ESTIMATING THE COSTS OF GREENHOUSE GAS EMISSIONS FROM TRANSPORTATION

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1 INTRODUCTION

In 2004, in collaboration with provincial and territorial departments of transport, Transport Canada launched the Full Cost Investigation of Transportation in Canada (FCI) three-year Project. The objective of the FCI is to estimate the full costs of the different modes of transportation in Canada as well as the costs associated with transport infrastructures, services and vehicles, used for the movement of people and goods for the year 2000. The FCI project also seeks to capture social costs imposed by transportation activities such as costs related to accidents, congestion delays, noise pollution, environmental damages including air pollution costs generated by greenhouse gas emissions (GHG).

GHG from anthropogenic sources are in all likelihood enhancing the natural greenhouse effect of the atmosphere. The Intergovernmental Panel on Climate Change in one of its latest review stated:

> **"There is new and stronger evidence that most of the warming observed over the last 50 years is attributable to human activities."**
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> (IPCC Synthesis Report 2001)

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[1] Views expressed in this paper benefited from numerous exchanges between the author and the Transport Canada FCI team and the provincial FCI Task Force members. However, these views do not necessarily reflect those of either Transport Canada or the FCI Task Force.

GHG emissions contribute to global temperature increases that impose long-term costs on society and on the environment, on a global scale. The pervasive uncertainty due to the lack of scientific understanding of the potential climate change impacts make it extremely difficult to accurately assess the nature and scale of the cost tied to one tonne of CO_2 equivalent (i.e., GHG unit cost). Despite these constraints, attempts to quantify the costs associated with GHG emissions present an indicative measure of the potential impacts of climate change.

As part of the broad spectrum of economic and social costs associated with the transportation sector in Canada, the complex issue of climate change cannot be overlooked. In general, GHG emissions associated with transportation activities increase in parallel with economic activities growth. The costs of GHG emissions arising from transportation activities in Canada are included in the FCI spearheaded by Transport Canada.

The objective of this paper is two-fold. Firstly, it provides a description of the methodology used to assess the costs of GHG emissions from transportation in Canada. Secondly, using data on the GHG emissions obtained from the Office of Energy Efficiency, the costs of GHG emissions are calculated for the year 2000. As is generally highlighted in other similar valuation exercises, estimating carbon price is fraught with difficulty and uncertainty given the volatility of the carbon market.

2 METHODOLOGY

2.1 THEORETICAL BASIS

One way of measuring GHG emissions cost, converted in tonnes of CO_2 equivalent, would be to assess the total cost of future climate change for a number of scenarios and to divide this cost by the volume of GHG emissions calculated in tonnes of CO_2 (t CO_2) equivalent in order to obtain a unit cost. In a recent report, a British economist, Sir Nicholas Stern[2], assessed such scenarios. The main conclusion is that the cost of inaction could be much greater (from 5% to 20% of the

[2] Stern Review: "*The Economics of Climate Change*" 2006

GDP) than the cost of action (about 1% of the GDP per year). In other words, it appears that the unit costs could vary greatly depending on the path of abatement chosen by the international community. At its highest level, if no abatement is made, the unit cost could be as high as US$85 /t CO_2 equivalent. At the other end of the spectrum, abating anthropogenic GHG emissions could be as low as US$5/ t CO_2. The magnitude of the abatement cost may vary significantly according to the respective economic sectors, the abatement technique as well as the timeframe used to achieve the emission reductions.

An alternative way of deriving the cost of a tonne of CO_2 equivalent is to use carbon prices on carbon markets. Under the Kyoto Protocol[3], the creation of market mechanisms called the Kyoto Mechanisms identified the marginal cost of GHG abatement.

The European Union[4] created a tradable permit system for carbon that imposes emission limits on large industrial sectors and a carbon exchange that indicate the carbon price even prior to the first commitment period (2008-2012). The European Union's Emissions Trading Scheme (EU ETS) is considered the largest and most robust carbon trading scheme (while also having the highest carbon prices) and hence largely drives the price of project credits. The EU ETS tradable carbon instrument is referred to as European Allowance (EUA) and is denominated in a tonne of CO_2 equivalent. Tradable units generated under the Kyoto Protocol for compliance of GHG emissions reductions include Certified Emission Reduction (CERs) from the Clean Development Mechanism and Emission Reduction Units (ERUs) from Joint Implementation could be used for compliance under the EU ETS. The market for CERs is relatively active given the level of activity in the EU ETS. ERUs from the EU itself will however be created in Phase 2 of the EU ETS (2008-2012)[5].

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[3] United Nations Framework Convention on Climate Change "Reporting Requirements", 2004

[4] European Union *"Greenhouse gas emission allowance trading scheme*", 2003

[5] Report of the New Zealand Treasury *"Price of Kyoto Compliant Emission Units"*, August 2006

Unlike a mature commodity market, the carbon market is in its infancy where uncertainty prevails with regard to the future stability of the international institutional framework that created the carbon market. There is no single method to determine the unit carbon price. Other alternative approaches would include the World Bank's valuation approach. World Bank data on carbon prices, expressed in terms of a range. Similarly, *Point Carbon* also estimated another range of carbon price per tonne of CO_2 equivalent. Also, as mentioned above, the Stern Review Report recently provided a wider range of estimates of carbon prices that is estimated as "higher than typical numbers in the literature", mainly attributable to risk being treated explicitly in the calculations.

In this paper, the unit price of carbon on the *European Carbon Exchange*[6], the most liquid exchange for EUAs, is used to assess the unit value of GHG emissions from transportation activities in Canada. It should be noted that this abatement unit value would correspond to the unit marginal cost of climate change if the emission target would be equal to the optimal level of emissions (i.e., where global marginal damage per tonne of CO_2 equivalent equals the marginal cost of abatement). We implicitly assumed this herein.

2.2 DATA SOURCES

2.2.1 Emissions Data

Countries that ratified the 1992 *United Nations Framework Convention on Climate Change* report their quantities of GHG emissions. In Canada, Environment Canada is responsible for producing the national inventory of GHG emissions. The *Office of Energy Efficiency* attached to *Natural Resources Canada*, in turn organizes the above GHG inventory in sub-activities that match the need of the FCI.

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6 Data on transaction volume and on price of carbon on *the European Carbon Exchange* is available at: www.europeanclimateexchange.com

The data produced by the *Office of Energy Efficiency* was used as a primary source to compute the GHG emission costs in the transportation sector for the year 2000. GHG emissions inventory for the transportation sector is disaggregated by mode, by freight and passenger activities and by province, to the extent possible.

2.2.2 Monetary Unit value Data

As mentioned in section 2.1, the *European Carbon Exchange* where EUAs are traded, is used as the source of the unit value of a tonne of CO_2 equivalent. Given that currently Canada does not have a very active carbon market, the European carbon market provides a better perspective on the value of a tonne of CO_2.

A lower and upper limit to define the unit cost of a tonne of CO_2 equivalent in Canada were deemed appropriate, rather than a single and most recent figure. This approach explicitly accounts for the risk factor that is reflected in the instability of the carbon price during the past year on the European carbon market. Risk is a major determinant of price. The limits chosen to assess the GHG cost from transportation activities in Canada are 15 € and 30 € per tonne of CO_2 equivalent.

In comparison with the alternative valuation approaches[7], *World Bank* data on carbon prices, defined a wide range for carbon price from US$ 3 to US$ 24 per tonne of CO_2 equivalent. This range is based on observed data but does not yet fully incorporate the effects of the sharp declines in EUA price in May 2006. As a result, *World Bank* data may cause a negative average price bias. *Point Carbon* also estimated a different range for carbon price between US$ 7.60 and US$ 12.50 per tonne of CO_2 equivalent. The *Stern Review Report* estimated an even wider range of carbon prices between US$5 and US$85 per tonne of CO_2 equivalent.

[7] Report of the New Zealand Treasury *"Price of Kyoto Compliant Emission Units"*, August 2006

2.2.3 Conversion Method

Carbon prices are expressed in nominal Euro (€) on the *European Carbon Exchange* for the year 2006. However, for the purpose of the FCI, Canadian dollars are required for the year 2000. As a result, the following conversions and sequence of calculations are required to compute the unit cost of GHG emission:

1. Converting current value expressed in Euro into Canadian dollars using an average of 2006 daily exchange rates
2. Deflating Canadian dollars from year 2006 to year 2000 using the Consumer Price Index
3. Calculating the lower and upper limit of the unit cost of GHG emission in terms of a tonne of CO_2 equivalent

Hence the formula for calculating the unit cost of GHG emission cost, expressed as a tonne of CO_2 equivalent, is as follows:

Unit cost of GHG emission = $€U \times (C\$ / €) \times (CPI_{2000} / CPI_{2006})$

Where:
U = the unit cost of a tonne of CO_2 equivalent in expressed in Euro

C$ / € = the exchange rate expressed as an average of 2006 daily exchange rates

CPI_{2000} / CPI_{2006} = the deflation of prices from year 2006 to year 2000

3 Application of the Methodology and Cost Estimates

3.1 APPLYING THE METHODOLOGY

3.1.1 Emissions Data

Table 3-1 presents a breakdown of GHG emissions for the transportation sector in Canada, by mode, type of vehicle and passenger or freight activities from 1998 to 2002.

Table 3 1: Greenhouse Gas Emissions in Canada for 1998-2002
(Mt[8] of CO_2 equivalent)

	1998	**1999**	**2000**	**2001**	**2002**
Marine					
All Marine	9.0	8.5	8.6	9.3	8.4
Rail					
Freight	6.0	6.3	6.4	6.3	5.7
Passenger	0.2	0.2	0.2	0.2	0.2
Air					
Freight	0.7	0.8	0.9	0.8	1.0
Passenger	15.2	15.9	16.0	14.5	15.1
Road Freight					
Heavy Trucks	25.0	26.6	28.3	27.8	28.7
Medium Trucks	10.2	9.6	9.7	9.7	10.0
Freight Light Trucks	11.4	11.8	11.8	12.1	12.4
Road Passenger					
Inter-City Buses	0.5	0.5	0.5	0.5	0.5
Urban Transit	1.8	1.9	1.9	1.9	2.0
School Buses	1.3	1.3	1.3	1.2	1.1
Motorcycles	0.1	0.1	0.2	0.2	0.2
Passenger Light Truck	25.5	26.7	27.2	28.0	29.0
Large Cars	21.8	22.0	21.5	21.3	21.3
Small Cars	23.2	23.6	23.1	22.9	23.0
Total Transport					
Total Emissions	151.9	155.8	157.7	156.7	158.6

Data Source: Office of Energy Efficiency
(off-road emissions excluded)

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[8] The term Mt refers to mega-tonne, or one million of metric tonnes. GHG emissions are converted in tonnes of CO_2 equivalent by using their global warming potential (GWP) over 100 years relative to CO_2.

GHG emissions from transportation activities in Canada have remained fairly stable over the 1998-2002 period. The slight upward trend stemmed from the areas of trucking activities, freight by air, urban transit and the use of passenger light trucks. Although not reported in the above table, it is to be noted that transportation activities increased at a faster rate than energy efficiency gains over the same five-year period.

One of the limitations of the data set used is that the distinctions between urban and rural transportation activities (except in the case of intercity buses) as well as between international and domestic movements of ships and aircrafts are not captured.

Table 3.2 shows a breakdown of GHG emissions of the transportation sector by passenger and freight activities, by province for the year 2000.

In 2000, GHG emissions from the Canadian transportation sector totalled about 158 Mt. The majority of these GHG emissions were generated by passenger activity, more particularly in Ontario followed by Quebec. As for the freight activities, most of the emissions originated from Ontario, followed by Quebec, Alberta and British Columbia and Territories.

3.1.2 Monetary Unit Value Data

As mentioned, given the instability of the carbon price, it is proposed to use a range of values to assess the greenhouse gas cost from transportation activities in Canada. The lower and upper limits chosen in the GHG unit cost calculations are 15 € and 30 € per tonne of $CO2$ equivalent respectively, as per the European carbon market.

In terms of price trend, after a period of more or less steady growth from June 2005 to April 2006 over which the carbon price fluctuated between 20 € and 30 €, the carbon price drastically fell to around 10 € in May 2006 to bounce back to about 16 € afterwards. It has since then remained fairly stable.

Table 3 2: Greenhouse Gas Emissions by Province for the year 2000
(in Mt of CO_2 equivalent)

Provinces	Freight	Passenger	Total
Newfoundland and Labrador	1.75	1.88	3.63
Prince Edward Island	0.34	0.42	0.76
Nova Scotia	2.86	2.94	5.80
New Brunswick	2.79	2.28	5.07
Quebec	12.80	18.35	31.15
Ontario	20.71	33.97	54.68
Manitoba	1.93	3.13	5.06
Saskatchewan	2.68	2.57	5.26
Alberta	11.97	10.03	22.01
British Columbia and Territories	11.27	13.06	24.32
Total Emissions	**69.10**	**88.64**	**157.74**

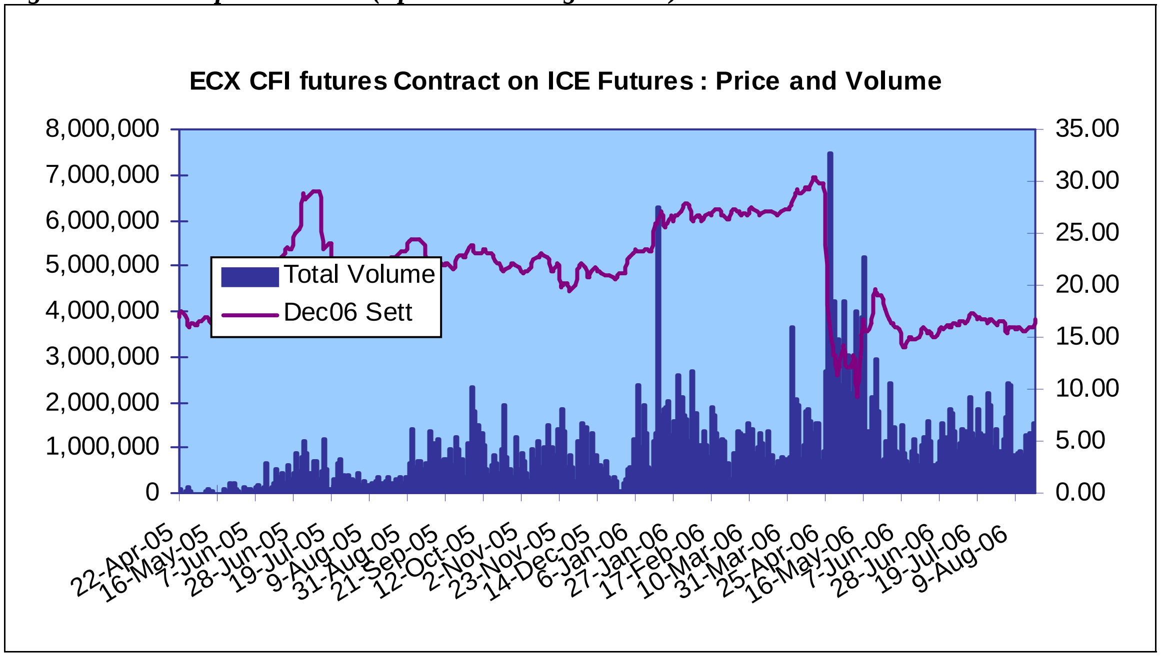
(off-road emissions excluded)

Despite the existence of banking provisions, incorporated in the EU cap and trade emissions reduction program, the EU market experienced significant price volatility which is considered a common phenomenon in the nascent stage of emission markets. Banking of allowances enables inter-temporal trading that lead to flexibility to deal with uncertainties, environmental and cost-savings gains and dampens potential allowance price volatility[9].

Figure 3-1 illustrates the price volatility on the *European Carbon Exchange* (ECX). As mentioned in section 2.2.2, the ECX is the source of the unit value of a tonne of CO_2 equivalent.

[9] "*Emissions Trading in the US: Experience, Lessons, and Considerations for Greenhouse Gases*", Pew Center on Global Climate Change, pp 37.

Figure 3 1 Carbon price on ECX (April 2005 to August 2006)



Source: www.europeanclimateexchange.com

The price crash occurred over a short time period when a number of EU countries released their actual emissions data for 2005, indicating that actual emissions were much lower than the forecast level. This in turn implied a potential excess of EU allowances (EUAs) already allocated for the first phase (2005-2007). The dramatic price drop in the price of EUAs in May 2006 is generally attributed to over-allocation based on inaccurate historical emission baselines that led to surplus allowances[10]. It is to be noted that the initial EUAs were made without access to verified historical emissions data.

The steps to calculate the unit cost of GHG emission, expressed as per tonne of CO_2 equivalent, are as follows:

Converting Euro into Canadian dollars (2006) with an average of 2006 daily exchange rates: C$ / € = 1.4

Deflating prices between CPI_{2000} and CPI_{2006}: 116 / 130 = 0.89

Hence, according to the formula in section 2.2.3, GHG emission unit cost, expressed in year 2000 Canadian dollars is:

Lower unit cost = 15 € × 1.4 × 0.89 = C$18.69 /t CO_2 equivalent.

Higher unit cost = 30 € × 1.4 × 0.89 = C$37.38 /t CO_2 equivalent.

3.2 COST ESTIMATES

Table 3 shows the results of the calculation of the costs associated with GHG emissions from transportation activities, disaggregated by province and by freight and passenger activities. The results are presented for the lower and upper limit values of C$18.69 and C$37.38 /t CO_2 equivalent. GHG emissions costs from all transportation activities in Canada are estimated at an annual cost of C$3 or C$6 billion dollars for the lower and upper limit values.

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[10] 2006 GHG Market Report "*"Financing Response to Climate Change:* Moving in Action", IETA, page 38.

These results are a multiplication of emissions in tonnes by unit price per tonne. Costs were generated for all segments of the transportation activities with measurable GHG emissions. Due to the high level of uncertainty tied to both of the unit values, the results should also be interpreted with the same level of caution.

Table* 0-1*: Greenhouse gas costs estimates per province for the year 2000 **(in Millions of year 2000 C$)**

	High Costs		
Provinces	**Passenger**	**Freight**	**Total**
Newfoundland and Labrador	$ 70.18	$ 65.55	$ 135.72
Prince Edward Island	$ 15.83	$ 12.53	$ 28.36
Nova Scotia	$ 110.05	$ 106.73	$ 216.78
New Brunswick	$ 85.21	$ 104.33	$ 189.54
Quebec	$ 685.95	$ 478.62	$ 1164.57
Ontario	$ 1269.85	$ 773.98	$ 2043.83
Manitoba	$ 117.01	$ 72.18	$ 189.19
Saskatchewan	$ 96.22	$ 100.36	$ 196.58
Alberta	$ 75.02	$ 447.54	$ 822.56
British Columbia and Territories	$ 487.10	$ 421.27	$ 909.26
Total	**$ 3313.32**	**$ 2583.08**	**$ 5896.40**

(off-road emissions excluded)

The province of Ontario generated most of the GHG emissions, whether by passenger or freight activities, and its total costs of GHG emissions were also the highest at about C$1 billion. Ontario is highly active in the four modes of transportation. The province has the largest cross-border crossing for trucks and cars; it also has the highest heavy truck fleet with the most vehicle-km. Similarly for light vehicles, Ontario has the most vehicles, vehicle-km, passenger-km and litres of fuel purchased. In terms of rail, Ontario remained the largest contributor to rail export volume and value. Marine freight traffic is also predominant in Ontario with a number of its ports located along the Great Lakes and the St. Lawrence Seaway[11].

Quebec comes in second position with GHG emission costs of C$582 million, followed by British Columbia and Territories at C$455 million and then Alberta with $411 million. Prince Edward Island is the least GHG emission-generating province with a total cost of C$14 million.

Except in the cases of New Brunswick, Saskatchewan and Alberta, generally GHG emissions from passenger activities exceed those from freight activities.

More disaggregated information on the cost of GHG emissions generated from transportation activities are presented in the full paper available on the FCI web site.

4 CONCLUSION

The transportation sector and its generally unsustainable patterns, represents one of the major sectors contributing to GHG emissions.

The objectives of this paper are to provide a methodology to estimate the unit cost of GHG emissions and to calculate the value of the unit cost of GHG emission generated by transportation activities in Canada for the *Full Cost Investigation*. Based on the emission data obtained from the *Office of Energy Efficiency* and observed carbon price on the *European market*, annual cost estimates of GHG emissions generated by all transportation activities in Canada would be C$3 and C$6 billion dollars for the lower and upper limit values respectively in the year 2000 alone.

Out of all provinces, Ontario generates the most GHG emissions both in terms of passenger and freight activities with a total of 55 Mt corresponding to GHG emissions costs of about C$1 billion. Quebec is second generating most of the GHG emission (31 Mt) and bearing GHG emission costs of C$582 million, followed by British Columbia

[11] Transport Canada, "*Transportation in Canada 2005*", Annual Report

and Territories with 24 Mt and GHG emission costs of C$455 million and then the province of Alberta with 22 Mt at a cost of C$411 million. Prince Edward Island is the least GHG emission-generating province with a total of 0.76 Mt corresponding to cost of C$14 million.

To be useful, these GHG emissions by mode and their costs shall be compared with the levels of activity of the modes, which are measured either by passenger-kilometre or by tonne-kilometre. The resulting "emission intensities" and "unit GHG costs" shall then be used to compare modes on specific itineraries and on specific origin-destination pairs along with the other externality costs measured in the FCI.

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