THE GREENING OF CANADA'S ROAD MOTOR VEHICLES: AN ASSESSMENT

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Introduction

There is a growing recognition of the relationship between patterns of urban land use and related levels of air pollutants (Abotalebi and Kanaroglou, 2015; Dimatulac & Maoh, 2016; Glaeser, 2011; Giuliano & Agarwal, 2011; Tyler, 2000; Zimmerman & Wiginton, 2016). The connection in this relationship is evolving land use patterns in Canada which have helped to encourage and sustain a dependency on motor vehicles. Consequently, Greenhouse Gas (GHG) emissions in Canada from the operation of motor vehicles increased by over one-third (35%) from 1990 to 2007, whereas the growth rate of population was less than 20% over the same period (Terefe, 2010).[1]

As party to the 2016 United Nations Framework Convention on Climate Change's Paris Agreement, Canada has committed to reducing its GHG emissions to 30% below 2005 levels by 2030. With transport there are two complementary approaches to help reach this reduction target. The first is to encourage a modal shift (Gullo & Rosales, 2016). In the urban context, this shift would be from motor vehicles to public transit, relying on policy options of full-cost pricing (e.g. tolling) and related land-use planning (e.g. Smart Growth, intensification). The second approach is to encourage more fuel efficient fleets. For the road motor vehicle fleet, this would entail a higher proportion of alternative fuel vehicles (AFV).[2]

This study investigates the extent to which provincial vehicle registration files (VRF) can be used as a source of information to profile the road motor vehicle fleet by fuel type. Such a profile is critical as a benchmark going forward in order to track changes in the motor vehicle fleet composition. The paper begins with an overview of the relationship between transportation and urban form as well as the current contribution of the transportation sector to Canada's GHG emissions. After describing the provincial VRFs, the paper defines a typology and then estimates the motor vehicle fleet by fuel type. We conclude with an examination of possible next steps in this effort.

Context

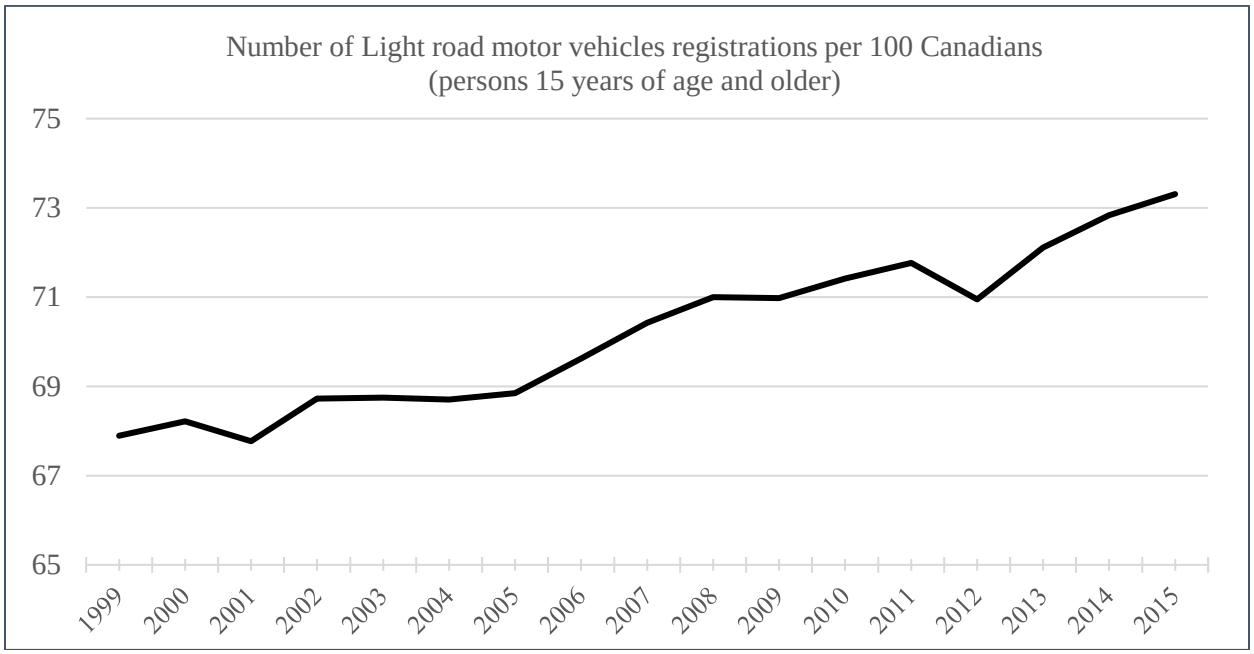
Despite some lingering skepticism, the science linking carbon dioxide (CO_2) and other GHG emissions with discernible impacts on climatic conditions has become non-refutable. Environment and Climate Change Canada (ECCC) asserts that "warming is unequivocal and human influence on the climate system is clear".[3] Increases in CO_2 emissions, the principal GHG, are due primarily to fossil fuel use, with a significant contribution from the transportation sector. ECCC further asserts that any mitigation strategy would require zero or even negative emission growth from the transportation sector. As such, AFVs are now considered as a key element of such a strategy.

** Estimates of road motor vehicles by fuel type produced as part of this research effort are experimental in nature and should not be considered as official statistics sanctioned and released by Statistics Canada.*

Transportation and Urban Form

The relationship between urban form and travel behaviour underlies the excessive dependency on motor vehicle use (McKeown & Mongrain, 2017). Not only is this relationship symbiotic, the interdependency changes over time because of the durability of the built environment. In Canada, the total extent of built-up Census Metropolitan Areas (CMAs) – defined as a high percentage of impervious surfaces such as roadways, parking lots and roof tops – was 14,546 square kilometres (km^2) in 2011, up from 5,651 km^2 in 1971 (Wang, 2016). Concomitantly, the average CMA population density dropped from about 3,460 persons/km^2 to 2,250 persons/km^2 over the same period.[4] And according to initial results from the 2016 Census, this decentralization has continued (Statistics Canada, 2017).

Between 2011 and 2016, population growth was higher in lower density peripheral municipalities (+6.9%) of CMAs, compared with their higher density central municipalities (+5.8%). All else being equal, as population density declines, it becomes more difficult to service a population effectively with public transit, irrespective of technology. Declining urban density has been associated with a variety of external costs, including pollution, as the number of light road motor vehicles registered in Canada continues to grow. By 2015, there were relatively more motor vehicles at the disposal of Canadians with almost 74 light motor vehicles registered for every 100 Canadians aged 15 years or older, up from 68 in 1999 (Figure 1).[5]



Source: Statistics Canada, Vehicle Registrations CANSIM 405-0004

Figure 1. Road motor vehicle registrations in Canada, 1999 to 2015

Greenhouse Gas Emissions

In 2014, Canada's total GHG emissions was estimated to be 732 mega-tonnes of carbon dioxide equivalent (Mt CO_2 eq) (EEEC, 2016). It was estimated that CO_2 emissions accounted for 78% of this total and the majority resulted from the combustion of fossil fuels. To apprise the development of mitigation policies, it is essential to allocate these emissions to the economic sector from which they originate. In 2014, the transportation sector was responsible for about 23% of the total emissions, second only to the oil and gas extraction sector (EEEC, 2016).

As such, it is apparent that the transportation sector in general, and motor vehicles specifically, are an important target for GHG emission reductions. As mentioned previously, one approach to help achieve these reductions is by increasing the prevalence of AVFs among the motor vehicle fleet. Increasing the prevalence would reduce emissions in two ways. First, in most cases AVFs require fewer units of energy output per kilometre of vehicle operated since such they are designed and manufactured explicitly to improve fuel efficiency (e.g. aerodynamic and lighter materials). Secondly, the alternative fuels typically have a lower emission intensity per unit of energy output.[6]

The Vehicle Registration Files

In Canada, the registration of road motor vehicles is a provincial responsibility with every jurisdiction having a similar process and, as a by-product, each maintaining a Vehicle Registration File (VRF). Statistics Canada relies on these VRFs for statistical reasons; in the past for example, the VRFs were used as the sampling frame for the Canadian Vehicle Survey. Statistics Canada continues to use the VRFs to produce counts of vehicles by size and type. These counts are an indicator of fiscal capacity used by Finance Canada in calculations pursuant to the Federal-Provincial Fiscal Arrangements Act (i.e. provincial equalization). Each registered vehicle on these files has a unique Vehicle Identification Number (VIN), assigned by the manufacturer, which contains an array of information including fuel type and fuel efficiency ratings.

Data and Typology

Statistics Canada released the 2015 motor vehicle counts in July of 2016 and it was decided to use the fourth quarter VRFs to develop an experimental profile of Canada's motor vehicle fleet by fuel type. The number of vehicles registered in Canada in the final quarter of 2015 was 33,575,384.[7] Each VRF has a different record layout and a VIN decoder designed by *VinPower* was used to produce comparable categories, including fuel type (e.g. gasoline, electric) and hybrid type (i.e. full electric, partial electric) across the VRFs. Excluding vehicles without a fuel type, the roughly 24.5 million vehicles were then categorized according to fuel type and hybrid type fields (Figure 2).[8]

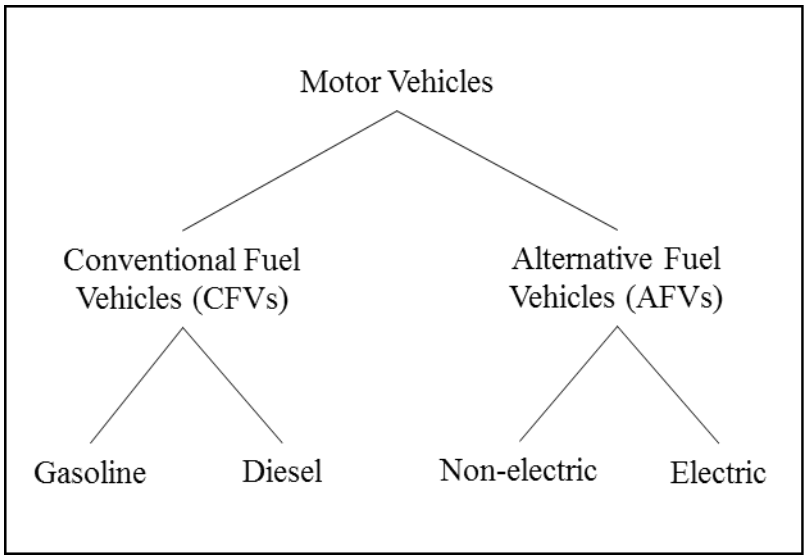


Figure 2. Typology of Road Motor Vehicles by Fuel Type

The typology first divides conventional fuel vehicles (CFVs) from AFVs. The CFVs consist of those vehicles with engines that use either motor gasoline or diesel. The AFVs were further assigned to either a

non-electric or electric category. The former consisted of an array of fuels including Ethanol (blend), Methanol (blend), Natural gas (compressed or liquefied), Propane (or liquefied petroleum gas) and Other fuel type combinations such as diesel and natural gas. The electric vehicle (EV) category was further broken down into full EVs or hybrid EVs (i.e. with gasoline or other fuels). These categories were defined based on observed frequencies and the U.S. Energy Information Agency's (EIA) categories for comparability.

Road Motor Vehicles by Fuel Type

The prevalence of most AFVs in Canada is relatively low. CFVs account for over 90% of the motor vehicle fleet, slightly lower in the Atlantic and Prairie regions (Table 1).[9] The lower rates in both these regions reflect a relatively higher prevalence of AFV ethanol blend vehicles. Such vehicles, often referred to a flex-fuel vehicles, are able to operate using E85, a fuel blend of 85% denatured ethanol fuel and 15% gasoline by volume. It should be noted that there is some debate as to whether ethanol contains less energy than gasoline and therefore delivers less fuel when burned.[10] Moreover, ethanol takes a lot of energy to produce, which is not factored into GHG emissions attributed to the transportation sector. The other non-electric AFV fuel combinations are quite negligible, accounting for an average of 5 or less motor vehicles per 10,000 nationally and in each region.

Table 1. The Prevalence of Canada's Motor Vehicle Fleet by Fuel Type, 2015

	Atlantic Region	**Central Canada**	**Prairie Provinces**	**West Coast**	**Territories**	**Canada**
CFV	***88.41%***	***90.93%***	***87.17%***	***91.92%***	***86.25%***	***90.05%***
Gasoline	*83.40%*	*86.04%*	*76.00%*	*83.53%*	*72.64%*	*83.32%*
Diesel	*5.01%*	*4.89%*	*11.17%*	*8.39%*	*13.61%*	*6.73%*
AFV: Non-Electric	***11.22%***	***8.35%***	***12.39%***	***6.89%***	***13.49%***	***9.26%***
Ethanol blend	*11.19%*	*8.34%*	*12.33%*	*6.86%*	*13.47%*	*9.24%*
Other fuel combinations	*0.03%*	*0.01%*	*0.05%*	*0.03%*	*0.02%*	*0.02%*
AFV: Electric	***0.37%***	***0.73%***	***0.44%***	***1.18%***	***0.26%***	***0.70%***
Full EV	*0.00%*	*0.04%*	*0.00%*	*0.05%*	*0.01%*	*0.03%*
Hybrid EV	*0.37%*	*0.69%*	*0.44%*	*1.13%*	*0.25%*	*0.67%*
Total*	***100%***	***100%***	***100%***	***100%***	***100%***	***100%***

**Total excludes vehicles with no fuel type*

As noted by others, the relatively low prevalence of EVs in Canada indicates that they remain price uncompetitive with CFVs (Abotalebi & Kanaroglou, 2015). Moreover, there are technical limitations in terms of both range and re-fueling infrastructure as well as battery re-charge time. Nationally, the prevalence of EVs was about 0.7% or about 7 out of every 1,000 vehicles (Table 1). This prevalence was a little higher on the west coast at over 11 EVs per 1,000 and slightly lower in the east at less than 4 EVs per 1,000. It is also important to note that over 95% of EVs on the road in Canada are of the hybrid variety. In the case of hybrid EVs, the engine uses a combination of electricity with gasoline or some other fuel type.

Other variables on the VRF include weight, type, use (commercial or non-commercial), fuel efficiency ratings (AMG city and highway) as well the geographic location to which the vehicle is registered. With the Postal Code Conversion File (PCCF), location could be used to create any standard Statistics Canada

geography, such as CMAs for example. To illustrate the small area potential without using the PCCF, we produced counts of the road motor vehicle fleet for selected cities using postal code geography (Figure 2). That is, counts for these cities were created based on the first three characters of the postal code or the Forward Sortation Area (FSA). [11]

Table 2. The Prevalence of the Motor Vehicle Fleet by Fuel Type, Selected Cities, 2015

	Montreal	Ottawa	Toronto	Vancouver
CFV	***93.03%***	***90.88%***	***91.46%***	***92.49%***
Gasoline	*88.80%*	*87.94%*	*87.45%*	*85.80%*
Diesel	*4.23%*	*2.94%*	*4.01%*	*6.69%*
AFV: Non-Electric	***6.14%***	***8.04%***	***7.41%***	***5.97%***
Ethanol blend	*6.12%*	*8.01%*	*7.37%*	*5.93%*
Other fuel combinations	*0.01%*	*0.02%*	*0.05%*	*0.05%*
AFV: Electric	***0.84%***	***1.08%***	***1.13%***	***1.54%***
Full EV	*0.06%*	*0.04%*	*0.05%*	*0.08%*
Hybrid EV	*0.78%*	*1.05%*	*1.08%*	*1.47%*
Total*	***100%***	***100%***	***100%***	***100%***

**Total excludes vehicles with no fuel type*

As with the regional estimates, the prevalence of AVFs in these major cities is quite low. The major difference, perhaps reflecting an urban versus rural dimension, is the lower prevalence of Ethanol blend AFVs and the higher prevalence of EVs in these selected cities. Indeed, there is more than 1 EV per every 100 registered motor vehicles in Ottawa, Toronto and Vancouver. It may be that differences in climatic conditions account for the relatively lower prevalence in Montréal and higher prevalence in Vancouver. Also, provincial incentive programs may be a factor. Again, the vast majority of the EVs registered in these cities consist of the hybrid variety. And with geography from the PCCF, the prevalence of AFVs could be estimated for standard geographies and smaller areas to enable investigations such as, for example, emission scenario modeling (see Dimatulac & Maoh, 2016).

Summary and Next Steps

This research used the provincial and territorial VRFs to profile the road motor vehicle fleet by fuel type and results indicate that the prevalence of AFVs is quite low. EVs appear to remain price uncompetitive with CFVs and, as such, take-up is not likely to be significant without continued public policy incentives (Abotalebi & Kanaroglou, 2015).[12] The recent decline in the price of crude oil will not help. Since 2010, the monthly spot price for West Texas Intermediate peaked at US$105.80 per barrel in June of 2014 and sat just under $50 by the end of 2016. However, battery and re-charging technology is improving and the new generation of EVs will have longer range. In the case of non-electric AFVs, the prevalence appears to be higher at first glance. However, the lack of re-fueling infrastructure for flex-fuel E85 vehicles as well as the ongoing scientific debate on their CO_2 emissions may call into question their status as AFVs.

Nevertheless, it is essential to start benchmarking the composition of Canada's road motor vehicles by fuel type. With the transportation sector in general, and road motor vehicles in particular, considered as an important part of any mitigation strategy to help achieve Canada's GHG emissions reduction commitments, establishing such a benchmark is critical. After this proof of concept, there is a need to conduct additional

analysis. There is a need to refine the definitions as well as merger and matching routines to ensure similarity of concepts and validity of counts across the VRFs. In addition, it would be interesting to profile the fleet by fuel type and by age of vehicle. Finally, there is a need to use the PCCF to establish a standard geographic classification field to enable further applications.

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Endnotes

[1] The estimates were derived using Statistics Canada's Material and Energy Flow Accounts (MEFA) and Canadian Vehicle Survey (CVS). The MEFA records the flow of materials and energy in the form of natural resources and wastes between the economy and the environment. A vehicle-based survey, the CVS provided estimates of activity (fuel consumed, distance travelled) by vehicles registered in Canada.

[2] An alternative fuel vehicle uses a fuel other than traditional petroleum fuels such as gasoline. AFV also refers to any technology of powering an engine that does not involve solely petroleum.

[3] See ECCC website: http://ec.gc.ca/sc-cs/Default.asp?lang=En&n=A5F83C26-1 (accessed 14/02/17).

[4] Two factors that may influence this finding. First, 1976 was the first census for which Place of Work data from the previous Census was used to determine the component Census Sub-divisions (municipalities). Second, these CMA geographic building blocks (CSD or municipalities) have tended to increase in land area size over time, due to municipal amalgamations in several provinces.

[5] There may not be a direct, proportional relationship between vehicle registrations per capita and total vehicle-kilometres operated; however, an increase in the former may result in some increase in the latter.

[6] Each fuel emits a different amount of CO_2 in relation to energy produced. The American Energy Information Agency estimates that gasoline emits 157.2 pounds of CO_2 per million British Thermal Units compared to 117.0 pounds for natural gas (http://www.eia.gov/tools/faqs/faq.cfm?id=73&t=11, accessed 14/02/17). Electric vehicles would be even lower, particularly if hydro and other renewals are used to generate the electricity.

[7] Statistics Canada receives the VRFs quarterly. The 4th quarter count of total vehicles registered is slightly higher than the official count of 33,168,805 which is an average of the four quarters during the year (see Statistics Canada CANIM table 405-0004).

[8] There were more that 9 million other types of vehicles such as trailers and non-road vehicles which were excluded from the typology.

[9] The higher prevalence of diesel CFVs in the north and the prairie regions reflects differences by type of vehicle. In both regions, all 3 provinces and all 3 territories have a greater proportion of medium and heavy duty trucks compared to the Canadian average (see Statistics Canada, CANSIM Table 405-0004).

[10] Ethanol, made from corn, is a form of combustible alcohol that can power engines. The American government has been promoting ethanol as an alternative to gasoline, not so much as a way to reduce GHG emissions but rather to lessen dependence on foreign oil. In fact, there are conflicting scientific studies that indicate producing ethanol may or may not increase CO_2 emissions (see *Consumer Reports*, accessed 16/02/17: http://www.consumerreports.org/cro/2011/01/the-great-ethanol-debate/index.htm). U.S. federal regulations have encouraged North American automakers to produce flex-fuel vehicles that can operate on E85. However, currently less than 1 out of every 50 American service stations offers E85. In Canada, the first E85 station began operating in 2014 and there are now just a handful of such stations across the country. Indeed, some owners may not even be aware that they own flex-fuel vehicles capable of operating on E85.

[11] For example, the city of Toronto was defined by parsing 'M' from the postal code field and the other cities based on FSAs that fall within their political boundaries. It should be noted that the postal geography is not always congruent with statistical geography in that FSA boundaries do not respect Census Divisions.

[12] For example, British Columbia has the Clean Energy Vehicle Program with monetary incentives for the purchase or lease of a new battery electric or plug-in hybrid EV. Similarly Ontario has the Electric Vehicle Incentive Program and Quebec has a Drive Electric program that offers rebates on purchase or lease of EVs and charging stations.