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ScienceDirect

Transportation Research Part D 12 (2007) 474–487

TRANSPORTATION RESEARCH PART D

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Canada's voluntary agreement on vehicle greenhouse gas emissions: When the details matter

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Abstract

The 2005 voluntary agreement between the automobile industry and Canadian government to reduce greenhouse gas emissions from passenger vehicles is evaluated. We analyze the likely effect of the agreement on emissions, and on use of biofuels and advanced vehicle technologies. We conclude that the impact on emissions could be far less than suggested, possibly even zero, even if automobile companies fully comply. The pros and cons of the Canadian agreement are assessed and compared with other voluntary and mandatory greenhouse gas reduction programs. Some lessons learned include the importance of specific performance metrics to evaluate progress, use of precise baseline measurements and methods, and an appreciation of the asymmetry in information between most governments and the affected industries.

Keywords: Climate change; Greenhouse gas emissions; Fuel economy; Vehicle; Voluntary agreement

1. Introduction

On April 5 2005, the Canadian automobile industry signed a memorandum of understanding (MOU) with the Government of Canada to reduce greenhouse gas (GHG) emissions from vehicles. The Canadian MOU commits major auto manufacturers and the Government of Canada to cooperate to reduce light duty vehicle GHG emissions in the year 2010 by 5.3 million metric tonnes (MT) of carbon dioxide equivalent (CO_2e) relative to a reference case (Natural Resources Canada, 2005a). As part of the agreement, the auto industry is to offer, market, and deploy GHG emission reduction technologies to vehicle consumers, and the government is to educate consumers about vehicle maintenance and vehicle purchasing options that result in GHG emission reductions.

The initiative is a departure from Canada's standard practice of imitating US automobile regulatory actions. Historically, Canadian automobile emissions and fuel efficiency characteristics were harmonized with comparable light duty vehicle standards set by the US Environmental Protection Agency and the US National Highway Traffic and Safety Administration. Canadian adoption of US emissions and fuel consumption rules is generally formalized by a series of MOU agreements between the Canadian Government and the

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1361-9209/$ - see front matter
doi:10.1016/j.trd.2007.06.003

automotive industry trade associations; examples include agreements for adoption of fuel consumption targets consistent with US corporate average fuel economy (CAFE) standards, US Tier 1 emission standards (model years 1994–2000), the US National Low Emission Vehicle program (2001–2003), and US Tier 2 emissions standards (2004–2009) (Natural Resources Canada, 2005b).

The voluntary GHG agreement was championed as an expedient and effective way to reduce GHGs, bypassing contentious rules in favor of a voluntary measure that neither forces specific technology, adds new regulations, nor imposes fines for non-compliance. Then Natural Resources Minister, Hon. John Efford, commented, "This is a good deal for the economy, the environment and consumers" (Canadian Press, 2005). Ford of Canada Chief Executive Officer and chair of the Canadian Vehicle Manufacturers' Association, Joe Hinrichs, cited industry's long history of producing more environmentally friendly vehicles and stated, "We remain committed to doing our fair share to reduce GHG emissions while contributing to economic growth" (Canadian Press, 2005). Environmental group representatives praised the commitment, estimating that it would increase fuel economy by 25%, stating it would offer consumers "greater choice of efficient, low-emitting cars in the very near future," and predicting that it could strengthen efforts in the US to reduce GHG emissions from light duty vehicles (Plungis and Mayne, 2005).

Although the MOU was heralded as a "win–win" situation, a careful analysis was apparently never conducted. Here we analyze the true impact of the voluntary agreement. How much of the GHG-reductions would take place anyway as a result of already scheduled reductions in vehicle criteria emissions? How much effect will the agreement have on new vehicles relative to changes and improvements already planned? And how does this new agreement compare with other light duty vehicle initiatives around the world, especially in Europe, Japan, and the California?

As of spring 2007, automotive climate change policy in Canada is under review. Canada is falling short of meeting its Kyoto Protocol targets, in large part due to its inability to deliver the planned emission reductions from the transportation sector (Jaccard et al., 2006). In October 2006, a legislative bill was introduced that would follow up the voluntary GHG MOU with mandatory vehicle regulations from 2011 and beyond (Government of Canada, 2006); the legislation has not been enacted.

2. Background

The objectives here are to forecast near-term vehicle technology trends that impact GHG emissions in Canada and determine how they could be credited toward the emission targets of the voluntary agreement, to compare the likely effectiveness of the Canadian initiative with regulatory and market instruments elsewhere, and to assess the use of environmental voluntary agreements.

To analyze the impact of the Canadian agreement, we begin with the officially designated reference case for baseline GHG emissions as established by the text of the agreement. We then analyze changes in GHG emissions likely to result from regulatory initiatives already in place and business-as-usual actions by industry and use this information to update the baseline. These analyses and forecasts are constructed by connecting official government data sources (Energy and Environmental Analysis, Inc, 1999; Environment Canada, 1999; Natural Resources Canada, 1999, 2005c,d) with technical literature on GHG emission reduction technologies. We then compare the updated baseline to the official reference case, and compare both to the emission reduction targets. This new analysis suggests that the voluntary agreement could require much less additional effort by the automakers than widely believed. Crediting (or not crediting) various business-as-usual actions plays a large role in determining compliance requirements.

The second objective is to compare the impact of the Canadian MOU with related programs internationally. The Canadian MOU is the latest of numerous national initiatives around the world aimed at reducing GHG emissions from automobiles. In Europe, voluntary agreements by automakers call for an approximate 25% reduction in the carbon dioxide (CO_2) emission rate of light duty vehicles between 1995 and 2009 (Commission of the European Communities, 2006). Standards in Japan require fuel economy improvements of approximately 23% between 1995 and 2010 (Ministry of Land, Infrastructure and Transport, 2001). China has enacted fuel consumption standards for new light duty vehicles for the first time (Standardization Administration of China, 2005). California's proposed climate change standard would reduce climate change emissions by about 30% for light duty vehicles by model year 2016 (California Air Resources Board, 2004), and other US states are committed to the California regulation. In addition, non-CO_2 regulatory initiatives in Europe and California are aimed at mitigating GHG emissions from mobile air-conditioning systems in Europe and in California (European Union, 2004; California Air Resources Board, 2004). An and Sauer (2004) compare these international initiatives in terms of their impact on new vehicle fuel consumption. The new Canadian voluntary agreement is compared with the other related international climate change mitigation and energy-related policies for vehicles.

The effectiveness of the Canadian automaker MOU is also assessed with respect to other voluntary agreements and more rule-based policy approaches. Numerous industries and governments are confronted with the option of negotiating informal contracts, such as the Canadian MOU, in lieu of binding regulations. Specific agreements with the automotive industries in the European Union and Australia offer the most direct comparison with this Canadian case, and therefore are examined further below for differing features.

More generally, the research literature has chronicled in detail the advantages and potential pitfalls of informal contracts. Confining our discussion here to the most pertinent environmental government industry agreements, we find several studies that define and summarize the key features and lessons learned from such agreements. Voluntary environmental approaches are generally viewed as having the advantages of avoiding mandates, fines, costly compliance testing, government oversight, and the potential for lawsuits, but eliciting smaller responses than other approaches (Organisation for Economic Co-Operation and Development, 1999, 2003). To formulate optimal agreements, the 1999 Organisation for Economic Co-Operation and Development report recommends the following features: clearly define targets, characterize the business-as-usual scenario before setting targets, create a credible regulatory threat to induce industry action beyond business-as-usual, ensure credible monitoring by independent organizations; encourage third party participation with public transparency, enact penalties for non-compliance, and conduct information-oriented activities such as technical support workshops. Krarup (1999) suggests that policymakers also be sensitive to the reality that incomplete or asymmetric information between government and industry in negotiating voluntary agreements can make it "difficult for the regulator to design optimal regulation and choose optimal policy." With the Canadian case study, we build upon the voluntary agreement literature, offering additional insights on the effectiveness of voluntary versus mandatory measures and the extent to which voluntary agreements live up to their billing.

3. Analysis

The official reference case used for the 2005 voluntary agreement is documented and analyzed below for year 2010 GHG emissions. The reference case used 1999 data assumptions. In the following subsections, five sets of vehicle and fuel trends and government programs that emerged between 1999 and 2005 are discussed that result in changes in GHG emissions different than those assumed in the 2005 agreement. The effect of these pre-agreement 1999–2005 trends on passenger vehicle GHG emissions through 2010 are assessed and compared to the reference case.

3.1. Reference case

Fig. 1 shows the official reference case light duty vehicle GHG emissions as established by the Canadian MOU. This official reference case is used as a starting point for our analysis. The official reference case is based upon the 2010 forecast in Road Vehicle & Fuels Technology Measures Analysis (Energy and Environmental Analysis, Inc, 1999), with data from Canada's Emissions Outlook: An Update (Natural Resources Canada, 1999). The reference case GHG emissions are based on estimates of vehicle use (kilometer/year), vehicle stock characteristics (including new vehicle sales and retirement), and GHG emission factors. These variables differ by vehicle type (passenger cars, light trucks), fuel type (gasoline or diesel), calendar year, and vehicle model year. The analysis includes the following GHG emissions: carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), and hydrofluorocarbons (e.g., HFC-134a). The gases are equated to an equivalent value (CO_2e).

This analysis considers automotive technologies and practices that impact the following endogenous variables that are considered to be under direct industry control, including vehicle consumption of new vehicles, non-CO2 emissions from vehicles (CH_4 and N_2O), emissions associated with air-conditioners, use of alternative

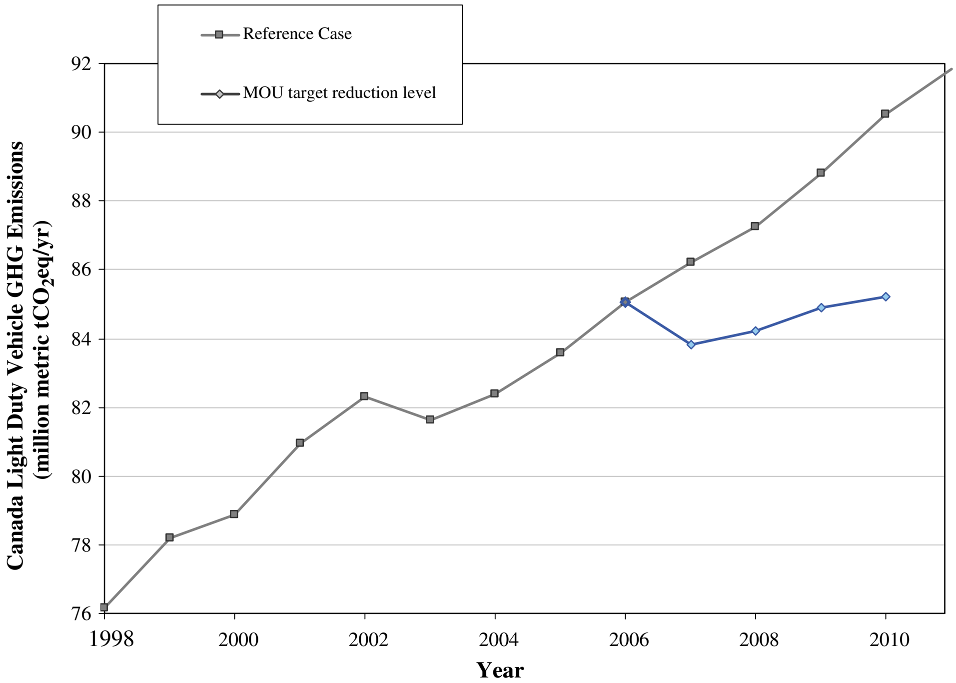

Fig. 1. Light duty vehicle greenhouse gas emissions – reference case and MOU agreement target reductions.

fuels, and "on-road" fuel consumption correction factors for vehicles. These variables are to be monitored and credited as they contribute toward the industry's GHG-reduction targets (Reilly-Roe, 2005).

The official reference case for the 2005 agreement, as mentioned, was established from 1999 data. Although the MOU oversight committee can update the 1999 data to include technology trends that have transpired or been initiated by the time of the 2005 agreement, they have not done so as this paper is written in the spring of 2007. Five likely business-as-usual industry actions that affect GHG emissions are examined that could be incorporated into an updated baseline.

3.2. Five greenhouse gas reduction technologies and practices

We analyze five technology-related effects where current automotive trends will impact GHG emissions in the Canadian light duty vehicle fleet by 2010. The technologies and practices that are analyzed here were chosen because they will likely have significant quantifiable impacts on GHG emissions by 2010, occur independent of the GHG agreement, and currently are not incorporated into the official reference case. Some of the technologies are already in the marketplace while others are expected to be adopted by 2010 as a result of government regulation and/or market competition.

We analyze the expected deployment, impacts on GHG emissions, and likelihood that the technology deployment would have occurred independent of the Canadian MOU on GHG emissions (Lutsey, 2006). The considered technologies and their deployment schedules were already established (that is, already occurred or are set to occur by regulation or industry agreement) previous to the signing of the Canadian MOU agreement. However, these technologies were not incorporated in the official reference case data assumptions because of the outdated 1999 data that was used to set the MOU baseline and targets.

We emphasize that the prime uncertainty, and speculation, in this study is whether and how the MOU monitoring committee accounts for pre-MOU trends in determining auto industry compliance (and less so in the uncertainty of forecasting future technology deployment). The five technology effects can be used by the auto industry to meet the Canadian voluntary agreement targets. Alternatively, the effects could reasonably be included in a new updated reference case emissions baseline, and would therefore not be eligible for emission reductions credit toward the agreement. After we analyze the five technology effects, we consider the impact of crediting the GHG-reducing technologies versus including them in updated baseline emissions for the reference case.

3.2.1. Tested fuel consumption of new vehicles

New vehicle fuel consumption trends, already occurring prior to the signing of the voluntary auto agreement in Canada, might contribute to GHG-reductions that can be applied toward the Canadian MOU. The deployment of technologies that improve vehicular fuel consumption is one of the more evident approaches to be applied by automakers to meet the GHG-reduction pact. Two types of light duty vehicle fuel consumption improvements can be measured – those measured directly through standardized tests conducted by automakers and regulators, and those that are not. We define the others as "on-road" improvements, and address them in the next subsection. Test-cycle measurements are used by regulators to determine compliance by vehicle suppliers with regulatory fuel economy or emission standards. Using these tests, automakers report emissions and fuel economy for new vehicles each year.

We focus on two fuel efficiency trends that are captured by the fuel economy tests, but which are currently not incorporated in the official MOU reference case. The first relates to updating of the MOU's official reference case fuel consumption rates for new vehicles from the older forecasted 1999 data. Fig. 2 shows the official reference case fuel consumption data for passenger cars and light trucks for 1996 through 2010. Also shown are actual model year 2000 to 2004 fuel consumption data, which are up to 4% below the reference data for these model years. Because the majority of these model year 2000 to 2004 vehicles are in the fleet through the year 2010, they substantially impact the GHG emissions estimations for the MOU. By not updating the reference case fuel consumption, automakers would be credited with fuel efficiency improvements in vehicles that were already in the fleet at the time of the MOU signing in 2005.

A second fuel efficiency trend that is independent of, but significant to, the GHG MOU is the adopted, but yet-to-be-implemented regulatory increase in light truck fuel economy. By previous voluntary agreement of the automakers, Canadian light duty vehicle Company Average Fuel Consumption (CAFC) targets are harmonized, or set to be equivalent to, the US light duty CAFE regulations[1] (Natural Resources Canada, 2005b). Therefore, the Canadian vehicle manufacturers are committed to improvements in new vehicle fuel consumption to stay on par with US light truck fuel economy standards, which includes new US light trucks standards for model years 2008 through 2010 (National Highway Traffic and Safety Administration, 2005b). The CAFE increase in light truck fuel economy from 22.0 to 23.5 miles per-gallon is equivalent to a decrease in fuel consumption from 10.7 to 10.0 L/100 km between model years 2007 and 2010. Considering that light duty fuel economy of Canadian vehicles has historically always been higher than those of the US CAFE averages, it would be expected that Canadian light trucks have an average fuel economy at least as high as the new proposed US light truck CAFE values for model years 2008 through 2010 – without the GHG MOU in place.

The impact of the two fuel efficiency actions is shown in the first two rows of Table 1. Updating the model year 2000 to 2004 vehicle fuel consumption alone would amount to decreasing 2010 GHG emissions by 1.21 MT CO_2e emissions, or 23% of the target MOU emission reduction total. The impact of business-as-usual light truck fuel consumption improvements consistent with the US CAFE regulations for light trucks through 2010 would be a decrease of 0.59 MT CO_2e emissions in the year 2010, or 11% of the MOU total for that year. To emphasize, the current MOU reference case does not incorporate these two fuel efficiency trends; therefore, currently, automakers could be credited with accomplishing 34% of the MOU target 2010 GHG emission reductions for these trends that very likely would have occurred anyway.

3.2.2. On-road vehicle efficiency

On-road or in-use vehicle efficiency improvements with accompanying GHG impacts are more difficult to validate. They reflect real driving behavior, not laboratory tests, and can vary considerably across drivers and

[1] US CAFE regulations relate to "fuel economy" measured in miles per-gallon. Canadian CAFC limits relate to "fuel consumption," measured in liters-per-hundred-kilometers. These variables have an inverse relationship.

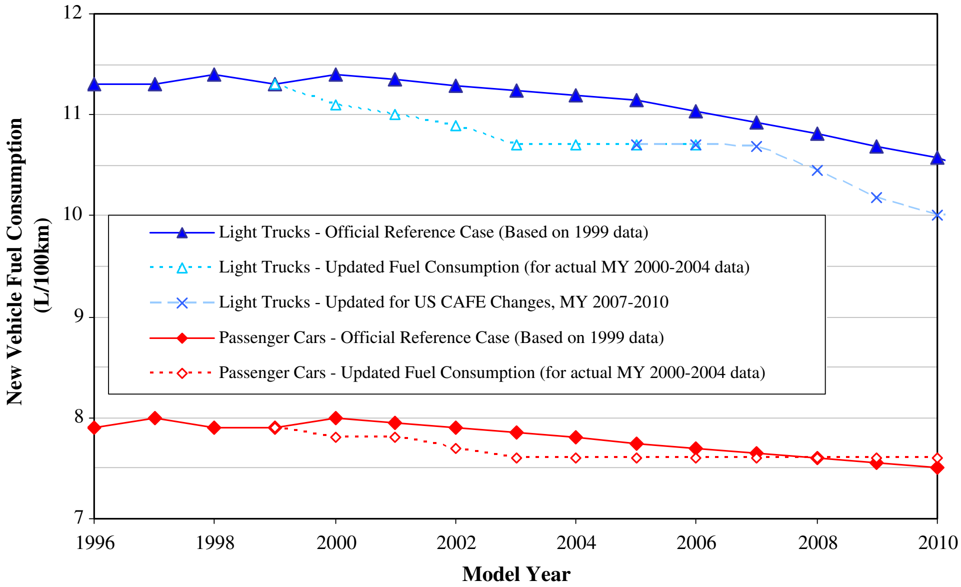

Fig. 2. Reference case and updated fuel consumption for new vehicles in Canada for model years 1996 through 2010.

Table 1
Technology trend impacts on greenhouse gas emissions in 2010

Technology trend for light duty vehicles that impact greenhouse gas emissions by 2010	Emission reduction in Canadian light duty fleet in 2010 (MT CO_2e)	Percent of GHG MOU emission reduction target in 2010 (%)
Updated test-cycle fuel consumption data for model years 2000–2004	1.21	22.8
US corporate average fuel economy light truck standard for model years 2005–2010	0.59	11.1
On-road correction factor improvements from supplemental federal test procedure program and tire pressure monitoring systems for model years 2000–2010	1.12	21.2
Tier 2 criteria pollutant regulations with low-sulfur fuel impact on N_2O and CH_4 emissions for years 2000–2010	1.66	31.3
Increased ethanol fuel mixing in motor gasoline from 0.6% to 3.7% (by volume) per Ethanol Expansion Program for years 2002–2010	0.68	12.8
Mobile air-conditioning technology improvements comparable to upcoming California and Europe regulations for model years 2007–2010	0.71	13.4

MOU = memorandum of understanding; GHG = greenhouse gas.

vehicles and over time as vehicles age. This type of efficiency improvement can be altered by driver education initiatives and can be measured with surveys and data collection of actual vehicle usage.

We consider two government programs unrelated to climate change (criteria emissions and tire safety) that are likely to impact vehicle climate change emissions. In 1996 the US Environmental Protection Agency (US EPA) revised the federal test procedure to include a Supplemental Federal Test Procedure (SFTP), which took into account real-world vehicle conditions such as aggressive driving and air-conditioning operation (US Environmental Protection Agency, 1996). The objective was to measure real-world criteria pollutant emissions more accurately, but this test also is used to measure fuel economy and CO_2 emissions. It helps document the gap between actual "on-road" fuel economy and lab-tested fuel economy, a well known phenomenon (McNutt et al., 1982). Adjustment factors were put forward by US EPA in the early 1980s to decrease tested "highway" fuel economy by 22% and tested "city" fuel economy by 10% (Hellman and Murrell, 1984), or about 15% for the average mix of driving at that time. The gap seems to have widened (see e.g., Mintz et al., 1993). The US Department of Energy estimates that the gap between rated and on-road energy use in light duty vehicles is now about 20% . The Canadian MOU reference baseline assumes an average 20% fuel consumption correction (Natural Resources Canada, 1999). The impact of the SFTP program modifications could impact the fuel economy shortfall by 1–2% over model years 2000–2002 (German, 1997).

The second "on-road" fuel consumption measure we consider relates to a new National Highway Traffic and Safety Administration safety regulation that mandates tire pressure monitoring technology onboard new vehicles. The new mandated tire pressure monitoring systems (TPMSs) warn drivers if tires are significantly under-inflated, are fully deployed in new vehicles by 2008, and improve in-use fuel economy by 0.5% (National Highway Traffic and Safety Administration, 2005a). TPMS technology is mentioned in the GHG MOU (Natural Resources Canada, 2005a), and a statement by the Canadian auto industry suggests that TPMS technology is one method for which it intends to be credited for MOU GHG emission reductions (Canadian Vehicle Manufacturers Association, 2005). The net impact of both "on-road" effects is estimated to improve the shortfall between rated and in-use vehicles from 20% to 18% for new vehicles, phased in according to the schedules of the SFTP and tire regulations. As shown in the third row of Table 1, the impact of this on-road factor improvement trend on 2010 GHG emissions is to decrease GHG emissions by 1.12 MT CO_2e emissions, or 21% of the target MOU emission reduction.

3.2.3. Nitrous oxide and methane emissions

Another technology trend that results in GHG-reductions that would also occur irrespective of the Canadian GHG automotive agreement is the non-CO_2 GHG emission reductions that result from criteria pollutant regulations. Greenhouse gas emission reductions from US and Canada automobiles will result from the US Environmental Protection Agency's Tier 2 emission program which reduces vehicle exhaust emissions of the criteria pollutants oxides of nitrogen (NO_x) and hydrocarbons (HC). Tier 2 rules, finalized in 1999, lower tailpipe emissions of NO_x by 77% for passenger cars and 95% for light trucks from Tier 1 emission levels and are to be phased in on new vehicles from model years 2004–2009, along with a sulfur reduction in motor gasoline (US Environmental Protection Agency, 1999). Likewise, Canadian emissions levels are set to reduce in line with the US Tier 2 emission and low-sulfur gasoline standards according to the 1999 Canada Environmental Protection Act (Environment Canada, 1999; Natural Resources Canada, 2005c; General Motors Canada, 2005). Because nitrous oxide (N_2O), a species of NO_x in vehicle exhaust, is a GHG, the Tier 2 emission standards with low-sulfur fuel will result in GHG emission reductions. Potential reductions of hydrocarbons, specifically their GHG component methane (CH_4), are also analyzed in this section.

Although these Tier 2 regulations originated in 1999, their effect on GHG emissions are not incorporated into the reference case of the 2005 GHG MOU. At present, it is uncertain whether the effect of those regulations will be credited toward the Canadian MOU 2010 GHG-reduction target. The issue is not directly addressed in the official MOU text, and there are conflicting statements from industry in various media sources on the issue of crediting reductions from N_2O emissions. In one news story on the MOU signing, an auto industry executive was cited as "adamant that there is 'no double billing for NO_x,' allowed per the agreement" (Inside Washington Publishers, 2005). However, a different industry statement implies that the Canadian auto industry expects to be credited with GHG emission reductions for their action in response to the Tier 2 criteria pollutant emission regulations; in a statement on automaker voluntary commitments to climate change, the industry commits to "Continued introduction of Tier 2 level emissions control systems which reduce N_2O emissions from new vehicles and, in conjunction with cleaner fuels, the N_2O emissions of the entire fleet" (Canadian Vehicle Manufacturers Association, 2005). The counterpoint to including these reductions is that these N_2O Tier 2 emissions reductions were established in 1999 and would occur regardless of the signing of the Canadian MOU on GHG emissions.

We estimate N_2O and CH_4 emissions trends from Natural Resources Canada's (NRCan) emissions data program, GHGenius, version 3.0 (Natural Resources Canada, 2005c), and we compare these emissions forecasts against the official MOU reference case emission levels (from Natural Resources Canada, 1999) to determine likely near-term GHG emission reductions. For years 2005 through 2010, average gram-per-mile light duty vehicle N_2O emissions are 58–59% below their reference case emission levels, whereas CH_4 emissions are only modestly (less than 10%) lower then the reference. Shown in the fourth row of Table 1, the impact of these criteria pollutant emission trends for model year 2000 and later vehicles on 2010 GHG emissions is a decrease of 1.66 MT CO_2e emissions, or 31% of the target MOU emission reduction total.

3.2.4. Increased ethanol mix in gasoline

Another established Canadian program with GHG-reduction potential that could be included in the Canadian GHG MOU reference case – but currently is not – is the 2003 Ethanol Expansion Program (EEP) to increase the use of ethanol in motor gasoline. Ethanol derived from agricultural crops is a renewable fuel that harnesses CO_2 from the atmosphere to store energy in a chemical form that can be used to produce liquid fuels for vehicles. The net cycle of growing and harvesting crops, transporting and chemically converting the crop to usable fuel for vehicles, and combusting the fuel for motor vehicle propulsion can offer net GHG-reductions, depending on crop feedstock and process characteristics. Although there is considerable uncertainty, conventional near-term ethanol from corn is widely held to offer some GHG benefit (Wang et al., 1999; Farrell et al., 2006; Hill et al., 2006). Mixing ethanol into motor gasoline in blend proportions up to 10% can be done without vehicle modifications.

It is uncertain whether or not increased ethanol blending in gasoline will be officially considered for potential GHG-reductions toward the MOU. The MOU oversight committee has not weighed in on this issue, but automotive industry press releases routinely list the use of increased alternative fuels such as ethanol as one of the approaches the industry is taking to help reduce automobile GHG emissions to meet the voluntary agreement with the government of Canada. Listed along with efforts on deploying advanced lower fuel consumption technologies, the "Canadian Automotive Industry has voluntarily agreed to develop and introduce alternative fuel compatible vehicles" and "encourage the expanded use of alternative fuels, such as ethanol" (Canadian Vehicle Manufacturers Association, 2005).

However, a statement from a Canadian government official suggests that increased ethanol blending is outside of the purview of the MOU agreement. A Natural Resources Canada official states, "Credit for the use of E-10 (a blend of 10% ethanol and 90% gasoline) cannot be applied to the 5.3 MT target as increased production and use of ethanol fuel is being attributed to the government's Ethanol Expansion Program or related measures" (Khanna, 2005). Although the government official's language indicates that ethanol is unlikely to be included, automakers' statements to the contrary lead us to consider ethanol as a GHG reduction trend that may potentially be counted toward the MOU target.

We consider ethanol-related GHG-reductions toward the voluntary agreement based on the life-cycle GHG emission reductions from the 2003 Canadian ethanol expansion government program. The EEP would increase ethanol production from 200 million liters in 2002 to 1.4 billion liters in 2010, increasing the percentage of E-10 from approximately 7% to 35% over that period (Natural Resources Canada, 2005d). For this analysis, the ethanol expansion from 2002 to 2010 is assumed to be a linear increase from 0.6% to 3.7% of the total gasoline mix over this time period.

We apply the life-cycle emission benefits from the "corn-based near-future" mixed in E-10 motor gasoline from Wang et al. (1999) to estimate the GHG emission benefits of the EEP program on light duty vehicle from 2000 to 2010. The Wang et al. (1999) result of about 25% GHG benefit from corn-based ethanol that we apply is between two recent studies (Farrell et al., 2006; Hill et al., 2006) reporting 12–13% GHG benefits and the Canadian agency (Natural Resources Canada, 2004) value of "up to 40%," that does not readily disclose research sources and methods. Using the official MOU reference case fuel GHG content of 2311 gram CO_2 per liter of motor fuel, the change in the fuel GHG content with the ethanol expansion from 0.6% (in 2002) to 3.7% (in 2010) results in reducing the GHG content from 2311 to 2293 gram CO_2 per liter of motor fuel by year 2010. As shown in the fifth row of Table 1, the impact of this ethanol mixing trend on 2010 GHG emissions is to decrease GHG emissions by 0.68 MT CO_2e emissions, or 13% of the target MOU emission reduction total.

3.2.5. Mobile air-conditioning systems

Technology trends in mobile air-conditioning (MAC) systems offer further potential GHG-reductions that could be included in the official reference case for the Canadian voluntary GHG agreement. Here we discuss two near-term technologies: refrigerant (i.e., hydrofluorocarbon R-134a) GHG emission reductions from lower-leak components, charge reduction, or an alternative refrigerant, and improved MAC system efficiency to reduce fuel consumption and tailpipe CO_2 emissions. Consideration of these technologies and their impact in Canada follows from the work of researchers and regulators in California and Europe. Vehicles in Europe, in connection with joint regulatory-industry deliberations over reducing emissions to contribute to overall Kyoto Protocol reductions, are set to phase in lower-leak MAC systems in all new vehicles by 2011, and phase out the conventional refrigerant, R-134a, for new vehicles between 2011 and 2017 (European Union, 2004). In the proposed California climate change regulations for vehicles, the technology assessment assumes the use of a lower-leak system with the use of refrigerant R-152a, to be fully deployed across new light duty vehicles by model year 2016 (California Air Resources Board, 2004).

We estimate the GHG-reduction potential of MAC systems by model year 2010 based on work of the California regulatory assessment that formulates the emission reduction credits to be granted for given MAC system improvements for the California GHG vehicle standards. The California Air Resources Board regulatory research concludes that "low leak" technology and switching new vehicles from HFC-134a (with a global warming potential (GWP) of 1300) to HFC-152a (GWP of 120) offers a potential reduction of 3.0 g CO_2e per-mile. For MAC efficiency technologies with fuel use reductions that lead to tailpipe CO_2 emission reductions, we consider increased efficiency variable displacement compressors (VDCs) and improved control systems that offer reductions of 7.5 g CO_2e per mile for passenger cars and 10.0 g CO_2e per-mile for light trucks (which on average have somewhat larger air conditioning loads and larger compressors than passenger cars).

We assume the two MAC technologies are deployed together on new vehicles from model year 2007 to 2009 to correspond with the timing of the European directive (that limits leakage of refrigerant systems) and to precede by two years the California regulation (for the 2012 "near-term" standards that promote low-leak and high-efficiency MAC systems). The impact of the two MAC technology advances, a lower-leak refrigerant HFC-134a and an improved efficiency MAC system, deployed together on new vehicles is a reduction in GHG emissions of 10.5 (for cars) and 13.0 (for light trucks) grams-per-mile CO_2e. As shown in the sixth row of Table 1, the impact of these MAC improvement trends on 2010 GHG emissions is to decrease GHG emissions by 0.71 MT CO_2e emissions, or 13% of the target MOU emission reduction total.

4. Results

4.1. Greenhouse gas reduction crediting scenarios

Including the five existing technology trends in the official MOU reference case substantially impacts the overall emission reduction that the agreement will bring about. In Table 1, we summarize the total emission reductions that result from the technology trends and regulatory changes for 2010, and the percent of the 5.3 MT CO_2e target that each trend could be responsible for in 2010 if they were credited.

With the prevailing uncertainty about which of these existing technology trends will be credited as new reductions or as a new updated reference, we explore a full range of scenarios. Results here are highlighted for a "full mix" strategy, where all of the technology trends are credited as new reductions toward the MOU and an "all new efficiency" strategy, where none of the pre-existing trends are credited toward the MOU reduction targets (i.e., where the trends are included in an updated emissions reference case and therefore the achievement of the 5.3 MT CO_2e target will require new, additional vehicle fuel efficiency technologies).

Fig. 3 shows the impact of not updating the MOU reference case for technology trends. Instead this figure assumes that the automakers are credited with the GHG emission impacts of all of the discussed technology trends. For this "full mix" scenario, no new efficiency improvements would be needed to satisfy the MOU. With this most inclusive approach to what is allowable for GHG-reduction credit, emission reduction credits would be granted for all initiatives that reduce GHG emissions regardless of whether the reductions are the result of (a) outdated reference case projections, (b) technologies already deployed at the time of the MOU signing, (c) previously established agreements or programs, or (d) regulations crafted for reasons other than climate change.

For the "all new efficiency" scenario, we consider that the voluntary agreement is met with only new additional vehicle fuel efficiency technology that has improved rated test-cycle fuel consumption rates. In this scenario, we consider that the baseline reference case would be adjusted downward to reflect the impacts of each

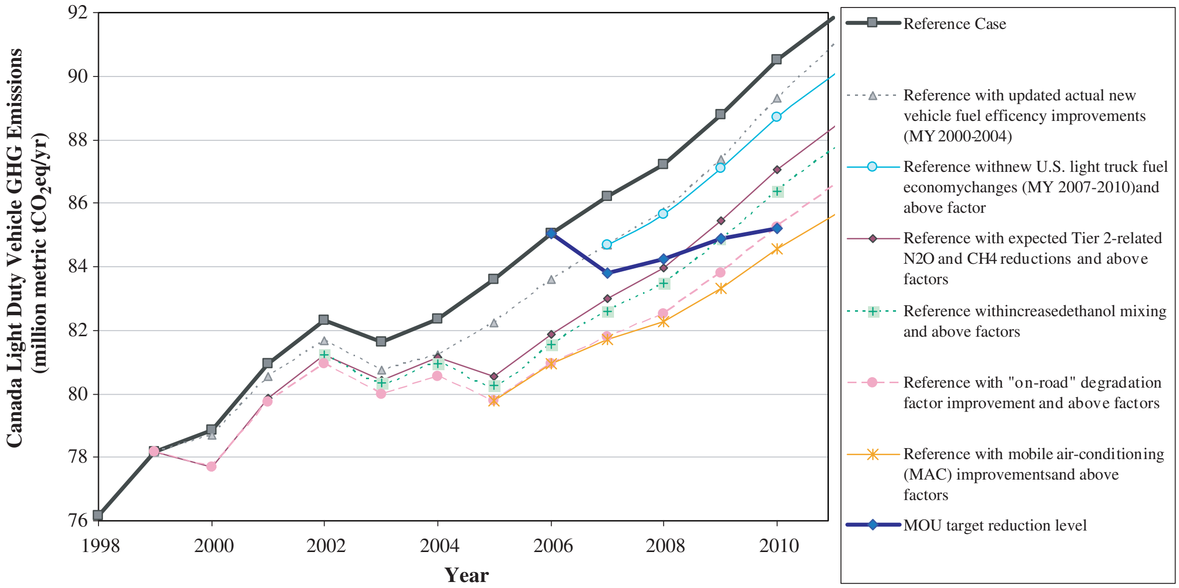

Fig. 3. Light duty vehicle greenhouse gas reference case with the impact of "full mix" of technology trends that impact greenhouse gas emissions, compared with the MOU target.

of the GHG-reductions of the existing technology trends. This scenario represents a stricter definition of which reductions are to be credited toward the MOU, by excluding pre-existing trend effects. Fig. 4 shows the required fuel consumption improvements for this "fuel efficiency only" approach. For both passenger cars and light truck vehicle types, a reduction of new vehicle fuel consumption by 18% from 2004–2009 is sufficient to achieve the MOU targets for 2009 and 2010. This is equivalent to raising average new vehicle fuel economy by 5.8 miles per gallon (6.8 mpg for cars, 4.9 mpg for light trucks). The resulting fleet GHG-reductions are shown with respect to the MOU target emissions in Fig. 5.

4.2. Potential impact of greenhouse gas reduction crediting

For the two scenarios, we quantify the effects of the GHG crediting scenarios on actual reductions, assuming that industry does not choose to deploy more efficiency or other low-GHG technology advancements than would be needed to comply with the MOU. For each GHG-reduction resulting from some other established pre-existing program that is credited toward the 5.3 MT CO_2e MOU target emission reductions, the effectiveness of the MOU in further reducing GHG emissions from automobiles is diminished by the amount of that GHG-reduction. For the extreme "full mix" crediting scenario, it is possible for the agreement target of 5.3 MT CO_2e to be achieved with no new emission reduction programs being implemented. Whereas for the "full new efficiency" scenario the agreement goal would be met with all new vehicle efficiency improvements.

4.3. Comparison of greenhouse gas reduction initiatives

Fig. 6 shows the range of effects that the Canadian GHG MOU could have on vehicle fuel consumption (measured in L/100 km), as compared with fuel consumption and GHG initiatives in other countries (with non-Canada data based on An and Sauer, 2004). Regulations bind average new vehicle fuel consumption rates in the US, Japan, and China, whereas the GHG emission rates of new passenger vehicles in the European Union and Australia are set to improve according to voluntary commitments from automakers. Unlike the Canadian voluntary agreement, though, the European and Australian commitments are based on average vehicle per-kilometer measurements, not overall emission tonnage targets. Currently auto firms in Europe

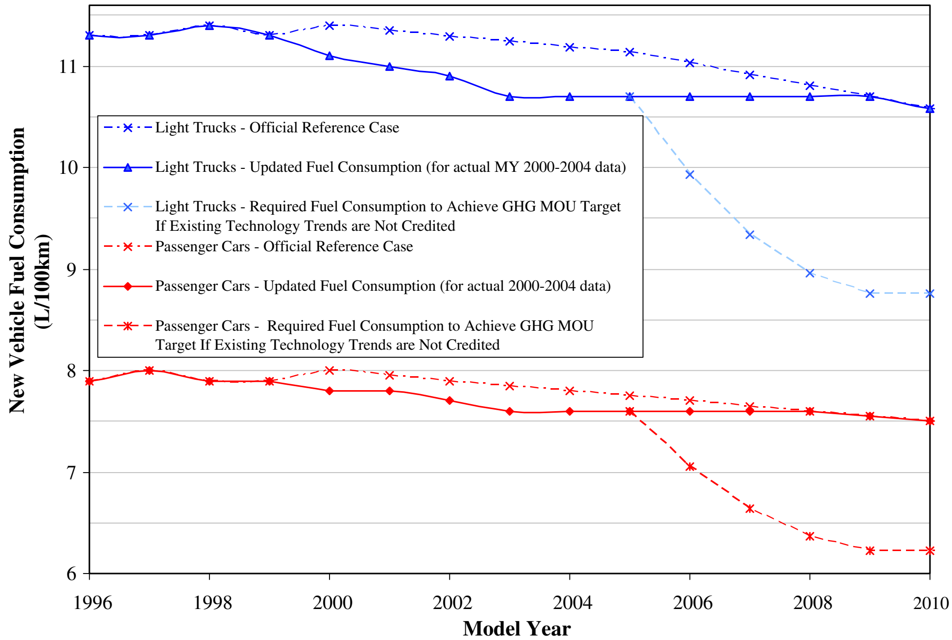

Fig. 4. Reference and updated new vehicle fuel consumption, and required additional fuel consumption improvement for "all new efficiency" scenario to achieve GHG MOU target for 2010.

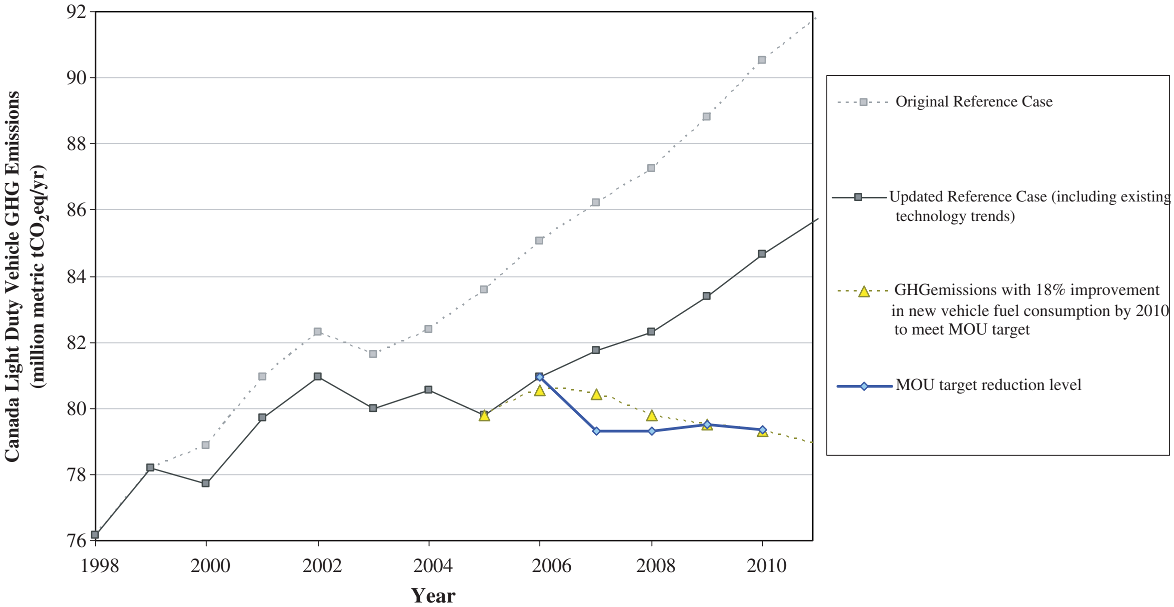

Fig. 5. Light duty vehicle greenhouse gas emissions reference case, updated reference case for existing technology trends, and "all new efficiency" scenario to achieve the MOU target for 2010.

"met all their obligations stated in their Commitments" through 2004, but will "have to substantially increase their efforts" to meet the final targets for 2008 and 2009 (Commission of the European Communities, 2006). Of the national GHG and fuel initiatives, it is only the Canadian voluntary agreement that offers such a wide

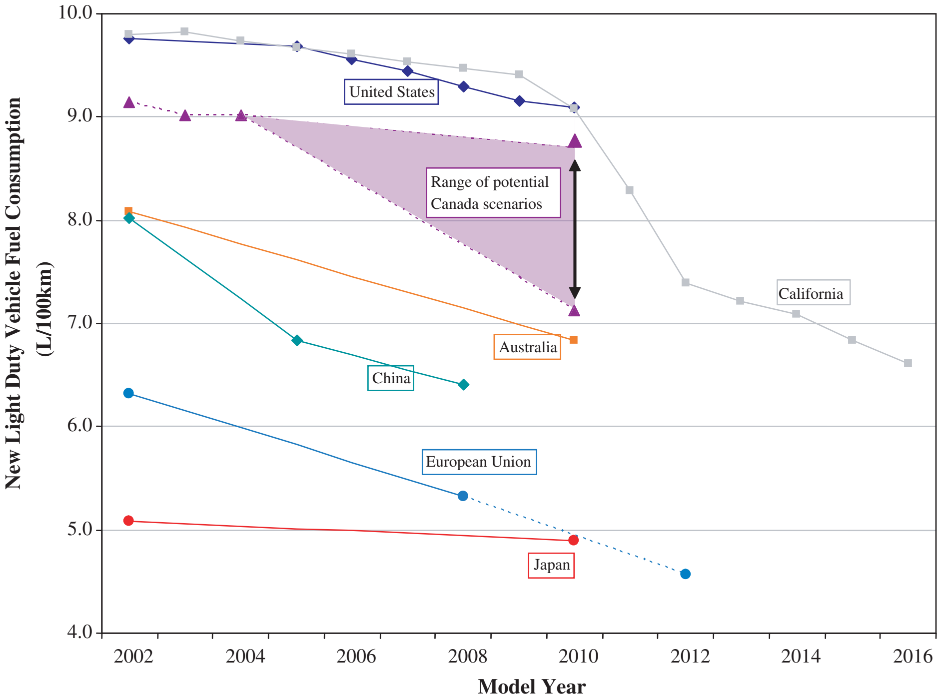

Fig. 6. Comparison of national light duty vehicle fuel consumption and greenhouse gas emission initiatives.

range of potential outcomes in new vehicle fuel consumption (and GHG emission) rate, with a range of impacts over the 2004 to 2010 timeframe for new vehicle fuel consumption in Canada from 3% to 18%, as estimated from this analysis.

The review of previous work highlighted numerous potential determinants in the emission reduction performance of voluntary agreements, and it seems that the Canadian MOU – with its modest potential impact and high level of uncertainty about its outcome as compared with other international initiatives – is compromised by several of those factors. First, the creation of the Canadian MOU could be subject to improper establishment of a reference case and incomplete information by the agreement parties previous to the signing of the agreement. Whether the reference baseline for the Canadian agreement includes or excludes various already set to occur emission reduction trends results in a 0% to 18% swing in the impact on new vehicle per-mile GHG emissions. This large variation clearly attests to the importance of explicitly defining the reference industry activity before the signing of voluntary agreements. Second, it is conceivable that the auto industry readily knew the extent to which their technology deployment from other already established non-GHG programs could be applied toward the GHG pact, while government authorities may not have known such information.

A third factor that could disadvantage the Canadian government-automaker agreement's performance is the type of metric employed. Whereas the European voluntary agreement and the other regulatory mandates of other countries use robust and unambiguous metrics, such as grams-per-mile, miles-per-gallon, liters-per-kilometer, the Canadian agreement was made in terms of a relatively indeterminate "millions of metric tonnes" metric that is subject to myriad assumptions and variables that can confound and/or detract from achievement of the agreement's objectives. It is conceivable that a gross overall highest-level metric like this was seen as desirable for choosing the MOU goal to allow the fullest possible flexibility of options to automakers. However, doing so could easily have clouded agreement participants' vision from the smaller details of how the baseline would be determined, how the agreement could be met, and which existing programs and trends could be credited. The combination of these shortcomings appears to open the door for the auto industry in Canada to evade more substantial technology deployment changes that they face in other markets around the world.

5. Conclusions

This paper examines the effects of 2005 Canadian MOU on GHG emissions from automobiles. We highlighted several ways in which existing technology trends could be credited toward the Canadian MOU emission targets. At one extreme, using the "full mix" scenario, the MOU target could be achieved with little or no new vehicle fuel consumption improvement beyond existing business-as-usual trends. At the other extreme, in the "all new efficiency" scenario, there is an 18% reduction in fuel consumption and CO_2 emission rate reduction for new vehicles over the period of 2004 to 2010. Where between the low (0%) and high (18%) new fuel efficiency improvements that new 2010 vehicles will end up depends on the crediting of potential GHG-reduction trends discussed in this analysis.

The Canadian agreement contrasts markedly with other voluntary and regulatory agreements around the world for reducing GHG emissions and fuel consumption from vehicles. The impact is less and the uncertainty is higher. The potentially limited overall impact of the Canadian GHG initiative opens the door for the auto industry in Canada to evade more substantial technology deployment changes that they face in other markets around the world, where more demanding and clearly-stated targets for new vehicles are established.

The voluntary approach to environmental policy, such as the Canadian agreement, has the advantages of avoiding mandates, fines, costly compliance testing and government oversight, and the potential for lawsuits. However, this case study underscores three factors that may compromise the potential impact of a voluntary emission reduction agreement. First, an indeterminate performance metric, such as "millions of tonnes of emissions," by which to evaluate the auto industry's progress, immediately introduces ambiguity about assumptions and uncertainty about agreement outcomes. Second, an unclear pre-agreement establishment of reference industry emissions confounds the ability to determine which industry actions are "business-as-usual" and which are "new," therefore jeopardizing whether new emission reduction technologies will be needed at all.

Finally, the industry signing a voluntary agreement possesses a better understanding of how the implementation of the agreement can be met. It knows what it can do at what cost and it has additional critical knowledge of how other initiatives, including those indirectly related, could contribute to the target emission reductions. This is a case of asymmetric information. Industry participants might well use their deeper knowledge to recharacterize already established technology trends, thus evading more rapid technology changes and expenses while scoring environmental public relations benefits.

Acknowledgements

The authors thank the William and Floral Hewlett Foundation for its support of this work. Thanks to Kenneth Colburn of Symbiotic Strategies for his guidance and critical review. They also gratefully acknowledge Roland Hwang of the Natural Resources Defense Council for his early input, Paul Khanna and Natural Resources Canada for their review, and the anonymous journal referees for their critical comments.

References

An, F., Sauer, A., 2004. Comparison of passenger vehicle fuel economy and GHG emission standards around the world. Pew Center on Global Climate Change, Arlington.

California Air Resources Board, 2004. Initial Statement of Reasons for Proposed Rulemaking, Public Hearing to Consider Adoption of Regulations to Control Greenhouse Gas Emissions from Motor Vehicles, CARB, Sacramento.

Canadian Press, 2005. Canadian automakers hail agreement to reduce greenhouse gases. <http://www.canada.com/businesscentre/story.html?id=def09b63-ba76-494a-9b42-9864cd1b2940> (accessed 17.10.2005).

Canadian Vehicle Manufacturers Association, 2005. CVMA: current issues: climate change. <http://www.cvma.ca/eng/issues/climate-change.asp> (accessed 11.10.2005).

Commission of the European Communities, 2006. Communication from the Commission to the Council and the European Parliament: Implementing the community strategy to reduce CO_2 emissions from cars. In: Fifth Annual Communication on the Effectiveness of the Strategy, COM (2006) 463 final, Brussels.

Energy and Environmental Analysis, Inc., 1999. Canadian transportation table study 3: road vehicle and fuels technology measures analysis, Arlington, Virginia.

Environment Canada, 1999. Sulphur in Gasoline Regulations (SOR/99-23), Canada Environmental Protection Act, EC, Ottawa.

European Union, 2004. Climate change: commission welcomes political agreement in the council to reduce emissions of fluorinated greenhouse gases. <http://europa.eu.int/rapid/pressReleasesAction.do?reference=IP/04/1231&format=HTML&aged=0&language=EN&guiLanguage=en> (accessed 25.10.2005).

Farrell, A.E., Plevin, R.J., Turner, B.T., Jones, A.D., O'Hare, M., Kammen, D.M., 2006. Ethanol can contribute to energy and environmental goals. Science 301, 506–508.

General Motors Canada (GM Canada), 2005. Vehicle emissions & fuels.<http://www.gmcanada.com/inm/gmcanada/english/about/Environment/environment_Tailpipe.html> (accessed 18.10.2005).

German, J., 1997. Federal test procedure revisions and real-world emissions. In: DeCicco, J., DeLucchi, M. (Eds.), . In: Transportation, Energy, and Environment: How Far Can Technology Take us. American Council for an Energy-Efficient Economy, Washington DC.

Government of Canada, 2006. Canada's clean air act delivered to Canadians. <http://www.ec.gc.ca/press/2006/061019_n_e.htm> (accessed 23.01.2007).

Hellman, K.H., and Murrell, J.D., 1984. Development of adjustment factors for the EPA city and highway MPG values. Society of Automotive Engineers, Paper 840496, Warrendale.

Hill, J., Nelson, E., TIlman, D., Polasky, S., Tiffany, E., 2006. Environmental, economic, and energetic costs and benefits of biodiesel and ethanol biofuels. Proceedings of the National Academy of Sciences of the United States of America 103, 11206–11210.

Inside Washington Publishers, 2005. Canada, automakers reach historic pact on greenhouse gas emissions. Washington, DC.

Jaccard, M., Rivers, N., Bataille, C., Murphy, R., Nyboer, J., Sadownik, B., 2006. Burning our money to warm the planet: Canada's ineffective efforts to reduce greenhouse gas emissions. C.D. Howe Institute, No. 234, Toronto.

Khanna, P. 2005. Natural Resources Canada. Personal communication. December 5.

Krarup, 1999. The efficiency of voluntary approaches – a CAVA literature survey. Paper No. 99/08/2, Ecole des Mines de Paris, Paris.

Lutsey, N. 2006. Impact of Canada's voluntary agreement on greenhouse gas emissions from light duty vehicles. Institute of Transportation Studies, Paper UCD-ITS-RR-06-02, Davis.

McNutt, B.D., Dulla, R., Crawford, R., McAdams, H.T., Morse, N., 1982. Comparison of EPA and on-road fuel economy – analysis approaches, trends and imports. Society of Automotive Engineers, Paper 820788, Warrendale.

Ministry of Land, Infrastructure and Transport, 2001. Interim report on target standards for fuel consumption. <http://www.mlit.go.jp/english/mot_news/mot_news_981014/mot_news_981014_2.html> (accessed July 15).

Mintz, M.M., Vyas, A.D., and Conley, L.A., 1993. Difference between EPA-test and in-use fuel economy: are the correction factors correct?, Paper 931104, 72nd Annual Meeting of the Transportation Research Board, Washington, DC.

National Highway Traffic and Safety Administration, 2005a. Federal motor vehicle safety standards; tire pressure monitoring systems; controls and displays; final rule. From 49 CFR parts 571 and 585, US Department of Transportation, Washington, DC.

National Highway Traffic and Safety Administration, 2005b. Preliminary regulatory impact analysis: corporate average fuel economy and CAFE reform for MY 2008-2011 light trucks. US Department of Transportation, Washington, D.C.

Natural Resources Canada, 1999. Canada's emissions outlook: an update, <http://www.nrcan.gc.ca/es/ceo/update.htm> (accessed 12.10.2005).

Natural Resources Canada, 2004. Benefits: societal and economic benefits. <http://oee.nrcan.gc.ca/transportation/fuels/ethanol/benefits.cfm?attr=8> (accessed 26.10.2005).

Natural Resources Canada, 2005a. Memorandum of understanding between the government of Canada and the Canadian automotive industry respecting automobile greenhouse gas emissions. <http://www.nrcan-rncan.gc.ca/media/mous/2005/20050405_e.htm> (accessed 5.10.2005).

Natural Resources Canada, 2005c. GHGenius downloads. <http://www.ghgenius.ca/downloads.php> GHGenius, Version 3.0. (Accessed 12.10.2005).

Natural Resources Canada, 2005d. Backgrounder: ethanol expansion program. <http://www.nrcan.gc.ca/media/newsreleases/2005/200550a_e.htm> (accessed 29.10.2005).

Natural Resources Canada, 2005b. Backgrounder: the government of Canada's voluntary agreements with the automotive industry." <http://www.nrcan-rncan.gc.ca/media/newsreleases/2005/200522b_e.htm> (accessed 20.10.2005).

Organisation for Economic Co-Operation and Development, 1999. In: Carraro, C., Leveque, F. (Eds.), Voluntary Approaches for Environmental Policy: An Assessment. Kluwer Academic Publishers., Boston.

Organisation for Economic Co-Operation and Development, 2003. Voluntary Approaches for Environmental Policy: Effectiveness, Efficiency ad Usage in Policy Mixes, Boston.

Plungis, J., and Mayne, E., 2005. Automakers go green in Canada, curbing emissions. *The Detroit News*. <http://www.detnews.com/2005/autosinsider/0504/09/B01-141349.htm> April 6.

Reilly-Roe, P., 2005. Voluntary commitment by the motor vehicle industry to reduce GHG emissions in Canada – part of Canada's climate change plan." In: Tenth Biennial Conference on Transportation Energy and Environmental Policy, Asilomar.

Standardization Administration of China, 2005. Announcement of newly approved national standards of p.r. china" <http://www.sac.gov.cn/cgi-bin/english/showbulgbe.asp?id=665&year=2004&num=9&tnums=71&cnt=8&pdate=2004-9-13> (accessed 14.11.2005).

US Environmental Protection Agency, 1996. Regulatory Impact Analysis (Final Rule): Federal Test Procedure Revisions. Washington, DC.

US Environmental Protection Agency, 1999. Tier 2 vehicle and gasoline sulfur program final rule. <http://www.epa.gov/tier2/finalrule.htm> (accessed 11.10.2005).

Wang, M., Saricks, C., and Santini, D., 1999. Effects of fuel ethanol use on fuel-cycle energy and greenhouse gas emissions. Argonne National Laboratory, US Department of Energy. ANL/ESD-38, Argonne.