Pacific Analytics Inc.

ASSESSING VEHICULAR GHG EMISSIONS

A Comparison of Theoretical Measures and Technical Approaches

Prepared for: the CEEI Working Group

2008

P.O. Box 5103 Victoria, BC V8R 6N3 - JimJ_PA@shaw.ca

COMMUNITY ENERGY AND EMISSIONS INVENTORY OBJECTIVES

In its work investigating greenhouse gas emissions (GHGs), the Community Energy and Emissions Inventory (CEEI) Working Group has been examining various methods for providing estimates of vehicle emissions to community stakeholders at the municipal level. A number of groups in British Columbia and elsewhere also have been looking at this question, either for their own community/region or for all regions within the province. As a follow-up to their work, the CEEI thought it would be useful and informative if a brief paper were developed outlining the various theoretical methods that could be used to estimate GHG emissions at the local level and, as well, a description of the extant models now employed to calculate those emissions, identifying in particular the limitations and advantages of each Models structure.

Despite the shortcomings described below, the CEEI is committed to developing estimates of community-based vehicular emissions for the year 2007 (and the re-working of 2005 estimates) using a model developed by HES Ltd. (TEEM™). In the future, however, the CEEI wishes to develop its own in-house model that will be capable of measuring community-based emissions accurately and in a timely manner. Exactly how this CEEI model will be put in place – whether it will be based on the existing TEEM™ approach, whether there are other, proprietary models that could be purchased, or whether the CEEI will choose to develop a model customised to its own needs, is still being assessed. Ultimately, it is hoped that this Report will help inform and possibly guide the decision as to the precise needs and structure of the emissions model that the CEEI will need to adopt for estimating community emissions, and will help channel the efforts of the CEEI to improving those components of the model that will require the most attention.

INTRODUCTION

When calculating vehicular GHG emissions in a community, there are two main theoretical measures that can be calculated: the first is an accounting of all emissions generated by vehicles in the community irrespective of whether those vehicles are resident in the community; and the second is an accounting of all emissions by vehicles resident in the community irrespective of whether the emissions are made within or outside the community itself. To use an analogy from National Accounting parlance, the first can be termed “Gross Domestic Emissions” or “GDE” and the second “Gross Resident Emissions” or “GRE”.[1]

[1] In National Accounting, the sum of economic activity in a region is measured in two ways. The first way is referred to as Gross Domestic Product (GDP) and is defined as the value of all final goods and services produced in a region in one year, irrespective of who in the region is generating that activity. The second measure, labelled Gross National Product (if a country) or Gross Provincial Product (if a province) is defined as the value of all final goods and services produced by citizens of the region, irrespective of where that economic activity takes place. In a nutshell, GDP is equal to the total output of a region while GNP (GPP) is the total output of nationals of the region.

Both measures are “correct”; they are simply measuring different concepts and provide different information. Generally speaking, GDP is the common measurement noted in the media, in large part because GDP is much easier and much timelier to measure than GNP. However, GDP does not, itself, necessarily provide a good measure of domestic well-being. As an exaggeration, if all of the economic activity in a region is generated by a foreign company and all profits expatriated, then, while the GDP of a region might be high, the value going to local citizens (GNP) quite low. In this case, being able to report GNP would be a much better gauge of local well-being. It should be noted that when National Accounting first began, GNP was the preferred measure, It should be noted that each of these measures is "correct"; but each is measuring a different set of emissions and providing different information to stakeholders. As such, there is no theoretical reason to accept or reject one or the other measure; what is important is that the information being generated is understood by and useful to stakeholders in their quest to reduce GHGs in their community. Some stakeholders have argued that community decision-makers have little control over the behaviour of resident vehicles travelling outside their community but can influence the behaviour of non-resident vehicles travelling inside the community by, for instance, increasing parking costs. Accordingly, these stakeholders have the view that it is the tracking of Gross Domestic Emissions (GDE) that is paramount. In contrast, other local stakeholders take the view that municipal actions will disproportionately affect local vehicles owned by community residents (e.g., measures to change local land use, changes to local transit, outreach efforts to encourage behaviour changes, etc.) and therefore it is the tracking of Gross Resident Emissions (GRE) that are most important.

Of course, in the ideal world, it would be useful to have data on both measures, but this is not always possible. Indeed, much like the National Accounting alternatives of GDP vs GNP, the choice of which measurement to track often boils down to which measurement can most accurately be calculated in a timely manner. From the perspective of measuring *trends* in GHG emissions, it also would be useful to be able to backcast emissions to earlier years, requiring the availability of historical inputs to the measures. The two measures are examined from this perspective in more depth below.

A COMPARISON OF THEORETICAL MEASURES

In the following sections, the two theoretical measures (GDE and GRE) are discussed in more detail and where appropriate, the underlying data requirements of each measure under discussion are broadly assessed in terms of the data accuracy, regional and community availability, completeness, effort and cost to generate, and timeliness of updates.

A. The Gross Domestic Emissions (GDE) Measure

The GDE approach attempts to measure GHG emissions linked to the consumption of fuel within the geography of the community irrespective of where the vehicle is resident. Emissions are only counted if the vehicle is physically consuming fuel within the community boundaries; a resident vehicle commuting to another municipality or region (for work or pleasure) will only contribute to emissions for that portion of travel that occurs inside the community boundaries. At the same time, emissions from vehicles travelling from other communities (including tourist vehicles and vehicles passing through to other communities) will have their emissions included for that portion of travel occurring in the community.

Measuring fuel consumption of all the vehicles travelling within the community is logistically very difficult without access to on-board GIS-enabled tracking systems.[2] As a consequence, the application of the GDE approach usually has an important underlying supposition: the assumption

---

but technical difficulties in measuring GNP in a timely manner resulted in GDP becoming the de facto measurement of choice.

[2] This may be a possibility in the future. There is a pilot project beginning soon in Manitoba where GIS-enabled black boxes are being installed in a select number of vehicles and the driving patterns and characteristics will be monitored in real time.

that the consumption of fuel within a community (i.e., the integral measure of GDE) is equal to the sales of fuel within that same community.

Theoretically, there is no justification for this assertion, and indeed no statistical analysis has ever provided any validation for this assumption, other than claiming that since the measurements of the two values are sometimes "close", they therefore ought to be equal. And while for larger agglomerations (such as Metro Vancouver) this assumption may be "close" (however that is defined) to being valid, for the majority of municipalities in the Province it is highly unlikely that such an assumption will be valid. For instance:

i. Any fuel price differential between communities will draw sales to the lower priced community without adding appreciably to fuel consumption in the community. Fuel sales in Abbotsford, for example, are disproportionately higher (hence disproportionately lower in surrounding MetroVan municipalities) due to Abbotsford not having a Transit Tax added to fuel prices. Similarly, long-haul trucks tend to fill up in the Fraser Valley (where prices are cheapest) before heading eastward. As a consequence, using fuel sales to proxy fuel consumption would be erroneous.

ii. Communities located on major highway thoroughfares can expect higher sales even though most of the actual consumption of fuel will take place further down the road. Communities along the TransCanada then, would likely see their fuel sales much higher than actual consumption within their municipality boundaries.

iii. Communities servicing large wilderness tourism areas generally will see higher-than-expected fuel sales from what is actually consumed within its municipal boundaries. Communities such as Golden, for example, experience very large increases in fuel sales during the summer, although most tourists would not consume the fuel in Golden itself.

iv. Communities near the US or Alberta borders will likely experience lower-than-expected sales as consumers travel to the US or Alberta for shopping. Residents of the Northeast for instance are notorious for their cross-border shopping, many choosing to make weekly or biweekly excursions to Alberta towns solely to save on taxes.[3] Similarly, smaller communities without large retail outlets can expect to lose sales as residents do their main shopping outside the smaller community.

Theoretically then, the accuracy of using fuel sales to approximate fuel consumption at the municipal level is problematic. There is, however, another, more practical issue, and that has to do with the coverage of the available fuel sales data for municipal regions. The Ministry of Finance does provide accurate fuel sales data (based on transit tax payments) for three broad regions: MetroVan, the Capital regional District (CRD), and all other regions of the Province.[4] Kent Marketing does purport to provide regional fuel sales data, but it concentrates it coverage on cities, larger towns and major highway service stations, and excludes all fuel sales from CardLock facilities, making the data on diesel sales unreliable for estimating heavier-duty truck emissions. After

[3] The BC Government, following numerous complaints by retailers in the Northeast, recently completed a study examining the possibility of reducing or eliminating the PST in the Northeast (and some East Kootenay communities) in an effort to stem the tide of people crossing the borders for shopping.

[4] Data for MetroVan and CRD are provided by the Ministry of Finance through its fuel taxation database which identifies payments for the regional transit tax. These data are considered accurate (although there is some question as to reporting date: are fuel taxes paid in a specific month allocated to that month or to the month in which the actual sales took place), but are not broken down by municipality, preventing the data as issued by MoF from being used for municipal estimation.

aggregating their data, Kent ends up providing coverage for approximately 63 unique areas of the province. In doing so, however, it does two things: first, it aggregates a number of municipalities into one measure (the sales data for "Smithers", for example, includes sales for Telkwa, Hazelton, Moricetown). This means that for most communities in the Province (e.g., Smithers) using the Kent data for their community would not be meaningful. Second, the Kent data ignore many rural fuel retailers where a large proportion of local population resides. While these rural provides are likely small, it does mean that the sum of sales estimated by Kent Marketing for a region will not be equivalent to actual sales.

No in-depth analysis of the Kent Marketing data has be undertaken by the CEEI or other government groups to my knowledge. That is, what are the differences between the Non-MetroVan/CRD data from Kent and the provincial taxation data for the same Non-MetroVan/CRD area? Assuming there are differences, are these differences stable (i.e., are the growth rates more-or-less the same) or is there an evolving pattern over time? As well, are there discontinuities or "jumps" in the data (a cursory glance of the data over time suggests that there are) that might compromise the accuracy of the Kent data? What about the diesel estimates? Are these useful for estimating emissions from light duty diesel vehicles? These are the kinds of questions that need to be examined before use of the Kent fuel sales data should be contemplated.

Without an analysis such as above, it is not clear whether the available regional fuel sales data from Kent Marketing are sufficiently accurate or regionally complete to be used as proxies for estimating fuel consumption at the municipal level.[5] The simple observations noted above (e.g., that not all service stations are monitored; that not all municipalities are not identified separately; that discontinuities appear in some of the values, etc.) suggests that using the Kent data as municipal proxies could be problematic. It also needs to be noted that using the Kent Marketing data will incur a substantial cost to the Ministry (~$35,000 per year) and would likely result in residual disclosure of the data to other parties, something I doubt Kent Marketing would appreciate.

B. The Gross Resident Emissions (GRE) Measure

The GRE measure (sometimes known as the "Resident-Based Measure") attempts to calculate GHG emissions generated by a community's resident vehicles regardless of where those emissions may occur. In this case, emissions generated by a vehicle travelling <u>outside</u> its community are attributed to the resident community. This would include all GHGs generated by, say, a vehicle being used to commute to a work location in another municipality, or by residents travelling for tourism purposes to other parts of BC, Canada or elsewhere. At the same time, vehicular traffic in the community by non-resident vehicles (say, by commuters from other municipalities or by tourists) would not be counted.

GRE emissions theoretically are easy to calculate and are equal to the identity:

GRE Emissions = (# of Vehicles X Avg. Fuel Efficiency X Avg. VKT) X Unit Emissions

where # of Vehicles equals the number of vehicles in the community, Avg. Fuel Efficiency is equal to the weighted average fuel efficiency (litres/100km) of vehicles in the community, Avg. VKT is

[5] It is possible (in the "future") that municipal-based fuel sales will be available. The recent media attention regarding the cost of gasoline has prompted a renewed call for NRCan to survey each municipality in the country in order to provide consumers with accurate information on prices and price trends. The Minister in charge has voiced his support.

equal to the average kilometres travelled each year by the average vehicle in the community, and Unit Emissions refers to the amount of GHG emissions per litre of fuel consumed.

More accurate estimation of GRE emissions usually entail disaggregating the identity into separate vehicle classes (e.g., compacts, SUVs, etc.) and summing. More accurate still is sub-dividing the vehicle classes by fuel type (e.g., gasoline, diesel, etc.), by licence type (i.e., driven for work or for pleasure), and by model year of the vehicle.

Estimating the # of Vehicles

From a practical measurement standpoint, determining the number of vehicles in a community by vehicle class, fuel type, licence type, and model year is a question of data availability, not a question of theoretical limitations. Within the context of CEEI work, the ICBC database of vehicles in the past has presented some difficulties with identifying accurately community vehicle characteristics.[6] Significant progress by the Community Energy and Emissions Inventory (CEEI) Working Group (via the "VIN" Project) has been made of late to ensure a high level of accuracy in vehicle identification and assigning vehicle characteristics (e.g., vehicle class, fuel type, engine displacement, transmission type, etc.). Some additional (minor) problems remain with missing and/or invalid postal codes, but it is fair to say that determining a breakdown of the number of vehicles by class, by fuel type etc. in a community is now far more accurate than previous.[7]

Estimating Avg. Fuel Efficiency

In the context of the CEEI work, estimating Avg. Fuel Efficiency by vehicle class, fuel type and model year has also improved immeasurably in the last months, again due to the recently completed CEEI "VIN project". With more complete identification of Make, Model, Transmission Type, and Fuel Type the ICBC data now has NRCan/USEPA fuel efficiency ratings attached to virtually all individual vehicles (where such ratings exist) and therefore, when averaged across all vehicles in a class, the average rating, even at the community level, should be considered sufficiently accurate for the purposes of CEEI estimation.

Nevertheless, three outstanding problems still exist. The first is that fuel efficiency ratings only exist for passenger vehicles, light duty trucks, and a sample of other, larger trucks. As such, it still will be necessary to estimate fuel efficiencies for those remaining vehicles if this methodology is to be used for all vehicle types in a community.[8]

A second problem is a statistical data problem and, in theory, is easily solved given time. Nevertheless, it should be noted since the problem still exists at this time. The USEPA recently undertook a major revision to its methodology for estimating city and highway fuel efficiency ratings

---

[6] For example, of the just over 3 million unique vehicles in 2007 Quarter 2, almost 650,000 (20%) had a Model description containing "OTHER", indicating that no model description is available. Accordingly, it is not possible to identify a specific vehicle class based on NRCan data and thus assignment of a vehicle class must be estimated from other characteristics (e.g., Make, NVW/GVW, Body Style, etc.).

[7] Although not anticipated to influence substantively the data results, there are still some questions regarding fleet vehicles that are registered in the region of the head office (most often in the MetroVan area) but generally are based and driven in other regions.

[8] Real-world efficiencies are difficult to estimate for larger vehicles since most larger vehicles are used to haul goods or large numbers of people, adding to the weight and consequently reducing the fuel efficiency of the engine compared to an empty vehicle. Some preliminary econometric analysis has been undertaken by MoT using smaller vehicle characteristics (e.g., net vehicle weight, drive train, transmission, etc.) and efficiencies to estimate larger vehicle efficiencies based on large vehicle characteristics (e.g., gross vehicle weight, drive train, etc.), however this work needs to be undertaken in more detail if it is to be used in any future analysis.

going back to at least the model year 1990. While the adjusted efficiency ratings are different for each make/model/model year of vehicle, the upshot is that average efficiencies across the board are between 5% and 10% lower for 2008 model year vehicles under the new methodology than under the older methodology. At some point it will be necessary to obtain the EPA database for all vehicles going back in time and adjust the existing NRCan ratings. In the interim, for the CEEI purpose of estimating community energy and GHG emission inventories for 2007, efficiencies will be adjusted by a value of 7.5% for all make/models and model years, the same correction factor used recently to estimate emissions from the Province's own vehicle fleet.

A third problem relates to the fact that fuel efficiencies decay over time as a vehicle ages and the engine loses, for example, compression. Hence, the efficiency rating for a new 1995 vehicle in 1995 as reported by NRCan will be different than in 2008. Some work on estimating these decay factors is being undertaken by MoT, but as yet no reliable estimates are available.

Despite the small problems associated with determining the number of vehicles (by class, fuel type, etc.) and the average efficiencies of these vehicles in each community, the general consensus by present users at MoT is that these data are highly accurate at the municipal level and furthermore are easily updated in a timely fashion at relatively low cost. It also is true that historical estimates, going back to at least 2000, are easily calculated. The same cannot be said of community estimates of VKT.

<u>Estimating Avg. VKT</u>

Estimates of average VKT (vehicle kilometres travelled) can be assembled from a variety of sources, but almost all published estimates depend on surveys of individuals. For the Passenger/Light Duty truck component, for instance, Transport Canada undertakes the Canadian Vehicle Survey, in which a rolling sample of individuals are contacted and asked to maintain a log of their driving characteristics, including how many kilometres they drive. Despite the inherent problems with a self-administered survey/log and the relatively low response rate (less than 60% of respondents initially given the log provide any results), much effort is expended to ensure a relatively high degree of accuracy.[9] Unfortunately for CEEI purposes, the sample size for BC is too small to enable any regional measures of VKT to be extracted, and therefore the Canadian Vehicle Survey data are not a reliable source for estimating municipal or even Regional District VKT. Furthermore, the estimates are generally dated (at the time of writing – November 2008 – the latest estimates are for 2005).

In addition, in its modelling of truck activity (including their "Emissions Calculator" model) Transport Canada in conjunction with Natural Resources Canada has developed estimates of annual kilometres driven for a range of larger truck types based on the Mobile6 road vehicle classification system. These VKT estimates take as its primary data source the annual Canadian Vehicle Survey (larger vehicle survey) augmented by the occasional National Roadside Study, the annual Truck and Trucking Origin and Destination Survey, the annual Canadian Vehicle Fleet Survey, Customs data, plus various trucking data and characteristics collected at the provincial level. The total VKT data are distributed across provinces and by vehicle type and while there are critics of the estimates, especially for the detailed vehicle types at the provincial level, the overall estimates are consistent

[9] As far as I know, no assessment of the Transport Canada results vis a vis other provincial measures has been undertaken. Given the now high degree of accuracy of provincial-level vehicle counts and characteristics and average fuel efficiency rates, it might be an interesting exercise to see how well the Transport Canada data for provincial-level vehicle counts, implicit fuel efficiencies and fuel sales concur with the Ministry of Finance, the CEEI, and/or the MoT estimates of the same measures.

with Transport Canada's understanding of truck activity in Canada. Unfortunately, Transport Canada does not provide any sub-provincial breakdowns of the estimates, and therefore the data are limited in their usefulness for sub-provincial estimates of GHG emissions. Furthermore, because of the lack of detail at the passenger vehicle level, it is not possible to track changes in VKT for say, SUVs as compared to say, Compacts.[10]

While other survey estimates of VKT exist,[11] another potential source of local-level VKT are those estimates generated by traffic models such as EMME. These models track vehicle behaviour and travel patterns by zone and estimate pass-through travel to other zones (see **TransLink** below for a more detailed explanation of EMME). Although the purpose of the EMME Model is for traffic planning, it is possible to apply a series of roll-ups from average hourly movements to average daily traffic in order to estimate an annual average VKT. While there are some serious data limitations to this methodology (many of the inputs are based on Census data and surveys), and at present very few municipalities or Regional Districts actually use the EMME Model to produce such data, where such data exist it would be worth pursuing, if for nothing else, to at least confirm the local estimates of VKT that eventually are going to be used by the CEEI.[12]

Notwithstanding the potential usefulness of the foregoing data, the most promising source for estimating VKT is based on AirCare data. AirCare requires all vehicles in MetroVan and the Fraser Valley with a Net Vehicle Weight of less than 5000 KGs and older than 7 years (older than 3 years prior to 2003; 5 years prior to 2006) to be tested every two years. As part of this testing, the odometer reading is recorded. By comparing odometer readings for individual vehicles over time, one is able to develop a database of estimated VKT for different vehicle classes.

The major strength of using the AirCare data to estimate average VKT is that it is possible not only to determine average VKTs for different vehicle classes; it is also possible to use the data to determine what variables influence VKT and by how much. For instances, how does VKT for a specific class of vehicle (say, gasoline-powered SUVs driven for pleasure only) respond to changes in fuel prices, or changes in income levels, or changes to the age of the vehicle, or changes in transit costs, or whether the vehicle is driven by a man or woman, or whether the age of the person driving is over 65, etc. etc. In a nutshell, not only can the AirCare data provide an accurate and credible estimate of Lower Mainland driving patterns, but, contingent on the inclusion of other data, it also could provide valuable information on why VKT changes over time.

Nevertheless, there are important limitations to the AirCare data for estimating VKT, the most serious being that AirCare data are available only for vehicles registered in the two Regional Districts in the Lower Mainland (RD9 – Fraser Valley; and RD 15 - MetroVan). As a consequence, even if the

[10] The use of the Transport Canada passenger vehicle data at a regional level assumes that the <u>mix</u> of passenger vehicles in a region is the same as in the province as a whole. That is, even if people drive their SUVs and their Compacts exactly the same VKT in a region as the province in general, but that region has significantly more SUVs than the provincial average, then using provincial VKT will not estimate regional VKT correctly. And, of course, we also know that people in different regions drive different distances.

[11] A few communities undertake household surveys in order to obtain a snapshot of traffic behaviour and issues. These surveys often provide a reasonable (subject to the limitations of relatively small surveys) of the general VKT pattern in the town/region. However, given that most of these surveys are undertaken only every five years, the efficacy of using such data to infer regional VKT profiles in later years is suspect.

[12] To my knowledge, several municipalities besides MetroVan and the CRD are now examining the possibilities of using the EMME Model for their own traffic planning. Kelowna, Kamloops and Vernon, for instance, are in the process of determining whether there are sufficient data to populate the EMME Model and whether the results would be credible.

AirCare data provide highly accurate and timely estimates of VKT (which the belief of those presently using the data), there still needs to be a way to use this information to estimate VKT in other communities outside the Lower Mainland.

Under the above methodology, VKT for a vehicle class is estimated by specifying logged econometric equations using Panel data and explanatory variables such as real fuel prices (a lagged specification), average real disposable incomes (lagged), vehicle age, etc. The resulting coefficients can be applied to values in different years and, with appropriate adjustments, to different regions.[13] The question becomes, how does one determine the appropriate regional adjustment?

The solution proposed by the CEEI is to make use of regional samples of vehicles from ICBC's Vehicle Transfer database.[14] All vehicles that transfer their registration from one person/company to another are required to provide information on, among other characteristics, the odometer reading. Using the same econometric coefficients estimated when determining Lower Mainland VKT (using the AirCare data), an estimate of the expected odometer reading for each vehicle in the sample is calculated ("expected", that is, if regional vehicle VKT behaviour is the same as in the Lower Mainland). Contrasting these "expected" values to actual values from the transfer data gives a regional adjustment factor.[15]

The initial Vehicle Transfer project is taking a sample of roughly 10,000 vehicles spread across the 14 different ICBC Rating Territories for 4 different vehicle classes (Gasoline Small Cars, Gasoline Large Cars, Gasoline SUVs/Trucks, and Diesel SUVs/Trucks) and 2 different license types (for work and for pleasure only). This will provide a sample of roughly 90 records per vehicle type.

The outcome of the exercise will be an adjustment factor (say, 1.11) for each vehicle type and Rating Territory that can be applied to the VKT estimates for each vehicle type in the Lower Mainland to calculate an estimate of VKT by vehicle type for each Rating Territory, with each municipality in a specific Rating Territory receiving the same VKT values.

The reader should recognise that this is an interim project and that further work will be necessary in order to derive more accurate and credible estimates at the municipal level. Further work is required because:

1. The present sample size is relatively small. Expanding the sample size such that, at a minimum, estimates by Regional District can be calculated for all vehicle types, fuel

[13] Applying the coefficients to different years implicitly assumes that the behavioural response to each variable, say, increasing incomes is more-or-less the same over time (e.g., a 10 percent increase in real per capita incomes results in a, say, 4 percent increase in VKT). Applying the coefficients to different regions implicitly assumes that the behavioural response in the different regions is equal to the behavioural response in the Lower Mainland (this does NOT mean that the VKTs are the same; it does mean that **<u>if</u>** fuel prices are the same and average real per capita incomes are the same and the average age of vehicles is the same, then VKT will be the same.

[14] Of course, if the sample of Vehicle transfer data were large enough, then the econometric analysis could be undertaken on the Vehicle Transfer sample itself. However, at this time, only a small sample (roughly 10,000 vehicles in total for all regions – or perhaps 100 per vehicle class and region) is being drawn from the transfer database. In contrast, the usable AirCare sample size is roughly 4 million for all vehicles.

[15] Using coefficients from the AirCare analysis assumes that vehicles in other regions have the same "response" to changes in fuel prices, regional incomes and the like, but have a different overall average VKT. That is, a change of say, 10% in real regional per capita income will cause the same percentage change in VKT travelled in a year in the region as the same percentage change in the Lower Mainland. As more Transfer files are collected, a more robust estimate may be possible following the same methodology used in the Lower Mainland.

types and license types. As a rough approximation, the same sample size will likely need to be increased 10 fold;

2. While it would be difficult to collect Transfer records from previous periods (the records are not kept; rather they are transferred to microfiche), there will be an ongoing requirement to collect data each year (preferably each quarter) in order to pick up changes in regional VKT over time. Note that this requirement would also fulfil the requirement to expand the sample size;
3. Larger vehicles are not represented at present. Using the Vehicle Transfer data to calculate VKT estimates for Motor homes and heavy-duty trucks, and possibly Motorcycles would be useful;
4. In the present CEEI exercise, the adjustment factor is being applied to actual VKT estimates for the Lower Mainland. Theoretically, it would be much better to apply the specific coefficients determined for each vehicle type using the AirCare data to actual vehicle characteristics in each municipality. This would ensure characteristics such as vehicle age and local fuel prices are fully accounted for in the municipal estimates. [16]

Estimating Unit Emissions

The first three elements (# of Vehicles X Avg. Efficiency X Avg. VKT) of the GRE identity estimates total fuel consumption in litres. In order to derive GHG emissions, it is necessary to multiply by the amount of emissions each litre of fuel produces. For CO_2, the major GHG, there are standard, fixed emission factors that are applied per litre of fuel burned. For other GHG gases (e.g., methane, nitrous oxide) the rate of emissions per litre of fuel theoretically are linked to driving conditions and speed, weather, maintenance level of the engine, etc. However, from a practical standpoint, most GHG calculators (see, for instance, the USEPA Greenhouse Gas Equivalent Calculator[17]) use a standard, fixed rate per litre consumed for each vehicle type.[18]

C. Concluding Remarks and Some Recommendations

The following itemises the limitations of the two measures:

1. **Gross Domestic (GDE) Emissions**:
   a. practically speaking, determining the count (or Total VKT) of all vehicles travelling within a community's boundaries is only possible at this time by using a travel demand model such as EMME. Given the extensive data requirements and cost of implementing EMME at the community level, having EMME estimates for all communities in the province is simply not possible;

[16] To re-iterate: if say, Pickups in the Lower Mainland are estimated to have driven 17,500 Kms in 2007 based on the econometric equation for Pickups using AirCare data, then the regional adjustment factor is applied to this 17,500 value for each region. The (better) alternative would be to apply the econometric coefficients to the vehicle mix in each region, and then apply the adjustment factor. This alternative approach would take into account the differing mix of Pickups in each region (e.g., differing regional fuel prices, differing regional incomes, differing vehicle ages, differing driver age and sex mix, differing vehicle licensing (pleasure or work), etc.).

[17] http://www.epa.gov/cleanrgy/energy-resources/calculator.html

[18] See, for example, http://www.ec.gc.ca/pdb/ghg/inventory_e.cfm

b. the roll-up methodology for generating annual Total VKT estimates from hourly traffic flows via the EMME model is not considered reliable by those familiar with the EMME model. It is this unreliability that forces most users of EMME (or other traffic demand models) to benchmark the VKT estimates to regional fuel sales;

c. using fuel sales to proxy fuel consumption, even for fairly large regions, is not theoretically correct for a number of substantive reasons and, while benchmarking to fuel sales may prevent serious under- or over-estimation by the EMME roll-up methodology, benchmarking to fuel sales does NOT equate to assessing fuel consumption;

d. even for those communities that do implement an EMME-type travel demand model, the use of historical data inputs (often 5-10 years out of date) generally negates the use of EMME-based VKT data for annual monitoring of changes in emission trends;

e. any attempt to develop historical estimates of GDE emissions based on travel demand models is quite difficult to do accurately since the extensive data inputs based on surveys are rarely available for the past. Consequently, little or no analysis of trends would be possible using this measure.

2. Gross Resident (GRE) Emissions

a. in the GRE identity - # of Vehicles X Avg. Efficiency X Avg. VKT X Unit Emissions - measurements of the first two elements are relative strong as is the final element. The only, somewhat minor, problems are: not every vehicle has an accurate postal code designation; some vehicles (especially when part of a fleet) may be registered at the head office in one location but operated in another location; fuel efficiencies are theoretical and may not represent actual efficiencies, especially when local driving conditions and/or driving behaviour differ from test conditions/assumed driving behaviour; and fuel efficiencies decay over time depending in part on the maintenance history of the vehicle (this decay rate can be proxied, but not captured perfectly by econometrically estimating decay rates by age of vehicle);

b. there are some difficulties with the estimation of average VKT for larger vehicles. The AirCare data are able to generate accurate and very credible estimates of VKT for all types of older passenger vehicles and light duty trucks plus some smaller heavy-duty trucks resident in Lower Mainland/Fraser Valley communities. Therefore the present data limitations are for all larger heavy vehicles and for all vehicles outside the Lower Mainland/Fraser Valley regions;

c. while the CEEI “Vehicle Transfer” project will provide a preliminary adjustment factor for other regions, there are two remaining difficulties. First, the sample size is quite small (with the consequence that only Rating Territories are assessed, not all Regional Districts) and therefore it will be necessary to expand the data collection should the initial results show promise. Second, it will not be possible to calculate regional adjustment factors for previous years. This means that the 2008 factors will have to be applied to all earlier years, despite the possibility that the true factors are changing over time.

d. the present methodology for generating regional estimates applies adjusted Lower Mainland VKT estimates for each major vehicle type. Implicitly, this approach does not take into account the vehicle mix in each region (mix in terms of vehicle makes/models and in terms of vehicle ages). As mentioned before, a better methodology would be to apply the econometric coefficients calculated for the Lower Mainland to the specific vehicle mix in each municipality.

Each measure of emissions (GDE and GRE) provides different information to stakeholders and depending on the needs of each stakeholder, each would be useful to calculate. However, given the limitations inherent in each measure, it is clear that the Gross Resident Emissions (GRE) measure has substantive advantages.

1. given the data accuracy and completeness of the first two elements of the GRE identity (# of Vehicles and Avg. Efficiency) they do not really have to be "estimated", rather the compiled results effectively can be treated as actuals;
2. both elements can be easily and quickly updated to current values at minimal cost. In addition, the data also can be easily backcast to the year 2000 (data for prior years are not available due to ICBC changing computer systems at that time), if that should prove valuable to the CEEI Working Group;
3. the structure of all elements would enable the CEEI to generate carbon emission estimates at any locational level, including CSD (i.e., all municipalities plus all rural areas) and electoral areas.
4. the third element (Avg. VKT) has extremely strong estimates for all passenger vehicle classes and light duty trucks and vans for the Lower Mainland and these VKT data can be backcast to give valid estimates for all years back to 2000.
5. the trends in the sub-components intrinsic to each element could provide valuable information to local governments and provincial stakeholders. For instance, the Total # of Vehicles element is comprised of New Vehicles, Reactivated Vehicles, Vehicles brought into each location by migrants (international, interprovincial and intra-provincial migrants) and remaining Vehicles.

A COMPARISON OF TECHNICAL APPROACHES

The previous section described the two general theoretical measures and the detailed inputs that can be used to determine GHG emissions from vehicles. The following section describes a number of technical approaches or Models that are used by various groups in British Columbia and elsewhere to generate practical estimates of vehicle GHG emissions.

A. The TransLink Model

The TransLink Model is not explicitly designed to estimate fuel usage and/or GHG emissions. Nevertheless, the outputs of the Model can be used to assist in the calculation of GHG emissions, specifically in providing estimates of the most difficult variable to assess: Vehicle Kilometres Travelled (VKT) for the Lower Mainland.

Estimating Model Components

The underlying core of the TransLink Model is EMME/2, a state-of-the-art travel demand forecasting and traffic planning software package which is used, among other things, to estimate the number of vehicle trips occurring during the AM peak hour from one "zone" to another "zone" within the TransLink boundaries (there are altogether roughly 750 "zones"). Given these estimates of peak hour traffic for each zone, the model is able to calculate the average daily traffic (ADT) benchmarked to historical data collected in an Origin & Destination Survey which TransLink undertakes every five years and the occasional household survey and traffic count survey. Knowing the ADT and knowing the average kilometre distances between zones enables the Model to determine a value of average daily VKT (vehicle kilometres travelled) for each zone and, by summing, the total VKT for all zones together. Dividing by the number of vehicles on the road, gives the average VKT for all vehicles travelling within the TransLink area.

The EMME software disaggregates these trips by purpose (i.e., work or pleasure) and by four gross vehicle type (passenger vehicles, light trucks, heavy trucks and transit vehicles) and also derives measures of average vehicle speeds under various driving conditions (i.e. congestion), behaviours and time of day. In addition, the Model includes a socio-economic component that uses generalised costs (see below) to reach an equilibrium solution for travel demand (and ultimately, after all the roll-ups, VKT). Travel costs are a mixture of travel time costs, out-of-pocket costs (e.g. parking) and operating costs (fuel prices, maintenance costs, insurance, etc.). Travel demand responds to changing demographics (aging of population, changes in population distribution, etc.), changing job types and locations, changes in travel time preferences, and the like plus changes in relative costs of a vehicle travel versus the cost of other travel modes (e.g., transit). Accordingly, when fuel prices increase both vehicle costs and transit costs will rise, and therefore there may be little impact on travel demand and hence estimated VKT.

It should be noted, however, that, as a General Equilibrium Model, EMME/2 calculates an "optimal" solution to traffic demand/behaviour based on long-term patterns rather than explicitly estimating year-to-year changes in demand. Accordingly, the annual behavioural responses to demographic changes, changes in relative travel costs and the like are offset somewhat by the fixed nature of much of the historical input data which are re-calibrated only every five years. As a consequence, one cannot rely on the accuracy of the estimated annual trends.

Likewise, the nature of the modelling process for "sunk" costs (such as insurance, financing and, indeed, fuel costs) versus out-of-pocket expenses (such as parking costs or tolls) is such that out-of-pocket expenses typically have a larger impact on traffic demand and driving behaviour (e.g., changes in routes taken, bridge travel, etc.).

Conclusion

The TransLink Model is different from many models designed to estimate GHG emissions. Most models apply some form of the identity: # of Vehicles X Fuel Efficiency X VKT to calculate fuel consumption in litres and then apply factors to convert litres of fuel to GHG emissions. The TransLink model, in contrast, applies "emissions-per-kilometre" factors to the total VKT estimate to generate total emissions. The emissions-per-kilometre factors implicitly take into account average fuel efficiencies (again, these are historical estimates that are not updated on a regular basis) as well as driver behaviour (specifically, driving speeds) and driving conditions within the TransLink region.[19]

There are a large number of limitations and assumptions embedded in the EMME Model and the results it generates:

i. The EMME Model requires a large number of data inputs and, as a consequence, full updating of the Model is usually undertaken only every five years or so. For instance, a major input source is the Census Track data, yet because of the difficulties in updating all the data, the present Model is still using 2001 Census data. Similarly, the results of the Origin & Destination Survey are used to validate the results of the Model, but is only done and entered into the Model every five years;

ii. In the EMME Model, long-term behavioural patterns are highly dependent on these input data. As a consequence, many behavioural changes since the last update (in this case, 2001) are not fully captured and thus may not reflect accurately changes in VKT. In a nutshell, this means that relying on EMME results to determine changes in VKT on an annual basis is problematic and because of the relatively muted impact of changes in fuel prices it is likely that the calculated changes will under-estimate the true changes, leading to incorrect information flowing to stakeholders and decision-makers;

iii. The roll-up methodology from peak hour travel demand estimates to Average Daily Travel and eventually to annual travel demand is suspect, and as a result, the estimated VKT values are not considered by TransLink personnel to be reliable. Rather, TransLink overrides the EMME-generated VKT values by benchmarking these values to total fuel sales within the TransLink region. Effectively, then, TransLink assumes fuel sales are equivalent to fuel consumption in the region and only uses the EMME Model to "allocate" VKT to vehicle classes;

iv. Applying emission factors to VKT estimates rather than explicitly modelling fuel efficiencies makes it difficult, if not impossible, to capture major shifts in vehicle technology that seems to be happening of late.

v. The structure of the TransLink Model is such that it is difficult to assess the changes in the underlying components affecting changes in emissions over time. For example, without explicit changes to the Model, it is hard to assess properly how the movement to hybrid and possibly electric vehicles will affect future emissions.

B. The MetroVan Model

The MetroVan Model is designed in part to evaluate historic level s of GHG emissions within the MetroVan region, but more as a GHG emissions forecasting tool to enable analysts to judge the impact of specific Regional District initiatives on carbon emissions. As such, considerably more effort has been spent on developing the long-term forecast assumptions than on developing detailed estimates of historic fuel consumption and emissions. That said, in a nutshell, the MetroVan Model has adopted the GRE (Gross Resident Emissions) identity:

[19] One of the difficulties of using Lower Mainland VKT data to estimate VKT estimates in other regions of the province (whether these data come from TransLink or AirCare or other sources) is that driving conditions outside the Lower Mainland (and perhaps the CRD) can be radically different, in terms of snow, mountainous terrain, more gravel roads, etc.

GR Emissions = # of Vehicles X Avg. Fuel Efficiency X Avg. VKT X Unit Emissions

However, in large part because of their lack of confidence in some of the input values, particularly average Fuel Efficiencies and average VKT, they have chosen to benchmark the Model's results to Total Fuel Sales in the Regional District. As such, it combines the GRE approach with the GDE approach. The upshot of benchmarking to fuel sales is, of course, that all the inherent problems with the general GDE approach (see above) are embedded in the MetroVan approach.[20] The following describes in more detail the MetroVan methodology.

Estimating # of Vehicles

The number of vehicles (by model year) is identified from the ICBC data (based on the Rating Territory) and split into four main vehicle types (passenger vehicles, light trucks, heavy trucks, and transit buses) and further split by the Mobile 6 breakdown.[21] No information on municipal location of vehicles or on license type (i.e., driven for work or for pleasure) is included in the Model. The latest data in the Model is from 2005 Q2. This would mean that the MetroVan Model requires a "forecast" of many input variables in order to estimate current values.

It also should be noted that using a single quarter (in this case, Q2) to estimate annual emissions may bias the results for two reasons. One, the number of vehicles in a quarter may not match the average number of vehicles in the year (for instance, many vehicles are not licensed in the winter); and two, with population growth, it is likely that there are many more vehicles registered in the latter part of a year and likely most of these vehicles will be new vehicles with fuel efficiencies quite different from the average of the stock. It also may be true that ignoring the proportion of time the vehicle is on the road during the quarter or year and/or whether a vehicle is registered but in storage could affect the accuracy of the results.[22]

For forecasting purposes (and in the MetroVan Model determining values for 2007 would require a "forecast"), the total number of vehicles is pushed forward based on a stock-to-population ratio multiplied by projected population in the MetroVan region (the latest forecast assumes a slightly shrinking stock-to-population ratio over time). The population forecast is for all age groups as produced by BC STATS. This declining vehicle ownership ratio is somewhat of a surprise. When only the driving age group 15-75 is used, the trend for all BC is an increasing ratio. While this assumption would have no bearing on CEEI requirements (the CEEI does not provide forecasts at this time and uses the latest vehicle stock data), it does represent a major assumption for MetroVan and it might be worthwhile for them to re-visit this assumption.

In terms of estimating future vehicle types, historical shares of each vehicle type are calculated and these are pushed forward in time, suggesting that the share of 'New" vehicles purchased by vehicle type is the same as the share of extant vehicles, although there is the ability to change such

[20] It also is true that the VKT estimates are taken from the TransLink model which itself is benchmarked to regional fuel sales. As such, there is a double benchmarking to fuel sales, reinforcing the problems associated with the GDE approach.

[21] Vehicle type is determined based on Body Style, GVW and NVW. It is not clear how MetroVan addresses the data issues contained in the ICBC data (e.g., the numerous records without a fuel designation, the many vehicles without correct Make/Model specifications, etc.). Given the changes in the CEEI approach for 2007, it might be worthwhile to re-visit the report done for CEEI comparing the MetroVan estimates with those produced for the CEEI for 2005, but updating it to 2007 CEEI estimates.

[22] If a vehicle is registered for even 1 day during the quarter, it will be classed as "registered" in the ICBC database.

shares. Given the rapid change in the types of vehicles purchased in the last while (both in size and in fuel type), this is a restrictive assumption that ought to be examined more closely.[23]

Estimating Avg. Fuel Efficiencies

Fuel efficiency ratings by vehicle type are taken from EPA studies of "average" fuel efficiency of US vehicles and converted into litres/100 kms. No attempt has been made to use NRCan's Make/Model fuel efficiency ratings mapped to each vehicle in the MetroVan region which would take into account actual vehicle efficiency ratings (rather than using average US ratings) and also would incorporate the actual mix of vehicles (both in terms of vehicle make and models and in terms of vehicle model years) found in BC. Given the new information coming forward from the CEEI "VIN Mapping" project, it might be worthwhile for MetroVan to compare their fuel efficiency assumptions with those produced by the CEEI.

Similarly, there has yet to be any adjustment made for the change in EPA methodology (with the average vehicle having its fuel efficiency reduced by between 5 percent and 10 percent) nor is any adjustment made for a decaying fuel efficiency of older vehicles.

Estimating Avg. VKT

Estimates of Total VKT for the MetroVan region for three of the four vehicle categories (passenger vehicles, light trucks, and heavy trucks) for the year 2003 were provided by TransLink, those estimates themselves derived through the EMME TransLink Model. Total VKT for transit vehicles based on internal TransLink fleet records were provided for the year 2005. The 2003 Total VKT data were expanded to 2005 estimates by growing the data by 1.75% per year (presumably this is the population growth rate in MetroVan, but no reason for selecting this growth rate was given in the documentation).

The Total VKT estimates were then disaggregated across the 31 different Mobile6 categories. For the first 6 vehicle types (LDV, LDT1, LDT2, LDT3, LDT4, and HDV2B), the AirCare data odometer readings and vehicle stock are used.[24] In a nutshell, using a sample of each vehicle type, a simple average of annual kilometres driven is calculated and adjusted by a fixed decay rate (e.g., 2.37% per year for LDT1 – passenger vehicles) to account for the fact that older vehicles are driven less.[25] These estimates of VKT are multiplied by the appropriate vehicle stock in MetroVan to get a Total VKT by the first 6 Mobile6 vehicle types. The sum of the VKT estimates were then benchmarked to the Total VKT estimate provided for by TransLink. For the remaining vehicle types, VKT estimates from Transport Canada were used.[26]

The result of evaluating the equation:

Total Fuel Consumption = Avg. Fuel Efficiency X Total VKT

[23] MoT, for instance, estimates New Vehicle class proportions econometrically, relating the proportions of each vehicle class to variables such as regional real per capita incomes, real fuel prices, and real new vehicle purchase cost by vehicle class.

[24] The MetroVan methodology is based on average annual kilometre accumulation for a sample of MetroVan vehicles found in the AirCare data. As such, it is different from the AirCare analysis undertaken by MoT which determines average VKT econometrically.

[25] The decay rates are taken from an internal study by AirCare.

[26] Transport Canada estimates provincial-level VKT for a Mobile6 breakdown of vehicles. While using a provincial average for estimating regional behaviour could be problematic, the fact that MetroVan represents a large proportion of the provincial heavy vehicle activity means that serious mis-estimation is unlikely.

for each vehicle category and summing the values is an estimate of fuel consumption that does not equal fuel sales in the MetroVan region. As such, the MetroVan Model adjusts the results so that the two estimates are equated. Since the TransLink estimates are themselves benchmarked to fuel sales, this effectively converts the MetroVan Model to a Gross Domestic Emissions (GDE) measure, that is, a measure tracking the emissions of all vehicles travelling within the MetroVan region rather than a measure tracking emissions of vehicles resident in MetroVan.[27]

Estimating Unit Emissions

The MetroVan Model applies Unit Emissions based on Environment Canada's *National Inventory Report: Greenhouse Gas Sources and Sinks in Canada 1990-95.* The CO_2 emissions are standard fixed rates, while the methane and NO_2 emissions are differentiated by vehicle class.

Conclusion

As stated earlier, the MetroVan Model is a forecasting model, enabling MetroVan personnel to estimate the impacts of various initiatives on future GHG emissions. While the used of relatively dated input data on vehicle numbers, fuel efficiencies and VKT would not affect greatly the overall efficiency of the Model when projecting out 20 years, the MetroVan Model does not, in my opinion, develop annual estimates of GHG emissions that are accurate and that could be used to assess annual progress. As such, from the perspective of the CEEI, the MetroVan Model structure as is should not be adopted for the purposes of estimating annual community emissions.

C. The Ministry of Transportation Model

The MoT Model is designed as a regional[28] Fuel Tax Impact forecasting model (quarterly forecasts out to the year 2025) for all vehicles in the Province in order to provide the Ministry of Transportation (MoT) and the Ministry of Finance (MoF) with estimates of future tax revenues (MoT's capital plan depends on such future taxes) as well as a credible methodology for allocating fuel GST back to regions/municipalities. It follows the basic GRE identity:

GR Emissions = # of Vehicles X Avg. Fuel Efficiency X Avg. VKT X Unit Emissions

Estimating # of Vehicles

The individual vehicle records (2000 Q1 to 2008 Q2) are derived from the ICBC database and processed through postal codes[29] to allocate each vehicle to the appropriate CD and CSD[30] and the

[27] As mentioned in the first section of this report, there is no conceptual linkage between fuel consumption and fuel sales. It is unclear whether this benchmarking to done because of greater confidence in the TransLink estimates or whether MetroVan is actually aiming to calculate Gross Domestic Emissions rather than Gross Resident Emissions.

[28] The Model forecasts emissions at the Regional District level (Regional Districts are equivalent to Statistics Canada's Census Divisions) but can be augmented to estimate at the CSD (Census Sub-Division) level, the latter including both municipalities and rural census regions (East Kootenay, for instance, has 7 designated municipalities and another 6 designated rural areas (excluding 4 Reserves). As well, if required, the Model could be expanded to electoral areas.

[29] The 2007 Q2 data, for instance, contains 13,490 records without valid BC postal codes (e.g., postal codes from outside BC or a blank postal code field) plus another indeterminate number with incorrectly inputted postal codes. Considerable effort has been expended to ensure that records with missing or inaccurate postal codes are allocated as accurately as possible based on other ICBC data.

[30] The data programmes generate historical data (to 2008 Q2) at both the CD and CSD level, but the standing MoT Forecasting Model at this time only generates forecasts at the CD level.

percentage of time on the road.[31] Each vehicle's characteristics (make, model, fuel, displacement, etc.) are determined first by using a programme to map characteristics to the vehicle's Vehicle Identification Number (VIN) contained in the ICBC data. For those vehicles that have an invalid VIN or for whose VIN is not in the VIN Mapping tables (mostly heavy vehicles), the characteristics (e.g., body-style, NVW, GVW, etc.) from the ICBC database are used to establish its vehicle class.

Estimating Avg. Fuel Efficiencies

Using these vehicle characteristics, a concordance map is created for linking vehicle characteristics to the Natural Resources Canada (NRCan) database of vehicle fuel efficiencies. These data (1977 to 2008) do not cover all vehicles since some imported passenger vehicles are not in the database plus heavier vehicles are excluded because their fuel efficiencies depend on their loads. Nevertheless, well over 90 percent of the approximately 4.0 million unique passenger vehicles and light trucks in BC over the 2000 – 2008 period are assigned fuel efficiencies and detailed vehicle class (two-seater, sub-compacts, compacts, mid-size, full-size, wagons, SUVs, pickups, and vans).[32] In addition, a large number of HDV2B (Mobile 6 definition) heavier vehicles are given efficiency ratings. Efficiency ratings for the remaining vehicles (motorcycles, motor homes, medium-duty vehicles by type, heavy duty vehicles by type) are either approximated from studies or are estimated based on econometric relationships between vehicle type, fuel type, NVW/GVW, engine displacement, and transmission type. Preliminary work on determining efficiency decay rates (that is, how the efficiency of an engine declines as the vehicle ages) using data from the AirCare database has been started, but no robust estimates are available now (although the Model has been designed to incorporate such decay rates).

Estimating Avg. VKT

Not surprisingly, the estimation of VKT has presented the MoT modellers with its most difficult problem. From the AirCare data, quarterly estimates of VKT for a large number of vehicles (resulting in roughly 4 million data points) are derived and these are used in econometric equations by vehicle type (class, fuel and license).[33] The data allow for estimation at the CSD level within the AirCare catchment area, but this has not been addressed at this time. The equations at the CD level are VERY strong (adjusted R^2s in the 0.90 range) and produce elasticities (e.g. a 2.0 – 2.5 percent change in fuel demand for every 10 percent change in real fuel price) that are exactly what would be expected.

The results of the econometric analysis based on the AirCare data provide very credible quarterly VKT estimates by vehicle type and CD within the Lower Mainland, but the problem remains as to how to estimate equivalent VKT estimates for locations outside the AirCare area. This is being

[31]. Since a vehicle can be registered in different regions during a quarter and have different values for licensing (i.e., driven for work or pleasure), gender of driver (M/F), age (16-24, 25-64, 65+) and may not be registered for the entire quarter, the multiple records are allocated to the region where the registration time is highest.

[32] In addition, the US Environmental Protection Agency (EPA) has revised its methodology for estimating fuel efficiencies. On average, the 2008 efficiencies are approximately 5-10 percent lower under the new methodology than under the old methodology. The CEEI is attempting to get the detailed make/model/model year database of changes from the EPA; in the interim, efficiencies have been adjusted by an average of 7.5 percent.

[33] The equations are logged equations using Panel data. The methodology regresses VKT for each vehicle against quarterly dummies, real fuel prices (a lagged specification), average real per capital incomes (a lagged specification), and model age. Further estimation work is being done to incorporate, age of driver, gender of driver, transit costs, and fuel efficiencies and a number of other variables that may influence kilometres driven have been proposed (e.g., population density, kilometres of roads, etc.).

addressed by the “Vehicle Transfer” project initiated by the CEEI with preliminary results expected late October. Effectively, the Vehicle Transfer project is using ICBC data from vehicles that have changed registration recently (and therefore have their odometer reading recorded) and using this information in conjunction with the AirCare data econometric results to determine adjustment factors for different regions in the province outside the Lower Mainland. The efficacy of benchmarking regional fuel consumption to the Kent Marketing data was reviewed (and will be reviewed again), but the differences in both regional absolute values and regional growth rates has led MoT to reject this at the moment.

Estimating Unit Emissions

The MoT Model was not designed explicitly to calculate GHG emissions. Nevertheless, by combining the estimates of vehicle registration, average efficiencies and estimated VKTs by vehicle type and region, the MoT Model generates estimates of fuel consumption by CD (or CSD if expanded) and from that estimate of CO_2 are calculated. At present, estimates of other GHG emissions (methane and NO_2) are not calculated at this time.

Conclusion

The MoT Model is designed as a “what-if” scenario-testing model, so there are many variables that can be shocked. For each CD (or CSD later) the Model is designed to do quarterly shocks for CD-specific clear gas and diesel prices (shocks to crude plus each fuel tax), average per capita incomes (CD specific), new vehicle efficiencies (by vehicle class and fuel), population by age cohort (CD specific), total new vehicle sales and share of total sales (by vehicle class, fuel and CD), total vehicle imports and share of total sales (by vehicle class, fuel and CD), and attrition rates (enabling one to test the implications of eliminating, say, all vehicles whose model year is prior to1985). MoT also is integrating the relative purchase cost of new vehicles (by vehicle class and fuel) into the New Vehicle Proportion econometric equations so that the Model can determine the impact of, say, PST changes on compact or hybrid vehicles.

The MoT Model has been in development for the past year-and-a-half and presently generates historical and forecasted quarterly estimates of fuel consumption, tax receipts and CO_2 emissions at the CD level for vehicle model years 1985 (and earlier) to 2008 for 9 sub-categories of passenger vehicles, four fuel types and two license categories. From the perspective of CEEI requirements, the MoT forecasting model has three major limitations which would need to be addressed:

1. Inclusion of heavy trucks (Mobile6 categories) – note that the historical data to 2008 Q2 are already estimated;
2. Inclusion of Motorcycles, Motorhomes, and Public Transportation categories (Transit buses, Taxis, Interurban Buses, School Buses, etc.);
3. Expansion to the CSD level – note that data at the CSD level are already calculated for the historical data to 2008 Q2;

Development of the MoT model is continuing and will include:

1. Econometric estimation of forecasted New Vehicle sales and characteristics;
2. Inclusion of fuel efficiency decay rates;
3. Inclusion of methane and NO_2 emission factors;
4. Inclusion of a Tourism sub-module;
5. Inclusion of sub-regional population forecasting module.

D. Hyla Environmental Services Ltd.'s (HES) Transportation Energy and Emissions Model™ (TEEM™)

HES' TEEM™ is a GRE-based model, using the basic GRE identity:

GR Emissions = # of Vehicles X Avg. Fuel Efficiency X Avg. VKT X Unit Emissions

TEEM™ is a proprietary application that was initially developed by HES to provide community transportation greenhouse gas emission estimates for HES' local government clients. The model was designed to use summarized, unique vehicle record data purchased from commercial sources[34]. TEEM™ is currently used by HES to provide the CEEI with the transportation component of GHG estimates for all local governments in the Province[35]. Since TEEM™ was initially designed to estimate fuel consumption for HES' local government clients, providing the CEEI with estimates of annual GHG emissions for all local governments in the Province is a natural progression of the pre-existing capabilities of TEEM™.

Estimating # of Vehicles

TEEM™ categorises vehicles into Mobile 6c vehicle classes using various combinations of vehicle model, body style, rate class, and GVW/NVW. For 2005 and 2007 CEEI reports, the Mobile 6c vehicle classes are summarised into broad categorizations as follows: passenger vehicles; light duty vehicles; medium duty vehicles; motorhomes; motorcycles; scooters; and, a number of heavy vehicle classes (e.g., commercial truck, commercial pickup, commercial bus, school bus, transit bus, emergency, and long-haul carrier) all broken down by fuel type. There is no breakdown of passenger vehicles into sub-classes (e.g., Compacts, SUVs, etc.) nor is there a breakdown of passenger vehicles by license type (e.g., whether a vehicle is driven for pleasure only). The broad categorizations are easily re-categorized into groupings of the client's choosing.

The vehicle data for 2005 CEEI reports used ICBC records for the second quarter of the year. Quarter two data were used because all four quarterly datasets were not made available to the CEEI at the time 2005 CEEI reports were developed. In the absence of a complete set of data, HES chose quarter two because it would provide a full representation of the range of vehicles on the road in a given year, although the resulting fuel consumption values would be overestimated. For 2007 CEEI reports, quarter 2 data are again use, but percent time on the road will be used for the final fuel calculations for each vehicle. For the sake of consistency, 2005 CEEI reports will be recalculated by HES and redistributed by the CEEI to local government using quarterly data.

Each unique vehicle in TEEM™ is allocated to census division and census subdivision based on the postal code of the registered owner. As indicated previously, a small number of records in the ICBC data do not contain a postal code (~0.07% in 2005) or the postal code of the registered owner is out of province (~0.38% in 2005). In both instances, TEEM™ does not allocate these vehicles to a census subdivision or census division[36].

---

[34] The original data sets used by HES prior to their work with the CEEI were purchased from a private company who purchased the detailed data from ICBC. Since working with the CEEI, the data come directly from ICBC.

[35] Province-wide geopolitical units include 161 Census Subdivisions (e.g., municipalities, electoral areas, and Indian reserves) and 28 Census Divisions (i.e., Regional Districts).

[36] It is possible to assign the vehicle to a rating territory, although there are 28 census division and only 14 rating territories, and therefore, rating territory is too coarse for the purposes of the CEEI. ICBC considers the rating territory breakdown, or the specific community for which the vehicle is primarily driven, as strictly protected confidential business information, and is not releasing this information to the CEEI

Estimating Avg. Fuel Efficencies

TEEM™ incorporates a VIN decoder for major automobile manufacturers[37] which decodes the majority of passenger vehicles, and light and medium duty trucks. HES began to develop a decoder for VINs primarily to identify the ~690,000 vehicles in the 2005 ICBC dataset that were not described in sufficient detail to allow the algorithm in TEEM™ to automatically match a vehicle to its fuel efficiency rating.[38]

TEEM™ uses fuel efficiency ratings for vehicles from 1985 to 2008 from NRCan and fuel efficiency ratings from 1974 to 1984 from USEPA data. Additional fuel efficiencies for vehicle models prior to 1974 are estimated using historical data from a variety of sources including the coarse fuel efficiencies in the USEPA's Mobile 6, converted to Canadian standards. For those VINs that neither TEEM™ nor the VIN Mapping project were able to decode (e.g., ~42,000 unique vehicles of a total 3.0 million records in the 2007 Q2 ICBC dataset), fuel efficiencies are assigned based on model, body style, rate class, and GVW/NVW. Most of these records are large trucks and/or propane conversions that do not have corresponding fuel efficiency ratings. It is not apparent how HES determines fuel efficiencies for these larger vehicles, but it is able to provide fuel efficiencies through HES' work with public and private sector fleets for a number of heavy specialised vehicles where no fuel efficiency estimate is available from other sources. These efficiency data are based on actual fuel consumed and corresponding vehicle kilometres travelled from fuel pump records for individual vehicles. For propane conversions, fuel efficiencies from the USEPA's fuel economy listing for alternative fuel vehicles and HES' reviews of manufacturer's listings for alternative fuel conversion kits are used.

Estimating Avg. VKT

TEEM™ generally uses provincial-level VKT estimates developed by Transport Canada for each vehicle class and, where appropriate, vehicle-specific VKTs from HES' work with private and public sector fleets. Even at the provincial level, the Transport Canada data, as explained earlier in Part I of this Report, has a number of drawbacks, not the least being that the latest data are for 2005 and therefore the Model doe not account for any differences in VKT between 2007 and 2005. At the regional level these are problems are compounded. Those problems, together with the fact that using VKT estimates for passenger vehicles as a whole means there is no ability to monitor changes in VKT by different types of passenger vehicles, means that the VKT methodology in TEEM™ needs further effort, especially if one of the goals of the CEEI is to assess year-over-year changes and not just generally trends over time.

Nevertheless, with regional adjustment factors coming from CEEI's "Vehicle Transfer" project for passenger vehicles, a first cut to adjust passenger vehicle VKT to reflect regional differences at the regional level will be made and included in the 2007 CEEI reports. It must be re-iterated however, that this adjustment methodology in itself is not ideal and that continued work on this will be necessary.

Conclusion

Like most models, TEEM™ is in constant development. Since the estimation of the 2005 community estimates, TEEM™ has improved its estimation of vehicles counts by community as well

[37] Chevrolet / GMC / Pontiac / Oldsmobile / Cadillac, Ford / Buick / Mercury / Lincoln, Dodge / Chrysler / Jeep / Plymouth, Honda / Acura, Toyota / Lexus, Nissan / Infinity, Audi, BMW, Eagle, Geo, Hyundai, Isuzu, Jaguar, Kia, Land Rover, Mazda, Mercedes Benz, Mitsubishi, Porsche, Saab, Saturn, Subaru, Suzuki, and Volvo

[38] For example, ~360,000 vehicles are described as Other Type 2 two and four wheel drive (e.g., Other Type 2 2WHDR and Other Type 2 4WHDR).

as making significant enhancements to its procedures for estimating fuel efficiencies. Accordingly, from the standpoint of the # of vehicles and avg. fuel efficiencies, TEEM™ appears to generate both credible and accurate estimates. From the perspective of future CEEI requirements, however, TEEM™ has a number of limitations which would need to be addressed, the last being the most critical to developing accurate and credible results at a community level:

1. It would need to estimate emissions for all four quarters;
2. Its breakdown of passenger vehicles is limited, and because of this, in its estimation of community VKTs, TEEM™ implicitly assumes that the vehicle mix (i.e., the proportion of say, SUVs to Compacts) is the same as for the province as a whole;
3. In a similar vein to 2. above, because of the substantive difference in VKT between vehicles that are driven for pleasure only and vehicles driven to/for work, it would be important to apportion vehicles by that criterion in order to ensure that the community mix of driving behaviour is explicitly accounted for;
4. Using provincial-level values of VKT as the methodology for estimating community-level VKT has very serious limitations, even when combining it with regional data from the CEEI's "Vehicle Transfer" project. Community differences in VKT occur not only because of the aforementioned differences in "mix", but also because fuel prices are different, incomes are different, geography is different, the age and sex mix of drivers are different, transit options are different, population density is different, etc. etc. Unless this issue is resolved, the estimates of year-over-year changes in emissions at the community would not, in my opinion, be sufficiently accurate for what the CEEI should be attempting to achieve in the longer run.

E. The Whistler Model

The Resort Municipality of Whistler (RMoW) has initiated its own vehicle GHG emissions estimation process based on the GDE measure of counting emissions from all vehicles travelling within its municipal boundaries.[39] Calculations are based on results of an EMME simulation of average daily traffic demand done for the municipality in 2002 and later rolled up to an annual estimate by a consulting firm. The difficulty and high cost of updating the EMME Model for Whistler has precluded revising traffic demand estimates (effectively total VKT within Whistler boundaries) indeed, given the EMME Model run in 2002 would have used input data based on 1996 Census data, applying the results to today would be highly problematic. Instead, the Resort presently uses a single location traffic count to estimate two-way traffic flows and applies the growth rate of this traffic increase to the estimate determined using the 2002 EMME results. Of course, all of the caveats associated with the TransLink Model are equally true for the Whistler data.

The Whistler approach is attempting to count emissions from all vehicles travelling in Whistler, not just vehicles residing in Whistler. However, somewhat surprisingly, they implicitly assume that average vehicle efficiency has not changed over time; that is, all the vehicles travelling into Whistler in 2008 have the same average fuel efficiency as in 2002. While it is not possible to determine an

[39] Whistler has chosen to calculate GDE emissions because it believes the municipality has greater control and influence over vehicles travelling within its boundaries (through initiatives such as reduced parking, increased transit availability, and the like) than over the travelling patterns of its residents who very often travel outside the municipality (to, say, the Lower Mainland). In addition, according to Whistler staff, ICLEI recommends the GDE measure. Nevertheless, Whistler would welcome GRE measures to contrast their own GDE estimates, as long as they are able to continue to pursue their own emissions calculations.

exact picture of the vehicle mix (in terms of vehicle type and vehicle age), it ought to be possible to approximate changes in the vehicle mix using a subset of data for Lower Mainland vehicles. Doing this would enable Whistler to estimate how average fuel efficiencies have changed, and this could be applied to the present estimates.

F. Australian and New Zealand Initiatives

Work in Australia and New Zealand have focused on estimating GRE (resident-based) measures of emissions, believing that those are the only emissions that can be calculated in any practical manner.

Australia's privacy laws have made it difficult for GHG emission modellers to obtain detailed vehicle records from government and therefore they have been forced to base their analysis on census estimates of total vehicles per capita on the road, with little ability to breakdown emissions or factors affecting emissions by vehicle class other than the total breakdown provided by the census (passenger, light truck, heavy truck, and bus). Fuel efficiencies are based on Australian studies of average fuel consumption which themselves are highly influenced by USEPA studies of fuel consumption. Estimates of VKT are taken from a national survey of driving behaviour similar to the Canada Vehicle Survey. Needless-to-say, the output is questionable at this time.

New Zealand also follows a GRE approach to emissions calculations. It has more detailed information on vehicle numbers and types (12 classes), but uses aggregate fuel efficiency ratings from Australia (effectively from the USEPA). Where New Zealand differs greatly from Australia is their method for estimating VKT.

New Zealand has an AirCare-type system that requires light vehicles (including motorcycles, mopeds, and the like) in the country to undergo testing on an annual basis (older vehicles actual have to be inspected every six months)and as part of this testing, odometer readings are taken. From these data average annual VKT per vehicle class is calculated based on simple averaging (total VKT divided by total vehicles tested). While this approach is far superior to using survey data as Australia does, the New Zealand approach does not attempt to determine the underlying factors influencing VKT (through an econometric analysis). As such, it is similar to the MetroVan approach, with the exception that the New Zealand data, because of the annual inspection requirement for all vehicles, would provide more robust estimates.

The inspection requirement does not include heavy trucks, and therefore New Zealand uses data derived from a Truck Survey undertaken every other year.

CONCLUDING REMARKS AND RECOMMENDATIONS

The objective of this Report is to inform decision-makers as to the state of community-level vehicular GHG emissions modelling and to provide feedback as to how a CEEI model ought to be structured in the future if it is to offer consistent and accurate estimates of vehicular GHG emissions over time. It should be emphasised that the following recommendations refer to what the CEEI ought to adopt in the coming years as it enhances its emissions assessment capabilities. In the interim and in the absence of securing actual VKT data through annual ICBC odometer readings, the CEEI ought to maintain for the 2007 estimates its present course of using the HES model for producing public estimates of vehicular GHG emissions and entertain for later years further refinement of estimated VKTs through the use of ICBC Vehicle Transfer Forms and applying the VKT econometric coefficients to the specific vehicle mix in each municipality.

The recommendations outlined in the first part of this Report suggested that adopting a GRE (Resident-Based) approach to modelling GHG emissions at the community level would be the most efficient and cost-effective and, indeed, is the only practical alternative at this time. The question of whether it would be advisable to benchmark community fuel consumption to estimated fuel sales has been answered to the extent that fuel sales in itself is not a measure of fuel consumption and that, further, there have been no reliable studies to indicate that the existing fuel sales data are accurate enough at the community level (or even Regional District level) to be used as a benchmark. Until such studies are available, it is my recommendation that the CEEI model NOT benchmark to fuel sales and that additional modelling efforts focus on improving estimates of community-level VKT.

Given that overarching recommendation, the following outlines a series of other recommendations as to the structure the future CEEI Vehicle Emissions Model should take.

1. The basic structure of the Model ought to follow the GRE identity for fuel consumption (# of Vehicles X Avg. Efficiency X Avg. VKT) and use the Environment Canada's Unit Emission factors by vehicle type in order to derive GHG emission values from the fuel consumption estimates;

2. Vehicle estimates should be extracted from ICBC's registered vehicles database. Allocation by postal code should be flexible, enabling the Model to identify vehicle stock at various regional levels (e.g., Regional Districts, all Census Sub-divisions, not just municipal locations, electoral areas, etc.). ICBC should be asked to consider providing a field containing city in order to allocate non-existent or invalid postal codes; similarly, ICBC should be asked for information (if it exists) that may be able to allocate properly the over 12,000 non-BC postal codes in the database;

3. While Mobile6 may be the standard used by Transport Canada for classifying vehicles, the CEEI ought to consider a further sub-classification of passenger vehicles into (say) the passenger vehicle classes used by NRCan (e.g., Two Seaters, Subcompacts, Compacts, Mid Size, Full Size, SUVs, Pickups, and Vans). A breakdown of passenger vehicles is, in our opinion, imperative in order to calculate better estimates of community VKTs. We also believe this information could be relevant to many stakeholders, particularly since the thrust of many provincial policies is to provide incentives to citizens to adopt smaller, more fuel efficient passenger vehicles;

4. In order to capture seasonal differences in the number of vehicles on the road and the number of kilometres driven, it is important that the model estimate quarterly emissions and that the annual estimate provided to communities be the sum of the quarterly estimates;

5. Not all vehicles are registered fulltime over a quarter (e.g., many vehicles are only registered for the summer months, beginning in June). Accordingly, the number of vehicles ought to be adjusted for such part-time activity each quarter. It also is important to ensure that vehicles registered but in storage are excluded from all estimates;

6. The CEEI should make a concerted effort to obtain historical USEPA fuel efficiency adjustment factors for vehicle make/models in order to provide more accurate estimates of historical average fuel efficiencies. Tied to this, the CEEI also should endeavour to incorporate efficiency decay rates into their estimates;

7. Given the major differences in VKT between those driving passenger vehicles to/for work purposes and those driving for pleasure only, it is recommended that the future CEEI Model attempt to differentiate between those vehicle driving purposes;
8. Given the importance of accurate and credible VKT estimates to estimating GHG emissions at the community level, it is imperative that the CEEI model have a methodology that does not rely so heavily on dated provincial VKT estimates produced by Transport Canada and regional estimates derived from Lower Mainland driving characteristics, but that is able to account for differences in specific regional vehicle mix, regional driving behaviour and differences in regional economic, social, demographic and geographical attributes.
9. In reference to Point 8 above, three recommendations should be noted:
    a. At present, regional VKT estimates are based on Lower Mainland VKT estimates which are then adjusted by regional factors determined in the ICBC Transfer Form study. Prior to applying the ICBC Transfer Form methodology for adjusting regional VKT estimates, it is recommended that the CEEI should first endeavour to estimate Passenger Vehicle and Light Duty Truck VKT estimates at the municipal level based on applying AirCare econometric coefficients to the specific municipal vehicle mix.
    b. T\It is recommended that the ICBC Transfer Form methodology be expanded in order to increase sample size, increase the number of regions being estimated, include greater vehicle class breakdowns, and include a licensing type (Pleasure or Work) distinction.
    c. Finally, it is recommended that the CEEI pursue with ICBC personnel the idea of ICBC collecting (either all vehicles or to start a sample) of odometer readings at the time of insurance renewal. Specifically, it is recommended that the CEEI propose that a full business case be developed in order to determine the overall cost, effort and time that would be required in order to implement such a collection. Issues that would need to be addressed would include programming time/effort for enhancing the database system, the administrative effort that ICBC would have to expend, and the training that would have to be provided to AutoPlan brokers in order that the odometer readings are collected properly.

Figure 1: A Matrix of Model Characteristics

	TransLink	MetroVan	HES Ltd.	MOT
Measure	**GDE**	**GRE/GDE blend**	**GRE**	**GRE**
Vehicle Characteristics				
Vehicle Source	ICBC data	ICBC data; no geography; no license type	Complete ICBC data	Complete ICBC data
Vehicle Classes	Mobile 6C	Mobile 6C	Mobile 6C	Mobile 6C plus Pass. Vehicles split into 9 separate classes
Limitations		Last vehicle data is 2005; vehicles without postal code not assigned; uses only 1 quarter for estimation	Vehicles without postal code not assigned; uses only 1 quarter for estimation	Model still being expanded to include heavy vehicles
Fuel Efficiencies				
Passenger/Light Duty Truck Source	Efficiencies not explicitly used	Avg. US EPA Values by Class	NRCan data applied to individual vehicle augmented by EPA vehicle data	NRCan data applied to individual vehicle augmented by EPA vehicle data
Large Vehicle Source	Efficiencies not explicitly used	Avg. US EPA Values by Class	Uses efficiencies from USEPA; some specialised vehicle fleet data directly from sources	Medium trucks efficiencies are econometrically determined based on GVW.
Limitations		Estimates not specific to MetroVan; does not recognise different vehicle mix in MetroVan.	USEPA fuel efficiencies for heavy vehicles not necessarily good proxy for BC heavy vehicles.	Limited work on heavy vehicle component.
VKT				
Passenger/Light Duty Truck Source	Determined from EMME roll-up of hourly travel demand: results are for Total VKT then split among vehicle classes	Supplied by TransLink	BC provincial average from Transport Canada; augmented by data from Transfer Project data.	Econometrically determined from AirCare data for each Vehicle Class, Fuel and License Type and Model Year: coefficients applied to CDs to capture local mix of vehicles.
Large Vehicle Source	Determined from EMME roll-up of hourly travel demand: results are for Total VKT then split among vehicle classes	Supplied by TransLink	BC average from Transport Canada/USEPA; some specialised vehicle fleet data directly from sources	Methodology not complete
Limitations	EMME rollup has many potential errors, esp for estimating year-over-year changes	Same as TransLink	Local VKT estimates do not take into account different vehicle mix, different fuel prices, and different regional incomes.	Econometrics needs to include more regional values (e.g. pop density, kilometres of road, etc.) to capture regional variations.
Geography				
	MetroVan CD	MetroVan CD	All CDs and CSDs	All CDs, historical data generated for all CSDs (municipalities and rural regions),
Benchmarking				
	Benchmarked to Regional Fuel Sales	Benchmarked to Regional Fuel Sales	No benchmarking	No benchmarking