PREPARED BY:

PREPARED FOR:
Environment and Energy Division, City of Toronto
Professor John Robinson

TABLE OF CONTENTS

PROJECT DESCRIPTION

The purpose for this report is to understand what and how a "consumption-based" emissions inventory approach could be applied to the City of Toronto.

Currently, the City uses a greenhouse gas inventory approach based on the Global Protocol for Community-Scale Greenhouse Gas (GHG) Emission Inventories (GPC). This is a "production-based" emissions inventory approach using Scope 1 (direct emissions from combustion of fuels for heating, transportation etc.) and Scope 2 (indirect emissions from purchased electricity, heat or steam etc.) emissions measurements. The City performs this reporting by aggregating energy, waste, and transportation data from the respective City departments.

However, the City wishes to explore the possibility of a "consumption-based" emissions inventory approach. This approach could reflect all GHG emissions (direct and product lifecycle) associated with the goods and services consumed by city's residents.

The City is hoping to get a better understanding of how to define and measure a consumption-based inventory. Drawing from best practices from other jurisdictions, the City wants to identify what methodologies are most applicable and practical in the Toronto context. The City is also asking how to better communicate emissions measurement to residents.

MAIN CONCERNS OF THE CITY

Below are the main concerns outlined by the City and to be addressed through this report:

- Understand how to define and design a consumption-based emissions inventory approach
- Identify what methodologies are most applicable and practical in the Toronto context drawing from other jurisdictions
- Determine how to better communicate emissions measurement to residents

METHODOLOGY EMPLOYED

In order to address these concerns, we employed the following methodology:

We conducted a literature review of existing research and applications of technical and conceptual aspects of models in consumption-based emissions measurement. In addition, through the literature review we examined the implications of a consumption-based inventory approach as it applies to the City. To fill gaps in this literature analysis, in addition to providing more targeted and direct applications to the City, we conducted interviews with topic area experts as well as officials within the City to provide more insight into the consumption profile of the City in general.

We chose this methodology in order to gain a better understanding of best practice across the jurisdictions that currently employ or have undertaken studies to evaluate the utility of employing a consumption-based emissions inventory approach. Conducting a review of these applications provided us with considerable guidance on how the City should apply these models in its own context.

MAIN FINDINGS FROM JURISDICTIONAL REVIEW

Jurisdictional Selection

While the concept and application of consumption-based emissions measurement is rather new, the technical approach to doing so has been researched widely and several key cities have begun applying these models and methods to their own city contexts. These cities include, but are not limited to, London, Portland, San Francisco, and Seattle. We chose these cities because of their existing efforts in studying consumption-based approaches, but also because they were cities specifically highlighted by the City of Toronto in starting this study. Conducting a review of these city experiences and applications can provide considerable guidance on how a model can be employed for the City of Toronto.

Data Collection

For each of the cities, we evaluated the models based on several key common criteria to allow for comparability. These measures include: definition of a consumption-based approach; consumer profile used in disaggregating consumption data; current technical approach of measurement of emissions in the examined region; frequency and boundaries of emissions measurement; existence of constituent programs in the region; key influencers of policy; and other key actors. By comparing various jurisdictions across these criteria, we identified the process of implementation for a consumption-based approach and the technical resources required, as well as the potential political considerations and implications to take into account in order to leverage these findings for the City of Toronto.

Comparative Review

For the purposes of a comparative review, we focused on the following four criteria from our wider list of original criteria: (1) Definition of a Consumption-Based Approach, (2) the Consumer Profile Used, (3) the Description of that Consumer Profile, and (4) the Consumption-Based Approach Measurement of Emissions undertaken by the City. We chose to focus on these four criteria because we believe they are the most salient for an easy cross comparison of the different – and similar – approaches taken. Our main findings are shown below.

Criteria Summary Table

	London	Portland	San Francisco	Seattle
Definition of a Consumption-Based Approach	Supply of emissions from the consumption of goods and services; captures direct and life-cycle GHG emissions for all goods and services consumed by residents of a city.	"Consumption-based" carbon emissions inventory models carbon emissions from the full lifecycles of goods and services, including production, pre-purchase transportation, wholesale and retail, use and disposal.	CBEI's consumption-based methodology tracks financial flows and attributes greenhouse gas emissions to the "consumption" (the end use or final purchase, not as an input to production or for resale) of goods and services. Every region is assigned the emissions embedded in the goods and services used by its households (and a few other kinds of "final consumers" discussed below), and no region is assigned emissions for goods produced in-region but purchased elsewhere.	"Consumption-based" approaches are inclusive of emissions associated with consuming goods and materials in a community, regardless of where the emissions are released. For example, one way to consider emissions associated with goods and materials is to count all the emissions associated with the goods and materials (and services) consumed in Seattle, regardless of where they were made.
Consumer Profile Used	Households, capital, government, other		Households, government entities, business capital investment	
Description of that Consumer Profile	Household further disaggregated into: Food and drink, utility services, household, transport services, private services and other goods and services.		Based on spending by households as well as government entities and certain categories or purchases made by businesses (capital and inventory formation), regardless of where in the world the emissions are produced.	
Consumption-Based Approach Measurement of Emissions	Conceptual equation understood as Consumption-based emissions = (production-based emissions) - (emissions from exports production) + (emissions from the production of imports)		This method estimates GHG emissions by multiplying consumption (in dollar terms) with the emissions intensity (CO2- equivalent per dollar) of that consumption.	

MOTIVATIONS TO EMPLOY CONSUMPTION-BASED EMISSIONS INVENTORY

Through this literature review, we identified four key motivations for the City of Toronto to employ a consumption-based emissions inventory approach to complement its existing production-based emissions inventory.

- Consumption-based measurement provides a way of capturing the full life-cycle of emissions associated with the production, use, and disposal of a good or service.[1] This demonstrates a more robust and detailed picture of emissions associated with the production of a specific good.
- This process provides data on the impact of consumer behaviour on GHG emissions, which is not captured in a strictly production-focused territorial emissions measurement.[2]
- Consumption-based emissions measurement provides a new platform for the development of policies aimed at emissions abatement.[3]
- Consumption-based emissions measurement, which can take a multi-regional approach, provides a wider scope for measuring GHG emissions, especially in the context of increasing international trade and global supply chain networks.[4]

Taken with the existing production-based measurement, the introduction of consumption-based emissions inventory provides a more complete picture of impacts on emissions from both the supply side and demand side.
While no specific policies are currently employed targeting the mitigation of consumption-based emissions, there are a few policy levers to address consumer behaviour and the political distribution of emissions responsibility between importers and exporters (discussed in Implications and Trade-offs section).[5]

RECOMMENDATIONS

Potential Methods for Consumption-based Emissions Measurement

Put simply, consumption emissions track the life-cycle of a given good or service that is being consumed. This includes all stages of production, consumption and use, and final disposal and requires a life-cycle analysis to track emissions and transactions at each of these stages. The basic overall calculation for building a national consumption-based emissions inventory is equal to the emissions resulting from domestic consumption, less the embodied emissions of exports, plus the embodied emissions of imports [6]:

$$= GHG^{\text{domestic consumption}} - GHG^{\text{exports}} + GHG^{\text{imports}}$$

---

[1] King Country and Stockholm Environment Institute. "Greenhouse Gas Emissions in King County: An Update Geographic- plus Inventory, a Consumption-based Inventory, and an Ongoing Tracking Framework." 2012. http://www.kingcounty.gov/~/media/services/environment/climate/documents/2008/ghg-inventory-summary.ashx?la=en. p. 9.

[2] Ibid.

[3] C. Lininger, "Consumption as a Base for Emission Accounting and as a Policy Base," in Consumption-Based Approaches in International Climate Policy, (Switzerland: Springer International Publishing, 2015), p. 23.

[4] Justin Kitzes, "An Introduction to Environmentally-Extended Input-Output Analysis," Resources, 2, (2013): 489-503, doi: 10.3390/resources2040489, p. 501.

[5] For a further discussion here, please see: C. Lininger, "Consumption as a Base for Emission Accounting and as a Policy Base," in Consumption-Based Approaches in International Climate Policy, (Switzerland: Springer International Publishing, 2015), p. 23., and Droege 2011; Droege et al. 2009.

[6] Baptise Boitier, "CO_2 emissions production-based accounting vs. consumption: Insights from the WIOD databases," (2012): http://www.wiod.org/conferences/groningen/paper_Boitier.pdf, p. 2.

A similar mathematical logic can be applied to calculating the consumption emissions for a municipality such as the City of Toronto. In order to determine the embodied emissions in the overall equation above, the calculations must consider each part of the supply chain's economic activity and emissions at each transaction.

Two potential methods of calculating consumption emissions will form the focus of this report. The first uses life-cycle emission factors and economic consumption data. The second employs environmentally extended input-output analysis using production emissions inventory, economic output, and consumption data to find the total emissions intensity vector.

Method One: Using Life-Cycle Emissions Factors

An emission factor is defined as, "the average emission rate of a given GHG for a given source, relative to units of activity."[7] As such, emissions factors are typically expressed as GHGs per unit of activity (such as 1 lb of CO_2e/kWh). Emission factors can measure the ratio of emissions per one unit of activity and can then be used to calculate an estimation of emissions for a broad range of productive activities. Another mechanism of emission factors is to measure full life-cycle emission factors, which capture the cradle to grave emissions of a given process, product, or service. The calculation of consumption-based emissions would entail multiplying this emission factor by economic final demand to attain the CO_2e per unit of economic consumption.

An example of using life-cycle emission factors is presented by the United States' Environmental Protection Agency (EPA) in an analysis of the Life-cycle GHG emissions for carpet and personal computers in 2003.[8] The EPA analysed life-cycle emission factors for carpet as part of an effort to foster product stewardship, and in diverting carpet waste from landfills to provide a clear argument for carpet recycling programs.[9] The EPA focused on personal computers as part of the recognition of a growing proportion of electronics as part of the waste stream, a rapid increase in sales of electronics, and potential toxicity of electronic components.[10] The EPA calculated life-cycle emission factors by measuring activity at each stage of the product's direct and secondary manufacturing processes.[11] For each carpet and personal computer, the life-cycle emission factors are presented as units of metric tons CO_2e per ton of product. For example, the study found that in an analysis measuring carbon dioxide emissions (CO_2) and fugitive methane emissions (CH_4), energy used over the process of carpet production results in 0.94 MtCO_2e per one ton of carpet produced.[12]

There are two options for using life-cycle emission factors to calculate consumption emissions for the City of Toronto. First, the City may undertake a similar process to the EPA and construct its own emissions factors unique to the products or commodity groups found within the consumption profiles. Second, the City may use available databases that provide access to internationally applied life-cycle emission factors.

With respect to the second option, several databases exist for retrieving emissions factors to perform the relevant calculations. The Greenhouse Gas Protocol (GHG Protocol) endorses the Intergovernmental Panel on Climate Change (IPCC) database as being compliant with GHG Protocol standards and as representing full life-

---

[7] "Definitions," United Nations Framework Convention on Climate Change, accessed March 2017 at http://unfccc.int/ghg_data/online_help/definitions/items/3817.php

[8] "Background Document for Life-Cycle Greenhouse Gas Emission Factors for Carpet and Personal Computers," U.S. Environmental Protection Agency, (2003), EPA530-R-03-018, https://www3.epa.gov/warm/pdfs/CarpetPCReport_11_21.pdf.

[9] Ibid., p. 1.

[10] Ibid.

[11] Ibid., p. 2.

[12] Ibid., p. 4.

cycle emission factors using process calculations (similar to the EPA method described above).[13] The GHG Protocol also identifies several third-party databases that provide data on product life-cycle and corporate value chain emissions.[14] These include both international and domestic country databases. Those applicable to Canada include the Canadian Raw Materials Database,[15] the Athena Institute Database[16], and Encompass Database.[17]

Each life-cycle emission factor method has important advantages and disadvantages as summarized below:

<table>
<tr><th></th><th>Using Existing Life-Cycle Emissions Factors</th><th>Calculating Emissions Factors Specific to the City</th></tr>
<tr><td>Advantages</td><td>• Less resource intensive
• Readily accessible and easy to use</td><td>• Context specific
• Not vulnerable to rigid classification systems or inconsistencies in international measurement protocols</td></tr>
<tr><td rowspan="2">Disadvantages</td><td>• Might provide a less accurate picture of the City of Toronto's consumption emissions
• Unclear information on data collection, verification, and calculation</td><td>• Highly resource intensive
• Requires large amounts of data, which might not be available at the outset</td></tr>
<tr><td colspan="2">Emission factors are dynamic and must change with modifications to product manufacturing. Especially with life-cycle emission factors, which must capture each stage of the production process.</td></tr>
</table>

Method Two: Environmentally extended Input-Output Analysis

Another method for calculating the full life-cycle of consumption-based emissions focuses mostly on economic calculations rather than physical calculations through input-output analysis. To first track all stages and inputs of production, input-output analysis offers the ability to capture the intermediate demand associated with the output from a given sector or industry. This can be further disaggregated down to

[13] "IPCC Emissions Factor Database," Greenhouse Gas Protocol, 2012, accessed March 2017, retrieved from: http://www.ghgprotocol.org/Third-Party-Databases/IPCC-Emissions-Factor-Database.

[14] "Life Cycle Databases," Greenhouse Gas Protocol, 2012, accessed March 2017, retrieved from: http://www.ghgprotocol.org/Third-Party-Databases.

[15] "Canadian Raw Materials Database," Greenhouse Gas Protocol, 2012, accessed March 2017, retrieved from: http://www.ghgprotocol.org/Third-Party-Databases/Canadian-Raw-Materials-Database.

[16] "Athena Institute Database," Greenhouse Gas Protocol, 2012, accessed March 2017, http://www.ghgprotocol.org/third-party-databases/Athena-Institute.

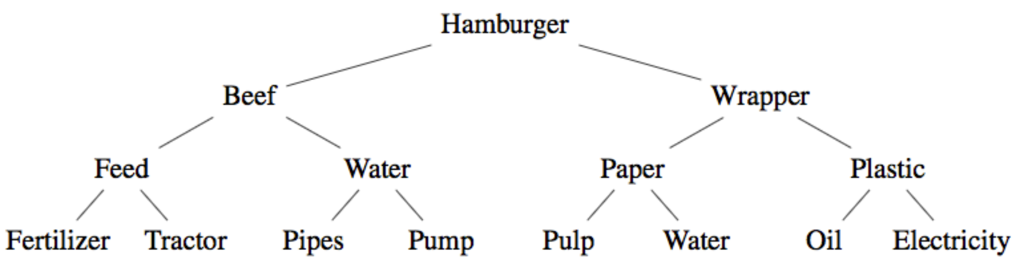
[17] "Encompass Database," Greenhouse Gas Protocol, 2012, accessed March 2017, http://www.ghgprotocol.org/Third-Party-Databases/Encompass.

commodities, depending on the level of data available. The environmental impacts associated with the full life-cycle of production and final consumption can be outlined through environmentally extended input-output analysis (EEIO). This section will summarize and explain the logic behind input-output analysis. It will then outline the introduction of the environmental factors within EEIO analysis, which provides the basic mathematical foundation of CBEI. While this section provides a broad logical overview of the model, its calculation, and its limitations, the next section provides more detailed explanation of the recommended methodology for the City of Toronto.

The input-output model was first introduced by Wassily Leontief to demonstrate the interdependencies within an economy, a model that would later earn him a Nobel Prize in Economics.[18] It was initially presented in 1936 as a closed model whereby all outputs in an economy are also used as inputs creating a loop of production and intermediate consumption, but has since been modified for various scenarios.[19] For example, an open model treats final demand, such as household consumers, as exogenous to the production activities.[20] This method of treating final consumption as separate from production activities will be the approach recommended for tracing consumption-based emissions. It is important to note, however, that at this stage one assumption is that while it is an open model, it is a closed economy—meaning that there are no imports or exports. The treatment of imports and exports will be introduced when discussing EEIO analysis and the CBEI model case study.

The basic idea is that for a given output of goods, the economy satisfies intermediate demand for the inputs of those goods needed for production. Ideally, this can be traced backwards from the final good to capture all inputs required to produce that good. A simple example illustrating this process is given by Justin Kitzes through the production of a hamburger.[21] To further simplify the example, the two components of the hamburger include the beef and the wrapper. In order to supply the beef, the beef producer requires food and water for the cows, while the wrapper requires paper and plastic. Moving further up the production process, to supply the feed requires fertilizer and a tractor, and so on. These are known as upstream inputs, as they are upstream from the final good.

Figure 1: Production Tree[22]



[18] Thijs ten Raa, The Economics of Input-Output Analysis (Cambridge: Cambridge University Press, 2005), retrieved from: http://dlia.ir/Scientific/e_book/Social_Sciences/Economic_Theory_Demography/HB_135_147_Mathematical_Economics_/002211.pdf, p. 11.

[19] Ibid.

[20] Justin Kitzes, "An Introduction to Environmentally-Extended Input-Output Analysis," Resources, 2, (2013): 489-503, doi: 10.3390/resources2040489, p. 493

[21] Ibid., p. 491.

[22] Justin Kitzes, "An Introduction to Environmentally-Extended Input-Output Analysis," *Resources,* 2, (2013): 489-503, doi: 10.3390/resources2040489. p. 491.

EEIO analysis eliminates the need to manually construct production trees by mathematically tracking the upstream life-cycle emissions of a commodity or service through intermediate transactions and emissions intensity. It uses economic output of a given sector or commodity group, and the emissions inventory of that sector or group, to calculate the direct intensity vector.[23] This analysis will offer three potential methods of performing life-cycle calculations based on the best practices used in the cities examined:

1. The Leontief Inverse Matrix $F = f\,(I\text{-}A)^{-1}$;
2. Gross output as a proxy variable; and
3. Gross demand as a proxy variable.

Each potential method attempts to reach the goal of calculating the full life-cycle of emissions attributable to the upstream production process of a good or service.

1. Leontief Inverse Matrix: EEIO Mathematical Calculation

First, this section will explain each of the variables associated with the Leontief inverse matrix. It will then explain how these variables work together to perform the calculation itself.

The Direct Intensity Vector (or Coefficient) (f)

In a closed model and closed economy, all the output of a sector goes toward final consumption as there are no intermediate transactions between businesses in the production process. In reality, there is a great degree of intermediate consumption between businesses in addition to final demand, otherwise known as an open model. Therefore, the direct intensity coefficient is only the first step in determining the full life-cycle of emissions related to the consumption of a commodity or service.

Nonetheless, the calculation of the direct intensity coefficient uses only two pieces of data after determining the emissions source groupings (by commodity group, subcategory etc.). The first piece of data required is the emissions inventory, or any other environmental impact, attributable to that sector grouping.[24] This information can be collected from existing production-based emissions inventory reports, as well as any other required emissions reporting from the private sector. More on data collection will be discussed in the following section. The second piece of data required to calculate the direct intensity coefficient is the economic output of that sector.[25] Total output is recorded as part of an input-output matrix, or as part of publically available national or provincial economic data. The calculation is as follows:

$$\frac{\text{Emissions inventory } (CO_2e)}{\text{Economic output } (\$)}$$

In a closed model, the direct intensity coefficient can be multiplied by final consumption to give the amount of emissions associated with consumption activity. However, in an open model, this fails to capture the entirety of life-cycle emissions associated with the intermediate demand in the production process.

Technical Coefficient Matrix (A)

The technical coefficient matrix is the second step needed to calculate the Leontief inverse matrix, which measures the amount of inputs a sector must receive from every other sector to generate one dollar of

[23] Ibid., p. 494.

[24] Ibid., p. 495.

[25] Ibid.

output.[26] This is calculated by using two pieces of data. The first is the total inputs into a sector, which can be found from input-output tables. The second piece of data is the total output of that same sector, which can also be found using input-output tables. The calculation is as follows:

$$\frac{\text{Total inputs into a sector (\$)}}{\text{Total output of that sector (\$)}}$$

Identity Matrix (I)

The definition of the identity matrix is, "a square matrix in which all the main diagonal elements are 1's and all the remaining elements are 0's."[27] It is also known as the n x n matrix, the unit matrix, or the elementary matrix.[28] For this report, the key takeaway of using the identity matrix is that the product of the identity matrix will always equal the original A matrix. This means that in the practical calculation, it does not change the values given by the A matrix.

Putting it All Together

The calculation of the Leontief inverse equation requires the following pieces of data: total inputs for a sector in monetary terms, total output of that sector in monetary terms, and the emissions inventory of that sector in units of emissions per unit of activity. The product of this equation gives the total intensity vector, F, which reports the total upstream emissions, or any other environmental impact, to produce $1 of output toward final consumption in a given sector.[29]

The next step – determining the consumption emissions of goods from that sector – is calculated using the final demand or consumption data. In order to find the total upstream emissions relating to the final consumption of a given good or sector, the total intensity vector is multiplied by final consumption activity in dollars.[30]

2. Gross output as a proxy variable

The above calculation uses mathematical linear algebra to determine the intermediate activity that occurs within the production process. However, a proxy variable that measures intermediate inputs of sectors and commodities is gross output. The U.S. Bureau of Economic Analysis defines gross output as a measure of a given industry's sales or receipts, including intermediate inputs.[31] Intermediate inputs are defined as the value of foreign and domestically produced goods or services used as, "energy, materials, and purchased services as part of an industry's production process."[32] In the U.S., gross output data correspond to 402 industries and 69 commodities.[33]

---

[26] Ibid.

[27] "Identity Matrix," iCoachMath.com, accessed March 2017, http://www.icoachmath.com/math_dictionary/identity_matrix.html

[28] Ibid.

[29] Justin Kitzes, "An Introduction to Environmentally-Extended Input-Output Analysis," Resources, 2, (2013): 489-503, doi: 10.3390/resources2040489, p. 498.

[30] Ibid.

[31] "Frequently Asked Questions: Gross Output and GDP," Bureau of Economic Analysis U.S. Department of Commerce, accessed March 2017, https://www.bea.gov/faq/index.cfm?faq_id=1034.

[32] Ibid.

[33] Ibid.

In Canada, gross output data is provided for the provincial level through Statistics Canada's (StatCan) CANSIM table 381-0031 in terms of annual dollars in millions.[34] Industries are presented based on Input-Output Industry Classification (IOIC). Data is based on the 2015 Canadian System of Macroeconomic Accounts.

Gross output can be used as a proxy measure for intermediate activity in the production process, such that total consumption emissions of a sector or industry is equal to:

(1) Emissions intensity =

$$\frac{\text{Emissions Inventory (CO2e)}}{\text{Gross Output (\$)}}$$

(2) Consumption emissions =

$$\text{Emissions intensity x final demand}$$

However, we caution that the value of gross output may bring forward some double counting. This is because the measure of gross output reflects both the sales of final products and intermediate inputs in an economy.[35] Therefore, more research must go into separating these aggregated measures.

3. Gross demand as a proxy variable

As with gross output, gross demand can be used as a proxy that measures intermediate inputs of sectors and commodities for a consumption-based emissions calculation. This method uses both final demand and intermediate demand to calculate consumption, while direct coefficients are used for the emissions intensity. gross demand is most often calculated using input-output matrices.

(1) Gross Demand = Final Demand + Intermediate Demand

(2) Emissions Intensity = $\frac{\text{Total Emissions (CO2e)}}{\text{Economic Output (\$)}}$

(3) Consumption Emissions = Gross Demand x Emissions Intensity

Benefits and Limitations of using EEIO

One of the main benefits of using EEIO is that it captures upstream impacts on the environment of downstream consumption.[36] Moreover, even when using the Leontief inverse equation, it presents a linear model that may be compiled into an Excel workbook tool. Within larger economies, it provides a way of using existing publically available input-output data to track more diverse production processes that encompass a multitude of intermediate transactions.[37] For these reasons, variations of EEIO have been used in each of the cities examined as part of this study's jurisdictional review.

---

[34] Statistics Canada. Table 381-0031 - Output, by sector and industry, provincial and territorial, annual (dollars), CANSIM (database). (accessed: April 10 2017)

[35] "Frequently Asked Questions: Gross Output and GDP," Bureau of Economic Analysis U.S. Department of Commerce, accessed March 2017, retrieved from: https://www.bea.gov/faq/index.cfm?faq_id=1034.

[36] Justin Kitzes, "An Introduction to Environmentally-Extended Input-Output Analysis," Resources, 2, (2013): 489-503, doi: 10.3390/resources2040489. p. 499.

[37] Ibid., p. 500.

The most pronounced benefit of EEIO over using process life-cycle emissions factors is that it can be tailored to the specific economic and environmental context of the geographic boundaries of measurement in a less resource intensive approach relative to calculating unique life-cycle emissions factors. Whereas using life-cycle emissions factors makes a high degree of assumptions regarding their applicability to the City of Toronto's specific context, EEIO can be manipulated using economic data and city specific emissions inventories to more closely match the consumption profile of the City.

Another major benefit of using EEIO analysis is that the measure of environmental impacts is not constrained to examining air emissions. An example of applying a broader range of environmental impact analysis using EEIO is given by a study of the use of forest resources in Finland.[38] The authors examined land use, employment, and import impacts in addition to direct GHGs resulting from forest industries in Finland's economy in 2005.[39] From this analysis, they were able to identify the increased embodied environmental impacts of the forestry industry relative to their direct impacts.[40]

However, EEIO still faces several significant limitations worth acknowledging. First, it is limited by data availability. As mentioned, input-output data is only disaggregated to the provincial level in Canada, so certain assumptions may have to be made to retrieve City of Toronto specific data. Another issue with input-output data is that environmental impacts are constrained to the classifications given by the sector or commodity classifications in the existing tables. This means there may be some complication in reconciling environmental data (such as existing GHG emissions inventories) to the categories in the input-output tables. In addition, EEIO only captures emissions associated with the existence of an economic transaction.[41] While potentially a minor limitation in the urban context of the City, unpaid activities or other activities that represent consumption in the absence of an economic transaction (such as cutting down a tree for firewood) will not be captured within EEIO analysis.

OUTLINE OF RECOMMENDED MODEL AND METHODS

The following section will first provide an example of the calculation process through a case study of how Oregon's model is applied, and how it could apply in Toronto. It will then outline the recommended methods in the practical application of a consumption-based methodology.

An Example of the Model

As mentioned previously, there are a number of methods a jurisdiction can employ to calculate consumption-based emissions using the CBEI model. The exact model used is at the discretion of the jurisdiction. The following section gives a description of the model and calculations used to measure the total consumption-based emissions inventory for both the state of Oregon and the city of Portland[42].

---

38 Tuomas Mattila, Pekka Leskinen, Ilmo Maenpaa, and Jyri Seppala, "An Environmentally Extended Input-Output Analysis to Support Sustainable Use of Forest Resources," The Open Forest Science Journal, 4, (2011): 15-23. retrieved from: https://benthamopen.com/contents/pdf/TOFSCIJ/TOFSCIJ-4-15.pdf.

39 Ibid., p. 15.

40 Ibid., p. 22.

41 Justin Kitzes, "An Introduction to Environmentally-Extended Input-Output Analysis," Resources, 2, (2013): 489-503, doi: 10.3390/resources2040489. p. 500.

42 State of Oregon Department of Environmental Quality and Stockholm Environment Institute. "Consumption-Based Greenhouse Gas Emissions Inventory for Oregon – 2005." 2011. http://www.deq.state.or.us/lq/pubs/docs/ConsumptionBasedGHGEmissionsInventoryORSummaryReport.pdf

In general, the CBEI model calculates the consumption-based emissions for each commodity sector in a jurisdiction's profile in order to determine the entire consumption-based emissions inventory for the jurisdiction.

The city's total consumption-based emissions, in its simplest form is:

$$C = \sum_{x=0}^{n} Consumption * Total\ Emissions\ Intensity$$

Where:

Consumption-Based Emissions = C = kgs

X = a commodity sector; n = the set of commodities in the city's consumption profile

Consumption-based emissions (C) are expressed in kilograms. The two main components in the calculation of consumption-based emissions are:

A. Consumption, in dollars, and
B. Total emissions intensity, in kilograms per dollar.

Case Study: Oregon's CBEI Model Application

A. Consumption

Consumption in this case is expressed through gross demand. In order to categorize for future use, demand is often broken down by commodity sector. The number of commodity sectors used is at the discretion of the jurisdiction – the inventory can be calculated using high-level sector categorizations, or through greater sector disaggregation. For example, a jurisdiction can look at the food sector broadly, or it can disaggregate food into more detailed categories like grains, fruits and vegetables, meat products etc. The State of Oregon uses a profile of 509 commodities in its calculations.[43] Thus, Oregon would sum together the consumption-based emissions of 509 different commodities in order to calculate its total consumption-based emissions inventory. The number of commodities in a jurisdiction's profile is expressed by "n".

Understandably, the more the jurisdiction disaggregates the commodity sectors, the more accurate the depiction of its consumption-based emissions profile. However, the City's ability to do so depends on the availability of data, as well as the resources and time available for measurement.

Among the jurisdictions studied in this report, for each commodity it was common practice to break down consumption into four different consumer types:

1. Households,
2. Government,
3. Business Investment in Capital Goods, and
4. Business Investment in Inventory (when products are made but not sold in a given year).

Therefore, for each commodity, X:

Total Consumption = Household Consumption + Government Consumption + Business Investment

Where Consumption is expressed through ***Gross Demand:***

Gross Demand = (Final Demand) + (Intermediate Demand) = (Direct Demand) + (Indirect Demand)

Therefore, the following calculations will be identical for each consumer type. Variables written in blue are given variables. For each given variable, it will be necessary for the city to collect the appropriate data. A complete table of the necessary data requirements for this model will follow this section. Further, the variables that are coded in green are calculated using the other given variables.

Final Demand

As goods are often produced elsewhere, it is necessary to collect consumption data based on production location. Production emissions can vary greatly based on geography, and thus it is important to determine the geographic areas from which goods and services come. The model typically separates gross demand into three regions: local, regional, and global demand. Therefore, import data is crucial to understanding consumption-based emissions.

---

[43] State of Oregon Department of Environmental Quality and Stockholm Environment Institute. "Consumption-Based Greenhouse Gas Emissions Inventory for Oregon – 2005." 2011. http://www.deq.state.or.us/lq/pubs/docs/ConsumptionBasedGHGEmissionsInventoryORSummaryReport.pdf

U.S. jurisdictions calculate the production location mix of demand in a similar way. Each jurisdiction calculates the local final demand of:

1. Local goods and services,
2. National goods and services, and
3. Foreign goods and services.

1. Local Goods and Services:

The City's Final Demand for City Produced Goods and Services = A

$$The\ City's\ Total\ Final\ Demand - Total\ Final\ Imports\ to\ the\ City = A$$

2. National Goods and Services:

In order to calculate the local final demand of each commodity based on production location, final import demand is needed for each commodity used in the model. It is common to assume that the final import rate of a commodity is the same across each institution (households, government, and business investment).

Canada's Foreign Import Rate = FIR

$$\frac{Canada's\ Imported\ Total\ Final\ Demand}{Canada's\ Total\ Final\ Demand} = FIR$$

The City's Final Demand for Canadian Produced Goods and Services = B

$$Total\ Final\ Demand * (1 - FIR) = \mathrm{B}$$

The City's Final Demand for Imports into the City from the Rest of Canada = C

$$B - A = \mathrm{C}$$

3. Foreign Goods and Services:

The City's Final Demand for Foreign Goods = D

$$Total\ Final\ Demand * FIR = \mathrm{D}$$

Intermediate Demand

For consumption-based emissions accounting, tracking the intermediate inputs is essential. Therefore, it is common for jurisdictions to use a dollar amount to determine demand and to track the flow of money through the supply chain, as money is an appropriate proxy for determining production activity. In the jurisdictions studied, this was most commonly completed by organizing the inputs needed to produce final demand by producing industry, and using input-output matrices in order to track the flow of money.

In a number of the jurisdictions in the US, these input-output matrices were provided by IMPLAN. IMPLAN is an American economic company that provides data and modeling to different sectors and regions in order to assess economic impacts.[44] The data and analysis services provided by IMPLAN are available for purchase via www.implan.com. In addition to U.S. data, IMPLAN has regional economic research data for Canada at both the national and provincial level, for over 100 sectors. However, it is important to note that for Ontario, this

[44] IMPLAN. www.implan.com

information is only available for 2012, as the data comes from StatCan. StatCan publishes input-output matrices online, so the City of Toronto could utilize StatCan as a resource to determine intermediate demand. StatCan provides this information at both the national and provincial level, and thus some data manipulation may be necessary in order to translate this information for City use.

Gross Demand

In order to determine gross demand, the model then multiplies final demand by the input-output matrices for each location. In general, gross demand is:

Gross Demand = (Final Demand)*(Input-output multiplier)

City Gross Demand for ***City Products*** = X

$$A * City\ Leontief\ Inverse\ Matrix = X$$

City Gross Demand for ***Canadian Products*** = Y

$$B * (Multiplier\ from\ matrix) = Y$$

City Gross Demand for ***Products from the rest of Canada*** (not including the city) = Z

$$Y - X = Z$$

City Gross Demand for ***Foreign Goods*** is only comprised of City final demand for foreign goods, as intermediate demand for these goods can be captured by using existing data for foreign emissions intensities. This is explained in better detail below. Thus,

City Gross Demand for Foreign Goods = City Final Demand for Foreign Goods

B. Total Emission Intensities

The City's total emissions intensities should also be broken down by commodity sector and are expressed in kilograms per dollar spent. Total emissions intensity is made up of two components: direct and indirect emissions intensities. For products made within City boundaries and within National boundaries, direct coefficients are calculated to find consumption-based emissions for goods demanded from these jurisdictions. Since gross demand was found for both regions, including final and intermediate demand, only direct coefficients are necessary to produce consumption-based inventories. However, for foreign produced goods and services, only final demand was found previously, creating the need for an emissions intensity that includes both direct and indirect coefficients.

1. **City Direct Coefficients**

$$\frac{Total\ Emissions\ for\ the\ Sector - Direct\ Fuel\ Emissions}{Total\ Industry\ output\ for\ the\ Sector\ (in\ \$)} = \frac{KG}{\$} = CIT$$

$$Total\ Industry\ Output = City\ Gross\ Demand + Direct\ and\ Indirect\ City\ Exports$$

2. **Canada Direct Coefficients**

$$\frac{Total\ Emissions\ for\ the\ Sector}{Total\ Industry\ Output\ for\ the\ Sector\ (in\ \$)} = \frac{KG}{\$} = CAN$$

3. **Foreign Direct and Indirect Coefficients**

Foreign direct and indirect coefficients were most often found using existing data. American jurisdictions used Multi-Regional Input-Output Analysis (MRIO). MRIO is a method of measuring cross-border production emissions. National input-output matrices have been created to determine the connection between different sectors of production, making it possible to trace the consumption and production in an economy. However, as production becomes increasingly global, there has been more of an effort to create these same tables for goods and services that are traded internationally. MRIO thus offers the ability to trace consumption of products through the global supply chain.[45] MRIO tables are often not as extensive as national input-output matrices. Therefore, data from MRIO must be mapped to the national and city level commodity sectors. For example, Oregon had to map 57 MRIO sectors to IMPLAN's 509 sectors[46].

Consumption-Based Emissions

Remember:

C = Consumption*Emissions Intensity = Gross Demand*Emissions Intensity

Consumption-Based Emissions Produced from City Goods and Services

$$CIT * X = C^1$$

Consumption-Based Emissions Produced from Canadian Goods and Services

$$(CAN * B) - L = C^2$$

Consumption-Based Emissions Produced from Foreign Goods and Services

$$D * MRIO\ direct\ and\ indirect\ coefficients\ for\ Canadian\ Imports = C^3$$

Consumption-Based Emissions Produced from Foreign Intermediate Goods Used in City and Canadian Goods and Services

$$(B * MRIO\ Canada\ Global\ Coefficients) - (B * MRIO\ Canada\ Direct\ and\ Indirect\ Coefficients) = C^4$$

Total consumption-based emissions for the City of Toronto for a given Consumer Type:

$$C^1 + C^2 + C^3 + C^4$$

Remember, there are 4 consumer types, thus,

Household + Government + Business = A Commodity's Consumption-Based Emissions Inventory = X

Where, X = A Commodity Sector

Therefore,

$$C = X1 + X2 + X3 + \ldots\ldots + Xi$$

Where, C is the jurisdiction's Total Consumption-Based Emissions Inventory

---

[45] Edgar G. Hertwich and Glen P. Peters. "Multiregional Input-Output Database." OPEN:EU . http://www.oneplaneteconomynetwork.org/resources/programme-documents/WP1_MRIO_Technical_Document.pdf.

[46] State of Oregon Department of Environmental Quality and Stockholm Environment Institute. "Consumption-Based Greenhouse Gas Emissions Inventory for Oregon – 2005." 2011. http://www.deq.state.or.us/lq/pubs/docs/ConsumptionBasedGHGEmissionsInventoryORSummaryReport.pdf

Data Collection

The following table is a consolidation of the necessary data required to populate the variables used in the CBEI model. Possible data sources have been identified in order to help the City begin its data collection efforts. As can be seen below, a number of these data requirements need to be collected at the city level. However, some of the sources mentioned could only be located at the provincial and national level. Thus, the data from some of these sources may need to be manipulated in order to determine numbers for the City.

Figure 2: Data Needed for CBEI Model

Type of Data Needed	Level of Data	Possible Sources
Total Final Demand	City and National	StatCan
Total Final Imports	City and National	StatCan
Intermediate Demand (Input-Output Matrices)	City and National	StatCan Input-Output Matrices
Total Emissions per Sector	City and National	Toronto's GHG Inventory
Economic Output per Sector	City and National	StatCan
Direct & Indirect Emission Coefficients	Global	MRIO - 2008 Study

The Greenhouse Gas Protocol's *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories*[47] lays the groundwork for much of the practical elements of this methodology. While not strictly focused on consumption-based emissions, it outlines the accepted best practices for laying down the boundary of emissions calculation for cities. Another key source is the British Standard Institute's *PAS 2070: 2013 Specification for the assessment of greenhouse gas emissions of a city: Direct plus supply chain and consumption-based methodologies*. The PAS 2070 is a methodological specification document developed for London and other cities looking to explore an extended supply-chain focused greenhouse gas inventory, including consumption-based inventory.[48]

Timeline of assessment

The GHG Protocol identifies the accepted timeline of calculating emissions for cities as within a single reporting year covering a continuous period of 12 months.[49] This recommendation is supported by the PAS 2070, which notes that this time-period of assessment is accepted internationally.[50] While the time-period of

---

[47] "Global Protocol for Community-Scale Greenhouse Gas Emission Inventories: An Accounting and Reporting Standard for Cities," Greenhouse Gas Protocol, retrieved from: http://www.ghgprotocol.org/city-accounting.

[48] "PAS2070: Specification for the assessment of greenhouse gas emissions of a city: direct plus supply chain and consumption-based methodologies" BSI Standards Limited, 2013, retrieved from: http://shop.bsigroup.com/Browse-By-Subject/Environmental-Management-and-Sustainability/PAS-2070-2013/.

[49] "Global Protocol for Community-Scale Greenhouse Gas Emission Inventories: An Accounting and Reporting Standard for Cities," Greenhouse Gas Protocol, retrieved from: http://www.ghgprotocol.org/city-accounting. p. 29.

[50] "PAS2070: Specification for the assessment of greenhouse gas emissions of a city: direct plus supply chain and consumption-based methodologies" BSI Standards Limited, 2013, retrieved from: http://shop.bsigroup.com/Browse-By-Subject/Environmental-Management-and-Sustainability/PAS-2070-2013/. p. 7.

the assessment should reflect a continuous 12-month period, the frequency of calculation is at the discretion of the City.

Consumer Groups

The PAS 2070 consumption methodology separates consumers into households, government, and business capital investment.[51]

- Household consumption captures both upstream and downstream emissions resulting from the consumption expenditure of households within the assessment period.[52]
- Government consumption includes national and municipal expenditure on behalf of residents within the city boundary.[53] Moreover, municipal and national government expenditure can be considered as an aggregate group—especially in a system where the national government expenditure is carried out through the municipal government by way of funds transfer.[54] Government expenditure further includes final consumption through non-governmental organizations that are supported by government funding.[55]
- Finally, business capital expenditure is understood as the expenditure for the purposes of activities including starting a new company or purchasing new infrastructure.[56] The treatment of the consumption of equipment and inventory is discussed in the *Consumption-Based Emissions Inventory for San Francisco*.[57] The San Francisco report outlines that the purchase of inventory or equipment not sold within a given year are treated as direct consumption in the business category.[58] Because of inventory turnover within a business' fiscal year, the majority of businesses' consumption is not direct consumption, but rather intermediate consumption in the supply-chain of goods and services.[59]

Assessment boundaries and physical boundary

There is an important distinction between the assessment boundary and the physical boundary. The assessment boundary outlines the goods and services encompassed within the consumption-based methodology, while the physical boundary considers the City's borders and limits. The physical boundary of the assessment is flexible and should be defined by the City. Section 3.1.9. of London's PAS2070 methodology defines the city boundary as the border of a city or urban area, which is geopolitical and to be defined by municipal government.[60]

The map below shows the City of Toronto's jurisdictions and physical boundaries, including the metropolitan Toronto and the amalgamated boroughs.

---

[51] Ibid., p. 19.

[52] Ibid., p. 20.

[53] Ibid., p. 21.

[54] Ibid.

[55] Ibid.

[56] Ibid., p. 3

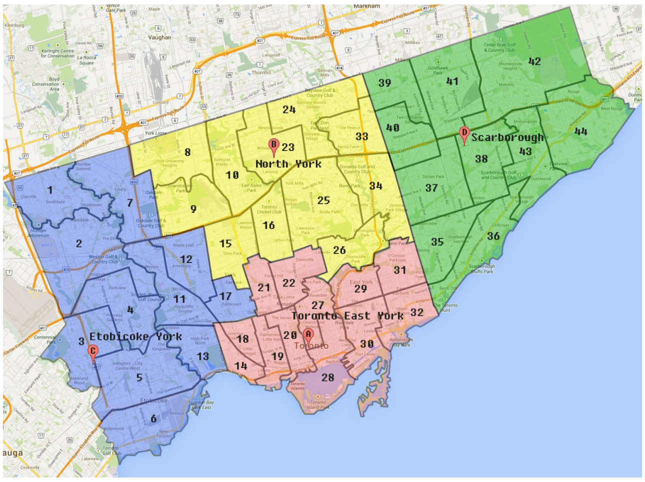
[57] "Consumption-Based Emissions Inventory for San Francisco," Stockholm Environment Institute, (2011), https://sfenvironment.org/sites/default/files/fliers/files/sf_consumption_based_emissions_inventory.pdf

[58] Ibid., p. 15.

[59] Ibid.

[60] "PAS2070: Specification for the assessment of greenhouse gas emissions of a city: direct plus supply chain and consumption-based methodologies" BSI Standards Limited, 2013, retrieved from: http://shop.bsigroup.com/Browse-By-Subject/Environmental-Management-and-Sustainability/PAS-2070-2013/, p. 9.

Figure 3: City-Wide War Boundary Map[61]



The physical boundary may span city-wide or may be restricted to one of the above regions as a pilot program. However, it should be noted that the calculation process is highly data intensive, and finding data gets increasingly difficult as the physical boundary is reduced. Therefore, for the purposes of using the most robust data already available, this methodology recommends constructing a model that spans the full physical boundary for the City of Toronto as an amalgamated physical assessment boundary.

The PAS2070 defines the assessment boundary as the, “definition of which processes and goods and services are included in the assessment, and which ones are not.”[62] On this point, the City of Toronto has a great degree of flexibility. The following options are open to the City in terms of defining its assessment boundary:

- To include the full available list of commodities and services that make up the consumption profile of the City of Toronto.
- By first assessing government procurement as a testing phase of the program.
- By first assessing the full life-cycle consumption-based emissions of city projects and services, such as the building or repair of city infrastructure, or the running or upgrading of public transit.

The last two options have the advantage of using more accessible streams of data from government activities and purchases in the immediate start of calculating emissions using this method. Another key advantage with focusing on one consumer group, such as government consumption, is that the smaller scale and fewer resources required relative to calculating a full consumption-based emissions inventory allows for a relatively less resource intensive transition and calculation period. However, it is important to note that this does not mean that the business and household consumer groups should be eliminated entirely. Intuitively, household consumption will make up a significant proportion of consumption emissions for the cities that have already calculated their consumption inventories in net-importing cities. Therefore, the full spectrum of consumer groups and goods and services must be included as part of the calculations to be complete and provide an accurate picture of the City of Toronto’s consumption-based emissions inventory. However, as mentioned earlier, the City enjoys a degree of flexibility as to how this assessment boundary will be carried out and the timelines over which it may complete its consumption emissions inventory.

---

[61] Retrieved from: http://www1.toronto.ca/wps/portal/contentonly?vgnextoid=2ca5045b4f870410VgnVCM10000071d60f89RCRD

[62] "PAS2070: Specification for the assessment of greenhouse gas emissions of a city: direct plus supply chain and consumption-based methodologies" BSI Standards Limited, 2013, retrieved from: http://shop.bsigroup.com/Browse-By-Subject/Environmental-Management-and-Sustainability/PAS-2070-2013/, p. 9.

Greenhouse Gases, Scope, and Sources

The types of emissions included as part of the assessment should follow the seven greenhouse gases identified under the Kyoto Protocol (please see Figure 3).[63] The conversion of the listed GHGs under the scope of this assessment should be converted to CO_2e using the 2006 IPCC Guidelines for global warming potential coefficients.[64] As reporting on these emissions is currently required for territorial, or production, focused emissions using these as a basis for consumption focused emissions measurement can allow for useful comparability. This is somewhat built into the calculation of consumption emissions, as EEIO analysis uses production focused GHG inventories as its basis of emissions measurement.

Figure 4: Greenhouse Gases Required for National GHG Inventory Reporting Under the Kyoto Protocol[65]

Greenhouse Gas	Abbreviation
Carbon dioxide	CO_2
Methane	CH_4
Nitrous oxide	N_2O
Hydrofluorocarbons	HFCs
Perfluorocarbons	PFCs
Sulfur hexafluoride	SF_6
Nitrogen trifluoride	NF_3

The GHG Protocol also provides summarized definitions and categorization of the different scope of emissions sources to be used for city inventories. Under this framework, scope 1 emissions are defined as emissions resulted from sources within the city boundary.[66] Scope 2 emissions are understood as the result of the use of grid-supplied electricity, heat, steam, and cooling within the city boundaries.[67] Finally, scope 3 emissions are understood as encompassing all other emissions that occur outside of the city, but as a result of activities taking place within the city.[68] Therefore, under these definitions, a consumption-based inventory would encompass all three scopes of emissions to account for emissions resulting within the city's boundaries, but also the emissions that result from production activities outside of the city to satisfy the city's consumption activity.

[63] Ibid.

[64] "PAS2070: Specification for the assessment of greenhouse gas emissions of a city: direct plus supply chain and consumption-based methodologies" BSI Standards Limited, 2013, retrieved from: http://shop.bsigroup.com/Browse-By-Subject/Environmental-Management-and-Sustainability/PAS-2070-2013/, p. 4

[65] "Global Protocol for Community-Scale Greenhouse Gas Emission Inventories: An Accounting and Reporting Standard for Cities," Greenhouse Gas Protocol, retrieved from: http://www.ghgprotocol.org/city-accounting, p. 30.

[66] "Global Protocol for Community-Scale Greenhouse Gas Emission Inventories: An Accounting and Reporting Standard for Cities," Greenhouse Gas Protocol, retrieved from: http://www.ghgprotocol.org/city-accounting, p. 31.

[67] Ibid.

[68] Ibid.

The sources of emissions should focus on the full life-cycle of sectors or commodities. The method used by the City of Toronto to disaggregate the sources of GHG emissions will vary depending on the data available and the requisite or desired level of analysis. For example, San Francisco develops its sources of emissions based on commodity groupings, location of emissions, and life-cycle phase. It began its analysis with commodities as part of 440 sectors.[69] These were then aggregated into 62 subcategories, and 16 categories such as clothing, services.[70]

In the case of San Francisco, the locations of emissions are broken down by three categories:

- Emissions resulting from goods produced and consumed in San Francisco.[71]
- Emissions resulting from goods produced within the United States, outside of San Francisco, but for the consumption of San Francisco consumers.[72]
- Emissions resulting from goods produced outside of the United States, for San Francisco consumption.[73]

The life-cycles are broken down by the embedded pre-purchase emissions and end use emissions. Pre-purchase emissions are a result of the: production phase, pre-purchase transportation, wholesale and retail.[74] End-use emissions are a result of: use phase, and post-consumer disposal phase.[75] The use phase accounts for emissions because of use by the final consumer, such as electricity emissions resulting from turning on a computer.[76] King County, Washington – the county in which Seattle resides – uses a similar method of grouping.[77] While the life-cycle phase disaggregation and location of emissions might be useful to the City of Toronto to employ, it is unclear whether the City could have access to the same detailed level of commodities. Therefore, the City may have to focus strictly on higher-level aggregated industry data as previously discussed in the data collection section above.

Communication of Results

This section discusses the methodology for developing a communication strategy of the results and process of consumption-based emissions inventory measurement to the public and key stakeholders. This section draws on the U.S. EPA guidance on the significance and approaches of communicating the results of climate and energy data to the public and key stakeholders.

---

[69] "Consumption-Based Emissions Inventory for San Francisco," Stockholm Environment Institute, (2011), retrieved from: https://sfenvironment.org/sites/default/files/fliers/files/sf_consumption_based_emissions_inventory.pdf, p. 16.

[70] Ibid.

[71] Ibid., p. 19.

[72] Ibid.

[73] Ibid., p. 20.

[74] Ibid.

[75] Ibid., p. 21.

[76] Ibid.

[77] King Country and Stockholm Environment Institute. "Greenhouse Gas Emissions in King County: An Update Geographic- plus Inventory, a Consumption-based Inventory, and an Ongoing Tracking Framework." 2012. http://www.kingcounty.gov/~/media/services/environment/climate/documents/2008/ghg-inventory-summary.ashx?la=en, p. 19-23.

The EPA separates communication into two different types of communication strategies: one-way communication and two-way communication.[78] One-way communication encompasses efforts to share information, which may in turn be used to foster awareness, education, or a public sharing of success.[79] Two-way communication, by contrast, encourages a dialogue between government and stakeholders.[80] This might include gathering feedback on a particular policy move or plans through a consultation period, or negotiating an implementation plan for project managers. The EPA further recommends using both forms of communication, and focusing on simple messages, consistent repetition, using multiple channels of information dissemination, and employing trusted sources.[81] In order to achieve this goal, the EPA separates its recommended communication strategy of emissions inventories, or other related environmental projects, into the following six-step process:[82]

---

[78] "Reach Out & Communicate about Climate & Energy," United States Environmental Protection Agency, 2016, accessed March 2017, retrieved from: https://www.epa.gov/statelocalclimate/reach-out-communicate-about-climate-energy.

[79] Ibid.

[80] Ibid.

[81] Ibid.

[82] Ibid.

1. **Define objectives:** the entity must clearly define its goals in communicating with the public which will inform its communication platforms and strategies. In the context of this project for the City of Toronto, a key objective might be engaging with infrastructure managers to discuss the implementation of consumption-based inventories and the impact it might have on the use of building materials. Another key objective might be communicating results with the public for the purposes of education, or justifying the objectives of reducing GHGs resulting from consumption activities. A third potential objective could be to engage with the public through a survey to determine consumption activity of businesses and households to expand the City's available data.

2. **Define and understand audiences:** this step focuses on clearly defining the audience of a clear communications strategy, which will largely depend upon the objectives defined in Step 1.

3. **Develop and test key messages and frames:** this step focuses entirely on determining what might motivate target audiences toward achieving the objectives determined in Step 1. For example, if the goal of the City is to encourage a dialogue with household consumers to educate them on consumption-based emissions, and potentially motivate change in consumption patterns, the message relayed must resonate with individual actors, be both easily accessible and readily available, and provide clear alternatives. The use of negative or positive framing will also have to be weighed against one another to determine an appropriate strategy. The EPA recommends that this might include the use of story-telling to draw in more readers, using simple data to communicate complex technical information, and using a distinct communication method for different audience groupings.[83] More work on this must be done, but can only be carried out once the City can determine the clear objectives of its communication strategy.

4. **Develop a timeline:** this might include a timeline of critical milestones in achieving a consumption inventory, developing goals for reductions in consumption-based emissions and milestones in reaching those goals, or attaining a breadth of reach in the communications strategy. In addition, different groups might be best to communicate with to achieve the objectives over the timeline. For example, during the construction of the consumption-based inventory, technical groups of managers or procurement officers could be most relevant to the objective at that time. Once the inventory is complete, education could be the key objective at that time. Finally, once policy is developed, motivational or persuasive techniques could be most beneficial to the public to achieve broad policy uptake.

5. **Identify channels:** this step involves determining the proper channels of conducting communications over a broad range of platforms. For example, communications over the City of Toronto website could be useful for requesting feedback on potential policy options or reduction strategies. However, in order to reach a broader audience for educational purposes, a more accessible platform could serve the objective more appropriately.

6. **Select methods and trusted messengers:** for an established municipal government, such as the City of Toronto, this final step might already be established as part of the City's wider communications strategy. Therefore, the greatest work must be done in determining the core objectives of communication, the appropriate audience over the course of the established timeline, and the key messages to relay. Finally, this should be an organic process that can be shaped by changing policy strategies, emissions data, and economic data as both the market patterns and emissions levels might be altered in the future.

---

[83] Ibid.

Communication within TransformTO

The TransformTO project already provides a significant platform for communication with the community and key stakeholders in developing this strategy. The second TransformTO report is set to be released in May 2017 to outline the City's long-term approach to reach the goal of reducing emissions by 80% by 2050.[84] As part of the existing community engagement as part of the TransformTO strategy development, it has been identified that rethinking consumption as well as production processes is a key thematic goal. For example, Ward 13, *Group C. Rethinking Our Economy-Developing Our Local Sharing Economy*, identified that a key problem is unsustainable modes of production and consumption in Toronto's current economy.[85]

With the existing data from community engagement, technical modeling, and clear goals and timelines for reducing GHG emissions, this report's recommendations can assist in developing communications for the City's objectives and goals by calculating a consumption-based inventory in a way that is already accessible to the public and positioned as a response to public concern.

IMPLICATIONS AND TRADE-OFFS

Policy Responses

Incorporating a consumption-based inventory into a city's emissions reporting has significant policy implications. This is especially true in net-importing cities, such as Toronto. For reasons mentioned above, emissions inventories are likely to be higher in these jurisdictions. Public demand to curb emissions may increase as a result.

However, there is a large gap between public expectations and the reality of the city's ability to regulate against consumption emissions. A city or country cannot control the carbon intensities of the goods and services produced in other jurisdictions. Even if this were possible, it still fails to address the fact that emissions may be rising because a city (including households, government, and business investment) is ultimately just consuming a higher volume of goods and services – not necessarily consuming more carbon intensive products. Though the City cannot force behaviour change, a consumption-based emissions inventory reporting approach can potentially empower parts of the public to more actively control for and understand their contribution to City emissions. Information provision therefore becomes a useful tool in promoting behavioural changes.

One possible way to do so is by using sensitivity analysis in the measurement of consumption-based emissions. In both the City of San Francisco[86] and Portland[87] studies discussed above, the authors include different "what-if" scenarios outlining how emissions might change if purchasing choices shifted to goods from different sources (in state, out of state, abroad). For example, in the San Francisco study, the authors ask:

- What if everything purchased in SF that is made in SF were instead made in the rest of California (at California average emission intensities);
- What if everything purchased in SF that is made in SF were instead made in the rest of the U.S. (at U.S. average emission intensities); and

---

[84] "TransformTO," The City of Toronto, 2017, retrieved from: http://www1.toronto.ca/wps/portal/contentonly?vgnextoid=ba07f60f4adaf410VgnVCM10000071d60f89RCRD.

[85] Stephen G. Robinson, "Summary Report: Ward 13 Brainstorm for a Sustainable City," City of Toronto, (2016), p. 6

[86] "Consumption-Based Emissions Inventory for San Francisco," Stockholm Environment Institute, (2011), https://sfenvironment.org/sites/default/files/fliers/files/sf_consumption_based_emissions_inventory.pdf

[87] State of Oregon Department of Environmental Quality and Stockholm Environment Institute. "Consumption-Based Greenhouse Gas Emissions Inventory for Oregon – 2005." 2011. http://www.deq.state.or.us/lq/pubs/docs/ConsumptionBasedGHGEmissionsInventoryORSummaryReport.pdf

- What if everything purchased in SF that is made in the US were instead made in another country (at the average emissions intensities of current U.S. imports)[88]

The main issue with this approach is that the product of these what-if analyses are often aggregate figures, implying that constituents may not be able to gain great insight into how their individual purchasing patterns (from various sources) might increase or decrease emissions – in the same vein as a carbon footprint model. Therefore, it may not be entirely relevant for the City to use at this point.

There are other examples of how the City might look to shape residents' consumption behaviour. The use of eco-labelling in order to encourage more sustainable consumption and discourage food waste is one way.[89] Another comes from the cities of San Francisco and Los Angeles, which have passed City resolutions campaigning for "Meatless Mondays" in support of comprehensive sustainability and health efforts.[90] Finally, local governments may even change the way they complete recycling calculations to reward programs based on GHG impact rather than raw tonnage.[91]

Though households are generally the largest emitters from a consumption point of view, governments also contribute to emissions in their procurement decisions. The City could start mandating consumption emissions reporting in future request for proposals (RFP) on municipal projects. The City can also control its own consumption, by pursuing more sustainable and less carbon intensive procurement policies. The Ontario Government's Climate Change Strategy even outlines procurement as method to help drive a carbon neutral agenda.[92] Green procurement can be applied to a variety of goods, including paper products (recycled, chlorine-free), heating appliances, information technology equipment, cleaning products, packaging, furniture, motor vehicles, and energy and waste services.[93]

The main takeaway, however, is that it is quite difficult to regulate consumption, specifically among households and businesses. This is because the majority of policy responses are voluntary in nature. Should a consumption-based emissions inventory be pursued and reported, it would be critical for City policymakers to communicate the potential discrepancy between the expectation and reality for curbing consumption-based emissions.

Risks/Obstacles

If the City were to begin measuring and publishing consumption-based emissions, we have identified four major risks and obstacles that the Environment and Energy Division might encounter in addition to the limitations outlined throughout the report. In addition to the disconnect between policy action and expectation discussed in the previous section there are a few others worth noting, listed below:

1. The potential lack of final consumption data for the City of Toronto specifically (across consumer segments), critical for calculating a consumption-based emissions inventory. Without it, the City would need to make a few key assumptions the calculation, perhaps even deriving estimated City of Toronto specific figures from provincial or national level statistics;

---

[88] Elizabeth Stanton (2011). "Consumption-Based Emissions Inventory for San Francisco." Stockholm Environment Institute, retrieved from: https://sfenvironment.org/sites/default/files/fliers/files/sf_consumption_based_emissions_inventory.pdf

[89] International Institute for Sustainable Development (2016). "Benefits of Eco-Labeling." IISD, retrieved from: https://www.iisd.org/business/markets/eco_label_benefits.aspx

[90] Alexandra Sifferlin (2012). "Los Angeles City Council Declares Mondays "Meatless." Time, retrieved from: http://healthland.time.com/2012/11/12/los-angeles-city-council-declares-mondays-meatless/

[91] Interview with Pete Erickson, March 29 2017

[92] Government of Ontario (2016). "Ontario's Climate Change Strategy." Government of Ontario, retrieved from: https://www.ontario.ca/page/climate-change-strategy#section-7

[93] OECD (2008). "Promoting Sustainable Consumption." OECD, retrieved from: https://www.oecd.org/greengrowth/40317373.pdf

2. A potential resource (human capital) gap for undertaking CBEI alongside the required production-based emissions measurement. This might be a short-term issue, as the process by which to complete the measurement becomes more institutionalized; and finally,
3. The cost (in both dollars and time) associated with completing the CEBI analysis. This cost will be higher depending on how the City chooses to conduct the analysis. Using the environmentally-extended input-output analysis as a basis for CBEI is more expensive because of its more granular and accurate approach to measurement. Conversely, using the third-party life-cycle emissions factors is less costly largely because it requires less work to complete the calculation. The exact costs are unclear and should be assessed by the City from a more detailed cost-benefit point of view.

Political Calculation

It is worth noting that the choice of an accounting methodology – consumption-based or production-based – is an inherently political decision. GHG emissions accounting rules, although technical, have significant implications for international climate negotiations, domestic mitigation policies, and global consumption patterns.[94] Accounting methodologies influence the international politics of climate change because taken in isolation, they distort the true impact of a city's GHG emissions impact. Using only a production-based emissions inventory approach without accounting for consumption has two significant impacts: 1) it diverts political attention away from consumption as a driver of emissions growth,[95] and 2) it may lead to decisions to reduce domestic emissions which produce negative impacts on overall global emissions.

With respect to the first impact, studies show that as cities undergo socioeconomic development, they transition from net-exporters to net-importers.[96] However, if only a production-based emissions inventory approach is used through that transition, it would appear as though the city were reducing its overall emissions, when in reality, emissions are only shifting from one jurisdiction to another. The Province of Ontario provides an illustrative example:[97] between the period of 1997 to 2009, Ontario saw a reduction in their production-based emissions (see Figure 5). However, this masks the increase in its consumption-based emissions – part of the reason why Ontario has reduced their GHG emissions is that the province has simply shifted production of goods and serviced consumed to other locations.[98]

However, the case of Ontario also illustrates the necessity of using a consumption-based emissions inventory approach in parallel to a production-based emissions inventory approach. If Ontario had only looked at consumption emissions, the province would not have been incentivized to pursue important policy gains on the production side. For example, a consumption-based inventory approach would likely not have pushed Ontario to decide to phase out coal by 2007.[99] These examples reiterate the necessity of looking at both production and consumption when it comes to emissions accounting.

---

[94] Paul G. Harris and Jonathan Symons. "Norm conflict in climate governance: greenhouse gas accounting and the problem of consumption." Global Environmental Politics 13, no. 1 (2013): p. 9.

[95] Paul G. Harris and Jonathan Symons. "Norm conflict in climate governance: greenhouse gas accounting and the problem of consumption." Global Environmental Politics 13, no. 1 (2013): p. 9.

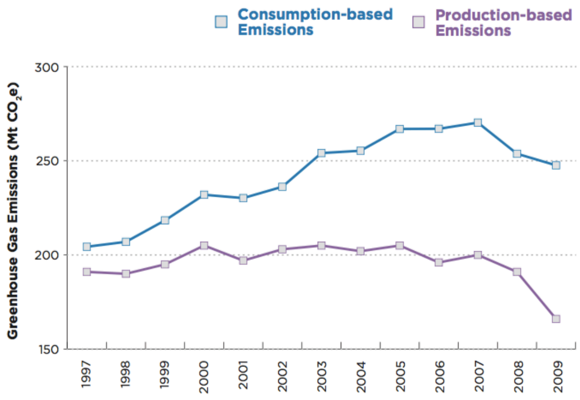
[96] Zhifu Mi, Yunkun Zhang, Dabo Guan, Yuli Shan, Zhu Liu, Ronggang Cong, Xiao-Chen Yuan, and Yi-Ming Wei. "Consumption-based emission accounting for Chinese cities." Applied Energy 184 (2016): 1073-1081.

[97] Environmental Commissioner of Ontario. "Greenhouse Gas Progress Report 2016." http://docs.assets.eco.on.ca/reports/climate-change/2016/2016-Annual-GHG-Report-EN.pdf.

[98] Ibid.

[99] Ontario Ministry of Energy. "The End of Coal." http://www.energy.gov.on.ca/en/archive/the-end-of-coal/.

Figure 5: Ontario's consumption- and production- based greenhouse gas emissions[100]



This leads to the second impact: when jurisdictions treat emissions from local production differently than from emissions embedded in imports, they can produce unintended negative impacts on global emissions. For example, if policies incentivize expansion of production to less energy efficient locations or in locations with less stringent environmental regulations,[101] the global emissions may actually increase.

Given the disparities in how much some countries produce and consume compared to others, an approach to GHG emissions accounting that incorporates both production-based emissions measurement *and* consumption-based emissions measurement can provide a more complete picture of each city's carbon footprint on the world's climate.[102]

CONCLUSION

In summary, this report assists the City of Toronto in: (1) understanding how to define and design a consumption-based emissions inventory approach, (2) identifying what methodologies are most applicable and practical in the Toronto context drawing from other jurisdictions, and (3) determining how to better communicate emissions measurement to residents.

This report has outlined a number of options to choose from in adopting a consumption-based emissions inventory approach, along with the advantages and disadvantages to each. While the model to apply is up to the discretion of the City, given the analysis outlined in this report, our overall recommendation is for the City to pursue a consumption-based emissions inventory approach in parallel with their current production-based emissions inventory approach.

Adopting a consumption-based emissions inventory approach in addition to measuring production-based emissions would make the City of Toronto a leader among the world's major cities, including the C40,[103] and could help spearhead this approach worldwide. A consumption-based inventory emissions approach could act as a key building block towards helping Toronto establish itself as a leader for cities in addressing climate change.

---

[100] Brett Dolter and Peter Victor (2016) "Casting A Long Shadow: The Implications of Demand-based accounting of Canada's Greenhouse Gas Emissions: Supplementary Material" *Ecological Economics*. 127, pp. 156-164.

[101] Paul G. Harris and Jonathan Symons. "Norm conflict in climate governance: greenhouse gas accounting and the problem of consumption." Global Environmental Politics 13, no. 1 (2013): p. 14-7.

[102] Environmental Commissioner of Ontario. "Greenhouse Gas Progress Report 2016." http://docs.assets.eco.on.ca/reports/climate-change/2016/2016-Annual-GHG-Report-EN.pdf.

[103] C40 is a network of the world's megacities committed to addressing climate change. C40 supports cities to collaborate effectively, share knowledge and drive meaningful, measurable and sustainable action on climate change.

REFERENCES

“Athena Institute Database.” *Greenhouse Gas Protocol*. 2012. Accessed March 2017. Retrieved from: http://www.ghgprotocol.org/third-party-databases/Athena-Institute.

“Background Document for Life-Cycle Greenhouse Gas Emission Factors for Carpet and Personal Computers.” *U.S. Environmental Protection Agency*. (2003). EPA530-R-03-018. https://www3.epa.gov/warm/pdfs/CarpetPCReport_11_21.pdf.

Boitier, Baptiste. “CO_2 emissions production-based accounting vs. consumption: Insights from the WIOD databases.” (2012): http://www.wiod.org/conferences/groningen/paper_Boitier.pdf.

“Canadian Raw Materials Database.” *Greenhouse Gas Protocol*. 2012. Accessed March 2017. Retrieved from: http://www.ghgprotocol.org/Third-Party-Databases/Canadian-Raw-Materials-Database.

City of San Francisco and Stockholm Environment Institute. “Consumption-Based Emissions Inventory for San Francisco.” 2011. Retrieved from: https://sfenvironment.org/sites/default/files/fliers/files/sf_consumption_based_emissions_inventory.pdf.

City of Toronto. "Toronto's 2013 Greenhouse Gas Inventory." http://www.toronto.ca/legdocs/mmis/2016/pe/bgrd/backgroundfile-87697.pdf.

“Definitions.” *United Nations Framework Convention on Climate Change.* accessed March 2017 at http://unfccc.int/ghg_data/online_help/definitions/items/3817.php.

Dolter, Brett and Peter Victor. “Casting A Long Shadow: The Implications of Demand-based accounting of Canada’s Greenhouse Gas Emissions: Supplementary Material” *Ecological Economics*. 127. 2016.

“Encompass Database.” *Greenhouse Gas Protocol.* 2012. Accessed March 2017. Retrieved from: http://www.ghgprotocol.org/Third-Party-Databases/Encompass.

“Frequently Asked Questions: Gross Output and GDP.” *Bureau of Economic Analysis U.S. Department of Commerce*. Accessed March 2017. https://www.bea.gov/faq/index.cfm?faq_id=1034.

“Global Protocol for Community-Scale Greenhouse Gas Emission Inventories: An Accounting and Reporting Standard for Cities.” *Greenhouse Gas Protocol*. Retrieved from: http://www.ghgprotocol.org/city-accounting.

Government of Ontario. “Ontario’s Climate Change Strategy.” *Government of Ontario*. 2016. Retrieved from: https://www.ontario.ca/page/climate-change-strategy#section-7

"Greenhouse Gas Progress Report 2016." *Environmental Commissioner of Ontario.* Retrieved from: http://docs.assets.eco.on.ca/reports/climate-change/2016/2016-Annual-GHG-Report-EN.pdf.

Harris, Paul G. and Jonathan Symons. "Norm conflict in climate governance: greenhouse gas accounting and the problem of consumption." *Global Environmental Politics* 13, no. 1 (2013).

Hertwich, Edgar G. and Glen P. Peters. "Multiregional Input-Output Database." OPEN:EU . http://www.oneplaneteconomynetwork.org/resources/programme-documents/WP1_MRIO_Technical_Document.pdf.

“Identity Matrix.” iCoachMath.com. Accessed March 2017. http://www.icoachmath.com/math_dictionary/identity_matrix.html.

IMPLAN. www.implan.com

"IPCC Emissions Factor Database." *Greenhouse Gas Protocol*. 2012. Accessed March 2017. Retrieved from: http://www.ghgprotocol.org/Third-Party-Databases/IPCC-Emissions-Factor-Database.

International Institute for Sustainable Development. "Benefits of Eco-Labeling." *IISD*. 2016. Retrieved from: https://www.iisd.org/business/markets/eco_label_benefits.aspx

Interview with Pete Erickson, March 29 2017

King Country and Stockholm Environment Institute. "Greenhouse Gas Emissions in King County: An Update Geographic-plus Inventory, a Consumption-based Inventory, and an Ongoing Tracking Framework." 2012. Retrieved from: http://www.kingcounty.gov/~/media/services/environment/climate/documents/2008/ghg-inventory-summary.ashx?la=en.

Kitzes, Justin. "An Introduction to Environmentally-Extended Input-Output Analysis." *Resources*. 2. (2013): 489-503, doi: 10.3390/resources2040489.

"Life Cycle Databases." *Greenhouse Gas Protocol*. 2012. Accessed March 2017. Retrieved from: http://www.ghgprotocol.org/Third-Party-Databases.

Lininger, C. "Consumption as a Base for Emission Accounting and as a Policy Base." in Consumption-Based Approaches in International Climate Policy. Switzerland: *Springer International Publishing*. 2015.

Mattila, Tuomas Pekka Leskinen, Ilmo Maenpaa, and Jyri Seppala. "An Environmentally Extended Input-Output Analysis to Support Sustainable Use of Forest Resources." The Open Forest Science Journal, 4. (2011): 15-23. Retrieved from: https://benthamopen.com/contents/pdf/TOFSCIJ/TOFSCIJ-4-15.pdf.

Mi, Zhifu, Yunkun Zhang, Dabo Guan, Yuli Shan, Zhu Liu, Ronggang Cong, Xiao-Chen Yuan, and Yi-Ming Wei. "Consumption-based emission accounting for Chinese cities." *Applied Energy*. 184 (2016): 1073-1081.

OECD. "Promoting Sustainable Consumption." *OECD*. 2008. Retrieved from: https://www.oecd.org/greengrowth/40317373.pdf

"PAS2070: Specification for the assessment of greenhouse gas emissions of a city: direct plus supply chain and consumption-based methodologies." *BSI Standards Limited*. 2013. Retrieved from: http://shop.bsigroup.com/Browse-By-Subject/Environmental-Management-and-Sustainability/PAS-2070-2013/.

Peters, Glen P., and Edgar G. Hertwich. "CO2 embodied in international trade with implications for global climate policy." (2008): 1401-1407.

Raa, Thijs ten. The Economics of Input-Output Analysis. Cambridge: *Cambridge University Press*. (2005). Retrieved from: http://dlia.ir/Scientific/e_book/Social_Sciences/Economic_Theory_Demography/HB_135_147_Mathematical_Economics_/002211.pdf

"Reach Out & Communicate about Climate & Energy." *United States Environmental Protection Agency*. 2016. Accessed March 2017. Retrieved from: https://www.epa.gov/statelocalclimate/reach-out-communicate-about-climate-energy.

Robinson, Stephen G. "Summary Report: Ward 13 Brainstorm for a Sustainable City." *City of Toronto*. (2016).

Sifferlin, Alexandra. “Los Angeles City Council Declares Mondays “Meatless.” *Time*. 2012. Retrieved from: http://healthland.time.com/2012/11/12/los-angeles-city-council-declares-mondays-meatless/

Stanton, Elizabeth. “Consumption-Based Emissions Inventory for San Francisco.” *Stockholm Environment Institute*. (2011). Retrieved from: https://sfenvironment.org/sites/default/files/fliers/files/sf_consumption_based_emissions_inventory.pdf

State of Oregon Department of Environmental Quality and Stockholm Environment Institute. “Consumption-Based Greenhouse Gas Emissions Inventory for Oregon – 2005.” 2011. Retrieved from: http://www.deq.state.or.us/lq/pubs/docs/ConsumptionBasedGHGEmissionsInventoryORSummaryReport.pdf

Statistics Canada. Table 381-0031 - Output, by sector and industry, provincial and territorial, annual (dollars), CANSIM (database). (accessed: April 10 2017).

"The End of Coal." *Ontario Ministry of Energy*. http://www.energy.gov.on.ca/en/archive/the-end-of-coal/.

“TransformTO.” *The City of Toronto*. 2017. Retrieved from: http://www1.toronto.ca/wps/portal/contentonly?vgnextoid=ba07f60f4adaf410VgnVCM10000071d60f89RCRD.