer, which is a treadmill-like device that allows the wheels of a vehicle to turn while the vehicle remains stationary (the wheels of a vehicle are positioned on top of a set of cylindrical rolls that absorb the motion of the wheels). Precise forces, calculated on the basis of a vehicle's mass and aerodynamic characteristics, are applied to the dynamometer rolls to reproduce the forces that a vehicle would experience were it moving through the air rather than remaining stationary. The vehicle is then operated over a specific driving cycle, which is essentially a continuous speed versus time schedule, so that specific wheel speeds are attained at specific increments of time. There are specific tolerances applied so that actual speeds must be within a limited deviation from desired speeds in order for the test to be valid. Emissions of hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NO_x), and carbon dioxide (CO_2)are measured throughout the test and the carbon emitted as HC, CO, and CO_2 is used to calculate associated fuel consumption (on the basis of carbon mass balance -- i.e., the carbon in the fuel is emitted as either HC, CO, or CO_2). In this way, all test vehicles are subjected to substantially identical testing.

[9] The "bag" nomenclature is derived from the practice of collecting a proportional sample of exhaust from each of the three test components in individual physical sample bags.

Figure 1. Speed/Time Characteristics of the City Fuel Economy Test Cycle



The first 505 seconds of the cycle are repeated (as Bag 3) after the completion of Bag 2 and a 10 minute engine-off period.

Figure 2. Speed/Time Characteristics of the Highway Fuel Economy Test Cycle

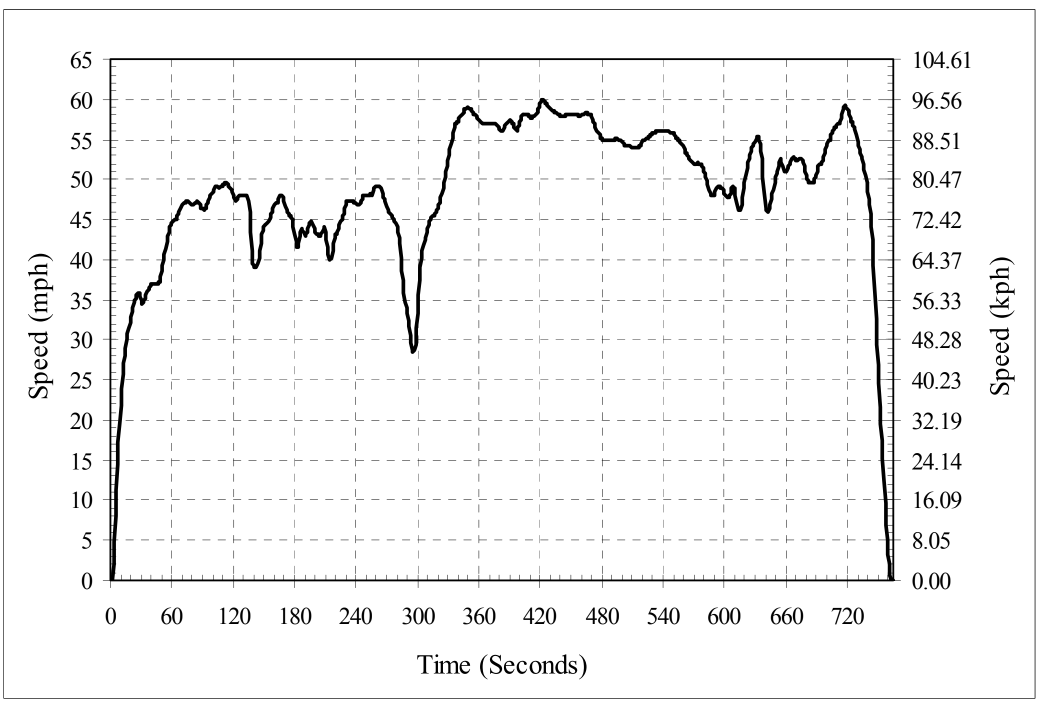


Table 2. Regulatory Fuel Economy Test Cycle Statistics

Cycle Statistic	Units	UDDS	FTP	FTP Bags 1 & 3	FTP Bag 2	HFET
Cycle Duration	seconds	1369	1874	505	864	765
	minutes	22.82	31.23	8.42	14.40	12.75
Cycle Distance	miles	7.4504	11.0414	3.5910	3.8594	10.2567
	kilometers	11.9902	17.7694	5.7792	6.2110	16.5065
Cycle Average Speed	mph	19.59	21.21	25.60	16.08	48.27
	kph	31.53	34.14	41.20	25.88	77.68
Cycle Maximum Speed	mph	56.70	56.70	56.70	34.30	59.90
	kph	91.25	91.25	91.25	55.20	96.40
Cycle Average Acceleration	mph/sec	0.897	0.901	0.913	0.888	0.384
	kph/sec	1.444	1.451	1.470	1.428	0.618
Cycle Maximum Acceleration	mph/sec	3.30	3.30	3.30	3.30	3.20
	kph/sec	5.31	5.31	5.31	5.31	5.15
Cycle Maximum Deceleration	mph/sec	-3.30	-3.30	-3.30	-3.30	-3.30
	kph/sec	-5.31	-5.31	-5.31	-5.31	-5.31
Cycle Idle Time	seconds	241	335	94	147	4
	minutes	4.02	5.58	1.57	2.45	0.07

The standardized highway test is generally only referred to as the Highway Fuel Economy Test procedure (HFET or HWFET). The lack of confusing nomenclature, as compared to the multiple names by which the standardized city test might be referenced, results from the fact that the HFET is almost exclusively used for fuel economy testing purposes, while the standardized city cycle, in addition to its use for fuel economy testing, is the backbone of the U.S. and Canadian emissions testing programs (for determining compliance with exhaust emission standards). The HFET procedure is specifically defined in 40 CFR 600.111 and consists of one complete execution of a 765 second driving cycle as defined in 40 CFR Part 600, Appendix I. Figure 2 provides a graphic depiction of HFET, while Table 2 presents a number of descriptive cycle statistics.

Canadian test procedures specifically reference the U.S. Code of Federal Regulations and are conducted in a fashion identical to those of the U.S. Although current Canadian fuel economy requirements are voluntary, guidelines for the program are published annually. The current guidelines cover the 2009 vehicle model year.[10],[11] These guidelines provide informational elements specific to the Canadian fuel economy program, but are effectively constructed to rely exclusively on referenced U.S. fuel economy program requirements related to test methods and

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10 Transport Canada, "Transport Canada Voluntary Motor Vehicle Fuel Consumption Program, Guidelines for Determination and Submission of Fuel Consumption Data, Model Year - 2009," TP 6890/E, December 2007.

11 Transport Canada, "VFEIS, Vehicle Fuel Economy Information System, Data Element Dictionary, 2009 Model Year," TP5529E.

procedures. Canadian emission standards and associated test procedures, which are incorporated into the Canadian fuel economy program guidelines by reference, are administered through regulations adopted under the Canadian Environmental Protection Act of 1999.[12] Like the fuel economy guidelines, the emission standard regulations effectively reference corresponding U.S. emissions test procedures. Given this intentional alignment, fuel economy testing and procedural requirements are effectively identical in Canada and the U.S.[13]

The actual calculations for determining fuel economy have evolved somewhat over the years, but can generally be expressed as follows:

$$\text{Fuel Economy} = \frac{\text{grams Carbon per Gallon of Fuel}}{(\text{CWF} \times \text{HC}) + (0.429 \times \text{CO}) + (0.273 \times \text{CO}_2)} \qquad (1)$$

where: Fuel Economy = miles per gallon (rounded to the nearest tenth),
CWF = carbon weight fraction of fuel,
HC = hydrocarbon emissions in grams per mile,
CO = carbon monoxide emissions in grams per mile, and
CO_2 = carbon dioxide emissions in grams per mile.

The 0.429 factor applied to CO is the fractional weight of carbon in CO. It is determined by dividing the mole weight of carbon in CO (12.01115) by the mole weight of CO (28.01055). Similarly, the 0.273 factor applied to CO_2 is the fractional weight of carbon in CO_2. It is determined by dividing the mole weight of carbon in CO_2 (12.01115) by the mole weight of CO_2 (44.00995).

Prior to 1988, the carbon content of gasoline (the numerator in equation 1 above) was specified as 2,421 grams of carbon per U.S. gallon, which equates to an equivalent mass of 8,871grams of CO_2 per U.S. gallon (or 19.56 pounds of CO_2 per U.S. gallon).[14] In that same era, the carbon weight fraction of gasoline was specified as 0.866 (86.6 percent of fuel mass is carbon).[15] Since 1988, the carbon weight fraction of gasoline has been measured and the overall carbon content of gasoline has been calculated from measured test fuel properties as follows:

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[12] Environment Canada, "On-Road Vehicle and Engine Emission Regulations," Canada Gazette, Part II, Volume 137, Number 1, January 1, 2003

[13] The form in which the associated data are compiled and presented may differ (e.g., fuel economy is expressed in terms of miles per U.S. gallon in the U.S. as opposed to liters per 100 kilometers and miles per Imperial gallon in Canada), but the underlying procedural requirements are identical.

[14] Grams CO_2 per gallon equals grams carbon per gallon times the mole weight of CO_2 (44.00995) divided by the mole weight of carbon (12.01115).

[15] Assuming a hydrogen to carbon ratio of 1.85:1 (i.e., $CH_{1.85}$) for hydrocarbon emissions, the fractional weight of carbon in HC is 0.866, as determined by dividing the mole weight of carbon (12.01115) by the mole weight of HC (12.01115+[1.008×1.85]=13.87595)

$$\text{grams Carbon per Gallon of Fuel} = \frac{51{,}740{,}000 \times CWF \times SG}{(0.6 \times SG \times NHV) + 5{,}471} \qquad (2)$$

where: gallon = U.S. gallon,
CWF = carbon weight fraction of fuel,
SG = specific gravity of fuel, and
NHV = net (lower) heating value of fuel (in Btu per pound).

Although the properties of gasoline vary somewhat across batches, typical values demonstrate the equivalence of the pre- and post-1988 methods. For a fuel with a carbon weight fraction of 0.868, a specific gravity of 0.745, and a net heating value of 18,478 Btu/lb, equation 2 evaluates to 2,437 grams carbon per U.S. gallon. Similarly, a fuel with a carbon weight fraction of 0.866, a specific gravity of 0.739, and a net heating value of 18,272 Btu/lb would generate an estimated 2,440 grams carbon per U.S. gallon. Both values are within 1 percent of the pre-1988 constant of 2,421.

For diesel fuel, the pre-1988 methodology is still used, with an assumed fuel carbon content of 2,778 grams per U.S. gallon and a fuel carbon weight fraction of 0.866. The method for other fuels is similar, but includes appropriate corrections for variations in fuel properties and additional carbon-containing exhaust products (e.g., methanol and formaldehyde for methanol fuel).

It is perhaps important to note that the fuel economy value is expressed in volumetric terms (e.g., per gallon) of the fuel being consumed. With the exception of non-liquid fuels, there is no correction to standardize fuel economy values for differences in volumetric energy content. For example, the fuel economy of diesel vehicles is expressed per unit volume of diesel fuel and the fuel economy of gasoline vehicles is expressed per unit volume of gasoline fuel. Since diesel fuel generally contains about 10 percent more energy per unit volume than gasoline, diesel fuel economy on a unit energy basis is about 9 percent lower relative to a gasoline vehicle than it is on a unit volume basis. In effect, fuels with higher volumetric energy contents have an inherent volumetric fuel economy advantage relative to fuels with lower volumetric energy contents. This can, of course, be corrected by introducing a standardized volumetric energy content into the calculation process, but such a correction is not part of the current fuel economy test procedure (except in the case of non-liquid fuels, where factors to calculate "gallon equivalents" are included and by definition must be based on a "standard" unit volume energy content).

The fuel economy for the city and highway tests is first determined separately.[16] A composite fuel economy value is then calculated by weighting fuel consumption over the city test by 55

[16] Note that the gram per mile exhaust emissions values used to calculate fuel economy over the city test are the bag-weighted composite emission rates determined in accordance with 40 CFR 86.144 as follows:

$$EFcity = 0.43 \times \left(\frac{E_{B1} + E_{B2}}{D_{B1} + D_{B2}} \right) + 0.57 \times \left(\frac{E_{B3} + E_{B2}}{D_{B3} + D_{B2}} \right)$$

where: EF_{city} = weighted grams per mile over the city test,
E_{B1} = measured mass of emissions (in grams) during the Bag 1 portion of the test,

percent and fuel consumption over the highway test by 45 percent as follows:

$$\text{Composite Fuel Economy} = \frac{1}{\left(0.55 \times \frac{1}{\text{City mpg}}\right) + \left(0.45 \times \frac{1}{\text{Highway mpg}}\right)} \quad (3)$$

where: Fuel Economy = miles per gallon (rounded to the nearest tenth),
City mpg = miles per gallon over the city test, and
Highway mpg = miles per gallon over the highway test.

This composite fuel economy value is the value used to determine manufacturer compliance with regulatory fuel economy requirements. Although not strictly part of the test procedure (which is applied to individual vehicles to determine fuel economy as described above), the basic methodology employed to determine compliance with regulatory fuel economy requirements consists of the calculation of a production-weighted corporate (i.e., manufacturer-specific) average fuel economy (CAFE) value as follows:

$$\text{CAFE} = \frac{\text{Total Vehicles Produced}}{\sum_{i=1}^{\text{number of models}} \left(\text{Vehicles Produced}_i \times \frac{1}{\text{Composite Fuel Economy}_i}\right)} \quad (4)$$

This CAFE value is then compared to any associated regulatory standards to determine compliance.[17] Strictly speaking, there can be additional nuances to the compliance calculation. For example, in the U.S., compliance calculations are performed separately for domestic passenger cars, import passenger cars, and (domestic plus import) light trucks. There are also adjustments to the calculated CAFE value for passenger cars to account for changes that have occurred in the fuel economy test procedure since 1975. Finally, there are also fuel specific credits allowed for vehicles powered by non-gasoline fuels. Dedicated alcohol and natural gas vehicles are treated as if their fuel economy is 6.67 (specifically 0.15^{-1}) times greater than measured, while dual fuel alcohol and natural gas vehicles are treated as if their fuel consumption is the average of their unadjusted fuel consumption when operating on gasoline and 0.15 times their fuel consumption when operating on the non-gasoline fuel. The fuel economy of diesel fueled vehicles is not adjusted (but diesel vehicles do retain their inherent volumetric

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E_{B2} = measured mass of emissions (in grams) during the Bag 2 portion of the test,
E_{B3} = measured mass of emissions (in grams) during the Bag 3 portion of the test,
D_{B1} = measured distance (in miles) during the Bag 1 portion of the test,
D_{B2} = measured distance (in miles) during the Bag 2 portion of the test, and
D_{B3} = measured distance (in miles) during the Bag 3 portion of the test.

Thus, the weighted composite emission rate represents an emission rate that assumes that 43 percent of VMT is comprised of trips that consist of a cold start (Bag 1) followed by stabilized operation (Bag 2) and that 57 percent of VMT is comprised of trips that consist of a hot start (Bag 3) followed by stabilized operation (Bag 2) -- with start and stabilized operations respectively representing about 48.2 percent (3.5910 miles) and 51.8 percent (3.8594 miles) of a standardized 7.4504 mile trip (as indicated in Table 1).

[17] In Canada, the CAFC value used for compliance purposes is simply the inverse of the CAFE value used in the U.S. (with an appropriate conversion in units from U.S. gallons per mile to liters per 100 kilometers).

energy content advantage relative to gasoline vehicles as described above). The maximum increase in CAFE due to non-gasoline fuel adjustments is 1.2 miles per U.S. gallon per year.[18]

Summary of Differences Between Canada and the U.S.: None.

3.0 Consumer Fuel Economy Information

Both Canada and the U.S. provide fuel economy information to consumers in two basic forms. First, labels affixed to new vehicles provide fuel economy information for the specific vehicle to which the label is affixed. Second, an annual booklet-type consumer guide presents information for all vehicles sold in the associated model year.[19] The information for a given model is identical to that provided on its associated label. However, the provided fuel economy information is *not* the same as the fuel economy value measured for CAFE or CAFC compliance purposes (as described in Section 2.0). The information is based on the CAFE/CAFC compliance data, but reflects adjustments designed to better match the fuel economy consumers might observe during "real world" driving. Figures 3 through 7 present examples of the Canadian and U.S. consumer fuel economy labels and annual fuel economy consumer guide data.

Prior to model year 2008, the procedures used by both Canada and the U.S. to develop consumer fuel economy information were very similar. Both countries applied specific adjustment factors to the city and highway fuel economy values measured for CAFE/CAFC compliance purposes (as described in Section 2.0 above), and both countries applied the adjustments to fuel economy measurements rather than fuel consumption. In Canada, the adjustment factors were 0.90 for the city fuel economy and 0.85 for the highway fuel economy. In the U.S., the adjustment factors were 0.90 for the city fuel economy and 0.78 for the highway fuel economy. The combined (city/highway) fuel economy is then recalculated using the adjusted city and highway fuel economy. Mathematically this process is expressed as follows:

$$\text{Adjusted City Fuel Economy (mpg)} = 0.90 \times \text{Unadjusted City Fuel Economy (mpg)} \quad (5)$$

$$\text{Adjusted Highway Fuel Economy (mpg)} = \text{haf} \times \text{Unadjusted Highway Fuel Economy (mpg)} \quad (6)$$

where: haf = 0.85 in Canada and 0.78 in the U.S.

$$\text{Composite Adjusted mpg} = \frac{1}{\left(0.55 \times \frac{1}{\text{Adj City mpg}}\right) + \left(0.45 \times \frac{1}{\text{Adj Highway mpg}}\right)} \quad (7)$$

[18] The non-gasoline fuel credits are currently scheduled to be phased-out in the U.S. between the 2015 and 2020 vehicle model years (49 U.S.C. 32906, as amended by the Energy Independence and Security Act of 2007). The maximum 1.2 mpg adjustment extends through model year 2014, and then declines by 0.2 miles per U.S. gallon per year in model years 2015 through 2020.

[19] In Canada, this annual consumer guide is known as the *Fuel Consumption Guide*. Its U.S. counterpart is the *Fuel Economy Guide*.

Figure 3. Sample 2008 Canadian Vehicle Label

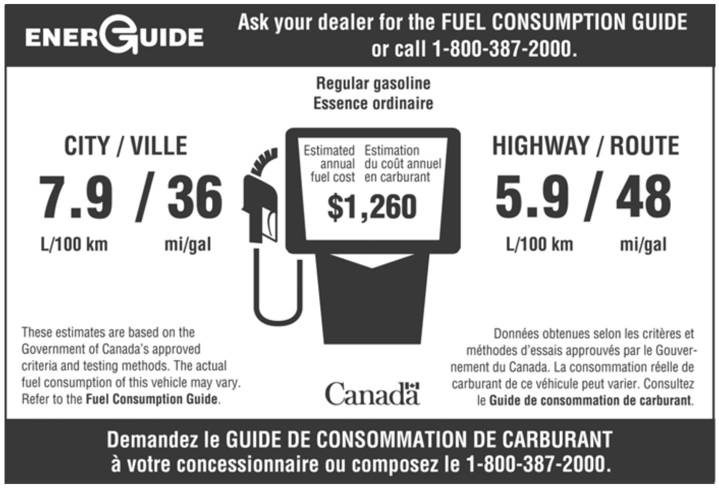


Figure 4. Sample 2008 U.S. Vehicle Label

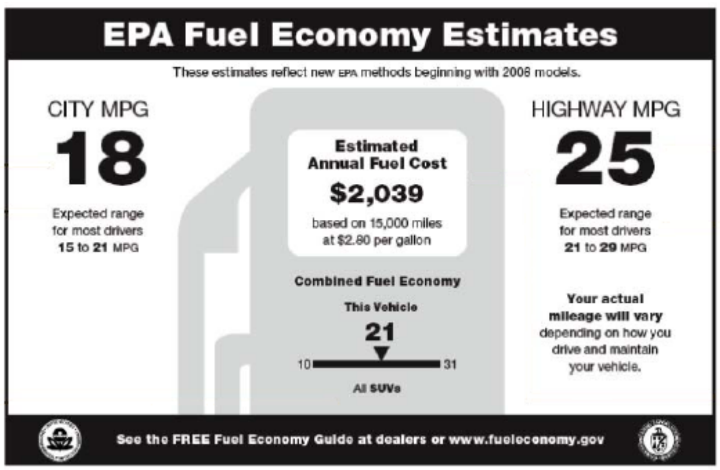


Figure 5. Sample 2007 U.S. Vehicle Label

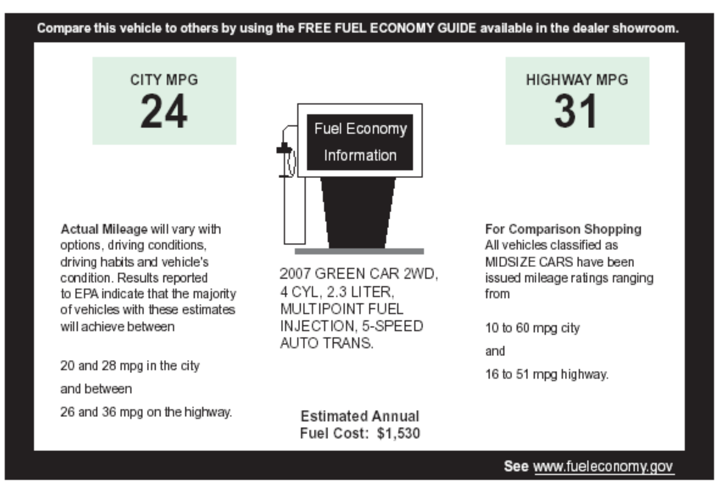


Figure 6. Sample Page from the 2008 Canadian Consumer Guide

A — AUTOMOBILES

MANUFACTURER / CONSTRUCTEUR — MODEL / MODÈLE	CLASS / CATÉGORIE	ENGINE SIZE / CYLINDRÉE	N° OF CYLINDERS / CYLINDRES	FUEL TYPE / CARBURANT	TRANSMISSION No. of GEARS / Nbre de VITESSES OVERDRIVE / SURMULTIPLICATION	CONSUMPTION / CONSOMMATION L/100 km City / VILLE	L/100 km Highway / ROUTE	mi./gal. City / VILLE	mi./gal. Highway / ROUTE	$ PER YEAR / PAR AN	Litres FUEL (L) / YEAR CARBURANT (L) / AN	CO_2 EMISSIONS (kg) / YEAR ÉMISSIONS DE CO_2 (kg) / AN
ACURA												
CSX	C	2.0	4	X	M5+	8.7	6.4	32	44	1,386	1540	3696
CSX	C	2.0	4	Z	M6+	10.2	6.8	28	42	1,740	1740	4176
CSX	C	2.0	4	X	S5E	9.5	6.5	30	43	1,458	1620	3888
RL AWD	M	3.5	6	Z	S5E	12.9	8.4	22	34	2,160	2160	5184
TL	M	3.2	6	Z	S5E	11.6	7.5	24	38	1,960	1960	4704
TL	M	3.5	6	Z	M6+	11.6	7.3	24	39	1,940	1940	4656
TL	M	3.5	6	Z	S5E	12.3	7.8	23	36	2,060	2060	4944
TSX	C	2.4	4	Z	M6+	10.8	7.2	26	39	1,840	1840	4416
TSX	C	2.4	4	Z	S5E	10.5	7.0	27	40	1,780	1780	4272
ASTON MARTIN												
DB9 COUPE AUTO	S	5.9	12	Z	S6	19.2	11.3	15	25	3,120	3120	7488

Figure 7. Sample Page from the 2008 U.S. Consumer Guide

	Trans Type / Speeds	Eng Size / Cylinders	MPG City / Hwy	Annual Fuel Cost	Notes
HONDA					
Accord 2-door Coupe	A-5	2.4/4	21/30	$1,751	
	M-5	2.4/4	22/31	$1,680	
	A-5	3.5/6	19/28	$1,911	
	M-6	3.5/6	17/25	$2,100	
► Civic Hybrid	**AV**	**1.3/4**	**40/45**	**$1,000**	**HEV**
HYUNDAI					
Accent	A-4	1.6/4	24/33	$1,499	
	M-5	1.6/4	27/32	$1,449	
JAGUAR					
X-Type	A-5	3.0/6	16/22	$2,502	P
KIA					
Rio	A-4	1.6/4	25/35	$1,449	
	M-5	1.6/4	27/32	$1,449	
LEXUS					
GS 450h	A-S6	3.5/6	22/25	$1,958	P HEV
MAZDA					
3	M-5	2.0/4	24/32	$1,554	
	A-S4	2.0/4	23/31	$1,617	
	M-5	2.3/4	22/29	$1,680	
	A-S5	2.3/4	22/29	$1,751	

In Canada, the resulting values are converted to liters per 100 kilometers rounded to the nearest tenth and miles per Imperial gallon rounded to the nearest integer, while the resulting fuel economy values are retained in miles per U.S. gallon rounded to the nearest integer in the U.S.[20] Due to the different definitions of a gallon, miles per gallon fuel economy data in Canada do not match miles per gallon fuel economy data in the U.S. The Canadian miles per gallon data will be about 20 percent higher. In both Canada and the U.S., the rounding process makes it effectively impossible to "unadjust" published consumer fuel economy values into their original CAFE/CAFC counterparts without a loss in precision.

Table 3 illustrates the associated loss in precision for a set of hypothetical city and highway fuel economy values. As indicated, the reconstituted CAFE/CAFC fuel economy values vary from the actual CAFE/CAFC data by -0.4 to +0.5 miles per U.S. gallon. As would be expected, the actual precision loss for integer-level consumer data (miles per U.S. gallon and miles per Imperial Gallon) is ±0.5 miles per gallon (relative to nearest tenth CAFE/CAFC data), while that for the nearest tenth liters per 100 kilometer data is ±0.1 miles per gallon. Thus, while CAFE/CAFC data can be approximated from published consumer estimates, it cannot be defined with certainty.

Prior to 2008, neither the Canadian nor U.S. consumer data included the composite adjusted fuel economy value either on the vehicle label or in data in the annual consumer guide. This value was, however, used to calculate an estimated annual fuel cost that was included on both the vehicle label and in the annual consumer guide. In determining annual fuel use, both Canada and the U.S. assumed that 55 percent of annual mileage was city driving and 45 percent of annual mileage was highway driving, and, as shown in equation 7, this is equivalent to assuming an annual average fuel economy that is equal to the composite adjusted fuel economy. In Canada, annual average fuel consumption is multiplied by an assumed 20,000 kilometers of annual travel to determine annual fuel use estimates, while the U.S. assumed annual travel of 15,000 miles (24,140 kilometers). Both countries then multiply annual fuel use by an assumed average fuel cost (per unit volume) to derive an estimate of overall annual fuel costs. The unit volume fuel costs vary annually, but the values specific to a given year do allow the underlying composite adjusted fuel economy to be reconstituted from the published consumer fuel cost information.

For example, using the example data from Table 3, the composite unadjusted CAFE/CAFC fuel economy (using equation 3) is 29.0 miles per U.S. gallon. Similarly, the composite adjusted fuel economy (using equation 7) is 25 miles per U.S. gallon (reported to the nearest integer). At 15,000 miles per year, the latter value would yield an annual fuel consumption estimate of 600.0 U.S. gallons. Using the U.S.-assumed per-gallon fuel cost estimate of $2.65 for regular unleaded gasoline for 2007, this yields an annual 2007 fuel cost estimate of $1,590 (U.S. dollars). One can easily work backwards to recalculate the assumed composite adjusted fuel economy value of 25 miles per U.S. gallon. However, to reconstitute the CAFE/CAFC value of 29.0, one needs to

[20] There are 4.54609188 liters per Imperial gallon and 3.78541178 liters per U.S. gallon, so fuel economy in miles per Imperial gallon (as published on the Canadian vehicle fuel economy label and in the Canadian consumer guide) will be 1.2 times greater than miles per U.S. gallon (as published on the U.S. vehicle fuel economy label and in the U.S. consumer guide). To convert from liters per 100 kilometers to miles per Imperial gallon, take the inverse of liters per 100 kilometers and multiply by 282.481053. To convert from miles per Imperial gallon to liters per 100 kilometers, take the inverse of miles per Imperial gallon and multiply by 282.481053.

Table 3. Example of Precision Loss in Estimating CAFE Fuel Economy from Consumer Fuel Economy Data

Metric	Units	City CAFE	Highway CAFE	Calculation Methodology
CAFE	mpg	24.6	37.0	A = test data rounded to the nearest tenth
Consumer Adjustment Factor	mpg	0.9	0.85	B = fixed adjustment factors for Canada
Consumer Calculation	mpg	22.14	31.45	C = A × B
Reported Consumer Data	mpg	22	31	D = C rounded to the nearest integer
Reconstituted CAFE (from Consumer mpg)	mpg	24.4	36.5	E = D/B, rounded to the nearest tenth
Reconstitution Error	mpg	-0.2	-0.5	F = E - A
Consumer Calculation	lit/100 km	10.62396	7.479001	G = (1/C) × cf1
Reported Consumer Data	lit/100 km	10.6	7.5	H = G rounded to the nearest tenth
Reconstituted CAFE (from Consumer lit/100 km)	mpg	24.7	36.9	I = ((1/H) × cf1)/B, rounded to the nearest tenth
Reconstitution Error	mpg	+0.1	-0.1	J = I - A
Consumer Calculation	mi/gal	25.85904	37.76989	K = C × cf2
Reported Consumer Data	mi/gal	27	38	L = K rounded to the nearest integer
Reconstituted CAFE (from Consumer mi/gal)	mi/gal	25.0	37.2	M = (L × (1/cf2))/B, rounded to the nearest tenth
Reconstitution Error	mpg	+0.4	+0.2	N = M - A

mpg = miles per U.S. Gallon (as reported to U.S. consumers)
lit/100 km = liters per 100 kilometers (as reported to Canadian consumers)
mi/gal = miles per Imperial gallon (as reported to Canadian consumers)
cf1 = 3.78541178 lit/U.S. gal × 0.621371192 mi/km × 100
cf2 = 4.54609188 lit/Imperial gal × (1/3.78541178 lit/U.S. gal)

know the net (composite) consumer adjustment factor (which depends on the relationship between the city and highway fuel economy values, which can and do vary across vehicles). Since the city and highway CAFE/CAFC values are known in this example, the factor can be calculated as 0.862069 (25/29.0), but without the CAFE/CAFC city and highway data it is not possible to estimate this value precisely. Thus, as with the consumer fuel economy estimates, there is a loss in precision associated with trying to reconstitute CAFE/CAFC data from the consumer fuel cost estimate.

From equations 3 and 5-7, it can be shown that the composite adjustment factor is *approximately* equal to:

$$\text{Composite Adjustment Factor} = \frac{0.55 + \left(\frac{0.45}{x}\right)}{\left(\frac{0.55}{0.9}\right) + \left(\frac{0.45}{(\text{haf})(x)}\right)} \tag{8}$$

where: x = unadjusted highway fuel economy divided by unadjusted city fuel economy, and
haf = 0.85 in Canada and 0.78 in the U.S.

Mathematically, equation 8 is an *exact* representation of the composite adjustment factor. However, because the adjusted fuel economy values are rounded prior to consumer publication, some of the precision of the equation is lost. In addition, neither of the values required to calculate the "x" factor are known from the consumer data, but the approximate ratio can be estimated from the (again rounded) consumer city and highway fuel economy values. In the Table 3 example, the ratio would be 31/0.85 divided by 22/0.9, or 1.491979. Plugging this into equation 8 yields a composite adjustment factor of 0.881633 (about 2.2 percent higher than the 0.862069 value calculated from the known adjusted and unadjusted composite fuel economies), which further leads to an estimated CAFE/CAFC (i.e., unadjusted) fuel economy estimate of 25 divided by 0.881633, or 28.4 miles per U.S. gallon -- an estimation error of -0.6 miles per U.S. gallon relative to the known unadjusted composite fuel economy of 29.0 miles per U.S. gallon. Thus, as with the reconstituted city and highway fuel economy estimates, any reconstitution of the composite CAFE/CAFC fuel economy from the published consumer fuel cost data will be imprecise.

The Canadian consumer guide also includes an estimate of annual vehicle CO_2 emissions. This estimate is based on the annual fuel consumption estimate as described above, multiplied by a fuel specific CO_2 emission rate. For gasoline, the assumed emission rate is 2.4 kg CO_2 per liter of fuel (20.0 pounds CO_2 per U.S. gallon), while that for diesel fuel is 2.7 kg CO_2 per liter of fuel (22.5 pounds CO_2 per U.S. gallon). While these data are informative, their limitations are identical to those discussed above for annual fuel use with regard to any ability to reconstruct CAFE/CAFC fuel economy estimates from published consumer information. The U.S. consumer guide does not include vehicle-specific information on CO_2 emissions.

Note that the examples in this section are based on a vehicle fueled by regular unleaded gasoline. However, the basic approach is identical for all vehicular fuels. Although the specific values of fuel prices, etc. may vary, the approach underlying the estimation of the consumer fuel economy data and all identified issues therewith are unaffected.

Beginning with the 2008 model year, the methodology used in the U.S. to derive the consumer fuel economy estimates has changed from that described above for model year 2007 and earlier.[21] The fixed city and highway fuel economy adjustment factors (0.9 and 0.78 respectively) are no longer used to estimate consumer fuel economy values. Instead, emissions are measured over a series of five test cycles and the results of these emissions measurements are weighted to estimate expected consumer fuel economy values. The actual equations used to estimate the consumer fuel economy values are quite complex, so that presenting them in this document would be confusing and add little context. Instead, a narrative description of the process is more coherent in the context of this report.

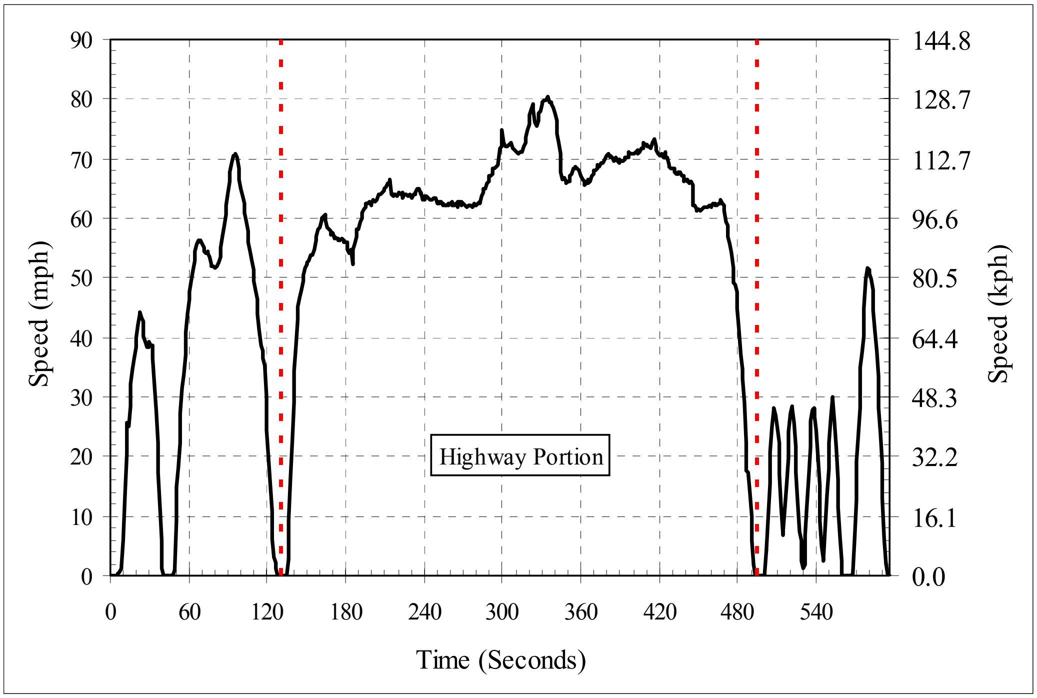
To derive the so-called "5 cycle fuel economy" values, which are the fuel economy values reported on U.S. vehicle fuel economy labels and in the U.S. fuel economy consumer guide beginning in model year 2008, emissions are measured over five test cycles instead of the two (city and highway cycles) described in Section 2.0 above. The calculation of CAFE fuel economy has not changed (it still relies on emissions collected over the two -- city and highway cycles -- described in Section 2.0). However, emissions from three additional test cycles are used to estimate consumer fuel economy in lieu of the fixed adjustment factors previously used (0.9 for the city fuel economy and 0.78 for the highway fuel economy as described above). Fuel economy measured over the standard city and highway test cycles (as described in Section 2.0) is combined (in a specified weighted format) with fuel economy measured over three additional cycles: the US06 cycle, the SC03 cycle, and the cold temperature FTP cycle.

The cold temperature FTP cycle is identical to the city fuel economy cycle as described in Section 2.0 (and presented in Figure 1 of that section), except it is performed at an ambient temperature of 20°F (-6.67°C) instead of within the standard 68-86°F temperature range allowed for the standard city fuel economy cycle. The cold temperature test measures emissions and fuel economy in colder driving conditions. The US06 cycle is designed to measure emissions under aggressive and high frequency transient driving conditions, conditions more representative of typical consumer operation than the standard city and highway fuel economy cycles. The SC03 test cycle is designed to measure emissions under high temperature ambient conditions with the vehicle air conditioning system operating. Figures 8 and 9 depict the US06 and SC03 driving cycles, while Table 4 presents a number of descriptive cycle statistics. Together, fuel economy measurements from these three "new" cycles are combined (in a specified weighted fashion) with fuel economy measurements from the standard CAFE city and highway cycles to derive so-called 5 cycle fuel economy (or consumer fuel economy) estimates. Again, this revised consumer procedure in no way affects U.S. CAFE measurements, which continue to be determined in accordance with the procedures described in Section 2.0.

The general effect of the revised U.S. procedure to estimate consumer fuel economy values, will be such that average consumer fuel economy estimates will decline from those estimated under the model year 2007 and earlier procedure (i.e., multiply CAFE city fuel economy by 0.9 and CAFE highway fuel economy by 0.78). While it is not possible to compare the increased stringency of the new procedures to the old procedures in any precise way since the new procedures will affect different vehicles differently, it is possible to make some generalizations based on EPA test data. In developing the revised test procedure, the EPA compared the

[21] The approach to estimating consumer fuel economy estimates in Canada has not changed from the methods described for model year 2007.

Figure 8. Speed/Time Characteristics of the US06 Fuel Economy Test Cycle



The city portion of the cycle is comprised of the periods before and after the highway portion.

Figure 9. Speed/Time Characteristics of the SC03 Fuel Economy Test Cycle

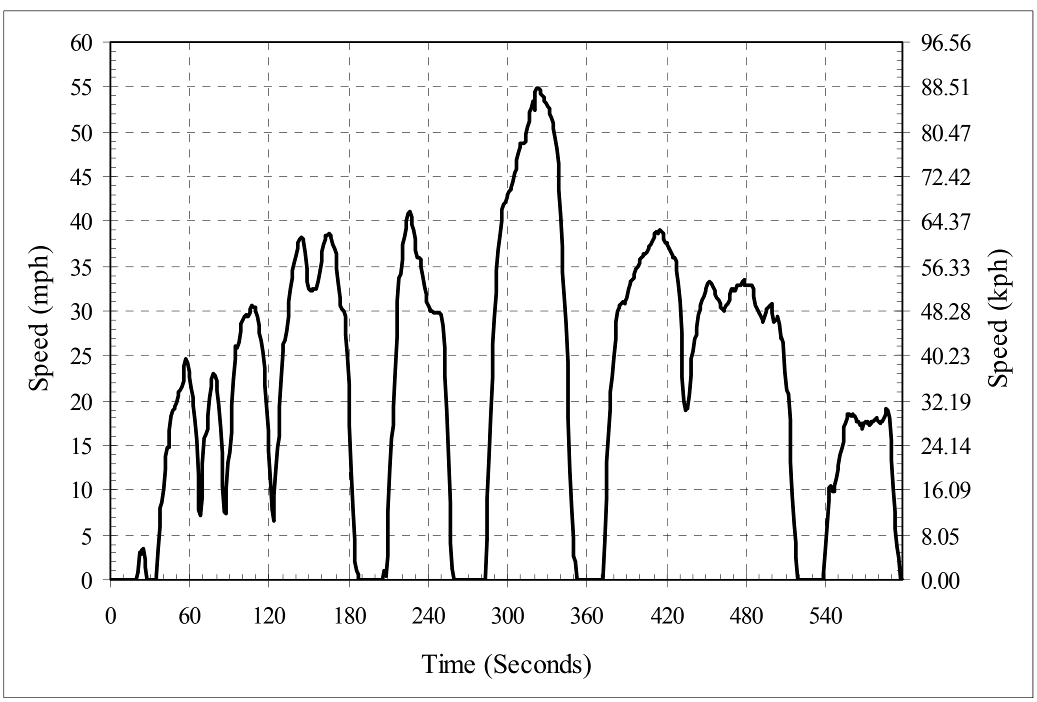


Table 4. U.S. Consumer Fuel Economy Test Cycle Statistics

Cycle Statistic	Units	FTP_{75}	HFET	US06	SC03	FTP_{20}
Cycle Duration	seconds	1874	765	596	598	1874
	minutes	31.23	12.75	9.93	9.97	31.23
Cycle Distance	miles	11.0414	10.2567	8.0080	3.5795	11.0414
	kilometers	17.7694	16.5065	12.8876	5.7606	17.7694
Cycle Average Speed	mph	21.21	48.27	48.37	21.55	21.21
	kph	34.14	77.68	77.84	34.68	34.14
Cycle Maximum Speed	mph	56.70	59.90	80.30	54.80	56.70
	kph	91.25	96.40	129.23	88.19	91.25
Cycle Average Acceleration	mph/sec	0.901	0.384	1.383	0.958	0.901
	kph/sec	1.451	0.618	2.226	1.542	1.451
Cycle Maximum Acceleration	mph/sec	3.30	3.20	8.40	5.10	3.30
	kph/sec	5.31	5.15	13.52	8.21	5.31
Cycle Maximum Deceleration	mph/sec	-3.30	-3.30	-6.90	-6.10	-3.30
	kph/sec	-5.31	-5.31	-11.10	-9.82	-5.31
Cycle Idle Time	seconds	335	4	35	108	335
	minutes	5.58	0.07	0.58	1.80	5.58
Engine Start Condition		Cold	Warm	Warm	Warm	Cold
Laboratory Temperature	°F	68-86	68-86	68-86	95	20
	°C	20-30	20-30	20-30	35	-6.67
Air Conditioning Status		Off	Off	Off	On	Off

consumer fuel economy of a number of test vehicles as calculated using both the old and new procedures.[22] Generally, for conventional gasoline and diesel vehicles, the revised procedures are equivalent to average adjustment factors of about 0.78 for the city cycle and 0.70 for the highway cycle, as compared to respective factors of 0.9 and 0.78 under the old procedure. For hybrid-electric vehicles the impacts of the new procedures are greater, with the revised procedure generally equivalent to an average adjustment factor of about 0.70 for both the city and highway cycles, as compared to respective factors of 0.9 and 0.78 under the old procedure.

The bottom line is that the revision in test procedures renders it much more difficult to reconstitute CAFE fuel economy values from associated consumer information. To accomplish such reconstitution with any precision would require detailed vehicle-specific test data for all five consumer fuel economy cycles -- and since the standard CAFE cycles constitute two of the five consumer fuel economy cycles, actual CAFE fuel economy values will be as readily available (and far more precise) than any reconstituted CAFE estimate. At this time, it is unclear whether Canada intends to revise their consumer fuel economy estimates similarly.

[22] U.S. Environmental Protection Agency, "Final Technical Support Document, Fuel Economy Labeling of Motor Vehicle Revisions to Improve Calculation of Fuel Economy Estimates," EPA420-R-06-017, Table III.D-1, December 2006

Differences Between Canada and the U.S.: Prior to vehicle model year 2008, the consumer fuel economy procedures in Canada and the U.S. were procedurally identical. Both countries adjusted CAFE/CAFC fuel economy measurements to estimate consumer fuel economy. However, there were important differences in adjustment and calculation values. Both countries used city cycle adjustment factors of 0.9, but Canada used a highway cycle adjustment of 0.85 while the U.S. used a value of 0.78. Both countries applied the adjustment factors to fuel economy, as opposed to fuel consumption, estimates. In calculating annual fuel use statistics, Canada assumed annual travel of 20,000 kilometers, while the U.S. assumed 15,000 miles (24,140 kilometers). For 2008 and newer model year vehicles, Canada continues to rely on this same CAFE/CAFC adjustment approach, while the U.S. has implemented a revised approach based on weighted fuel economy values measured over five specific test cycles. This new approach is fundamentally different than the CAFE/CAFC adjustment approach and represents the only major procedural difference between the Canadian and U.S. fuel economy programs.

4.0 California GHG Emissions Measurement Procedures

In administering their GHG emissions standards for light duty vehicles, California relies almost exclusively on the CAFE/CAFC fuel economy measurement procedures described in Section 2.0 above. The only exceptions are related to N_2O (nitrous oxide), CH_4 (methane), and air conditioning emissions.

The California regulations[23] establish standards for light duty vehicles and medium duty passenger vehicles in terms of CO_2-equivalent emissions in grams per mile, defined as follows:

$$CO_2\text{-eq} = CO_2 + (296 \times N_2O) + (23 \times CH_4) - \text{A/C Allowance} \quad (9)$$

where: CO_2-eq = GHG emissions in grams CO_2-equivalent per mile,
CO_2 = carbon dioxide emissions in grams per mile,
296 = the 100 year global warming potential of N_2O,
N_2O = nitrous oxide emissions in grams per mile,
23 = the 100 year global warming potential of CH_4,
CH_4 = methane emissions in grams per mile, and
A/C Allowance = air conditioning emissions allowances.

CO_2, N_2O, and CH_4 emissions are measured using the city and highway fuel economy test procedures previously described in Section 2.0 above. Note that as described in Section 2.0, CO_2 emission measurements are used (along with measurements for other carbon containing emission species) to calculate vehicle fuel economy based on a carbon mass balance approach (i.e., comparing the amount of carbon in the fuel to the rate at which carbon is being emitted allows the rate of fuel consumption to be calculated). For GHG emissions determination, the CO_2 emissions measured over the same tests are used directly. N_2O and CH_4 emissions are also measured over the same tests, so that the test procedures for the California GHG regulations are identical to the fuel economy test procedures previously described.

[23] Title 13, California Code of Regulations, Section 1961.1, "Greenhouse Gas Exhaust Emission Standards and Test Procedures - 2009 and Subsequent Model Passenger Cars, Light Duty Trucks, and Medium Duty Vehicles."

Due to the relatively minor emission rate of N_2O, California allows vehicle manufacturers to use a "default" value of 0.006 grams per mile if lieu of actually measuring the N_2O emission rate (if the manufacturer so decides). Combining this value with a global warming potential of 296 for N_2O yields a "default" N_2O emission rate of 1.8 grams CO_2-equivalent per mile. Although California does not provide a similar default emissions allowance for CH_4, as it is generally measured during standard fuel economy testing for non-GHG emissions purposes, a general significance estimate can be derived from typical emission rate values. For current generation conventional fueled vehicles, a typical CH_4 emission rate is on the order of 0.005 grams per mile. Combining this estimate with a global warming potential of 23 for CH_4 yields a typical CH_4 emission rate of 0.1 grams CO_2-equivalent per mile. The CH_4 emission rates of natural gas powered vehicles can, however, be significantly higher. By comparison, CO_2 emission rates for conventional fueled vehicles are on the order of 250-500 grams per mile, with smaller more efficient vehicles on the lower end and larger less efficient vehicles on the upper end of the range. Thus, although total California GHG emissions measurements include CO_2, N_2O, and CH_4, CO_2 is by far the most important.

Air conditioning allowances are provided for both direct emissions (refrigerant emissions due to leakage) and indirect emissions (emissions associated with the load an air conditioner places on a vehicle engine). Direct emissions allowances can be obtained for both low-leak air conditioning designs and air conditioning systems that use a refrigerant with a reduced global warming potential (relative to HFC-134a, the baseline refrigerant). Indirect emissions allowances can be obtained for an air conditioning system that is more efficient than the assumed baseline system. Test procedures for determining air conditioning allowances are not currently specified in the California regulations, but the parameters for an engineering demonstration (i.e., necessary air conditioning components and elements of design) are delineated so that vehicle manufacturers can obtain California approval of specific air conditioning allowances by submitting the appropriate engineering demonstration materials to the state. Generally, such allowances would be on the order of 3-9 grams CO_2-equivalent per mile for direct emissions (with the upper end of the range applicable to an advanced air conditioning system using CO_2 refrigerant) and 7-10 grams CO_2-equivalent per mile for indirect emissions. Although these allowances are generally more significant to overall California GHG emission measurements than emissions of N_2O and CH_4, they are still minor relative to CO_2 emissions.

An upstream GHG adjustment factor is applied to non-gasoline and non-diesel fueled vehicles to account for differences in GHG emissions during the production and distribution of such fuels. For example, for natural gas, liquid petroleum gas, and 85 percent ethanol blends, the upstream adjustment factors are 1.03, 0.89, and 0.74 respectively. This adjustment does not affect the actual GHG test procedures in any way, but rather is applied to post-test emissions measurements to derive a net "gasoline equivalent" emission estimate.

Just as California relies on the standard fuel economy test methods described in Section 2.0 above, they also retain the standard fuel economy test cycle weightings. GHG emissions measured over the city test cycle are weighted using a factor of 55 percent and GHG emissions measured over the highway test cycle are weighted using a factor of 45 percent (see equation 3 in Section 2.0 above for these same weightings as applied to fuel economy measurement). Since there is no GHG standard for individual vehicles, California combines the calculations described in equations 3 and 4 (from Section 2.0) into a single fleetwide compliance determination for each vehicle manufacturer as follows:

$$\text{GHG} = \frac{0.55\left[\sum_{i=1}^{\text{num models}}\left(\text{Veh Prod}_i \times \text{City GHG}_i\right)\right] + 0.45\left[\sum_{i=1}^{\text{num models}}\left(\text{Veh Prod}_i \times \text{Hwy GHG}_i\right)\right]}{\text{Total Vehicles Produced}} \quad (10)$$

where: GHG = composite GHG in grams CO_2-equivalent per mile,
City GHG = city cycle GHG in grams CO_2-equivalent per mile,
Hwy GHG = highway cycle GHG in grams CO_2-equivalent per mile,
Veh Prod = number of vehicles produced, and
num models = number of model test groups.

Thus, in summary, California (to determine GHG emission standard compliance) relies on the existing test procedures and weighting factors currently used for standard fuel economy testing in both Canada and the U.S. The state does add measurement requirements for methane and, if desired by the vehicle manufacturer, nitrous oxide. The former is not currently required for fuel economy testing, except for natural gas fueled vehicles, but is required to be measured over the same test cycles for non-fuel economy emissions standard compliance purposes and thus imposes no additional burden on industry. As indicated, California provides a non-measurement alternative for the latter, so that including N_2O as a measured emission species in solely left to the discretion of the vehicle manufacturer. All air conditioning emission estimates are based on engineering, rather than laboratory, analysis and thus also impose no additional emissions testing burden. In short, the California GHG program imposes no additional emissions testing burdens. Instead, the program simply requires data collected over the standard fuel economy test cycles to be mathematically processed to derive required GHG emission estimates.

5.0 Grouping of Vehicles for Fuel Economy Testing Versus California GHG Testing

Due to regulatory and procedural alignment (as discussed in Section 2.0 above), the grouping of vehicles for fuel economy testing purposes is effectively identical in Canada and the U.S. In reviewing this section, readers will readily recognize that fuel economy grouping requirements are somewhat clumsily defined due to complex vehicle classification schemes, hierarchical testing and reporting requirements, overlapping regulatory requirements (e.g., emissions versus fuel economy testing), and data reporting requirements that range across vehicle classification levels (e.g., how vehicles are grouped for CAFE/CAFC compliance purposes versus how they are grouped for the development of consumer information). While a genuine attempt has been made to review these vehicle grouping requirements with clarity, the actual nomenclature used in the fuel economy regulations has been retained to avoid introducing further potential confusion due to differences in terminology.

Under U.S. fuel economy regulations (and under Canadian guidelines by reference), the basic units of fuel economy testing are the *certification vehicle* and the *fuel economy data vehicle* (40 CFR 600.010). A *certification vehicle* is basically a vehicle used to demonstrate compliance with emission regulations, which under fuel economy regulations (40 CFR 600.010) must also be used for fuel economy determination. A *fuel economy data vehicle* is any other vehicle used for fuel economy determination. Although *fuel economy data vehicles* are not *certification vehicles* per se (in that they are not used for emissions compliance purposes), they are subject to the same testing criteria once they are selected for fuel economy testing (since fuel economy regulations require that they follow the same testing procedures as *certification vehicles*). Thus, the same grouping and test vehicle selection requirements apply.

Each *certification vehicle* must be selected from the *vehicle configuration* within a *test group* that is expected to represent the worst-case emissions compliance burden for the test group (40 CFR 86.1828). A *test group* consists of vehicles that are identical in terms of their engine combustion cycle, engine type, fuel used, basic fuel metering system, engine displacement (within a range of ±15 percent or 50 cubic inches), number of combustion chambers (cylinders), arrangement of the combustion chambers, exhaust catalyst construction and precious metal composition, exhaust catalyst loading per unit of engine displacement (to the nearest tenth, or an alternative, similarly effective emissions control statistic), and applicable emission standards (40 CFR 86.1827 and 86.1820).

Each *test group* is composed of multiple *vehicle configurations*, with each *vehicle configuration* defined as vehicles that have an identical *basic engine*, *engine code*, *inertia weight class*, *transmission configuration*, and *axle ratio*. (40 CFR 86.1803 and 40 CFR 600.002). A *basic engine* is a unique combination of manufacturer, engine displacement, number of cylinders, fuel system (e.g., type of fuel injection), catalyst usage, and other engine and emission control system characteristics specified by the EPA (40 CFR 86.1803 and 40 CFR 600.002). As defined in Transport Canada's fuel economy guideline document, the characteristics that may determine a distinct *basic engine* include:[24]

- engine usage (passenger car engines are separate from those used for trucks, vans and special purpose vehicles),
- engine type (Otto cycle versus diesel cycle versus turbine, etc.),
- block configuration (in-line versus V-block, etc.),
- fuel type (regular gasoline versus premium gasoline versus diesel, etc.),
- engine manufacturer,
- engine displacement,
- number of cylinders,
- fuel system (as distinguished by number of carburetor barrels or use of fuel injection),
- type of fuel injection (throttle body versus multi-point, etc.),
- use of a catalyst,
- use of a turbocharger,
- use of a supercharger,
- use of a feedback fuel system,

[24] Transport Canada, "VFEIS, Vehicle Fuel Economy Information System, Data Element Dictionary, 2009 Model Year," TP5529E.

- use of variable valve timing, and
- any other engine and emission control system characteristics which would be expected to cause differences in fuel economy.

A *transmission configuration* is subdivision of a *transmission class* and consists of transmissions having the same basic type (e.g., manual, automatic, semi-automatic), number of forward gears, drive system (e.g., front wheel drive, rear wheel drive; four wheel drive), type of overdrive (e.g., final gear ratio less than 1.00, separate overdrive unit), torque converter type (e.g., non-lockup, lockup, variable ratio), and other transmission characteristics that are significant including gear ratios, torque converter multiplication ratio, stall speed, shift calibration, and shift speed (40 CFR 86.1803 and 40 CFR 600.002). As defined in Transport Canada's fuel economy guideline document, the characteristics that may determine a distinct *transmission class* include:[25]

- type of transmission (manual versus automatic versus semi-automatic versus continuously variable, etc.),
- number of forward gears,
- driveline configuration (front versus rear versus 4 wheel drive),
- use of overdrive (with separate transmission classes for overdrive, electronic overdrive and computer controlled automatic electronic overdrive),
- type of torque converter (lockup versus non-lockup versus variable ratio),
- use of shift indicator lights (with separate transmission classes for different shift indicator light systems),
- use of an engine management system (e.g., a stop-start engine device),
- multi-mode transmissions (automatic, manual, or semi-automatic transmissions that have operator selectable features are separate transmission classes, with the number of different modes available also determining a separate transmission class),
- use of free-wheeling or declutching devices, and
- transmissions with variable operator-selectable lockup characteristics (with differences in the number of ranges available also determining a separate class).

Each *vehicle configuration* is further classified into a particular *subconfiguration* that is effectively established by the vehicle characteristics that affect the fuel economy testing procedures themselves. Since vehicles are tested in a stationary fashion on a dynamometer, it is necessary to simulate the forces that would otherwise be imposed on the vehicle by its mass and aerodynamic characteristics as it moved. This is accomplished through the determination of a specific vehicle test weight and road load horsepower curve, which are used to set the resistance characteristics of the dynamometer during the fuel economy test. Since these characteristics can vary for vehicles within a given *vehicle configuration*, actual fuel economy test vehicles are selected from individual *subconfigurations*. In Canada, the vehicle *subconfiguration* is also known as the *test vehicle level*.

[25] Transport Canada, "VFEIS, Vehicle Fuel Economy Information System, Data Element Dictionary, 2009 Model Year," TP5529E.

Thus, each fuel economy test vehicle represents a specific *subconfiguration* within a specific *vehicle configuration* that belongs to a specific *test group*. A given *test group* can have multiple *vehicle configurations*, which in turn can have multiple *subconfigurations*. Manufacturers are not required to test vehicles in each *subconfiguration*, but it is possible that they will do so. *Certification vehicles* must be selected for testing if they represent the worst-case emissions compliance burden for the *test group*. Thus, they will belong to a particular *subconfiguration*. Fuel economy testing is also required for the *subconfiguration* with the highest projected model year sales within the *vehicle configuration* with the highest projected model year sales in each *base level* (a *base level* is composed of *vehicle configurations* with common a basic engine, inertia weight class, and transmission class). Such vehicles may or may not belong to the same *subconfiguration* as *certification vehicles*. Finally, vehicle manufacturers must test sufficient vehicles to quantify fuel economy at the *vehicle configuration* level for at least 90 percent of their annual production. To satisfy this requirement, additional fuel economy test vehicles are required for *vehicle configurations* not otherwise associated with *certification vehicles* or other *fuel economy data vehicles*.

As indicated, the fuel economy test vehicle classification scheme is quite discriminating and is designed to ensure that fuel economy test vehicles truly represent the fuel economy of their specific *subconfigurations*. Once collected, *subconfiguration* fuel economy data are aggregated (on a production weighted basis) to produce fuel economy statistics at the *vehicle configuration* level, the *base level* (vehicle configuration data aggregated by common basic engine, inertia weight class, and transmission class), the *model type* level (base level data aggregated by car line,[26] basic engine, and transmission class), and overall CAFE/CAFC levels. *Model type* data (adjusted as necessary for onroad conditions, as described in Section 3.0 above) are the data used for vehicle labeling and consumer fuel economy guide purposes.

For purposes of its light duty vehicle GHG standards, California defines a *GHG vehicle test group* to be vehicles that have an identical *test group*, *vehicle make and model*, *transmission class and driveline*, *aspiration method*, *camshaft configuration*, *valvetrain configuration*, and *inertia weight*.[27] Since California adopts the federal definition of test group by reference, the *GHG vehicle test group* is entirely consistent with the federal definition of *vehicle configuration* (as each of California's included classification criteria also affect the classification of a vehicle into a specific fuel economy basic engine or transmission configuration). Moreover, since fundamental fuel economy testing requirements are defined at the vehicle configuration level,[28] the fundamental "grouping" of vehicles for California GHG testing is entirely consistent with the "grouping" requirements of the U.S. and Canadian fuel economy programs.

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[26] A car line is group of vehicles within a vehicle make that have a degree of commonality in construction (e.g., body, chassis). Passenger cars, station wagons, sport utility vehicles, vans, and pickup-trucks constitute separate car lines. The actual definition is codified at 40 CFR 86.1803 and 40 CFR 600.002.

[27] Title 13, California Code of Regulations, Section 1961.1(e)(3), "Greenhouse Gas Exhaust Emission Standards and Test Procedures - 2009 and Subsequent Model Passenger Cars, Light Duty Trucks, and Medium Duty Vehicles."

[28] Although fuel economy test vehicles are actually selected at the subconfiguration level, selected vehicles are intended to represent the vehicle configuration group of which they are a member.

The only additional test vehicle identification requirement potentially imposed by California is not related to the grouping of test vehicles per se, but rather to the requirement that specific test vehicles be selected on the basis of worst-case GHG emissions.[29] Although the worst-case criterion is also consistent with the approach for selecting a *certification vehicle* for testing under the fuel economy program, it is possible that the expected worst-case criteria emissions *certification vehicle* may be of a different *vehicle configuration* than the expected worst-case GHG emissions test vehicle required to be tested under the California program. Thus, although the vehicle "grouping" requirements of the two programs are entirely consistent, it is possible that vehicle manufacturers may have to test additional vehicles to comply with both fuel economy and California GHG requirements.

In terms of how this might differentially affect compliance with the California emission standards in Canada and the U.S., there is no difference. Since the grouping requirements of the Canadian and U.S. fuel economy programs are identical, any issues associated with vehicle testing for California GHG compliance will apply equally in both Canada and the U.S. Additionally, as described in more detail in Section 7.0 below, a detailed review of model year 2007 fuel economy data for Canada and the U.S. reveals that the specific manufacturers marketing light duty vehicles in the two countries are substantially identical. Of the 40 passenger car makes reflected in the U.S. fuel economy program, 35 were similarly reflected in the Canadian program. The only U.S. makes not reflected in the Canadian data were Aston Martin, Lotus, Mercury, Roush Performance, and Spyker. There were no makes reflected in the Canadian data that were not also reflected in the U.S. data. The situation for light duty trucks is similar. Of the 35 makes reflected in the U.S. fuel economy program, 31 were similarly reflected in the Canadian program. The only U.S. makes not reflected in the Canadian data were Isuzu, Mercury, Porsche, and Roush Performance. There were no light truck makes reflected in the Canadian data that were not also reflected in the U.S. data. Thus, application of the California GHG program in Canada will also not impose additional testing burdens on Canadian-only manufacturers.

6.0 Using Fuel Economy Data to Derive GHG Emission Estimates

At issue is whether there are administrative or cost efficiencies associated with allowing the use of (suitably converted) Canadian or U.S. fuel economy data to demonstrate compliance with British Columbia GHG emissions requirements. Although it is difficult to envision a scenario under which significant, or any, efficiencies accrue through the formal linkage of GHG and fuel economy requirements, the specific response depends largely on the GHG emission requirements adopted by British Columbia. This report examines two potential scenarios: (1) that British Columbia adopts the specific requirements of the California light duty vehicle GHG program, or (2) that British Columbia adopts their own independent light duty vehicle GHG emission standards and compliance procedures.

Under both scenarios, the potential for efficiency through fuel economy linkage is discussed in the context of the current fuel economy program. Recognize, however, that perhaps the biggest

[29] California Environmental Protection Agency, Air Resources Board, "California Exhaust Emission Standards and Test Procedures for 2001 and Subsequent Model Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles," Part I, §G2.3.2, as Amended through May 2, 2008.

risk of designing a GHG program around a specific fuel economy program is that the fuel economy program around which the design was developed is not guaranteed to remain static over time. Should modifications in the underlying fuel economy program occur, the potential exists for those changes to fundamentally alter any relationship that previously existed between the GHG and fuel economy programs. In effect, there is significant risk in basing a provincial GHG program on the requirements of a national fuel economy program, even if otherwise beneficial near term efficiencies may be available.

6.1 Adoption of the California Light Duty Vehicle GHG Program

Under a scenario in which British Columbia adopts the standards and requirements of the California light duty vehicle GHG program, it is difficult to envision any efficiencies in either administrative functionality or cost (to either British Columbia or vehicle manufacturers) in basing compliance decisions on fuel economy data. Conversely, it is easy to envision a host of inefficiencies (and thus added costs) that might arise from basing compliance determinations on converted fuel economy data. The specific reasons for this conclusion are as follows:

- The California program is itself based on the same test methods used to generate CAFE/CAFC fuel economy data. As a result, the basic data required to demonstrate compliance with the California program is co-generated with the data required to demonstrate CAFE/CAFC compliance. Using the CAFE/CAFC data in lieu of the co-generated California GHG data would actually create inefficiency in the data compilation process as an additional CAFE/CAFC conversion step would have to be defined and administered specifically for British Columbia when the very data required to demonstrate compliance with California requirements is readily available.

  The only possible exception is related to air conditioning allowances under the California program, as these are not estimated through a laboratory testing procedure. Removing these allowances would alleviate vehicle manufacturers from having to submit associated engineering demonstrations to California for approval, but would also create a separate program in British Columbia so that manufacturers seeking to demonstrate GHG compliance in the two areas (i.e., California and British Columbia) would be subject to two separate compliance methodologies, which is inherently inefficient and more costly. Moreover, eliminating these allowances would force manufacturers to meet British Columbia GHG standards that are effectively more stringent (and thus more costly).

  In the interest of maximizing the efficiency (and minimizing the costs) of their GHG program, California designed the program to efficiently mesh with existing fuel economy testing requirements. Deviating from their standard design will almost assuredly add, rather than alleviate, inefficiency.

- Using consumer-level fuel economy data (i.e., fuel economy data provided on vehicle informational labels and in annual consumer guides) for compliance demonstration purposes is problematic for two reasons. First, the data reflect an inherent loss in efficiency relative to CAFE/CAFC compliance data. In other words, consumer data demonstrate a lower fuel economy (and higher equivalent GHG emissions) than CAFE/CAFC compliance data. Thus, using such data for GHG compliance determinations would subject vehicle manufacturers to effectively more stringent GHG compliance requirements if they were held to the same standards established in California.

Of course, consumer-level data can be converted in into CAFE/CAFC-equivalent fuel economy estimates. However, the loss in precision associated with such conversion is discussed in detail in Section 3.0 of this report. As there is no means of overcoming such loss, manufacturers (and British Columbia officials) would have to agree to ignore this loss in precision for any use of consumer data to be feasible. Given that vehicle manufacturers already have the very CAFE/CAFC data being reconstituted, it is difficult to see any scenario in which the addition of a conversion step to reconstitute already available data would add efficiency to the compliance demonstration process.

In summary, adopting the California GHG standards as established by California and replacing the California compliance system with an alternative that relies on surrogates for the specific data required under the compliance demonstration procedures established by California adds only inefficiency to the compliance system. The California system is already designed to mesh efficiently with the CAFE/CAFC compliance process (as detailed in Section 4.0 above).

6.2 Adoption of a British Columbia-Specific Light Duty Vehicle GHG Program

Under a scenario in which British Columbia adopts their own independent light duty vehicle GHG standards and compliance requirements, it is possible that system efficiency and cost reduction (in British Columbia) could accrue by basing compliance decisions on (suitably converted) fuel economy data. However, for this to occur, vehicle manufacturers would have to agree to the inherent loss in GHG emissions precision (presumably as a tradeoff to additional testing or data manipulation requirements that would otherwise accrue under an alternative testing requirement). For such a scenario to be viable, the following would have to hold true:

- The British Columbia program would include emission standards applicable to CO_2 emissions per se, not CO_2-equivalent emissions. Under the California GHG program, the latter include GHG contributions due to nitrous oxide, methane, and air conditioning emissions -- none of which can be estimated from CAFE/CAFC compliance data. CAFE/CAFC compliance data can be converted to CO_2 emissions equivalents by multiplying fuel economy estimates by standard fuel carbon contents (which would vary by fuel type). This effectively allows CAFE/CAFC compliance data to be converted into grams of CO_2 per unit distance travelled and compared to a suitably developed emission standard. This would alleviate the requirement to specify either separate or unique testing requirements for British Columbia-specific emission standards, but would also focus the program solely on tailpipe CO_2 emissions and eliminate credit for GHG reducing technologies that do not affect tailpipe CO_2 (e.g., reduction in air conditioning refrigerant leakage or movement to a lower global warming potential refrigerant).

  Recognize, however, that such a program would be unique from that of California and would require similarly unique emission standards defined with the nature of the compliance demonstration program in mind. Creation of this unique program would place an added burden on British Columbia regulators during the program development stage (since they could not simply adopt California's program). Additionally, the program would also create a distinct compliance burden for vehicle manufacturers. Given the international nature of the light duty vehicle market, it is very likely that every manufacturer seeking to demonstrate compliance in British Columbia will also be seeking to demonstrate compliance in California. To the extent that the compliance demonstration requirements in the two jurisdictions are unique, the compliance burdens for manufacturers will be greater than would be the case if British Columbia simply adopted the California program outright. Generally, manufacturers prefer not to create unique emission standards and compliance programs, but that preference could be affected by the relative stringency of the British Columbia program relative to that of California. For equal stringency programs, it is almost certain that manufacturers would prefer a single unified program (i.e., adoption of the California program) over any compliance efficiency created through the use of converted fuel economy data.

- As was the case under the scenario addressing the adoption of the California GHG program in Section 6.1, using consumer-level fuel economy data (i.e., fuel economy data provided on vehicle informational labels and in annual consumer guides) for compliance demonstration purposes remains problematic under a unique British Columbia GHG program for two reasons. First, the data reflect an inherent loss in efficiency relative to CAFE/CAFC compliance data. In other words, consumer data demonstrate a lower fuel economy (and higher equivalent GHG emissions) than CAFE/CAFC compliance data. For a British Columbia-specific program, CO_2 emission standards could be set with this lower fuel economy in mind, but this would result in unique program that is tied to consumer-level data rather than CAFE/CAFC data per se.

  Consumer-level data can be converted in into CAFE/CAFC-equivalent fuel economy estimates. However, the loss in precision associated with such conversion is discussed in detail in Section 3.0 of this report. As there is no means of overcoming such loss, manufacturers (and British Columbia officials) would have to agree to ignore this loss in precision for any use of consumer data to be feasible. Given that vehicle manufacturers already have the very CAFE/CAFC data being reconstituted, it is difficult to see any scenario in which the addition of a conversion step to reconstitute already available data would add efficiency to the compliance demonstration process.

In summary, it is possible to create a unique British Columbia GHG emissions program and compliance system that relies on CAFE/CAFC fuel economy data. This would create efficiencies relative to defining a similarly unique British Columbia GHG testing program. However, this efficiency would come with the tradeoff of imposing distinct compliance requirements for British Columbia and California (and the other jurisdictions that have adopted California's program) and it is likely that vehicle manufacturers would value the negative aspects of such a tradeoff higher than any CAFE/CAFC data efficiencies. Of course, only the manufacturers can answer this question with certainty, but it difficult to reconcile support for a unique British Columbia program with historic opposition to other distinct regulatory programs.

The bottom line is that using the CAFE/CAFC test procedures to generate the specific emissions data required to quantify GHG emissions adds little additional burden to the existing CAFE/CAFC test. Moreover, vehicle manufacturers are already required to collect this data for California compliance purposes so that the use of CAFE/CAFC data per se adds little, if any, efficiency to an already defined emissions testing system. It is possible to design a system around the CAFE/CAFC data, but there is little, if any, advantage to doing so. Even if an advantage did exist, reliance on CAFE/CAFC data would tie any British Columbia program to a CAFE/CAFC system that is subject to potential change. Should future changes to the CAFE/CAFC system render that system incompatible with any adopted British Columbia GHG program, British Columbia would be forced to respond with appropriate GHG program revisions.

7.0 Legal, Institutional, and Operational Context for Fuel Economy Testing in Canada

At this time, the Canadian fuel economy program continues to function under a voluntary agreement with the motor vehicle industry. This relationship will, however, change in the near future as Canada announced, in October of 2006, its intention to implement mandatory light duty vehicle fuel economy standards. It is expected that these mandatory standards will take effect beginning with vehicle model year 2011, the first model year that follows the expiration of a current GHG MOU with the motor vehicle industry.

Fuel economy testing for light duty vehicles in Canada dates back to the 1978 vehicle model year. Like the U.S., Canada implemented a number of programs in response to the 1973 OAPEC (Organization of Arab Petroleum Exporting Countries) oil embargo. Among these was a 1976 Joint Government-Industry Voluntary Fuel Consumption Program. This voluntary program resulted in the establishment of annual Company Average Fuel Consumption (CAFC) targets that have continued to this day. Under this program, the motor vehicle industry subjects vehicles to fuel economy testing, compiles annual CAFC statistics, and provides fuel economy information to consumers in the form of labels that are affixed to new vehicles that are offered for sale. Canada, in turn, collects fuel economy data from vehicle manufacturers and annually publishes that data in the form of a consumer fuel economy guide (originally entitled the annual Fuel Economy Guide, but now released as the annual Fuel Consumption Guide).

Three agencies administer various aspects of the Canadian Voluntary Fuel Consumption Program. The main agency is Transport Canada, which is responsible for overall program administration, including the development of annual CAFC targets and associated program procedures and data collection methods. Natural Resources Canada compiles and releases the annual Fuel Consumption Guide. Environment Canada is tangentially involved in the program through its responsibility as the administrator of the Canadian On-Road Vehicle and Engine Emission Regulations. While these regulations establish motor vehicle emission standards, rather than fuel economy standards per se, fuel economy testing is performed simultaneously with emission standard testing and all vehicles used to demonstrate compliance with emission standards are included in the determination of CAFC. Thus it is important that the Canadian emission standard regulations established by Environment Canada remain consistent with the Canadian fuel economy requirements established by Transport Canada.

This administrative approach mimics that of the U.S., where Transport Canada performs functions similar to the National Highway Traffic Safety Administration of the U.S. Department of Transportation, and Environment Canada performs functions similar to the U.S. Environmental Protection Agency (although the U.S. Environmental Protection Agency takes a more active role in establishing fuel economy test procedures and collecting fuel economy data in the U.S.). The annual fuel economy guide functions of Natural Resources Canada are handled jointly by the U.S. Department of Energy and the U.S. Environmental Protection Agency.

This similarity is not coincidental, as the Canada Voluntary Fuel Consumption Program is designed to be harmonious, to the maximum extent possible, with the U.S. Corporate Average Fuel Economy (CAFE) program. This approach is intended to recognize the integrated nature of the North American motor vehicle market and ensure that the same vehicle designs can be offered in both Canada and the U.S. All CAFC targets established to date have been set to be equivalent in stringency to U.S. CAFE standards. Additionally, Canadian fuel economy guidelines (describing vehicle testing and compliance demonstration methods) and regulations on vehicle emission standards and associated test procedures and compliance demonstration methods (which are integrated into Canadian fuel economy procedures) are designed to be both consistent with, and reference directly to the maximum extent possible, corresponding procedures and regulations in the U.S.

Canadian guidelines for the Voluntary Fuel Consumption Program are published annually. The current guidelines covering the 2009 vehicle model year are contained in a Transport Canada publication entitled "Transport Canada Voluntary Motor Vehicle Fuel Consumption Program, Guidelines for Determination and Submission of Fuel Consumption Data, Model Year - 2009" (TP 6890/E, December 2007). Similarly titled versions of this publication exist for earlier model years. A companion publication entitled "VFEIS, Vehicle Fuel Economy Information System, Data Element Dictionary, 2009 Model Year" (TP5529E) provides fuel economy data coding and reporting information. While these documents provide informational elements specific to the Canadian fuel economy program, the guidelines are effectively constructed to rely exclusively on referenced U.S. fuel economy program requirements related to test methods and procedures.

The Canadian emission standards and associated test procedures, which are incorporated into the Canada fuel economy program guidelines by reference, are administered under regulations adopted under the Canadian Environmental Protection Act of 1999. The current regulations, entitled "On-Road Vehicle and Engine Emission Regulations," were published by Environment Canada in the Canada Gazette (Part II, Volume 137, Number 1) on January 1, 2003. Like the fuel economy guidelines, the emission standard regulations "continue the past approach of aligning with the federal emission standards of the United States Environmental Protection Agency (U.S. EPA) …"[30] As such, the regulations almost exclusively reference corresponding U.S. emissions regulations, including the incorporation of emission standards themselves by

[30] Environment Canada, "Regulatory Impact Analysis Statement" (for the On-Road Vehicle and Engine Emission Regulations), Canada Gazette, Part II, Volume 137, Number 1, January 1, 2003.

reference. Given this intentional alignment, fuel economy testing and procedural requirements are effectively identical in Canada and the U.S.[31]

It should be recognized that fuel economy testing (both in Canada and the U.S.) is a "self-testing" requirement imposed on motor vehicle manufacturers. While there is no requirement that manufacturers conduct such testing in their own laboratories (as opposed to an independent laboratory testing facility), manufacturers are responsible for collecting and submitting the necessary data. For CAFE/CAFC purposes, vehicle manufacturers must test a sufficient number of vehicles to reflect the fuel economy of at least 90 percent of their production.[32] Government's role is limited to administration and oversight. Both Canada and the U.S. perform confirmatory testing for a subset of vehicles to ensure compliance. The U.S. confirms 10-15 percent of tests annually (on a random basis). It is not clear whether Canada runs a similar program at this time due to the voluntary nature of the CAFC targets.

To confirm the equivalency of the Canadian and U.S. approaches, data from the 2007 fuel economy guides from both countries were examined.[33] Data from the 2008 guides were not used due to a fundamental change in the methods used to estimate fuel economy guide data in the U.S. that began with the 2008 model year, a change that has not yet been adopted in Canada. This change is discussed in detail in Section 3.0 above. While the difficulties in converting fuel economy guide data to CAFE/CAFC equivalents are also described in detail in Section 3.0, it is possible to determine the relative similarity of reported data for the two countries.

Due to the manually intensive nature of matching vehicle records from the Canadian and U.S. fuel economy guides, the data comparison was limited to passenger car records. The Canadian guide contained records for 566 vehicle configurations (*model types* in the nomenclature of the fuel economy regulations), while the U.S. guide contained records for 612 vehicle configurations. 533 vehicle configurations matched across the two datasets (thus there were 33 unique configurations in the Canadian dataset and 79 unique configurations in the U.S. dataset).[34] Of

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[31] The form in which the associated data are compiled and presented may differ (e.g., fuel economy is expressed in terms of miles per U.S. gallon in the U.S. as opposed to liters per 100 kilometers and miles per Imperial gallon in Canada), but the underlying procedural requirements are identical.

[32] This does not mean they must test 90 percent of their vehicles, but rather at least one vehicle that is representative of the fuel economy performance of the various vehicles comprising their overall fleet. For example, suppose a manufacturer sells 1000 vehicles of type A, 1000 vehicles of type B, and 1000 vehicles of type C. That manufacturer must then test at least three vehicles, one each of types A, B, and C (as together these three types cover 100 percent of production). In actuality they will test more than this due to related regulatory requirements, but they must test at least three vehicles to achieve the required 90 percent coverage.

[33] Natural Resources Canada, "Fuel Consumption Guide 2007." U.S. Department of Energy and U.S. Environmental Protection Agency, "Fuel Economy Guide, Model Year 2007." To facilitate comparison, the Canadian data were downloaded in electronic tabular format from the Natural Resources Canada website: http://oee.nrcan.gc.ca/transportation/tools/fuelratings/fuel-consumption.cfm?attr=8, as it existed on September 22, 2008, and the U.S. data were downloaded in electronic format from the joint U.S. Department of Energy and U.S. Environmental Protection Agency website: http://www.fueleconomy.gov/feg/download.shtml, as it existed on September 22, 2008.

[34] With two modest exceptions, all of the unique configurations were associated with "mainline" global motor vehicle manufacturers and not local or regional manufacturers. All 33 of the unique Canadian configurations were associated with mainline manufacturers (3 Acura, 4 BMW, 6 Chrysler, 5 Mercedes-Benz, 1 Mitsubishi, 5

the 533 matching vehicle configurations in the datasets, 3 indicated no Canadian fuel economy estimates. Of the remaining 530 configurations, 459 (87 percent) indicated matching fuel economy estimates for city driving and 445 (84 percent) indicated matching fuel economy estimates for highway driving.[35] An additional 66 and 71 indicated estimates for city and highway driving (respectively) that varied by ±1 miles per U.S. gallon. Thus, of the 530 matching vehicle configurations with fuel economy data, 525 (99.1 percent) indicated city driving estimates and 516 (97.4 percent) indicated highway driving estimates that were within 1 mile per U.S. gallon. Since, as described in Section 3.0 above, ±1 mile per U.S. gallon is within the uncertainty that arises from the loss in precision associated with the rounding of consumer fuel economy data, this exercise confirms the statistical identicality of the Canadian and U.S. fuel economy data.[36]

Despite the fact that the current fuel economy program is Canada is voluntary, there is existing statutory authority in Canada for a mandatory program. This authority actually dates from the 1982 passage of the Motor Vehicle Fuel Consumption Standards Act (MVSFCA). Because vehicle manufacturers agreed to voluntarily comply with the requirements of the act, the MVSFCA was not proclaimed (i.e., its provisions were not put into statutory effect) until very recently. Following a 2006 notice of intent, the MVSFCA was officially proclaimed on November 2, 2007. A regulatory adoption process is currently underway, with mandatory national fuel efficiency standards expected to go into effect beginning in vehicle model year 2011. While it is too early to say with any certainty how the implementation of a mandatory CAFC program might affect the long term relationship between the stringency identicality of current Canadian and U.S. fuel economy requirements, it is unlikely such a relationship will be severed in the near term. The U.S. is in the process of significantly tightening motor vehicle fuel

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Pontiac, 4 Suzuki, 4 Volkswagen, and 1 Volvo). All but 6 of the unique U.S. configurations were associated with mainline manufacturers (6 Aston Martin, 3 Audi, 1 Bentley, 10 BMW, 3 Cadillac, 2 Chevrolet, 3 Chrysler, 1 Dodge, 1 Honda, 8 Lincoln-Mercury, 2 Lotus, 1 Maserati, 6 Mercedes-Benz, 2 Mitsubishi, 7 Nissan, 1 Rolls-Royce, 1 Saturn, 2 Subaru, 7 Suzuki, 3 Toyota, and 3 Volvo). The only two "specialized" manufacturers were Roush Performance (2 vehicle configurations) and Spyker (4 vehicle configurations). Roush is a U.S. manufacturer that builds performance enhanced versions of the Ford Mustang and F-150 pickup. Spyker Cars is a small Dutch sports car company. Although no matching of truck configurations was performed, truck manufacturers from the Canadian and U.S. fuel economy guides were compared and 31 mainline truck manufacturers were common to both. There were no unique truck manufacturers in the Canadian guide and 4 in the U.S. guide (Isuzu, Mercury, Porsche, and Roush Performance).

[35] Comparing fuel economy estimates requires converting the Canadian liters per 100 kilometer data to miles per U.S. gallon (miles per U.S. gallon = 1/[liters per 100 kilometer/100/3.78541178/0.621371192], rounded to the nearest integer). For highway driving, an additional adjustment is made to account for the fact that the highway estimates are based on a laboratory fuel economy adjustment factor of 0.85 in Canada and 0.78 in the U.S. The converted Canadian estimates are then compared directly to the published U.S. estimates.

[36] Of the vehicle configurations that were not within ±1 miles per U.S. gallon, all 5 of the city fuel economy values were within ±2 miles per U.S. gallon as were 12 of the 14 highway fuel economy values. The other 2 highway fuel economy values indicated a Canadian fuel economy 3 miles per U.S. gallon greater than the indicated U.S. value. It is likely that these data reflect reporting errors rather than significant fuel economy differences. In conducting the data matching exercise, it was necessary to correct a number of reporting or transcription errors related to other vehicle data such as engine displacement, transmission type, etc. and it seems unlikely that similar errors would not also appear in the reported fuel economy fields. However, given the small number of discrepancies, no additional effort was devoted to isolating a specific definitive source for these larger discrepancies.

economy standards through at least 2020, and likely through 2030.[37] Given the continued existence of a North American marketplace for motor vehicles that is larger than either Canada or the U.S. individually, it seems most likely that Canada and the U.S. will continue to work cooperatively on the establishment of motor vehicle fuel economy standards.

Such a conclusion is strongly supported by Canada's stated clean air policy:

> *Transportation is one of the largest sources of greenhouse gas and air pollutant emissions in Canada. As part of a broader transportation policy package, a mandatory fuel-efficiency standard, beginning with the 2011 model year, will be developed through a process that will involve input from all the stakeholders, and it will be published by the end of 2008. It will be designed for Canada to maximize our environmental and economic benefits and will be benchmarked against a stringent, dominant North American standard. To do so, the federal government intends to work in close collaboration with the U.S. government pursuing the concept of a Clean Auto Pact, towards establishing an environmentally ambitious North American regulatory standard for cars and light-duty trucks.*[38]

This policy is reiterated by Transport Canada in their background materials associated with the ongoing development of the mandatory regulations.[39]

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37 Under the Energy Independence and Security Act of 2007, the U.S. statutory fuel economy target for vehicle model year 2020 is 35 mpg for cars and light trucks combined. The combined fuel economy target for each model year from 2021 through 2030 is mandated to be set at the maximally feasible level.

38 Her Majesty the Queen in Right of Canada, represented by the Minister of Environment, "Regulatory Framework for Air Emissions," Catalogue number: En84-53/2007, ISBN 978-0-662-69717-6, 2007.

39 Her Majesty the Queen in Right of Canada, represented by the Minister of Transport, "A Better Canada - A Cleaner Environment: The Development of Motor Vehicle Fuel Consumption Regulations, TP 14759, Catalogue number T46-45/2008, ISBN 978-0-662-05357-6, January 17, 2008.