Summary evaluation of life-cycle greenhouse gas emissions involved in online purchase versus in-store purchase of MEC goods

REPORT PRODUCED FOR MOUNTAIN EQUIPMENT CO-OP

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1 Executive Summary

This report provides preliminary estimates of the possible greenhouse gas impacts for MEC members choosing between driving to their local MEC store versus ordering online. The scope of the study is limited to the implications of this narrow choice, assuming that a decision about *what* to buy has already been made.

Approach

Where possible, the approach taken is to make use of economic input-output tables of all sectors across an entire economy. This allows estimation of the complete upstream impact of a market decision. For example, the full incremental impact of sending an extra package by post includes not just the tailpipe emissions of the truck carrying the parcel, but also the appropriate fraction of the emissions embodied in producing the petrol, maintaining the truck, and even those of mail sorting and administration.

Such a detailed model of economy-wide interactions and environmental impacts is only available for the U.S.A., so appropriate conversions are made for our economy and supplementary estimates are made where needed. Use of the economic model has the advantage of ecompassing indirect effects but the disadvantage of not being very specific to the way MEC and Canada Post carry out their operations in the particular case of interest.

Calculations are based on emissions rates from several sources in addition to the input-output model and on detailed purchasing and shipping information from MEC operations in 2007.

Findings

For each of several components of the shipping, distribution, and shopping processes, greenhouse gas emissions are estimated in equivalent mass of CO_2. For each MEC outlet, a "break-even" distance between a member's home and the nearest MEC store is calculated. These are the threshholds beyond which a member wishing to minimise her climate impacts would be better off to order online than to visit a store in person. These distances range from about 1 to about 5 km for a representative purchase.

In order to put the entire question in perspective, emissions embodied in manufacture of a sample product and in its transport across the Pacific Ocean from a Chinese port were crudely estimated and found to be much larger than those from domestic distribution and shipping. This calculation indicates that the biggest greenhouse gas issues may remain beyond those addresed in this study: sourcing and production of the good itself and the effects of availability and marketing on demand and consumer behaviour.

Uncertainties

The figures reported from this study represent reasonable estimates of the order of magnitude of emissions rather than calibrated measurements. A number of limitations of the study, mostly related to availability of detailed emissions data, are described in the report. Because estimates of several of the components of emissions were of comparable value, the “break-even distance” between member and store may change considerably when more precise measurements of emissions from MEC and Canada Post operations are available.

Recommendations

Some of the key recommendations of this study are:

- Total greenhouse gas emissions are essentially the same for a driver 5 km from a store and any urban resident using online ordering. Therefore, at the moment MEC is doing the right thing by providing both online and in-store shopping options.

- Members who live further than 10 km from their local store could be advised to avoid dedicated car trips in favour of online ordering.

- For follow-up studies on this topic, better data from Canada Post regarding the life-cycle greenhouse gas accounting of their operations would be desirable.

- MEC can have a significant impact on greenhouse gas emissions from its online ordering operations through a careful choice of packaging materials and of low-impact operations at its Distribution Centre.

2 Statement and scope of problem

MEC members who live near a retail store and who tend to drive to their local store have a choice between ordering online and buying in-store. Because all goods pass through MEC's sole distribution centre (DC) in Surrey, BC, these two routes to the member's home have quite different paths and may have substantially different impacts on greenhouse gas emissions, in particular as a function of how far the member needs to drive to reach a store. This study is a first assessment of the answer to the question, "(When) should a member wishing to minimise her greenhouse gas impact choose to drive to an MEC store rather than order online?".

The larger context to this question involves

- the full life-cycle impact analysis for purchasing items in MEC's catalogue – *i.e.* including emissions embodied in production, etc;
- demand (*i.e.,* behavioural) impacts of offering (and promoting) goods through online ordering and in a store;

and so on. These issues are beyond the scope of the study, although the first may be addressed tangentially.

3 Identified contributions to CO_2 emissions

A simplified account of the path from producer to consumer through the two delivery methods is outlined in this section. For the purposes of demonstration, I will use a sample purchase of a pair of MEC Truant Pants and an MEC Truant Jacket. Together, these sold in 2007 for $355 and have mass just over 1 kg. These goods are made in China. Therefore, regardless of how they get to the consumer, they embody emissions associated with

- sourcing of materials and production of the good in China
- marine shipping to North America
- ground transport to Surrey DC
- stocking and shipping activities at the DC

After the member makes an order, one of two sequences happens. The contributions to emissions analysed in this study are:

1. If member requests mail delivery through a web order,
    - packaging (cardboard, tape, padding)
    - shipping operations (labour) at DC to collect ordered items and package them for Canada Post
    - Canada Post ground delivery to member's house

2. If member makes a dedicated car trip to the shop,
    - truck freight from DC to member's local store
    - member's car trip from home to store and back

In the second case, I ignore DC operations for sorting and shipping as well as in-store stocking because items in bulk will require relatively small contributions per item. I also ignore the effect on resources of store staff for consultation and checkout in the case of an in-store purchase; I have assumed that this is small for a customer who knows what she wants.

Each of these steps may involve deeper life-cycle impacts; for instance the use of a private car incurs impacts due to depreciation of the car — and hence vehicle manufacture, maintenance, and end-of-life emissions — as well as the tailpipe emissions.

4 Approach: Economic Input/Output - Life Cycle Analysis

For analysis of economy-wide (upstream) implications of a change in output for a particular sector, Carnegie Mellon University's Green Design Institute makes available an economic input-output life cycle analysis (EIO-LCA) model for the US economy in 1997.[1]

> Input-output analysis, developed by Wassily Leontief (for which he received a Nobel Prize in 1973), is a technique for capturing all the economy-wide interdependencies. It has been extensively used for planning throughout the world. It is used to estimate additional production required in all the sectors of the economy to support increases in output of any given sector. Our economic input-output analysis-based life-cycle analysis (EIO-LCA) method involves augmenting conventional economic input-output tables with appropriate sectoral environmental impact indices which can then be used to analyze economy-wide environmental impacts of changes in the output of selected industrial sectors. We employ the most detailed (485 sectors) and the most recent (1992) [now 1997] input-output tables for the U. S. and augment them with various sectoral environmental effect vectors. ...
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> EIO-LCA using only the published input-output tables has the advantage of tracing out full direct and indirect environmental impacts of outputs of industry sectors. However, it suffers from limitations of high levels of aggregation.[2]

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[1] See "Use of Economic Input-Output Models for Environmental Life Cycle Asessment," C. Hendrickson, A. Horvath, S. Joshi and L. B. Lave, Environmental Science & Technology, April 1998. The model is available from the web site *http://www.eiolca.net.*

[2] C. Hendrickson, A. Horvath, S. Joshi, O. Juarez, L. Lave, H. S. Matthews, F. C. McMichael and E. Cobas-Flores, "Economic Input-Output-Based Life-Cycle Assessment (EIO-LCA)", available from *http://www.eiolca.net.*

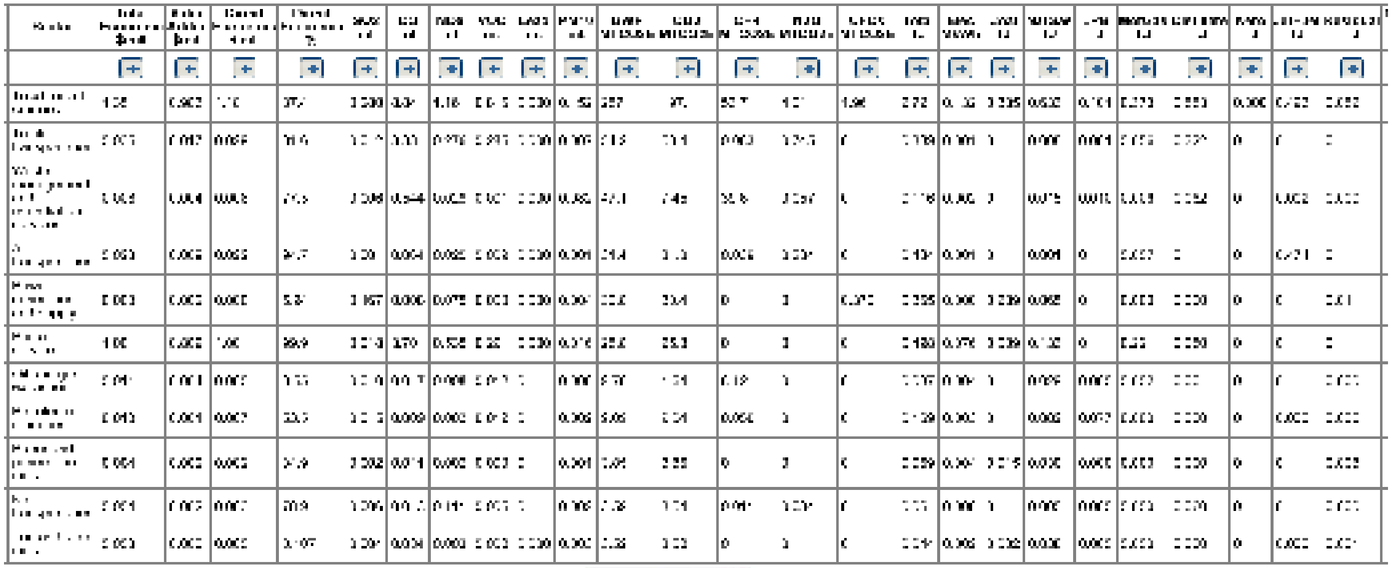

Table 1: An example economic input/output life cycle analysis for the “postal service” industry. Including all upstream industrial inputs, 1 M$ (US$,1997) of extra activity in this sector produces 257 tonnes of greenhouse gases, measured in CO_2-equivalent mass.

Table 1 on page 6 shows a sample calculation from the EIO-LCA model. Values shown indicate the economy-wide impact of creating 1M$ (1997US$) of additional output (measured in producer cost) in the postal service industry. Each row represents an economic sector which will supply resources towards the final output. The rows have been ordered by the column labeled "GWP MTCO2E", which is the global warming potential measured in equivalent megatonnes of CO_2. Other environmental and economic impacts are also available. One may note that in this case the portion of the total carbon impact that comes from the postal service's direct operations themselves (25.8 MT) is small. That is, most of the impact comes through indirect increased demand for trucking, waste management, air transport, and power. The EIO-LCA approach is the correct way to fully account for the total incremental effect of extra economic demand.

5 Embodied emissions figures used

For consistency and comparability, I have used EIO-LCA values for most components of emissions calculations. Where these are not available, I have sought other sources, as described below.

5.1 EIO-LCA values

There is no EIO-LCA model available for Canada. In addition, macroeconomic parameters have changed in Canada and the US since 1997 and have diverged between the two countries considerably since then. Also, Canada is less densely settled, so it is likely that a higher proportion of costs in some industries are due directly to long-distance transport. Nevertheless, the economies have some overall similarity. A conversion of the Carnegie Mellon model to contemporary Canadian values provides a good first pass at aggregated emissions figures here.

I have converted values from the US 1997 model to approximate prices in the Canadian economy. Based on the 1997 exchange rate of 1.4 and inflation in Canada of 22%, I have assumed that 1 1997 US$ has equivalent value $1.4 \times 1.22 = 1.7$ CDN$ in 2007. Using this conversion, calculations of carbon intensities from the EIO-LCA model for certain industrial sectors are shown in Table 2 on page 8.

5.2 Trans-Pacific shipping (China to BC)

This is included only as an approximation useful for getting perspective on the problem.

The return trip distance from China to BC is 11200 km. Typical marine shipping efficiencies quoted by different sources[4] are on the order of 15 g/tonne/km for "tailpipe" emissions only. I could not find a value for life-cycle emissions from shipping, but they may be as much as a factor of several times more.

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[4] For instance, the European Environment Agency TERM 2003 27 EEA 31, or Lloyd's Register Marine Directorate.

1997 U.S. industrial sector	Embodied emissions intensity kgCO$_2$e/2007CDN$
US postal service	0.15
Couriers	0.61
Trucking	1.25
Packaging (“coated and laminated packaging materials”)	0.57
Sporting and athletic goods manufacturing	0.42
Cut and sew apparel manufacturing	0.4
Warehousing and storage	0.78
Warehousing and storage (without upstream sectors)[3]	0.5

Table 2: Converted EIO-LCA embodied carbon impacts for the Canadian economy in some chosen industries.

5.3 Car travel

The tailpipe emissions of a 2002 Honda civic are about 0.17 kg/km CO$_2$-equivalent. A more typical value quoted for an average car, and used in this study, is 0.29 kg/km; however, once again, this may be an underestimate for the life-cycle impact of making a trip in one’s car.

5.4 Alternate freight data

A recent study of life-cycle air emission factors for road, air, and rail freight provides one comparison point for the EIO-LCA values. They find that

- road emission factors vary by up to 55% between different classes of truck, varying from $1 \times 10^{-4}\,\mathrm{km}^{-1}$ to $2 \times 10^{-4}\,\mathrm{km}^{-1}$; these factors are consistent with several other sources found.
- fuel combustion (“tailpipe emissions”) account for nearly 80% of total embodied emissions for truck freight transport.[5]

6 Other data used

Also used in these calculations were:

- a detailed breakdown of sales, costs, mass, and transaction size for each product from online purchases and from each store in 2007
- an account of freight shipping costs to each store for 2007

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[5] Facanha, Cristiano, and Arpad Horvath, “Evaluation of Life-Cycle Air Emission Factors of Freight Transportation”, Environ. Sci. Technol. 2007, 41, 7138-7144.

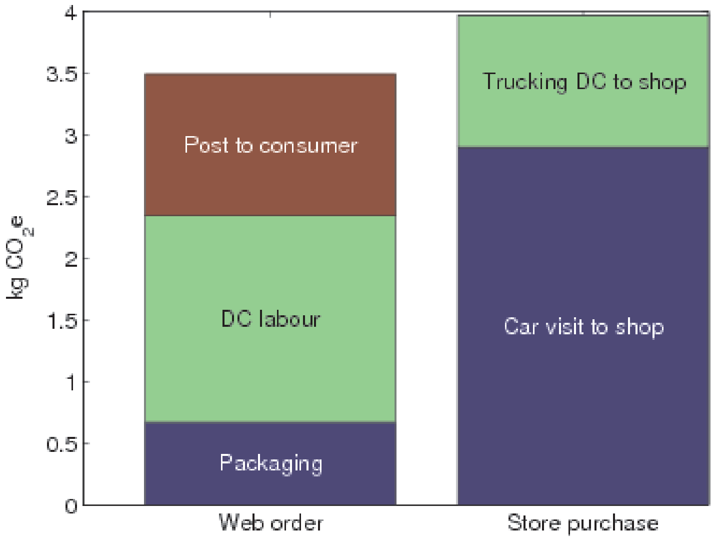

Figure 1: Embodied CO_2 emissions starting from the DC for a sample web purchase of MEC Truant Pants and Jacket by a *Toronto* customer 5 km from the store.

- total shipping packaging budget for 2007
- a detailed price schedule for Canada Post parcel packages

7 Results

Table 3 on page 10 summarises the main results. Further detail is available from me where needed. The righthand column shows the estimate of a "break-even" distance between a store and a member's home. For members living further away than this distance, the estimate of emissions from ordering online is lower than the estimate of emissions from shopping in-store; and *vice versa.* The precision on this estimate is not better than a factor of two.

Figures 1 to 3 compare the web and in-store options for the case of a member who lives 5 km from the store and who is buying Truant Pants and Jacket. Figure 1 on page 9 shows estimates for a Toronto member, Figure 2 on page 11 for a Calgary member, and Figure 3 on page 11 for a Vancouver member.

For perspective, I have made crude estimates of the other embodied emissions involved in the consumption choice of the Truant Pants and Jacket. Figure 4 on page 12 shows the various components for a web purchase, including the emissions embodied in manufacture of the product and in its transport across the Pacific Ocean. Figure 5 on page 12 shows the analogous case for the in-store purchase.

Store name	Truck freight cost ($/kg)	EIO-LCA: truck freight emissions, ($kgCO_2e/kg$)	Alternate estimate: truck freight emissions ($kgCO_2e/kg$)	Road distance (km)	Canada Post rate code	Canada post cost ($ for 1 kg item)	Canada Post emissions ($kgCO_2e$ for 1 kg item)	Break-even distance from home to store (km)
Vancouver	0.09	0.11	0.01	32	1	3.56	0.54	4.8
Calgary	0.37	0.46	0.15	958	21	6.45	0.98	4.9
Toronto	0.85	1.07	0.69	4383	31	7.59	1.15	4.2
Ottawa	1.06	1.32	0.76	4817	31	7.59	1.15	3.7
Edmonton	0.48	0.6	0.2	1264	21	6.45	0.98	4.7
Halifax	2.2	2.74	0.97	6149	31	7.59	1.15	1.3
Winnipeg	0.93	1.16	0.36	2292	31	7.59	1.15	4.0
Montreal	0.95	1.19	0.77	4911	31	7.59	1.15	4.0
Quebec City	1.23	1.53	0.81	5163	31	7.59	1.15	3.4
North Vancouver	0.12	0.15	0.01	36	1	3.56	0.54	4.7
Victoria	0.54	0.68	0.01	63	2	4.15	0.63	3.9

Table 3: Tabulated emissions estimates by store, based on a 1 kg order.

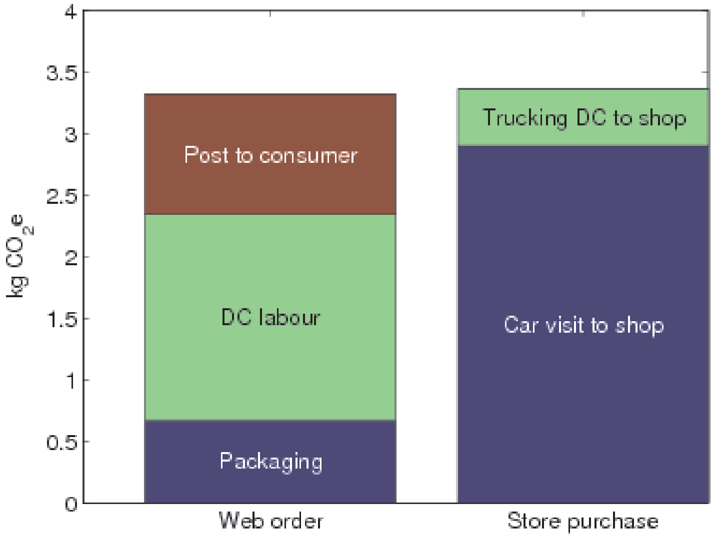

Figure 2: Embodied CO_2 emissions starting from the DC for a sample web purchase of MEC Truant Pants and Jacket by a *Calgary* customer 5 km from the store.

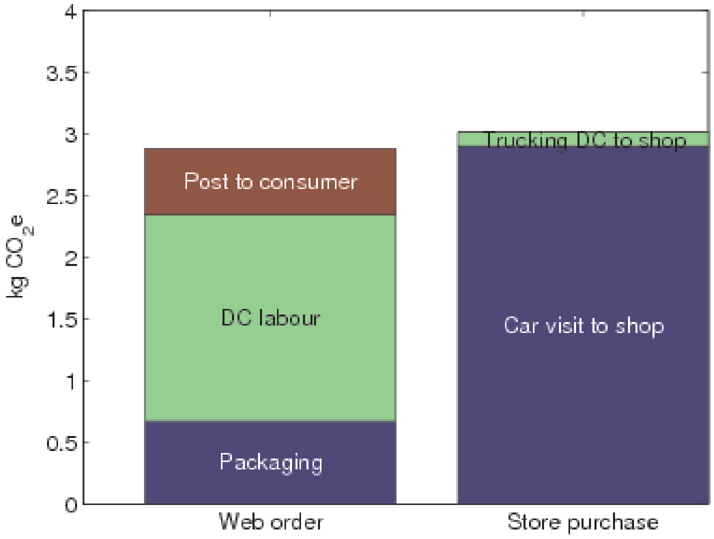

Figure 3: Embodied CO_2 emissions starting from the DC for a sample web purchase of MEC Truant Pants and Jacket by a *Vancouver* customer 5 km from the store.

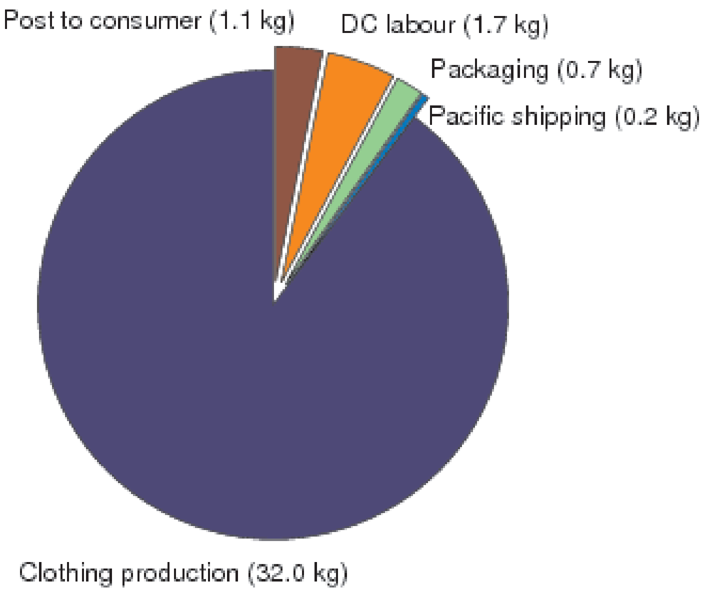

Figure 4: Embodied CO_2 emissions for a sample web purchase of MEC Truant Pants and Jacket by a Toronto customer.

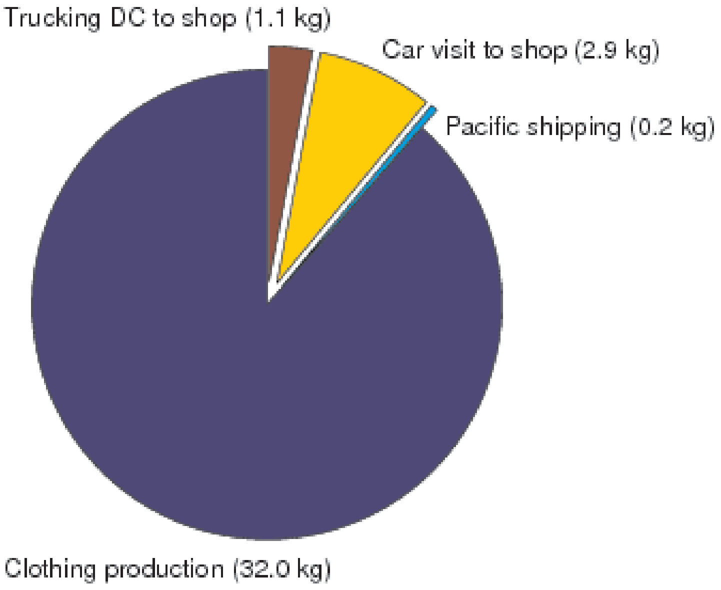

Figure 5: Embodied CO_2 emissions for a sample in-store purchase of MEC Truant Pants and Jacket by a Toronto customer who drives 5 km from her home to the store.

8 Sensitivity analysis

A thorough sensitivity analysis is far beyond the scope of the current work. Instead I point out some of the major assumptions I have made and some noteworthy points of uncertainty in available parameters. See also Section 5.

- Unfortunately Canada Post rate codes give the same answer for all stores east of Calgary. As a result, emission factors for postal service to eastern MEC stores are all alike in this study and do not reflect the greater distance to some stores.

- Most postal activity does not involve parcels; therefore, the aggregate emission intensity for the industry may not reflect a realistic value for sending MEC goods by parcel post. Also, as mentioned earlier, the factor is likely underestimated in the conversion from the US market. However, Table 2 on page 8 shows that the emission factor for couriers, who use more air shipment and make more dedicated trips, is only four times higher. This indicates that the value I have used is not likely to be much too low.

- When calculating the average mass of a package sent for a web order based on its contents, it appeared to be considerably lower than the value indicated based on postal rates and the average rate MEC actually paid to Canada Post. This indicates that packages end up weighing considerably more than their contents. I have assumed that packaging adds at least 75% to the package weight above the contents.

- A good measure for the carbon intensity of the packaging that MEC uses could not be found. The closest EIO-LCA industry (coated packaging) may not be representative of the cardboard, duct tape, and filler that is relevant for MEC. Use of recycled fibre shipping boxes, recycled box tape, and other ecological packing materials may significantly affect this figure.

- The difference in embodied emissions between trucking an item as MEC freight to a store versus sending it by Canada Post may be as large as the other relevant components of packaging, member automobility, and DC web order operations. Therefore, these two routes from the DC to the member's locale cannot be considered equivalent from the emissions point of view, and a more detailed analysis of both would be necessary to further refine estimates. Clearly, detailed accounting of Canada Post's operations are beyond MEC's control.

- Using the life-cycle emission factors for truck freight given in Section 5.4 along with the road distance to each store from the DC results in lower calculated emissions than when the EIO-LCA values for the shipping industry are used. The alternative values are smaller by up to nearly a factor of three in some cases (and more for BC stores). I have stuck with the EIO-LCA values since they are being used to compare to the postal service values, which are also industry-wide averages from the EIO-LCA.

- The values shown for trans-Pacific shipping are likely underestimated. They are based on tailpipe emissions, not industry operations and EIO-LCA analysis.

9 Conclusions

Despite the preliminary nature of this study, its use of sector-wide estimates of full cost carbon accounting provides a good idea of the relative magnitudes of some key components. While all specific numbers should be taken only as crude estimates, the following conclusions can be made from the study.

- Shipping and postal impacts within Canada appear to be much larger than trans-Pacific shipping impacts.
- It seems likely that consideration of embodied carbon in the product itself may overwhelm that from the distribution and delivery processes and choices.
- Total greenhouse gas emissions are essentially the same for a driver 5 km from a store and any urban resident using online ordering. MEC is doing the right thing by providing both options.
- Those who can avoid using a car to get to an MEC store can avoid several kg of CO_2 emissions by choosing to visit the shop rather than order online.
- Because several components of emissions from both the web order and the store purchase are of comparable magnitude, policy conclusions are highly susceptible to refinements of the calculations. Therefore, a major conclusion of this work is that an extreme policy conclusion (for instance, that retail shops are obselete) is not likely to be indicated. Instead, increased co-op resources should be devoted to more detailed environmental accounting of each of the operations components. Using currently available industry-average figures, it appears that no assessed component can be eliminated as insignificant compared with the others.

10 Recommendations

Based on the conclusions of this study, the following recommendations may be considered:

1. Continue to promote both online ordering and in-store purchase as ways for members to select and buy their goods.
2. As a guideline, members who live further than 10 km from their local store should likely order online rather than make a dedicated car trip to the store, all else being equal.
3. Request from Canada Post some life-cycle greenhouse gas accounting for their services.
4. Analyse the embodied greenhouse gas content of packaging materials carefully, and select ecological packaging materials based on CO_2 as well as other impacts.
5. Assess the larger picture before devoting too many resources to the distribution details: for instance, informing consumers of the embodied carbon estimate of each catalogue item would be a great service and might address the two biggest issues I see in overall impacts: greenhouse gases embodied in production and MEC's effect on consumption choices.
6. I or someone else could parameterise the results found here (appropriately augmented) in order to provide a web script which would suggest the carbon impact of planned shipping options to online purchasers. This could be an early part of the feature suggested above – to estimate greenhouse impacts for all goods.