Light Duty Vehicle
Fuel Economy and Greenhouse Gas Emissions

Analysis of GHG Emission Reductions
Due to California and CAFE/CAFC Standards

Draft Final Report

Prepared for:

BRITISH COLUMBIA
The Best Place on Earth

British Columbia Ministry of Environment
2975 Jutland Rd, 3rd Floor
Victoria, British Columbia V8T5J9
www.gov.bc.ca

Prepared by:

Meszler
Engineering Services

906 Hamburg Drive
Abingdon, Maryland 21009
410-569-0599
www.meszler.com

March 27, 2009

Table of Contents

Page

List of Tables

List of Figures

List of Figures
(continuation)

Page

1.0 Introduction

This report presents information requested by the British Columbia Ministry of Environment with regard to a comparison of the greenhouse gas (GHG) emissions impacts of adopting the California GHG emission standards for light duty motor vehicles versus the impacts that would result from expected CAFE/CAFC[1] standards. Although the CAFE/CAFC programs do not establish GHG standards per se, the CAFE/CAFC standards indirectly affect GHG emissions through reductions in vehicle fuel consumption. Since the majority of current motor vehicle fuels contain carbon, consumption of these fuels produces carbon dioxide (CO_2) -- the main greenhouse gas associated with light duty vehicle use. Thus, reducing the use of such fuels, through CAFE/CAFC (or any other fuel conservation program), reduces GHG emissions.[2]

California adopted light duty vehicle GHG emission standards in 2004. The standards were scheduled to take effect with the 2009 vehicle model year, but have not been enforced to date due to the U.S. Environmental Protection Agency's (EPA's) December 2007 decision to deny California an enforcement waiver required under the U.S. Clean Air Act.[3] That decision is currently being reconsidered under the new Obama administration and it is widely believed that it will be overturned and California will be allowed to enforce their standards. Fourteen other states in the U.S. have already adopted the California standards and several others are expected to do so in the near future.[4] At least two Canadian provinces, British Columbia and Quebec, are

---

[1] CAFE is an acronym for Corporate Average Fuel Economy, which is the name of the U.S. program requiring manufacturers of light duty vehicles sold in the U.S. to achieve specified fuel economy requirements. CAFC is an acronym for Company Average Fuel Consumption, which is the Canadian counterpart to the U.S. CAFE program.

[2] It is important to note that the relationship between fuel consumption and GHG emissions *requires* specific assumptions about the fuel being consumed. Opponents of the California GHG emission standards often cite a relationship between fuel consumption and CO_2 emissions as a rationale for assuming the equivalency of GHG emission and fuel consumption standards -- but such an argument *requires* that the fuels themselves do not change. For example, a diesel vehicle just meeting a specific CAFE/CAFC standard emits more CO_2 than a gasoline vehicle just meeting that same standard. Thus, the increased dieselization of a fleet of vehicles just meeting CAFE/CAFC standards could lead to an increase in CO_2 emissions even though fuel consumption has not changed. Conversely, substitution of a lower carbon fuel such as ethanol, natural gas, hydrogen, etc. could lead to a reduction in CO_2 emissions for a constant level of fuel consumption. Additionally, CAFE/CAFC standards do not affect GHG emissions such as those associated with air conditioning load and refrigerant leakage, which are not detected during the CAFE/CAFC test, but are regulated under the California GHG emission standards. It is, therefore, shortsighted to assume that GHG emission and fuel consumption standards are equivalent. A GHG standard promotes GHG emissions certainty (and fuel consumption uncertainty) versus a CAFE/CAFC standard that promotes fuel consumption certainty (and GHG emissions uncertainty). Nevertheless, it is possible to compare CAFE/CAFC and GHG standards if one assumes specific fueling characteristics. For this analysis, it is assumed that the fuels utilized under the two programs are identical, and unchanged from those forecasted under British Columbia baseline conditions. In other words, this analysis provides an accurate comparison of the two alternatives if neither affects the choice of future motor vehicle fuel.

[3] The U.S. Clean Air Act grants California the unique authority (in recognition of the states pioneering efforts in the motor vehicle emissions reduction arena) to establish its own motor vehicle emission standards. However, such standards require the U.S. EPA to "waive" a Clean Air Act prohibition against state-specific standards, and the EPA (for the first time in the long history of independent California emission standards) decided not to grant such a waiver for the GHG emission standards, citing a lack of compelling and extraordinary conditions.

[4] The U.S. Clean Air Act prohibits states other than California from establishing their own emission standards, but does allow certain states (those with air quality problems) to adopt California's standards.

also currently in the process of adopting the California standards. As adopted, the California program sets GHG emission standards for vehicle model years 2009 through 2016, but the state has also committed to adopting specific standards for vehicle model years 2017 through 2020 as part of a phase two rulemaking.[5] Although the first model year to be regulated under the proposed British Columbia program is still to be determined, the California program option evaluated in this analysis would start with the 2011 vehicle model year and includes the California standards as defined through vehicle module year 2020. Standards are assumed to remain unchanged for all model years after 2020. Table 1 presents a summary of the California program standards.

Both Canada and the U.S. have administered fuel consumption programs for light duty motor vehicles since the 1978 vehicle model year. In the U.S., CAFE standards are expressed in terms of vehicle miles per U.S. gallon consumed (mpg), as measured over a specified set of test conditions. Canadian CAFC targets (to date, the Canadian program has been voluntary) are expressed in units of liters consumed per 100 vehicle kilometers (lit/100km), as measured over

Table 1. California GHG Standards

Vehicle Model Year	PC/LDT1 (CO_2-eq)		LDT2-4/MDPV (CO_2-eq)		Comment(s)
	g/mi	g/km	g/mi	g/km	
2009	323	200.7	439	272.8	Not Effective in British Columbia
2010	301	187.0	420	261.0	Not Effective in British Columbia
2011	267	165.9	390	242.3	Assumed Implementation Year for BC
2012	233	144.8	361	224.3	*The first model year to be regulated under the proposed BC program is still to be determined. Model year 2011 implementation was assumed for this analysis only.*
2013	227	141.1	355	220.6	
2014	222	137.9	350	217.5	
2015	213	132.4	341	211.9	
2016	205	127.4	332	206.3	
2017	195	121.2	310	192.6	
2018	185	115.0	285	177.1	
2019	180	111.8	270	167.8	
2020+	175	108.7	265	164.7	

Notes: (1) PC means passenger car.
(2) LDT1 means class 1 light duty trucks (trucks with a gross vehicle weight less than or equal to 6,000 pounds (2,721.6 kg) and a curb weight less than or equal to 3,450 pounds (1,564.9 kg).
(3) LDT2-4 means class 2, 3, and 4 light duty trucks (trucks with a gross vehicle weight less than or equal to 8,500 pounds (3,855.6 kg) that are not LDT1). This is the federal definition of these vehicles, California generally refers to them collectively as LDT2.
(4) MDPV means medium duty passenger vehicle (vehicles with a gross vehicle weight greater than 8,500 pounds (3,855.6 kg) but less than 10,000 pounds (4,536.0 kg) that are designed primarily for the transportation of people).
(5) gCO_2-eq/mi is a measure of GHG emissions expressed as grams of carbon dioxide equivalent per mile (non-CO_2 emission species such as methane, nitrous oxide, and air conditioner refrigerant are converted to CO_2 equivalents by multiplying their actual emission rates by their global warming potentials and then summing the resulting GHG emissions estimates with measured CO_2 emissions, which by definition have a global warming potential of unity).
(6) gCO_2-eq/km is a measure of GHG emissions expressed as grams of carbon dioxide equivalent per kilometer (calculated in the same fashion as gCO_2-eq/mi).

---

[5] See "Comparison of Greenhouse Gas Reductions Under CAFE Standards and ARB Regulations Adopted Pursuant to AB1493," California Air Resources Board, January 2, 2008.

the same testing conditions employed in the U.S. Historically, the Canadian targets and U.S. standards have been of equivalent stringency, as depicted in Table 2. In 2007, Canada indicated its intent to establish mandatory fuel consumption standards beginning with vehicle model year 2011. To date, such standards have not been established, and it is expected that Canadian regulators are awaiting the outcome of an ongoing federal rulemaking in the U.S., which would establish more stringent CAFE standards for model year 2011 through 2015 vehicles.[6]

Under the Energy Independence and Security Act of 2007, the U.S. has established a statutory fuel economy target of 35 mpg (6.7 lit/100km) for passenger cars and light trucks combined for vehicle model year 2020. As the first formal step in the process of establishing regulatory standards to meet this target, the National Highway Traffic Safety Administration (NHTSA) of the U.S. Department of Transportation published (in May of 2008) a notice of proposed rulemaking (NPRM) to establish standards for vehicle model years 2011 through 2015.[7] To date, this rulemaking has not been finalized, but NHTSA did release an associated Final Environmental Impact Statement (FEIS) in October 0f 2008.[8] This FEIS is significant because it included reference to NHTSA's "final" standards for vehicle model years 2011 through 2015, and these standards were significantly less stringent than those of the notice of proposed rulemaking. However, NHTSA did not finalize the rulemaking before the change of administrations in the U.S., so the specific standards for model year 2011 through 2015 vehicles remain uncertain.

The form of the CAFE standards proposed by NHTSA is such that the specific standard for a vehicle is dependent on its size, expressed in terms of its footprint, where footprint is defined as the product of its wheelbase and its track width.[9] This essentially means that the fleet average standard for any given model year is subject to change, should the size of the affected vehicle fleet change (relative to that forecasted when the standard was developed). As a result, it is not possible to define future CAFE standards with certainty and this is one aspect of the comparison with the California GHG standards that should be expressly understood -- namely that:

> ***The California GHG standards provide certainty within each of the affected vehicle classes. Conversely, CAFE standards can vary with changes in the size of affected vehicles, so any associated fuel consumption or emissions analysis is inherently uncertain.***

---

[6] See for example, "Federal gov't slow on stricter fuel regulations," The StarPhoenix, CanWest Publishing Inc., January 7, 2009. In this article, Chris Day, the press secretary to Canadian Transport Minister John Baird is quoted as stating that the "government's goal is to have new fuel-emissions standards in place for the 2011 model year, but it's prudent to wait for the incoming (U.S.) administration. The government is of the view we need one dominant North American standard."

[7] U.S. Department of Transportation, National Highway Traffic Safety Administration, "Average Fuel Economy Standards, Passenger Cars and Light Trucks; Model Years 2011-2015," Notice of Proposed Rulemaking, Federal Register, 73FR24352, May 2, 2008.

[8] U.S. Department of Transportation, National Highway Traffic Safety Administration, "Final Environmental Impact Statement, Corporate Average Fuel Economy Standards, Passenger Cars and Light Trucks, Model Years 2011-2015," October 2008.

[9] Wheelbase and track width are automotive (and in this case regulatory) terms that respectively signify the longitudinal and lateral distance between tire centerlines.

Table 2. Historic Canadian CAFC Targets and U.S. CAFE 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

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.

It is important to note that the U.S. CAFE rule does establish certain limited backstops. *Domestically produced passenger cars* must meet a minimum standard of 27.5 mpg (8.6 lit/100km) -- the CAFE standard that has existed for passenger cars since model year 1985 -- or 92 percent of the projected fleet average CAFE value for all passenger cars in the associated model year, whichever is greater. Thus, if the projected CAFE value for model year 2015 passenger cars is 35.7 mpg (6.6 lit/100km), no manufacturer can be subject to a standard that is less than 32.84 mpg (7.16 lit/100km). *No equivalent backstops exist for either imported passenger cars or any light truck.*

The projected fleet average CAFE values as presented in the NHTSA NPRM and FEIS are summarized in Table 3. As indicated above, the projected CAFE standards for the FEIS are significantly less stringent than those of the NPRM. In fact, the projected FEIS standard for model year 2011 light trucks is actually less stringent than the already adopted standard for that same model year.[10] Although this differential and the reduced stringency of the FEIS standards are curious, the long term impacts are muted by the fact that regardless of the specific model year 2011 through 2015 standards, the fleet average fuel economy for model year 2020 is statutorily set at 35 mpg (6.72 lit/100km). Thus, a reduced stringency in model year 2011 through 2015 simply means that the standards for model years 2016 through 2020 will increase quicker under the FEIS proposal than the NPRM proposal. By model year 2020, both approaches should be of similar stringency.

Table 3. Projected CAFE Standards

Vehicle Model Year	CAFE Standards (mpg)				CAFE Standards (lit/100km)			
	Passenger Cars		LDT/MDPV		Passenger Cars		LDT/MDPV	
	NPRM	FEIS	NPRM	FEIS	NPRM	FEIS	NPRM	FEIS
2011	31.20	30.10	25.00	22.80	7.54	7.81	9.41	10.32
2012	32.80	31.90	26.40	24.40	7.17	7.37	8.91	9.64
2013	34.00	32.30	27.80	25.10	6.92	7.28	8.46	9.37
2014	34.80	32.90	28.20	25.30	6.76	7.15	8.34	9.30
2015	35.70	33.40	28.60	26.00	6.59	7.04	8.22	9.05

Standards for vehicle model years 2016 through 2020 are estimated based on compliance with the 2020 statutory target of 35 mpg (combined car and light truck fuel economy).

2016	36.44	34.66	29.19	26.98	6.46	6.79	8.06	8.72
2017	37.19	35.97	29.79	28.00	6.33	6.54	7.90	8.40
2018	37.95	37.32	30.40	29.05	6.20	6.30	7.74	8.10
2019	38.73	38.73	31.03	30.15	6.07	6.07	7.58	7.80
2020+	39.53	40.19	31.67	31.28	5.95	5.85	7.43	7.52

Notes: (1) LDT means light duty trucks (trucks with a gross vehicle weight less than or equal to 8,500 pounds (3,855.6 kg)

(2) MDPV means medium duty passenger vehicle (vehicles with a gross vehicle weight greater than 8,500 pounds (3,855.6 kg) but less than 10,000 pounds (4,536.0 kg) that are designed primarily for the transportation of people).

(3) The model year 2016 through 2020 standards assume a constant annual increase in both car and light duty truck standards after model year 2015 as required to meet a combined (car and light duty truck) fuel economy target of 35 mpg in model year 2020.

---

[10] See U.S. Department of Transportation, National Highway Traffic Safety Administration, "Average Fuel Economy Standards for Light Trucks Model Years 2008-2011," Final Rule, Federal Register, 71FR17566, April 6, 2006. In the preamble for this rule, NHTSA projects a fleet average fuel economy of 24.0 mpg in model year 2011. Of course, it is possible that NHTSA's projected fleet characteristics have changed since the 2006 adoption of this rule, but substituting the CAFE standard parameters for model year 2011 trucks as adopted under the rule into the CAFE standard footprint function and evaluating the function for the effective fleet average footprint implied by NHTSA's fuel economy projections from their recent proposed rulemaking for model years 2011 through 2015 results in an estimated fleet average fuel economy for light trucks of 23.5 mpg, still greater than the fleet average projection of 22.8 reported in the FEIS. In this context, "effective" fleet average footprint is the vehicle footprint that would result in a CAFE standard exactly equal to NHTSA's projected fleet average standard.

Under the approach employed in this analysis, there is some residual difference between the NPRM and FEIS approach to CAFE. This results from the fact that this analysis assumes that both passenger car and light duty truck standards increase by the same constant percentage after model year 2015 to produce a combined (projected) fleet average standard of 35 mpg (6.72 lit/100km) in model year 2020. Of course, the percentage differs between the NPRM (2.06 percent per year) and the FEIS (3.77 percent per year) since they start at different model year 2015 stringencies, but since the FEIS standards for model year 2015 are 6.4 percent less stringent for passenger cars versus 9.1 less stringent for light duty trucks, the model year 2020 standards for passenger cars and light duty trucks are not identical in the two approaches (see Table 3). Given that the mix of passenger cars and light duty trucks can vary, the NPRM and FEIS approaches are evaluated as CAFE alternatives in this analysis.

It is also important to note that other than the 35 mpg (6.72 lit/100km) target for model year 2020, there are currently no specific proposals for standards after model year 2015. This analysis assumes that the same approach employed for model year 2011-2015 standards will ultimately be employed to produce model year 2016 through 2020 standards. Thus, like the model year 2011-2015 standards, the model year 2016-2020 standards are assumed to vary with vehicle footprint. This analysis further assumes that, for baseline analysis purposes, the effective vehicle footprint will not change after model year 2015 (sensitivity analysis designed to evaluate the potential impact of changes in footprint on the relationship between CAFE and California GHG standard impacts is performed).

In this analysis, the term "effective" fleet average footprint is meant to indicate the vehicle footprint that would result in a CAFE standard exactly equal to NHTSA's projected fleet average standard. It is perhaps not obvious why such terminology need be adopted and employed, so a bit more in-depth discussion of NHTSA's most recent approach to CAFE might be helpful. The proposed CAFE standards for model years beginning in 2011 are based on the following constrained logistic curve function:

$$\text{CAFE Standard} = \frac{1}{\frac{1}{a} + \left(\frac{1}{b} - \frac{1}{a}\right)\left(\frac{e^{((FP-c)/d)}}{1 + e^{((FP-c)/d)}}\right)}$$

where: a, b, c, and d are curve parameters as defined in Table 4, and

FP is vehicle footprint in square feet (to the nearest tenth).

Table 4 presents the specific values for the function parameters. If this function is then evaluated for a range of vehicle footprints, the model year-specific curves presented in Figures 1 through 4 are derived. From these curves, it is obvious that the proposed approach to CAFE is such that the standard for any given vehicle varies in accordance with its footprint only over a limited range. Once a footprint reaches a certain minimum value, the CAFE standard reaches a

Table 4. Curve Structure for Proposed CAFE Standards

Model Year	Passenger Car Curve Parameter				Light Truck Curve Parameter			
	a	b	c	d	a	b	c	d
Proposed (MY11-MY15) and Estimated (MY16-MY20) NPRM CAFE Standard Curves								
2011	38.20	25.80	45.88	1.60	30.90	21.50	51.94	3.80
2012	40.00	27.40	45.79	1.54	32.70	22.80	51.98	3.82
2013	40.80	28.70	45.70	1.48	34.10	23.80	52.02	3.84
2014	41.20	29.90	45.61	1.42	34.10	24.30	52.06	3.86
2015	41.70	31.20	45.51	1.36	34.30	24.80	52.11	3.87
2016	42.5590	31.8427	45.51	1.36	35.0066	25.3109	52.11	3.87
2017	43.4357	32.4987	45.51	1.36	35.7277	25.8323	52.11	3.87
2018	44.3305	33.1682	45.51	1.36	36.4637	26.3644	52.11	3.87
2019	45.2437	33.8514	45.51	1.36	37.2149	26.9075	52.11	3.87
2020	46.1757	34.5488	45.51	1.36	37.9815	27.4618	52.11	3.87
Estimated (MY11-MY20) FEIS CAFE Standard Curves								
2011	36.8532	24.8904	45.88	1.60	28.1808	19.6080	51.94	3.80
2012	38.9024	26.6482	45.79	1.54	30.2227	21.0727	51.98	3.82
2013	38.7600	27.2650	45.70	1.48	30.7881	21.4885	52.02	3.84
2014	38.9506	28.2675	45.61	1.42	30.5933	21.8011	52.06	3.86
2015	39.0134	29.1899	45.51	1.36	31.1818	22.5455	52.11	3.87
2016	40.4843	30.2904	45.51	1.36	32.3574	23.3954	52.11	3.87
2017	42.0105	31.4323	45.51	1.36	33.5772	24.2774	52.11	3.87
2018	43.5943	32.6173	45.51	1.36	34.8431	25.1927	52.11	3.87
2019	45.2378	33.8470	45.51	1.36	36.1567	26.1424	52.11	3.87
2020	46.9433	35.1230	45.51	1.36	37.5198	27.1280	52.11	3.87

maximum and once a footprint reaches a certain maximum value, the CAFE standard reaches a minimum. Footprints below the effective minima and footprints above the effective maxima have no additional impact on the CAFE standard. Moreover, the rate of change of the CAFE standard with footprint (in the affected range of footprints) in not linear, but rather is greatest in the midrange between the effective minima and maxima. The net effect is that the fleet average CAFE standard can be quite different than the standard that would be implied if one evaluated the CAFE standard function for the fleet average footprint. Thus, this analysis utilizes the term "effective" fleet average footprint to account for the various nonlinearities of the CAFE function, with the effective fleet average footprint signifying the footprint which would evaluate to the projected fleet average CAFE value for any given vehicle type and model year.

This is especially important is considering the footprint sensitivity impacts discussed in this report. These impacts are associated with changes in the effective fleet average footprint, which can be quite different than changes in the actual fleet average footprint. As shown, CAFE is not sensitive to vehicles with footprints below the curve minima or above the curve maxima (except those in which a footprint change would move them above the minima or below the maxima) and the rate of CAFE change is not linear between these points, so a change in footprint is viewed in

Figure 1. NPRM CAFE Standard Curves for Passenger Cars (see note)

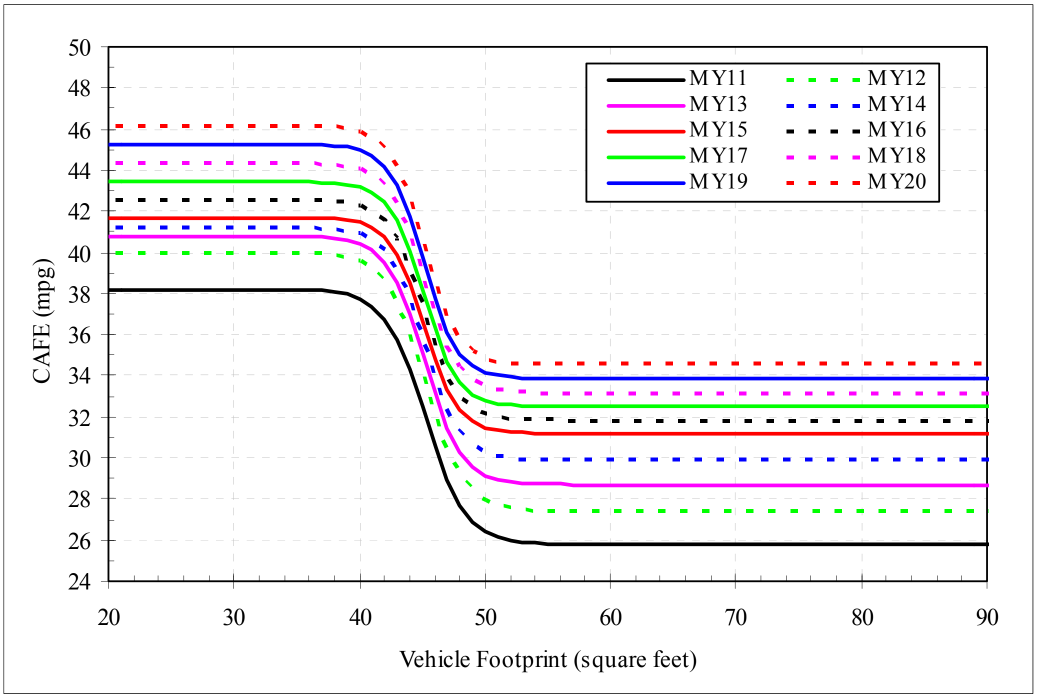
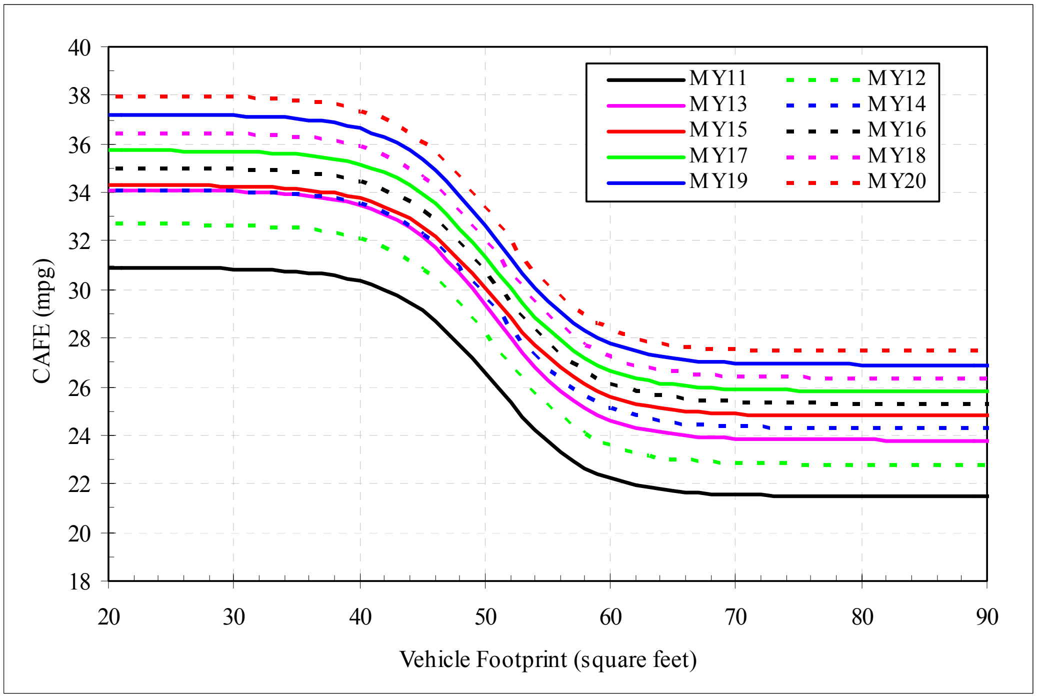


Figure 2. NPRM CAFE Standard Curves for Light Duty Trucks (see note)



Note: The NPRM provides curves for vehicle model years 2011-2015 only. The curves for MY16-MY20 are estimated from the MY15 curve and the constant annual increase required to attain a statutory target of 35 mpg by MY20 from the projected MY15 fleet average standard.

Figure 3. FEIS CAFE Standard Curves for Passenger Cars (see note)

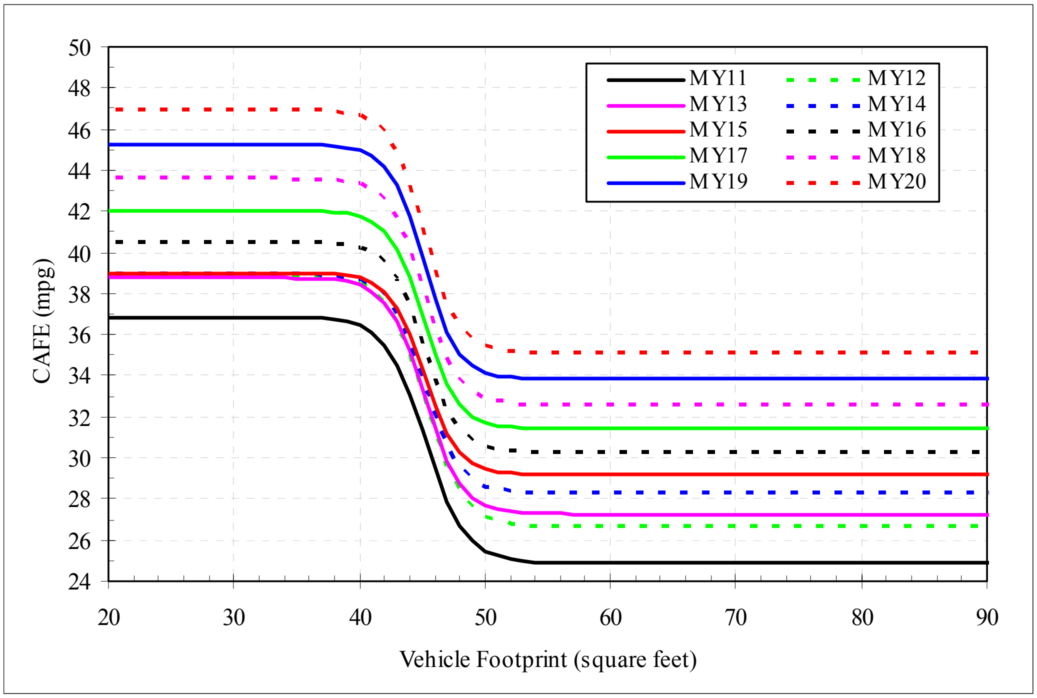
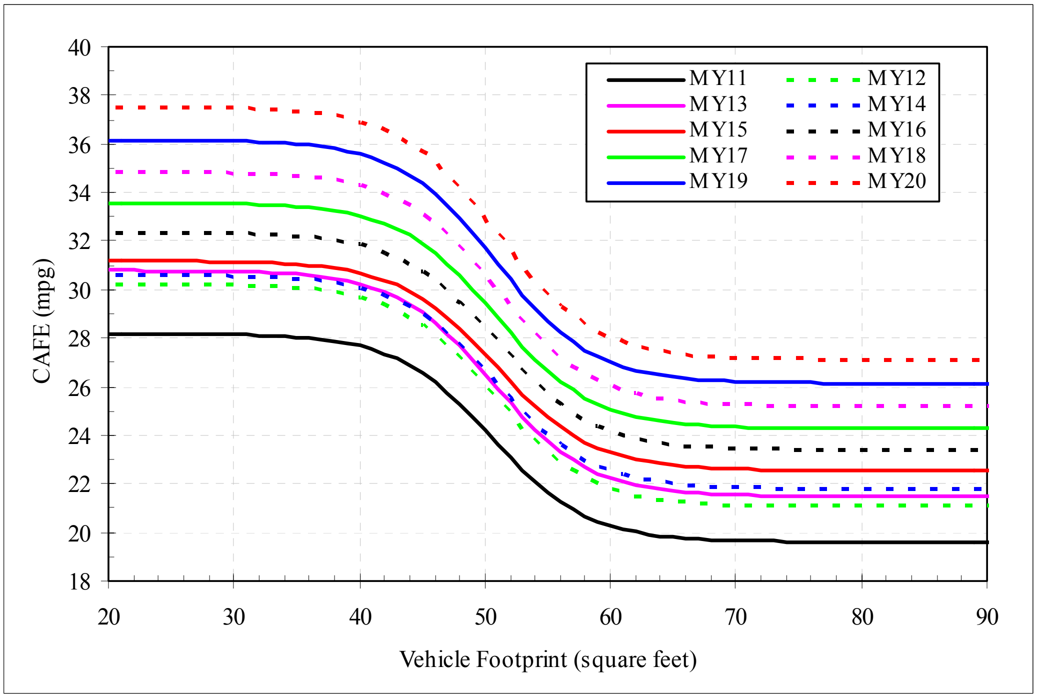


Figure 4. FEIS CAFE Standard Curves for Light Duty Trucks (see note)



Note: The FEIS does not provide curves. The MY11-MY15 curves are estimated by adjusting NPRM curves for the difference between FEIS and NPRM projected fleet average standards. The MY16-MY20 curves are estimated like those for the NPRM (see Figures 1 and 2).

the context of a change in demand for fuel economy, which translates to a change in effective, not necessarily actual, average vehicle footprint.

Finally, the data in Table 4 allow for a better understanding of how the model year 2016 through 2020 CAFE curves under the NPRM approach and the model year 2011 through 2020 CAFE curves under the FEIS approach were developed. First, curve parameters "c" and "d," which roughly equate to the footprint midpoint of the logistic curve and the rate of change of CAFE with footprint were left unchanged from the NHTSA values on which they were based. For the FEIS curves for model year 2011 through 2015, the base curves were the corresponding NPRM curves for the same model years. For the NPRM model year 2016 through 2020 curves, the base curve was the NPRM curve for model year 2015. Similarly, for the FEIS model year 2016 through 2020 curves, the base curve was the FEIS curve for model year 2015.

The parameters "a" (CAFE maxima) and "b" (CAFE minima) were adjusted as follows. The fractional change in fuel consumption for the projected fleet average fuel economy in the model year for which the curve was being developed (see Table 3) relative to that of the base year from which the curve was being developed (see Table 3) was calculated. This same fractional change was then applied to the minima and maxima fuel consumption parameters for the base year curve to develop corresponding minima and maxima fuel consumption parameters for the model year for which the curve was being developed. The values expressed to four decimal places in Table 4 depict the estimated values of the developed curve parameters, and the complete curves are depicted in Figures 1 through 4 above.

Ultimately, this analysis estimates the GHG emissions impacts of the proposed and estimated CAFE standards and compares these estimates to corresponding estimates developed for the California GHG emission standards. In addition, the sensitivity of these impact estimates to potential changes in fleet composition (both vehicle class and footprint) is also evaluated. ***The analysis assumes that Canadian CAFC standards will be of a stringency identical to that of the proposed and estimated U.S. CAFE standards.***

2.0 Analytical Approach

The basic approach employed to assess both CAFE/CAFC and California GHG standard impacts on emissions in British Columbia uses projected fuel sales as the fundamental parameter for developing GHG emissions estimates under baseline and alternative CAFE/CAFC and California GHG futures. For the baseline future, total fuel sales are allocated to specific vehicle classes and model years using baseline fuel consumption estimates from the MOBILE6.2 emission factor model in conjunction with fleet characterization data expressed as vehicle age distributions, diesel sales fractions, vehicle mileage accumulation rates, and vehicle class-specific vehicle kilometers of travel (VKT) fractions, each developed locally for British Columbia or derived from the MOBILE6.2 emission factor model. These same fleet characterization data in conjunction with the fuel consumption impacts estimated for the alternative CAFE/CAFC and California GHG standard futures are used to estimate the overall change in CO_2, CH_4 (methane), N_2O (nitrous oxide), air conditioning refrigerant, and total GHG emissions. Emission impacts consider the change in VKT due to changes in the cost of driving. Total vehicle sales are assumed to be unaffected by either the CAFE/CAFC or the California GHG program, but sensitivity analysis has been performed to estimate the impact of shifts in vehicle class-specific sales.

It is important to recognize that this approach fundamentally differs from an approach that relies more directly on a bottom-up model such as MOBILE6.2. Such bottom-up approaches rely on baseline fuel consumption and fleet characteristics to estimate GHG emissions per unit VKT (e.g., grams per mile, g/mi, or grams per kilometer, g/km) and then apply estimated VKT data to derive absolute GHG emissions. The weakness in this approach is that it substitutes relatively more uncertain *estimated* fuel consumption data for less uncertain *reported* fuel consumption data. For example, the bottom-up approach basically estimates GHG as follows:

$$\text{GHG} = \text{estimated fuel volume per VKT} \times \text{estimated VKT} \times \text{fuel carbon per unit fuel volume}$$

The potential problem is that estimated fuel volume per VKT (i.e., vehicle efficiency) times estimated VKT also produces an estimate for overall fuel consumption. Since data on overall fuel consumption is generally collected and reported, it is, for the most part, a *known* parameter (with some uncertainty of course). Adjustments are required when the bottom-up estimates are not consistent with the reported estimates, as is quite likely since estimating fuel consumption per VKT for all of the various vehicles that compose the subject fleet is fraught with uncertainty. The only effective options are to either alter estimated VKT or alter estimated fuel volume per VKT (vehicle efficiency). There are no other degrees of freedom. Analysts will be reluctant to alter estimated VKT since such estimates are used to derive non-GHG emission estimates for other emissions inventory purposes, so the only practical approach is to alter estimated fuel volume per VKT -- which then changes the relationship between baseline fuel consumption and scenario fuel consumption unless corresponding adjustments are applied to both. This can, of course, be accomplished, but it can also be easily avoided by giving primacy to total *reported* fuel consumption.

Under a reported fuel consumption approach, GHG estimates are generally produced as follows:

$$\text{GHG} = \text{reported total fuel volume} \times \text{fuel carbon per unit fuel volume}$$

Of course this vastly oversimplifies the estimation process since the reported fuel volume must be disaggregated into its component vehicle types and ages to accurately estimate the near term impacts of programs that alter fuel consumption.[11] Moreover, the fuel disaggregation process relies on the same fuel volume per VKT (vehicle efficiency) estimates used in the bottom-up approach. However, there is a key difference. Whereas the bottom-up approach requires the *explicit* adjustment of the fuel volume per VKT estimates to derive total GHG estimates that are consistent with total estimated VKT, the reported fuel consumption approach *inherently* assumes that any error in the fuel volume per VKT estimates is unbiased and spread consistently across

---

[11] This is due to the fact that the impacts of these programs must be phased-into the overall fleet through the sale of new, lower consumption, vehicles and the retirement of older, higher consumption, vehicles. Thus, the age distribution and rate of fleet turnover are critical elements for accurately determining impacts until such time as the entire fleet is replaced. Long term impacts can be assessed directly from total fuel sales (but they implicitly assume a complete fleet turnover).

the various estimates for each vehicle type and age. In effect, the *relative* fuel consumption estimates for the various types are unaffected by the error and the uncertain estimates can be used directly to disaggregate total fuel consumption into its component parts without error (or, more accurately, any additional error due to the fuel volume per VKT estimates). There is a degree of freedom not available in the bottom-up approach.[12]

Since it is expected that reported fuel sales are more accurate than fuel volume per VKT (vehicle efficiency) estimates and the other myriad fleet characterization estimates used to derive overall vehicle class and age-specific fuel consumption (as alluded to above), this analysis relies on reported fuel sales as its fundamental analysis parameter. It is expected that this approach will produce more accurate GHG emission estimates, but readers should use caution in comparing estimates from this analysis to estimates derived using alternative methods, such as a bottom-up MOBILE6.2 analysis.

British Columbia fuel sales data for calendar years 1993 through 2007, as obtained from Statistics Canada, were used as the basis for this analysis.[13] Through a monthly Road Motor Vehicle Survey, Statistics Canada obtains fuel sales statistics from provincial and territorial agencies responsible for administering motor fuel tax programs in Canada. These data are then published annually.

---

[12] Of course, one would expect overall vehicle fuel use and VKT estimates to be reasonably consistent regardless of the methodology employed in their development, so long as that methodology is technically correct and employed carefully. For validation purposes, light duty vehicle VKT estimates from the fuel use approach employed in this analysis were compared to those estimated for vehicles weighing less than 4.5 tonnes in British Columbia by Statistics Canada through their annual Canadian Vehicle Survey. The results for calendar years 2005 through 2007 are as follows (Statistics Canada data for 2008 were not available at the time of this analysis):

	This Analysis	Statistics Canada	Analysis to StatsCanada
2005	31,782	31,138	1.02
2006	31,992	29,730	1.08
2007	32,335	33,571	0.96

Clearly, the data are reasonably consistent, especially when the fact that the estimated decline in 2006 VKT for the Statistics Canada data occurs simultaneously with an estimated 8 percent increase in the vehicle population generating that VKT. Annual VKT per vehicle for the three year time series goes from 13,823 in 2005, to 12,218 in 2006, and back to 13,454 in 2007. In short, it appears that 2006 is an anomaly in the Statistics Canada data. It should also be recognized that the Statistics Canada estimates apply to vehicles up to 4.5 tonnes (9,920.1 pounds), while light duty vehicles are defined as vehicles up to 8,500 pounds (3.86 tonnes) in this analysis. While the overwhelming majority of vehicles under 4.5 tonnes are also under 3.86 tonnes, the differential should be recognized. Finally, it is important to understand that the Statistics Canada estimates are extrapolated from quarterly statistical surveys of vehicle owners. The Statistics Canada data can be found at:

Statistics Canada, “Canadian Vehicle Survey: Annual 2007,” Catalogue number 53-223-X, 2008,
Statistics Canada, “Canadian Vehicle Survey: Annual 2006,” Catalogue number 53-223-XIE, 2007, and
Statistics Canada, “Canadian Vehicle Survey: Annual 2005 (Revised),” Catalogue number 53-223-XIE, 2006.

[13] Statistics Canada, Table 405-0002, “Road motor vehicles, fuel sales, annual (litres × 1,000),” downloaded from http://cansim2.statcan.gc.ca/cgi-win/cnsmcgi.exe?Lang=E&CNSM-Fi=CII/CII_1-eng.htm on February 2, 2009.

To develop a baseline estimate of future fuel sales, it is necessary to employ estimated growth factors. Such factors can be developed on the basis of expected changes in fuel sales directly, or on the basis of expected changes in underlying vehicle efficiency and VKT. Since this analysis is focused on evaluating the potential GHG impacts of future alternative changes in vehicle efficiency, such changes must be explicitly considered and it is appropriate to forecast growth in terms of VKT (which can then be combined with forecasted changes in vehicle efficiency to estimate overall fuel use changes). For this analysis, three potential VKT growth options were evaluated as follows:

- Data on VKT estimates for the Lower Fraser Valley for 1980 through 2030 were obtained from Environment Canada. While these data cannot be used directly since they apply to a portion of British Columbia only, they can be used to derive expected growth data on a relative basis (i.e., percent change in VKT as opposed to absolute change in VKT). Growth factors through 2030 can be derived directly from the provided data. Estimated growth factors for 2031 through 2050 were developed through a regression analysis of the 2011 through 2030 data (data prior to 2011 exhibit significantly variable growth characteristics). While specific growth factors for any given year exhibit some variability, the annual average VKT growth rate for 2010-2050, as derived using this approach, is about 1.1 percent. Of the three options evaluated, this is the lowest imputed growth rate.

- The second option involves simply extrapolating the growth trends for the 1993 through 2007 fuel sales data into the future. To accurately undertake such an extrapolation, it is necessary to adjust the historic fuel sales data for underlying changes in annual average vehicle efficiency. This adjustment was performed using baseline class-specific vehicle efficiency data obtained from the MOBILE6.2 emission factor model, in conjunction with vehicle class-specific VKT fractions derived from the Environment Canada VKT data for the Lower Fraser Valley.[14] Here again, it is important to note that the VKT data are used on a relative, not absolute, basis (e.g., to derive the *fraction* of VKT accumulated by gasoline passenger cars, gasoline light trucks, etc.). Under this approach, the average annual change in VKT is estimated to be about 1.9 percent.

- The third option consisted of fuel consumption forecast data developed by Natural Resources Canada to produce the Canadian national energy forecast documented in *Canada's Energy Outlook: The Reference Case 2006* (CEO2006)[15] This forecast included estimates of British Columbia energy demand by transportation fuel type for forecast years 2005, 2010, 2015, and 2020 (as well as historic data for 1990, 1995, 2000, and 2004), along with assumed vehicle efficiency estimates for those same years. Correcting the energy demand estimates for changes in underlying vehicle efficiency allows an estimated annual VKT growth rate of about 2.4 percent to be developed.

---

[14] Although MOBILE6.2 is a U.S. model, the fact that the U.S. CAFE and Canadian CAFC programs are functionally equivalent allows its associated vehicle class-specific efficiency data to be used without adjustment for Canadian (and British Columbian) vehicles.

[15] Natural Resources Canada, "Canada's Energy Outlook: The Reference Case 2006," ISBN 0-662-43440-4, Catalogue Number M144-126/2006E-PDF, 2006.

The 2.4 percent growth estimate serves as the basis for the GHG estimates presented in this report. This option was selected for two primary reasons. First, the estimate is based directly on documented forecast data for British Columbia as opposed to a portion of British Columbia in the case of the Environment Canada data, and historic data extrapolation in the case of the 1993-2007 fuel use statistics (although the extrapolated growth rate is generally consistent with the CEO2006 growth rate). Second, the CEO2006 growth rate is consistent with an analysis of light duty vehicle registration data for British Columbia, which indicates that in the latest three year period, the population of such vehicles increased by 2.7, 2.8, and 2.6 percent per year (2005 to 2006, 2006 to 2007, and 2007 to 2008 respectively). It is, of course, also important to recognize that while absolute baseline emissions and the absolute emission reductions associated with the alternative CAFE/CAFC and California GHG futures are dependent on future growth in VKT (and fuel use), the relative differences between the two alternative futures is not. Nevertheless, a low growth future scenario was evaluated for sensitivity purposes and is included in the emissions impact results presented in this report.

Vehicle class-specific VKT fractions serve as a critical determinant in this analysis through two mechanisms. First, local VKT fractions are used to aggregate vehicle class-specific fuel efficiency values into aggregate efficiency estimates (e.g., passenger car fuel consumption and light truck fuel consumption are aggregated in accordance with their relative VKT shares). Such aggregation in conjunction with the estimated VKT growth rate allows for the estimation of overall future year fuel sales. Second, these overall fuel sales are then disaggregated into vehicle class-specific shares in accordance with VKT-weighted class-specific fuel consumption. The impacts of the alternative CAFE/CAFC and California GHG futures are then estimated by vehicle class and aggregated to derive overall impact estimates.

The vehicle class-specific VKT fractions used for this analysis are derived from the Environment Canada VKT data for the Lower Fraser Valley. These data are far superior to any other alternative data source available in that they have been independently developed for detailed British Columbia emissions modeling and are expressed at a level of resolution that requires virtually no additional disaggregation.[16] As indicated above, these data reflect only the Lower Fraser Valley portion of British Columbia, but they are used only in a relative sense, absolute VKT values from these data are not used in any portion of the analysis. VKT fractions for 2031 through 2050 were developed by adjusting the 2030 VKT fractions in accordance with the corresponding annual change in the default MOBILE6.2 VKT fractions.

The analysis includes a number of additional algorithms to apportion fuel use to individual model year vehicles within a specific vehicle class and estimate the rate at which these vehicles enter and exit the fleet. Such algorithms are critical in estimating the short run impacts that

---

[16] The sole exception is that it is necessary to disaggregate light duty diesel truck VKT fractions into their individual subclass components. The Environment Canada VKT data are based on 28 MOBILE6.2 vehicle classes, which combine light duty diesel truck subclasses 1 and 2 into a single class and light duty diesel truck subclasses 3 and 4 into a second single class. Since the California GHG standards for light duty truck subclass 1 are different than those for other light duty trucks, it is necessary to disaggregate the light duty diesel trucks classes. This is accomplished using the class-specific relationships for the corresponding light duty gasoline truck subclasses. The impacts of any error associated with this approach are undoubtedly minor due to the fact that the light duty diesel truck classes taken together comprise only about 0.5 percent of total VKT.

accrue immediately after the implementation of an alternative motor vehicle control since the impacts of that control take time to filter through the entire motor vehicle fleet. However, such algorithms have virtually no effect on long run impacts since a "pre-control" fleet of vehicles is eventually replaced in its entirely with a "post-control" fleet. Thus, while it is important to understand how the fleet turnover effects were modeled in this analysis, it is also important to recognize that such effects have no bearing on the full turnover impact estimates under either the CAFE/CAFC or California GHG alternative futures.

In emissions modeler jargon, there are three data elements necessary to model fleet turnover effects: registration age distributions, diesel sales fractions, and age-specific mileage accumulation rates. Registration age distributions describe the fraction of vehicles within a given vehicle class by age. Diesel sales fractions disaggregate these age components into their gasoline and diesel shares. Age-specific mileage accumulation rates define the differing usage rates of vehicles in within a class (average annual usage generally declines with age). Combined with the baseline vehicle fuel efficiency estimates for each vehicle class and model year, these data can be used to construct both calendar year-specific fuel consumption estimates for each vehicle class and a fleet turnover function that describes the impact an alternative model year fuel consumption estimate will have on the overall fleet. Evaluating this turnover function for the various CAFC/CAFC and California GHG standards defines the overall fleet impact by calendar year. While such data are critical for evaluating fleet turnover, it is also critical to recognize that registration age distributions, diesel sales fractions, and age-specific mileage accumulation rates are not used to estimate absolute fuel consumption or VKT, but rather to disaggregate independently estimated data into various underlying component vehicle shares.

For this analysis, generalized registration age distributions for light duty vehicles in British Columbia were developed from registration data records for 2005 through 2008. Since medium and heavy duty vehicles are not affected by either CAFE/CAFC or the California GHG standards as currently defined, MOBILE6.2 default registration age fractions were used for all non-light duty vehicle classes. Diesel sales fractions for light duty vehicles were similarly derived from British Columbia registration data for 2005 through 2008, while those for medium and heavy duty vehicles were taken from MOBILE6.2. In the absence of alternative reliable data and due to the fact that they are considered to be generally representative of the decline in vehicle usage rates with age, age-specific mileage accumulation rates for all vehicle classes were taken from MOBILE6.2.

Under a cooperative data sharing agreement with the Insurance Corporation of British Columbia (ICBC), the British Columbia Ministry of Environment provided historic registration data for each calendar quarter of 2005, 2006, 2007, and 2008. These data were analyzed to isolate light duty vehicles through a combination of body style and ICBC vehicle class information. Unfortunately, the ICBC registration process treats passenger cars and sport utility vehicles (SUVs) similarly, while passenger cars and SUVs are components of different vehicle classes from an emissions perspective. Through visual examination, it appeared that SUVs were registered with a "station wagon" body style. Since there are few actual station wagons marketed, all light duty vehicles with a "station wagon" body style were assumed to be SUVs. Light duty pickup trucks and vans were distinguishable through specific combinations of ICBC vehicle type and body style. Since gross vehicle weight (GVW) information is not reported for

SUVs, it was not possible to disaggregate light duty trucks into their component classes, but it was possible to develop overall distributions for passenger cars and all light duty trucks in the aggregate. Figures 5 and 6 depict the derived distributions.

As shown in Figures 5 and 6, both the passenger car and light truck distributions based on the ICBC data depict the effects of peaks and depressions in annual vehicle sales. While this is to be expected for historic data, it causes potential issues for future emissions estimation in that all historic peaks and depressions must ultimately work their way through the distributions as vehicles age and new sales "enter" the distributions. Since it is not reliably possible to forecast future deviations in vehicle sales, emissions forecasting typically relies on generalized registration age distributions (i.e., distributions with peaks and depressions "filtered" out), as depicted for the generalized MOBILE6.2 age distribution curves in Figures 5 and 6. To develop generalized curves for British Columbia, logistic curves were fit to the actual registration age data for years 2005 through 2008. Fit was optimized to maintain both a near unity slope between predicted and actual age fractions and good agreement (±5 percent) with the 50th and 95th percentile class-specific fleet ages implied by the British Columbia data. The generalized curves are presented in Figures 5 and 6 in prominent black font.

For light trucks, the 25th, 50th, 75th, and 95th percentile ages of the generalized age curves are all within ±5 percent of the ages implied by the actual British Columbia data since the distribution suffers from less variability than that for passenger cars. For passenger cars, the 25th and 75th percentile ages are respectively higher and lower than those of the actual British Columbia data since the generalized curve filters out the early model peaks and later model depressions of the British Columbia data. These generalized curves were used for all emissions estimation in this analysis.

Since LDT1[17] are generally utilized more like passenger cars than light duty trucks, the passenger car curve was used for both passenger car and LDT1 analysis. The similarity in passenger car and LDT1 functionality is symbolized quite nicely in Figure 5 by the similarity of the default MOBILE6.2 registration age fraction curves for the two vehicle classes (which are depicted for comparative purposes only). The overall light duty truck curve was used without change for all LDT2, LDT3, and LDT4 analysis. Here again, the distinction from LDT1 functionality is depicted nicely by the deviation in the respective default MOBILE6.2 age distribution curves in Figure 6 (which again are depicted for comparative purposes only).

Diesel sales fraction data were developed through the same ICBC data analysis used to develop the registration age distributions. The derived fractions are presented in graphic form in Figure 7.

---

[17] Light duty trucks (LDT) 1, 2, 3, and 4 are defined as follows. LDT1 are trucks with a gross vehicle weight (GVW) less than or equal to 6,000 pounds (2,721.6 kg) and a curb weight less than or equal to 3,450 pounds (1,564.9 kg). LDT2 are trucks with a GVW less than or equal to 6,000 pounds (2,721.6 kg) and a curb weight greater than 3,450 pounds (1,564.9 kg). LDT3 are trucks with a GVW greater than 6,000 pounds (2,721.6 kg) and less than or equal to 8,500 pounds (3,855.6 kg) and also with an adjusted loaded vehicle weight (ALVW) less than or equal to 5,750 pounds (2,608.2 kg). LDT4 are trucks with a GVW greater than 6,000 pounds (2,721.6 kg) and less than or equal to 8,500 pounds (3,855.6 kg) and also with an ALVW greater than 5,750 pounds (2,608.2 kg). ALVW is the average of a vehicle's curb weight plus 300 pounds (136.1 kg) and its GVW. These are standard definitions, but California often refers to LDT2, LDT3, and LDT4 in the aggregate as LDT2.

Figure 5. Registration Age Distributions for Passenger Cars

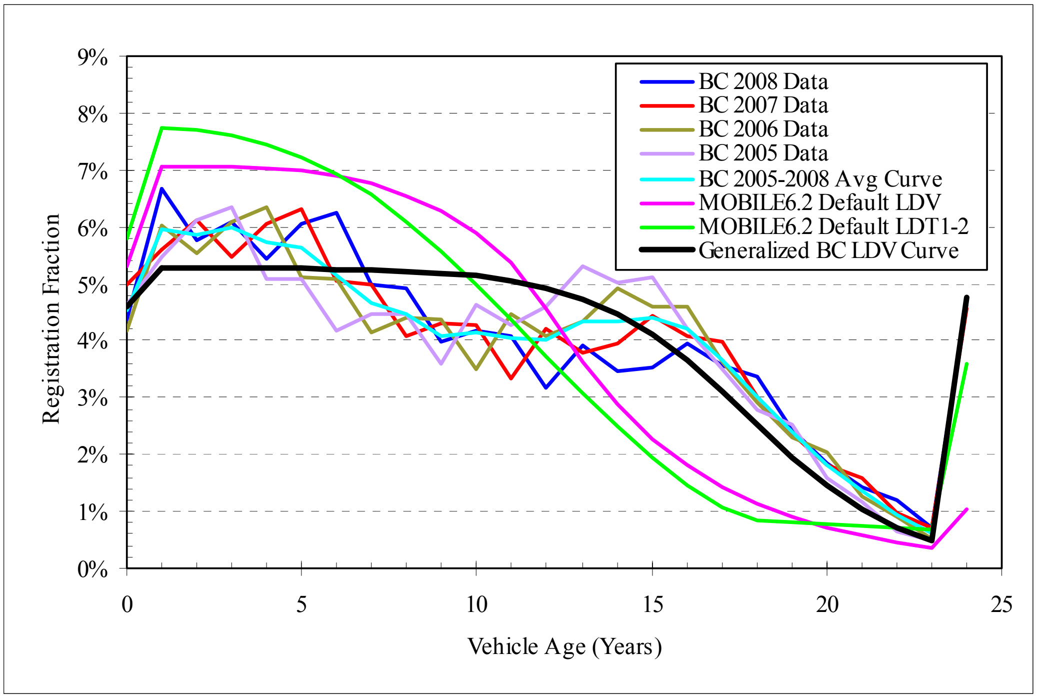


Figure 6. Registration Age Distributions for Light Duty Trucks

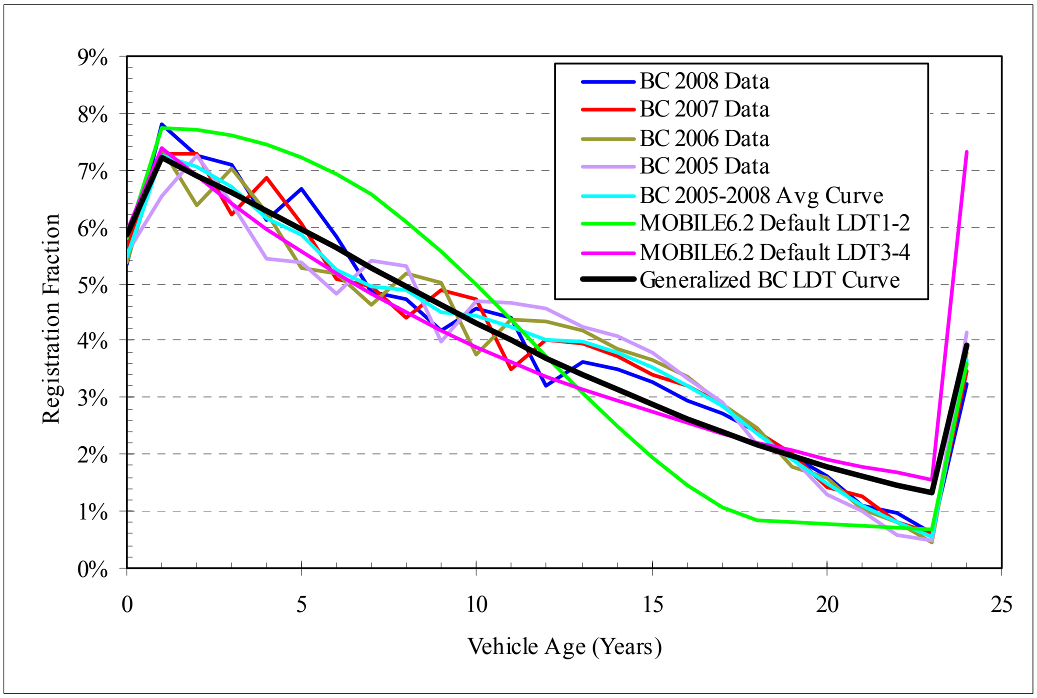
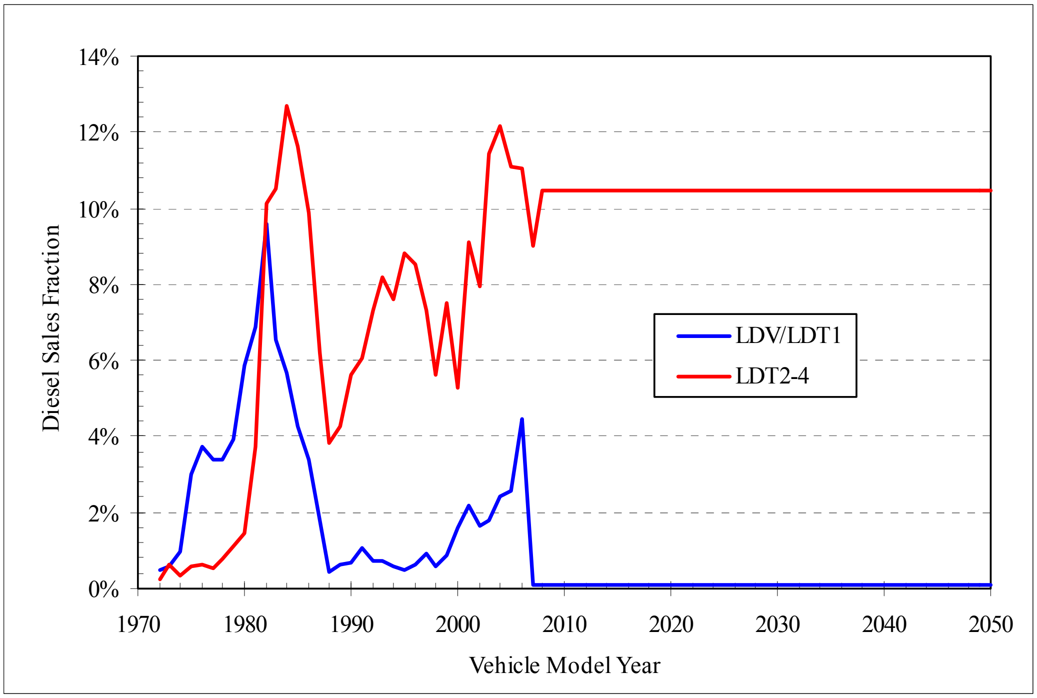


Figure 7. Diesel Sales Fractions



Here again, the fractions developed from the passenger car (also referred to as light duty vehicle, or LDV) data were used for both passenger car and LDT1 analysis, while the fractions developed for light duty trucks were used without change for all LDT2, LDT3, and LDT4 analysis.

All GHG impact estimates are expressed in terms of CO_2-equivalent (CO_2-eq) emissions. Readers wishing to compare the estimates to other impact estimates should also recognize that in this analysis, CO_2-equivalent is "as CO_2," not carbon. Carbon-specific impacts can be obtained by multiplying CO_2 impacts by 0.27 (or 12/44). CO_2-equivalent emissions include tailpipe CO_2, incremental tailpipe CO_2 due to air conditioning use (weighted by the load-adjusted fraction of VKT accumulated with the air conditioning activated), tailpipe methane (adjusted for global warming potential using a factor of 23), tailpipe N_2O (adjusted for global warming potential using a factor of 296), and released air conditioning refrigerant (adjusted for global warming potential using factors of 1,300 for HFC-134a, 120 for HFC-152a, and 4 for HFO-1234yf refrigerants, as applicable).

Air conditioning usage in British Columbia is estimated using data for Washington State in the U.S. as a surrogate. Data developed by the National Renewable Energy Laboratory in the U.S. estimates that air conditioning is utilized for 25 percent of VKT in Washington, as compared to

29 percent of VKT in California.[18] However, the average specific enthalpy of the ambient air during those operations in Washington is about 27 percent lower than average U.S. air conditioning operating conditions, as compared to about 17 percent lower than average in California. Thus, on a load-adjusted basis, California specific emission factors for air conditioning load are applied in British Columbia on the basis of air conditioning being utilized for only about 14.8 percent of total VKT (as compared to 29 percent in California).[19]

All baseline and alternative CAFE/CAFC and California GHG standard emission estimates are for light duty vehicles (passenger cars), light duty trucks, and medium duty passenger vehicles. Emissions from other medium duty vehicles, heavy duty vehicles and motorcycles are not reported as none are affected by either CAFE/CAFC or the California GHG standards. Since CAFE/CAFC requirements do not include testing of methane emissions, nitrous oxide emissions, air conditioning performance, or impose any restrictions on air conditioning refrigerant leakage, this analysis assumes no change in the emission rates of these GHG sources under the CAFE/CAFC program. Similarly, no change in either methane or nitrous oxide emissions is assumed for the California GHG standards, but it is assumed that both air conditioning load and refrigerant leakage rates are affected by the California program in response to specific GHG credits provided under the program. The specific emission rates for methane and N_2O, air conditioning efficiency impacts on emissions, and air conditioning refrigerant leakage rates assumed in this analysis are taken from the support documents for the California GHG standards. The same rates are applied under both the CAFE/CAFC and California GHG alternatives, as applicable.[20]

The analysis does consider the impact of "VKT rebound" on overall emissions impacts. The degree to which VKT will change in response to CAFE/CAFC or California GHG standards is uncertain. Most analyses, including this analysis, rely on an estimate of the elasticity of VKT with respect to the cost of driving to estimate the overall impacts on VKT. However, change in the cost of driving is only one aspect of the economic impacts of the CAFE/CAFC and California GHG standard programs. Such programs also affect vehicle purchase price, so that estimating vehicle usage impacts solely on the basis of changes in the variable cost of driving neglects (entirely) potential offsetting impacts of increased transportation expenditures associated with vehicle purchase. To the extent that these two price influences result in a net change in total transportation expenditures (under a constant VKT scenario) that is near zero, it is reasonable to expect an insignificant change in vehicle usage, and thus, an "effective" VKT elasticity that is also near zero. Of course, elasticity will diverge from zero (in either direction) as net savings (or costs) diverge from zero.

---

[18] See Johnson, V.H., National Renewable Energy Laboratory, "Fuel Used for Vehicle Air Conditioning: A State-by-State Thermal Comfort-Based Approach," 2002-01-1957, Society of Automotive Engineers, Inc., 2002 and Rugh, J. and Hovland, V., National Renewable Energy Laboratory, "National and World Fuel Savings and CO_2 Emission Reductions by Increasing Vehicle Air Conditioning COP," presented at the SAE Alternate Refrigerants Symposium, Phoenix, Arizona, July 15-17, 2003.

[19] The load adjustment is based on Figure D-4 in "Reducing Greenhouse Gas Emissions from Light-Duty Motor Vehicles," Northeast States Center for a Clean Air Future, September 2004.

[20] See California 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.

A literature review conducted for the U.S. Department of Energy, indicates the fuel price elasticity of VKT to be in the range of -0.1 to -0.2.[21] This same review indicated that the fuel *efficiency* elasticity of VKT could be much smaller, and may approach zero. Based on these data and the fact that variable operating costs impacts are but one aspect of the overall cost impacts of the CAFE/CAFC and California GHG standards programs, a best estimate for the "effective" VKT elasticity is likely to be in the range of 0.0 to -0.1. It is important to note that a "real world" opportunity to quantify the magnitude of VKT elasticity is provided by the fuel price increases observed between 2003 and the first half of 2008. During this period, fuel price increased by a factor of nearly three. An examination of U.S. VKT and fuel prices during this period indicates elasticity estimates of between -0.03 and -0.16, with an overall average of -0.10 -- estimates that are generally quite consistent with the cited literature estimates. Given these data, this analysis assumes a VKT elasticity estimate of -0.1.

Analysis impact estimates do *not* consider potential "upstream" emission reductions associated with reduced petroleum processing, etc. However, readers interested in considering the magnitude of such benefits can derive a rough estimate of incremental upstream benefits by multiplying analysis impacts by a factor of about 1.28. This factor is based on data presented in Appendix B of Argonne National Laboratory's "GREET 1.5 - Transportation Fuel-Cycle Model, Volume 1: Methodology, Development, Use, and Results" (August 1999) and Appendix B of Argonne National Laboratory's "GREET 1.5 - Transportation Fuel-Cycle Model, Volume 2: Appendices of Data and Results" (August 1999).

Similarly, criteria pollutant impacts due to CO_2 changes are also *not* estimated. While vehicle criteria pollutant emission standards are unchanged under either CAFE/CAFC or California GHG standards, changes in VKT can lead to proportional changes in vehicle criteria pollutant emissions, while reductions in fuel demand will lead to proportional reductions in upstream criteria pollutant emissions. The magnitude of the VKT-related impact is indicated by the change in vehicle VKT, a metric that is included in the tables presented in the results section of this report. The change in upstream emissions is indicated by the change in CO_2 emissions, such that emissions from fuel production and distribution would be expected to decline in proportion with CO_2 emissions. These two criteria pollutant impacts act in offsetting directions and the impact on CO_2 is much larger than the impact on VKT, so it is likely that any net effect will be small.

3.0 Analysis Results

As indicated in the introductory section of this report, there are design differences that complicate a direct comparison of the GHG emission benefits of the CAFE/CAFC and California GHG alternatives. Such differences include the fact that:

- The CAFE/CAFC standards regulate motor vehicle fuel consumption, reducing GHG emissions through the effect that changes in fuel consumption have on such emissions.

---

[21] See Greene, David L., "Why CAFE Worked," prepared for the U.S. Department of Energy, November 6, 1997.

In contrast, the California GHG standards regulate GHG directly. As a result, the CAFE/CAFC approach ensures a specific level of fuel consumption and an uncertain level of GHG control, while the California GHG standards ensure a specific level of GHG emissions and an uncertain level of fuel consumption.

- The CAFE/CAFC standards are dependent on the vehicle footprint characteristics of the affected fleet. If the footprint characteristics change, the effective CAFC/CAFC standard, and thus level of fuel consumption and associated GHG control, also changes.

- The CAFC/CAFC and California GHG standards vary by vehicle class, and the class definitions of the two programs are not consistent. The CAFE/CAFC program applies differential standards to passenger cars and light duty trucks. The California GHG program provides for a similar differential approach, but California includes LDT1 and passenger cars in a single class. This changes the distribution of vehicles subject to the differential standards and affects the *apparent* relative stringency of the two programs. For example, there are some years where the CAFE/CAFC standards for light duty trucks are *numerically* more stringent than the light duty truck standards of the California GHG program. However, such a comparison is not meaningful since some light duty trucks in California are subject to more stringent passenger car standards. The two programs can only be compared when a proper accounting of this differential class treatment is performed.

- The California GHG program allows vehicle manufacturers to determine whether to implement modifications to vehicle air conditioning technology to obtain certain specified GHG emission reduction credits. Whether manufacturers elect to implement such modifications determines the effective GHG emission limit for the non-air conditioning components of overall GHG emissions. Since the rate at which vehicle air conditioning is used varies in accordance with local climatology, vehicle manufacturer decision-making related to air conditioning can impact overall GHG emission reduction benefits for a given local area.

- The CAFE/CAFC program allows for alternative fueled vehicle (AFV) fuel consumption credits through vehicle model year 2019 (with the magnitude of allowable credits beginning to be phased out starting in model year 2014). The vehicle fleets of manufacturers choosing to take advantage of these credits will reflect a greater level of fuel consumption, and thus GHG emissions, than the CAFE/CAFC standards would otherwise imply. This net decline in CAFE/CAFC program effectiveness will linger until such vehicles are retired from the overall fleet.

- The CAFE/CAFC program is not yet fully defined (see Section 1). Standards for model years 2011 through 2015 have been proposed (denoted in this report as the NPRM standards), but not finalized. However, an environmental impact statement released in preparation for finalization of those proposed standards implied that the final standards (denoted in this report as the FEIS standards) would be significantly less stringent than those proposed. The decision to finalize the standards has been delayed due to the recent change in the U.S. presidential administration. Thus, the exact form of the CAFE/CAFC program is uncertain. This analysis has been conducted under the assumption that any interim CAFE/CAFC standards will ultimately demonstrate compliance with the statutorily required target of 35 mpg (6.7 lit/100km) for passenger cars and light trucks combined by vehicle model year 2020.

To measure the relative GHG emissions impact of the two alternative futures as accurately as possible, this analysis was performed (under the approach described in Section 2) to produce a reference case comparison as well as a number of sensitivity analysis comparisons designed to investigate the potential effect of the various program uncertainties.

3.1 The Reference Case Analysis Results

The reference case analysis makes the following assumptions relative to CAFE/CAFC and California GHG program uncertainties:

- The effective average footprint of the subject vehicle fleet is unchanged from baseline conditions, and baseline conditions are as defined by the proposed CAFE/CAFC standards.

- The fraction of manufacturers taking air conditioning load reduction credits under the California GHG program is 100 percent. While this may overstate such credits in the near term, it is likely that these credits will be fully utilized at some point due to the cost effectiveness of air conditioning improvements.

- The fraction of manufacturers taking air conditioning refrigerant leakage credits under the California GHG program is 100 percent. While this may overstate such credits in the near term, it is likely that these credits will be fully utilized at some point due to the cost effectiveness of air conditioning improvements.

- VKT is assumed to grow in accordance with the CEO2006 forecast for British Columbia.

- CAFE/CAFC standards for model years 2011 through 2015 are as defined in the CAFE/CAFC NPRM. Standards for model years 2016 through 2020 are developed under an assumption that passenger car and light duty truck standards increase by the same constant percentage annually to attain a combined 35 mpg (6.7 lit/100km) target in model year 2020.

- The fraction of manufacturers taking AFV credits under the CAFE/CAFC program is 100 percent. While this may overstate such credits in the near term, the effect over the long term is null in terms of annual reductions and minimal in terms of cumulative reductions since such credits are eliminated under the CAFE/CAFC program beginning in model year 2020.

Table 5 and Figures 8 through 10 depict the results of the reference case analysis. Under this analysis, the California GHG program outperforms the CAFE/CAFC program in terms of GHG emission reductions by a wide margin. By 2020, the California program reduces annual GHG

Table 5. Emissions Impact Estimates for the Reference Case Analysis

Calendar Year July 1 Fleet	Baseline LDV LDT MDPV GHG (Mt)	CAFE/ CAFC GHG (Mt)	CAFE/ CAFC GHG Reduced (Mt)	CAFE/ CAFC Percent GHG Change	CAFE/ CAFC Percent VKT Change	California Standards GHG (Mt)	California Standards GHG Reduced (Mt)	California Standards Percent GHG Change	California Standards Percent VKT Change	CAFE/ CAFC Cumulative GHG Reduced (Mt)	California Standards Cumulative GHG Reduced (Mt)
2005	9.63	9.63	0.00	0.0%	0.0%	9.63	0.00	0.0%	0.0%	0.00	0.00
2006	9.67	9.67	0.00	0.0%	0.0%	9.67	0.00	0.0%	0.0%	0.00	0.00
2007	9.75	9.75	0.00	0.0%	0.0%	9.75	0.00	0.0%	0.0%	0.00	0.00
2008	9.93	9.93	0.00	0.0%	0.0%	9.93	0.00	0.0%	0.0%	0.00	0.00
2009	10.10	10.10	0.00	0.0%	0.0%	10.10	0.00	0.0%	0.0%	0.00	0.00
2010	10.27	10.27	0.00	0.0%	0.0%	10.27	0.00	0.0%	0.0%	0.00	0.00
2011	10.44	10.42	0.02	-0.2%	+0.0%	10.39	0.05	-0.5%	+0.0%	0.02	0.05
2012	10.62	10.54	0.08	-0.7%	+0.1%	10.45	0.17	-1.6%	+0.2%	0.09	0.21
2013	10.80	10.63	0.17	-1.6%	+0.2%	10.49	0.31	-2.9%	+0.3%	0.27	0.52
2014	11.00	10.71	0.29	-2.7%	+0.3%	10.53	0.47	-4.3%	+0.4%	0.56	0.99
2015	11.20	10.78	0.43	-3.8%	+0.5%	10.56	0.64	-5.7%	+0.6%	0.99	1.64
2016	11.42	10.85	0.58	-5.1%	+0.6%	10.59	0.84	-7.3%	+0.7%	1.56	2.48
2017	11.65	10.90	0.75	-6.4%	+0.8%	10.58	1.07	-9.2%	+0.9%	2.31	3.55
2018	11.89	10.95	0.94	-7.9%	+0.9%	10.54	1.35	-11.4%	+1.1%	3.25	4.90
2019	12.14	10.99	1.14	-9.4%	+1.1%	10.48	1.66	-13.7%	+1.4%	4.40	6.56
2020	12.39	11.03	1.37	-11.0%	+1.3%	10.42	1.98	-15.9%	+1.6%	5.76	8.53
2021	12.66	11.07	1.59	-12.5%	+1.5%	10.37	2.29	-18.1%	+1.8%	7.35	10.82
2022	12.93	11.13	1.80	-13.9%	+1.6%	10.34	2.59	-20.0%	+2.0%	9.15	13.41
2023	13.21	11.21	2.00	-15.2%	+1.8%	10.33	2.88	-21.8%	+2.2%	11.15	16.29
2024	13.50	11.30	2.20	-16.3%	+1.9%	10.34	3.17	-23.4%	+2.4%	13.35	19.46
2025	13.80	11.41	2.39	-17.3%	+2.0%	10.36	3.44	-24.9%	+2.5%	15.74	22.90
2026	14.11	11.53	2.58	-18.3%	+2.1%	10.41	3.70	-26.2%	+2.7%	18.32	26.60
2027	14.43	11.67	2.76	-19.1%	+2.2%	10.48	3.95	-27.4%	+2.8%	21.08	30.56
2028	14.76	11.83	2.93	-19.8%	+2.3%	10.56	4.19	-28.4%	+2.9%	24.00	34.75
2029	15.09	12.01	3.09	-20.5%	+2.4%	10.67	4.42	-29.3%	+3.0%	27.09	39.17
2030	15.44	12.20	3.24	-21.0%	+2.4%	10.80	4.63	-30.0%	+3.1%	30.33	43.80
2031	15.79	12.39	3.40	-21.5%	+2.5%	10.94	4.85	-30.7%	+3.1%	33.72	48.65
2032	16.15	12.61	3.53	-21.9%	+2.5%	11.11	5.04	-31.2%	+3.2%	37.26	53.70
2033	16.52	12.85	3.67	-22.2%	+2.6%	11.29	5.23	-31.7%	+3.2%	40.92	58.93
2034	16.90	13.10	3.79	-22.5%	+2.6%	11.49	5.41	-32.0%	+3.3%	44.72	64.33
2035	17.29	13.36	3.93	-22.7%	+2.6%	11.69	5.60	-32.4%	+3.3%	48.65	69.93
2036	17.69	13.63	4.06	-22.9%	+2.7%	11.90	5.78	-32.7%	+3.3%	52.70	75.71
2037	18.10	13.92	4.18	-23.1%	+2.7%	12.15	5.95	-32.9%	+3.4%	56.88	81.66
2038	18.51	14.22	4.29	-23.2%	+2.7%	12.41	6.11	-33.0%	+3.4%	61.17	87.77
2039	18.94	14.54	4.41	-23.3%	+2.7%	12.67	6.27	-33.1%	+3.4%	65.58	94.04
2040	19.38	14.86	4.52	-23.3%	+2.7%	12.95	6.43	-33.2%	+3.4%	70.10	100.47
2041	19.83	15.19	4.64	-23.4%	+2.7%	13.23	6.60	-33.3%	+3.4%	74.74	107.07
2042	20.29	15.54	4.75	-23.4%	+2.7%	13.52	6.77	-33.3%	+3.4%	79.49	113.83
2043	20.76	15.89	4.87	-23.5%	+2.7%	13.83	6.93	-33.4%	+3.4%	84.36	120.76
2044	21.24	16.25	4.99	-23.5%	+2.7%	14.14	7.09	-33.4%	+3.4%	89.35	127.86
2045	21.73	16.63	5.10	-23.5%	+2.7%	14.47	7.26	-33.4%	+3.4%	94.45	135.12
2046	22.23	17.01	5.22	-23.5%	+2.7%	14.81	7.43	-33.4%	+3.4%	99.68	142.54
2047	22.75	17.41	5.34	-23.5%	+2.7%	15.15	7.60	-33.4%	+3.4%	105.02	150.14
2048	23.28	17.81	5.47	-23.5%	+2.7%	15.50	7.77	-33.4%	+3.4%	110.49	157.92
2049	23.81	18.22	5.59	-23.5%	+2.7%	15.86	7.95	-33.4%	+3.4%	116.08	165.87
2050	24.37	18.64	5.72	-23.5%	+2.7%	16.23	8.14	-33.4%	+3.4%	121.80	174.01

Figure 8. Reference Case Emissions

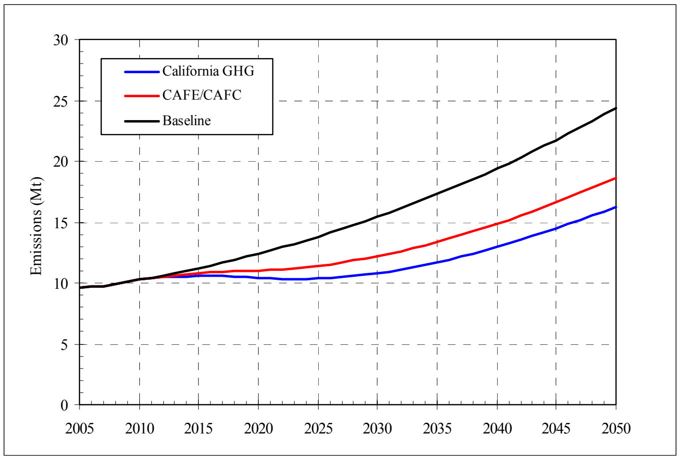


Figure 9. Reference Case Emission Reductions

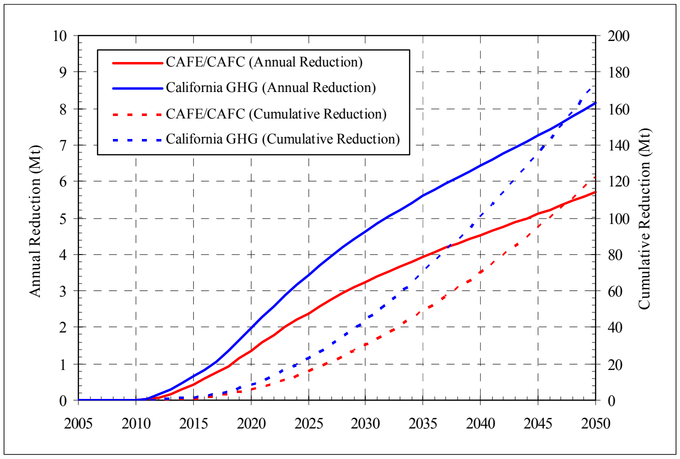
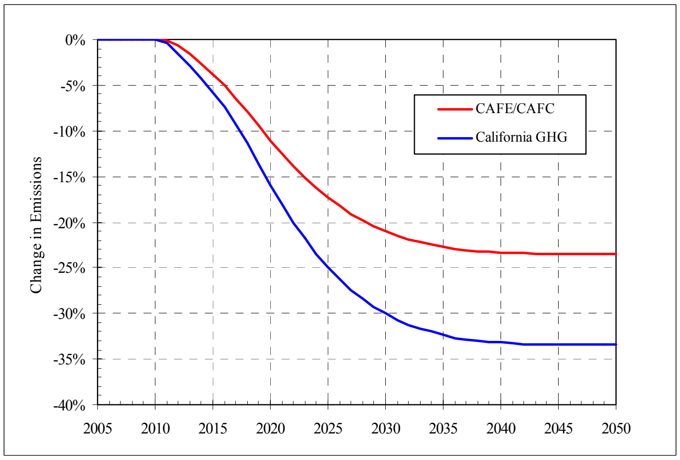


Figure 10. Reference Case Emissions Change



emissions from light duty vehicles by 15.9 percent as compared to 11.0 percent for the CAFE/CAFC program. Year 2050 emissions, which reflect the long term stabilization of both programs, reflect annual reductions of 33.4 percent under the California program as compared to 23.5 percent under CAFE/CAFC. In effect, the California program produces annual reductions that are over 40 percent higher than those of the CAFE/CAFC program. In terms of cumulative reductions, the California program will have eliminated 174 megatonnes (Mt) of GHG by 2050, as compared to 122 Mt for the CAFE/CAFC program.

3.2 The No AFV Credit Sensitivity Analysis Results

The "no AFV credit" sensitivity analysis makes the following assumptions relative to CAFE/CAFC and California GHG program uncertainties:

- The effective average footprint of the subject vehicle fleet is unchanged from baseline conditions, and baseline conditions are as defined by the proposed CAFE/CAFC standards. *(Same as reference case.)*

- The fraction of manufacturers taking air conditioning load reduction credits under the California GHG program is 100 percent. While this may overstate such credits in the near term, it is likely that these credits will be fully utilized at some point due to the cost effectiveness of air conditioning improvements. *(Same as reference case.)*

- The fraction of manufacturers taking air conditioning refrigerant leakage credits under the California GHG program is 100 percent. While this may overstate such credits in the near term, it is likely that these credits will be fully utilized at some point due to the cost effectiveness of air conditioning improvements. *(Same as reference case.)*

- VKT is assumed to grow in accordance with the CEO2006 forecast for British Columbia. *(Same as reference case.)*

- CAFE/CAFC standards for model years 2011 through 2015 are as defined in the CAFE/CAFC NPRM. Standards for model years 2016 through 2020 are developed under an assumption that passenger car and light duty truck standards increase by the same constant percentage annually to attain a combined 35 mpg (6.7 lit/100km) target in model year 2020. *(Same as reference case.)*

- The fraction of manufacturers taking AFV credits under the CAFE/CAFC program is zero percent. *(Reference case assumed 100 percent.)*

Table 6 and Figures 11 through 13 depict the results of the "no AFV credit" sensitivity analysis. Under this analysis, the California GHG program continues to outperform the CAFE/CAFC program in terms of GHG emission reductions by a wide margin. By 2020, the California program reduces annual GHG emissions from light duty vehicles by 16.0 percent as compared to

Table 6. Emissions Impact Estimates for the No AFV Credit Sensitivity Analysis

Calendar Year July 1 Fleet	Baseline LDV LDT MDPV GHG (Mt)	CAFE/ CAFC GHG (Mt)	CAFE/ CAFC GHG Reduced (Mt)	CAFE/ CAFC Percent GHG Change	CAFE/ CAFC Percent VKT Change	California Standards GHG (Mt)	California Standards GHG Reduced (Mt)	California Standards Percent GHG Change	California Standards Percent VKT Change	CAFE/ CAFC Cumulative GHG Reduced (Mt)	California Standards Cumulative GHG Reduced (Mt)
2005	9.63	9.63	0.00	0.0%	0.0%	9.63	0.00	0.0%	0.0%	0.00	0.00
2006	9.67	9.67	0.00	0.0%	0.0%	9.67	0.00	0.0%	0.0%	0.00	0.00
2007	9.75	9.75	0.00	0.0%	0.0%	9.75	0.00	0.0%	0.0%	0.00	0.00
2008	9.93	9.93	0.00	0.0%	0.0%	9.93	0.00	0.0%	0.0%	0.00	0.00
2009	10.10	10.10	0.00	0.0%	0.0%	10.10	0.00	0.0%	0.0%	0.00	0.00
2010	10.27	10.27	0.00	0.0%	0.0%	10.27	0.00	0.0%	0.0%	0.00	0.00
2011	10.44	10.39	0.05	-0.5%	+0.1%	10.39	0.05	-0.5%	+0.0%	0.05	0.05
2012	10.62	10.47	0.14	-1.3%	+0.2%	10.45	0.17	-1.6%	+0.2%	0.19	0.22
2013	10.80	10.53	0.27	-2.5%	+0.3%	10.49	0.31	-2.9%	+0.3%	0.46	0.53
2014	11.00	10.58	0.42	-3.8%	+0.4%	10.53	0.47	-4.3%	+0.4%	0.88	1.00
2015	11.20	10.63	0.57	-5.1%	+0.6%	10.56	0.65	-5.8%	+0.6%	1.45	1.65
2016	11.42	10.69	0.74	-6.4%	+0.8%	10.58	0.84	-7.4%	+0.7%	2.19	2.49
2017	11.65	10.74	0.91	-7.8%	+0.9%	10.58	1.07	-9.2%	+0.9%	3.10	3.57
2018	11.89	10.79	1.10	-9.3%	+1.1%	10.54	1.35	-11.4%	+1.1%	4.20	4.92
2019	12.14	10.83	1.30	-10.7%	+1.3%	10.48	1.66	-13.7%	+1.4%	5.51	6.58
2020	12.39	10.88	1.52	-12.2%	+1.4%	10.41	1.98	-16.0%	+1.6%	7.02	8.56
2021	12.66	10.93	1.72	-13.6%	+1.6%	10.37	2.29	-18.1%	+1.8%	8.75	10.85
2022	12.93	11.00	1.93	-14.9%	+1.7%	10.34	2.59	-20.1%	+2.0%	10.67	13.44
2023	13.21	11.09	2.12	-16.0%	+1.9%	10.33	2.89	-21.8%	+2.2%	12.79	16.33
2024	13.50	11.19	2.31	-17.1%	+2.0%	10.34	3.17	-23.5%	+2.4%	15.10	19.50
2025	13.80	11.31	2.49	-18.1%	+2.1%	10.36	3.44	-24.9%	+2.5%	17.59	22.94
2026	14.11	11.44	2.67	-18.9%	+2.2%	10.41	3.70	-26.2%	+2.7%	20.26	26.64
2027	14.43	11.59	2.84	-19.7%	+2.3%	10.47	3.96	-27.4%	+2.8%	23.10	30.60
2028	14.76	11.76	3.00	-20.3%	+2.4%	10.56	4.19	-28.4%	+2.9%	26.10	34.79
2029	15.09	11.94	3.15	-20.9%	+2.4%	10.67	4.42	-29.3%	+3.0%	29.25	39.22
2030	15.44	12.15	3.29	-21.3%	+2.5%	10.80	4.63	-30.0%	+3.1%	32.54	43.85
2031	15.79	12.35	3.44	-21.8%	+2.5%	10.94	4.85	-30.7%	+3.1%	35.98	48.70
2032	16.15	12.58	3.57	-22.1%	+2.6%	11.11	5.04	-31.2%	+3.2%	39.56	53.74
2033	16.52	12.82	3.70	-22.4%	+2.6%	11.29	5.23	-31.7%	+3.2%	43.25	58.97
2034	16.90	13.08	3.82	-22.6%	+2.6%	11.49	5.41	-32.0%	+3.3%	47.07	64.38
2035	17.29	13.33	3.96	-22.9%	+2.7%	11.69	5.60	-32.4%	+3.3%	51.03	69.98
2036	17.69	13.61	4.08	-23.1%	+2.7%	11.90	5.78	-32.7%	+3.3%	55.11	75.76
2037	18.10	13.90	4.19	-23.2%	+2.7%	12.15	5.95	-32.9%	+3.4%	59.30	81.71
2038	18.51	14.21	4.31	-23.3%	+2.7%	12.41	6.11	-33.0%	+3.4%	63.61	87.82
2039	18.94	14.52	4.42	-23.3%	+2.7%	12.67	6.27	-33.1%	+3.4%	68.03	94.09
2040	19.38	14.85	4.53	-23.4%	+2.7%	12.95	6.43	-33.2%	+3.4%	72.56	100.52
2041	19.83	15.19	4.64	-23.4%	+2.7%	13.23	6.60	-33.3%	+3.4%	77.20	107.12
2042	20.29	15.53	4.76	-23.4%	+2.7%	13.52	6.77	-33.3%	+3.4%	81.96	113.88
2043	20.76	15.89	4.87	-23.5%	+2.7%	13.83	6.93	-33.4%	+3.4%	86.83	120.81
2044	21.24	16.25	4.99	-23.5%	+2.7%	14.14	7.09	-33.4%	+3.4%	91.81	127.91
2045	21.73	16.63	5.10	-23.5%	+2.7%	14.47	7.26	-33.4%	+3.4%	96.92	135.17
2046	22.23	17.01	5.22	-23.5%	+2.7%	14.81	7.43	-33.4%	+3.4%	102.14	142.59
2047	22.75	17.41	5.34	-23.5%	+2.7%	15.15	7.60	-33.4%	+3.4%	107.48	150.19
2048	23.28	17.81	5.47	-23.5%	+2.7%	15.50	7.77	-33.4%	+3.4%	112.95	157.97
2049	23.81	18.22	5.59	-23.5%	+2.7%	15.86	7.95	-33.4%	+3.4%	118.54	165.92
2050	24.37	18.64	5.72	-23.5%	+2.7%	16.23	8.14	-33.4%	+3.4%	124.26	174.06

Figure 11. No AFV Credit Emissions

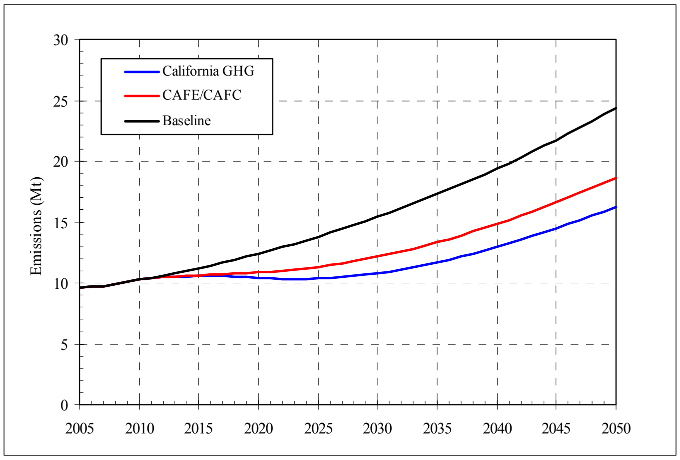


Figure 12. No AFV Credit Emission Reductions

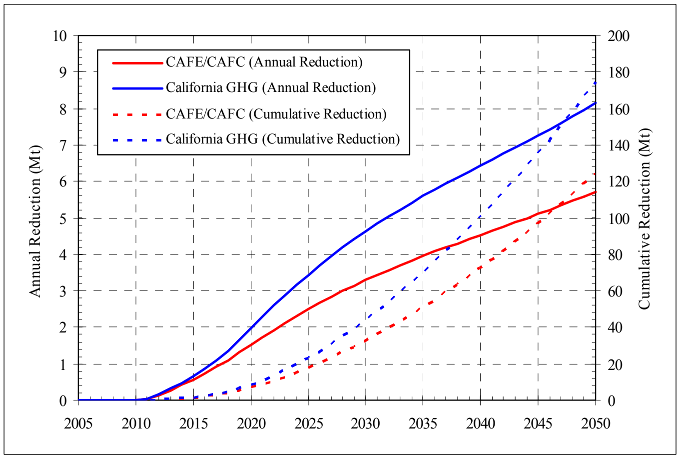
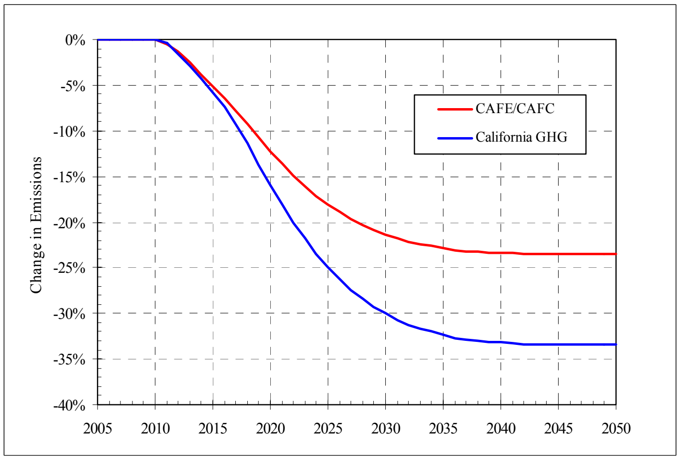


Figure 13. No AFV Credit Emissions Change



12.2 percent for the CAFE/CAFC program.[22] Year 2050 emissions, which reflect the long term stabilization of both programs, reflect annual reductions of 33.4 percent under the California program as compared to 23.5 percent under CAFE/CAFC (both unchanged from the reference case since all AFV credit vehicles have been retired from the fleet by 2050). In effect, the California program produces annual reductions that are over 40 percent higher than those of the CAFE/CAFC program. In terms of cumulative reductions, the California program will have eliminated 174 Mt of GHG by 2050, as compared to 124 Mt for the CAFE/CAFC program (i.e., the elimination of the AFV credits increases cumulative CAFE/CAFC program reductions by about 2.5 Mt by 2050).

3.3 The FEIS Sensitivity Analysis Results

The "FEIS" sensitivity analysis makes the following assumptions relative to CAFE/CAFC and California GHG program uncertainties:

- The effective average footprint of the subject vehicle fleet is unchanged from baseline conditions, and baseline conditions are as defined by the proposed CAFE/CAFC standards. *(Same as reference case.)*

- The fraction of manufacturers taking air conditioning load reduction credits under the California GHG program is 100 percent. While this may overstate such credits in the near term, it is likely that these credits will be fully utilized at some point due to the cost effectiveness of air conditioning improvements. *(Same as reference case.)*

- The fraction of manufacturers taking air conditioning refrigerant leakage credits under the California GHG program is 100 percent. While this may overstate such credits in the near term, it is likely that these credits will be fully utilized at some point due to the cost effectiveness of air conditioning improvements. *(Same as reference case.)*

- VKT is assumed to grow in accordance with the CEO2006 forecast for British Columbia. *(Same as reference case.)*

- CAFE/CAFC standards for model years 2011 through 2015 are as defined in the CAFE/CAFC FEIS. Standards for model years 2016 through 2020 are developed under an assumption that passenger cars and light duty truck standards increase by the same constant percentage annually to attain a combined 35 mpg (6.7 lit/100km) target in model year 2020. *(Reference case assumed NPRM standards in model years 2011 through 2015.)*

---

[22] The benefits for the California program increase slightly in the near term due to the fact that small and intermediate volume vehicle manufacturers are exempted from some elements of the California program during the years in which the CAFE/CAFC AFV credits are allowed. Since these manufacturers are subject to CAFE/CAFC during these years, their fuel consumption and GHG emissions decrease when the AFV credits are "removed," providing a small increase in the overall effectiveness of the California program (0.003 Mt in 2020).

- The fraction of manufacturers taking AFV credits under the CAFE/CAFC program is 100 percent. While this may overstate such credits in the near term, the effect over the long term is null in terms of annual reductions and minimal in terms of cumulative reductions since such credits are eliminated under the CAFE/CAFC program beginning in model year 2020. *(Same as reference case.)*

Table 7 and Figures 14 through 16 depict the results of the "FEIS" sensitivity analysis. Under this analysis, the California GHG program continues to outperform the CAFE/CAFC program in terms of GHG emission reductions by a wide margin. By 2020, the California program reduces annual GHG emissions from light duty vehicles by 15.9 percent as compared to 8.2 percent for the CAFE/CAFC program.[23] Year 2050 emissions, which reflect the long term stabilization of both programs, reflect annual reductions of 33.4 percent under the California program as compared to 23.4 percent under CAFE/CAFC.[24] In effect, the California program produces annual reductions that are over 40 percent higher than those of the CAFE/CAFC program. In terms of cumulative reductions, the California program will have eliminated nearly 174 Mt of GHG by 2050, as compared to 116 Mt for the CAFE/CAFC program (i.e., the substitution of FEIS standards for NPRM standards reduces cumulative CAFE/CAFC program reductions by about 6 Mt by 2050 due to less stringent standards in the model year 2011 through 2015 timeframe). It is also perhaps worth noting that the "FEIS" sensitivity analysis shows small negative CAFE/CAFC program benefits in the first years of the program. This results from the fact that the proposed FEIS light duty truck standard for vehicle model year 2011 is actually less stringent than the existing light duty truck standard for that same model year (which was adopted as part of the model year 2008-2011 light duty truck 2006 rulemaking process for CAFE/CAFC, and which is reflected in the baseline emission estimates for this analysis).

3.4 The No A/C Credits Sensitivity Analysis Results

The "no A/C credits" sensitivity analysis makes the following assumptions relative to CAFE/CAFC and California GHG program uncertainties:

- The effective average footprint of the subject vehicle fleet is unchanged from baseline conditions, and baseline conditions are as defined by the proposed CAFE/CAFC standards. *(Same as reference case.)*

---

[23] Here again, the benefits for the California program change slightly in the near term due to the fact that small and intermediate volume vehicle manufacturers are exempted from some elements of the California program during the years in which the FEIS (as opposed to the NPRM) CAFE/CAFC standards are in effect. Since these manufacturers are subject to CAFE/CAFC during these years, their fuel consumption and GHG emissions increase when the FEIS standards are assumed, providing a small decrease in the overall effectiveness of the California program (0.006 Mt in 2020). The increase is simply too small (in this case) to affect the percentage reduction expressed to one decimal place.

[24] The California program benefits are unchanged from the reference case since FEIS affected vehicles have been retired from the fleet by 2050. The CAFE/CAFC program benefits are slightly different (0.013 Mt) because the relationship between the CAFE/CAFC passenger car and light duty trucks standards is different in the FEIS than it is in the NPRM. This results in a situation where the combined car and light duty truck standard varies between the NPRM and FEIS (by a small amount) as changes in the makeup of the affected vehicle fleet occur over time.

Table 7. Emissions Impact Estimates for the FEIS Sensitivity Analysis

Calendar Year July 1 Fleet	Baseline LDV LDT MDPV GHG (Mt)	CAFE/ CAFC GHG (Mt)	CAFE/ CAFC GHG Reduced (Mt)	CAFE/ CAFC Percent GHG Change	CAFE/ CAFC Percent VKT Change	California Standards GHG (Mt)	California Standards GHG Reduced (Mt)	California Standards Percent GHG Change	California Standards Percent VKT Change	CAFE/ CAFC Cumulative GHG Reduced (Mt)	California Standards Cumulative GHG Reduced (Mt)
2005	9.63	9.63	0.00	0.0%	0.0%	9.63	0.00	0.0%	0.0%	0.00	0.00
2006	9.67	9.67	0.00	0.0%	0.0%	9.67	0.00	0.0%	0.0%	0.00	0.00
2007	9.75	9.75	0.00	0.0%	0.0%	9.75	0.00	0.0%	0.0%	0.00	0.00
2008	9.93	9.93	0.00	0.0%	0.0%	9.93	0.00	0.0%	0.0%	0.00	0.00
2009	10.10	10.10	0.00	0.0%	0.0%	10.10	0.00	0.0%	0.0%	0.00	0.00
2010	10.27	10.27	0.00	0.0%	0.0%	10.27	0.00	0.0%	0.0%	0.00	0.00
2011	10.44	10.48	-0.04	+0.4%	-0.0%	10.39	0.05	-0.4%	+0.0%	-0.04	0.05
2012	10.62	10.65	-0.04	+0.4%	-0.0%	10.45	0.16	-1.5%	+0.2%	-0.08	0.21
2013	10.80	10.81	-0.01	+0.1%	+0.0%	10.50	0.31	-2.8%	+0.3%	-0.08	0.52
2014	11.00	10.96	0.04	-0.4%	+0.1%	10.54	0.46	-4.2%	+0.4%	-0.04	0.98
2015	11.20	11.09	0.11	-1.0%	+0.2%	10.57	0.64	-5.7%	+0.6%	0.07	1.61
2016	11.42	11.20	0.22	-1.9%	+0.3%	10.59	0.83	-7.3%	+0.7%	0.29	2.45
2017	11.65	11.28	0.37	-3.2%	+0.4%	10.59	1.06	-9.1%	+0.9%	0.66	3.51
2018	11.89	11.34	0.55	-4.6%	+0.6%	10.55	1.34	-11.3%	+1.1%	1.21	4.85
2019	12.14	11.37	0.77	-6.3%	+0.8%	10.49	1.65	-13.6%	+1.4%	1.98	6.51
2020	12.39	11.38	1.01	-8.2%	+1.0%	10.42	1.97	-15.9%	+1.6%	2.99	8.48
2021	12.66	11.40	1.25	-9.9%	+1.2%	10.37	2.28	-18.0%	+1.8%	4.24	10.76
2022	12.93	11.44	1.49	-11.5%	+1.4%	10.34	2.59	-20.0%	+2.0%	5.73	13.34
2023	13.21	11.49	1.72	-13.0%	+1.5%	10.33	2.88	-21.8%	+2.2%	7.45	16.22
2024	13.50	11.56	1.94	-14.4%	+1.7%	10.34	3.16	-23.4%	+2.4%	9.39	19.39
2025	13.80	11.65	2.15	-15.6%	+1.8%	10.37	3.44	-24.9%	+2.5%	11.54	22.82
2026	14.11	11.75	2.36	-16.7%	+2.0%	10.41	3.70	-26.2%	+2.7%	13.90	26.52
2027	14.43	11.87	2.56	-17.7%	+2.1%	10.48	3.95	-27.4%	+2.8%	16.46	30.47
2028	14.76	12.01	2.75	-18.6%	+2.2%	10.57	4.19	-28.4%	+2.9%	19.20	34.66
2029	15.09	12.17	2.93	-19.4%	+2.3%	10.68	4.42	-29.3%	+3.0%	22.13	39.08
2030	15.44	12.34	3.10	-20.1%	+2.3%	10.81	4.63	-30.0%	+3.1%	25.23	43.71
2031	15.79	12.51	3.27	-20.7%	+2.4%	10.94	4.85	-30.7%	+3.1%	28.50	48.56
2032	16.15	12.72	3.43	-21.2%	+2.5%	11.11	5.04	-31.2%	+3.2%	31.93	53.60
2033	16.52	12.94	3.58	-21.7%	+2.5%	11.29	5.23	-31.6%	+3.2%	35.51	58.83
2034	16.90	13.18	3.72	-22.0%	+2.6%	11.49	5.40	-32.0%	+3.3%	39.23	64.23
2035	17.29	13.43	3.85	-22.3%	+2.6%	11.69	5.60	-32.4%	+3.3%	43.09	69.83
2036	17.69	13.69	4.00	-22.6%	+2.6%	11.91	5.78	-32.7%	+3.3%	47.08	75.61
2037	18.10	13.97	4.13	-22.8%	+2.7%	12.15	5.95	-32.9%	+3.4%	51.21	81.56
2038	18.51	14.27	4.25	-22.9%	+2.7%	12.41	6.11	-33.0%	+3.4%	55.46	87.67
2039	18.94	14.57	4.37	-23.1%	+2.7%	12.67	6.27	-33.1%	+3.4%	59.83	93.94
2040	19.38	14.89	4.49	-23.2%	+2.7%	12.95	6.43	-33.2%	+3.4%	64.32	100.37
2041	19.83	15.22	4.61	-23.3%	+2.7%	13.23	6.60	-33.3%	+3.4%	68.93	106.97
2042	20.29	15.55	4.73	-23.3%	+2.7%	13.52	6.77	-33.3%	+3.4%	73.67	113.73
2043	20.76	15.90	4.86	-23.4%	+2.7%	13.83	6.93	-33.4%	+3.4%	78.52	120.66
2044	21.24	16.26	4.98	-23.4%	+2.7%	14.14	7.09	-33.4%	+3.4%	83.50	127.76
2045	21.73	16.64	5.09	-23.4%	+2.7%	14.47	7.26	-33.4%	+3.4%	88.59	135.01
2046	22.23	17.02	5.21	-23.4%	+2.7%	14.81	7.43	-33.4%	+3.4%	93.80	142.44
2047	22.75	17.42	5.33	-23.4%	+2.7%	15.15	7.60	-33.4%	+3.4%	99.13	150.04
2048	23.28	17.82	5.45	-23.4%	+2.7%	15.50	7.77	-33.4%	+3.4%	104.59	157.82
2049	23.81	18.23	5.58	-23.4%	+2.7%	15.86	7.95	-33.4%	+3.4%	110.17	165.77
2050	24.37	18.66	5.71	-23.4%	+2.7%	16.23	8.14	-33.4%	+3.4%	115.88	173.91

Figure 14. FEIS Sensitivity Case Emissions

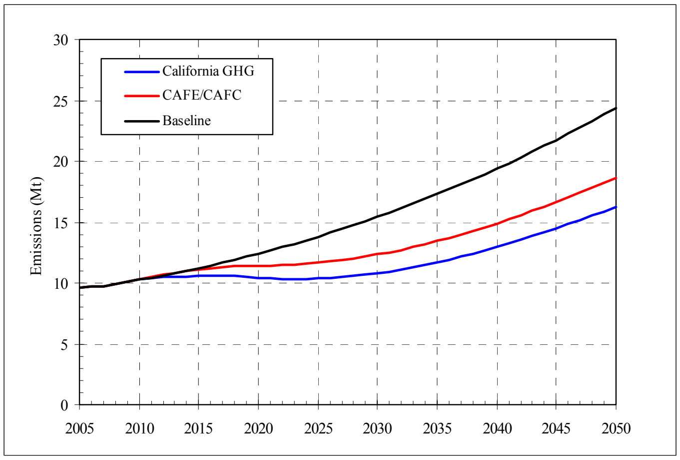


Figure 15. FEIS Sensitivity Emission Reductions

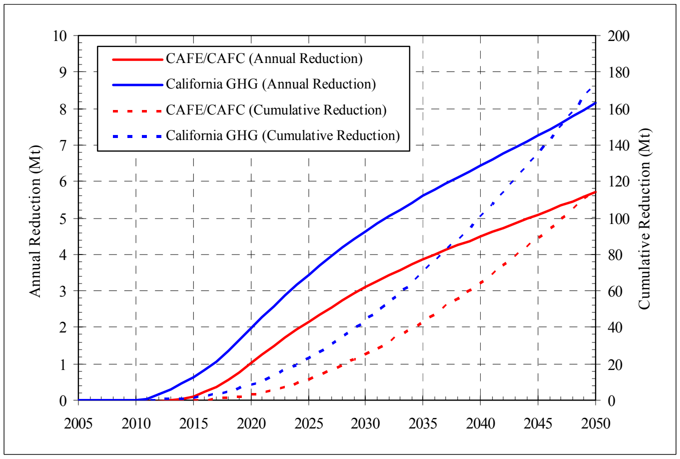
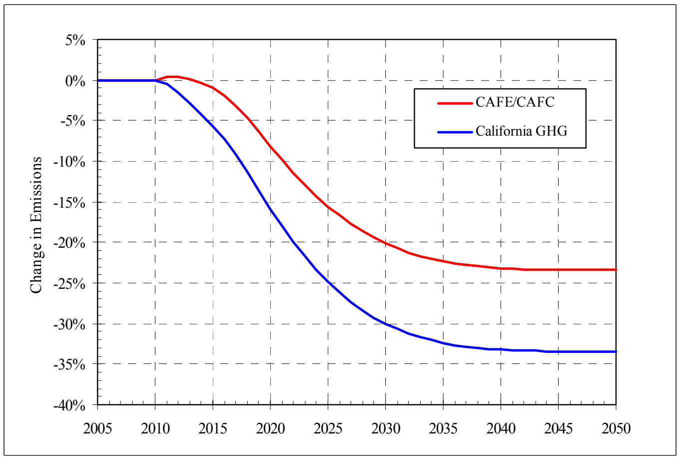


Figure 16. FEIS Sensitivity Emissions Change



- The fraction of manufacturers taking air conditioning load credits under the California GHG program is zero percent. *(Reference case assumed 100 percent.)*

- The fraction of manufacturers taking air conditioning refrigerant leakage credits under the California GHG program is zero percent. *(Reference case assumed 100 percent.)*

- VKT is assumed to grow in accordance with the CEO2006 forecast for British Columbia. *(Same as reference case.)*

- CAFE/CAFC standards for model years 2011 through 2015 are as defined in the CAFE/CAFC FEIS. Standards for model years 2016 through 2020 are developed under an assumption that passenger car and light duty truck standards increase by the same constant percentage annually to attain a combined 35 mpg (6.7 lit/100km) target in model year 2020. *(Same as reference case.)*

- The fraction of manufacturers taking AFV credits under the CAFE/CAFC program is 100 percent. While this may overstate such credits in the near term, the effect over the long term is null in terms of annual reductions and minimal in terms of cumulative reductions since such credits are eliminated under the CAFE/CAFC program beginning in model year 2020. *(Same as reference case.)*

Table 8 and Figures 17 through 19 depict the results of the "no A/C credits" sensitivity analysis. Under this analysis, the California GHG program continues to outperform the CAFE/CAFC program in terms of GHG emission reductions by a wide margin. By 2020, the California program reduces annual GHG emissions from light duty vehicles by 16.4 percent as compared to 11.0 percent for the CAFE/CAFC program.[25] Year 2050 emissions, which reflect the long term stabilization of both programs, reflect annual reductions of 34.2 percent under the California program as compared to 23.5 percent under CAFE/CAFC. In effect, the California program produces annual reductions that are over 45 percent higher than those of the CAFE/CAFC program. In terms of cumulative reductions, the California program will have eliminated 178 Mt of GHG by 2050, as compared to 122 Mt for the CAFE/CAFC program (i.e., cumulative California GHG program reductions in British Columbia increase by about 4.1 Mt by 2050 if manufacturers elect not to utilize air conditioning credits under the program).

---

[25] Emission reductions for the California program increase slightly due to the fact that the actual emission reductions associated with the air conditioning credits that vehicle manufacturers receive under the reference case are smaller than the credits would imply. This results from the fact that the credits are designed to account for air conditioning as it is used in California, which differs somewhat from the frequency of, and loading associated with, air conditioning usage in British Columbia. When manufacturers are assumed to not take advantage of the available air conditioning credits (as is the case in this sensitivity analysis), differences in California and British Columbia air conditioning usage characteristics no longer influence California program impacts.

Table 8. Emissions Impact Estimates for the California No A/C Credit Sensitivity Analysis

Calendar Year July 1 Fleet	Baseline LDV LDT MDPV GHG (Mt)	CAFE/ CAFC GHG (Mt)	CAFE/ CAFC GHG Reduced (Mt)	CAFE/ CAFC Percent GHG Change	CAFE/ CAFC Percent VKT Change	California Standards GHG (Mt)	California Standards GHG Reduced (Mt)	California Standards Percent GHG Change	California Standards Percent VKT Change	CAFE/ CAFC Cumulative GHG Reduced (Mt)	California Standards Cumulative GHG Reduced (Mt)
2005	9.63	9.63	0.00	0.0%	0.0%	9.63	0.00	0.0%	0.0%	0.00	0.00
2006	9.67	9.67	0.00	0.0%	0.0%	9.67	0.00	0.0%	0.0%	0.00	0.00
2007	9.75	9.75	0.00	0.0%	0.0%	9.75	0.00	0.0%	0.0%	0.00	0.00
2008	9.93	9.93	0.00	0.0%	0.0%	9.93	0.00	0.0%	0.0%	0.00	0.00
2009	10.10	10.10	0.00	0.0%	0.0%	10.10	0.00	0.0%	0.0%	0.00	0.00
2010	10.27	10.27	0.00	0.0%	0.0%	10.27	0.00	0.0%	0.0%	0.00	0.00
2011	10.44	10.42	0.02	-0.2%	+0.0%	10.39	0.05	-0.5%	+0.1%	0.02	0.05
2012	10.62	10.54	0.08	-0.7%	+0.1%	10.44	0.18	-1.7%	+0.2%	0.09	0.23
2013	10.80	10.63	0.17	-1.6%	+0.2%	10.47	0.33	-3.1%	+0.4%	0.27	0.56
2014	11.00	10.71	0.29	-2.7%	+0.3%	10.51	0.49	-4.5%	+0.5%	0.56	1.05
2015	11.20	10.78	0.43	-3.8%	+0.5%	10.53	0.67	-6.0%	+0.7%	0.99	1.72
2016	11.42	10.85	0.58	-5.1%	+0.6%	10.55	0.87	-7.6%	+0.9%	1.56	2.60
2017	11.65	10.90	0.75	-6.4%	+0.8%	10.54	1.11	-9.5%	+1.1%	2.31	3.71
2018	11.89	10.95	0.94	-7.9%	+0.9%	10.50	1.39	-11.7%	+1.4%	3.25	5.10
2019	12.14	10.99	1.14	-9.4%	+1.1%	10.43	1.71	-14.1%	+1.7%	4.40	6.81
2020	12.39	11.03	1.37	-11.0%	+1.3%	10.36	2.03	-16.4%	+1.9%	5.76	8.84
2021	12.66	11.07	1.59	-12.5%	+1.5%	10.31	2.35	-18.6%	+2.2%	7.35	11.19
2022	12.93	11.13	1.80	-13.9%	+1.6%	10.27	2.66	-20.6%	+2.4%	9.15	13.84
2023	13.21	11.21	2.00	-15.2%	+1.8%	10.26	2.96	-22.4%	+2.6%	11.15	16.80
2024	13.50	11.30	2.20	-16.3%	+1.9%	10.26	3.24	-24.0%	+2.8%	13.35	20.04
2025	13.80	11.41	2.39	-17.3%	+2.0%	10.28	3.52	-25.5%	+3.0%	15.74	23.56
2026	14.11	11.53	2.58	-18.3%	+2.1%	10.32	3.79	-26.9%	+3.1%	18.32	27.36
2027	14.43	11.67	2.76	-19.1%	+2.2%	10.38	4.05	-28.1%	+3.2%	21.08	31.40
2028	14.76	11.83	2.93	-19.8%	+2.3%	10.47	4.29	-29.1%	+3.4%	24.00	35.70
2029	15.09	12.01	3.09	-20.5%	+2.4%	10.57	4.52	-30.0%	+3.5%	27.09	40.22
2030	15.44	12.20	3.24	-21.0%	+2.4%	10.70	4.74	-30.7%	+3.5%	30.33	44.96
2031	15.79	12.39	3.40	-21.5%	+2.5%	10.83	4.96	-31.4%	+3.6%	33.72	49.92
2032	16.15	12.61	3.53	-21.9%	+2.5%	10.99	5.16	-31.9%	+3.7%	37.26	55.08
2033	16.52	12.85	3.67	-22.2%	+2.6%	11.17	5.35	-32.4%	+3.7%	40.92	60.43
2034	16.90	13.10	3.79	-22.5%	+2.6%	11.37	5.53	-32.7%	+3.8%	44.72	65.96
2035	17.29	13.36	3.93	-22.7%	+2.6%	11.56	5.73	-33.1%	+3.8%	48.65	71.68
2036	17.69	13.63	4.06	-22.9%	+2.7%	11.77	5.91	-33.4%	+3.8%	52.70	77.60
2037	18.10	13.92	4.18	-23.1%	+2.7%	12.01	6.08	-33.6%	+3.9%	56.88	83.68
2038	18.51	14.22	4.29	-23.2%	+2.7%	12.27	6.25	-33.7%	+3.9%	61.17	89.93
2039	18.94	14.54	4.41	-23.3%	+2.7%	12.53	6.41	-33.9%	+3.9%	65.58	96.34
2040	19.38	14.86	4.52	-23.3%	+2.7%	12.80	6.58	-33.9%	+3.9%	70.10	102.92
2041	19.83	15.19	4.64	-23.4%	+2.7%	13.08	6.75	-34.0%	+3.9%	74.74	109.67
2042	20.29	15.54	4.75	-23.4%	+2.7%	13.37	6.92	-34.1%	+3.9%	79.49	116.58
2043	20.76	15.89	4.87	-23.5%	+2.7%	13.67	7.09	-34.1%	+3.9%	84.36	123.67
2044	21.24	16.25	4.99	-23.5%	+2.7%	13.98	7.26	-34.2%	+3.9%	89.35	130.93
2045	21.73	16.63	5.10	-23.5%	+2.7%	14.31	7.42	-34.2%	+3.9%	94.45	138.35
2046	22.23	17.01	5.22	-23.5%	+2.7%	14.64	7.60	-34.2%	+3.9%	99.68	145.94
2047	22.75	17.41	5.34	-23.5%	+2.7%	14.98	7.77	-34.2%	+3.9%	105.02	153.72
2048	23.28	17.81	5.47	-23.5%	+2.7%	15.32	7.95	-34.2%	+3.9%	110.49	161.67
2049	23.81	18.22	5.59	-23.5%	+2.7%	15.68	8.14	-34.2%	+3.9%	116.08	169.80
2050	24.37	18.64	5.72	-23.5%	+2.7%	16.04	8.32	-34.2%	+3.9%	121.80	178.13

Figure 17. No A/C Credit Emissions

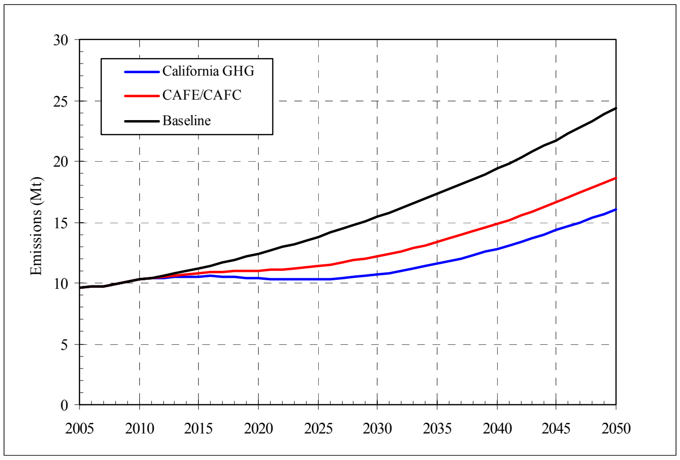


Figure 18. No A/C Credit Emission Reductions

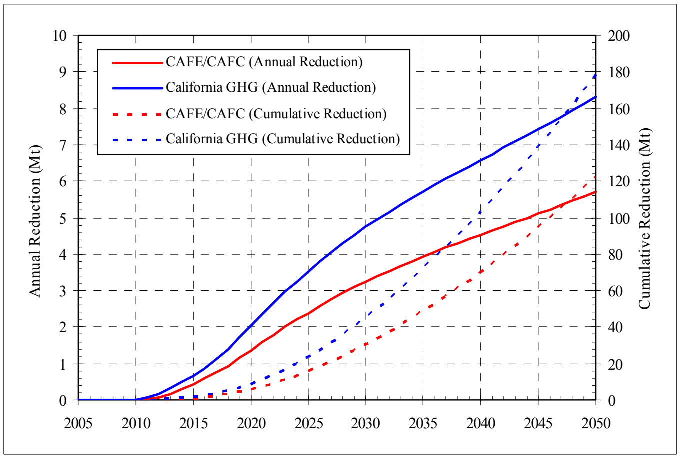
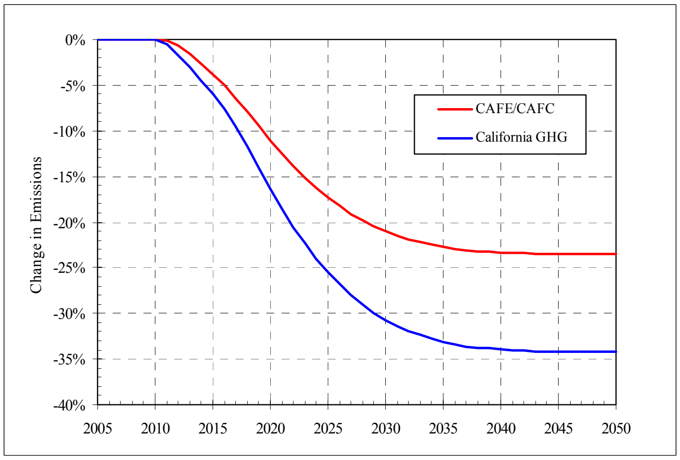


Figure 19. No A/C Credit Emissions Change



3.5 The Low Growth Sensitivity Analysis Results

The "low growth" sensitivity analysis makes the following assumptions relative to CAFE/CAFC and California GHG program uncertainties:

- The effective average footprint of the subject vehicle fleet is unchanged from baseline conditions, and baseline conditions are as defined by the proposed CAFE/CAFC standards. *(Same as reference case.)*
- The fraction of manufacturers taking air conditioning load reduction credits under the California GHG program is 100 percent. While this may overstate such credits in the near term, it is likely that these credits will be fully utilized at some point due to the cost effectiveness of air conditioning improvements. *(Same as reference case.)*
- The fraction of manufacturers taking air conditioning refrigerant leakage credits under the California GHG program is 100 percent. While this may overstate such credits in the near term, it is likely that these credits will be fully utilized at some point due to the cost effectiveness of air conditioning improvements. *(Same as reference case.)*
- VKT is assumed to grow in accordance with the growth rates implied by the Environment Canada VKT data for the Lower Fraser Valley portion British Columbia. *(The reference case VKT is assumed to grow in accordance with the CEO2006 forecast for British Columbia.)*
- CAFE/CAFC standards for model years 2011 through 2015 are as defined in the CAFE/CAFC NPRM. Standards for model years 2016 through 2020 are developed under an assumption that passenger cars and light duty truck standards increase by the same constant percentage annually to attain a combined 35 mpg (6.7 lit/100km) target in model year 2020. *(Same as reference case.)*
- The fraction of manufacturers taking AFV credits under the CAFE/CAFC program is 100 percent. While this may overstate such credits in the near term, the effect over the long term is null in terms of annual reductions and minimal in terms of cumulative reductions since such credits are eliminated under the CAFE/CAFC program beginning in model year 2020. *(Same as reference case.)*

Table 9 and Figures 20 through 22 depict the results of the "low growth" sensitivity analysis. As might be expected, the absolute emissions reductions under both programs decline (since baseline emissions growth declines), but the California GHG program continues to outperform the CAFE/CAFC program by a wide margin. By 2020, the California program reduces annual GHG emissions from light duty vehicles by 15.9 percent as compared to 11.0 percent for the CAFE/CAFC program (unchanged from the reference case, but measured from a lower emissions baseline). Similarly, 2050 emissions, which reflect the long term stabilization of both programs, continue to reflect annual reductions of 33.4 percent under the California program as compared to 23.5 percent under CAFE/CAFC. In effect, the California program still produces

Table 9. Emissions Impact Estimates for the Low Growth Sensitivity Analysis

Calendar Year July 1 Fleet	Baseline LDV LDT MDPV GHG (Mt)	CAFE/ CAFC GHG (Mt)	CAFE/ CAFC GHG Reduced (Mt)	CAFE/ CAFC Percent GHG Change	CAFE/ CAFC Percent VKT Change	California Standards GHG (Mt)	California Standards GHG Reduced (Mt)	California Standards Percent GHG Change	California Standards Percent VKT Change	CAFE/ CAFC Cumulative GHG Reduced (Mt)	California Standards Cumulative GHG Reduced (Mt)
2005	9.63	9.63	0.00	0.0%	0.0%	9.63	0.00	0.0%	0.0%	0.00	0.00
2006	9.67	9.67	0.00	0.0%	0.0%	9.67	0.00	0.0%	0.0%	0.00	0.00
2007	9.75	9.75	0.00	0.0%	0.0%	9.75	0.00	0.0%	0.0%	0.00	0.00
2008	9.90	9.90	0.00	0.0%	0.0%	9.90	0.00	0.0%	0.0%	0.00	0.00
2009	10.03	10.03	0.00	0.0%	0.0%	10.03	0.00	0.0%	0.0%	0.00	0.00
2010	10.15	10.15	0.00	0.0%	0.0%	10.15	0.00	0.0%	0.0%	0.00	0.00
2011	10.16	10.14	0.02	-0.2%	+0.0%	10.12	0.05	-0.5%	+0.0%	0.02	0.05
2012	10.18	10.10	0.07	-0.7%	+0.1%	10.02	0.16	-1.6%	+0.2%	0.09	0.20
2013	10.20	10.03	0.17	-1.6%	+0.2%	9.90	0.29	-2.9%	+0.3%	0.25	0.50
2014	10.22	9.95	0.27	-2.7%	+0.3%	9.79	0.44	-4.3%	+0.4%	0.53	0.93
2015	10.25	9.86	0.39	-3.8%	+0.5%	9.66	0.59	-5.7%	+0.6%	0.92	1.52
2016	10.31	9.79	0.52	-5.1%	+0.6%	9.56	0.76	-7.3%	+0.7%	1.44	2.28
2017	10.37	9.70	0.67	-6.4%	+0.8%	9.42	0.95	-9.2%	+0.9%	2.11	3.24
2018	10.44	9.61	0.82	-7.9%	+0.9%	9.25	1.19	-11.4%	+1.1%	2.93	4.42
2019	10.51	9.51	0.99	-9.4%	+1.1%	9.07	1.43	-13.7%	+1.4%	3.92	5.86
2020	10.58	9.41	1.17	-11.0%	+1.3%	8.89	1.69	-15.9%	+1.6%	5.09	7.54
2021	10.66	9.32	1.33	-12.5%	+1.5%	8.73	1.93	-18.1%	+1.8%	6.42	9.47
2022	10.75	9.25	1.49	-13.9%	+1.6%	8.59	2.15	-20.0%	+2.0%	7.91	11.62
2023	10.84	9.20	1.64	-15.2%	+1.8%	8.47	2.37	-21.8%	+2.2%	9.56	13.99
2024	10.93	9.15	1.78	-16.3%	+1.9%	8.37	2.56	-23.4%	+2.4%	11.34	16.55
2025	11.03	9.12	1.91	-17.3%	+2.0%	8.28	2.75	-24.9%	+2.5%	13.25	19.30
2026	11.13	9.09	2.03	-18.3%	+2.1%	8.21	2.92	-26.2%	+2.7%	15.28	22.22
2027	11.22	9.08	2.14	-19.1%	+2.2%	8.15	3.08	-27.4%	+2.8%	17.43	25.29
2028	11.32	9.08	2.24	-19.8%	+2.3%	8.11	3.22	-28.4%	+2.9%	19.67	28.51
2029	11.43	9.09	2.34	-20.5%	+2.4%	8.08	3.35	-29.3%	+3.0%	22.01	31.86
2030	11.53	9.11	2.42	-21.0%	+2.4%	8.07	3.46	-30.0%	+3.1%	24.43	35.32
2031	11.64	9.14	2.50	-21.5%	+2.5%	8.06	3.58	-30.7%	+3.1%	26.93	38.89
2032	11.76	9.18	2.57	-21.9%	+2.5%	8.08	3.67	-31.2%	+3.2%	29.50	42.56
2033	11.88	9.24	2.64	-22.2%	+2.6%	8.12	3.76	-31.7%	+3.2%	32.14	46.32
2034	12.00	9.31	2.69	-22.5%	+2.6%	8.16	3.84	-32.0%	+3.3%	34.83	50.16
2035	12.13	9.37	2.75	-22.7%	+2.6%	8.20	3.93	-32.4%	+3.3%	37.59	54.09
2036	12.26	9.45	2.81	-22.9%	+2.7%	8.25	4.01	-32.7%	+3.3%	40.40	58.09
2037	12.39	9.53	2.86	-23.1%	+2.7%	8.32	4.07	-32.9%	+3.4%	43.26	62.17
2038	12.53	9.63	2.91	-23.2%	+2.7%	8.40	4.13	-33.0%	+3.4%	46.16	66.30
2039	12.67	9.72	2.95	-23.3%	+2.7%	8.48	4.19	-33.1%	+3.4%	49.11	70.50
2040	12.82	9.83	2.99	-23.3%	+2.7%	8.56	4.25	-33.2%	+3.4%	52.11	74.75
2041	12.97	9.93	3.03	-23.4%	+2.7%	8.65	4.31	-33.3%	+3.4%	55.14	79.06
2042	13.12	10.05	3.07	-23.4%	+2.7%	8.75	4.38	-33.3%	+3.4%	58.21	83.44
2043	13.28	10.16	3.11	-23.5%	+2.7%	8.84	4.43	-33.4%	+3.4%	61.33	87.87
2044	13.44	10.28	3.16	-23.5%	+2.7%	8.95	4.49	-33.4%	+3.4%	64.48	92.36
2045	13.60	10.41	3.19	-23.5%	+2.7%	9.06	4.54	-33.4%	+3.4%	67.68	96.90
2046	13.77	10.54	3.23	-23.5%	+2.7%	9.17	4.60	-33.4%	+3.4%	70.91	101.50
2047	13.94	10.67	3.27	-23.5%	+2.7%	9.29	4.66	-33.4%	+3.4%	74.19	106.16
2048	14.12	10.81	3.32	-23.5%	+2.7%	9.40	4.72	-33.4%	+3.4%	77.50	110.88
2049	14.30	10.95	3.36	-23.5%	+2.7%	9.53	4.78	-33.4%	+3.4%	80.86	115.66
2050	14.49	11.09	3.40	-23.5%	+2.7%	9.65	4.84	-33.4%	+3.4%	84.26	120.50

Figure 20. Low Growth Emissions

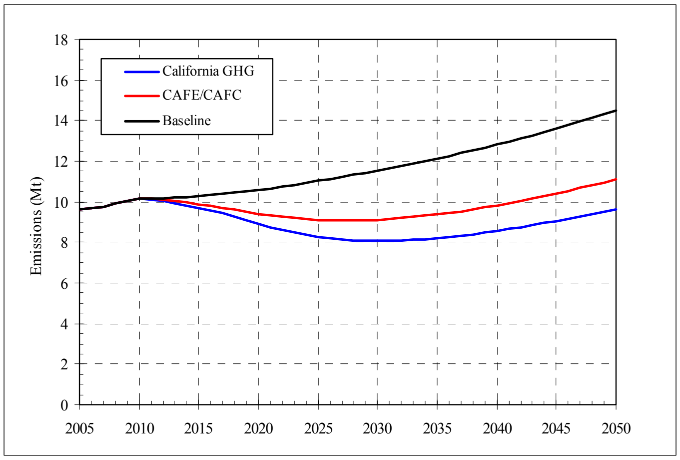


Figure 21. Low Growth Emission Reductions

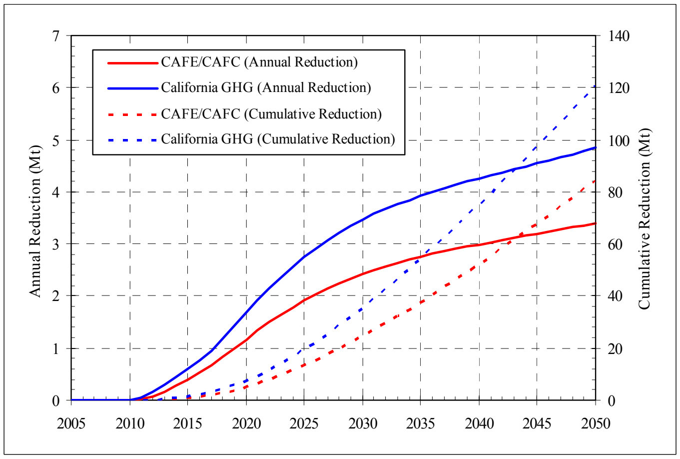
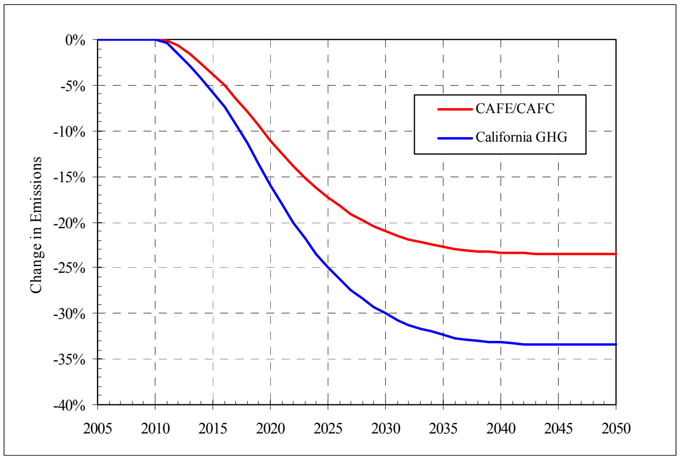


Figure 22. Low Growth Emissions Change



annual reductions that are over 40 percent higher than those of the CAFE/CAFC program. In terms of cumulative reductions, the California program will have eliminated nearly 121 Mt of GHG by 2050, as compared to 84 Mt for the CAFE/CAFC program (both considerably lower than the cumulative reductions under the reference case due to the reduced growth of baseline emissions).

3.6 The Minimum Footprint/No Class Shift Sensitivity Analysis Results

The "minimum footprint/no class shift" sensitivity analysis makes the following assumptions relative to CAFE/CAFC and California GHG program uncertainties:

- The effective average footprint of the subject vehicle fleet is reduced beginning in vehicle model year 2011 to a value that invokes the most stringent CAFC/CAFC standards. For passenger cars, the effective footprint was set at 35 square feet (3.3 square meters), while that for light duty trucks was set at 25 square feet (2.3 square meters). Since CAFE/CAFC standards increase in stringency as vehicle footprint decreases (up to a specific minimum vehicle footprint), this allows for the maximum possible CAFE/CAFE emissions impacts to be assessed. Moreover, under this sensitivity analysis, vehicles are assumed to remain within their baseline classes, so that no vehicle sales shift from an LDT2, LDT3, or LDT4 status to an LDT1 status and no light duty truck sales shift to a passenger car status, either of which would invoke more stringent fleet average California GHG standards. Thus this sensitivity analysis reflects the maximum possible CAFE/CAFC impacts while holding California GHG standard impacts constant. The scenario is *not* meant to reflect actual, or even possible, market conditions, but rather serve to define the bounding relationship between the two programs (i.e., is there a set of conditions, no matter how improbable, under which the CAFE/CAFC program can outperform the California GHG program?). Clearly, the likelihood that all passenger cars will shrink to a size of 7 by 5 feet (2.1 by 1.5 meters) and all light duty trucks will shrink to a size of 5 by 5 feet (1.5 by 1.5 meters) while simultaneously maintaining sufficient weight to avoid falling into the LDT1 class, is infinitesimally improbable. Accordingly, this is an academic case, not a market case. *(The reference case assumes an effective footprint that is unchanged from baseline forecast conditions.)*

- The fraction of manufacturers taking air conditioning load reduction credits under the California GHG program is 100 percent. While this may overstate such credits in the near term, it is likely that these credits will be fully utilized at some point due to the cost effectiveness of air conditioning improvements. *(Same as reference case.)*

- The fraction of manufacturers taking air conditioning refrigerant leakage credits under the California GHG program is 100 percent. While this may overstate such credits in the near term, it is likely that these credits will be fully utilized at some point due to the cost effectiveness of air conditioning improvements. *(Same as reference case.)*

- VKT is assumed to grow in accordance with the CEO2006 forecast for British Columbia. *(Same as reference case.)*

- CAFE/CAFC standards for model years 2011 through 2015 are as defined in the CAFE/CAFC NPRM. Standards for model years 2016 through 2020 are developed under an assumption that passenger cars and light duty truck standards increase by the same constant percentage annually to attain a combined 35 mpg (6.7 lit/100km) target in model year 2020. *(Same as reference case.)*

- The fraction of manufacturers taking AFV credits under the CAFE/CAFC program is 100 percent. While this may overstate such credits in the near term, the effect over the long term is null in terms of annual reductions and minimal in terms of cumulative reductions since such credits are eliminated under the CAFE/CAFC program beginning in model year 2020. *(Same as reference case.)*

Table 10 and Figures 23 through 25 depict the results of the "minimum footprint/no class shift" sensitivity analysis. Under this analysis, the CAFE/CAFC program does outperform the California GHG program in terms of GHG emission reductions, but not by a wide margin. By 2020, the California program reduces annual GHG emissions from light duty vehicles by 16.1 percent as compared to 19.6 percent for the CAFE/CAFC program.[26] Year 2050 emissions, which reflect the long term stabilization of both programs, reflect annual reductions of 33.4 percent under the California program as compared to 34.0 percent under CAFE/CAFC.[27] In effect, the CAFE/CAFC program produces annual reductions that are a bit less than 2 percent higher than those of the California GHG program. In terms of cumulative reductions, the California program will have eliminated 174 Mt of GHG by 2050, as compared to 184 Mt for the CAFE/CAFC program. Given the similarity in emission impacts between the two programs and the market unlikelihood of the actual scenario, the sensitivity analysis demonstrates the fact that it is very unlikely that market conditions will ever dictate a scenario in which the CAFE/CAFC program outperforms the California GHG program in terms of delivered GHG emission reductions. Additional sensitivity analysis, as summarized below, provides further support for such a conclusion.

3.7 The Crossover Footprint/No Class Shift Sensitivity Analysis Results

The "crossover footprint/no class shift" sensitivity analysis makes the following assumptions relative to CAFE/CAFC and California GHG program uncertainties:

- The effective average footprint of the subject vehicle fleet is reduced beginning in vehicle model year 2011 to a value that generates similar CAFE/CAFC and California GHG program emission reductions in 2050. For both passenger cars and light duty trucks, the effective footprint was set at 40 square feet (3.7 square meters). This scenario is

---

[26] As with other cases where CAFE/CAFC standards change, the benefits for the California program change slightly in the near term due to the fact that small and intermediate volume vehicle manufacturers are exempted from some elements of the California program during the early model years of the program. Since these manufacturers are subject to CAFE/CAFC during these years, their fuel consumption and GHG emissions decrease when the alternative CAFE/CAC standards are assumed, providing a small increase in the overall effectiveness of the California program (0.013 Mt in 2020).

[27] The California program benefits are unchanged from the reference case since the early model year vehicles affected by the alternative CAFE/CAFC standards have been retired from the fleet by 2050.

Table 10. Emissions Impact Estimates for the Minimum Footprint/No Shift Analysis

Calendar Year July 1 Fleet	Baseline LDV LDT MDPV GHG (Mt)	CAFE/ CAFC GHG (Mt)	CAFE/ CAFC GHG Reduced (Mt)	CAFE/ CAFC Percent GHG Change	CAFE/ CAFC Percent VKT Change	California Standards GHG (Mt)	California Standards GHG Reduced (Mt)	California Standards Percent GHG Change	California Standards Percent VKT Change	CAFE/ CAFC Cumulative GHG Reduced (Mt)	California Standards Cumulative GHG Reduced (Mt)
2005	9.63	9.63	0.00	0.0%	0.0%	9.63	0.00	0.0%	0.0%	0.00	0.00
2006	9.67	9.67	0.00	0.0%	0.0%	9.67	0.00	0.0%	0.0%	0.00	0.00
2007	9.75	9.75	0.00	0.0%	0.0%	9.75	0.00	0.0%	0.0%	0.00	0.00
2008	9.93	9.93	0.00	0.0%	0.0%	9.93	0.00	0.0%	0.0%	0.00	0.00
2009	10.10	10.10	0.00	0.0%	0.0%	10.10	0.00	0.0%	0.0%	0.00	0.00
2010	10.27	10.27	0.00	0.0%	0.0%	10.27	0.00	0.0%	0.0%	0.00	0.00
2011	10.44	10.29	0.16	-1.5%	+0.2%	10.39	0.05	-0.5%	+0.0%	0.16	0.05
2012	10.62	10.24	0.37	-3.5%	+0.4%	10.44	0.17	-1.6%	+0.2%	0.53	0.22
2013	10.80	10.19	0.61	-5.7%	+0.7%	10.48	0.32	-3.0%	+0.3%	1.14	0.55
2014	11.00	10.15	0.85	-7.7%	+0.9%	10.52	0.48	-4.4%	+0.4%	1.99	1.03
2015	11.20	10.12	1.09	-9.7%	+1.1%	10.54	0.66	-5.9%	+0.6%	3.07	1.69
2016	11.42	10.09	1.34	-11.7%	+1.3%	10.57	0.86	-7.5%	+0.7%	4.41	2.55
2017	11.65	10.06	1.59	-13.7%	+1.6%	10.56	1.09	-9.3%	+0.9%	6.00	3.63
2018	11.89	10.03	1.86	-15.7%	+1.8%	10.52	1.36	-11.5%	+1.1%	7.87	5.00
2019	12.14	9.99	2.14	-17.7%	+2.0%	10.47	1.67	-13.8%	+1.4%	10.01	6.67
2020	12.39	9.96	2.43	-19.6%	+2.2%	10.40	1.99	-16.1%	+1.6%	12.45	8.66
2021	12.66	9.94	2.72	-21.5%	+2.4%	10.36	2.30	-18.2%	+1.8%	15.16	10.96
2022	12.93	9.94	2.99	-23.2%	+2.6%	10.33	2.60	-20.1%	+2.0%	18.16	13.56
2023	13.21	9.95	3.26	-24.7%	+2.8%	10.32	2.89	-21.9%	+2.2%	21.42	16.46
2024	13.50	9.99	3.52	-26.0%	+3.0%	10.33	3.18	-23.5%	+2.4%	24.93	19.63
2025	13.80	10.04	3.76	-27.3%	+3.1%	10.36	3.45	-25.0%	+2.5%	28.70	23.08
2026	14.11	10.11	4.00	-28.4%	+3.2%	10.40	3.71	-26.3%	+2.7%	32.70	26.79
2027	14.43	10.20	4.23	-29.3%	+3.3%	10.47	3.96	-27.5%	+2.8%	36.94	30.75
2028	14.76	10.31	4.45	-30.1%	+3.4%	10.56	4.20	-28.5%	+2.9%	41.38	34.95
2029	15.09	10.44	4.65	-30.8%	+3.5%	10.67	4.43	-29.3%	+3.0%	46.04	39.38
2030	15.44	10.59	4.84	-31.4%	+3.6%	10.80	4.64	-30.0%	+3.1%	50.88	44.02
2031	15.79	10.74	5.05	-32.0%	+3.6%	10.93	4.85	-30.7%	+3.1%	55.93	48.87
2032	16.15	10.93	5.22	-32.3%	+3.7%	11.10	5.05	-31.3%	+3.2%	61.15	53.92
2033	16.52	11.13	5.39	-32.7%	+3.7%	11.29	5.23	-31.7%	+3.2%	66.55	59.15
2034	16.90	11.34	5.56	-32.9%	+3.7%	11.49	5.41	-32.0%	+3.3%	72.10	64.55
2035	17.29	11.52	5.77	-33.4%	+3.8%	11.69	5.60	-32.4%	+3.3%	77.88	70.15
2036	17.69	11.75	5.93	-33.5%	+3.8%	11.90	5.78	-32.7%	+3.3%	83.81	75.94
2037	18.10	12.01	6.09	-33.7%	+3.8%	12.15	5.95	-32.9%	+3.4%	89.90	81.89
2038	18.51	12.27	6.24	-33.7%	+3.8%	12.41	6.11	-33.0%	+3.4%	96.14	88.00
2039	18.94	12.54	6.40	-33.8%	+3.8%	12.67	6.27	-33.1%	+3.4%	102.54	94.27
2040	19.38	12.82	6.56	-33.8%	+3.8%	12.95	6.43	-33.2%	+3.4%	109.10	100.70
2041	19.83	13.11	6.72	-33.9%	+3.8%	13.23	6.60	-33.3%	+3.4%	115.82	107.30
2042	20.29	13.41	6.88	-33.9%	+3.9%	13.52	6.77	-33.3%	+3.4%	122.70	114.06
2043	20.76	13.71	7.04	-33.9%	+3.9%	13.83	6.93	-33.4%	+3.4%	129.74	120.99
2044	21.24	14.03	7.21	-34.0%	+3.9%	14.14	7.09	-33.4%	+3.4%	136.95	128.09
2045	21.73	14.35	7.38	-34.0%	+3.9%	14.47	7.26	-33.4%	+3.4%	144.33	135.35
2046	22.23	14.68	7.55	-34.0%	+3.9%	14.81	7.43	-33.4%	+3.4%	151.88	142.77
2047	22.75	15.02	7.73	-34.0%	+3.9%	15.15	7.60	-33.4%	+3.4%	159.61	150.37
2048	23.28	15.37	7.90	-34.0%	+3.9%	15.50	7.77	-33.4%	+3.4%	167.51	158.15
2049	23.81	15.73	8.09	-34.0%	+3.9%	15.86	7.95	-33.4%	+3.4%	175.60	166.10
2050	24.37	16.09	8.27	-34.0%	+3.9%	16.23	8.14	-33.4%	+3.4%	183.88	174.24

Figure 23. Minimum Footprint/No Shift Emissions

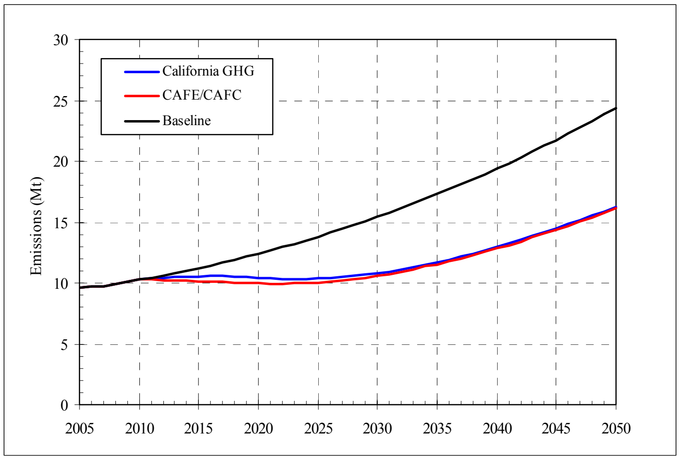


Figure 24. Minimum Footprint/No Shift Reductions

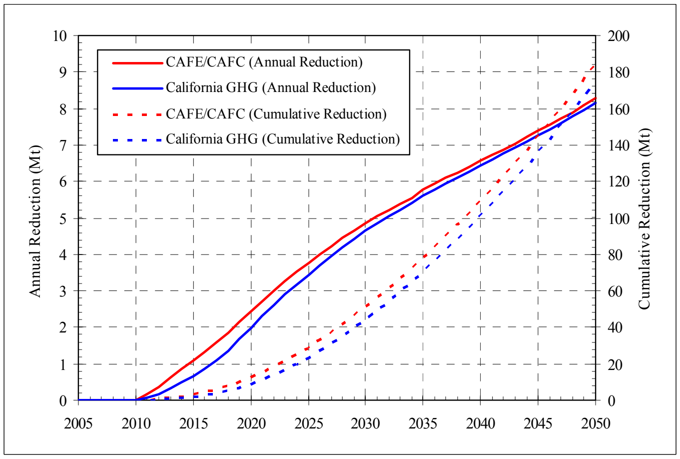
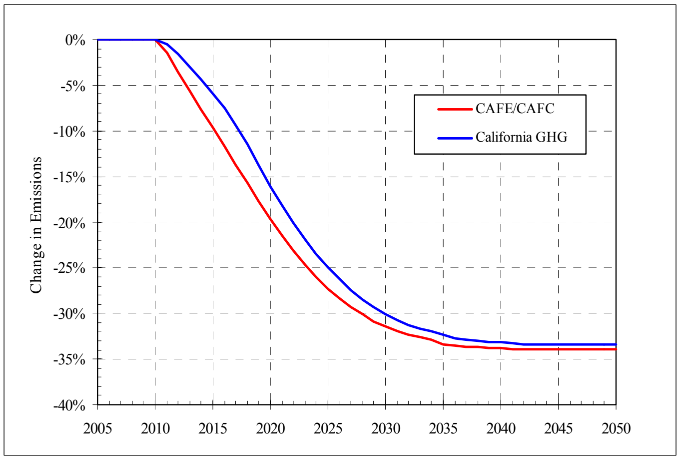


Figure 25. Minimum Footprint/No Shift Change



designed to expand upon the previous "minimum footprint/no class shift" scenario by defining that footprint value at which the two programs become equivalent. However, under this sensitivity analysis, vehicles are still assumed to remain within their baseline classes, so that no vehicle sales shift from an LDT2, LDT3, or LDT4 status to an LDT1 status and no light duty truck sales shift to a passenger car status, either of which would invoke more stringent fleet average California GHG standards. Thus this sensitivity analysis seeks to define CAFE/CAFC impacts that are equivalent to California GHG standard impacts that are held constant. As with the "minimum footprint/no class shift" scenario, this scenario is *not* meant to reflect actual market conditions, but rather serve to define the point at which the two programs would become equivalent under academic conditions. As with the "minimum footprint/no class shift" scenario, the likelihood that all passenger cars and light duty trucks will shrink to a size of 8 by 5 feet (2.4 by 1.5 meters), with all light trucks simultaneously maintaining sufficient weight to avoid falling into the LDT1 class, is quite improbable.[28] Accordingly, this is another academic case, not a market case. *(The reference case assumes an effective footprint that is unchanged from baseline forecast conditions.)*

- The fraction of manufacturers taking air conditioning load reduction credits under the California GHG program is 100 percent. While this may overstate such credits in the near term, it is likely that these credits will be fully utilized at some point due to the cost effectiveness of air conditioning improvements. *(Same as reference case.)*
- The fraction of manufacturers taking air conditioning refrigerant leakage credits under the California GHG program is 100 percent. While this may overstate such credits in the near term, it is likely that these credits will be fully utilized at some point due to the cost effectiveness of air conditioning improvements. *(Same as reference case.)*
- VKT is assumed to grow in accordance with the CEO2006 forecast for British Columbia. *(Same as reference case.)*
- CAFE/CAFC standards for model years 2011 through 2015 are as defined in the CAFE/CAFC NPRM. Standards for model years 2016 through 2020 are developed under an assumption that passenger cars and light duty truck standards increase by the same constant percentage annually to attain a combined 35 mpg (6.7 lit/100km) target in model year 2020. *(Same as reference case.)*
- The fraction of manufacturers taking AFV credits under the CAFE/CAFC program is 100 percent. While this may overstate such credits in the near term, the effect over the long term is null in terms of annual reductions and minimal in terms of cumulative reductions since such credits are eliminated under the CAFE/CAFC program beginning in model year 2020. *(Same as reference case.)*

---

[28] The effective average fleetwide footprint for passenger cars and light duty trucks under NHTSA-defined baseline conditions is about 45.5 square feet (4.2 square meters) and 52.5 square feet (4.9 square meters) respectively.

Table 11 and Figures 26 through 28 depict the results of the "crossover footprint/no class shift" sensitivity analysis. Under this analysis, the CAFE/CAFC program and California GHG program are essentially equivalent over the long term. There are differences in 2020, when the California program reduces annual GHG emissions from light duty vehicles by 16.0 percent as compared to 19.1 percent for the CAFE/CAFC program.[29] However, 2050 emissions, which reflect the long term stabilization of both programs, reflect annual reductions of 33.4 percent under the California program and 33.3 percent under CAFE/CAFC.[30] The net difference between the two programs in 2050 is 0.03 Mt. In terms of cumulative reductions, the California program will have eliminated 174 Mt of GHG by 2050, as compared to 180 Mt for the CAFE/CAFC program.

3.8 The 100 Percent Increase in Fuel Price Sensitivity Analysis Results

The "100 percent increase in fuel price" sensitivity analysis makes the following assumptions relative to CAFE/CAFC and California GHG program uncertainties:

- The effective average footprint *and vehicle class shares* of the subject vehicle fleet change in response to increases in fuel prices beginning in vehicle model year 2015. Fuel price in this context is used as a driver for changes in consumer preference, which is reflected as increased demand for fuel efficiency that translates into both reduced vehicle size and shifts away from light duty trucks toward passenger cars. This scenario is designed to better reflect the actual market conditions that might result from changes in consumer demand (i.e., it is intended to overcome the academic limitations of the previous "no class shift" scenarios). Thus, the net effect of changes in consumer demand for fuel efficiency are measured as impacts on both the CAFE/CAFC and California GHG programs, *as well as the baseline conditions against which these program impacts are measured*, in response to vehicle downsizing and class shifting. *(The reference case assumes an effective footprint that is unchanged from baseline forecast conditions.)*

  To estimate the potential impacts of the fuel price-driven market shifts, it was necessary to develop specific analysis algorithms and assign values to certain response parameters. The approach and values developed for this analysis should be considered approximate as both were developed within the constraints imposed by project resources and do not reflect the results of a full scale economic analysis.

  The fuel price elasticity of fuel efficiency demand was assumed to be equivalent to the assumed variable driving cost elasticity of VKT (which was assumed to be -0.10, as documented in Section 2). Based on this elasticity and an assumed change in fuel price,

---

[29] As with other cases where CAFE/CAFC standards change, the benefits for the California program change slightly in the near term due to the fact that small and intermediate volume vehicle manufacturers are exempted from some elements of the California program during the early model years of the program. Since these manufacturers are subject to CAFE/CAFC during these years, their fuel consumption and GHG emissions decrease when the alternative CAFE/CAC standards are assumed, providing a small increase in the overall effectiveness of the California program (0.012 Mt in 2020).

[30] The California program benefits are unchanged from the reference case since the early model year vehicles affected by the alternative CAFE/CAGC standards have been retired from the fleet by 2050.

Table 11. Emissions Impact Estimates for the Crossover Footprint/No Shift Analysis

Calendar Year July 1 Fleet	Baseline LDV LDT MDPV GHG (Mt)	CAFE/ CAFC GHG (Mt)	CAFE/ CAFC GHG Reduced (Mt)	CAFE/ CAFC Percent GHG Change	CAFE/ CAFC Percent VKT Change	California Standards GHG (Mt)	California Standards GHG Reduced (Mt)	California Standards Percent GHG Change	California Standards Percent VKT Change	CAFE/ CAFC Cumulative GHG Reduced (Mt)	California Standards Cumulative GHG Reduced (Mt)
2005	9.63	9.63	0.00	0.0%	0.0%	9.63	0.00	0.0%	0.0%	0.00	0.00
2006	9.67	9.67	0.00	0.0%	0.0%	9.67	0.00	0.0%	0.0%	0.00	0.00
2007	9.75	9.75	0.00	0.0%	0.0%	9.75	0.00	0.0%	0.0%	0.00	0.00
2008	9.93	9.93	0.00	0.0%	0.0%	9.93	0.00	0.0%	0.0%	0.00	0.00
2009	10.10	10.10	0.00	0.0%	0.0%	10.10	0.00	0.0%	0.0%	0.00	0.00
2010	10.27	10.27	0.00	0.0%	0.0%	10.27	0.00	0.0%	0.0%	0.00	0.00
2011	10.44	10.29	0.15	-1.4%	+0.2%	10.39	0.05	-0.5%	+0.0%	0.15	0.05
2012	10.62	10.26	0.35	-3.3%	+0.4%	10.44	0.17	-1.6%	+0.2%	0.50	0.22
2013	10.80	10.22	0.58	-5.4%	+0.6%	10.48	0.32	-3.0%	+0.3%	1.08	0.55
2014	11.00	10.19	0.81	-7.4%	+0.9%	10.52	0.48	-4.4%	+0.4%	1.89	1.03
2015	11.20	10.16	1.04	-9.3%	+1.1%	10.54	0.66	-5.9%	+0.6%	2.93	1.69
2016	11.42	10.14	1.29	-11.2%	+1.3%	10.57	0.85	-7.5%	+0.7%	4.22	2.54
2017	11.65	10.11	1.54	-13.2%	+1.5%	10.56	1.09	-9.3%	+0.9%	5.76	3.63
2018	11.89	10.09	1.80	-15.2%	+1.7%	10.53	1.36	-11.5%	+1.1%	7.56	4.99
2019	12.14	10.06	2.08	-17.1%	+2.0%	10.47	1.67	-13.8%	+1.4%	9.64	6.66
2020	12.39	10.03	2.36	-19.1%	+2.2%	10.40	1.99	-16.0%	+1.6%	12.01	8.65
2021	12.66	10.01	2.64	-20.9%	+2.4%	10.36	2.30	-18.2%	+1.8%	14.65	10.95
2022	12.93	10.01	2.92	-22.6%	+2.6%	10.33	2.60	-20.1%	+2.0%	17.57	13.55
2023	13.21	10.03	3.18	-24.1%	+2.7%	10.32	2.89	-21.9%	+2.2%	20.74	16.45
2024	13.50	10.07	3.43	-25.4%	+2.9%	10.33	3.18	-23.5%	+2.4%	24.18	19.62
2025	13.80	10.13	3.68	-26.6%	+3.0%	10.36	3.45	-25.0%	+2.5%	27.85	23.07
2026	14.11	10.20	3.91	-27.7%	+3.2%	10.40	3.71	-26.3%	+2.7%	31.77	26.78
2027	14.43	10.29	4.14	-28.7%	+3.3%	10.47	3.96	-27.5%	+2.8%	35.91	30.74
2028	14.76	10.41	4.35	-29.5%	+3.4%	10.56	4.20	-28.5%	+2.9%	40.26	34.94
2029	15.09	10.54	4.55	-30.2%	+3.4%	10.67	4.43	-29.3%	+3.0%	44.81	39.37
2030	15.44	10.70	4.74	-30.7%	+3.5%	10.80	4.64	-30.0%	+3.1%	49.55	44.00
2031	15.79	10.85	4.94	-31.3%	+3.6%	10.93	4.85	-30.7%	+3.1%	54.50	48.86
2032	16.15	11.03	5.12	-31.7%	+3.6%	11.10	5.05	-31.3%	+3.2%	59.61	53.90
2033	16.52	11.23	5.29	-32.0%	+3.6%	11.29	5.23	-31.7%	+3.2%	64.90	59.13
2034	16.90	11.45	5.45	-32.2%	+3.7%	11.49	5.41	-32.0%	+3.3%	70.35	64.54
2035	17.29	11.63	5.65	-32.7%	+3.7%	11.69	5.60	-32.4%	+3.3%	76.00	70.14
2036	17.69	11.87	5.81	-32.9%	+3.7%	11.90	5.78	-32.7%	+3.3%	81.82	75.93
2037	18.10	12.13	5.97	-33.0%	+3.8%	12.15	5.95	-32.9%	+3.4%	87.79	81.87
2038	18.51	12.39	6.12	-33.1%	+3.8%	12.41	6.11	-33.0%	+3.4%	93.91	87.98
2039	18.94	12.67	6.27	-33.1%	+3.8%	12.67	6.27	-33.1%	+3.4%	100.18	94.25
2040	19.38	12.95	6.43	-33.2%	+3.8%	12.95	6.43	-33.2%	+3.4%	106.61	100.69
2041	19.83	13.24	6.59	-33.2%	+3.8%	13.23	6.60	-33.3%	+3.4%	113.20	107.28
2042	20.29	13.54	6.75	-33.3%	+3.8%	13.52	6.77	-33.3%	+3.4%	119.94	114.05
2043	20.76	13.85	6.91	-33.3%	+3.8%	13.83	6.93	-33.4%	+3.4%	126.85	120.98
2044	21.24	14.17	7.07	-33.3%	+3.8%	14.14	7.09	-33.4%	+3.4%	133.92	128.07
2045	21.73	14.49	7.24	-33.3%	+3.8%	14.47	7.26	-33.4%	+3.4%	141.16	135.33
2046	22.23	14.83	7.40	-33.3%	+3.8%	14.81	7.43	-33.4%	+3.4%	148.56	142.76
2047	22.75	15.17	7.58	-33.3%	+3.8%	15.15	7.60	-33.4%	+3.4%	156.14	150.36
2048	23.28	15.52	7.75	-33.3%	+3.8%	15.50	7.77	-33.4%	+3.4%	163.89	158.13
2049	23.81	15.88	7.93	-33.3%	+3.8%	15.86	7.95	-33.4%	+3.4%	171.82	166.09
2050	24.37	16.25	8.11	-33.3%	+3.8%	16.23	8.14	-33.4%	+3.4%	179.93	174.23

Figure 26. Crossover Footprint/No Shift Emissions

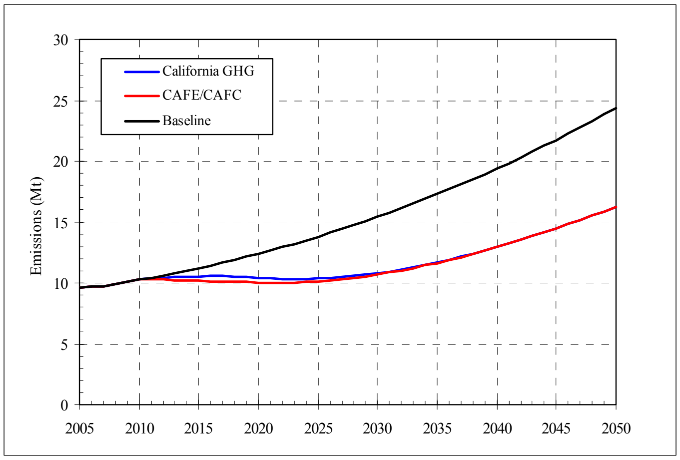


Figure 27. Crossover Footprint/No Shift Reductions

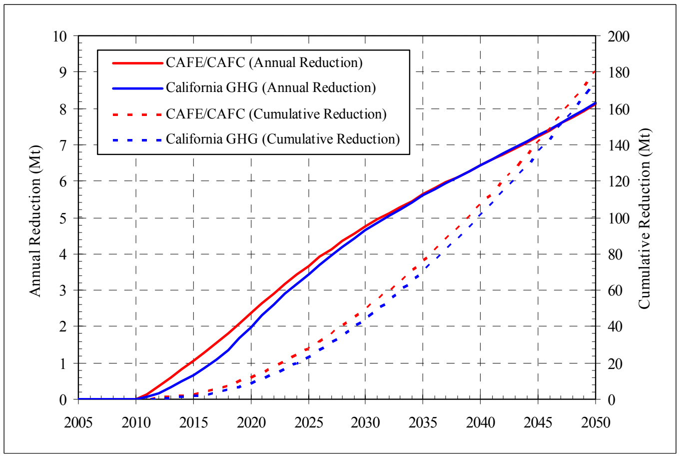
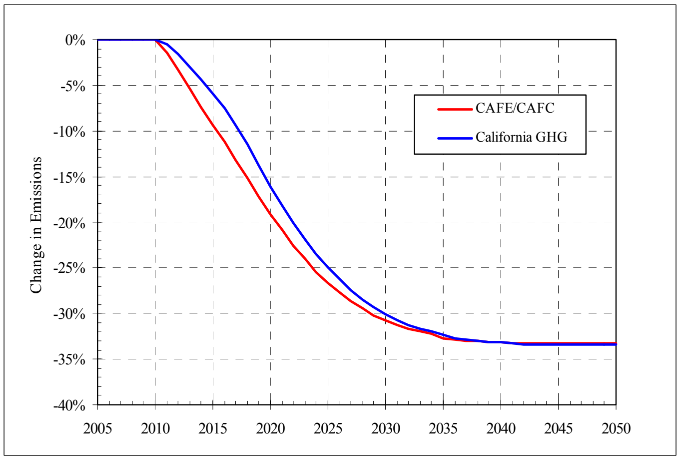


Figure 28. Crossover Footprint/No Shift Change



in this case 100 percent, the net change in fuel efficiency demand was calculated.[31] The new effective CAFE/CAFC "standard" was calculated from the standards in effect in the absence of the efficiency demand change and the CAFE/CAFC logistic functions were then evaluated to determine the effective average vehicle footprint required to achieve this new efficiency demand level.

To estimate the change in vehicle class shares in response to this new level of efficiency demand (and associated change in vehicle footprint), footprint data for light duty trucks for model year 2006 were examined. From these data the fraction of light duty trucks that were LDT1, LDT2, LDT3, and LDT4 for any given footprint were calculated. These fractional data were then regressed against vehicle footprint to derive estimated slopes for the change in each vehicle class fraction with changes in footprint. These regression results were then normalized to develop probability functions for the class fractions associated each vehicle footprint. Figure 29 presents the resulting functions in graphical form.

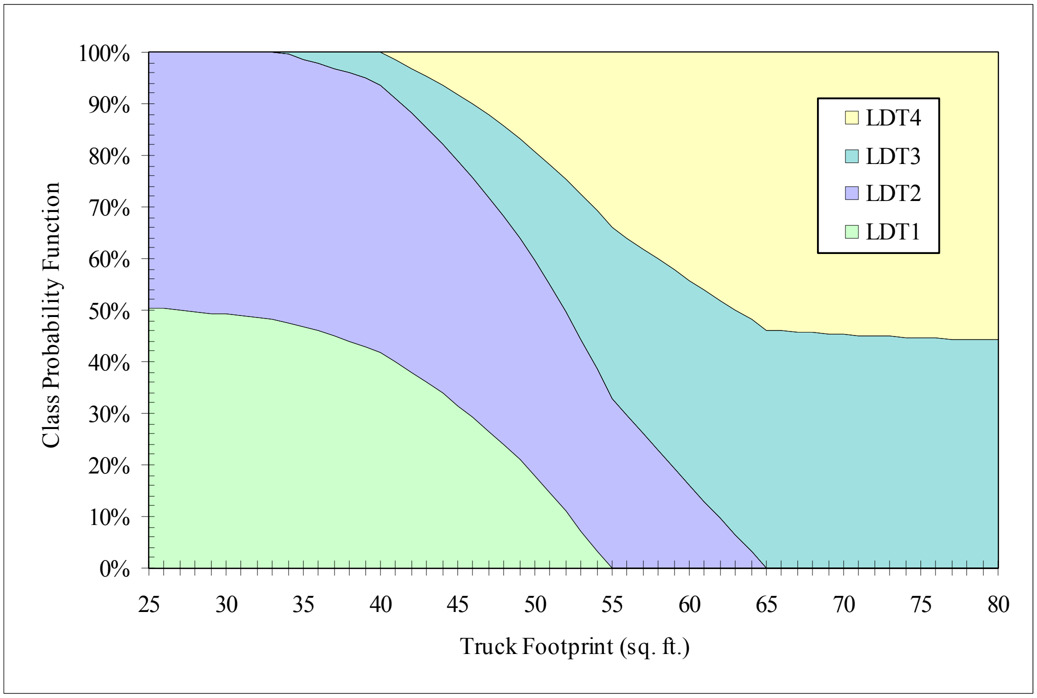
The probability function was not utilized directly, but rather to estimate the *change* in light duty truck class fractions that would accrue from a change in the effective average vehicle footprint associated with an increased level of efficiency demand. The baseline class shares were estimated as described in Section 2. These shares are associated with the constant fuel price efficiency demand and baseline effective average light duty truck footprint. Comparing the probability distributions for the baseline effective average light duty truck footprint to those for the efficiency demand-induced revised effective average footprint, provides an estimate for the expected *change* in truck class share. For example, if the LDT1 probability distribution share at a baseline footprint of 45 square feet (4.2 square meters) was 0.32 and the share at a revised footprint of 43 square feet (4.0 square meters) was 0.36, then the baseline LDT1 share is expected to increase by 12.5 percent (0.36/0.32). This same procedure was employed to estimate the change in LDT1, LDT2, LDT3, and LDT4 class shares.

One additional class shift estimate is required, namely the fraction of demand that shifts from light duty trucks to passenger cars. To estimate the magnitude of this effect, monthly and year-to-date vehicle sales for July 2007 and July 2008 were examined. During this period, there was a general economy-induced decline in overall vehicle sales, but also a sharp increase consumer demand for efficiency due to rapidly increasing fuel prices. The combined effects of these influences is reflected in overall light duty vehicle sales declines of 10-15 percent, but much larger declines of 20-30 percent for light duty trucks. If it is assumed that the drop in both passenger car and light duty truck sales would mimic the overall sales decline of 10-15 percent in the absence of confounding fuel price increases, the sales estimates under such an assumption (i.e., reflecting no

---

[31] The change in fuel efficiency demand was calculated in ten percent change increments to avoid applying the assumed elasticity value to very large changes in fuel price. In other words, the net change in efficiency demand is calculated as the effective demand change for a ten percent fuel price change raised to a power equal to the number of ten percent changes that would be required to achieve the overall fuel price change. For example, a 100 percent increase in fuel price reflects about 7.3 ten percent changes, so the net effect of the 100 percent price increase equals the ten percent change effect raised to the 7.3rd power.

Figure 29. Probability Distributions for Light Duty Trucks



accompanying change in efficiency demand) as compared to the actual sales data (i.e., reflecting the accompanying change in efficiency demand) imply an effective class shift out of the light duty truck segment and into the passenger car segment that is equal to about 42-48 percent of the change in light trucks sales. In other words, about 45 percent of consumers that would have bought a truck in the absence of the fuel price change switched classes. Based on this estimate, this analysis assumes that 45 percent of any *increase* in light duty truck shares is indicative of a switch out of the light duty truck class and into the passenger car class.

Thus, for the LDT1 example above, 45 percent of the 12.5 percent LDT1 class share increase would accrue to passenger cars (for a 5.6 percent increase in the passenger car share) and the remaining 55 percent would accrue to the LDT1 class share (for a 6.9 percent increase in the LDT1 share). This process is repeated for all truck classes and the results are then normalized to derive adjusted passenger car, LDT1, LDT2, LDT3, and LDT4 shares. It is important to note that this analysis does not assume a lag in the ability of the market to satisfy the altered consumer demand, but rather estimates the impacts that would accrue if such demand were satisfied without delay. This approach isolates the effects of vehicle market response time from the efficiency demand-induced effects on CAFC/CAFE and California GHG program impacts.

- The fraction of manufacturers taking air conditioning load reduction credits under the California GHG program is 100 percent. While this may overstate such credits in the near term, it is likely that these credits will be fully utilized at some point due to the cost effectiveness of air conditioning improvements. *(Same as reference case.)*

- The fraction of manufacturers taking air conditioning refrigerant leakage credits under the California GHG program is 100 percent. While this may overstate such credits in the near term, it is likely that these credits will be fully utilized at some point due to the cost effectiveness of air conditioning improvements. *(Same as reference case.)*

- VKT is assumed to grow in accordance with the CEO2006 forecast for British Columbia. *(Same as reference case.)*

- CAFE/CAFC standards for model years 2011 through 2015 are as defined in the CAFE/CAFC NPRM. Standards for model years 2016 through 2020 are developed under an assumption that passenger cars and light duty truck standards increase by the same constant percentage annually to attain a combined 35 mpg (6.7 lit/100km) target in model year 2020. *(Same as reference case.)*

- The fraction of manufacturers taking AFV credits under the CAFE/CAFC program is 100 percent. While this may overstate such credits in the near term, the effect over the long term is null in terms of annual reductions and minimal in terms of cumulative reductions since such credits are eliminated under the CAFE/CAFC program beginning in model year 2020. *(Same as reference case.)*

Table 12 and Figures 30 through 32 depict the results of the "100 percent increase in fuel price" sensitivity analysis. Under this analysis, the California GHG program continues to outperform the CAFE/CAFC program by a wide margin. By 2020, the California program reduces annual GHG emissions from light duty vehicles by 16.3 percent as compared to 13.5 percent for the CAFE/CAFC program. Similarly, 2050 emissions, which reflect the long term stabilization of both programs, continue to reflect annual reductions of 34.2 percent under the California program as compared to 28.6 percent under CAFE/CAFC. In effect, the California program still produces annual reductions that are about 20 percent higher than those of the CAFE/CAFC program. In terms of cumulative reductions, the California program will have eliminated nearly 173 Mt of GHG by 2050, as compared to 144 Mt for the CAFE/CAFC program. The impact of the increased efficiency demand is greater under the CAFE/CAFC program since downsizing directly impacts both light duty truck and passenger car standards, while the impact on the California GHG program is reflected through class shifting effects alone.

Table 12. Emissions Impact Estimates for the 100 Percent Fuel Price Increase Analysis

Calendar Year July 1 Fleet	Baseline LDV LDT MDPV GHG (Mt)	CAFE/ CAFC GHG (Mt)	CAFE/ CAFC GHG Reduced (Mt)	CAFE/ CAFC Percent GHG Change	CAFE/ CAFC Percent VKT Change	California Standards GHG (Mt)	California Standards GHG Reduced (Mt)	California Standards Percent GHG Change	California Standards Percent VKT Change	CAFE/ CAFC Cumulative GHG Reduced (Mt)	California Standards Cumulative GHG Reduced (Mt)
2005	9.63	9.63	0.00	0.0%	0.0%	9.63	0.00	0.0%	0.0%	0.00	0.00
2006	9.68	9.68	0.00	0.0%	0.0%	9.68	0.00	0.0%	0.0%	0.00	0.00
2007	9.75	9.75	0.00	0.0%	0.0%	9.75	0.00	0.0%	0.0%	0.00	0.00
2008	9.93	9.93	0.00	0.0%	0.0%	9.93	0.00	0.0%	0.0%	0.00	0.00
2009	10.10	10.10	0.00	0.0%	0.0%	10.10	0.00	0.0%	0.0%	0.00	0.00
2010	10.27	10.27	0.00	0.0%	0.0%	10.27	0.00	0.0%	0.0%	0.00	0.00
2011	10.44	10.42	0.02	-0.2%	+0.0%	10.39	0.05	-0.5%	+0.0%	0.02	0.05
2012	10.61	10.54	0.08	-0.7%	+0.1%	10.45	0.17	-1.6%	+0.2%	0.09	0.22
2013	10.80	10.63	0.17	-1.6%	+0.2%	10.48	0.32	-2.9%	+0.3%	0.27	0.53
2014	11.00	10.71	0.29	-2.7%	+0.3%	10.52	0.47	-4.3%	+0.4%	0.56	1.01
2015	11.17	10.69	0.47	-4.2%	+0.5%	10.51	0.65	-5.9%	+0.6%	1.03	1.66
2016	11.35	10.67	0.68	-6.0%	+0.7%	10.49	0.85	-7.5%	+0.7%	1.72	2.52
2017	11.54	10.63	0.90	-7.8%	+0.9%	10.45	1.09	-9.4%	+0.9%	2.62	3.61
2018	11.74	10.61	1.14	-9.7%	+1.1%	10.38	1.37	-11.6%	+1.2%	3.76	4.97
2019	11.96	10.58	1.38	-11.6%	+1.3%	10.29	1.67	-14.0%	+1.4%	5.14	6.64
2020	12.18	10.54	1.64	-13.5%	+1.6%	10.20	1.98	-16.3%	+1.6%	6.78	8.62
2021	12.42	10.53	1.89	-15.3%	+1.8%	10.13	2.29	-18.4%	+1.9%	8.68	10.92
2022	12.66	10.52	2.14	-16.9%	+1.9%	10.08	2.59	-20.4%	+2.1%	10.82	13.50
2023	12.92	10.54	2.38	-18.4%	+2.1%	10.05	2.87	-22.3%	+2.3%	13.19	16.38
2024	13.18	10.58	2.61	-19.8%	+2.3%	10.03	3.15	-23.9%	+2.4%	15.80	19.53
2025	13.46	10.63	2.83	-21.0%	+2.4%	10.04	3.42	-25.4%	+2.6%	18.63	22.95
2026	13.74	10.70	3.05	-22.2%	+2.6%	10.06	3.68	-26.8%	+2.7%	21.68	26.64
2027	14.04	10.78	3.26	-23.2%	+2.7%	10.10	3.93	-28.0%	+2.9%	24.93	30.57
2028	14.34	10.88	3.46	-24.1%	+2.8%	10.17	4.17	-29.1%	+3.0%	28.39	34.74
2029	14.65	11.01	3.65	-24.9%	+2.9%	10.26	4.39	-30.0%	+3.1%	32.04	39.13
2030	14.97	11.15	3.82	-25.5%	+2.9%	10.37	4.60	-30.7%	+3.1%	35.86	43.73
2031	15.30	11.29	4.01	-26.2%	+3.0%	10.48	4.82	-31.5%	+3.2%	39.87	48.55
2032	15.64	11.47	4.18	-26.7%	+3.1%	10.63	5.01	-32.0%	+3.3%	44.05	53.56
2033	15.99	11.66	4.33	-27.1%	+3.1%	10.81	5.19	-32.4%	+3.3%	48.38	58.75
2034	16.36	11.88	4.48	-27.4%	+3.1%	10.99	5.36	-32.8%	+3.3%	52.86	64.11
2035	16.73	12.10	4.63	-27.7%	+3.2%	11.18	5.55	-33.2%	+3.4%	57.49	69.67
2036	17.11	12.33	4.78	-27.9%	+3.2%	11.38	5.74	-33.5%	+3.4%	62.27	75.40
2037	17.50	12.58	4.92	-28.1%	+3.2%	11.61	5.90	-33.7%	+3.4%	67.19	81.30
2038	17.91	12.85	5.05	-28.2%	+3.2%	11.86	6.05	-33.8%	+3.5%	72.24	87.35
2039	18.31	13.11	5.20	-28.4%	+3.3%	12.10	6.21	-33.9%	+3.5%	77.44	93.56
2040	18.73	13.40	5.33	-28.5%	+3.3%	12.36	6.37	-34.0%	+3.5%	82.78	99.93
2041	19.16	13.70	5.46	-28.5%	+3.3%	12.63	6.53	-34.1%	+3.5%	88.24	106.46
2042	19.61	14.01	5.60	-28.5%	+3.3%	12.91	6.69	-34.1%	+3.5%	93.84	113.15
2043	20.06	14.33	5.73	-28.6%	+3.3%	13.21	6.85	-34.2%	+3.5%	99.57	120.01
2044	20.52	14.65	5.87	-28.6%	+3.3%	13.51	7.02	-34.2%	+3.5%	105.44	127.02
2045	21.00	14.99	6.01	-28.6%	+3.3%	13.82	7.18	-34.2%	+3.5%	111.45	134.20
2046	21.48	15.34	6.14	-28.6%	+3.3%	14.14	7.34	-34.2%	+3.5%	117.59	141.54
2047	21.98	15.69	6.29	-28.6%	+3.3%	14.47	7.51	-34.2%	+3.5%	123.88	149.06
2048	22.49	16.05	6.43	-28.6%	+3.3%	14.80	7.68	-34.2%	+3.5%	130.31	156.74
2049	23.01	16.43	6.58	-28.6%	+3.3%	15.14	7.86	-34.2%	+3.5%	136.89	164.60
2050	23.54	16.81	6.73	-28.6%	+3.3%	15.49	8.04	-34.2%	+3.5%	143.62	172.65

Figure 30. 100% Fuel Price Increase Emissions

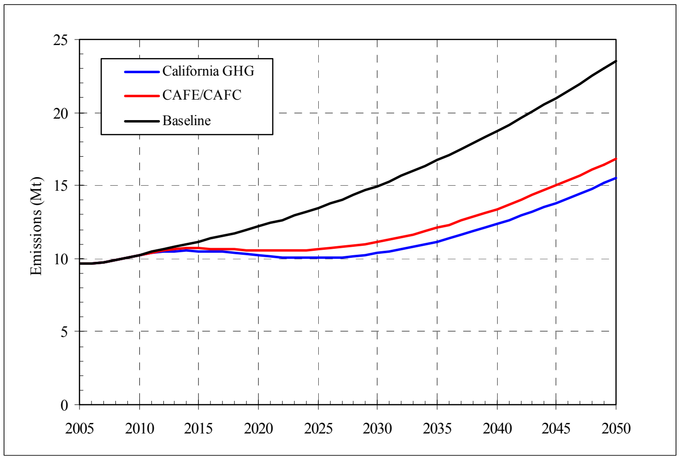


Figure 31. 100% Fuel Price Increase Reductions

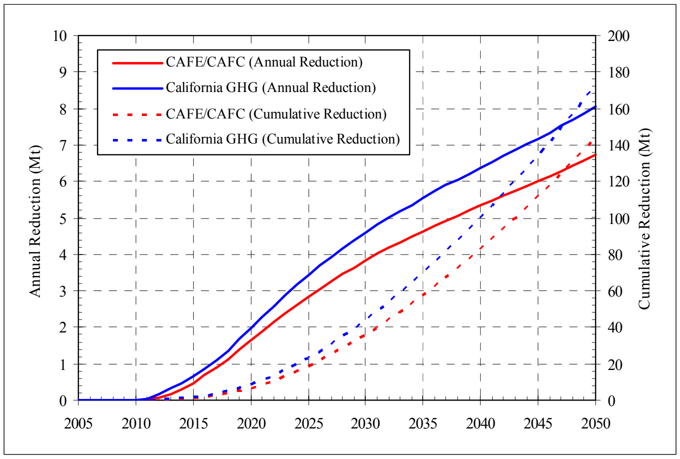
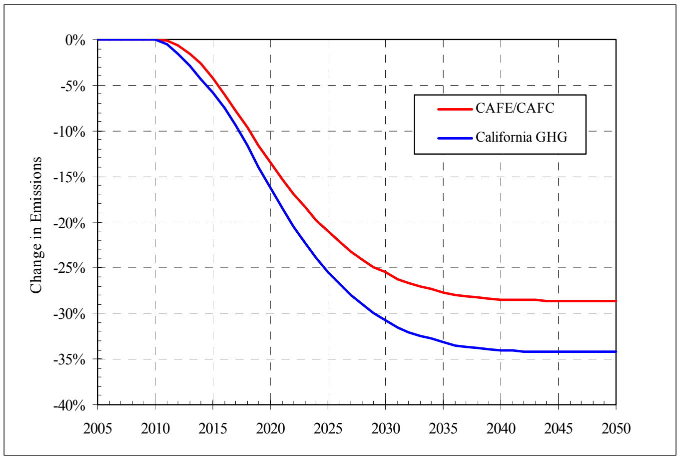


Figure 32. 100% Fuel Price Increase Change



3.9 The 200 Percent Increase in Fuel Price Sensitivity Analysis Results

The "200 percent increase in fuel price" sensitivity analysis makes the following assumptions relative to CAFE/CAFC and California GHG program uncertainties:

- The effective average footprint *and vehicle class shares* of the subject vehicle fleet change in response to increases in fuel prices beginning in vehicle model year 2015. Fuel price in this context is used as a driver for changes in consumer preference, which is reflected as increased demand for fuel efficiency that translates into both reduced vehicle size and shifts away from light duty trucks toward passenger cars. This scenario is designed to better reflect the actual market conditions that might result from changes in consumer demand (i.e., it is intended to overcome the academic limitations of the previous "no class shift" scenarios). Thus, the net effect of changes in consumer demand for fuel efficiency are measured as impacts on both the CAFE/CAFC and California GHG programs, *as well as the baseline conditions against which these program impacts are measured*, in response to vehicle downsizing and class shifting. The methodology used to estimate the impacts of the fuel price change is described in detail in Section 3.8, the only difference between this scenario and that documented in Section 3.8 is that this scenario assumes a tripling of fuel price as opposed to a doubling under the previous scenario. *(The reference case assumes an effective footprint that is unchanged from baseline forecast conditions.)*

- The fraction of manufacturers taking air conditioning load reduction credits under the California GHG program is 100 percent. While this may overstate such credits in the near term, it is likely that these credits will be fully utilized at some point due to the cost effectiveness of air conditioning improvements. *(Same as reference case.)*

- The fraction of manufacturers taking air conditioning refrigerant leakage credits under the California GHG program is 100 percent. While this may overstate such credits in the near term, it is likely that these credits will be fully utilized at some point due to the cost effectiveness of air conditioning improvements. *(Same as reference case.)*

- VKT is assumed to grow in accordance with the CEO2006 forecast for British Columbia. *(Same as reference case.)*

- CAFE/CAFC standards for model years 2011 through 2015 are as defined in the CAFE/CAFC NPRM. Standards for model years 2016 through 2020 are developed under an assumption that passenger cars and light duty truck standards increase by the same constant percentage annually to attain a combined 35 mpg (6.7 lit/100km) target in model year 2020. *(Same as reference case.)*

- The fraction of manufacturers taking AFV credits under the CAFE/CAFC program is 100 percent. While this may overstate such credits in the near term, the effect over the long term is null in terms of annual reductions and minimal in terms of cumulative reductions since such credits are eliminated under the CAFE/CAFC program beginning in model year 2020. *(Same as reference case.)*

Table 13 and Figures 33 through 35 depict the results of the "200 percent increase in fuel price" sensitivity analysis. Under this analysis, the California GHG program continues to outperform the CAFE/CAFC program, but the differences have become smaller. By 2020, the California program reduces annual GHG emissions from light duty vehicles by 16.5 percent as compared to 14.8 percent for the CAFE/CAFC program. Similarly, 2050 emissions, which reflect the long term stabilization of both programs, continue to reflect annual reductions of 34.6 percent under the California program as compared to 31.4 percent under CAFE/CAFC. In effect, the California program still produces annual reductions that are about 10 percent higher than those of the CAFE/CAFC program. In terms of cumulative reductions, the California program will have eliminated nearly 172 Mt of GHG by 2050, as compared to 155 Mt for the CAFE/CAFC program. The impact of the increased efficiency demand is greater under the CAFE/CAFC program since downsizing directly impacts both light duty truck and passenger car standards, while the impact on the California GHG program is reflected through class shifting effects alone.

3.10 The 500 Percent Increase in Fuel Price Sensitivity Analysis Results

The "500 percent increase in fuel price" sensitivity analysis makes the following assumptions relative to CAFE/CAFC and California GHG program uncertainties:

- The effective average footprint *and vehicle class shares* of the subject vehicle fleet change in response to increases in fuel prices beginning in vehicle model year 2015. Fuel price in this context is used as a driver for changes in consumer preference, which is reflected as increased demand for fuel efficiency that translates into both reduced vehicle size and shifts away from light duty trucks toward passenger cars. This scenario is designed to better reflect the actual market conditions that might result from changes in consumer demand (i.e., it is intended to overcome the academic limitations of the previous "no class shift" scenarios). Thus, the net effect of changes in consumer demand for fuel efficiency are measured as impacts on both the CAFE/CAFC and California GHG programs, *as well as the baseline conditions against which these program impacts are measured*, in response to vehicle downsizing and class shifting. The methodology used to estimate the impacts of the fuel price change is described in detail in Section 3.8, the only difference between this scenario and that documented in Section 3.8 is that this scenario assumes that fuel price changes by a factor of six as opposed to a doubling under the Section 3.8 scenario. *(The reference case assumes an effective footprint that is unchanged from baseline forecast conditions.)*

- The fraction of manufacturers taking air conditioning load reduction credits under the California GHG program is 100 percent. While this may overstate such credits in the near term, it is likely that these credits will be fully utilized at some point due to the cost effectiveness of air conditioning improvements. *(Same as reference case.)*

- The fraction of manufacturers taking air conditioning refrigerant leakage credits under the California GHG program is 100 percent. While this may overstate such credits in the

Table 13. Emissions Impact Estimates for the 200 Percent Fuel Price Increase Analysis

Calendar Year July 1 Fleet	Baseline LDV LDT MDPV GHG (Mt)	CAFE/ CAFC GHG (Mt)	CAFE/ CAFC GHG Reduced (Mt)	CAFE/ CAFC Percent GHG Change	CAFE/ CAFC Percent VKT Change	California Standards GHG (Mt)	California Standards GHG Reduced (Mt)	California Standards Percent GHG Change	California Standards Percent VKT Change	CAFE/ CAFC Cumulative GHG Reduced (Mt)	California Standards Cumulative GHG Reduced (Mt)
2005	9.63	9.63	0.00	0.0%	0.0%	9.63	0.00	0.0%	0.0%	0.00	0.00
2006	9.68	9.68	0.00	0.0%	0.0%	9.68	0.00	0.0%	0.0%	0.00	0.00
2007	9.75	9.75	0.00	0.0%	0.0%	9.75	0.00	0.0%	0.0%	0.00	0.00
2008	9.93	9.93	0.00	0.0%	0.0%	9.93	0.00	0.0%	0.0%	0.00	0.00
2009	10.11	10.11	0.00	0.0%	0.0%	10.11	0.00	0.0%	0.0%	0.00	0.00
2010	10.27	10.27	0.00	0.0%	0.0%	10.27	0.00	0.0%	0.0%	0.00	0.00
2011	10.44	10.42	0.02	-0.2%	+0.0%	10.39	0.05	-0.5%	+0.0%	0.02	0.05
2012	10.61	10.54	0.08	-0.7%	+0.1%	10.44	0.17	-1.6%	+0.2%	0.09	0.22
2013	10.80	10.62	0.17	-1.6%	+0.2%	10.48	0.32	-3.0%	+0.3%	0.27	0.54
2014	11.00	10.70	0.29	-2.7%	+0.3%	10.52	0.48	-4.4%	+0.4%	0.56	1.02
2015	11.13	10.63	0.50	-4.5%	+0.5%	10.47	0.66	-5.9%	+0.6%	1.06	1.68
2016	11.29	10.55	0.74	-6.5%	+0.8%	10.43	0.86	-7.6%	+0.8%	1.80	2.54
2017	11.45	10.47	0.98	-8.6%	+1.0%	10.36	1.10	-9.6%	+0.9%	2.78	3.64
2018	11.64	10.40	1.24	-10.7%	+1.2%	10.26	1.38	-11.8%	+1.2%	4.02	5.02
2019	11.83	10.33	1.51	-12.7%	+1.5%	10.16	1.68	-14.2%	+1.4%	5.53	6.70
2020	12.04	10.26	1.78	-14.8%	+1.7%	10.05	1.99	-16.5%	+1.7%	7.31	8.68
2021	12.26	10.21	2.05	-16.7%	+1.9%	9.97	2.29	-18.7%	+1.9%	9.36	10.97
2022	12.49	10.18	2.31	-18.5%	+2.1%	9.90	2.58	-20.7%	+2.1%	11.67	13.56
2023	12.73	10.16	2.56	-20.1%	+2.3%	9.86	2.87	-22.5%	+2.3%	14.24	16.42
2024	12.98	10.17	2.81	-21.7%	+2.5%	9.83	3.14	-24.2%	+2.5%	17.05	19.57
2025	13.24	10.19	3.05	-23.0%	+2.6%	9.83	3.41	-25.8%	+2.6%	20.10	22.98
2026	13.51	10.23	3.28	-24.3%	+2.8%	9.84	3.67	-27.2%	+2.8%	23.38	26.65
2027	13.79	10.28	3.51	-25.4%	+2.9%	9.87	3.92	-28.4%	+2.9%	26.89	30.57
2028	14.08	10.36	3.72	-26.4%	+3.0%	9.93	4.15	-29.5%	+3.0%	30.61	34.72
2029	14.38	10.45	3.93	-27.3%	+3.1%	10.01	4.38	-30.4%	+3.1%	34.54	39.09
2030	14.69	10.57	4.12	-28.1%	+3.2%	10.11	4.58	-31.2%	+3.2%	38.66	43.68
2031	15.01	10.68	4.33	-28.8%	+3.3%	10.21	4.80	-32.0%	+3.3%	42.99	48.48
2032	15.34	10.84	4.50	-29.4%	+3.4%	10.35	4.99	-32.5%	+3.3%	47.49	53.47
2033	15.68	11.01	4.67	-29.8%	+3.4%	10.52	5.17	-32.9%	+3.4%	52.16	58.63
2034	16.04	11.21	4.83	-30.1%	+3.4%	10.70	5.34	-33.3%	+3.4%	56.99	63.97
2035	16.40	11.40	4.99	-30.5%	+3.5%	10.87	5.53	-33.7%	+3.4%	61.99	69.49
2036	16.77	11.62	5.15	-30.7%	+3.5%	11.06	5.71	-34.0%	+3.5%	67.14	75.20
2037	17.16	11.86	5.30	-30.9%	+3.5%	11.29	5.86	-34.2%	+3.5%	72.44	81.07
2038	17.55	12.11	5.44	-31.0%	+3.5%	11.53	6.02	-34.3%	+3.5%	77.88	87.08
2039	17.94	12.33	5.61	-31.2%	+3.6%	11.76	6.18	-34.4%	+3.5%	83.48	93.26
2040	18.35	12.61	5.75	-31.3%	+3.6%	12.02	6.33	-34.5%	+3.5%	89.23	99.59
2041	18.77	12.89	5.89	-31.4%	+3.6%	12.28	6.49	-34.6%	+3.5%	95.11	106.08
2042	19.21	13.18	6.03	-31.4%	+3.6%	12.56	6.65	-34.6%	+3.5%	101.14	112.73
2043	19.65	13.48	6.17	-31.4%	+3.6%	12.84	6.81	-34.7%	+3.5%	107.32	119.54
2044	20.10	13.78	6.32	-31.4%	+3.6%	13.13	6.97	-34.7%	+3.5%	113.64	126.51
2045	20.57	14.10	6.47	-31.4%	+3.6%	13.44	7.13	-34.7%	+3.5%	120.10	133.64
2046	21.04	14.42	6.62	-31.4%	+3.6%	13.75	7.29	-34.7%	+3.5%	126.72	140.93
2047	21.53	14.76	6.77	-31.4%	+3.6%	14.07	7.46	-34.7%	+3.5%	133.49	148.39
2048	22.02	15.10	6.92	-31.4%	+3.6%	14.39	7.63	-34.7%	+3.5%	140.41	156.02
2049	22.53	15.45	7.08	-31.4%	+3.6%	14.72	7.81	-34.6%	+3.5%	147.49	163.83
2050	23.05	15.80	7.25	-31.4%	+3.6%	15.06	7.99	-34.6%	+3.5%	154.74	171.81

Figure 33. 200% Fuel Price Increase Emissions

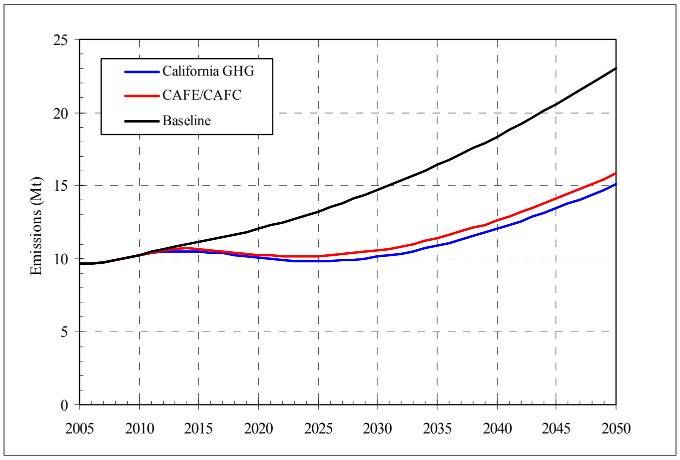


Figure 34. 200% Fuel Price Increase Reductions

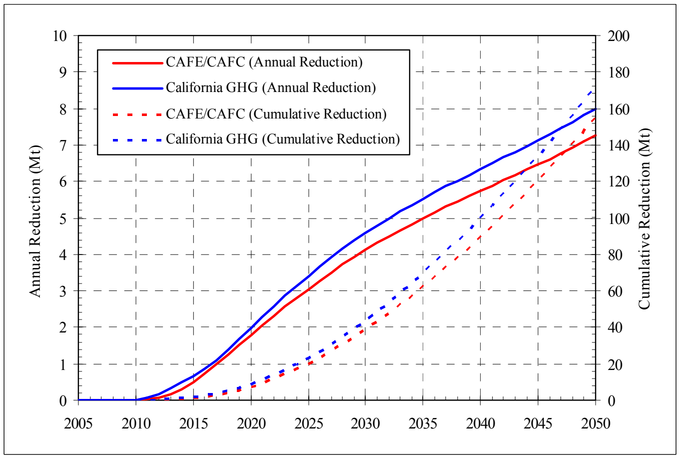
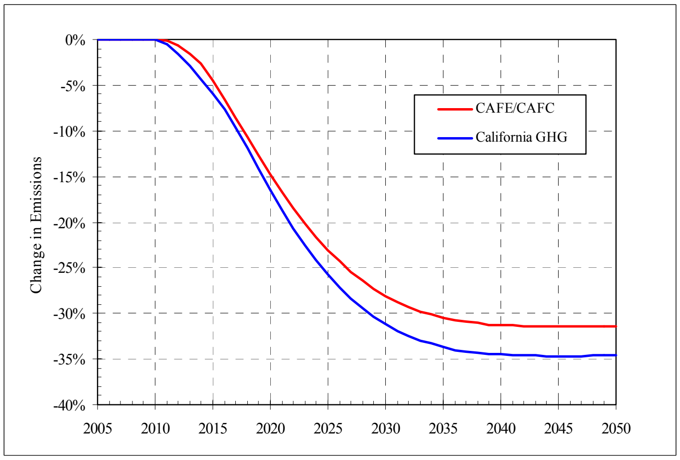


Figure 35. 200% Fuel Price Increase Change



near term, it is likely that these credits will be fully utilized at some point due to the cost effectiveness of air conditioning improvements. *(Same as reference case.)*

- VKT is assumed to grow in accordance with the CEO2006 forecast for British Columbia. *(Same as reference case.)*

- CAFE/CAFC standards for model years 2011 through 2015 are as defined in the CAFE/CAFC NPRM. Standards for model years 2016 through 2020 are developed under an assumption that passenger cars and light duty truck standards increase by the same constant percentage annually to attain a combined 35 mpg (6.7 lit/100km) target in model year 2020. *(Same as reference case.)*

- The fraction of manufacturers taking AFV credits under the CAFE/CAFC program is 100 percent. While this may overstate such credits in the near term, the effect over the long term is null in terms of annual reductions and minimal in terms of cumulative reductions since such credits are eliminated under the CAFE/CAFC program beginning in model year 2020. *(Same as reference case.)*

Table 14 and Figures 36 through 38 depict the results of the "500 percent increase in fuel price" sensitivity analysis. Under this analysis, the California GHG program continues to outperform the CAFE/CAFC program, but the differences have become modest. By 2020, the California program reduces annual GHG emissions from light duty vehicles by 17.0 percent as compared to 16.3 percent for the CAFE/CAFC program. Similarly, 2050 emissions, which reflect the long term stabilization of both programs, continue to reflect annual reductions of 35.8 percent under the California program as compared to 34.7 percent under CAFE/CAFC. In effect, the California program still produces annual reductions that are about 3 percent higher than those of the CAFE/CAFC program. In terms of cumulative reductions, the California program will have eliminated 171 Mt of GHG by 2050, as compared to 165 Mt for the CAFE/CAFC program.

As with the other fuel price change scenarios, the impact of the increased efficiency demand is greater under the CAFE/CAFC program since downsizing directly impacts both light duty truck and passenger car standards, while the impact on the California GHG program is reflected through class shifting effects alone. However, this scenario is essentially the bounding scenario for both programs since the fuel price change is so large that essentially all vehicles have moved out of the LDT3 and LDT4 classes and the effective footprint for both passenger cars and light trucks has reached the point where no further changes in CAFE/CAFC fuel consumption requirements are possible. Further reductions in GHG will be purely market driven (as, in fact, they likely will be well before fuel price changes by a factor of six) regardless of the GHG control program in effect. Nevertheless, based on this and the other fuel price change scenarios, it is virtually certain that the California GHG program will outperform the CAFE/CAFC program in terms of GHG reductions under any conceivably realistic scenario (given the current expected designs of both programs).

Table 14. Emissions Impact Estimates for the 500 Percent Fuel Price Increase Analysis

Calendar Year July 1 Fleet	Baseline LDV LDT MDPV GHG (Mt)	CAFE/ CAFC GHG (Mt)	CAFE/ CAFC GHG Reduced (Mt)	CAFE/ CAFC Percent GHG Change	CAFE/ CAFC Percent VKT Change	California Standards GHG (Mt)	California Standards GHG Reduced (Mt)	California Standards Percent GHG Change	California Standards Percent VKT Change	CAFE/ CAFC Cumulative GHG Reduced (Mt)	California Standards Cumulative GHG Reduced (Mt)
2005	9.64	9.64	0.00	0.0%	0.0%	9.64	0.00	0.0%	0.0%	0.00	0.00
2006	9.68	9.68	0.00	0.0%	0.0%	9.68	0.00	0.0%	0.0%	0.00	0.00
2007	9.76	9.76	0.00	0.0%	0.0%	9.76	0.00	0.0%	0.0%	0.00	0.00
2008	9.94	9.94	0.00	0.0%	0.0%	9.94	0.00	0.0%	0.0%	0.00	0.00
2009	10.11	10.11	0.00	0.0%	0.0%	10.11	0.00	0.0%	0.0%	0.00	0.00
2010	10.27	10.27	0.00	0.0%	0.0%	10.27	0.00	0.0%	0.0%	0.00	0.00
2011	10.44	10.42	0.02	-0.2%	+0.0%	10.39	0.05	-0.5%	+0.0%	0.02	0.05
2012	10.61	10.54	0.08	-0.7%	+0.1%	10.43	0.18	-1.7%	+0.2%	0.09	0.23
2013	10.80	10.62	0.17	-1.6%	+0.2%	10.47	0.33	-3.0%	+0.3%	0.27	0.56
2014	10.99	10.70	0.29	-2.7%	+0.3%	10.50	0.49	-4.5%	+0.4%	0.56	1.05
2015	11.06	10.53	0.53	-4.8%	+0.6%	10.38	0.68	-6.1%	+0.6%	1.09	1.73
2016	11.15	10.35	0.80	-7.2%	+0.8%	10.26	0.89	-7.9%	+0.8%	1.89	2.61
2017	11.26	10.19	1.07	-9.5%	+1.1%	10.14	1.12	-10.0%	+1.0%	2.96	3.74
2018	11.40	10.06	1.35	-11.8%	+1.4%	10.00	1.40	-12.3%	+1.2%	4.31	5.14
2019	11.56	9.93	1.63	-14.1%	+1.6%	9.87	1.70	-14.7%	+1.5%	5.94	6.83
2020	11.74	9.82	1.91	-16.3%	+1.9%	9.74	2.00	-17.0%	+1.7%	7.85	8.83
2021	11.93	9.74	2.19	-18.4%	+2.1%	9.63	2.30	-19.3%	+1.9%	10.04	11.13
2022	12.13	9.67	2.46	-20.3%	+2.3%	9.55	2.59	-21.3%	+2.2%	12.51	13.72
2023	12.35	9.62	2.73	-22.1%	+2.5%	9.48	2.87	-23.2%	+2.4%	15.24	16.58
2024	12.58	9.59	2.99	-23.8%	+2.7%	9.44	3.14	-24.9%	+2.5%	18.23	19.72
2025	12.82	9.58	3.24	-25.3%	+2.9%	9.42	3.40	-26.5%	+2.7%	21.47	23.12
2026	13.07	9.58	3.49	-26.7%	+3.0%	9.41	3.66	-28.0%	+2.8%	24.96	26.79
2027	13.34	9.60	3.73	-28.0%	+3.2%	9.43	3.91	-29.3%	+3.0%	28.69	30.69
2028	13.61	9.65	3.96	-29.1%	+3.3%	9.47	4.14	-30.4%	+3.1%	32.66	34.84
2029	13.89	9.71	4.18	-30.1%	+3.4%	9.53	4.37	-31.4%	+3.2%	36.84	39.21
2030	14.19	9.80	4.39	-30.9%	+3.5%	9.61	4.57	-32.2%	+3.3%	41.23	43.78
2031	14.49	9.88	4.61	-31.8%	+3.6%	9.70	4.79	-33.1%	+3.4%	45.84	48.57
2032	14.81	10.01	4.80	-32.4%	+3.7%	9.83	4.98	-33.6%	+3.4%	50.63	53.55
2033	15.13	10.16	4.97	-32.9%	+3.7%	9.98	5.15	-34.1%	+3.5%	55.61	58.70
2034	15.47	10.33	5.14	-33.2%	+3.8%	10.15	5.32	-34.4%	+3.5%	60.75	64.02
2035	15.82	10.50	5.32	-33.6%	+3.8%	10.30	5.51	-34.9%	+3.5%	66.07	69.53
2036	16.17	10.69	5.48	-33.9%	+3.9%	10.48	5.69	-35.2%	+3.6%	71.55	75.22
2037	16.54	10.90	5.64	-34.1%	+3.9%	10.70	5.85	-35.3%	+3.6%	77.19	81.07
2038	16.92	11.13	5.79	-34.2%	+3.9%	10.92	6.00	-35.4%	+3.6%	82.98	87.07
2039	17.29	11.32	5.97	-34.5%	+3.9%	11.14	6.15	-35.6%	+3.6%	88.95	93.22
2040	17.69	11.57	6.11	-34.6%	+3.9%	11.38	6.30	-35.6%	+3.6%	95.06	99.52
2041	18.09	11.83	6.26	-34.6%	+3.9%	11.63	6.46	-35.7%	+3.6%	101.32	105.98
2042	18.51	12.10	6.41	-34.6%	+3.9%	11.89	6.62	-35.8%	+3.6%	107.73	112.60
2043	18.93	12.37	6.56	-34.7%	+3.9%	12.16	6.77	-35.8%	+3.6%	114.30	119.37
2044	19.37	12.65	6.72	-34.7%	+3.9%	12.43	6.93	-35.8%	+3.6%	121.02	126.30
2045	19.81	12.94	6.87	-34.7%	+3.9%	12.72	7.09	-35.8%	+3.6%	127.89	133.39
2046	20.27	13.23	7.03	-34.7%	+3.9%	13.02	7.25	-35.8%	+3.6%	134.92	140.64
2047	20.73	13.54	7.19	-34.7%	+3.9%	13.32	7.42	-35.8%	+3.6%	142.12	148.06
2048	21.21	13.85	7.36	-34.7%	+3.9%	13.62	7.58	-35.8%	+3.6%	149.48	155.64
2049	21.69	14.17	7.53	-34.7%	+3.9%	13.94	7.76	-35.8%	+3.6%	157.00	163.40
2050	22.19	14.49	7.70	-34.7%	+3.9%	14.26	7.94	-35.8%	+3.6%	164.71	171.34

Figure 36. 500% Fuel Price Increase Emissions

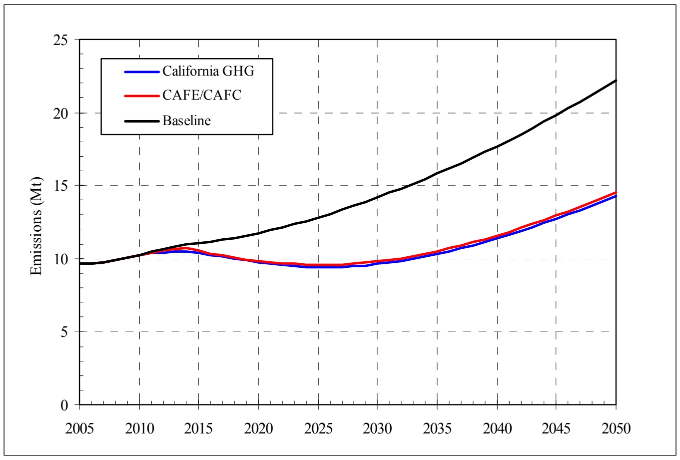


Figure 37. 500% Fuel Price Increase Reductions

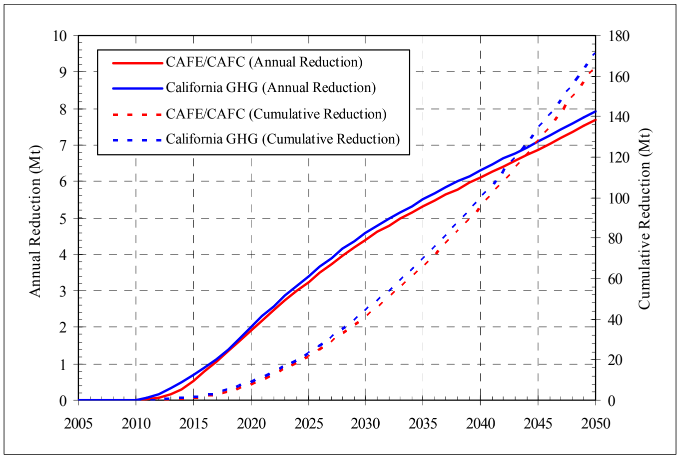
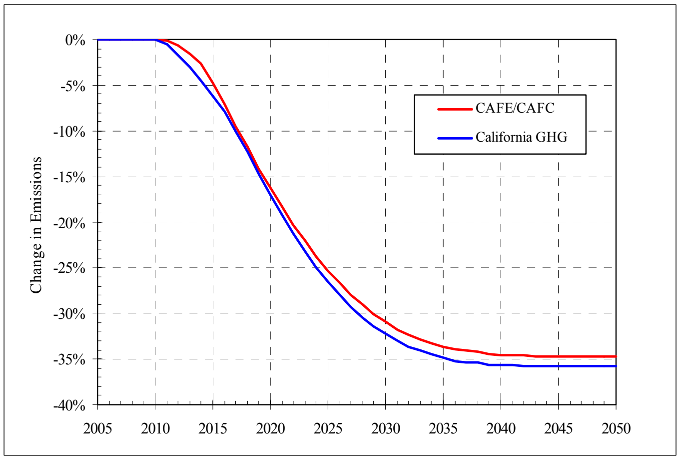


Figure 38. 500% Fuel Price Increase Change



3.11 The Maximum Potential CAFE/CAFC Backsliding Sensitivity Analysis

The "maximum potential CAFE/CAFC backsliding" sensitivity analysis makes the following assumptions relative to CAFE/CAFC and California GHG program uncertainties:

- The effective average footprint of the subject vehicle fleet is increased beginning in vehicle model year 2011 to a value that invokes the least stringent CAFC/CAFC standards. For passenger cars, the effective footprint was set at 47.4 square feet (4.4 square meters), while that for light duty trucks was set at 70 square feet (6.5 square meters). Since CAFE/CAFC standards decrease in stringency as vehicle footprint increases (up to a specific maximum vehicle footprint), this allows for the minimum possible CAFE/CAFE emissions impacts to be assessed. For *domestic* passenger cars, the CAFE/CAFC program includes a backstop that limits the decrease in CAFE/CAFC standard due to increasing footprint to 92 percent of the forecasted fleet average standard. This analysis assumes that import passenger car manufacturers will also achieve this minimal efficiency level to remain competitive, even though there is no statutory requirement that they do so. The passenger car footprint for this scenario has been set to maintain the 92 percent ratio (i.e., lower CAFE/CAFC passenger car standards are feasible based on the defined logistic parameters for the passenger car standards, but setting the scenario standards at such levels would violate the statutory backstop).

  Under this sensitivity scenario, vehicles are assumed to remain within their baseline classes, so that no vehicle sales shift from an LDT1 status to an LDT2, LDT3, or LDT4 status and no passenger car sales shift to light duty truck status, either of which would invoke less stringent fleet average California GHG standards. Thus this sensitivity analysis reflects minimum CAFE/CAFC impacts while holding California GHG standard impacts constant. The scenario is *not* meant to reflect actual market conditions, but rather serve to define the bounding relationship between the two programs. Clearly, the likelihood that all LDT1 will grow to a size of 10 by 7 feet (3.0 by 2.1 meters), while simultaneously staying below the maximum weight that will allow them to stay within in the LDT1 class, is improbable. This case is deigned to illustrate the potential *maximum* impacts of footprint increases under the CAFE/CAFC program, not reflect a market case of any given likelihood. *(The reference case assumes an effective footprint that is unchanged from baseline forecast conditions.)*

- The fraction of manufacturers taking air conditioning load reduction credits under the California GHG program is 100 percent. While this may overstate such credits in the near term, it is likely that these credits will be fully utilized at some point due to the cost effectiveness of air conditioning improvements. *(Same as reference case.)*

- The fraction of manufacturers taking air conditioning refrigerant leakage credits under the California GHG program is 100 percent. While this may overstate such credits in the near term, it is likely that these credits will be fully utilized at some point due to the cost effectiveness of air conditioning improvements. *(Same as reference case.)*

- VKT is assumed to grow in accordance with the CEO2006 forecast for British Columbia. *(Same as reference case.)*

- CAFE/CAFC standards for model years 2011 through 2015 are as defined in the CAFE/CAFC NPRM. Standards for model years 2016 through 2020 are developed under an assumption that passenger cars and light duty truck standards increase by the same constant percentage annually to attain a combined 35 mpg (6.7 lit/100km) target in model year 2020. *(Same as reference case.)*

- The fraction of manufacturers taking AFV credits under the CAFE/CAFC program is 100 percent. While this may overstate such credits in the near term, the effect over the long term is null in terms of annual reductions and minimal in terms of cumulative reductions since such credits are eliminated under the CAFE/CAFC program beginning in model year 2020. *(Same as reference case.)*

Table 15 and Figures 39 through 41 depict the results of the "maximum potential CAFE/CAFC backsliding" sensitivity analysis. Under this analysis, the California GHG program outperforms the CAFE/CAFC program in terms of GHG emission reductions by a very wide margin. By 2020, the California program reduces annual GHG emissions from light duty vehicles by 15.9 percent as compared to 4.3 percent for the CAFE/CAFC program. Year 2050 emissions, which reflect the long term stabilization of both programs, reflect annual reductions of 33.4 percent under the California program as compared to 15.3 percent under CAFE/CAFC. In effect, the California program produces annual reductions that are over 115 percent higher than those of the CAFE/CAFC program. In terms of cumulative reductions, the California program will have eliminated nearly 174 Mt of GHG by 2050, as compared to 74 Mt for the CAFE/CAFC program (i.e., backsliding under the CAFE/CAFC program could theoretically reduce cumulative CAFE/CAFC program reductions under a worst case scenario by about 48 Mt by 2050).

Although actual backsliding effects are likely to be smaller, it is clear that vehicle manufacturers can tradeoff the cost of increasing vehicle footprint against the cost of increasing fuel efficiency under the CAFE/CAFC program. No such allowance exists under the California GHG program, short of shifting sales out of the passenger car class and into the light duty truck class. While the potential for such class shifting is not to be taken lightly given the historic shifts that have occurred precisely to reduce CAFE/CAFC burdens, it is important to note that this same incentive exists under both the CAFE/CAFC and California GHG programs.

3.12 Analysis Scenario Summary

Table 16 presents a summary of the near and long term statistics discussed in the previous sections. The previous sections include more detailed tables and charts for each scenario, and the reader should consult those for additional analysis results. It is clear that the California GHG program generally provides GHG emission reductions that exceed those of the CAFE/CAFC program under any realistic set of analysis conditions, and in most cases, exceed CAFE/CAFC induced emission reductions by a wide margin.

Table 15. Emissions Impact Estimates for the CAFE/CAFC Backsliding Analysis

Calendar Year July 1 Fleet	Baseline LDV LDT MDPV GHG (Mt)	CAFE/ CAFC GHG (Mt)	CAFE/ CAFC GHG Reduced (Mt)	CAFE/ CAFC Percent GHG Change	CAFE/ CAFC Percent VKT Change	California Standards GHG (Mt)	California Standards GHG Reduced (Mt)	California Standards Percent GHG Change	California Standards Percent VKT Change	CAFE/ CAFC Cumulative GHG Reduced (Mt)	California Standards Cumulative GHG Reduced (Mt)
2005	9.63	9.63	0.00	0.0%	0.0%	9.63	0.00	0.0%	0.0%	0.00	0.00
2006	9.67	9.67	0.00	0.0%	0.0%	9.67	0.00	0.0%	0.0%	0.00	0.00
2007	9.75	9.75	0.00	0.0%	0.0%	9.75	0.00	0.0%	0.0%	0.00	0.00
2008	9.93	9.93	0.00	0.0%	0.0%	9.93	0.00	0.0%	0.0%	0.00	0.00
2009	10.10	10.10	0.00	0.0%	0.0%	10.10	0.00	0.0%	0.0%	0.00	0.00
2010	10.27	10.27	0.00	0.0%	0.0%	10.27	0.00	0.0%	0.0%	0.00	0.00
2011	10.44	10.53	-0.09	+0.8%	-0.1%	10.40	0.04	-0.4%	+0.0%	-0.09	0.04
2012	10.62	10.76	-0.15	+1.4%	-0.1%	10.46	0.16	-1.5%	+0.2%	-0.23	0.20
2013	10.80	10.96	-0.16	+1.4%	-0.1%	10.50	0.30	-2.8%	+0.3%	-0.39	0.51
2014	11.00	11.14	-0.14	+1.3%	-0.1%	10.54	0.46	-4.2%	+0.4%	-0.53	0.97
2015	11.20	11.29	-0.09	+0.8%	-0.1%	10.57	0.63	-5.6%	+0.5%	-0.62	1.60
2016	11.42	11.44	-0.01	+0.1%	+0.0%	10.60	0.83	-7.2%	+0.7%	-0.63	2.42
2017	11.65	11.56	0.09	-0.8%	+0.1%	10.59	1.06	-9.1%	+0.9%	-0.54	3.48
2018	11.89	11.68	0.21	-1.8%	+0.3%	10.55	1.34	-11.3%	+1.1%	-0.33	4.82
2019	12.14	11.77	0.36	-3.0%	+0.4%	10.49	1.65	-13.6%	+1.4%	0.04	6.47
2020	12.39	11.86	0.53	-4.3%	+0.5%	10.43	1.97	-15.9%	+1.6%	0.57	8.44
2021	12.66	11.96	0.70	-5.5%	+0.7%	10.38	2.28	-18.0%	+1.8%	1.27	10.72
2022	12.93	12.06	0.87	-6.7%	+0.8%	10.35	2.58	-20.0%	+2.0%	2.14	13.30
2023	13.21	12.19	1.03	-7.8%	+1.0%	10.34	2.88	-21.8%	+2.2%	3.16	16.17
2024	13.50	12.32	1.18	-8.7%	+1.1%	10.34	3.16	-23.4%	+2.4%	4.34	19.33
2025	13.80	12.48	1.33	-9.6%	+1.2%	10.37	3.43	-24.9%	+2.5%	5.67	22.76
2026	14.11	12.64	1.47	-10.4%	+1.3%	10.42	3.70	-26.2%	+2.7%	7.14	26.46
2027	14.43	12.82	1.61	-11.2%	+1.4%	10.48	3.95	-27.4%	+2.8%	8.76	30.41
2028	14.76	13.01	1.75	-11.8%	+1.4%	10.57	4.19	-28.4%	+2.9%	10.50	34.60
2029	15.09	13.22	1.87	-12.4%	+1.5%	10.68	4.42	-29.3%	+3.0%	12.38	39.02
2030	15.44	13.44	1.99	-12.9%	+1.6%	10.81	4.63	-30.0%	+3.1%	14.37	43.65
2031	15.79	13.67	2.12	-13.4%	+1.6%	10.94	4.85	-30.7%	+3.1%	16.49	48.49
2032	16.15	13.92	2.23	-13.8%	+1.7%	11.11	5.04	-31.2%	+3.2%	18.71	53.54
2033	16.52	14.19	2.33	-14.1%	+1.7%	11.29	5.23	-31.6%	+3.2%	21.04	58.76
2034	16.90	14.48	2.42	-14.3%	+1.7%	11.49	5.40	-32.0%	+3.3%	23.46	64.17
2035	17.29	14.79	2.50	-14.5%	+1.7%	11.69	5.60	-32.4%	+3.3%	25.96	69.76
2036	17.69	15.09	2.60	-14.7%	+1.8%	11.91	5.78	-32.7%	+3.3%	28.56	75.54
2037	18.10	15.40	2.69	-14.9%	+1.8%	12.15	5.95	-32.9%	+3.4%	31.26	81.49
2038	18.51	15.74	2.78	-15.0%	+1.8%	12.41	6.11	-33.0%	+3.4%	34.03	87.60
2039	18.94	16.08	2.86	-15.1%	+1.8%	12.67	6.27	-33.1%	+3.4%	36.90	93.86
2040	19.38	16.44	2.94	-15.2%	+1.8%	12.95	6.43	-33.2%	+3.4%	39.84	100.30
2041	19.83	16.81	3.02	-15.2%	+1.8%	13.23	6.60	-33.3%	+3.4%	42.86	106.90
2042	20.29	17.19	3.10	-15.3%	+1.8%	13.52	6.77	-33.3%	+3.4%	45.96	113.66
2043	20.76	17.58	3.18	-15.3%	+1.8%	13.83	6.93	-33.4%	+3.4%	49.14	120.59
2044	21.24	17.98	3.26	-15.4%	+1.8%	14.14	7.09	-33.4%	+3.4%	52.40	127.69
2045	21.73	18.39	3.34	-15.4%	+1.8%	14.47	7.26	-33.4%	+3.4%	55.74	134.94
2046	22.23	18.82	3.41	-15.4%	+1.8%	14.81	7.43	-33.4%	+3.4%	59.15	142.37
2047	22.75	19.26	3.49	-15.4%	+1.8%	15.15	7.60	-33.4%	+3.4%	62.64	149.97
2048	23.28	19.70	3.57	-15.3%	+1.8%	15.50	7.77	-33.4%	+3.4%	66.22	157.74
2049	23.81	20.16	3.66	-15.3%	+1.8%	15.86	7.95	-33.4%	+3.4%	69.87	165.70
2050	24.37	20.63	3.74	-15.3%	+1.8%	16.23	8.14	-33.4%	+3.4%	73.61	173.84

Figure 39. CAFE/CAFC Backsliding Emissions

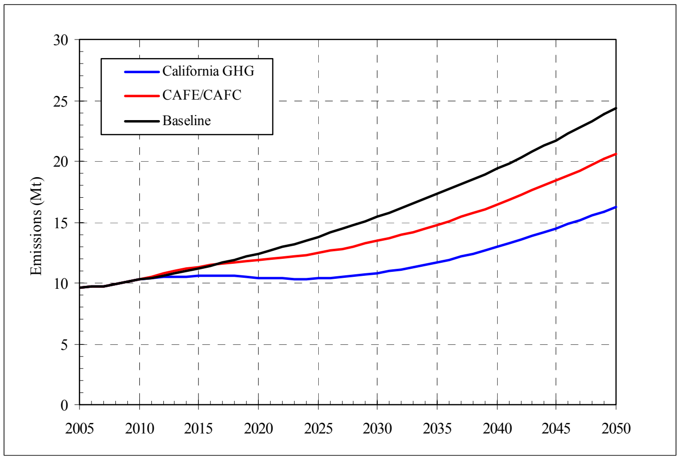


Figure 40. CAFE/CAFC Backsliding Reductions

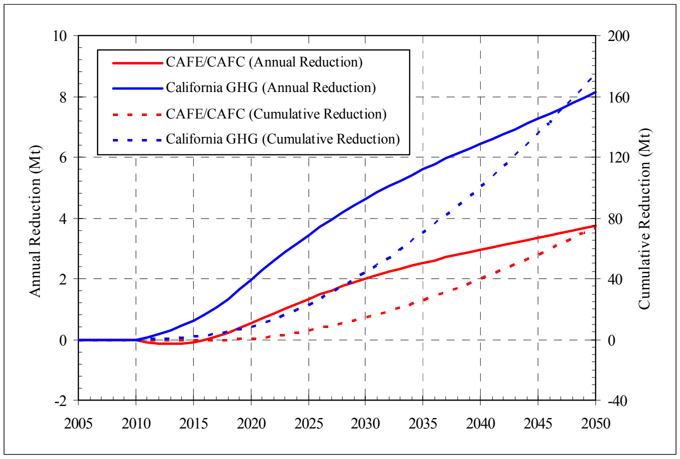


Figure 41. CAFE/CAFC Backsliding Change

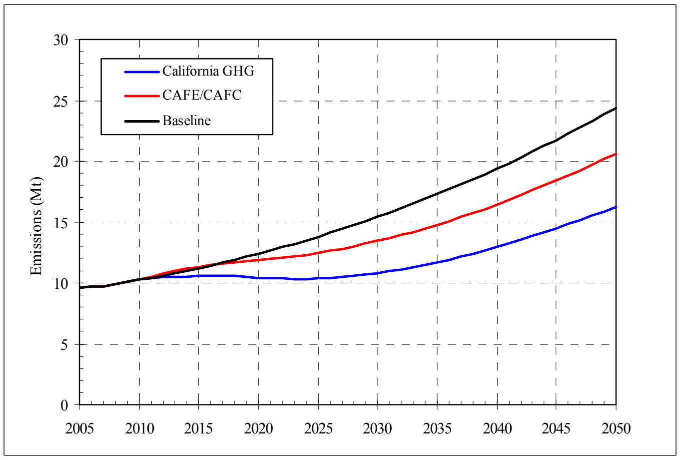


Table 16. GHG Emission Reduction Summary

Analysis Case	Annual GHG Reduction					Cumulative Reduction	
	CAFE/ CAFC (Mt)	California GHG (Mt)	California to CAFE/ CAFC	CAFE/ CAFC	California GHG	CAFE/ CAFC (Mt)	California GHG (Mt)
Calendar Year 2020							
Reference	1.37	1.98	+44.5%	11.0%	15.9%	5.76	8.53
No AFV Credit	1.52	1.98	+30.3%	12.2%	16.0%	7.02	8.56
FEIS	1.01	1.97	+95.0%	8.2%	15.9%	2.99	8.48
No A/C Credit	1.37	2.03	+48.2%	11.0%	16.4%	5.76	8.84
Low Growth	1.17	1.69	+44.4%	11.0%	15.9%	5.09	7.54
Min Footprint/No Shift	2.43	1.99	-18.1%	19.6%	16.1%	12.45	8.66
Crossover/No Shift	2.36	1.99	-15.7%	19.1%	16.0%	12.01	8.65
100% Fuel Price Increase	1.64	1.98	+20.7%	13.5%	16.3%	6.78	8.62
200% Fuel Price Increase	1.78	1.99	+11.8%	14.8%	16.5%	7.31	8.68
500% Fuel Price Increase	1.91	2.00	+4.7%	16.3%	17.0%	7.85	8.83
CAFE/CAFC Backsliding	0.53	1.97	+271.7%	4.3%	15.9%	0.57	8.44
Calendar Year 2050							
Reference	5.72	8.14	+42.3%	23.5%	33.4%	121.80	174.01
No AFV Credit	5.72	8.14	+42.3%	23.5%	33.4%	124.26	174.06
FEIS	5.71	8.14	+42.6%	23.4%	33.4%	115.88	173.91
No A/C Credit	5.72	8.32	+45.5%	23.5%	34.2%	121.80	178.13
Low Growth	3.40	4.84	+42.4%	23.5%	33.4%	84.26	120.50
Min Footprint/No Shift	8.27	8.14	-1.6%	34.0%	33.4%	183.88	174.24
Crossover/No Shift	8.11	8.14	+0.4%	33.3%	33.4%	179.93	174.23
100% Fuel Price Increase	6.73	8.04	+19.5%	28.6%	34.2%	143.62	172.65
200% Fuel Price Increase	7.25	7.99	+10.2%	31.4%	34.6%	154.74	171.81
500% Fuel Price Increase	7.70	7.94	+3.1%	34.7%	35.8%	164.71	171.34
CAFE/CAFC Backsliding	3.74	8.14	+117.6%	15.3%	33.4%	73.61	173.84

The technology “forcing” aspects of the CAFE/CAFC and California GHG program futures are similar, but the California GHG program will generally push technology implementation further due to the need to achieve more aggressive GHG reduction targets. Moreover, technologies that are implemented under the California GHG program will need to be considered more carefully from a GHG perspective than those under the CAFE/CAFC program. For example, diesel vehicle technology carries no “penalty” under the CAFE/CAFC program since the program treats a liter of diesel fuel as equivalent to a liter of gasoline. However, under the California program, the extra carbon contained in that liter of diesel fuel[32] will have to be accounted for.

---

[32] Diesel fuel generally contains about 15 percent more carbon per liquid volume. Diesel vehicles are also generally more efficient than gasoline vehicles, so there is a net carbon reduction associated with diesel fuel use. However, that reduction is lower than would be the case if the same level of efficiency were attained with gasoline.

While the California GHG program functions as a superior low carbon fuel incentive (since fuel carbon is explicitly accounted for under the program, while alternative fuel incentives under CAFE/CAFC are carbon independent and scheduled to be phased-out entirely by model year 2020), the specific near term technologies that are expected to be employed for compliance under the two alternatives are similar (albeit at different penetration rates as required by the stringency of the alternative standards). Such technologies include:

- improved lubricants and materials to reduce internal engine friction,
- improved intake and exhaust valve controls (in various configurations and designs),
- gasoline direct injection technology (in both stoichiometric and stratified lean burn configurations),
- turbocharging (and associated engine downsizing),
- cylinder deactivation systems,
- advanced transmission technology, including improved automatic transmission designs with significantly more speed ratios, "automated manual" designs (transmissions that are similar to manual transmissions in that they utilize clutches and do not have a torque converter, but which are electronically controlled rather than manually shifted), and continuously variable transmissions,
- electronically controlled accessories and power steering,
- various levels of battery-electric hybridization (ranging from "simple" idle-off systems to electric-only drive capability),
- lower drag vehicle designs, and
- lower rolling resistance tires.

Variable valve timing and/or lift systems (of varying complexities) are expected to achieve near universal application in the first few years of either the CAFE/CAFC or California GHG programs. Gasoline direct injection (GDI) technology will likely attain a penetration rate of 30 percent or more for both passenger cars and light duty trucks by model year 2015 and rates should continue to increase thereafter. Turbocharging, either alone or more likely in conjunction with GDI technology will similarly gain significant market share in the passenger car and smaller light truck segments, but will likely see limited application in the larger truck segments where designs tend to support extended periods of continuous high load operation. In these segments, and well as the larger passenger car segment, cylinder deactivation technology should provide efficiency benefits that are similar to turbocharged GDI technology. Advanced transmission technology, with a longer term move to automated manual technology, will become the standard transmission technology for both passenger cars and light duty trucks in the first few years of either the CAFE/CAFC or California GHG programs. More efficient accessories and electronic power steering will also become universal, as will idle-off and regenerative braking hybrid technology. As standards become more stringent, more advanced hybrid designs (including plug-in designs) will also penetrate the passenger car and light truck markets at greater rates.

Because most of these technologies scale efficiently across the entire range of light duty vehicles, the effect of potential changes in vehicle size (reflected either as changes in average vehicle footprint or changes in the market shares of the various light duty vehicle subclasses) is not likely to significantly alter the compliance strategies of vehicle manufacturers. Possible exceptions are limited, but include turbocharged GDI technology, which could be used to a greater extent in a downsizing market and to a lesser extent in upsizing conditions. Cylinder deactivation technology would likely exhibit the opposite trend since engine downsizing would likely accompany vehicle downsizing, and smooth transitions between cylinder de- and re-activation require a certain minimum number of cylinders (i.e., application on four cylinder engines is unlikely). Thus, for market conditions such as those observed in 2008 where consumer demand for small, efficient four cylinder engine designs increases, cylinder deactivation technology would likely give way to turbocharged GDI technology. Of course, the overall penetration rate of all technologies could decline somewhat in a downsizing market since smaller vehicles with smaller engines are inherently more efficient than the larger vehicles they displace, effectively diminishing the overall stringency of any standard that was developed under the assumption of a different vehicle market. Other technologies that might benefit from increased demand in smaller vehicles are continuously variable transmission technologies that can provide more reliable service in less demanding applications, and more complex hybrid systems due to both battery size, performance, and associated costs that can (currently) be limiting for larger vehicle applications.

Only the California GHG program promotes alternative air conditioning technology, which can provide significant GHG reduction benefits. More efficient air conditioning components, as well as improved conditioned air management systems, offer the potential to dramatically reduce the load that the air conditioning system places on a vehicle engine, providing for significant GHG reductions when the system is operational. Improved system design also has the potential to significantly reduce refrigerant leakage, providing both performance benefits and additional GHG reduction. Finally alternative, reduced global warming potential, refrigerants have the capability of reducing the GHG impacts of refrigerant leakage by 99 percent or more. The CAFE/CAFC alternative provides no incentive for such technology development.

In summary, both the CAFE/CAFC and California GHG programs offer the potential for significant GHG reductions from light duty vehicles. However, the California GHG program is superior, both in terms of design (since it regulates GHG directly) and stringency. Perhaps equally important is the fact that it is entirely likely that the very existence of the CAFE/CAFC program being evaluated in this analysis as an alternative to the California GHG program *is a direct response by U.S. federal regulators to the California program*. Prior to the adoption of the California GHG program, CAFE/CAFC passenger car standards had not changed since the 1985 model year (marking a full *quarter century* of inactivity before the more stringent standards are proposed to take effect beginning in vehicle model year 2011). Similarly, light duty truck standards changed by less than one percent between the 1987 and 2004 model years. An approximate seven percent reduction in light duty truck fuel consumption was implemented between the 2004 and 2007 model years, and that improvement was followed by a further eight percent reduction between the 2007 and 2011 model years -- but this latter reduction as well as the 2007 U.S. legislation that established the 35 mpg target, under which the CAFE/CAFC program alternative evaluated in this analysis was developed, were proposed only after California adopted their light duty vehicle GHG standards and applied for a federal waiver to allow associated enforcement. It can be no coincidence that after a full two years of indecision, the 2007 legislation (under which the CAFE/CAFC proposal was developed) was then used as an integral element of the justification for denying California (at least to date) its requested waiver.

Moreover, following this waiver decision, the very regulatory proposal required to implement the first few years of the CAFE/CAFC proposal has still not been finalized. There is no question that California action prompted the U.S. federal action that led to the CAFE/CAFC proposal and given California's history of promoting continuing motor vehicle technology advancement, it is likely that California regulators will continue to lead the way on this issue as GHG emission requirements for model year 2021 and later vehicles are evaluated.