THE CONTRIBUTION OF THE TRANSPORT SECTOR TO AN EFFICIENT GREENHOUSE GAS STRATEGY

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The intention of the paper is to examine the dimensions of greenhouse gas emissions from the transport sector in Canada, and to consider possible contributions of some major transport system changes and policy measures to the expressed national goals for reduction in emissions.

The Canadian Government's announced goal for greenhouse gas (GHG) reduction (by the Copenhagen Accord of December 2009) is to achieve a level of emissions 17% below the 2005 level. That would require emissions to fall to 607 megatonnes of CO_2-equivalent (Mt CO_2e). The last published National GHG Inventory showed emissions in 2009 as 690 Mt.[1] That figure was 17% greater than the level in 1990 (the base year for Canada's ill-fated participation in the Kyoto Accord), but actually 5% below the 2005 level, and nearly 8% below the peak reached in 2007. However, the reductions in 2008 and 2009 reflected the economic recession through those years, and the return to economic growth is expected to lead again to an increasing trend in annual emissions. The latest forecast by the National Energy Board (NEB) in late 2011 expects emissions to grow annually from 2009, reaching about 820 Mt in 2020, under anticipated economic conditions, and announced GHG reduction policies.[2] The 2020 goal would require a reduction of 213 Mt or 26% from that forecast.

In 2009, GHG from transport fuels accounted for 190 Mt CO_2e, or 27.5% of the national total. This was also a slight reduction from a peak of 197 Mt in 2007, reflecting the impact of the recession on transport activity in 2008 and 2009. The NEB forecast expects transport emissions to rise to 216 Mt in 2020, an increase from 2009 of 13.6%.

Interestingly, the forecast expects the annual rate of growth in transport emissions to 2020 to be lower than the rate in other sectors.

From 1990 to 2009, transport emissions grew by 30%, while the rate in other sectors grew by only 13%. From 2009 to 2020, the NEB forecasts transport emissions to grow by only 13.6%, while non-transport emissions grow by 22%. This would not be due to slower growth in transport activity, but to reductions in the emissions intensity of transport, particularly the expected effect of the CO_2 emission standards for new cars and light trucks, mandated in Canada from model year 2011.

Nevertheless, if national emissions are to fall by 26% below the forecast to meet the announced goal in 2020, the question remains what could or should be the contribution from the transport sector.

The paper does not attempt to examine the potentially large number of specific energy-saving changes that could be made to the transport system through government policies or voluntary actions (though it would certainly be a useful exercise to update and strengthen the broad consideration of measures by the Transportation Table for the National Climate Change Strategy development in 1999-2000). Rather the paper will try to indicate the potential for three major types of system changes frequently advocated to contribute significantly to a national, cross-sectoral emissions reduction strategy: modal shift, car and truck technology improvements, and increases in fuel prices.

To set the scene and illustrate further the nature of the challenge, we try to make some explicit comparisons of activity, fuel consumption and emissions among the main transport modes. Such comparisons were made by the author initially in the Transportation Table's "Foundation Paper" and final "Options Paper," the latter for calendar year 1997.[3] The estimates were updated to calendar year 2005 in an unpublished paper for Transport Canada by the author in 2009.[4] The comparisons are made in Table 1.

The table disaggregates total emissions reported in the National Inventory for 2005, of 173 Mt, by mode and sub-networks. It provides estimates for each category of fuel consumption, GHG emissions, activity in pass-km or tonne-km, and rates of fuel use and GHG per pass-km or tonne-km. Canadian researchers are well aware

Table 1: Indicators of total transportation fuel use and greenhouse gas emissions, 2005

Passenger	**Fuel billion litres**	**CO2e Mt**	**Propn. Transport GHG**	**Pass-km billion**	**Pass-km/litre**	**GHG grams per pass-km**
Non-urban						
Intercity car/pass. light trucks	13.00	30.82	0.178	323.3	25	95
Intercity commercial light trucks	1.50	3.56	0.021	33.1	22	108
Intercity bus	0.17	0.45	0.003	10.5	63	43
Intercity train	0.06	0.19	0.001	1.4	23	130
Plane (domestic)	3.29	8.57	0.050	62.6	19	137
Ferry	0.17	0.54	0.003	0.9	[5**]	[600**]
sub-total intercity	18.20	44.13	0.255	431.8	24	102
Urban						
Urban car/pass. light trucks	19.50	46.24	0.268	190.3	10	243
Urban commercial light trucks	2.25	5.37	0.031	18.8	8	285
Transit	0.51	1.42	0.008	16.2	32	87
School bus	0.22	0.58	0.003	7.2	34	80
sub-total urban	22.48	53.60	0.310	232.6	10	230
Total passenger	40.69	97.73	0.566	664.4	16	147
Freight	**Fuel billion litres**	**CO2e Mt**	**Propn. Transport GHG**	**Tonne-km billion**	**Tonne-km/litre**	**GHG grams per tonne-km**
Trucks - for-hire	7.43	19.99	0.116	233.6	31	86
Trucks - not for-hire	9.44	24.43	0.141			
Rail	2.11	6.34	0.037	352.9	167	18
Marine (domestic)	0.15	0.46	0.003	46.2	308	10
Total freight	19.13	51.22	0.296			
International/Other	**Fuel billion litres**	**CO2e Mt**	**Propn. Transport GHG**			
Aviation (internat., commercial, govt.)	3.63	9.48	0.055			
Marine: EC estimate of additional domestic emissions	1.77	5.44	0.031			
Marine: EC estimate of international bunker emissions	0.64	2.00	0.012			
Total international/Other	6.04	16.91	0.098			
Total, on-network	65.85	165.86	0.960			
Transport vehicles, off-network*		6.90	0.040			
Total including off-network use		172.76	1.000			

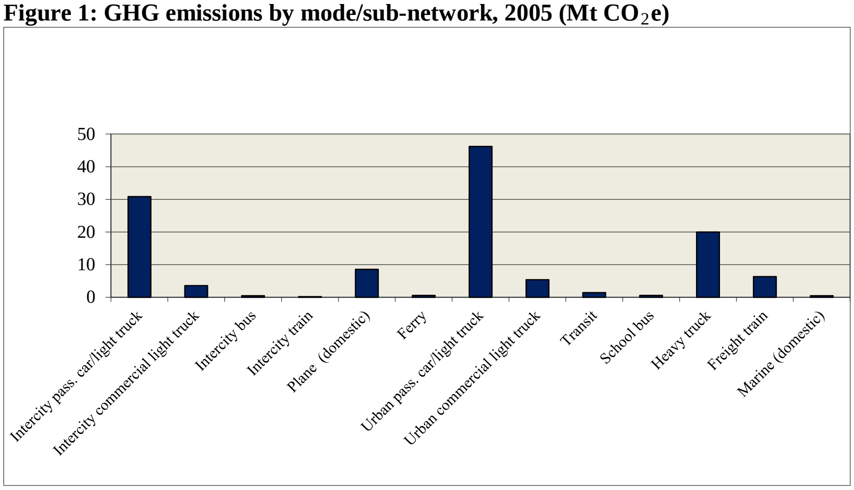
* obtained by deduction as residual from National Inventory.

** bracketed numbers over-simplistically assign all fuel use to passenger, ignoring vehicles and freight.

aware of the difficulties of creating such a table, particularly given the gaps and inconsistencies in reporting of activity, and of fuel consumption related to activity. Details of the derivation of the estimates are in the report to Transport Canada and earlier Transportation Table reports, and will not be explained here. In summary, however, the most reliable figures in the table are those for freight rail, domestic aviation and urban transit. Those for road vehicles are the most uncertain: it will be seen that no estimate is provided of activity for private trucking, notably, and the estimates for cars and light trucks are the author's interpretations of the various survey data and analyses made by federal departments (Environment, Transport, Natural Resources). In particular, the partitioning of car and light truck use between urban and non-urban networks and between commercial and private use, necessary for intermodal comparisons, relies on informed guesswork (explained at some length in the report to Transport Canada).

The following figure 1 shows the distribution of GHG emissions by the mode/sub-network classes, illustrating the overwhelming dominance of road vehicles, cars and light trucks being responsible for over 50% of emissions, and heavy trucks for another 26%. The message is clear that any large reductions in transport emissions can only come from road vehicles.

Figure 1: GHG emissions by mode/sub-network, 2005 (Mt CO_2e)



The intermodal comparisons are illustrated in Figures 2 and 3. First, for passenger modes, Figure 2 shows that estimated emissions per passenger-kilometre from cars/light trucks in urban areas were almost triple those from urban transit. In intercity use, however, the rate for cars and light trucks was only about 40% of the urban rate, due both to more efficient engine performance and higher average occupancies.And in intercity use, cars and light trucks had lower emissions per passenger-kilometre than passenger trains, given the equipment and average occupancy of those trains. Domestic aircraft operations showed an average emission rate only slightly higher than intercity trains. Intercity bus had by far the lowest rate, due largely to higher occupancy.

Figure 2: Emission rate comparisons – passenger modes 2005

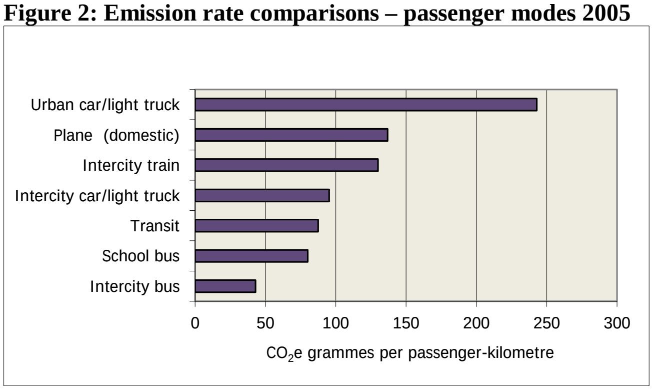
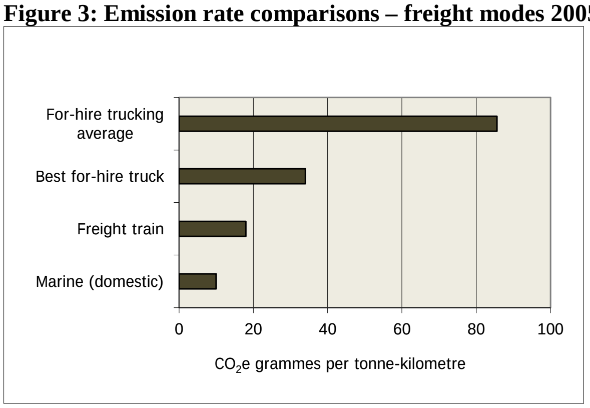


Figure 3 compares the estimated emission rates per tonne-km among the three surface freight modes. The differences need careful interpretation, as the nature of the freight carried and characteristics of service differ substantially among the modes. Importantly, rail and marine essentially provide only line-haul services for bulk traffic, while trucks provide local as well as line-haul services, including of course the pick-up and delivery required for much of the freight carried by the other modes. At face value, figure 3 shows domestic marine emissions were only about half those of rail, while truck emissions averaged nearly 5 times those of rail. However, if only line-haul trucking of bulk freight were considered, the comparison would be very different. Data on emission rates by truck configuration and haul is sparse, but the estimates of Truck Costs made for Transport Canada over the years allowed the author to infer that the emission rate per tonne-km for the standard largest Canadian configuration with a typical full load (an 8-axle Super B, bulk dry tanker, with a load of 43.8 tonnes) would be as low as 34 grams per tonne-km, or a little less than double the average rate for rail freight.

Figure 3: Emission rate comparisons – freight modes 2005



Implications of modal shift

The comparisons allow inferences of the effects on emissions if traffic could be shifted among modes, as often advocated – particularly shifts of urban passengers from cars to transit and of freight from truck to rail. Implications are shown in Tables 2 and 3.

Table 2 uses the estimates in Table 1 to calculate the effects on emissions if passenger-km on each of the main (surface) public passenger modes were hypothetically doubled by shifts from private-use cars/light trucks. For completeness, the table initially shows a shift to intercity train, but the estimates in Table 1 make it clear that any shift to intercity train, with current equipment and occupancies, would increase rather than lower emissions. If occupancies could somehow be raised, this conclusion could change, but adding services to new points or increasing frequencies would not automatically achieve that. However, intercity train provides such a small proportion of national passenger-km (about one-fifth of one percent), that any significant GHG savings would require some revolutionary change in both emissions intensity and traffic.

The table shows that doubling intercity passenger bus would reduce emissions, but the traffic is so limited that the savings would be only about half a megatonne.

Then the shift of most interest, from urban car/light truck to urban transit. Note that the illustration of doubling traffic is the same as showing the emission savings currently gained from the public modes. Table 2 shows that the 16.25 billion pass-km in urban transit in 2005effectively saved 2.5 Mt of GHG compared to the alternative use of private vehicles. If transit use were doubled, the savings would be another 2.5 Mt. Whether there is a realistic possibility of doubling transit use is a different research and policy issue: it is noteworthy that an expert Vision for Urban Transit a decade ago considered a 50% increase in transit visionary. The observation to be made here is that even a doubling would produce only 2.5 Mt, when total transport emissions are expected to be 216 in 2020, and the national goal for that year would require a reduction of 213 Mt.

Table 2: Implications of modal shifts from car to public transport (at current load factors)

	Pass-km diverted from car (billion)	Gasoline saved (million litres)	Additional diesel use (million litres)	Change in fuel (million litres)	Change in GHG (Mt)
Doubling of intercity train	1.43	57.47	61.76	-4.29	-0.05
Doubling of intercity bus	10.48	421.34	167.63	253.72	0.55
Doubling of transit	16.25	1664.67	511.25	1153.41	2.53

Table 3 illustrates the potential emissions reduction from freight mode shift by considering a hypothetical shift of 10% of freight from truck to rail. The nature of the competition between truck and rail, and the proportions of freight that are contestable between them, has been the subject of controversy, relatively unenlightened by analysis. An assessment for the Transportation Table by Transport Canada, based on a comparison of commodities and length of haul, concluded that 10% of truck freight was contestable by rail. If such a shift occurred from average truck fuel consumption and emissions rate per tonne-km to the average rail rate, Table 3 shows emissions could be reduced by 1.6 Mt. If alternatively, and more realistically, the shift was from that large truck configuration loaded with bulk traffic, at GHG emissions of 34 grams/tonne-km, the savings would be only about 0.4 Mt.

Table 3: Implications of modal shifts of 10% of for-hire trucking tonne-km to rail

	Tonne-km diverted from truck (billion)	Truck diesel saved (million litres)	Additional rail diesel (million litres)	Change in fuel (million litres)	Change in GHG (Mt)
At average for-hire truck emissions	23.36	0.74	0.14	0.60	1.58
At emissions of largest truck configuration	23.36	0.30	0.14	0.16	0.42

These illustrations allow the conclusion that modal shifts cannot make a large contribution to the target of a 213 Mt reduction in 2020.

Implications of improved road vehicle technology

Development of vehicle fuel-saving and GHG -reducing technologies have been relatively rapid worldwide in recent years, and will be accelerated in North America by mandatory standards for both light-duty and heavy-duty vehicles (LDVs and HDVs). Canadian standards have been adopted for CO_2 emissions from cars and light trucks of model years 2011-16, mirroring those in the US, designed by the US federal analysis to push technology to economically-efficient limits. The standards are expected to require about a 25% reduction in fleet average fuel consumption and GHG emissions in MY 2016 compared to MY 2011. The Canadian regulations were accompanied by a formal Regulatory Impact Analysis based on a cost-benefit analysis prepared for Environment Canada by the author.[5] Table 4 below illustrates the conclusions with the central assumptions of technology responses, vehicle sales, lifetime profiles of vehicle-km, money values of costs and benefits and discount rate.

Table 4: Estimated Impacts of Light-Duty Vehicle CO_2 Regulations for Model Years 2011-16, over Joint Lifetimes of Regulated Vehicles.

	Combined MYs 2011-16
Technology Costs ($m)	3,670
Benefits ($m)	
Pretax Fuel Savings	9,675
Cost of Noise, Collisions, Congestion	-487
Value of Reduced Refueling time	535
Value of Additional Driving	1,791
Value of changes in CACs	324
Value of reduction in GHGs	1,015
Sum of Benefits	12,852
NET BENEFIT $M	9,182
Fuel savings (billion litres)	28
Emission reductions (Mt CO2e)	91

The table shows that the standards are expected to produce savings of 28 billion litres and 91 Mt of GHG over the joint lifetimes of the vehicles of those six model years' vehicles. Technology costs of $3.7 billion would be substantially outweighed by fuel savings (pretax) of $9.7 billion. The remaining figures in the table show the estimated money values of reductions in GHG and CACs, the value of additional mobility from the expected rebound stimulation of vehicle-km, and reduced refuelling time, and the costs of additional accidents congestion and noise from the rebound. An overall net benefit was estimated at $9.2 billion. While there could still be substantial debate over the unit costs of technologies estimated for the US analysis (and used in the Canadian analysis), and the values assigned to the social costs and benefits, there is little doubt that the technological improvement required by the regulations will be cost-beneficial, and very effective in emissions reductions compared to other potential transport policies or programs. The analysis also considered the impacts on emissions by calendar year, assuming the model year 2016 standards are applied to all subsequent model years. The conclusion was that the standards will reduce GHG by 14.8 Mt in 2020 – of which 11.9 Mt would be from the use of vehicles (and therefore classed as transport sector emissions), and the rest from upstream reductions in fuel production.

Note that the NEB forecasts described took account of policies announced to 2011, including these LDV standards already imposed. However, they did not include standards for subsequent model years, for LDVs or HDVs. Standards for LDVs of increasing stringency have been announced but not finalized for model years 2017-25 in the US, requiring about another 25% improvement in average new vehicle fuel consumption and GHG in MY 2025 compared to MY 2011. The Government of Canada has stated its intention to introduce equivalent standards. These standards will have an increasing effect on annual total GHG emissions as an increasing proportion of the fleet is equipped to meet them, and as they increase in stringency to 2025. However, their effect in 2020 will be relatively minor – a rough estimate by the author is of a little over 1 Mt in that year.

CO_2 standards for new heavy-duty vehicles – trucks and buses – have also been announced in the US and Canada from model year 2014,with increasing stringency to model year 2017. The US standards have been announced formally with a published regulatory impact analysis, which expects them to be cost-beneficial, and to reduce GHG emissions in 2018 by 25 Mt, and in 2030 by 72 Mt. The Canadian standards and their impact analysis have not been published at the time of writing, but by inference from the US forecasts it can be guessed that the impact in Canada in 2020 is likely to be of the order of 2 Mt.

Increases in Fuel Prices

Fuel taxes of one sort or another are familiar and controversial objects of government policies. Canadian taxes are not high by the standards of developed countries – notably European;[6] and Canadian fuel taxes have not been explicitly justified either to finance infrastructure, or to charge for infrastructure or external costs, or to deliberately restrict driving. Proposals that they should meet some or all of those needs have been made, however – part of the justification for example of the recent consideration by Transport Canada of the Full Costs of

Transportation. For the purposes of the present paper, the issue is more narrowly the question whether increases in fuel prices could contribute substantially to achievement of the 2020 goal for national emissions.

The most justifiable increases in fuel prices for GHG-reduction purposes would be through carbon pricing. Given the intention to address carbon emissions in all sectors, and the expectation that the marginal cost of emission reduction varies substantially from sector to sector,[7] adopting a consistent price unit of carbon would lead to the most economically-efficient set of emission reduction measures. Recognition of this leads to the frequent advice of economists to adopt either carbon taxes or cap-and-trade systems. Carbon taxes would be applied on all fuels, raising prices of fuels in proportion to carbon content, therefore differing substantially among fuels. Cap-and-trade systems would place an overall cap on emissions and allow trading to determine a uniform price per unit of carbon. The prospect of carbon taxing is sufficiently controversial politically (not least in Canada) that cap-and-trade systems are being designed instead (and adopted most notably in the European Emission Trading Scheme). But part of the relative attractiveness of the proposed cap-and-trade schemes is that they would apply only to a limited set of emissions, usually effectively exempting transport fuels and heating fuels. They therefore sacrifice much of the potential impact and economic efficiency of universal carbon pricing through carbon taxes.

The appropriate levels of carbon taxes will differ of course by the magnitude of the goal to be achieved, and also by country, depending on the nature of economic activity, state of technology and all the other determinants of price elasticity for fuels in those countries. A worldwide debate about appropriate levels of carbon taxes has been vigorous, with some academics suggesting relatively low levels based on their analysis of the potential costs of climate damage – as low as $1-2 per tonne of CO_2, or less;[8] and at the other extreme the Stern Review suggesting as much as $85 per tonne of CO_2.[9]

In Canada, the suggested levels have been debated through various modeling efforts of the Federal Government and other agencies. The most recent and authoritative modeling has been for the National Round Table on the Environment and the Economy, in its “Achieving 2050: A Carbon Pricing Policy for Canada”[10] As the title suggests, their intention was to suggest a route to the aspirational goal of a reduction of 65% in GHG emissions from 2005 to 2050. They also considered how to achieve the announced 2020 goal. Their conclusion was that carbon pricing needed to be introduced immediately, rising to $100 per tonne of CO_2e by 2020, and as much as $300/tonne in 2050. These high values reflect the size of the challenges for Canada of meeting such goals given the nature of the economy and expected growth in population and economic activity.

The implications of such carbon taxes in transport can be analysed using estimates of elasticities of transport fuels. The appropriate elasticities for Canada are elusive, even for road gasoline, and much more so for other fuels. There is a wide range of findings from research studies of gasoline in developed countries. The Transportation Table for the National Climate Change Strategy resolved the uncertainty in research findings by asking a trio of world experts to judge the appropriate range of estimates for transport fuels.[11] Their judgement was that the price elasticity of road gasoline demand lay in the short run between -0.1 and -0.2, and in the long run (after 10 years) between -0.4 and -0.8, with the mid-points of those ranges being the most likely. For road diesel the ranges selected were -0.05 to -0.15 short-run and -0.2 to -0.6 long-run.

The author has recently undertaken a new review of the evidence for Transport Canada (unpublished).[12] The evidence now includes hundreds of individual estimates of road gasoline elasticities and a smaller number of road diesel elasticities, and fortunately some excellent meta-analyses of the findings. It also encompasses a recent estimation models. The most reliable methods now appear to show lower elasticities; and the most recent evidence appears to show that elasticities are declining, particularly in North America. Some of the best recent research worldwide appears to be that by Barla and colleagues at Université Laval, estimating both gasoline and diesel price elasticities in Canada.[13] These suggest gasoline price elasticity has recently been as low as -0.5 in the short run and -0.1 in the long run; and that diesel price elasticity is as low as -0.2 long-run (their short-run estimate was insignificantly different from zero). With the normal variability in fuel consumption and the extraordinary volatility of Canadian fuel prices in recent years, these estimates are subject to substantial uncertainty. But the apparent decline in recent years has been observed also in some of the best US research.[14]

The effects of potential carbon taxes on gasoline and diesel has been estimated by the author using the range of possible elasticities, together with forecasts of baseline fuel sales and fuel prices from the NEB. A carbon tax of $100/tonne of CO_2e would be approx. 25¢ per litre of gasoline and 28¢ per litre of diesel. Given the difference between short-run and long-run elasticities, the timing of the increases is important: the effect will be much less in 2020 if the carbon tax were introduced only in that year rather than earlier. To provide an optimistic estimate of the potential effects of such taxes, the author assumed that the tax is introduced immediately, in 2012, and increased in equal annual increments to reach the full $100/tonne in 2020. Results are shown in Table 5.

Table 5: GHG Impacts (Mt CO_2e) from Carbon Tax of $100/t CO_2e

Elasticity assumptions	Road Gas	Road Diesel	Other fuels	Total
Transportation Table elasticities	-6.05	-3.62	-2.08	-11.8
Assumed lower elasticities	-2.07	-1.84	-2.08	-6.0

With such a tax, and if elasticities were as high for gasoline and diesel as the medians quoted above from the Transportation Table study, the reduction in road gasoline and diesel emissions in 2020 would be 9.7 Mt. If the tax were also applied to all other transport fuels (as it should be for efficiency), and their elasticities were as assumed by the Transportation Table, another 2 Mt reduction could be achieved, for a total of 11.7 Mt in 2020. However, if the elasticities of road gasoline and diesel have declined substantially as suggested by the recent research, say to as low as -0.05 short-run and -0.2 long-run for both gasoline and diesel (i.e. not quite as low as suggested by the Canadian estimates of Barla *et al*), the emission reductions from road gasoline and diesel in 2020 would be less than 4 Mt. Assuming the elasticities for fuels in the other modes had not also declined, the total emissions reduction achieved from transport would be less than 6Mt in 2020. That such a carbon tax could achieve the reduction in emissions needed to meet the 2020 goal illustrates the expectations in the national models that price increases in other fuels and sectors – notably coal – would produce most of the reductions.

Conclusions

Canada's GHG emission target for 2020 would require a reduction of 213 Mt CO_2e or 26% from forecast emissions in that year – almost equal to the entire forecast transport sector emissions.

Modal shift from cars and trucks might be desirable to reduce congestion or achieve other social goals, but has limited potential to reduce GHG. Even shifts sufficient to double all public transit and intercity bus passenger use and move 10% of for-hire truck traffic to rail would jointly achieve only about 4 Mt a year.

Road vehicle technology improvements by regulation will have a large effect on emissions. The car/light truck standards recently mandated for model years 2011-16 are expected to reduce emissions by about 15 Mt in 2020; but that is already factored into the national forecast for 2020. New standards are expected for cars/light trucks from model year 2017 and for heavy trucks from 2014, which will eventually also bring large annual reductions. However, by 2020 they will provide only about 3 Mt for additional savings.

Increases in fuel prices could be effective in reducing fuel consumption and GHG emissions in all modes. The most efficient pricing strategy for emissions reduction would be through a cross-sectoral carbon tax. Expert modelling for NRTEE suggested a carbon tax of $100/tonne CO_2e would be needed to achieve the 2020 target. Estimates of fuel price elasticities suggest such a tax might produce reductions of emissions from transport fuels of 6-12 Mt in 2020.

In combination, these major measures in the transport sector would probably reduce emissions by less than 20 Mt, or less than 10% of the forecast total in 2020.

[1] Environment Canada: "National Inventory Report 1990–2009: Greenhouse Gas Sources and Sinks in Canada," 2011.

[2] National Energy Board: "Canada's Energy Future: Energy Supply and Demand Projections to 2035", November 2011. The report does not provide GHG, therefore the figures quoted are conversions from energy in petajoules to GHG by the author.

[3] See Transportation Climate Change Table: "Foundation Paper on Climate Change", Dec 1998; and "Transportation and Climate Change: Options for Action", Nov 1999.

[4] Lawson J: "Modal Comparisons of Fuel Use and Greenhouse Gas Emission Rates 2005," prepared for Transport Canada Environmental Policy Branch, November 2009.

[5] Lawson, J: "Technical Report on Analysis of Proposed Regulation of Passenger Automobile and Light Truck Greenhouse Gas Emissions", prepared for Environment Canada, March 2010, and released by Environment Canada on publication of draft regulations on April 1, 2010.

[6] Canadian taxes are unusual in their variety, however, with Federal and Provincial excise taxes, Provincial Sales taxes and Federal value-added taxes, and surcharges by some local governments, and with some taxes charged on other taxes!

[7] As confirmed by cross-sectoral analysis in many jurisdictions, and cross-sectoral or jurisdictional modeling, including that for the development of Canada's National Strategy in 1999-2000.

[8] See the survey of values from research in Tol, RSJ: "The marginal damage costs of carbon dioxide emissions: an assessment of the uncertainties", *Energy Policy*, 33, 2064-2074, 2005, and Tol, RSJ: "The social cost of carbon: trends, outliers and catastrophes", Economics: The Open-Access, Open-Assessment E-Journal, Vol. 2, 2008-25, August 12, 2009..

[9] Stern Review on the Economics of Climate Change, UK Treasury, 2006..

[10] NRTEE: "Achieving 2050: A Carbon Pricing Policy for Canada", 2009.

[11] See results of review in Hagler Bailly Canada: "Potential for Fuel Taxes to Reduce Greenhouse Gas Emissions in Transportation: Fuel Tax Policies Report", June 1999.

[12] Lawson, J: "Review of the Evidence on Transport Fuel Price Elasticities", prepared for Transport Canada, Environmental Policy Directorate, final draft March 2011.

[13] Barla, P, Lamonde, B, Miranda-Moreno, LF, Boucher, N: "Traveled distance, stock and fuel efficiency of private vehicles in Canada: price elasticities and rebound effect," *Transportation*, 36, 389–402 (2009); Barla, P, Tagne Kuelah, J-R: "The demand for road diesel in Canada", Center for Data and Analysis in Transportation (CDAT), Département d'économique, Université Laval, Rapport CDAT11-02, Mars 2011;

[14] Small, K A, Van Dender, K: "Long run trends in transport demand, fuel price elasticities and implications of the Oil Outlook for Transport Policy", in Joint OECD/ITF Transport Research Centre, Paris, France: *Oil Dependence: Is Transport Running Out of Affordable Fuel*?, OECD/ITF 2008; and Hughes, J E, Knittel, C R, Sperling, D: "Evidence of a Shift in the Short-Run Price Elasticity of Gasoline Demand", *The Energy Journal*, 29 (1), 113-34 (2008).