PUTTING TRANSPORTATION EMISSION REDUCTION STRATEGIES IN PERSPECTIVE: WHY INCREMENTAL IMPROVEMENTS WILL NOT DO

by

JOSHUA ENGEL-YAN, IBI GROUP

BRIAN J. HOLLINGWORTH, IBI GROUP

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ABSTRACT

Governments at all levels have recently been setting new aggressive targets for reduced GHG emissions, but despite improvements in vehicle fuel efficiency and pollutant emission rates, the trend in urban areas is towards increased fossil fuel use (and thus, GHG emissions) per capita for transportation. By all accounts, the contribution of urban motorized transport to climate change will continue growing unless per capita GHG emissions can be decreased more quickly than the rate of population growth.

Municipalities across the country have outlined various strategies for reducing GHG emissions from transportation, but to date, few have linked the relative impacts of these strategies with stated targets. Fewer still have looked at the combined impacts of behavioral and technological changes for reducing GHG emissions, in comparison to what can realistically be expected from each approach.

Using the Greater Toronto and Hamilton metropolitan region as an example, this paper quantifies the GHG impacts of several different levels of transit service ranging from "business as usual" to a very high level of transit investment with supporting TDM measures and technological advancements. Urban transportation emissions in the region are assessed using transportation demand models and Transport Canada's Urban Transportation Emissions Calculator. Results show that the highest level of transit service increases will reduce GHG per capita emissions by approximately 30%, which only just off-sets the impacts of population growth. These results indicate that municipalities across Canada cannot rely on transit improvements alone to address sustainability objectives and aggressive GHG reduction targets; but must also consider a broad range of strategies in the areas of technology, active transportation and TDM.

Key Words: greenhouse gas emissions, mode split targets, transportation planning, sustainable transportation

Introduction

Moving towards a more sustainable future will require a sustainable transportation system, characterized by five C's: conserving, clean, capable, compatible (with liveable communities), and cost-efficient. The first two characteristics dealing with the consumption of energy and natural resources, and the emissions of greenhouse gases (GHGs) and other pollutants likely pose the greatest threats to sustainability in terms of climate change and future fuel constraints. The International Panel on Climate Change has recommended that emissions be reduced to stabilize the concentration of GHGs in the atmosphere.

Canadians are among the world's largest producers of greenhouse gases (GHGs) per capita and transportation is among the largest contributors at 27 per cent of Canada's total emissions. The majority of these emissions (~2/3) originate in urban areas. Accordingly, addressing emissions from transportation in urban areas must be a focal point of GHG reduction strategies.

This paper begins with a review of current GHG emission reduction targets across Canada and puts these into context with actual GHG trends. A discussion of potential strategies is provided along with a snapshot of results from other studies on the relative impacts of these strategies on GHG mitigation.

Finally, the paper outlines several potential scenarios for the Greater Toronto and Hamilton Area in terms of increases transit service increases and quantifies their impact on GHG emissions.

Emerging Targets for Greenhouse Gas Emissions

In light of growing concerns about climate change, governments at all levels have, or are in the process of developing Climate Change Action Plans. Almost all of these plans set out specific targets for reducing GHG emissions. Table 1 provides a sampling of targets by province, territory and selected major urban centre, along with the current Federal Government target of 20% below 2006 levels by 2020.

Current targets vary in terms of reference year (i.e. base year from which targets are set), future year and percentage reduction. Variations also exist in the scope of the targets, with some cities identifying more aggressive targets for corporate operations compared to the entire City. Some climate change plans identify specific targets for each sector (e.g. transportation), while others simply identify an overall target. As shown, there is a wide range in the magnitude of GHG reduction targets, from bringing emissions back to 1990 levels to reducing emissions to 80% below 1990 levels by 2050. One of the most recent documents is the City of Toronto's *Change is in the Air: Toronto's Commitment to an Environmentally Sustainable Future*[1], which targets a 6% cut in GHG emissions from the Toronto urban area by 2012 (based on 1990 levels), a 30% cut by 2020, and an 80% reduction by 2050. The targets mirror recently announced European Union goals.

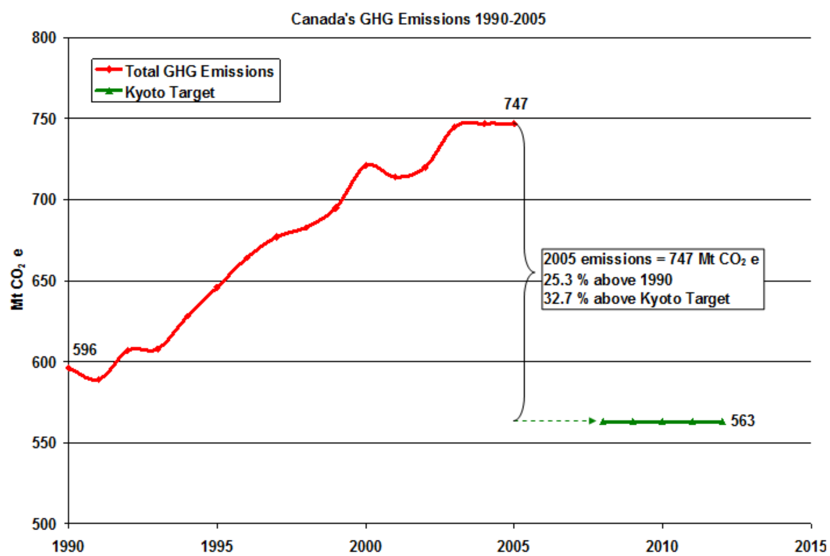
Table 1: Federal, Provincial, Territorial and Selected City Greenhouse Gas Reduction Targets (All Sectors)

	Detail(s)	Target Reduction (%)	Target Date	Baseline year
City (year of implementation)				
Toronto	Entire City	6%	2012	1990
	Entire City	30%	2020	1990
	Entire City	80%	2050	1990
Ottawa (2003)	Cities own operations	20%	2007	1990
	Community	20%	2012	1990
Halifax (2005)	Entire City	20%	2012	2002
Calgary (2006)	Entire City	50%	2012	1990
Vancouver (2007)	First Target	33%	2020	2007
	Second Target	80%	2050	1990
Saskatoon	Entire City	6%	2013	1990
	City's Corporate Operations	10%	2013	1990
St. John's	Corporate	20%	2010	1994
	Community	6%	2010	1994
Winnipeg	Entire City	20%	2018	1998
Provinces (year of implementation)				
Alberta (2008)	Province-wide	14%	2050	2005
British Columbia (2007)	Province-wide	33%	2020	2007
Manitoba (2002)	First Target	below 2000	2010	2000
	Second Target	6%	2012	1990
New Brunswick (2007)	Province-wide	10%	2020	1990
Newfoundland and Labrador (2007)	Province-wide	10%	2020	1990
Nova Scotia	Province-wide	10%	2020	1990
Ontario	Province-wide	6%	2014	1990
	Province-wide	15%	2020	1990
	Province-wide	80%	2050	1990
Prince Edward Island (2001)	First Target	equal 1990	2010	1990
	Second Target	10%	2020	1990
Quebec (2006)	Province-wide	6%	2012	1990
Saskatchewan (2007)	Province-wide	32%	2012	1990
Territories				
Nunavut	no explicit target			
Northwest Territories	no explicit target			
Yukon	no explicit target			
Federal (2007)	Canada-wide	20%	2020	2006

Source: Compiled from Municipal, Provincial and Federal government publications

One element that is consistent in all of the targets is that the ability to meet the targets within the timeframes specified will require a substantial change from current trends. As discussed in the next section, even stabilizing emissions at 1990 levels implies significant change. According to Environment Canada, total GHG emissions in Canada in 2005 & 2004 were about 747 Mt CO_2e, a level that is 25.3 % above the revised 1990 total of 596Mt and 32.7% above the Kyoto target[2]. Emissions from the transportation sector have grown faster than the national rate. Transportation sector emissions were 32.8% higher in 2005 than they were in 1990. As a result, the challenges in meeting aggressive emissions reduction targets, when expressed on an absolute basis, are significant as highlighted graphically on Figure 1.

Figure 1: Canada's Greenhouse Gas Emissions 1990-2005



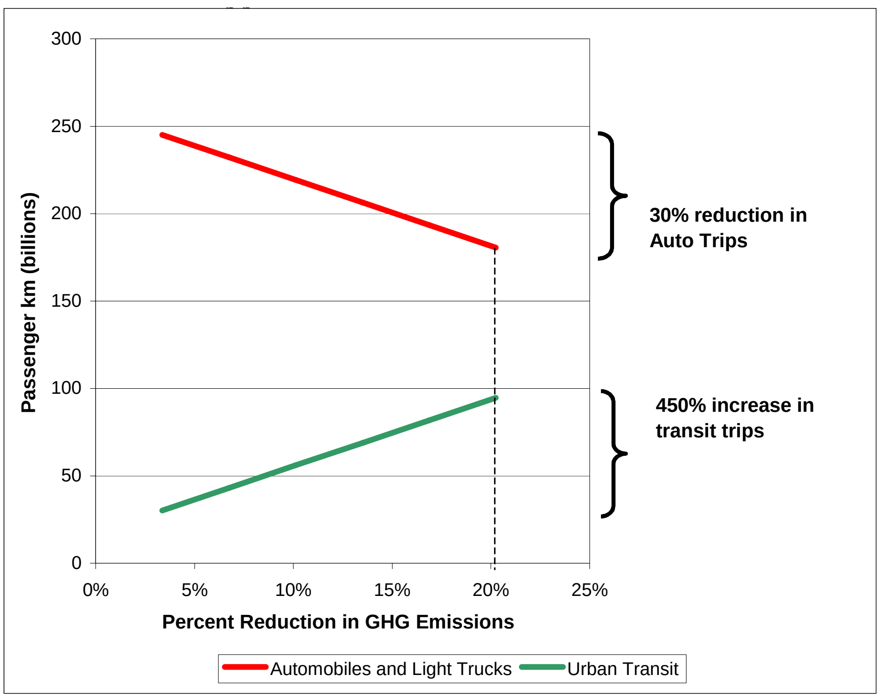
The Challenge in Meeting Targets

To date, there has been little discussion regarding the scale of changes that will need to occur in order to meet the various GHG reduction targets being set out at all levels of government. The challenge in meeting emissions targets that are set based on current or historical values is that population, and hence transportation activity and emissions, will continue to grow. For example, in simple terms, if population increases by 1% per year between now and 2020, and there are no changes in behaviour or technology, emissions from transportation sources will be 55% higher than 1990 levels[3]. So, for sake of argument, if the target is a 20% reduction from 1990 levels, people would either have to drive half as much or cars would need to be twice as fuel-efficient, on average.

Another challenge is that considerable emphasis is being placed on transit service increases to meet GHG emissions reduction goals. Yet, reducing GHG emissions is not as simple as putting more people on transit since transit vehicles also produce GHG emissions. On a per passenger-kilometre basis, the GHG efficiency of transit vehicles can vary widely based on type of vehicle (e.g. bus, LRT, commuter rail) and by load factor. Based on typical transit load factors and auto occupancies, transit riders produce about one third of the emissions as car drivers and passengers, when measured on a passenger-km basis.

To put this in perspective, Figure 2 provides a very simplistic illustration of the relationship between auto passenger-km, transit passenger-km and reductions in GHG emissions from the baseline. The underlying relationships are compiled based on actual estimates of urban transportation activity by mode in Canada[4], as well as accepted average emissions factors. For illustrative purposes, it is assumed that there would be a one to one transfer of auto passenger-kms to transit passenger-kms. In reality, there are many other factors at play including differences in trip lengths, shifts to other modes such as walking and cycling and changes in average transit load factors; however the point is to highlight the order of magnitude changes in transit that would be required to meet aggressive GHG targets in absence of intervening factors such as technology. In this simple example, achieving a 20% reduction in GHG emissions from urban transportation through mode shifts to transit alone implies a 450% increase in transit trips (or transit passenger-kilometres of travel). Such drastic increases are unprecedented in Canada and suggest that other strategies, in addition to mode shifts to transit, are necessary as discussed throughout this report.

Figure 2: Relationship Between Auto and Transit Passenger-kilometres and GHG Reduction



POTENTIAL STRATEGIES

Strategies for reducing GHG emissions from the transportation sector can be grouped into three general categories:

- **Travel demand**: reducing vehicle kilometres traveled;
- **Vehicle efficiency**: improving the energy efficiency of vehicles; and
- **Fuel carbon content**: reducing the carbon content of transportation fuels.

Based on review of the literature, the types of strategies available under each category and potential GHG emission reductions achievable are discussed[5].

Travel Demand

Strategies under this category focus on encouraging more sustainable travel behaviour through such approaches as:

- Transit investments that improve the competitiveness of transit versus the automobile (e.g., dedicated transit lanes, rapid transit, BRT, private shuttle services);
- Land use forms that increase the proximity between population, employment, and transit facilities, reduce travel distances and make walking, cycling, and transit modes more attractive (e.g., transit oriented development); and
- Transportation demand management measures that either create incentives to use the transportation system more efficiently (e.g., ridematching, preferential parking for carpools, improved logistics) or disincentives to driving alone (e.g., parking pricing, road pricing).

Long lists of such measures along with case studies and benchmarking are presented elsewhere[6]. A key finding is that any individual measure is unlikely to have a significant impact on GHG emissions if implemented in isolation. Indeed, an assessment of the potential for transit improvements to reduce GHG emission in Canada concluded that "capital investment in expanded transit systems appears to have relatively little impact on GHG reductions on its own unless accompanied by highly integrated and effective TDM measures"[7].

Looking to experiences elsewhere, large behavioural changes have been observed when transit and TDM have been combined. For example, targeted marketing in transit corridors has achieved increases of 30 per cent in transit usage in areas where the programs have been implemented[8]. In addition, research suggests that road pricing can reduce peak period travel on congested roads by up to 20 per cent[9]. The congestion charge in London was implemented in tandem with extensive improvements in transit service and CBD car trips have decreased by 26 per cent as a result[10]. Similar programs in Norway have induced a 10 percent decline in CBD travel during toll hours[11].

For goods movement, there are many opportunities to reduce shipping through improved logistics. Potential options include changes in vehicle load factors (i.e., how much of the capacity of a truck is used during shipment), space utilization, scheduling, packaging and handling systems, and numerous other supply-chain factors. For example, about 80 German cities have set up “City Logistic” projects whereby shipments are consolidated outside the city limits and better organized within the city[12].

Improving load factors has significant potential to reduce the need for trucking. Most truck fuel goes towards moving the truck rather than its payload. A half-loaded truck uses more than 90% of the fuel used per kilometre by a fully loaded truck[13]. Since it is estimated that approximately one third of total truck capacity on Ontario roads is not used[14], there is significant potential to consolidate loads, use fewer trucks, and reduce emissions.

A key advantage of travel demand measures is that, unlike fuel efficiency improvements and alternative fuels, travel demand approaches can be implemented at the local level. In addition, bringing origins and destinations closer together, reducing vehicle-kilometres of travel (VKT) and improving transportation options has many other benefits, such as improving equity, regional competitiveness, and quality of life and ensuring greater resilience against natural disasters or potential oil price shocks.

Vehicle Efficiency

Vehicle efficiency improvements likely have the largest potential to reduce GHG emission from the transportation sector. Reputable studies have indicated that there is potential to improve the efficiency of the light-duty fleet by 20 to 30 per within the next 15 years[15]. This will require large shifts towards hybrid vehicles.

Significant improvement in truck fuel efficiency is also possible. For heavy-duty vehicles, fuel-saving devices, such as aerodynamic improvements, speed limiters, and anti-idling devices, can deliver an estimated 22 per cent fuel savings in the short-term without changes to the engine[16]. Fuel efficiency for short-distance stop-and-go transport can be improved by about 50 per cent using technologies such as hybrid-electric vehicles[17].

On the more ambitious end, the U.S. Department of Energy, in collaboration with other federal agencies and truck manufacturers and suppliers, established the 21st Century Truck program in 2000 to dramatically improve the fuel economy of trucks in the United States. With a combination of engine, aerodynamic, rolling resistance, and materials technologies, the plan called for a 50 to 75 per cent improvement in fuel economy for light trucks, a 140 per cent improvement for medium-sized trucks, and a 60 per cent improvement for over-the-road tractor trailers, which were believed to be achievable with “aggressive development and implementation of technologies currently being considered but not yet commercially viable”[18].

The challenge to fuel efficiency measures is that improving the fuel efficiency of the fleet occurs slowly, since turnover of the fleet takes approximately 10 to 15 years. In addition, implementation requires strong direction from national governments and large investment by car manufacturers. Appropriate incentives and disincentives also need to be put in place to ensure that overall fleet efficiency improves. In the past decade, the majority of efficiency improvements have been offset by trends towards larger and more powerful vehicles.

Fuel Carbon Content

Substituting gasoline and diesel with alternative fuels that have lower carbon content, such as ethanol, biodiesel, hydrogen, or electricity, also has significant potential to reduce emissions. The International Energy Agency suggests that by 2030, approximately 20 to 40 percent of all transport fuels could come from alternative sources[19]. Further work is required to investigate the potential of alternative fuels.

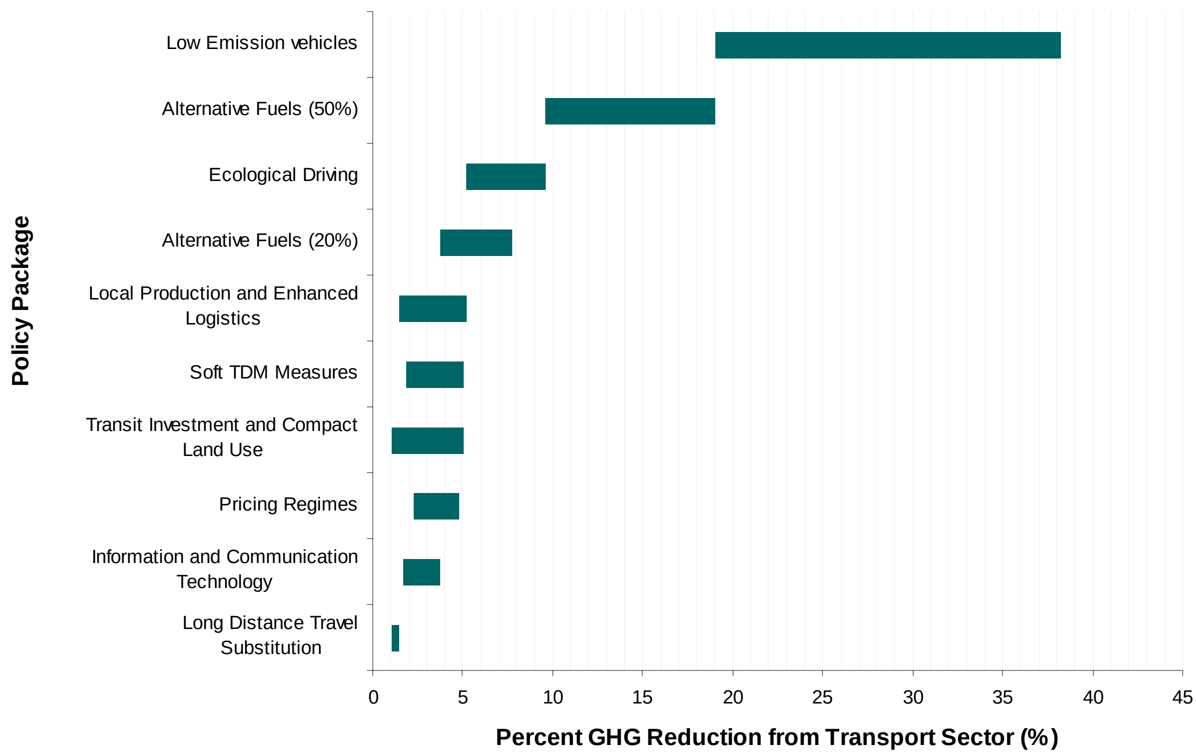
In jurisdictions where electricity is produced from lower-emitting sources, such as hydro, small-scale renewable sources (e.g., wind), and nuclear, shifting to electrically-powered transportation is a good emission reduction strategy. This can be achieved by enhancing the role of grid-connected transit vehicles (e.g., subways and streetcars) and shifting to electrically powered personal vehicles, such as plug-in hybrid electric vehicles. A recent study indicated that a 20 per cent penetration of plug-in hybrid electric vehicles (PHEV) by 2020 would be feasible.

Summary of Potential Options

A recent study examined the possibility of reducing transport GHG emissions in the U.K. by 60 per cent by 2030. In this analysis, ten policy packages were developed covering all modes of transport and dealing with technology, pricing, regulation, behaviour change, and land use. Figure 3 summarizes the GHG reduction potential of each policy package in terms of percent reduction from overall transport emissions. While the analysis was conducted from the UK, the relative reduction potential of each package is instructive. Key findings include:

- Vehicle efficiency improvement have the greatest potential to reduce emissions, estimated at approximately 20 to 35 per cent. While not often considered, driving practices can also be modified to improve fuel efficiency (e.g. lower speed limits, anti-idling devices, etc.).
- Measures to reduce auto transportation demand take many forms including transit and land use, soft TDM measures, pricing, and communications technology. Individually, these policy packages do not have a significant impact, but implemented together, they can reduce emissions by 10 to 25 per cent.
- Alternative fuels will also play a role in reducing GHG emissions. Depending on the level of use, alternative fuels can reduce emissions in the range of 5 to 20 per cent.

Figure 3: GHG Reduction Potential of Alternative Policy Packages



Source: Hickman, R. and Banister, D. 2006. Looking Over the Horizon: Visioning and Backcasting for UK Transport Review (VIBAT). Department for Transport – Horizons Research c 2004/2005

POTENTIAL TO REDUCE EMISSIONS IN THE GREATER TORONTO AND HAMILTON AREA

To put the potential of transportation emission reduction strategies in perspective, a preliminary analysis has been conducted of how to substantially reduce transportation GHG emissions in Canada's largest metropolitan region. The study area is the *Greater Toronto and Hamilton Area* (*GTHA*) ─ the metropolitan region encompassing the City of Toronto, the four surrounding regional municipalities (Durham, Halton, Peel and York) and the City of Hamilton (Figure 4).

This analysis examines the possibility of reducing transport GHG emissions to 50 per cent below 2006 levels over the next 25 years (i.e., by 2031). This target is ambitious, but falls within the range of reductions targeted across Canada. The horizon year of 2031 was selected based on a 25 year time span and availability of travel demand forecasts for this horizon.

Note that the analysis herein focuses on GHG emissions from passenger transport. Further work is required to assess emissions from goods movement.

Figure 4: The Greater Toronto and Hamilton Area

Approach

The analysis followed a four-step approach:

- **Establish baseline and set targets**
- **Develop alternative transit/land use scenarios**
- **Model travel demand and estimate emissions for each scenario**
- **Assess additional strategies required to meet targets**

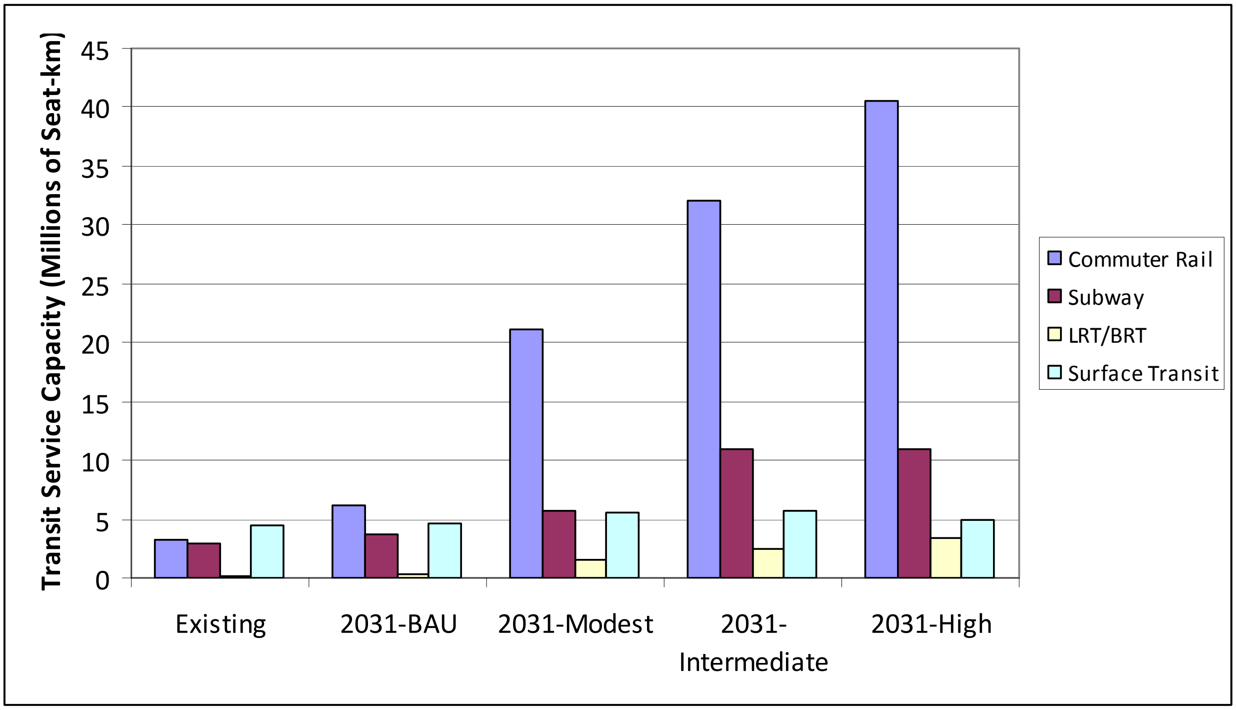
Baseline and future travel demand was estimated using the Greater Golden Horseshoe Model (the Ministry of Transportation of Ontario's transportation demand forecasting model covering the Greater Golden Horseshoe area[20]).

GHG emission estimates were developed using the Urban Transportation Emissions Calculator, which estimates annual emissions for light-duty passenger vehicles, commercial trucks, and transit vehicles including both emissions from vehicle operation and upstream emissions from production of electricity used by electric vehicles (i.e. trolleys and light rail) as well as from the production, refining and transportation of transportation fuels (i.e. from wells to pump)[21].

To test the impact of varying levels of transit investment on GHG emissions, four alternative transit/land use scenarios representing increasing transit investment were developed. The transit service capacity by mode for each scenario is summarized in Figure 5.

In terms of land use, the GTHA is among the most rapidly growing urban areas in Canada. Projections based on the Province of Ontario's Growth Plan, Places to Grow, forecasts population to increase by more than 40 per cent to approximately 8.6 million from the current 6 million. For modelling the scenarios, 2031 projections at the traffic zone level (~3000 zones) are consistent with the population and employment forecasts of the Growth Plan at the single and upper-tier level, consisting of population by age, occupation status, dwelling type, household structure and employment by type. All scenarios assume that the Growth Plan's minimum requirements for intensification and density have been met. Reflecting transit supportive land use initiatives, slightly higher gross population (i.e. employment + population) has been assumed at select transit hubs for the Intermediate and High scenarios.

Figure 5: Transit Service by Scenario



BAU = Business as Usual

The model used in the preparation of this paper has limitations that must be considered when interpreting its results like all state of practice models. Among them are the following:

Observed behaviour: the model captures people's current perceptions of the modes available and observed travel behaviour. As such, it may underestimate the impacts of new modes and aggressive policies that do not exist today, as there is no observed behaviour from which to extrapolate.

Modal bias: the model is not sensitive to changes in non-quantifiable measures, such as comfort, cleanliness and image. Hence, attitudes toward buses, for example, are assumed to be constant and only the impacts of changes in cost, in-vehicle and out-of-vehicle travel time and transfers are modeled.

Regional scale: the model is based on a grid of 3,000 traffic zones for the Greater Golden Horseshoe, which is at a scale too large to provide sufficient detail at a local level and for short trips.

Modelling error: error is inevitable given the aggregations and simplifications necessary to model every trip for every person in the Greater Golden Horseshoe.

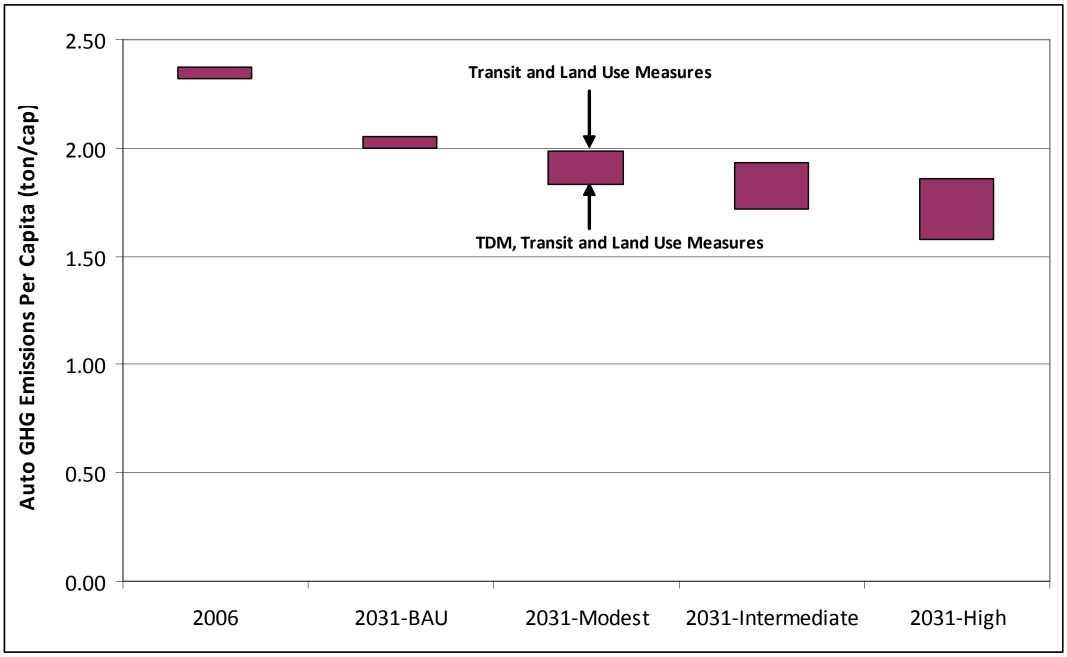
Results

While transit takes up an increasing share of travel, the automobile remains the dominant mode under all scenarios. Results are presented for auto GHG emissions in terms of per-capita emissions (Figure 6), and change in auto GHG emissions from existing levels (Figure 7 and Figure 8). A number of potential strategies were considered. Their effects were determined through modelling as well as benchmarking from the literature and an analysis of potential transferability to the GTHA.

Per-Capita Emissions

Figure 6 illustrates per-capita emissions by scenario in terms of ranges. The upper end of the range indicates the effect of transit investment and land use measures, while the lower end also includes the additional effect of aggressive TDM strategies to reduce vehicle- kilometres travelled, reduce traffic peaking, increase vehicle occupancy, encourage non-auto modes of transportation, and reduce non-essential travel. This includes extensive marketing and incentives regarding transit and carpooling, as well as some form of road pricing across the region.

Figure 6: Auto GHG Emissions Per Capita



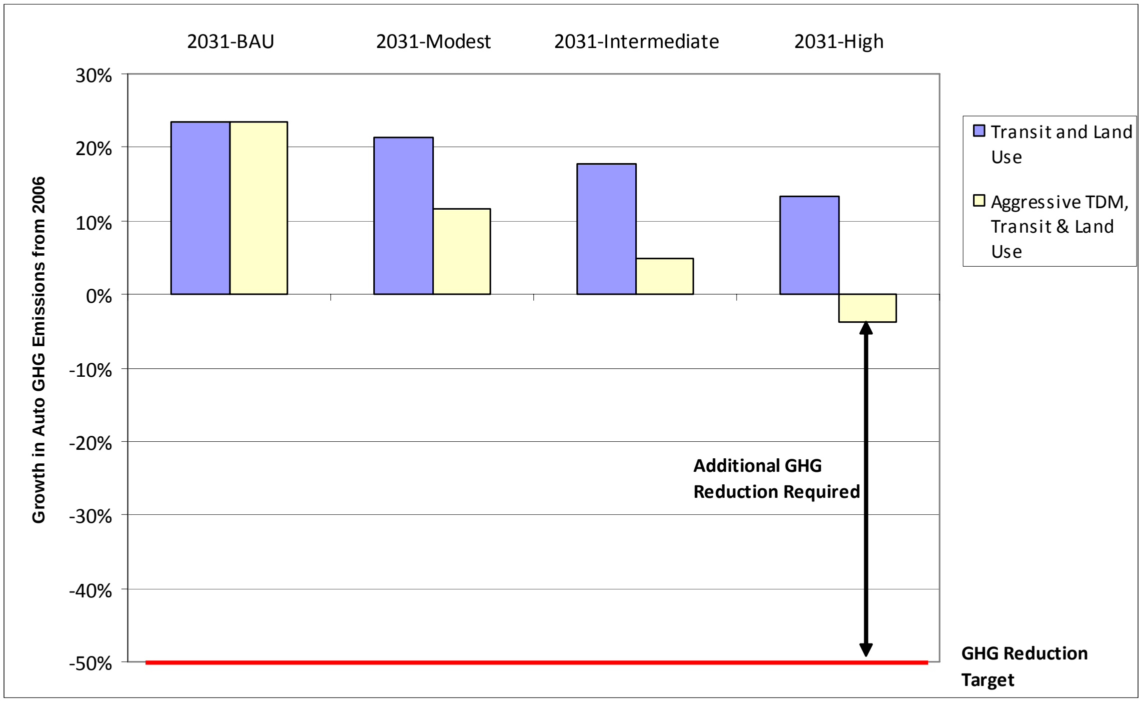
BAU = Business as Usual

The above graph indicates that per-capita emissions decrease for all future scenarios. For the Business as Usual (BAU) scenario, this is primarily due to more compact land use, while the role of transit is increasingly evident for the alternative scenarios. As discussed earlier, increased investment in transit allows TDM to have greater impact on travel as there are more transportation options for people to choose from. Expected reductions in per capita emissions range from 13% in the BAU scenario to 32% in the High Transit Investment scenario with aggressive TDM.

While reductions in per-capita emissions are substantial, they are largely offset by expected increases in population. Figure 7 illustrates the growth in auto GHG emissions from 2006 levels for each scenario considering for two groups of actions: (i) transit investments and land use concentration, and (ii) aggressive TDM, transit investments, and land use concentration. Under business as usual conditions, auto GHG emissions are expected to grow by 23%. This analysis shows that only with aggressive TDM, high transit investment, and land use concentration can we avoid growth in auto GHG emissions. Note that aggressive transit investment and aggressive TDM measures are mutually supportive and one would not be practical in the absence of the other[22].

The full range of travel demand measures are expected to reduce auto GHG emissions by 4% below 2006 levels; however, as shown, there is a large remaining gap to achieve the targeted 50% reduction in emissions by 2031.

Figure 7: Effect of Transit Investment, Concentrated Land Use, and Aggressive TDM on Auto GHG Emissions



BAU = Business as Usual

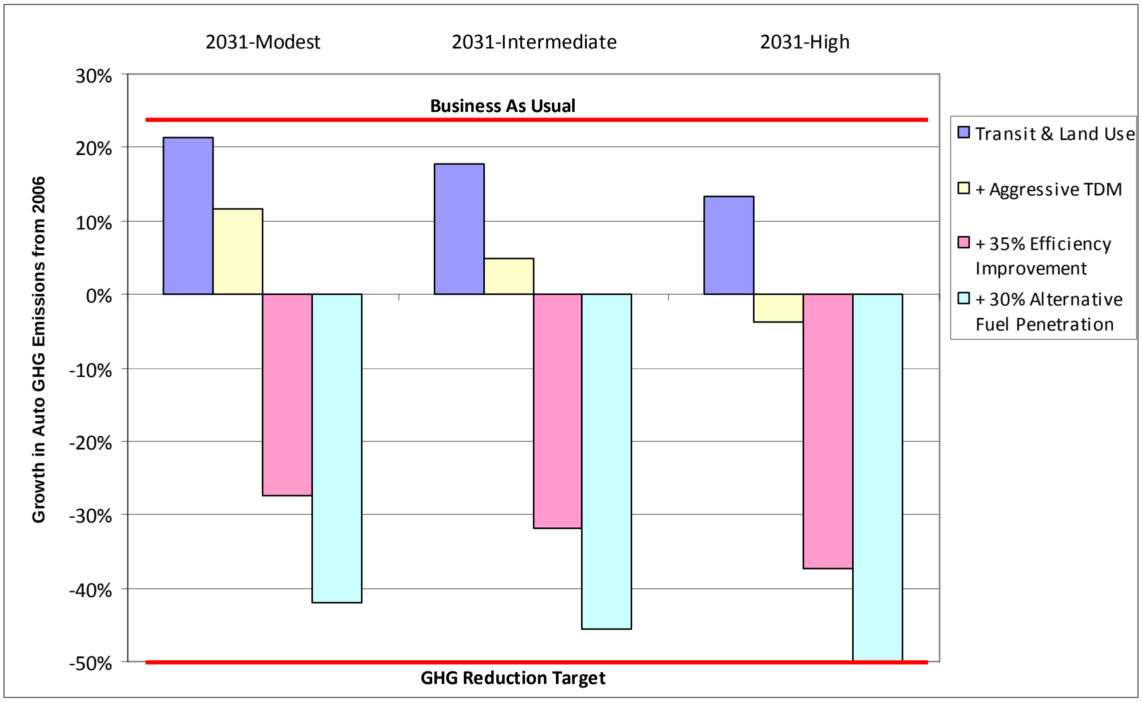
The key message from Figure 7 is that while measures aimed at reducing VKT and providing more transportation options are required and effective at reducing GHG emissions, the personal vehicle continues to be the dominant mode for travel. As such, additional measures to improve fuel efficiency and decrease the carbon content of fuel will be required to meet aggressive GHG reduction targets. Figure 8 builds on the results from Figure 7 and shows the cumulative effect of four groups of actions on the growth in auto GHG emissions from 2006 levels for each transit scenario:

- Transit investments and land use concentration;
- Aggressive TDM and the previous measures;
- A 35% improvement in fuel efficiency across the light duty passenger fleet and the previous measures; and
- A 30% penetration in alternative fuels across the light duty passenger fleet (assumed to provide a 20% reduction in auto GHG emissions) and the previous measures.

All of these packages are considered feasible in the next 25 years given that aggressive work towards implementation begins immediately. Rising oil prices as well as carbon taxation or caps, if implemented, will certainly play an important facilitating role.

Figure 8 illustrates that the GHG reduction target can be achieved given High transit investment along with the combined effect of TDM, vehicle efficiency improvements and significant penetration of alternative fuels

Figure 8: Combined Effect of Multiple Strategy Packages on Auto GHG Emissions



CONCLUSIONS

The challenge of trying to reduce or even hold the line on emissions in the context of a growing population cannot be overestimated. This paper has shown that even aggressive transit service level improvements and TDM measures will only just hold the line on GHG emissions from transportation, let alone meet drastic targets being set out by governements. This conclusion is not meant to suggest that investments in transit are not merited, but that other strategies such as fuel efficiency improvements and alternative fuels must also be pursued agressively and immediately.

One of the challenges in achieving targets for GHG reduction, particularly in the transportation sector, is that different levels of governement are responsible for different types of strategies. In general, the federal government is responsible for encourging or regulating improvements in vehicle efficiencies while municipalities are responsible for delivering transit improvements. This makes it all the more important for transportation engineers and planners to take a comprehensive approach to developing strategies to address climate change and to raise awareness of the magnitude of changes that are required.

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[3] Canada's GHG inventory reported emissions from Transportation sources were 150,000 kilotonnes in 1990 and 200,000 kilotonnes in 2005. Assuming an exponential growth rate of 1% per year from 2005 to reflect population growth results in a forecast of 232,000 kilotonnes, which is 55% higher than the 1990 level.

[4] Compiled from various reports including Sustainable Transportation Indicators Project, Centre for Sustainable Transportation in cooperation with IBI Group and Metropole Consultants, December 2002

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[20] The Golden Horseshoe is a densely populated and industrialized region or urban agglomeration centred around the west end of Lake Ontario in Southern Ontario. The built-up region extends from Niagara Falls at the eastern end of the Niagara Peninsula, wraps around Lake Ontario west to Hamilton, anchored by Toronto on the northwest shore of Lake Ontario, continuing to the east of Oshawa. The wider region spreads inland in all directions away

from the Lake Ontario shoreline, southwest to Brantford, west to the Kitchener-Waterloo area, north to Barrie and northeast to Peterborough.

[21] See http://www.tc.gc.ca/programs/environment/UTEC/menu-eng.htm

[22] Cansult and TSI Consultants. 2005. The Impact of Transit Improvements on GHG Emissions: A National Perspective. Transport Canada.