Canadian New Light Duty Vehicles: Trends in fuel consumption and characteristics (1988-1998)

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Introduction

Fuel consumption improvements in light-duty vehicles continue to be a major area of public and policy interest. Light-duty vehicles produce about 15 percent of all of Canada's emissions of carbon dioxide (CO_2), the pollutant that is the most prevalent compound associated with global warming, in addition to other gases that affect air quality and health.

Although new vehicles are cleaner and more efficient than vehicles produced 20 years ago, trends show that there are increasing numbers of more powerful vehicles, including more light trucks, travelling greater distances on our roads. This leads to higher fuel consumption and increasing emissions of CO_2 into the atmosphere, which pose a challenge for decision-makers trying to reduce emissions in the road transportation sector.

In 1982 Parliament passed the *Motor Vehicle Fuel Consumption Standards Act* (MVFCSA) to reinforce its belief in the necessity of an effective fuel consumption program in Canada. At that time, the motor vehicle industry gave its assurance that it would endeavour to meet the Act's requirements on a voluntary basis, and the Act was not proclaimed. Since then, manufacturers have met annual fuel consumption goals and have provided the government with sufficient information on new vehicle characteristics and fuel consumption to monitor progress.

All of the information provided by auto manufacturers is collected thought Transport Canada's Vehicle Fuel Economy Information System (VFEIS). This database is designed to collect the detailed level of data that would be required to support a legislated fuel consumption program if the MVFCSA were to be proclaimed. VFEIS currently records detailed vehicle descriptions, general test results and production volumes for new light-duty motor vehicles (passenger cars, vans, trucks, and special-purpose vehicles) for each model year. This information is used to confirm manufacturers' advertised fuel consumption label values and to calculate Company Average Fuel Consumption (CAFC) values for individual companies and for the new vehicle fleet.

NRCan's Transportation Energy Use Division supplements VFEIS with technology and performance-related data obtained from Energy and Environmental Analysis Inc. in order to perform trend analysis of new vehicle fuel consumption and characteristics. The new vehicle characteristics that are examined include fuel consumption, performance, weight, engine characteristics, transmission types, and size classes. This poster session will draw from NRCan's Vehicle Information System (VIS) to present fuel consumption and technology trends from1988–98.

Trends in new light-duty fuel efficiency

This chapter summarizes key trends related to the fuel consumption of new vehicles produced for sale in Canada for model years 1979 through 1998. The data used for this analysis are described in Appendix "A."

Light-duty vehicles considered in this analysis include passenger cars and light-duty trucks with a gross vehicle weight of less than 3855 kg. The truck category includes sport-utility vehicles, minivans, vans, and two- and four-wheel drive pickup trucks.

BACKGROUND

Prior to the 1973 oil crisis, vehicles were designed without any particular concern for fuel consumption. However, in most non-OPEC countries, the political consequences of the 1973 crisis and subsequent shortages in oil supply prompted steps to encourage and to force the production of more fuel-efficient cars. The United States and Canada implemented fleet standards and goals, respectively, while Europe and Asia favoured fuel taxation.

Today, as the theoretical life of the proven world petroleum reserves has risen to 41 years[1] compared to the 28 years predicted in 1980, the driving force for improved fuel economy has shifted more to concerns about emissions of greenhouse gases, primarily CO_2, and their effect on global climate change.

Fuel consumption improvements continue to be a major area of public and policy interest for two principal reasons:

(1) Light-duty vehicles contribute about 15 percent of all Canadian CO_2 emissions[2]. Vehicle fuel consumption is directly related to the emission of CO_2, the most prevalent compound associated with global warming.

(2) Most light-duty vehicles use petroleum products as fuel, and account for approximately 34 percent of all Canadian oil consumption[3].

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[1]Source: *BP AMOCO Statistical Review of World Energy 1999*

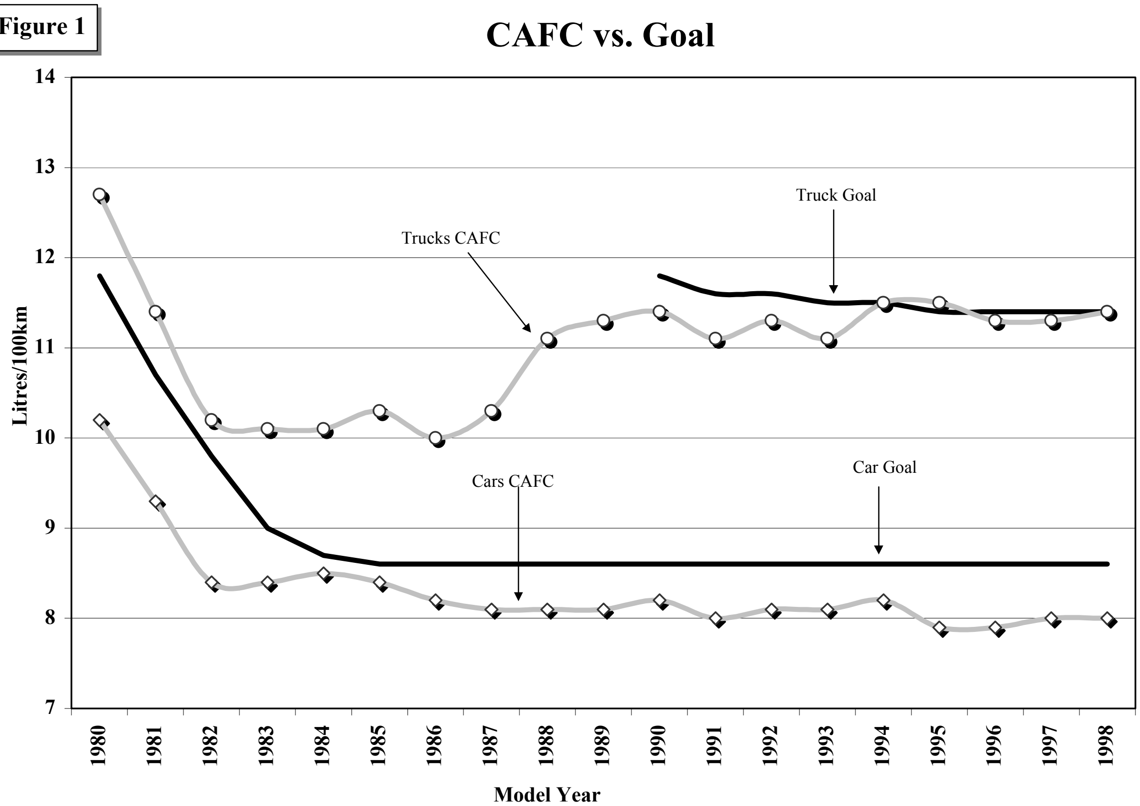
[2]Source: *Trends in Canada's Greenhouse Gas Emissions 1990–1997*; Environment Canada

[3]Source: *Quarterly Report on Energy Supply-Demand in Canada*; Statistics Canada,1997

CANADIAN VEHICLE FUEL CONSUMPTION TRENDS

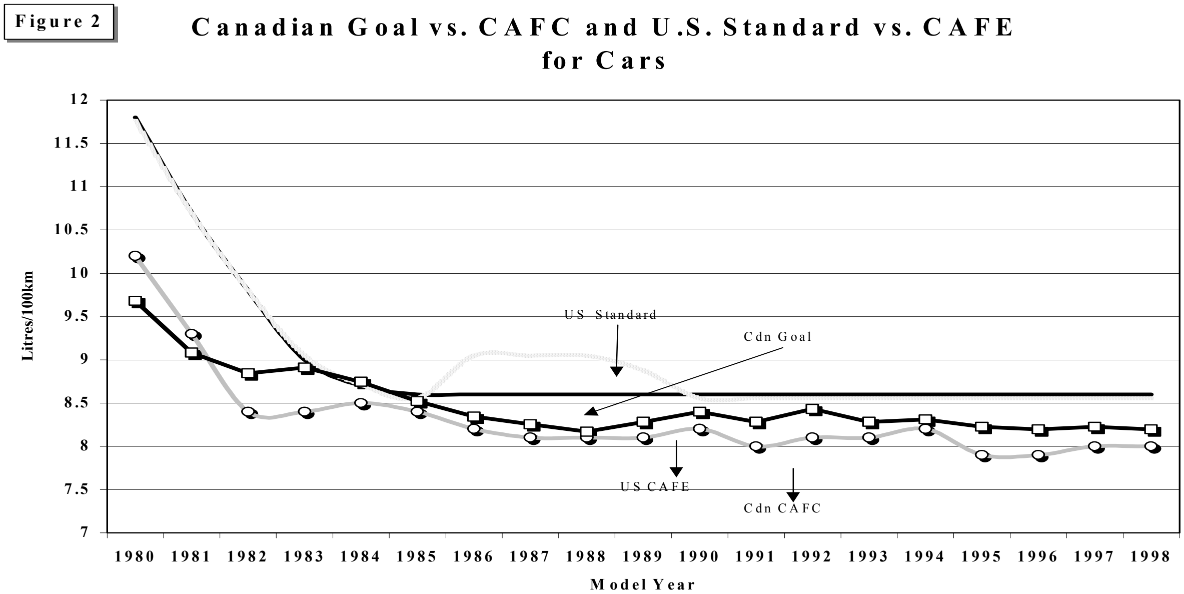
Under the guidelines of the Voluntary Fuel Consumption Program, vehicle manufacturers committed to meet Canadian Company Average Fuel Consumption (CAFC) goals for new passenger car and light-duty truck fleets if they were not more stringent than the standards legislated in the U.S. (see figure 1).

Figure 1



The Canadian voluntary goals were harmonized with the U.S. standards and are currently 8.6 L/100 km for the new passenger car fleet and 11.4 L/100 km for the new light-duty truck fleet. When the truck CAFC goal was instituted over 10 years ago, most trucks were used for commercial purposes only and for this reason were allowed a more lenient CAFC requirement.

On average, vehicle manufacturers have met and improved upon the CAFC goals, although several individual companies have not. In 1994, however, the Canadian light-duty truck fleet as a whole failed to meet the standard by nearly two percent. In the early 1980s, manufacturers improved fuel efficiency primarily by reducing vehicle weight and friction, reducing engine displacement and final drive ratios and improving engines and aerodynamics. In the early days of the program, and primarily in response to increasing fuel prices, market demand shifted towards smaller, more fuel-efficient vehicles. However, a decrease in the real price of gasoline since the mid-1980s, and improvements in vehicle technology have resulted in a market shift back to larger vehicles.



Figures 2 and 3 compare the Canadian and U.S. fleet averages for new passenger cars and light-duty trucks. Since 1979 the Canadian average new vehicle fleet fuel consumption has been marginally better than U.S. average by about 1.5 percent for cars, 1.5 percent for light-duty trucks and three percent for both combined (Figure 4). This could be partly related to the difference in the tax components (fuel, vehicle and income), and also to the different sales mix of vehicles in the two countries. The fuel efficiency requirement for cars is currently the same in both countries, although between 1986 and 1989 the U.S. CAFE was rolled back from its original legislated value and subsequently became less stringent than the Canadian CAFC. For those years the U.S. Secretary of Transportation exercised discretion allowed under the *Energy Policy and Conservation Act* of 1975 to reduce the standard by up to 1.5 mpg to accommodate U.S. domestic manufacturers that were unable to develop new technology quickly enough to meet the original schedule.

Figure 3

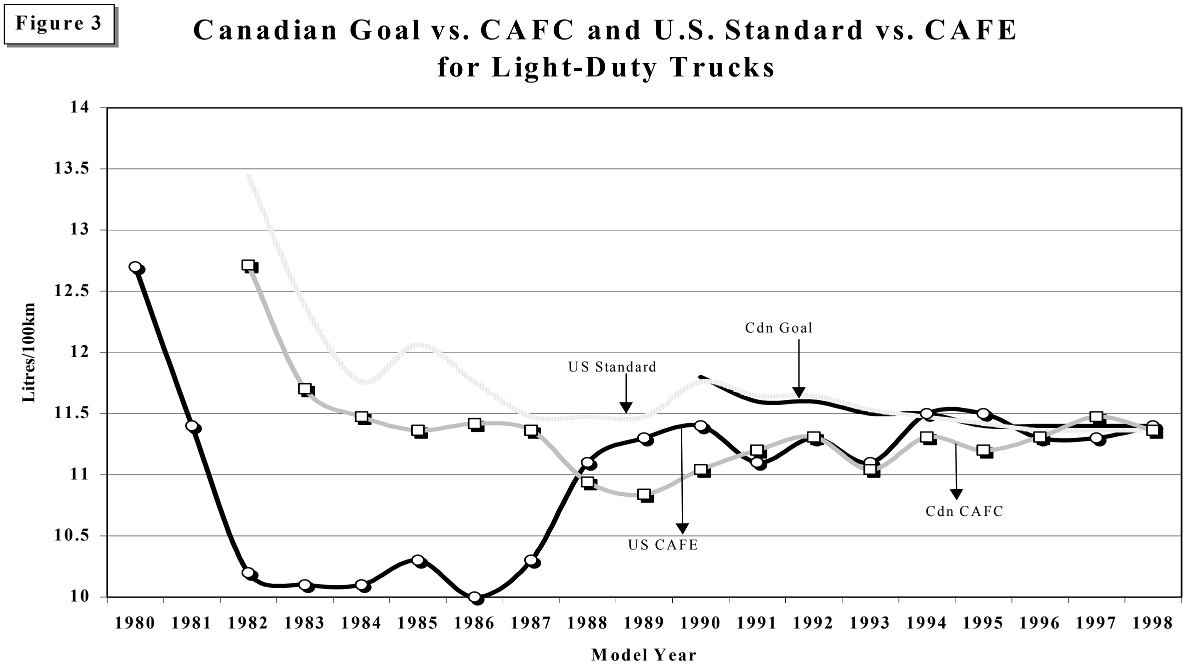
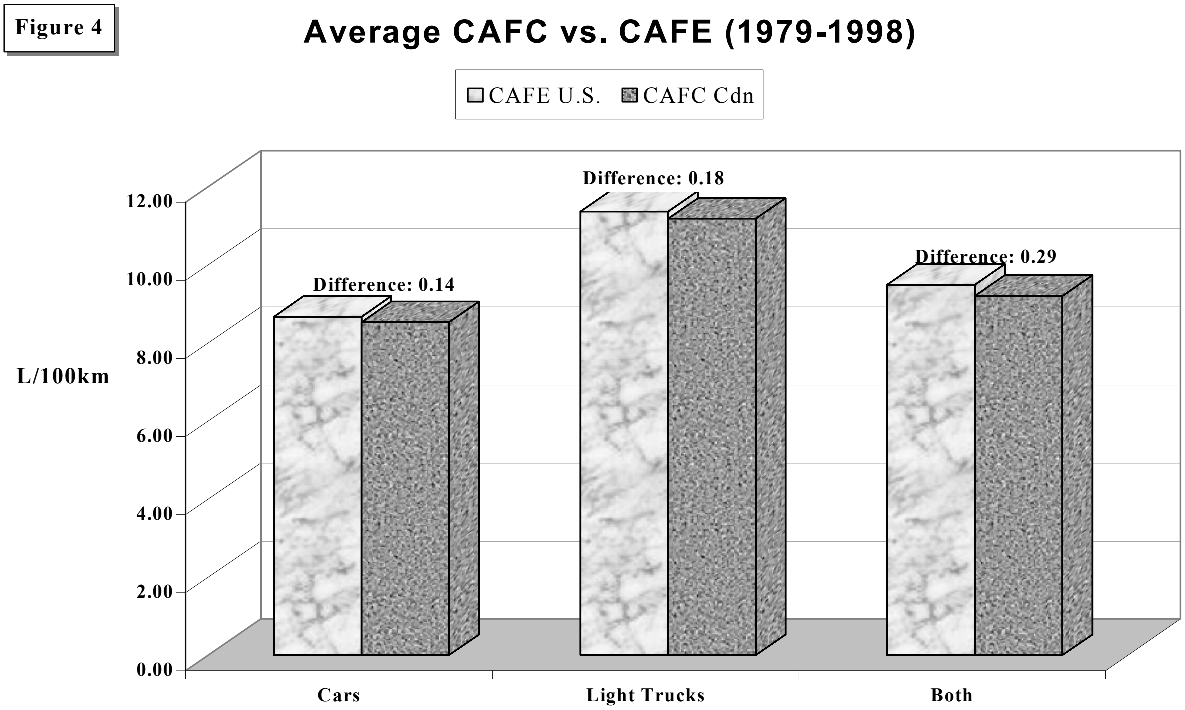
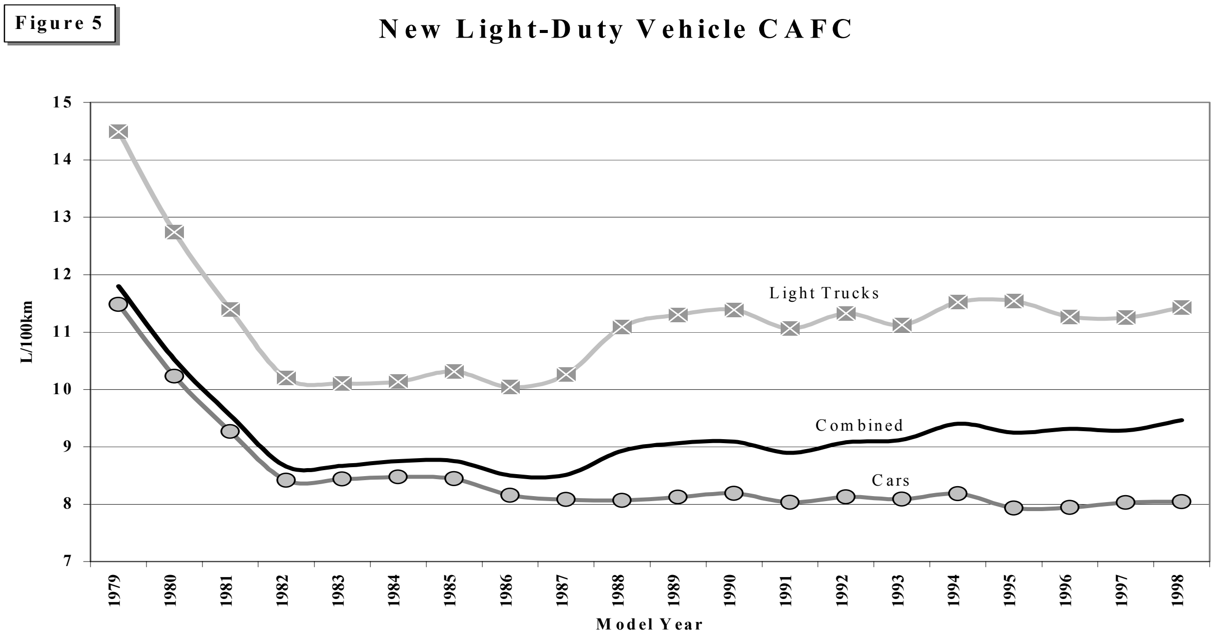


Figure 4



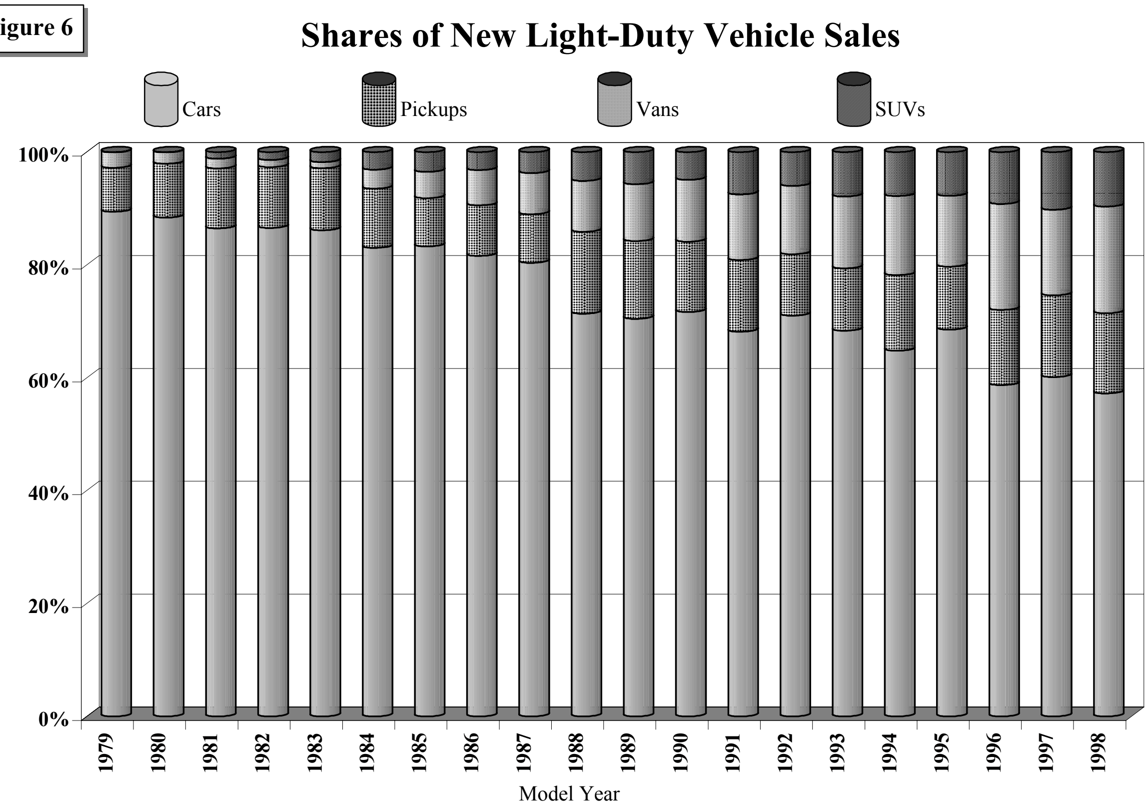
CANADIAN FLEET AVERAGE FUEL EFFICIENCY IS DETERIORATING

Figure 5



The combined fleet average fuel consumption of new light-duty vehicles improved steadily from the mid-1970s through the late 1980s, but has now started to rise. Viewed separately, the average fuel consumption for new passenger cars has been essentially flat since 1988, varying only between 7.9 L/100km and 8.2 L/100km, and now stands at 8.0 L/100km. Similarly, the average fuel consumption for new light-duty trucks has been largely unchanged since 1988, ranging from 11.1 L/100km to 11.5 L/100km, and is currently 11.4L/100km. However, the combined new vehicle fleet average has increased by an average of 0.1 L/100 km per year since 1993. For model year 1998, the CAFC for the Canadian new vehicle fleet was 9.5 L/(100 km) (Figure 5). The increasing market share of light-duty trucks (sport-utility vehicles (SUVs), vans and pickup trucks), which have a higher average fleet fuel consumption than cars, is an important reason for the increase in fuel consumption of the overall new light vehicle fleet. Sales of light-duty trucks (Figure 6) have risen steadily for 20 years and now make up 43 percent of the Canadian light vehicle market.

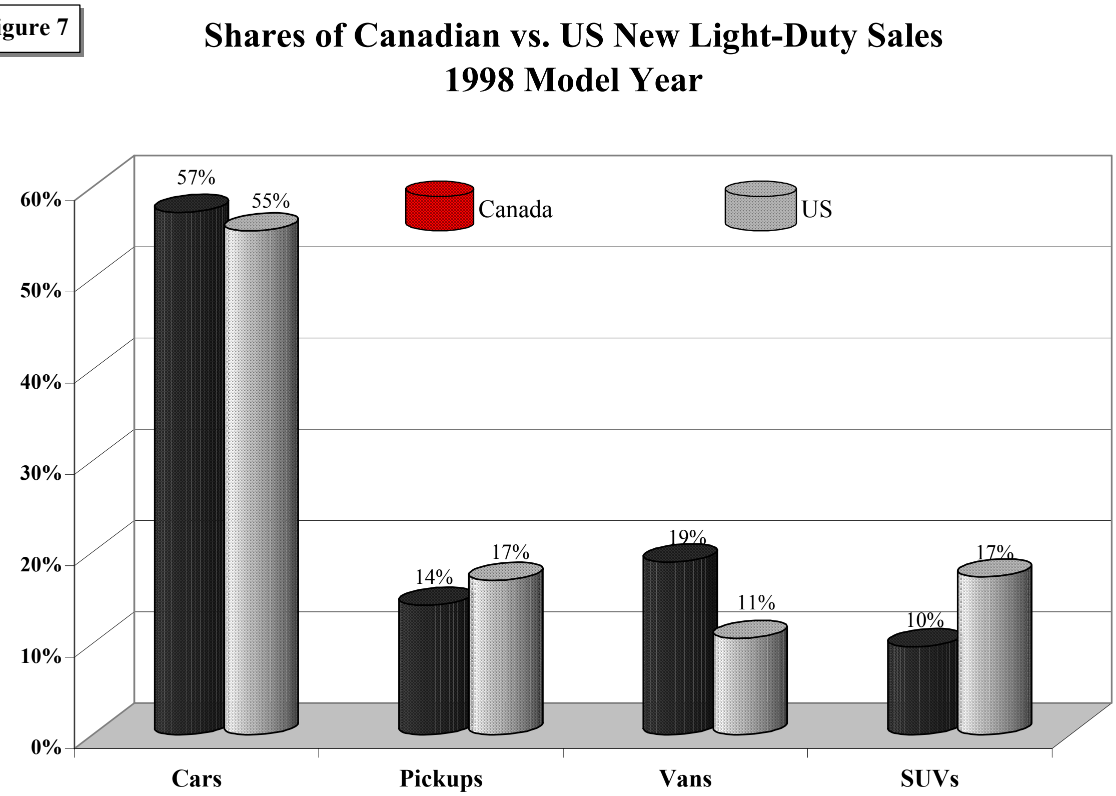
Figure 6



Growth in the light-duty truck market has recently been led by the explosive popularity of SUVs. SUV sales rose from less than 13 000 units in 1981 (less than one percent of the overall new light vehicle market) to more than 126 000 units in 1998 (10 percent of the market). Over the same period, the market share for minivans and full-size vans rose from two percent to 19 percent and for pickup trucks from 11 to14 percent. Between 1979 and 1998, the market share for new passenger cars and station wagons fell from 86 percent to 57 percent. This may be partially attributed to the fact that station wagons were no longer in demand as consumers switched to an alternative vehicle like a van or SUV.

The sales mix of cars, pickups, vans and SUVs between Canada and the U.S. is slightly different (Figure 7). For model year 1998, U.S. cars accounted for 55 percent of new vehicle sales compared to 57 percent in Canada. Thus Canadians purchased relatively fewer pickups (14 percent vs. 17 percent) and SUVs (10 percent vs. 17 percent) and more vans (19 percent vs. 11 percent).

Figure 7



CAR AND LIGHT-DUTY TRUCK SHARES AND FLEET FUEL CONSUMPTION

If SUVs and minivans had consumed the same amount of fuel as the average full-size passenger car for the last 10 years (the period 1988–98), the fleet average fuel consumption would have been improved by 1.5 percent.

Over the period 1988–98, sales of light-duty trucks with an average fuel consumption 29 percent higher than the average passenger car grew substantially. The market shift to light-duty trucks has had an expected detrimental effect on overall light-duty vehicle fuel consumption.

If car and truck market shares had remained constant at their 1988 level (about 70 percent and 30 percent respectively), all else being equal, the fleet average fuel consumption would have improved, on average, by about two percent [4]. This suggests that market sales shifts have worked against the fuel consumption gains made by cars and light-duty trucks.

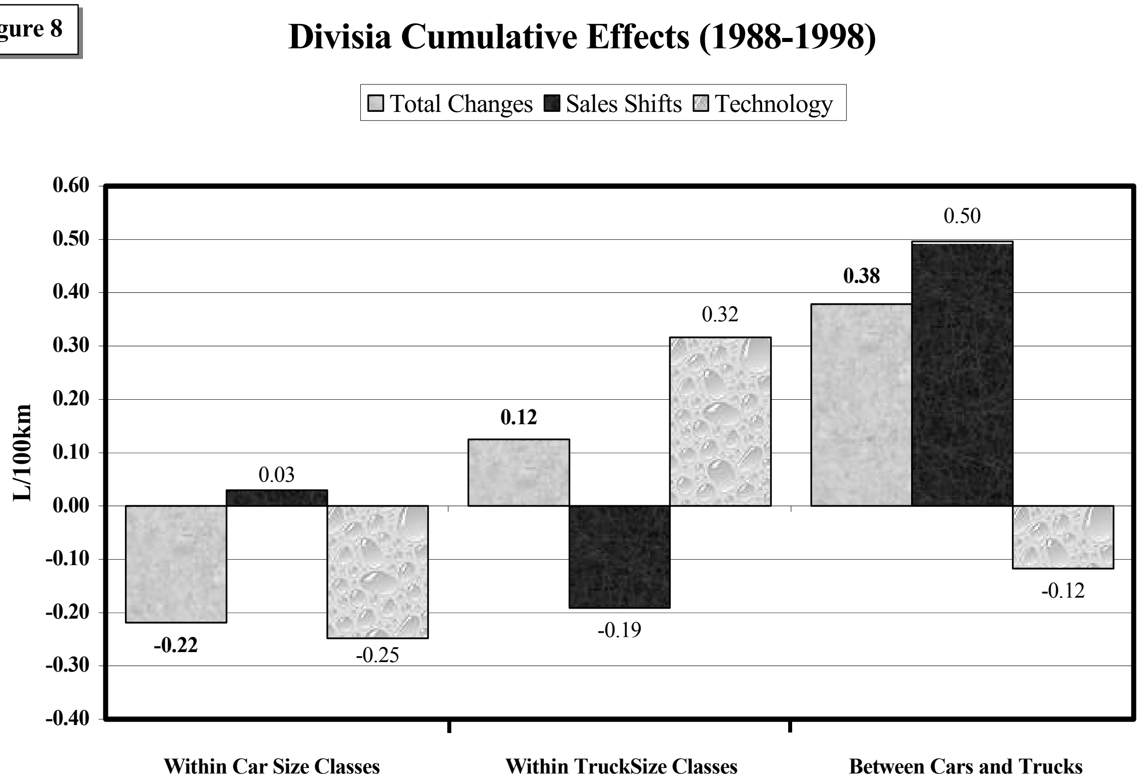
A closer look at the effect of all sales mix shifts on fuel consumption using a decomposition (Divisia) analysis for the period 1988–98 confirms this. The Divisia, which factors average fuel consumption changes into a sales mix shift (market share) component and a fuel consumption technology (L/100km) component, revealed that the sales shifts among vehicle size classes (i.e.

[4] It represents an average deterioration of 2 percent or alternatively a fleet average fuel consumption of 9.2 L/100km instead of 9.0L/100km over the 10-year period.

within cars and within light-duty trucks) were relatively minor factors in changes in overall light-duty vehicle fuel consumption since 1988. However, sales shifts between passenger cars and light-duty trucks had a more pronounced effect.

Taken alone, (Figure 8) the sales shift from cars to light-duty trucks increased the overall fuel consumption of light-duty vehicles by about 0.5 L/100km, while new technology accounted for an improvement of 0.1 L/100km. The combined effect of sales shifts and new technology between cars and trucks was a net deterioration of the new vehicle fleet of 0.4 L/100km over the 1988–98 period.

Figure 8



Within passenger cars, sales shifts had a minor, slightly negative effect on fuel consumption of 0.03 L/100km while technology improved it by about 0.25 L/100km, for a net improvement of 0.22 L/100km.

Within light-duty trucks, sales shifts had a beneficial impact of about 0.2 L/(100km) and technology changes brought a deterioration of about 0.3L/100km for a net deterioration of 0.1 L/100km. The beneficial sales shift impact within light-duty trucks is a result of the market penetration of smaller, more fuel-efficient SUVs, some of which are built on passenger car platforms (see figure 6). The SUVs and passenger vans consume less fuel than typical commercial light-duty trucks (pickup and cargo-van) and thereby contributed to the improvement of the average fuel consumption of the light-duty truck segment. However, the increases in sales of performance options such as 4X4 drive trains and enhanced horsepower for light-duty trucks have introduced technology that has been traded off against fuel efficiency improvements.

The net result of sales shifts within classes of cars and trucks and between cars and trucks has been a 0.4 L/100km deterioration in the fuel consumption of light-duty vehicles.

L/100KM IS TRADED FOR WEIGHT AND PERFORMANCE

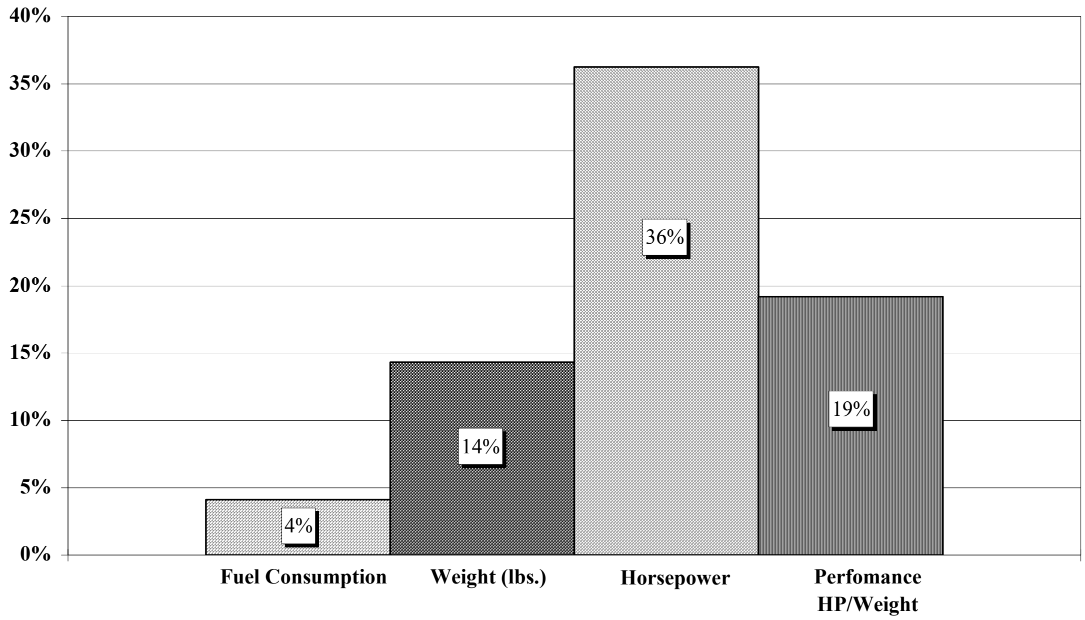
Consumer preferences for vehicle performance (acceleration), comfort, and safety have driven a trend in increased vehicle weight and improved performance to the detriment of fuel consumption. Based on a constant elasticity model[5], if the new 1998 light-duty vehicle fleet had shown the same average weight and performance as in 1988, it could have improved fuel consumption by1.3 L/100km.

Fuel-efficient technologies such as engines with more valves and more sophisticated fuel injection systems and transmissions with extra gears have continued to penetrate the new light vehicle fleet. However, the trend has clearly been to apply these new technologies to maintaining fuel consumption while increasing new vehicle weight, power, and performance. This is reflected in figure 9, showing heavier average vehicle weight (up 14 percent for new light vehicles since 1988), increasing average horsepower (up 36 percent for new light vehicles since 1988), and higher performance (19 percent more horsepower for new light vehicles since 1988). During the same period, average new light-duty vehicle fuel consumption deteriorated by four percent.

[5]See Appendix on Constant Elasticity Analysis for more detailed information

Figure 9

Percentage Change in Light-Duty Vehicle Characteristics Since 1988



APPENDIX A

Vehicle Fuel Economy Information System (VFEIS) and Vehicle Information System (VIS)

Transport Canada's VFEIS is a database designed to collect the detailed level of data that would be required to support a legislated fuel consumption program if the *Motor Vehicle Fuel Consumption Standards Act* were to be proclaimed. VFEIS currently records detailed vehicle descriptions, general test results and production volumes for new light-duty motor vehicles (passenger cars, vans, trucks, and special-purpose vehicles) for each model year. This information is used to confirm manufacturers' advertised fuel consumption label values and to calculate CAFC values for individual companies and for selected Canadian fleets. Fuel consumption data is also made available to other federal departments, provincial governments and the general public.

Apart from production volumes, the data submitted is equivalent to a portion of the information that is submitted to the U.S. EPA under its mandatory fuel economy compliance program.

NRCan's Transportation Energy Use Division supplements VFEIS with technology and performance-related data obtained from Energy and Environmental Analysis Inc. in order to perform trend analysis of vehicle fuel consumption and characteristics. NRCan has named this database the Vehicle Information System (VIS).

The fuel consumption (L/100km**)** data in this system has no correction factors such as those used in both the *Fuel Consumption Guide* and on vehicle labels for laboratory to on-road shortfall, nor does it include alternative fuels credits or adjustment test procedures.

Where only one L/100 km value is presented in this report, it represents a combined ratio of "55 percent city / 45 percent highway" with all values in L/100 km.

$L/100\ km_{55/45} = (.55x\ L/100\ km_{C} + .45xL/100\ km_{H})$

Where $L/100\ km_C$ is the fuel consumption calculated from the Federal Test Procedure (FTP) city driving cycle and $L/100\ km_H$ is the fuel consumption calculated from the FTP highway driving cycle.

All vehicle weight data are based on curb weight[6]. All interior volume data are based on the vehicle size categories appearing in the U.S. Department of Energy (DOE)/EPA *Fuel Economy Guide*.

The light-duty trucks are classified with gross vehicle weight ratings[7] (GVWR) of up to 3 855 kg for model years 1988 to 1999 and up to 2 727 kg before 1988. Vehicles with GVWR between 3 855 and 4 545 kg are classified as heavy-duty trucks under current Canadian regulations and have

[6]The weight of a motor vehicle with standard equipment, maximum capacity of fuel, oil, and coolant: and, if so equipped, air conditioning and additional weight of optional engine. Curb weight does not include the driver.

[7]The maximum loaded weight in pounds of a single vehicle.

not been included in the database. Omitting these vehicles from our analysis influences the overall averages for all light-duty truck variables. Currently, total sales of trucks with GVWR between 3 855 kg and 4 545 kg represent only about 5.5 percent of the total sales of trucks with GVWR less than 4 545 kg. If trucks with a GVWR between 3 855 kg and 4 545 kg had been included, the average fuel consumption would have been higher than the values reported here.

Appendix B

DIVISIA

To carry out this study, NRCan added the EPA's size classification to archival data from the VFEIS database. The EPA classifies cars into nine classes by interior volume: mini-compact, subcompact, compact, midsize, large, small wagon, midsize wagon, large wagon and two-seater, whereas light-duty trucks are classified by gross vehicle weight (e.g. truck weight plus carrying capacity) within six classes: 2X4 pickup, 4X4 pickup, small van, large van, small utility, large utility.

The Divisia technique breaks down the total changes in the average fuel consumption into its two components: vehicle market shares (sales shifts) and tested L/100km (technology). The Divisia was used to estimate these two effects between and within light-duty vehicles, which include passenger cars and light-duty trucks

The Divisia technique is used to explain changes over time in a variable that has a mutiplicative relationship (e.g. $f(x,y)=xy$). The Divisia breaks down the total changes in the variable among its mutiplicative component (e.g. x and y). In its continuous form, the Divisia involves the rules of partial and total differential.

The partial differential of $f(x,y)$ relative to x (e.g. how does $f(x,y)$ change when only x changes) is:

$$\frac{\partial f(x,y)}{\partial x} = \frac{\partial f(x,y)}{\partial x} * y$$

The partial differential of $f(x,y)$ relative to y (e.g. how does $f(x,y)$ change when only y changes) is:

$$\frac{\partial f(x,y)}{\partial y} = \frac{\partial f(x,y)}{\partial y} * x$$

The total differential of $f(x,y)$ relative to x and y (e.g. how does $f(x,y)$ change when x and y change simultaneously) is:

$$\frac{df(x,y)}{dy\,dx} = \frac{\partial f(x,y)}{\partial x} * y + \frac{\partial f(x,y)}{\partial y} * x$$

In our analysis the multiplicative relation is the following:

$$(1)\quad I = \sum_{I=1}^{n} \{ (e_i) * (s_i) \}$$

i= to the size class defined by the EPA
Where (I) is the average tested fuel consumption (L/100km) of vehicles within a category (e.g. car, truck or light-duty vehicle), e_i is the weighted average tested fuel consumption (L/100km) of all vehicles in size class i and $s_{i,}$ the sales share of all vehicles in size class i.

The Divisia method decomposes I into its changes over time. To do so we take the derivative of I equation (1) with respect to time (t). Following the total derivative rules we get:

$$(2)\ \frac{dI}{dt} = \sum_{i=1}^{n} \left\{ \frac{\partial e_i}{\partial t} * (s_i) + \frac{\partial s_i}{\partial t} * (e_i) \right\}$$

Equation (2) defines the Divisia for a continuous variable. Since we use annual data, we must approximate the continuous case by mean of year to year changes. In this case (s_i) and (e_i) of equation (2) are approximated by their two-year midpoint:

$$(3)\ I_t - I_{t-1} = \sum_{I=1}^{n} \{e_{i(t)} - e_{i(t-1)} * (s_{i(t)} + s_{i(t-1)}) / 2 + s_{i(t)} - s_{i(t-1)} * (e_{i(t)} + e_{i(t-1)}) / 2\}$$

CONSTANT ELASTICITY

A constant elasticity method is used to analyse the effects of weight and performance on fuel consumption. The constant weight and performance fuel consumption (*L/100km*$_t$) in any year **t** is given by the actual fuel intensity (L/100km$_t$) adjusted for weight and performance effects.

$$(1)\quad L/100km_t = \text{L/100km}_t\,(W_o/W_t)^{\alpha}\,(P_o/P_t)^{\beta}$$

W represents weight and **P** performance in years **t** and **o** (reference year). The parameter α and β are the constant elasticity used in a similar analysis done by D.L Greene in *Transportation Energy Efficiency Trend,* 1994.