# ESTIMATING THE IMPACT OF DEMOGRAPHICS AND AUTOMOTIVE TECHNOLOGIES ON GREENHOUSE GAS EMISSIONS

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# Estimating the Impact of Demographics and Automotive Technologies on Greenhouse Gas Emissions

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## ABSTRACT

If strategies for reducing Greenhouse Gas (GHG) emissions are to be effective, they must address the significant $CO_2$ contribution made by road transportation. This paper examines the effects that emerging ultra-low emission vehicle technology and demographics are likely to have on the magnitude of total $CO_2$ equivalent emissions from light duty vehicles over the next twenty years.

The results of the analysis indicate that increases in GHG emissions resulting from projected increases in total population, expected shifts in the national population age profile, and an anticipated continued 0.2% increase in annual per capita driving may be somewhat offset from the adoption of current hybrid electric-gasoline engine technologies. However, analysis in this paper shows that 39% of annual new light-duty vehicle sales would need to consist of hybrid vehicles in order to meet the target Kyoto GHG emissions, for the light-duty vehicle segment of the transportation sector. It seems unlikely that this level of market penetration can be achieved within the next decade and therefore, it appears highly likely that Canada will need to implement other additional measures to reduce GHG emissions.

## Introduction

The transportation sector consumes 30% of all energy used in Canada, with the vast majority of this energy derived from petroleum-based fuels. Road transportation accounts for almost 80% of petroleum consumed by the transportation sector. Aside from the concern regarding the transportation sector's dependence on petroleum, a non-renewable resource, there is increasing concern regarding the pollution generated by burning these fuels. Road transportation is responsible for more than 20% of the total annual $CO_2$ emissions, one of the major greenhouse gases. Road transportation is also responsible for 57% of annual CO emissions, 35% of $NO_x$ emissions, and 24% of volatile organic compound (VOC) emissions.

For strategies to be effective in reducing GHG emissions, they must address the significant $CO_2$ contribution that road transportation makes annually. While many potential reduction strategies exist, this paper examines two factors likely to have a significant influence on the level of $CO_2$ and other tail-pipe emissions generated, namely emerging ultra-low emission vehicle technology and demographics.

Several auto manufactures currently market hybrid gasoline/electric vehicles that consume significantly less fuel and produce significantly fewer tail-pipe emissions than conventional light-duty gasoline powered vehicles. For example, the 2002 Honda Insight has a reported EPA fuel consumption rate of 3.9L/100km and 3.2L/100km for city and highway driving respectively (Honda Canada, 2002). The Toyota Prius has a reported EPA fuel consumption rate of

4.5L/100km and 4.7L/100km for city and highway driving respectively (Toyota Canada, 2002). Additionally, over the next five years it is anticipated that other auto manufactures will introduce a greater variety of hybrid light-duty vehicles; however, precise fuel consumption rates for these vehicles are currently unknown (DeCicco, 2002).

The fuel consumption rates and associated emissions of current hybrid vehicles (Toyota Prius and Honda Insignt) are lower than similarly sized cars, powered by conventional gasoline combustion engines and significantly lower than the average fuel consumption rate for the existing in-use light-duty vehicle fleet (10.7L/100km).

Canada, as a signatory of the Kyoto Protocol, has committed itself to reducing total GHG emissions to 6% below 1990 levels by the year 2012 (Environment Canada, 2001). It has been suggested that the widespread adoption of hybrid engine technologies will result in a significant reduction in total fuel consumption and tail-pipe emissions by the light-duty vehicle sector, and that this reduction will be sufficient to meet the Kyoto commitment. However, in conjunction with changes in vehicle technology, the population profile in Canada is changing. The *baby-boomers*, representing 32% of the population, (those between the ages of 35 and 55) are ageing and their driving needs and driving characteristics are changing. In conjunction, the *echo* generation (those born in the 1980s), representing 20% of the population, is just now entering the work force and their per capita vehicle ownership and annual kilometres of driving are increasing significantly.

This paper examines the joint and separate impacts that a changing population profile and new vehicle engine technology will have on national GHG emissions from light-duty vehicles over the next two decades.

The next section describes the analytical approach taken to estimate future year GHG emissions. The analysis examines separately and in combination the effects of the changing population profile, hybrid vehicle technology, and increasing per capita annual driving. The analysis begins by quantifying emissions for the year 2001. Emission estimates are then made for 2011 and 2021 for several different scenarios. In the last section, conclusions and recommendations are made.

## Analysis

The estimation of GHG emissions can be broken down into the estimation for the base year (2001) and for future years. The next section presents the method used to make estimates for the base year, while the following section describes the analysis for the 2011 and 2021 time horizons.

### *Estimating Current Year Emissions*

As illustrated in Figure 1, the estimation of GHG emission for the base year is determined on the basis of total annual km driven, an average fleet fuel consumption rate, and a constant conversion from volume of fuel to mass of GHG $CO_2$ equivalent. Each of the elements of the process is described below.

1. Population projections by age cohort for years 2001, 2011, and 2021 (Table 1) were obtained from Statistics Canada (*Population Projections*, 2001). Only population projections for 2001 were used for base year analysis.

2. Total vehicle-km driven, by age cohort, was obtained from the *Canadian Vehicle Survey: Annual 2000* (Statistics Canada, 2001). The data reflects km driven by private vehicles weighing less than 4.5 tonnes (e.g. cars, SUVs, vans, but excluding off-road vehicles and motorcycles).
3. *Canada's Energy Outlook* (Natural Resources Canada (NRCan), 1997) indicates that annual km driven per capita is increasing at a rate of 0.2% per year.
4. Total vehicle-km driven for 2001 was estimated by applying the vehicle use growth factor of 0.2% from element 3.
5. Total vehicle-km was computed by summing vehicle-km drive across all age cohorts. The total vehicle-km driven by light-duty vehicles in Canada during the year 2001 is estimated to be 282.0 billion vehicle-km. This is equivalent to an average of 16,943 km/vehicle.
6. The average annual km driven per person was computed for each age cohort by dividing the total km driven by the cohort (element 4) by the population in the cohort (Table 2). It is evident from the data in Table 2 that on average people between the ages of 35 and 55 drive more km per year than do people in any other age cohort. This becomes important when changes in the population age profile are considered for estimating future GHG emissions.
7. For the base year, an average fleet fuel consumption rate of 10.7L/100km was used to convert total km driven to total volume of fuel consumed. The consumption rate was derived by dividing total gasoline fuel sales by total km driven in the year 2000, as this was the most current data available (Statistics Canada, *Canadian Vehicle Survey*, 2001). In both cases data from vehicles weighing 4.5 tonnes and less was used. The average fuel consumption rate is reduced for use in the calculation of fuel consumption in future years, according to the projected fuel consumption rates found in *Canada's Energy Outlook* (NRCan, 1997).
8. The total fuel consumption estimated for the base year (2001) was computed to be 30.3 billion litres (elements 5 and 7).
9. Green-house-gas emissions are computed on the basis of mass of $CO_2$ equivalent per volume of fuel. For gasoline, the GHG conversion factor is 2.72 kg/litre (Transportation Table, 1998). Therefore, for the base year, the use of light-duty vehicles produced an estimated 82.4 million tonnes of GHGs.

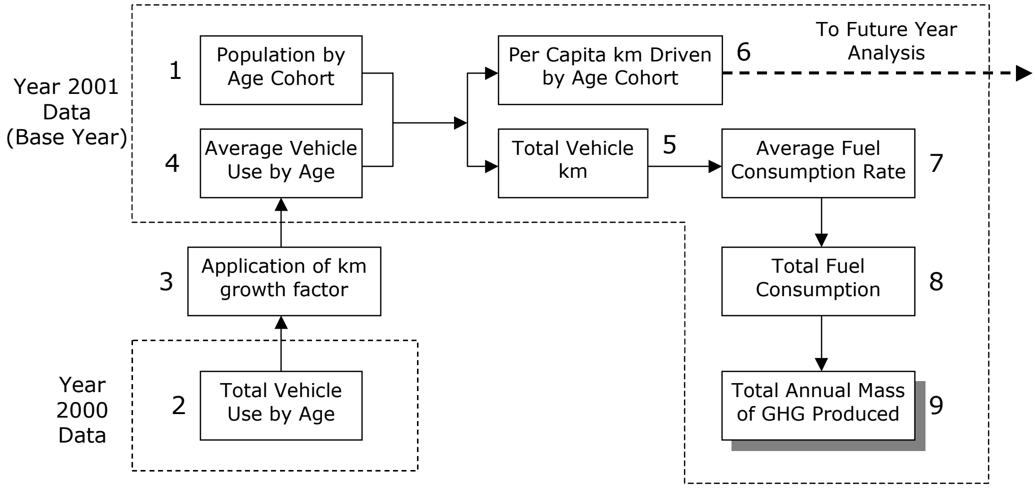


Figure 1: Flow chart of analysis method for computing Base Year GHG emissions

Table 1: Population projections for Canada
(Source: *Population Projections*, 2001)

| Age | 2001 | 2011 | 2021 |
|---|---|---|---|
| < 20 | 7,899,100 | 7,169,600 | 7,207,100 |
| 20-24 | 2,097,000 | 2,213,700 | 2,034,700 |
| 25-34 | 4,352,800 | 4,471,200 | 4,786,400 |
| 35-44 | 5,300,800 | 4,557,700 | 4,843,400 |
| 45-54 | 4,499,600 | 5,269,500 | 4,711,600 |
| 55-64 | 2,917,000 | 4,303,700 | 5,127,900 |
| 65-74 | 2,149,800 | 2,587,500 | 3,886,100 |
| 75-84 | 1,340,900 | 1,527,700 | 1,938,400 |
| 85 ≤ | 444,400 | 677,800 | 846,100 |
| Total | 31,001,400 | 32,778,400 | 35,381,700 |

Table 2: Average Annual km Driven per Capita by Age Cohort for 2001
(Derived from *Canadian Vehicle Survey*, 2001)

| Age Cohort | Avg. Annual km Driven per Person |
|---|---|
| < 20 | 806 |
| 20-24 | 6,513 |
| 25-34 | 9,789 |
| 35-44 | 15,798 |
| 45-54 | 15,761 |
| 55-64 | 12,336 |
| 65-74 | 10,440 |
| 75-84 | 4,275 |
| 85 ≤ | 1,170 |

## *Estimating Future Year Emissions*

The estimation of GHG emissions for the future considered the 2011 and 2021 time horizons. A number of different factors were considered in making these future year predictions. First, the fuel consumption characteristics of the future fleet were considered. Second, changes in population age profile. Third, a continuation of the current trend for a constant increase in the average km driven per year. Fourth, the continued growth of the vehicle fleet[1]. Different combinations of these factors result in the definition of five scenarios for comparison purposes. Each of these scenarios is described in the following sections. In each scenario, the method of computing GHG emission follows the general process illustrated in Figure 2.

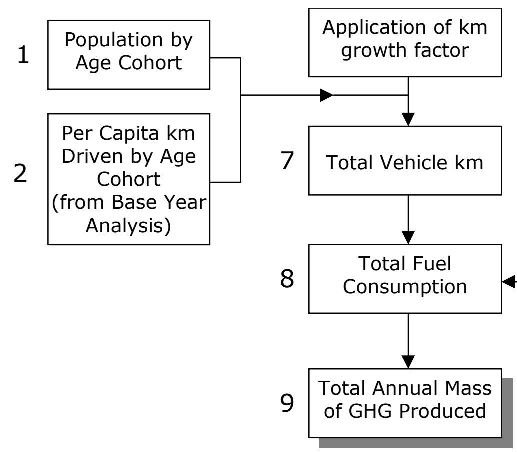


Figure 2: Flow chart of analysis method for computing future year GHG emissions

## Scenario 1: Conventional Vehicles and No Change in Population Profile

In Scenario 1, we assume that hybrid vehicle technology will not gain a significant market share of new vehicle sales. It is assumed, however, that other enhancements to conventional engine technology and to vehicles will occur and this will result in a reduction in average fuel consumption rate. The estimated fuel consumption rate is 10.24 L/100km for 2011 and 9.61L/100km for 2021 (NRCan, *Canada's Energy Outlook*, 1997). These improvements to conventional vehicle technology are assumed for all 5 scenarios. Total annual vehicle-km is assumed to increase at a constant rate of 0.2% per year (i.e. 2.02% greater than 2001).

## Scenario 2: Conventional Vehicles and Changes in Population Profile

Scenario 2 expands on Scenario 1 by explicitly considering the impact that the changing population profile will have on total vehicle-km driven. Instead of assuming a constant increase of 0.2% in annual vehicle-km, this scenario keeps the per capita vehicle-km constant for each age category, but considers the expected shift in population within each age category. Figure 3 illustrates this expected shift in age profile by portraying 2011 and 2021 population as a fraction of the 2001 population. It is evident that in both 2011 and 2021 there is expected to be a significant growth in the number of people above the age of 45 and a small reduction in the number of people below the age of 25. Based on the data in Table 2, it can be concluded that this shift will result in greater annual vehicle-km as the per capita vehicle-km for those in the older age categories is larger than for people in the younger age categories.

[1] The size of the year 2000 fleet was taken from the *Canadian Vehicle Survey* (Statistics Canada, 2001) and was then grown by 1.7% per year to estimate the size of the light-duty vehicle fleet in future years (NRCan, *Canada's Energy Outlook*, 1997). The hybrid fleet size was then taken as a proportion of the fleet.

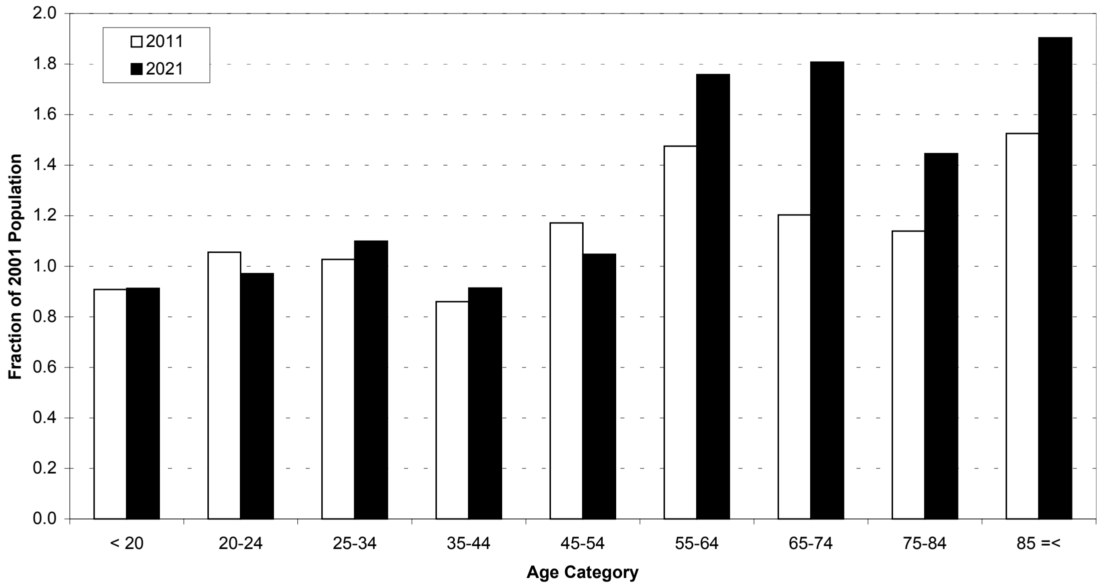


Figure 3: Projected population age profile as a fraction of the age profile for 2001

It must be noted that in this scenario no change in per capita driving is considered. However, it is considered likely that as the baby boomers age, the per capita vehicle-km driven by those older than 65 will also increase, as a result of a higher proportion of licensed drivers (compared to those older than 65 in 2001) and a greater habituated dependence on the automobile as a means of transportation.

### Scenario 3: Conventional Vehicles, Changes in Population Profile and Increased Driving

In this scenario we consider both the effects of changing population age profile (as described in Scenario 2) and increased annual driving. The increase in annual driving is assumed to be 0.2% per year and is applied to all age categories.

### Scenario 4: 10% Hybrid Vehicles

Scenario 4 is the same as Scenario 3 with the exception that 10% of new vehicle sales, beginning in 2001, are assumed to be hybrid vehicles. Hybrid vehicles are assumed to have an average fuel consumption rate of 4.2L/100km. Changes in population age profile as well as annual increases in per-capita vehicle-km are considered. The annual vehicle-km associated with hybrid vehicles is assumed to be 18% greater than the vehicle-km associated with the conventional fleet to reflect "rebound" phenomenon. Rebound reflects the increased driving that owners of hybrid vehicles are expected to do as a result of the lower operating cost due to the lower fuel consumption (Litman, 2001). This assumption is also applied to Scenario 5.

### Scenario 5: 35% Hybrid Vehicles

Scenario 5 is the same as Scenario 4 with the exception that 35% of vehicle sales are assumed to be hybrid vehicles.

## Results

The estimated GHG emissions for the base year and each of the 5 future year scenarios are illustrated in Figure 4. Several observations can be made on the basis of these results.

The results for Scenario 1 indicate that if expected changes in the population age profile are ignored, then reductions in GHG emissions of 2.8% and 6.8% are estimated for 2011 and 2021. These reductions are achieved solely from the introduction of more fuel efficient conventional gasoline engine technology. For 2011, the 4.6% reduction in fuel consumption is greater than the 2.02% increase in total vehicle-km and therefore the estimated reduction in GHG is 2.8%.

Comparing the results for Scenario 3 with Scenario 1 indicate the impact that changes in population age profile are likely to have on GHG emissions. Scenario 3 GHG estimates are 9.5% and 16.9% greater than the Scenario 1 results for 2011 and 2021 respectively. These increases are solely a result of a shift in the population age profile with more people in the age categories with higher per capita annual vehicle-km. These results clearly demonstrate the need to consider changes in population age profile in any analysis of future driving trends.

The results from Scenario 2 can be viewed as a more conservative estimate of future conditions for a conventional vehicle fleet. Unlike Scenario 3, in this scenario it is assumed that there is no global increase in annual vehicle-km of travel over the 20-year projection horizon. Average annual vehicle-km per capita is assumed to remain constant. While this scenario is more conservative than Scenario 3, it does not seem a realistic expectation given historical increases in annual vehicle-km. Nevertheless, even this conservative assessment indicates increases in GHG emission of 6.5% and 12.4% over Scenario 1 for 2011 and 2021 respectively.

Scenarios 4 and 5 illustrate the effect that the introduction of hybrid vehicle technology can have on future GHG emissions. Scenario 4 assumes that 10% of new vehicle sales will be hybrid vehicles. The results indicate that under these conditions, GHG emission in 2011 will be approximately equal to the emissions for 2001. These results also indicate that if 10% of new vehicles sales beginning in 2001 are hybrid vehicles, a reduction in GHG emissions of 6.2% for 2011 and 5.1% for 2021 over the levels expected for these years if no hybrid vehicles are introduced.

It is interesting to note that for both Scenarios 4 and 5, GHG emissions are estimated to be higher in 2021 than in 2011 despite increasing proportion of the in-use vehicle fleet that would be hybrid vehicles. This increase occurs primarily as a result of continued changes in the population profile which creates rather significant increases in total vehicle-km travelled.

The commitment that Canada made as part of the Kyoto Protocol is to reduce GHG emissions by 6% from the 1990 levels by the year 2012 (Environment Canada, 2001). The GHG emissions from private light-duty vehicles for 1990 are estimated to be 76.47 million tonnes. Therefore the target level of GHG emission to meet the Kyoto commitment is 72.15 million tonnes. It is evident from the results in Figure 4 that none of scenarios meet the Kyoto commitment. In fact, it would require that 39% of new vehicle sales be hybrid vehicles, in order for the estimated GHG emissions from light-duty vehicles to reach the Kyoto target levels. Given that hybrid engine technology is currently only available for a limited segment of the new vehicle market (e.g. compact cars), and that these cars cost significantly more than similar conventional models, it seems rather unlikely that a market penetration of 39% can be achieved in the near-term. It is reasonable to expect the price differential between similar hybrid vehicles and convention vehicles to narrow as production increases. Nevertheless, it would seem likely that the level of market penetration of hybrid vehicles necessary to reach the Kyoto target can only be achieved with the assistance of market stimuli, such as legislation and/or financial subsidies (e.g. green vehicle rebates for consumers) or penalties (e.g. higher gas tax). Interestingly, even with a 39% market penetration rate, GHG emissions will again be higher than the Kyoto commitment by the year 2021.

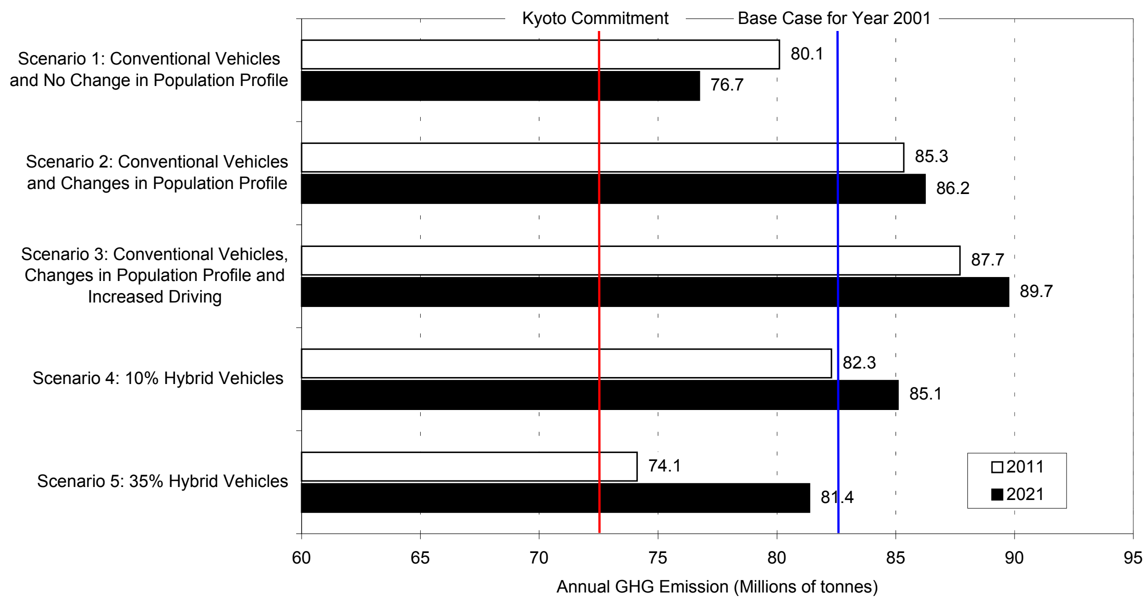


Figure 4: Estimated GHG emission for 2011 and 2021

## Conclusions and Recommendations

Changes in population age profile expected to occur in Canada over the next two decades will result in an 8.7% and a 17% increase in annual vehicle-km of travel over 2001 levels for 2011 and 2021 respectively. This change assumes average annual vehicle-km travelled per capita remains constant. Whether or not this is the case, the significant increase in total vehicle-km will overwhelm any projected improvements in conventional vehicle fuel economy.

The introduction of hybrid vehicle technology, having a significantly lower fuel consumption rate than conventional vehicle, has the potential to significantly reduce GHG emissions. However, it is estimated that 39% of new car sales, beginning in 2001, must be hybrid vehicles, for the private light-duty vehicle GHG emission to reach the Kyoto target in 2011. However, GHG emissions would likely increase beyond the Kyoto target by 2021 as a result of changes in Canada's demographic makeup.

This high level of market penetration is not likely to occur without external stimuli, such as legislation, and/or financial incentives/disincentives.

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