CITY OF VANCOUVER

SUMMARY REPORT

JANUARY 2018

[Revised March 2018]

ecoCity Footprint Tool Pilot

...ecological and carbon footprint analysis for achieving one planet living

FUNDED BY THE USDN INNOVATION FUND

PREPARED BY: BCIT Cora Hallsworth Consulting

SUMMARY

The City of Vancouver now has three ecological footprint and consumption-based emission inventory assessments. The first was for 2006, in which Dr. Moore tested the prototype version of the Tool for her PhD thesis research. An update was conducted for 2011; and through an Urban Sustainability Network (USDN) funded pilot, an additional update has been completed for the 2015 reporting year. This *Summary Report* presents the results of Vancouver's Consumption-Based Emission Inventory and Ecological Footprint, as created by the ecoCity Footprint Tool.

Background

The ecoCity Footprint Tool enables a community to evaluate its ecological footprint, 'territorial' greenhouse gas (GHG) emissions, and consumption-based GHG emissions. These inventories provide critical data to inform sustainable-consumption and climate mitigation efforts. Since the late '90s, governments have typically created GHG emissions inventories using an in-boundary or territorial approach, which identifies emissions from sources within the particular region. However, this form of inventory does not provide a complete picture of a community's impact on global climate change. It misses the climate impacts associated with the many goods a community consumes, because many of these goods are produced in other regions, often on other continents.

Although climate change is arguably the most pressing environmental issue we are currently facing, we are also bumping up against many other planetary boundaries. Due to unsustainable levels of consumption, global society today is demanding more in a year through consumption of energy and resources than nature can provide, and polluting more than nature can assimilate. The ecoCity Footprint Tool has the capacity to arm a community with the information it needs to act on global climate change and ecological overshoot.

Results

This report presents Vancouver's ecological footprint and consumption-based emission inventory results for 2015.

Ecological Footprint Assessment

The ecological footprint is measured in global hectares (gha). A global hectare represents the average of all biological productive land and aquatic area on Earth for a given year. An ecological footprint is an estimate of how much biologically productive land and water area an individual or population needs to produce all the resources it consumes and to absorb the wastes it generates. Based on current global population and biological productivity levels, an average of 1.7 hectares is available for each person on the planet.

Results show that Vancouver's *per capita* footprint is 3.4 gha/person.[1] This means Vancouver residents are consuming two times more of the earth's resources than what is currently available. Put another way, this means that approximately two earths would be required to support the global population if everyone had lifestyles comparable to an Vancouver resident.

 # Planets Required by Vancouver

[1] This per capita footprint includes an estimate of national and provincial services.

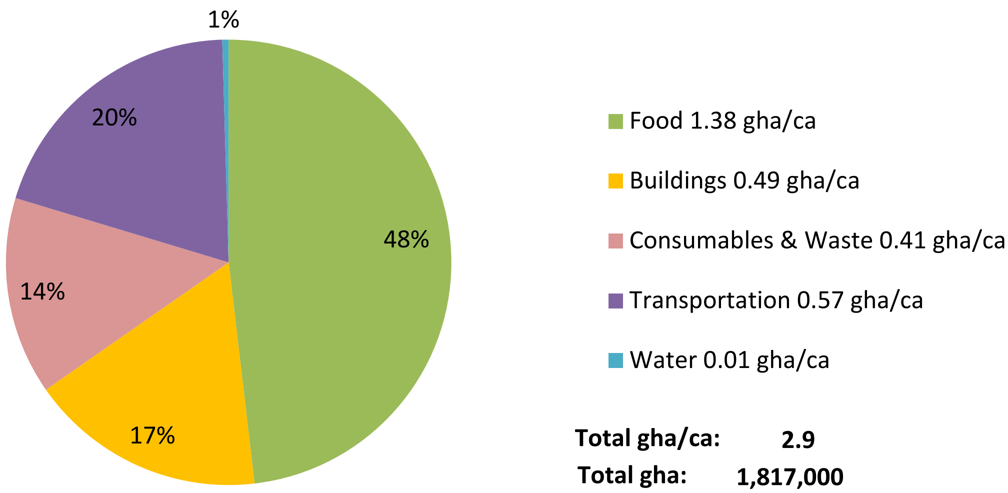

Figure 1: Summary of Ecological Footprint by Activity, 2015

Territorial GHG Emission Inventory and Consumption-Based Emission Inventory

The Consumption-Based Emissions Inventory (CBEI) presents the total GHG emissions resulting from the production and consumption of goods and services within a region, regardless of where those goods and services are produced. This form of inventory is generated using the data typically collected for a territorial inventory, including the energy used by buildings and transportation and the emissions associated with solid waste management; in addition to an evaluation of the emissions that result from the production and transport of all goods consumed within the region, as informed by life cycle assessment data. Total consumption-based emissions for Vancouver are 4,840 kilotonnes of carbon dioxide equivalent (ktCO2e), approximately double that of the territorial GHG emissions (see Figure 2).

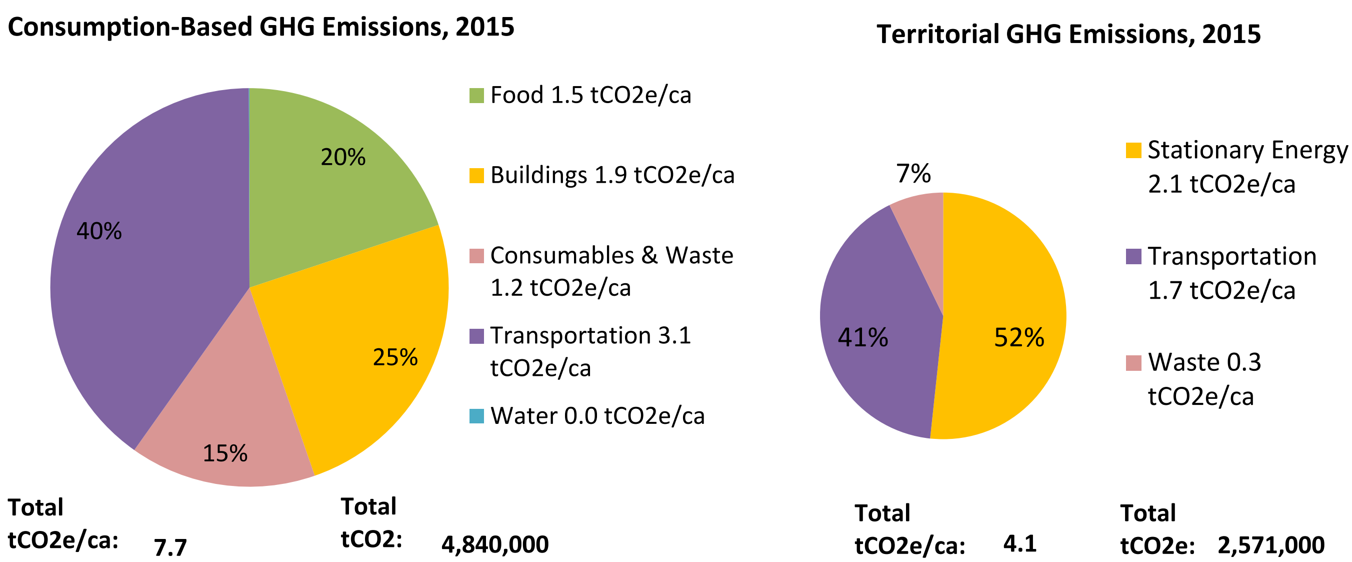

Figure 2 Comparison of Vancouver's 2015 Consumption-Based and Territorial GHG Emissions

Inventory Highlights

- For the CBEI, the largest impact category is transportation (40%) followed by buildings (25%); whereas for the ecological footprint (EF), the largest impact category is food (48%) followed by transportation (20%). Food impacts are the area in which these results vary most significantly. Food is only 20% of the total for the CBEI, but 48% of the EF; the primary driver for this difference is the land intensity of food production.

FOOD

- Only a small proportion of the impact of food is associated with transport of the food, whereas 98% of the footprint is associated with the amount of land and energy used in growing the food. Nearly one half of the food impacts are a result of animal proteins, particularly red meat and dairy products.
- Similar to the ecological footprint (EF), the majority of the CBEI for food is a result of animal proteins and dairy (74%). The main difference between the EF and the CBEI results are that dairy yields a greater GHG impact due to the energy intensity of dairy production, and meat yields a greater EF impact due to its intensity in land use demands.

    - ***Results demonstrate that the largest priority for reducing the Vancouver's food footprint is to target meat and dairy consumption, both in terms of reducing overall consumption levels and in terms of reducing the land and energy demands associated with their production.***

BUILDINGS

- *Operating energy of buildings dominates impacts for both the EF and the CBEI*.

    - ***The near-term priority should be to improve the efficiency of buildings and accelerate action to achieve the City of Vancouver's commitment to 100% renewable energy, with a longer-term objective of ensuring footprint impacts are considered in decisions about building materials.***

CONSUMABLES

- The footprint of consumables and waste is dominated by upstream impacts, namely the energy and materials that go into producing the goods that are consumed in the city.[2] City of Vancouver's consumables and waste footprint is dominated by paper, followed by plastic and "wood waste, textiles, and rubber".
- The CBEI for consumables shows that, in contrast to the EF, consumption-based emissions are higher from plastics (29%, compared to 18% for the EF); and much less for paper (22%, compared to 40% for the EF). These results are explained by the larger land footprint associated with production of paper, and the higher fuel intensity associated with plastic.

    - ***Results indicate the necessity to prioritize reduction in overall consumption, instead of focusing on end of stream waste management. Emphasis should be placed on priority material types, particularly paper and plastics.***

TRANSPORTATION

- Almost half of Vancouver's transportation ecological footprint is a result of fuel consumption for private vehicles, and adding the embodied energy of vehicles, private vehicle transportation represents nearly two-thirds of the footprint. Similar to the EF, two-thirds of the consumption-based emissions for transportation are associated with private vehicle travel.

    - ***A near-term priority is to continue to support a mode-shift away from private vehicle travel, continue to electrify the vehicle fleet (particularly transit); and to reduce the number of vehicles on the road by promoting active transportation, transit, and car-sharing. There are also***

[2] Operating energy for waste management facilities was not available for all locations, as discussed in Appendix B: Methodology, but the exclusion of data would be negligible compared to the embodied energy and embodied materials impacts of the consumables.

opportunities to reduce the embodied energy for transportation through car sharing and transit. The long-term priority should be to promote compact communities that are designed for active transportation and transit.

THE SUSTAINABILITY GAP

Vancouver's footprint, as estimated with the ecoCity Footprint Tool[3] is twice what is globally available (1.7 gha per person). This represents a sustainability gap of 50%. Put another way, this means that at least two Earths would be required to support the global population if everyone had lifestyles comparable to a Vancouver resident. From a climate perspective, in order to achieve the target of maintaining global temperatures below a 2 degree Celsius in warming, GHGs must be reduced to 2 tCO_2e per capita. Given Vancouver's current CBEI per capita emissions of 7.7 tCO_2e, GHG emissions would need to be reduced by 74%; and based on the GHG per capita emissions of 4.1 tCO_2e, they would need to be reduced by 51%.

[3] As noted in the methodology, the bottom-up approach employed in the ecoCity Footprint Tool results in an underestimate of the footprint.

ACKNOWLEDGEMENTS

This report has been prepared by Cora Hallsworth (Principal, Cora Hallsworth Consulting - CHC) and Dr. Jennie Moore (Associate Dean, School of Construction and the Built Environment, BCIT); with contributions and research provided by Ryan Mackie (CHC) and Jennifer Rae Pierce, PhD Candidate, University of British Columbia, and editing provided by Paramdeep Nahal, BCIT.

The authors would like to thank and acknowledge our project advisors and the many individuals who contributed time to this project. A special thank you to City of Vancouver staff: Leslie Ng, Lloyd Lee, Wendy Avis, Brad Badelt and Doug Smith; and to our project Advisors: Allison Ashcroft (Network Coordinator, CUSP) and Babe O'Sullivan (USDN); and the many staff members at the City whom contributed data and participated in workshops.

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Acronyms

AFOLU	Agricultural, Forest, and other Commercial Land Uses
BCIT	British Columbia Institute of Technology
CBEI	Consumption-Based Emission Inventory
EF	Ecological Footprint
eF Tool	ecoCity Footprint Tool
Gha	Global Hectares
gha/ca	Global Hectares per Capita (person)
GHG	Greenhouse Gas
GPC	Global Protocol for Community-Scale Greenhouse Gas Emission Inventories
HS	Harmonized System 10-digit merchandise codes by origin
ICI	Industrial Commercial and Institutional (sectors)
IPPU	Industrial Products and Pollutants
MV	Metro Vancouver
tCO_2e	Metric Tonnes Carbon Dioxide
USDN	Urban Sustainability Directors Network
VKT	Vehicle Kilometers Traveled

Definition of Terms

BASIC and BASIC+	Reporting levels in the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC).
Built Area	For the eF Tool, Built Area is the total municipal boundary excluding natural areas, where a natural area is a non-serviced area. For example, a treed park would be excluded, but agricultural land is included. In the eF Tool, the Built Area for the transportation sector is reported separately.
CO_2e	Carbon dioxide equivalent (CO_2e) expresses the impact of each different greenhouse gas in terms of the amount of CO_2 (carbon dioxide) that would create the same amount of warming. This enables reporting total gCO_2reenhouse gas emissions in one measurement.
Embodied Energy	The energy used in creating and delivering a particular material (e.g., consumable good or infrastructure), including the energy used for extraction of raw materials, manufacturing and transportation of the end product. In the eF Tool, energy associated with end of life (demolition, disassembly, etc.) is not included in Embodied Energy, as this energy is captured in waste handling.
Embodied Materials	Materials that are utilized in the manufacture of a consumable product or infrastructure, but that do not end up in the finished product. Examples are manufacturing wastage and temporary features used during manufacture.
Operating Energy	The energy used in the function of a product, building, vehicle, etc.
Scope 1-3	GHG emissions that are generated in-boundary (Scope 1), from grid supplied energy (Scope 2), and generated out-of-boundary (Scope 3).
Urban Metabolism	A study of the flow of energy and materials through the urban system.

CONTEXT

Scientists are suggesting that we have entered the era of the Anthropocene; an era in which humanity is the greatest force shaping earth's terrestrial systems. Currently, 50% of net primary production is in service of the human population and 80% of ecosystems are influenced by humans.[i] As a result, we are bumping up against important planetary boundaries,[ii] and are in a state of "ecological overshoot."[iii]

Ecological overshoot is measured using ecological footprint analysis, which assesses humanity's total demand on nature's services over a one-year period compared to the capability of biologically productive land and sea areas to meet that demand. Global society today is demanding more in a year through consumption of energy and resources than nature can provide, and polluting more than nature can assimilate. Simply stated, it would take 1.5 Earths to sustainably provide the ecological services we currently use.

Climate change is one of these critical areas of overshoot. Recently, Nation States from around the world, including Canada, ratified the Paris Agreement, committing to holding global temperature increase to below 2 degrees Celsius. The signatories are aiming to go beyond this commitment by staying below 1.5 degrees Celsius of warming, which scientists now suggest is the boundary threshold for avoiding the most negative and severe climate change impacts of a changing climate.

Cities account for only 3% of global land use, but they are responsible for the majority of global resource consumption.[iv] It is not the cities that are the problem, but the energy and resource intensity of our urban lifestyles that require vast land areas outside of the city to support it. The discrepancy between the small amount of land occupied by cities and the vast amount of land required to resource urban lifestyles is at the heart of the urban sustainability challenge.

The Ecological Footprint (EF) and the Consumption-Based Emission Inventory (CBEI) can help communities and governments tackle one of the root causes of global ecological overshoot and climate change: individual and collective consumption choices and habits.

What is a Territorial GHG Emissions Inventory?

Since the late 90's governments have typically created greenhouse gas emissions inventories using an in-boundary or territorial approach, which identifies emissions from sources within the region, plus electricity.

What is a Consumption-Based Emissions Inventory?

The consumption approach includes emissions released to produce goods and services consumed within a region, regardless of where they were originally produced. That is, it estimates global emissions resulting from local consumption habits. Typical emissions inventories include only emissions from sources within a given region's borders; however, with the globalization and integration of our economy, a significant amount of the emissions from the production, disposal, and transport of a region's goods occur in other regions. CBEI results can demonstrate the scale to which we are off-loading consumption-related emissions on to other jurisdictions. This will help encourage strategies that maximize global emission reductions. This form of inventory is of growing interest to governments that are keen to broaden and deepen their sustainability and climate-action efforts.

What is an Ecological Footprint?

The ecological footprint is an estimate of how much biologically productive land and water area an individual or population needs to produce all the resources it consumes and to absorb the waste it generates. It is measured in global hectares (gha) per capita, where a global hectare is a biologically productive hectare with globally averaged productivity for a given year.

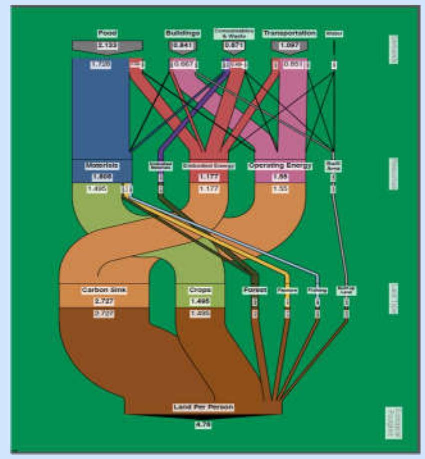
ECOCITY FOOTPRINT TOOL OVERVIEW

Dr. Jennie Moore, Associate Dean at BCIT, created the ecoCity Footprint Tool (eF Tool) as part of her PhD under the supervision of Dr. William Rees, founder of the ecological footprint concept. The goal in creating the eF Tool was to support policy-related decision-making aimed at reversing global **ecological overshoot**, namely by creating a community-scale **ecological footprint** using locally sourced data**.** A prototype of the Tool was initially used by the City of Vancouver in 2006. The outputs from the Tool are highly valued by the City and are informing the strategies, actions, and monitoring methods for their "Greenest City 2020 Action Plan".

The Tool was originally conceived for ecological footprint utility, but it also generates an urban metabolism, a traditional 'territorial' greenhouse gas (GHG) emission inventory, and a consumption-based emissions inventory. These inventories provide critical data to inform sustainable-consumption and climate mitigation efforts.

What is an Urban Metabolism?

The urban metabolism traces the flow of energy and materials through the urban system, and yields the data to inform the footprint and consumption inventory. The urban metabolism can be depicted visually using a SANKEY diagram (see below).



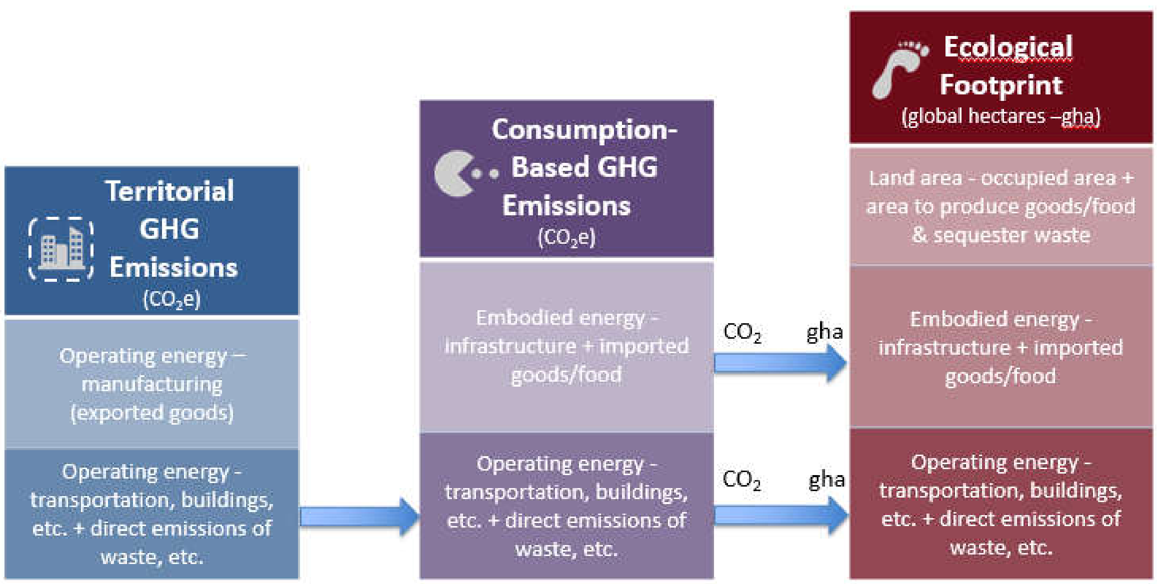


Figure 3 Comparison of the GHG Emission Inventories and Ecological Footprint Approaches

How Does the eF Tool Work?

Many existing ecological footprint and consumption-based greenhouse gas (GHG) inventory tools use the 'compound method' (a top-down approach that uses national and/or econometric data). But, the eF Tool uses the 'component method', which emphasizes the use of community-based data, and aligns with traditional spheres of planning at the local government level (see Figure 4, below). Real consumption data, collected through an urban metabolism study, provides the utility needed to directly link policy intervention to emission outputs at the local government scale. This provides a clear and transparent understanding of how city functions, across all sectors and service areas, affect the footprint. It also enables scenario analyses to forecast which policy interventions and changes could enable reductions in the city's energy and material flows, greenhouse gas (GHG) emissions, and ecological footprint.

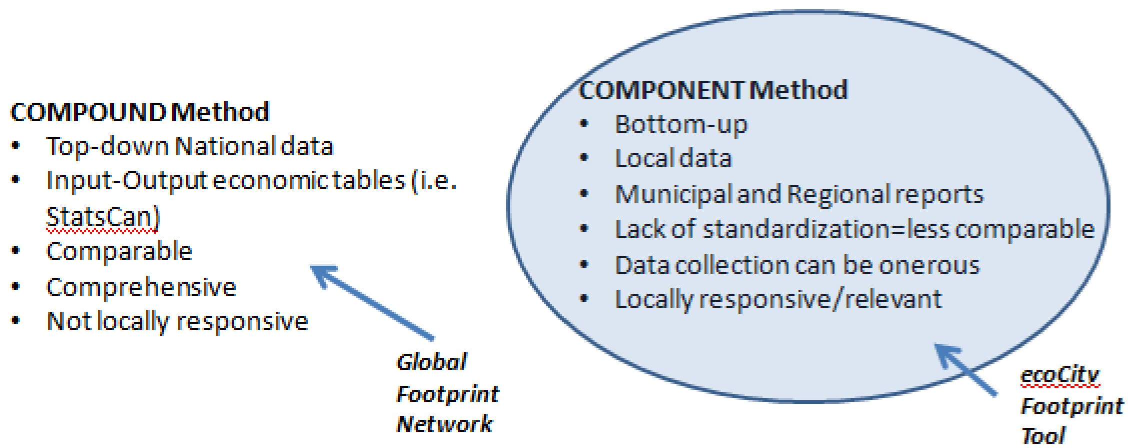


Figure 4 Two methods for calculating the Ecological Footprint

ecoCity Footprint Tool Application

Exploring consumption-based inventories and ecological footprints is a way for governments to broaden and deepen their sustainability and climate-action efforts. In particular, they provide a more robust understanding of emission sources and ecological impacts, and they can directly inform sustainable-consumption efforts.

The eF Tool also has the potential to help streamline data collection and reporting due to its capacity to create multiple outputs: the consumption-based inventory, the territorial inventory, as well as the ecological footprint.

PILOT PROJECT OVERVIEW

In 2017, with funding from the Urban Sustainability Directors Network (USDN), BCIT and its partners pilot tested the eF Tool with five USDN members– City of Victoria, City of Vancouver, City of North Vancouver, District of Saanich, and Iowa City (US).

The objectives of the pilot project were to:

1. Enhance, refine, and test the prototype eF Tool, including:
    - Aligning the tool with Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC)
    - Creating user guidance
    - Testing in a US context
2. Create consumption-based emission inventories, ecological footprints and GPC inventories for five pilot communities.
3. Scope out an online format of eF Tool.

A short video, *ecoCity Footprint Tool Webinar 2017,* provides an overview of both the Tool and the pilot project. It can be viewed at https://youtu.be/h-XsGQWmg-w.

PILOTING IN THE CITY OF VANCOUVER

In 2011 City of Vancouver Council adopted the Greenest City Action Plan, which outlines a path to become the greenest city in the world by 2020. The Plan includes a target to reduce community-based greenhouse gas emissions by 33% from 2007 levels by 2020 and a lighter ecological footprint goal to reduce the community's ecological footprint by 33% over 2006 levels. In November 2015, the City of Vancouver also committed to transitioning to 100% renewable energy before 2050.

The City of Vancouver now has three ecological footprint and consumption-based emission inventory assessments. The first was for 2006, in which Dr. Moore tested the prototype version of the Tool for her PhD thesis research. An update was conducted in 2011; and through this USDN funded pilot, an additional update has been completed for the 2015 reporting year.

The ecological footprint and CBEI results can continue to inform a broad set of planning initiatives at the City; including, for example: neighbourhood planning, local food strategy planning, sustainable transportation planning, and solid waste management planning. They can also continue to provide the framing for communications to engage residents and business in contributing to the City's sustainability and climate action objectives.

DATA COLLECTION AND ANALYSIS METHODOLOGY

The ecoCity Footprint Tool is aligned with the typical spheres, or categories, of municipal planning – buildings, transportation, waste and water; a fifth category – food - is also included, which is of growing interest to municipalities (see Figure 5). Data is collected on the total inputs in terms of materials, embodied energy, operational energy and direct built area for each of these categories; and they are evaluated sectorally – by residential, institutional, commercial, and industrial sectors. The Tool employs a bottom-up approach, prioritizing the use of community- and regional-scale data sources. However, in cases where local data is not available, assumptions or proxies are utilized.

Study Year

Ideally the reporting year would align with the national census reporting year (2016), however, since energy utility data for 2016 was not yet available, 2015 was selected as the reporting year for this study.

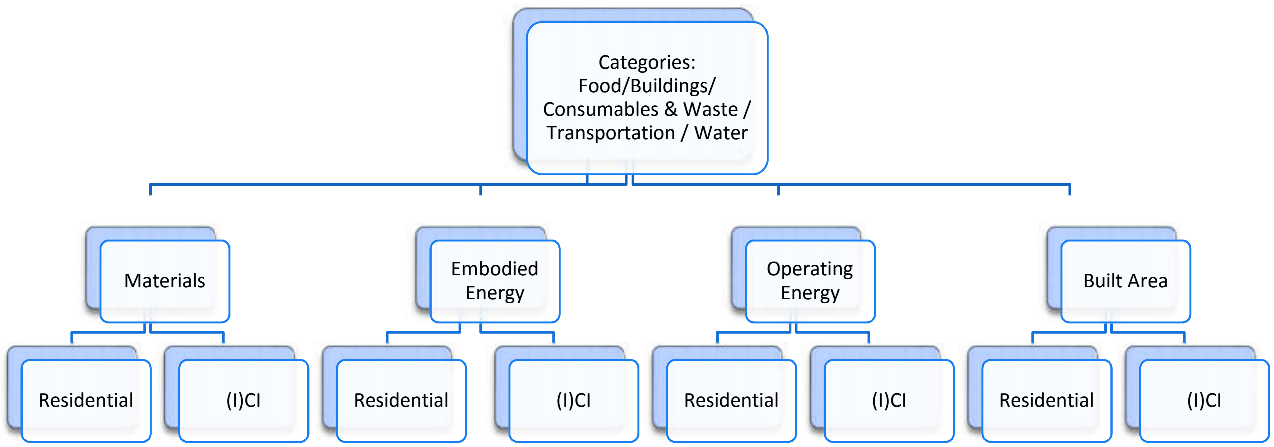


Figure 5: Data Inputs[4]

Key Assumptions and Limitations

As previously noted the eF Tool uses the bottom-up component method. This approach typically produces lower estimates than the top-down compound method. Similarly, community-scale inventories yield lower per capita results than national/provincial scale inventories. There are several reasons for the differences:

i. The bottom-up approach does not include emissions from national/provincial services, however an estimate of these can be added (the eF Tool increases the footprint by 18% to account for these sources, which is a conservative estimate).
ii. The bottom-up approach does not fully capture all life-cycle impacts of materials and energy used in what is being measured in the footprint components (e.g., embodied energy of fuel and airplanes are not currently included).

An overview of the data inputs required to generate the ecological footprint, CBEI and territorial GHG inventory, and key assumptions and limitations are presented in the table, below. A detailed overview of the methodology, data sources, and challenges and opportunities are presented in Appendix B.

[4] (I)CI refers to light industrial, commercial and institutional sectors.

Table 1. Key Assumptions and Limitations

CATEGORY	INPUTS	EF	CBEI	TERRITORIAL GHG INVENTORY	KEY ASSUMPTIONS AND LIMITATIONS
Food *Food available is measured as a proxy for food consumption and import distances are used to estimate food-kilometers travelled. Energy associated with the production and transportation of imported food is then estimated.*	Embodied energy and materials associated with food production (energy and materials used to produce and transport food)	✓	✓	✗	· Food consumption and 'food miles' statistics were not available at the local level; therefore, national averages were used as a proxy. Vancouver plans to conduct a food survey to derive local food estimates.
	Land used to produce food	✓	✗	✗	
Buildings and Stationary Energy *The embodied materials, embodied energy, operating energy, and the built area associated with residential, industrial and commercial buildings are evaluated to establish a material-flow analysis, assess the direct and embodied carbon, and evaluate the ecological footprint of these buildings.*	Operating energy used by buildings and related infrastructure	✓	✓	✓	· Institutional building accounts are aggregated with commercial accounts. · Some mixed-use commercial buildings contain residential units, and are thus their impact is included in the commercial sector. · Estimates for material composition and building lifespan are based on 2011 data as they are assumed to have not changed substantially between 2011 and 2015.
	Embodied energy and embodied materials of buildings	✓	✓	✗	
	Built area associated with buildings	✓	✗	✗	
Consumables and Waste *Data is collected on the:* · *quantity of solid and liquid waste generated by sector (residential, industrial, commercial and institutional) and by material type;* · *method in which materials are managed (i.e., landfilled, incinerated, recycled, composted);* · *energy consumption and emissions associated with waste management facilities, and transportation of waste;* *material composition and built area associated with waste management facilities.*	Operating energy used in waste management facilities and hauling waste	✓	✓	✓	· Data on the energy used at Cache Creek and Harvest Power have not been collected; however, these sources would have negligible impact to the overall footprint/inventory. · Composition data for waste and recyclables are based on region-wide totals.
	Direct emissions from waste facilities	✓	✓	✓	
	Embodied energy and materials associated with consumables (as inferred by waste stream)	✓	✓	✗	
	Built area associated with waste management	✓	✗	✗	

CATEGORY	INPUTS	EF	CBEI	TERRITORIAL GHG INVENTORY	KEY ASSUMPTIONS AND LIMITATIONS
Transportation *Evaluates the embodied materials and embodied energy of physical transportation infrastructure and vehicles, operating energy (fuel consumed by vehicles), and physical built area occupied by transportation infrastructure. Data is collected for private and commercial vehicles; transit; aviation travel; marine travel and off road vehicle use.*	Operating energy associated with to transportation (fuel use for private and commercial vehicles; aviation; marine vessels and off-road vehicles)	✓	✓	✓	· Air travel estimates are conservative as they do not include second-leg of flights; these estimates are also based on assumptions from YVR regarding percentage of travelers that are from the MV region. · BC Ferries data was limited to total fuel consumption. Due to the lack of passenger origin-destination information, total fuel consumption was allocated based on Vancouver's proportion of BC's population. This method does not account for the significant use of Ferries by tourists or the regional differences in ferry usage. · Cruise ship and off-road vehicle fuel use was not available.
	Embodied energy and embodied materials associated with private vehicles and transportation infrastructure	✓	✓	×	
	Built area associated with transportation	✓	×	×	
Water *Evaluates the embodied materials, embodied energy, operating energy, and built area impacts of the water distribution and purification system relied on by the municipality.*	Operating energy used in treating and conveying water	✓	✓	✓	· Estimates of built area and material composition of infrastructure are based on 2011 data as they are assumed to have not changed substantially between 2011 and 2015.
	Embodied energy and embodied materials associated with water infrastructure	✓	✓	×	
	Built area associated with water management	✓	×	×	

RESULTS

The following presents the results of the assessment of the City of Vancouver's: (1) Ecological Footprint (EF), (2) Consumption-Based Emission Inventory (CBEI), and (3) 'Territorial/GPC GHG emission inventory; as evaluated by the ecoCity Footprint Tool.

It is important to contextualize the results with the knowledge that Vancouver serves as a regional service centre to surrounding communities and tourists. Residents from neighbouring communities travel to Vancouver for work and entertainment generating waste and using energy, as do the many tourists. This yields an upward push on the city's footprint and emissions. To illustrate this point, we know that about twenty five percent of the regional population resides in Vancouver, but the City's contribution to the regional GDP is closer to forty percent.[5] This upward push on emissions is however compensated for by the compact form of the city, which drives down per capita energy consumption and GHG's compared to neighbouring communities.

This means that the waste generation and energy use associated with commercial sector in Vancouver is inflated due to the City's functioning as a service centre. In the future it would be interesting to explore the possibility of using GDP to scale the estimates of waste generation and energy use associated with the commercial sector so that it can be attributed more appropriately.

Ecological footprint and consumption-based emissions assessments have been completed for the years 2006, 2011 and 2015. As shown in Figure 6, between 2006 and 2015, Vancouver's consumption-based GHG emissions decreased 15% per capita, and its ecological footprint decreased 20% per capita. Due to a population rise of 9% over this time, overall reductions have been slightly less: total consumption-based emissions dropped by 8% and the ecological footprint has dropped by 13%.

It is important to note that the EF estimates for 2006 are different to what was previously reported due to methodological change with respect to the calculation of the food footprint.

[5] Lloyd Lee, City of Vancouver, personal communication, October 17, 2017.

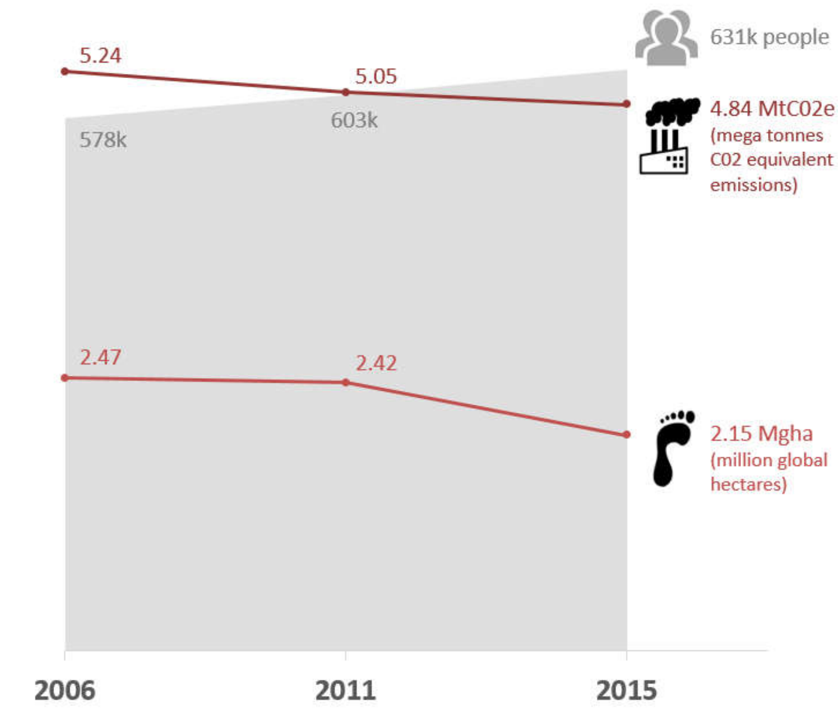


Figure 6: Vancouver's Per Capita CBEI and Ecological Footprint[6] Over Time

Ecological Footprint Assessment

The ecological footprint is measured in global hectares (gha). A global hectare represents the average of all biological productive land and aquatic area on Earth for a given year. An ecological footprint is an estimate of how much biologically productive land and water area an individual or population needs to produce all the resources it consumes and to absorb the wastes it generates. Based on current global population and biological productivity levels, an average of 1.7 hectares is available for each person on the planet.

 # Planets Required by Vancouver

Vancouver's total ecological footprint is 1,820,000 gha which is an area 170 times bigger than the City's municipal boundary. On a per capita basis, this is equivalent to 2.9 gha per person. These estimates exclude the resource demands associated with national and provincial services. An additional 18% would need to be included in the footprint to account for these national and provincial services, which would increase the estimate to 2,150,000 gha or 3.4 gha per person. This means that Vancouver's footprint, as estimated with the ecoCity Footprint Tool is twice what is globally available (1.7 gha per person). Put another way, this means that at least[7] two Earths would be required to support the global population if everyone had lifestyles comparable to a Vancouver resident.

[6] Including national and provincial services.

[7] As noted in the methodology, the bottom-up approach employed in the ecoCity Footprint Tool results in an underestimate of the footprint.

Vancouver's EF decreased from 4.27 gha/ca[8] in 2006 to 3.4 gha/ca in 2015. Figure 7 shows the details of the decrease in Vancouver's EF per capita over time. Transportation, buildings, and consumables and waste all decreased approximately 28% between 2006 and 2015, with transportation having the largest absolute change of 0.24 gha/ca. The food component decreased 10%. It should be noted that a portion of the food reduction may be due to changes in how Statistics Canada is reporting data.[9] As previously noted, the City of Vancouver is pursuing the collection of food consumption data at the local level, which should provide a more locally nuanced profile of food consumption.

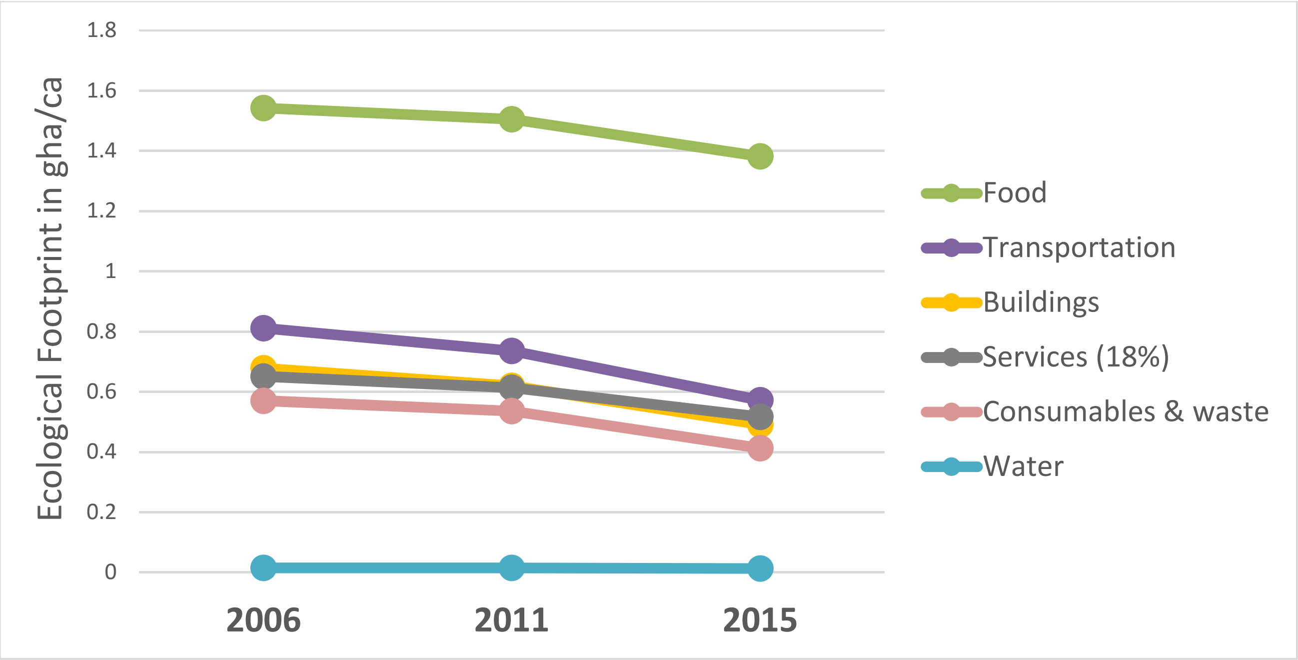


Figure 7: Ecological Footprint by Activity over Time

If we look at the various components of Vancouver's footprint for 2015, as shown in *Figure 8*, consumption of food represents the largest impact (48%), followed by a relatively even distribution between transportation (20%), buildings (17%), and consumables and waste (14%).

[8] Vancouver's initial ecological footprint results from 2006 were 4.97 gha/capita, however due to methodological changes the baseline has now been reduced to 4.27 gha/ca.
[9] For example, a large drop in nut consumption could be explained by reporting the hulled weight instead of the total weight of the nuts.

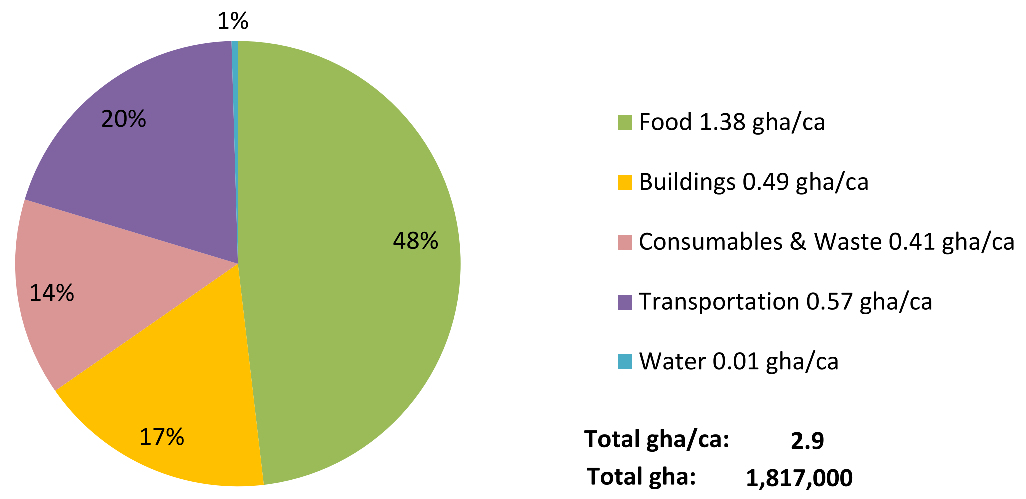


Figure 8: Summary of Ecological Footprint by Activity, 2015

Food Footprint

In considering the food footprint we see that only a small proportion of the impact is associated with transport of the food, whereas 98% of the footprint is associated with the amount of land and energy that are utilized in growing food (see Figure 9).

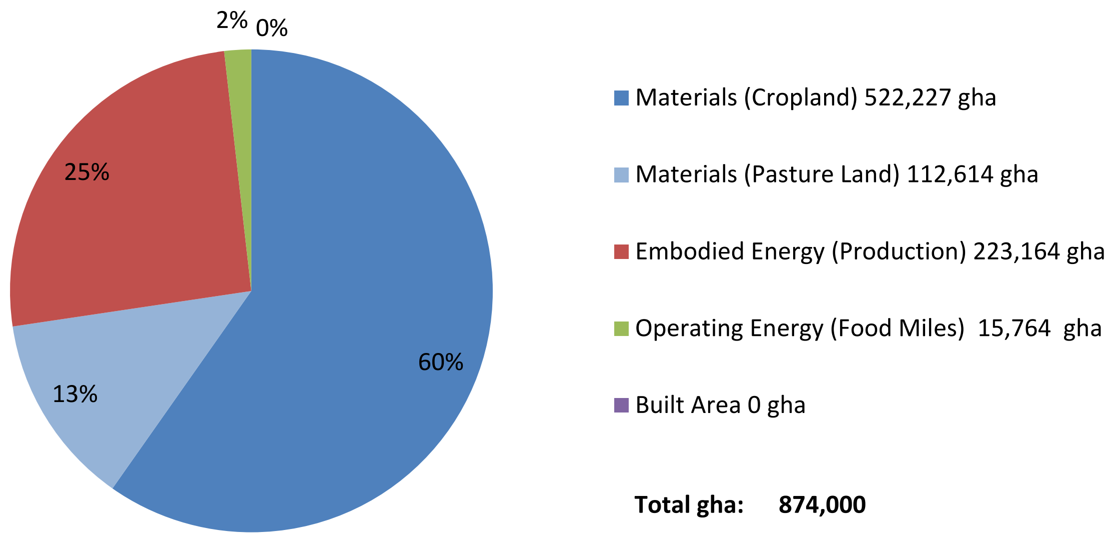


Figure 9: Food Footprint Summary, 2015

When we look at which types of food are having the largest impact on the footprint, three quarters of the footprint is a result of animal proteins, in particular red meat and dairy products (see Figure 10). **These results demonstrate that the largest priority for reducing Vancouver's food footprint is to target meat and dairy consumption, both in terms of reducing overall consumption levels and in terms of reducing the land and energy demands associated with their production.**

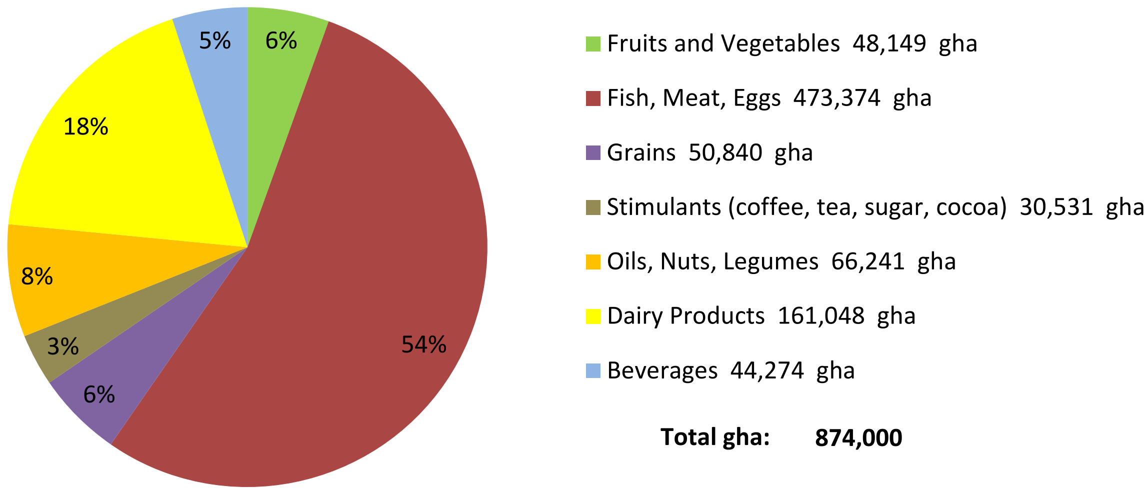


Figure 10: Food Footprint by Food Type, 2015

Buildings Footprint

As shown in Figure 11, more than three-quarters of the ecological footprint of Vancouver buildings is a result of operating energy. This is not to say that material choices for buildings are insignificant, but given that the impact of these materials are amortized over the entire lifespan of the building, their overall impact compared to fuel and electricity consumption becomes overshadowed.[10] However, as we transition to lower impact energy sources to operate our buildings, the impact of material choices will make up a greater percentage of the footprint. **The near term priority should be to improve the efficiency of buildings and accelerate action to achieve City of Vancouver's commitment to 100% renewable energy, with a longer term objective of ensuring footprint impacts are considered in decisions about building materials over their lifecycle.**

[10] There is an unresolved issue with the data for concrete resulting in under reporting of impacts of commercial/institutional embodied energy on EF and CBEI.

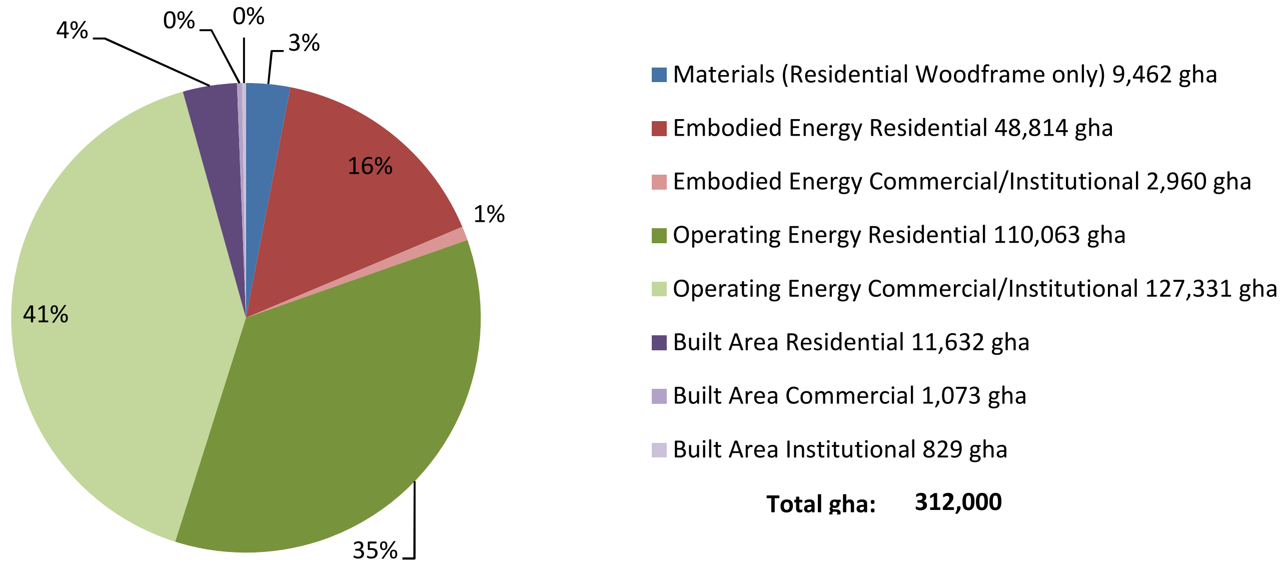


Figure 11: Buildings Footprint Detailed, 2015

Consumables and Waste Footprint

The footprint of consumables and waste is dominated by upstream impacts, namely the energy and materials that go into producing the goods that are consumed in the city. As shown in Figure 12, these upstream impacts – the embodied materials and embodied energy associated with the consumables – represent 90% of the consumables footprint. Embodied materials are those that are utilized in the manufacture of a consumable product or infrastructure but do not end up in the finished product; and embodied energy is the energy used in creating and delivering a particular material (e.g., consumable good or infrastructure). **These results suggest a need for a shift in the way we think about consumption. They emphasize the necessity to prioritize reducing overall consumption instead of end of stream waste management.**

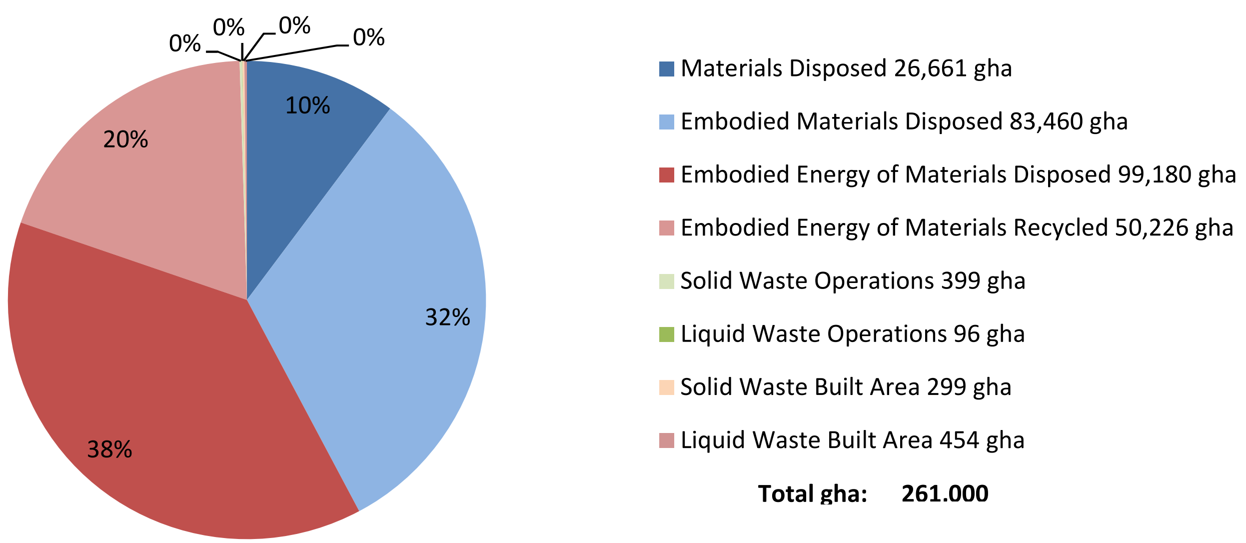


Figure 12: Consumables and Waste Footprint, 2015

It is also instructional to evaluate which consumables are yielding the largest impact on the footprint to develop targeted policy and communication measures. As shown in Figure 13, the City of Vancouver's footprint is dominated by paper, followed by plastic and "wood waste, textiles, and rubber".[11] Table A-1 Life Cycle Assessment Data for Consumables by Material Type in Appendix A, provides a detailed breakdown of footprint impacts by type (that is, by type of plastic, paper, etc.). Although textiles typically comprise a small portion of the waste stream by weight, their embodied energy and material are very high. Thus, textile consumption should continue to be a priority action area along with paper and plastics.

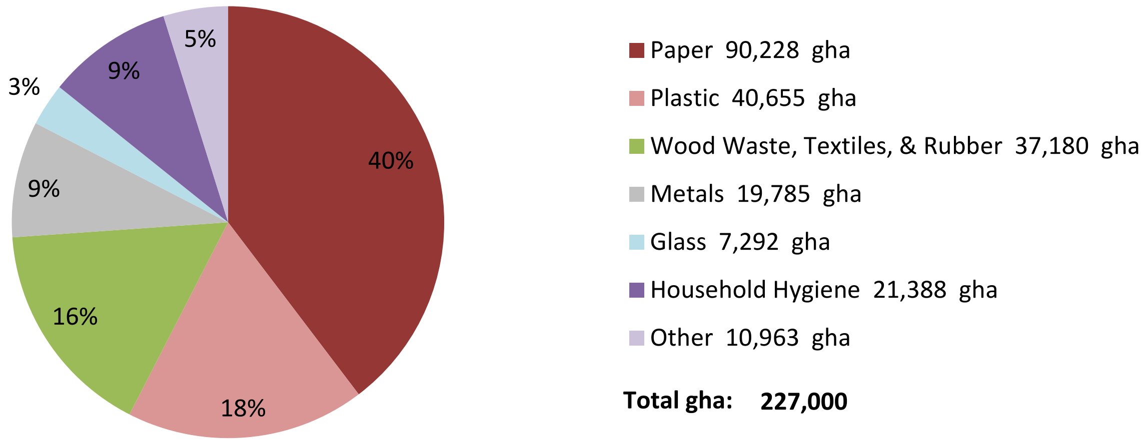


Figure 13: Consumables Footprint by Type, 2015

Transportation Footprint

Almost half of Vancouver's transportation footprint is a result of fuel consumption for private vehicles, and if we add in the embodied energy of vehicles, private vehicle transportation represents nearly two-thirds of the footprint. Air travel is also significant at 25%. A near term priority is to continue to support a mode-shift away from private vehicle travel, and to electrify the vehicle fleet (particularly transit) and reduce the number of vehicles on the road by promoting active transportation, transit, and car-sharing. There are also opportunities to reduce the embodied energy for transportation through car sharing and transit. The long term priority should be promoting compact communities that are designed for active transportation and transit.

[11] Total global hectares is lower in Figure 13 than it is in Figure 12 because Figure 13 only shows the LCA impacts of food, and does not include the EF and GHG impacts associated with waste management (operating energy and direct emissions from waste management).

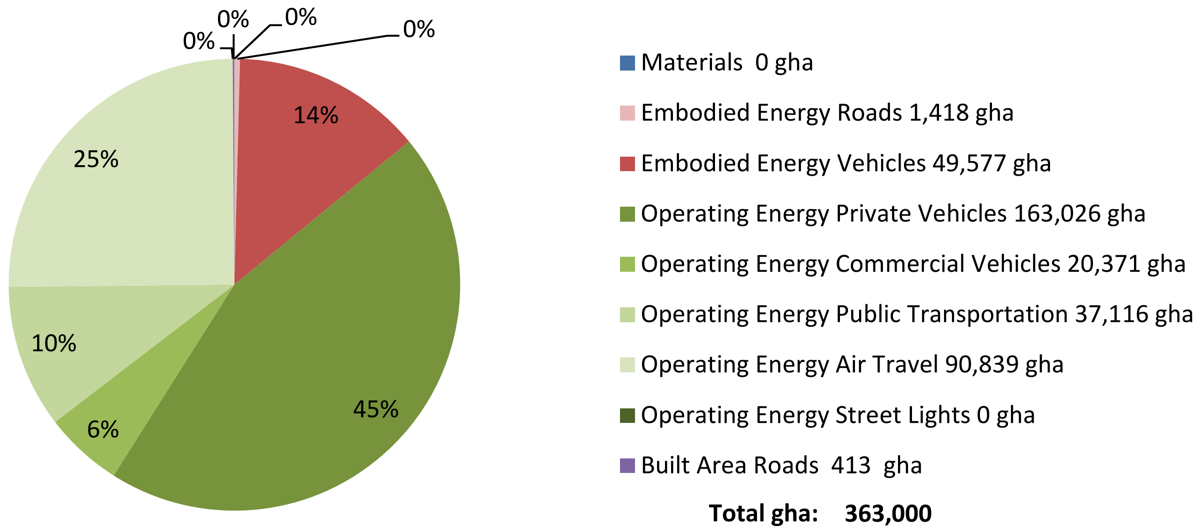


Figure 14: Transportation Footprint in Detail, 2015

Territorial GHG Emission Inventory

Through enhancements as part of the USDN pilot project, the eF Tool now provides a territorial GHG emission inventory which is compliant with GPC reporting protocols. A comprehensive GPC inventory and report has already been prepared internally. For the purposes of this report, we therefore, present only summary information on the territorial emission inventory, for the purposes of comparison with the Consumption-Based Emission Inventory. As shown in Figure 15, the total territorial emissions for Vancouver are 2,571 $ktCO_2e$[12], or 4.1 tCO_2e per capita.

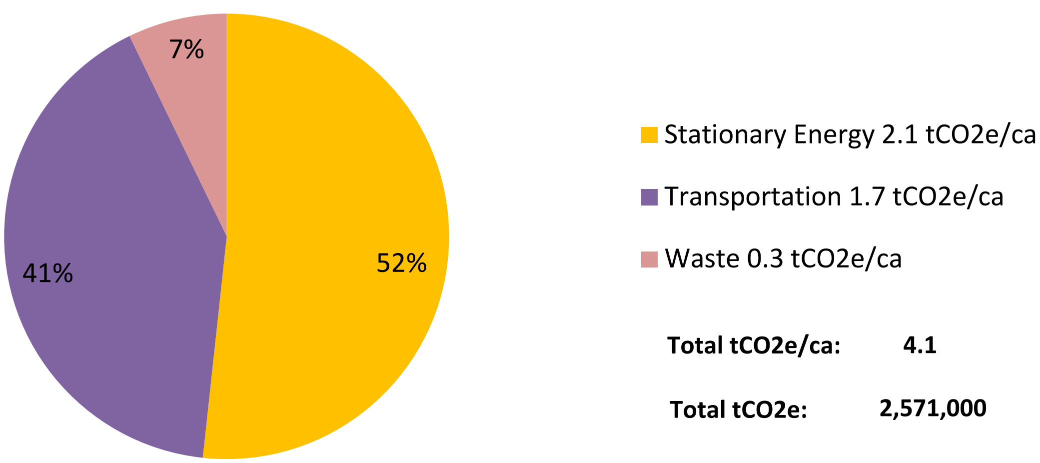


Figure 15: Territorial GHG Emissions Inventory (GPC Basic Inventory)

[12] Carbon dioxide equivalent (CO_2e) expresses the impact of each different greenhouse gas in terms of the amount of CO_2 (carbon dioxide) that would create the same amount of warming. This enables reporting total greenhouse gas emissions in one measurement.

Consumption-Based Emission Inventory

As previously noted, the Consumption-Based Emission Inventory (CBEI) presents the total GHG emissions resulting from production and consumption of goods and services within a region, regardless of where those goods and services are produced. This form of inventory is generated using the data typically collected for a territorial inventory, including the energy used by buildings and transportation and the emissions associated with solid waste management. It also includes the emissions that result from the production and transport of all goods consumed within the region, as informed by life cycle assessment data.

Figure 16 shows the details of the decrease in Vancouver's CBEI per capita over time. The impact of buildings, consumables and waste have the largest percentage change, having decreased approximately 25% between 2006 and 2015, with buildings having the largest absolute change of 0.6 tCO_2e/ca. Due to methodological differences transportation is not showing a decrease (e.g,. impacts of BC Ferries travel is now being included).

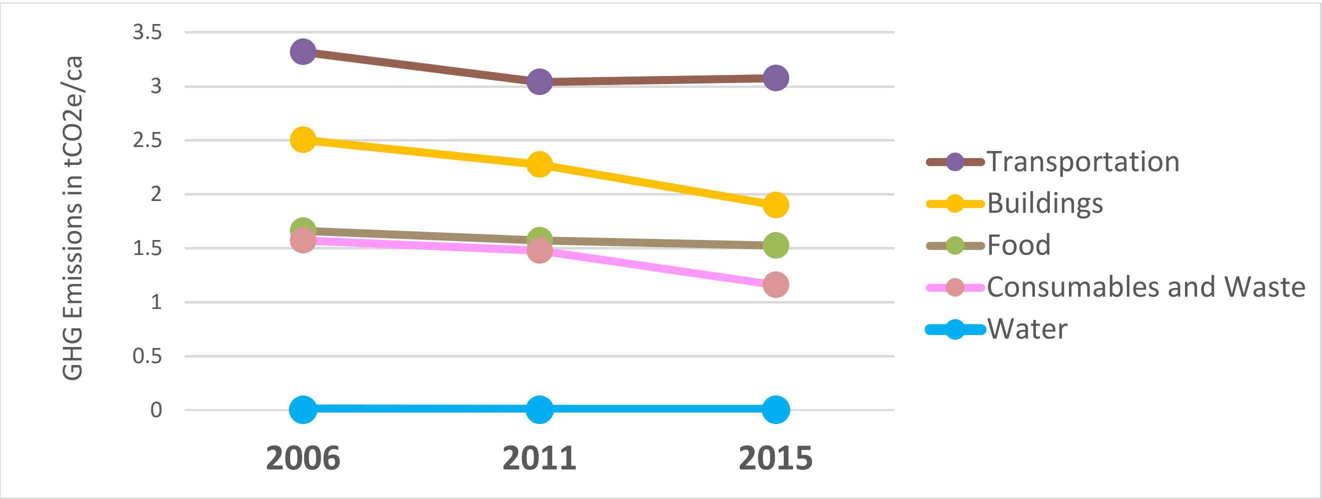


Figure 16: CBEI per Capita by Activity Over Time

Total consumption-based emissions for Vancouver were 4,840 $ktCO_2e$ in 2015 (see Figure 17), almost double the territorial emissions (see Figure 15). The difference is largely due to the upstream GHG impacts of food and other consumables, as well as the embodied carbon impacts of transportation infrastructure, which are included in a CBEI.

For the CBEI, the largest impact category is transportation (40%) followed by buildings (25%); whereas for the EF, the largest impact category is food (48%) followed by transportation (20%). Food impacts are the area in which these results vary most significantly. Food is only 20% of the total for the CBEI, but 48% of the EF; the primary driver for this difference is the land intensity of food production.

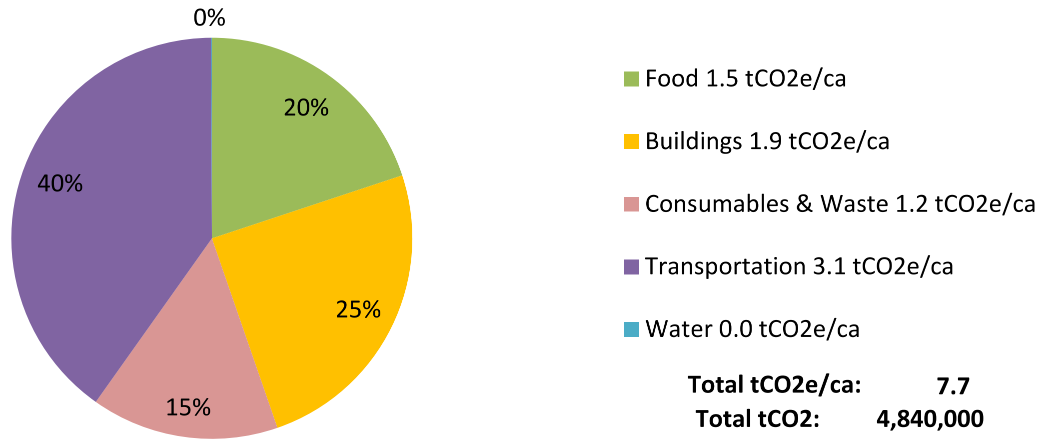


Figure 17: Summary of GHG Emissions from Consumption, 2015

CBEI of Food

To inform policy and planning decisions it is important to consider the varying contributions of each of the food types to the overall food emissions. Figure 18 shows that, similar to the ecological footprint (EF), the majority of the consumption-based emissions for food is a result of animal proteins and dairy (74%). The main difference between the EF and the CBEI results are that dairy yields a greater GHG impact due to the energy intensity of dairy production, and meat yields a greater EF impact due to its intensity in land use demands.

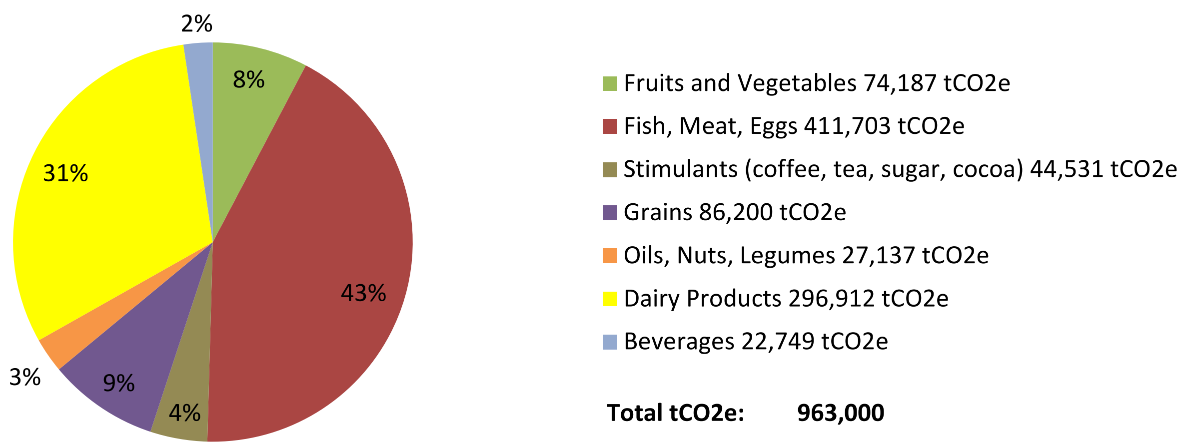


Figure 18: Greenhouse Gas Emissions Inventory of Food, 2015

CBEI of Buildings

As with the EF, the operating energy of buildings dominates the impact on the CBEI. There is an unresolved issue with the data for concrete resulting in under reporting the impacts of commercial/institutional embodied energy; however, it is expected that changes will not impact the overall emissions significantly or the trend of operating energy being the priority action area.

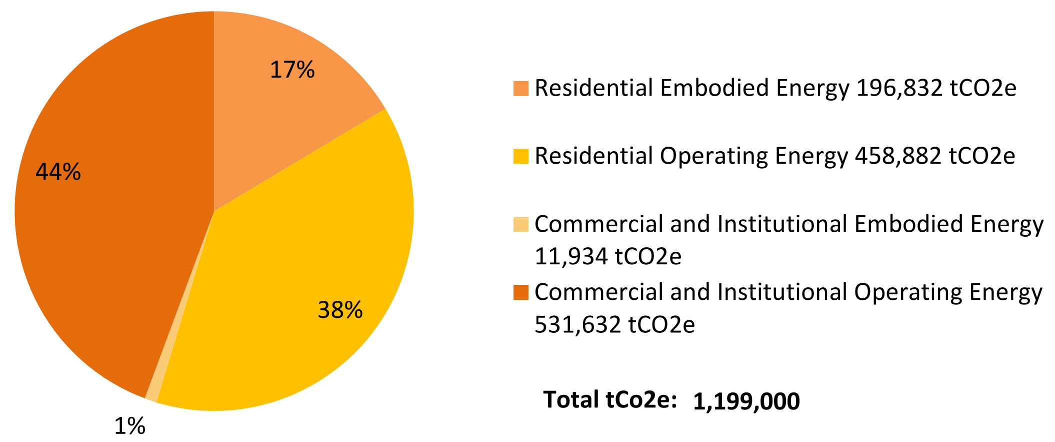


Figure 19: GHG Emissions Inventory of Buildings, 2015

CBEI of Consumables

The CBEI for consumables shows that the largest GHG impact is due to plastics (29%), as shown in Figure 20. When comparing CBEI results with the EF results, the consumption-based emissions are higher for plastics (29%, compared to 18% for the EF); and much less for paper (22%, compared to 40% for the EF). These results are explained by the larger land footprint associated with production of paper, and the higher fuel intensity associated with plastic. Table A-1 Life Cycle Assessment Data for Consumables by Material Type in Appendix A provides a detailed breakdown of GHG impacts by type (that is, by type of plastic, paper, etc.).

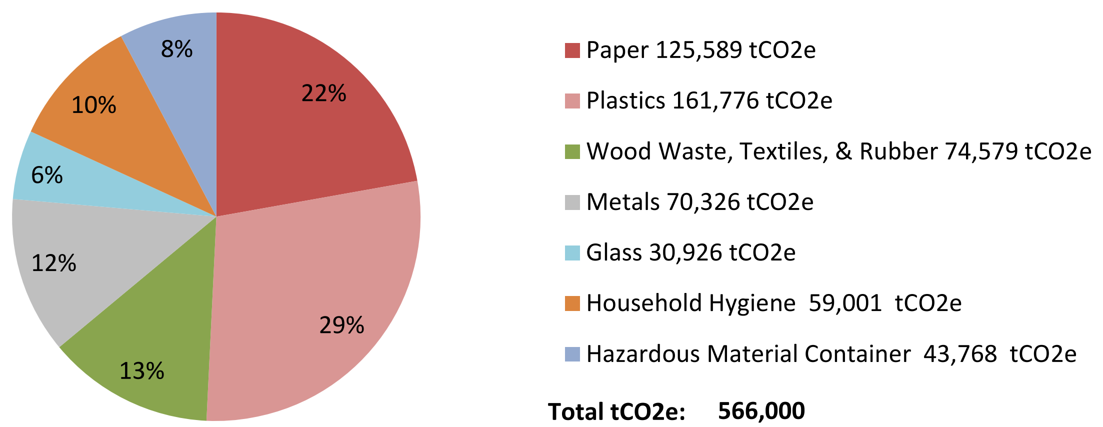


Figure 20: GHG Emissions Inventory of Consumables, 2015

CBEI of Transportation

Similar to the EF, the majority of the consumption-based emissions for transportation are associated with private vehicle travel (67%), as shown in Figure 21. Air travel also represents a significant component of the transportation CBEI (19%).

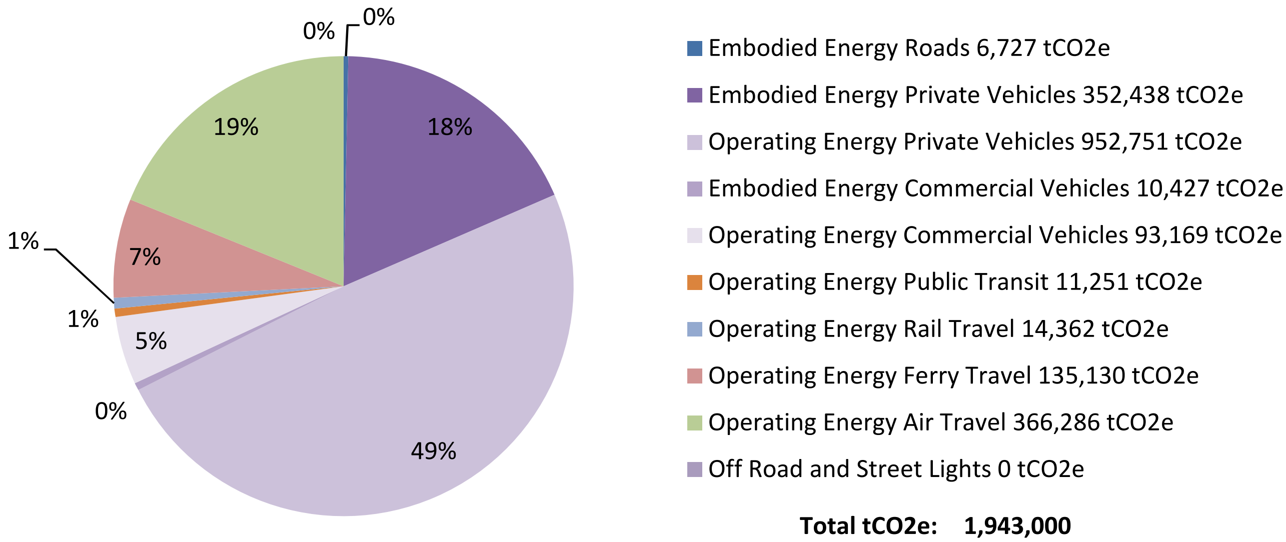


Figure 21: Greenhouse Gas Emissions Inventory of Transportation, 2015

THE SUSTAINABILITY GAP

To achieve 'One Planet Living' Vancouver's ecological footprint would need to reduce from 3.4 gha per capita[13] (including national and provincial services) to 1.7 gha per capita. This represents a sustainability gap of 50%. From a climate perspective, in order to achieve the target of maintaining global temperatures below a 2 degree Celsius in warming, GHGs must be reduced to 2 tCO_2e per capita. Given Vancouver's current CBEI per capita emissions of 7.7 tCO_2e, GHG emissions would need to be reduced by 74%; and based on the GPC per capita emissions of 4.1 tCO_2e, they would need to be reduced by 51%.

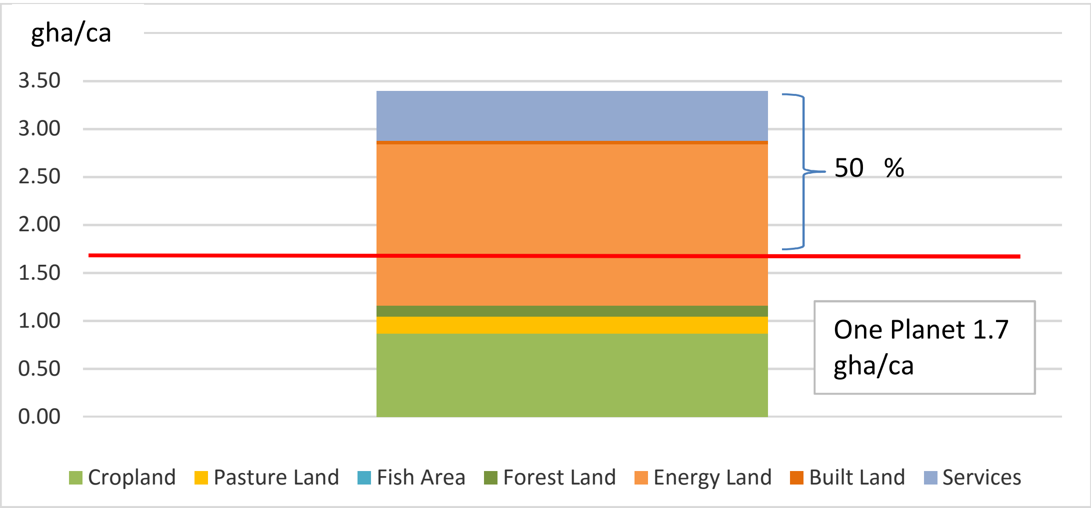


Figure 22: Sustainability Gap, 2015 (including national and provincial services)

[13] Vancouver's footprint, not including national and provincial services is 2.9 gha/person.

ONE PLANET SCENARIO

A One Planet Scenario for Vancouver is proposed for the portion of the city's footprint that is a direct result of local activity (excluding national and provincial services). To achieve the 1.7 gha per capita target the actual reductions would need to be greater to account for national and provincial services, and for those components that are not included in the bottom-up approach.

MEASURE	EF reduction (gha/capita)	GHG reduction (t CO_2e/capita)
Reduce beef (& substitute with chicken) & dairy (without substitution) by 50%[14]	0.24	0.2
Reduce consumption associated with food waste 25% (all categories except Oils, Nuts, Legumes in which the target is a 20% reduction)	0.46	0.5
Eliminate fossil fuel emissions in residential, commercial and institutional buildings	0.36	1.5
Reduce purchase of consumables by 25%*	0.08	0.2
Convert 50% gas private vehicles to electric	0.15	0.9

* Alternatively: Reduce paper consumption 33% (impact = 0.03 gha/0.1 tCO_2e); **and** reduce textiles consumption 40% (impact = 0.02 gha/0.1 tCO_2e); **and** reduce plastics consumption 50% (impact = 0.03 gha/0.2 tCO_2e).

The cumulative results of implementing these measures are shown in Figure 23 for the EF. The cumulative GHG reductions lower the GPC total to 1.7 tCO_2e per capita and the CBEI total to 4.7 tCO_2e per capita. In other words, the territorial emissions would be below the global 2 tCO_2e per capita target, but the CBEI emissions would not.

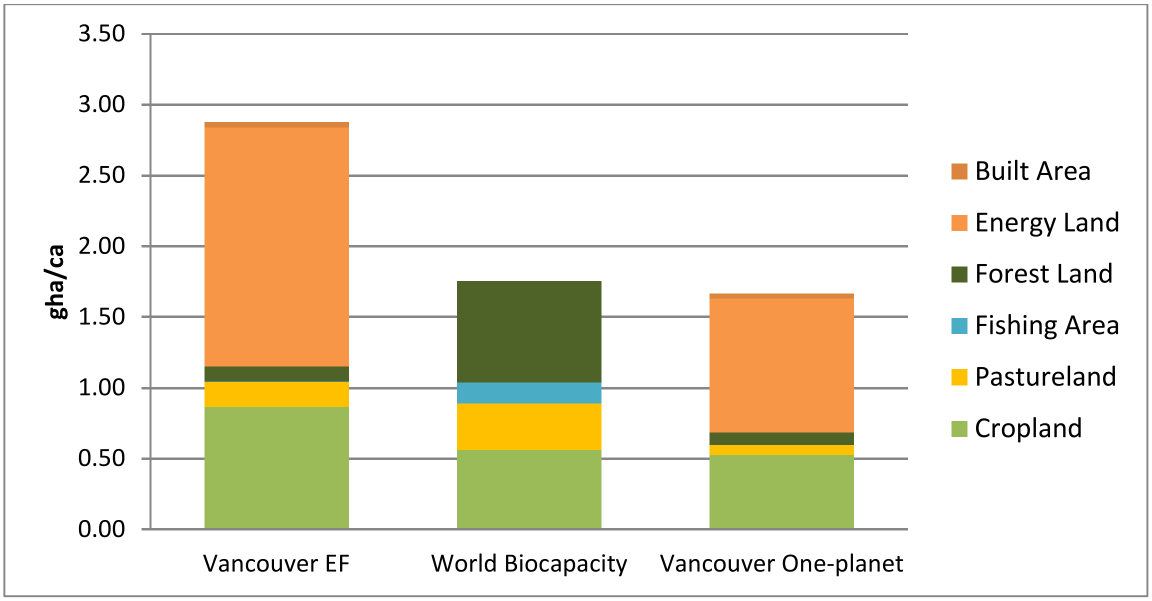


Figure 23: Vancouver's Current Ecological Footprint Compared to a One Planet Scenario

[14] When one food item is reduced, essential calories will need to be replaced with calories from another food group.

POLICY RESPONSES AND INTERVENTIONS

Through the Greenest City 2020 Action Plan, the City of Vancouver set a Lighter Footprint goal of reducing the city's ecological footprint by 33% over 2006 levels by 2020, as informed by Dr. Moore's research.

The ultimate objective is to achieve One Planet Living; and with respect to climate change, that means mitigating our emissions to the extent that we do not increase our planet's temperature more than 1.5 degrees Celsius.

> *One-planet living refers to a lifestyle that, if adopted by everyone, could be supported indefinitely by the regenerative capacity of Earth's ecosystems.*
>
> - *Wackernagel and Rees 1996*

CBEI and EF results highlight the need for the City, and other levels of government, to support a shift to a more sustainable pattern of consumption to achieve these goals. Specifically by:

- Expanding policies and regulations aimed at (1) influencing consumers and (2) ensuring that more sustainable options are available.
- Communicating the impact of purchasing decisions to residents, and encouraging their adoption of sustainable consumption behaviours.
- Lead by example through internal city leadership for example in sustainable purchasing.

Priority action areas identified by the ecoCity Footprint Tool results include:

- *Target the resource and climate impacts associated with food production and disposal.* For Vancouver, 48% of the EF and 20% of CBEI emissions are due to food consumption.
- *Decrease red meat and dairy consumption by substituting with legumes and white meat.* For Vancouver, red meat and dairy consumption is responsible for nearly 40% of the food component of the EF, and nearly 60% of food component of CBEI emissions.
- *Ensure that local food production has low resource intensity (in terms of fossil energy use and land area).* For Vancouver, 98% of the food footprint is associated with energy and land requirements, while transportation of this food represents only 2% of the food footprint.
- *Shift the focus from waste reduction to consumption reduction.* For Vancouver, 90% of the footprint associated with goods that we consume is due to production and transport, rather than use and disposal.
- *Reduce the consumption of paper and plastic,* which for Vancouver represent 58% of the EF and 51% of the CBEI associated with consumables and waste.
- *Reduce vehicle ownership and support this shift through effective land use planning,* use of which represents nearly three-quarters of both the ecological footprint and CBEI associated with transportation.
- *Move aggressively on the commitment to eliminate emissions from propane and natural gas usage in residential, commercial and institutional buildings,* which represents three-quarters of the ecological footprint and nearly 80% of the CBEI associated with buildings.

Potential Action Areas for City of Vancouver

High-level actions for each sphere of municipal planning are presented below, most of which are extracted from a companion report, prepared by One Earth: "Lighter Footprint Research Report" (Draft: 10 November 2017). It is recommended that the City review the results summarized in this report, and the proposed action areas presented in these two documents, to inform upcoming policy, planning and communication efforts. [*italicized items below are based on recommendations in the Lighter Footprint Research Report (One Earth, 2017), please refer to this report for more detail on these action items.]

Planning Sphere	Key Objectives	Instrument
FOOD	Reduce food waste Reduce meat and dairy consumption Obtain local data on food consumption impacts	· *Convene the highest impact groceries, restaurants, food services and retail in Vancouver to act on reducing wasted food by 50% by 2020, including by shifting the focus upstream towards prevention.* · *Embed requirements in City catering contracts that specify contractors to eliminate overproduction of food and reduce wasted food.* · *Develop and deliver a City-led communications and engagement program to accelerate resident food literacy as part of the national Love Food, Hate Waste campaign.* · *Actively participate in the National Zero Waste Council including in the Food Working Group to advance national action on wasted food.* · Promote sharing economy opportunities (e.g., community gardens). · Promote diet shifts (e.g., 'Meatless Mondays' Oregon; Celebrate the Harvest campaigns). · Adopt advanced purchasing standards (e.g., Emeryville Good Food Purchasing Program, EPA West Coast Forum on Materials and Climate's Climate Friendly Purchasing Toolkit).
BUILDINGS & INFRA-STRUCTURE	Increase efficiency (envelope 1st approach) Use building materials with lower embodied energy	· Implement government purchasing policies to favour recycled content/reused building materials. · Provide incentives for smaller and more energy efficient homes, and renewable technology incentives for homes and business. · Building codes that promote energy and material efficiency. · Connect additional houses to the district energy system. · *Support smaller houses development and co-housing initiatives.*

Planning Sphere	Key Objectives	Instrument
CONSUMABLES	Reduce the volume of individually owned goods Increase reuse	· *Work with partners to co-lead and deliver a Share Reuse Repair Lab.* · *Develop a consistent foundation for Share Reuse Repair through expanding dedicated City of Vancouver assets, resources and staff time for this sector.* · *Incorporate Share Reuse Repair incentives into economic and community development strategies.* · *Start a city-wide garage sale to celebrate Share Reuse Repair.* · *Continue to participate in the Textiles Leverage Lab and provide reuse, repair and recycling infrastructure for solutions such as a pop-up repair shop.* · Continue to support Vancouver's Green Bloc Neighbourhood Challenge. · Promote 'smart' buying practices – focusing on durability and buying fewer clothes (e.g., Oregon DEQ's Make Every Thread Count).
TRANSPORTATION	Reduce vehicle ownership Decrease vehicle travel Improve efficiency of vehicle fleet Better understand inter-urban transportation demand	· *Advance the Transportation 2040 strategy and accelerate the 66% walk, transit and cycling goal from 2040 to 2020* · Increase electrification of fleet. · Support and promote bike-sharing and car-sharing programs. · Continue to expand Active Transportation Initiatives. · Ensure neighbourhood plans contribute to compact urban development, smaller homes and walkable neighborhoods. · Undertake an 'Inter-urban' Transportation Demand Survey to gain a better understanding of residents out of boundary transportation habits (e.g., ferry, cruise, aviation).

City Initiatives

There are also overarching initiatives that the City can undertake to create a shift to more sustainable patterns of consumption, such as

- Update goal and target setting: consider adjusting GHG emission reduction goals to incorporate consumption-based emissions (e.g., Eugene, Oregon has developed science-based targets that used consumption-based emissions to set its "carbon budget", and a similar approach is being considered in Europe).

- Continue to integrate EF and CBEI results into reporting: include these results alongside the traditional territorial GHG emission inventory.

- Incorporate sustainable consumption principles into economic and community development strategies; for example, by implementing policies and bylaws that would attract low-carbon producers, promote work force development in the repair and reuse industries, and drive community investment in shared public goods such as arts, libraries, parks and recreation.

- Continue to use accessible framing, communications and metrics to advance sustainable consumption objectives as a means of engaging residents and businesses to shift to more sustainable consumption habits (e.g., 'One Planet Living' framing and metrics). Local governments are uniquely positioned to reach and influence these key stakeholders with the goal of building awareness, changing attitudes, and shifting consumption patterns.

- Support a community of action on Lighter Footprint by sharing information and facilitating and encouraging community leaders, i.e., by continuing Greenest City awards, community engagement activities, engagement of students through Greenest City Scholars and CityStudio.

- Engage with other levels of government to encourage and promote policies and regulations to shift to more sustainable patterns of consumption; in particular,

  - Design for the Environment practices that increase the longevity and reduce the resource intensity of products, and expand the potential for product reuse and recycling.

  - Product labelling to encourage the purchase of lower impact goods.

  - Expand extended producer responsibility programs to reduce waste disposal.

Additional Resources and Tools

Although the use of ecological footprint and CBEI results to inform community planning is a new and emerging area, there are some useful resources to guide governments and community builders in this work, for example:

USDN Sustainable Consumption Toolkit:

Launched in 2016, it includes a conceptual overview and a database of local actions. A refresh/update is planned for early 2018 (see: http://sustainableconsumption.usdn.org/)

Life Cycle Analysis studies:

The Oregon Department of Environmental Quality has produced several studies related to food and food-specific products such as wine and tomatoes.

Climate Friendly Purchasing Toolkit:

A resource for institutional purchasing from a consortium of west coast cities and states containing modules on many product categories such as IT, infrastructure, and food.

The Stockholm Environment Institute Working Paper: Reducing Greenhouse Gas Emissions Associated with Consumption: A Methodology for Scenario Analysis

Summarizes a methodology for constructing long-term scenarios of a transition to low-GHG consumption; and provides results of applying this methodology in Seattle, Washington (see: https://tinyurl.com/yaahjena).

NEXT STEPS

The BCIT project team is currently exploring opportunities to continue to refine the ecoCity Footprint Tool and to continue to work with the existing pilot communities.

Goals for the next phase of work are to:

- Roll-out an accessible version of the eF Tool, either via an online platform or in a downloadable format.
- Establish a peer exchange group consisting of the current pilot communities and future users of the Tool. This network will provide the opportunity to share in the learning of how the ecological footprint and CBEI results can be used to inform policy and planning at the municipal level.
- Continue to evolve the functionality of the eF Tool, including interactive scenario analysis capacity and adding capacity to enable the evaluation of the footprint impact associated with land use changes.
- Continue to partner with other actors to advance one-planet living in cities and globally.

APPENDIX A: LCA DATA FOR CONSUMABLES AND WASTE

The following presents the life cycle assessment data for the consumables by material type. This information is useful in targeting policy, planning and communication efforts to priority materials.

Table A-1 Life Cycle Assessment Data for Consumables by Material Type

Detail by Consumption	tCO2e/product	tCO2e	tCO2/t product	tCO2	LCA Factor	Embodied Energy Foot	LCA FACTOR	LCA FACTOR	Embodied Materials Footprint	Total LCA Factor	Footprint	
Paper		**30,829**		**30,829**	**energy**	**gha**	**materials-crops**	**materials-forests**	**gha**	**(gha/tonne)**		**gha**
Printed Paper	0.70	3,817	0.70	3,817	0.18	982		**1.29**	**7,034**	1.47	8,015.71	gha
News Print	0.85	932	0.85	932	0.21	231		**1.13**	**1,243**	1.34	1,474	gha
Cardboard and Boxboard	0.66	2,481	0.66	2,481	0.17	639		**1.47**	**5,527**	1.64	6,166	gha
Telephone Directories	0.70	-	0.70	-	0.21	-		**1.13**	**-**	1.34	0	gha
Other	0.70	23,598	0.70	23,598	0.21	7,079		**1.29**	**43,488**	1.50	50,568	gha
Plastic		**143,919**		**143,919**								
Film (bags)	3.38	53,487	3.38	53,487	0.85	13,439				0.85	13,439	gha
PET	4.93	4,669	4.93	4,669	1.23	1,165				1.23	1,165	gha
HDPE	2.92	2,896	2.92	2,896	0.73	724				0.73	724	gha
PVC	1.99	-	1.99	-	0.5	-				0.5	-	gha
Other	3.38	82,867	3.38	82,867	0.85	20,821				0.85	20,821	gha
Organic Waste												
Food waste (not to include in the EF)		-		-		-						
Yard and Garden		-		-		-						
Wood Waste	0.72	**5,048**	0.72	**5,048**	0.18	1,262		**0.41**	2,875	0.59	4,137	gha
Textile	15.00	**56,199**	15.00	**56,199**	3.76	14,087	**3.14**		11,764	6.9	25,852	gha
Rubber	6.37	**13,331**	5.42	**11,331**	1.6	3,346	**1.83**		**3,827**	3.43	7,174	gha
Other						-	**0.05**		**18**	0.05	18	gha
Metals		**19,811**		**16,839**								
Ferrous Food/Drink Packaging not Recycled	1.80	1,708	1.53	1,452	0.45	426				0.45	426	gha
Ferrous Other	1.80	98	1.53	83	0.45	24				0.45	24	gha
Non-Ferrous and Bimetallic	12.82	18,005	10.89	15,304	3.21	4,510				3.21	4,510	gha
Glass		**2,930**		**2,930**		-						
Food/Drink Packaging	0.65	1,215	0.65	1,215	0.16	304				0.16	304	gha
Other	0.65	1,715	0.65	1,715	0.16	422				0.16	422	gha
Household Hygiene		**59,001**		**50,150**		-						
Diapers	3.20	41,598	2.72	35,359	0.8	10,400	**0.36**		**4,680**	1.16	15,079	gha
Sanitary Napkins/Tampons	3.20	17,402	2.72	14,792	0.8	4,351	**0.36**		**1,958**	1.16	6,308	gha
Other	3.20	**9,301**	2.72	**7,906**	0.8	2,325	0.36		1,046	1.16	3,372	gha
Hazardous material Container	12.82	**43,768**	10.89	**37,203**	3.21	10,963				3.21	10,963	gha
Electronic waste	3.38	**6,678**	3.38	**6,683**	0.85	1,679				0.85	1,679	gha
TOTAL		390,815		354,450		**99,180**			**83,460**		182,640	gha

APPENDIX B: DATA COLLECTION METHODOLOGY

The following provides a detailed summary of the methodology and sources utilized in creating Vancouver's ecological footprint and GHG inventories. It also presents challenges and opportunities associated with the data collection process.

The following guidelines were applied when making decisions about data sources:

i) Accuracy: The goal is to achieve a high degree of accuracy, where accuracy is the degree of closeness to a measured value's actual value. (This contrasts with precision, in which the goal is to have measurements conform with one another.)

ii) Subsidiarity: Locally produced data is preferred, especially when local authorities trust the source's validity and use it to inform policies and management practices. Locally derived data reflect the nuance of the local community being profiled and can resonate more readily with local authorities who use these same data points to inform their work.

iii) Conservatism: In cases where two data sources equally meet the accuracy and subsidiarity criteria, the final decision is based on which data point represents a more conservative estimate. The purpose of this approach is to avoid overstating consumption amounts.

A detailed overview of the methodology by which ecological footprints are generated in the ecocity Footprint Tool are provided in Dr. Moore's thesis: Moore, Jennie Lynn (2013). Getting Serious About Sustainability: Exploring the Potential for One-Planet Living in Vancouver. A thesis submitted in partial fulfilment of the requirements for the Degree of Doctor of Philosophy, School of Community and Regional Planning, University of British Columbia. Available at: http://pics.uvic.ca/sites/default/files/uploads/publications/moore_jennie-UBC_0.pdf

Population

The number of people living in the municipality was based on the most recent census year (2016). In some cases, a ratio of the municipal population to the regional (Metro Vancouver) population was also required to allocate regional impacts to the municipality.

Sources

Statistics Canada. (Feb 8, 2017). *Census Profile, 2016 Census*. Retrieved from http://tinyurl.com/ydg48p58

Food

Evaluates the land area, materials, embodied and operational energy including for transportation of food from field to table. Food available is measured as a proxy for food consumption and import distances are used to estimate food-kilometers travelled. The energy associated with the production and transportation of imported food is then estimated.

Embodied Materials and Energy [Food]

Methodology

Food consumption was estimated using national Statistics Canada data from CANSIM Table 002-0011 which documents food availability per person by year (Statistics Canada, n.d.). Disaggregated food items are then organized into larger food groups to estimate average food consumption per-capita by food type. Life Cycle Assessment data from Dr. Moore's previous study (2013), which is built into the ecoCity Footprint Tool, is then used to determine the embodied energy of the food by type.

Sources

Statistics Canada. (n.d.). Table 002-0011: Food available in Canada, annual (kilograms per person, per year unless otherwise noted), *CANSIM.* Retrieved May 11, 2017, from http://www5.statcan.gc.ca/cansim/a47

Challenges and Opportunities

The biggest challenge concerning food consumption is the lack of readily available data sources since local governments typically do not track food-related data. Instead, national data from Statistics Canada was used to infer average consumption by food type. Accordingly, food consumption emissions and ecological footprints represent national averages rather than local profiles of the pilot cities.

However, City of Vancouver plans to undertake a localized food survey in Winter 2018, which will potentially be incorporated into the Metro Vancouver Food Waste Survey in 2019. It will be possible to use results from this survey to estimate local food consumption for the city and the region. City-specific food consumption data presents an opportunity to obtain improved statistics that represent each pilot city; but unfortunately, this is widely unavailable and still presents an overarching challenge.

Operating Energy [Food-Kilometers]

Methodology

To estimate distance travelled for Canadian food, a similar methodology was followed as outlined in Meidad Kissinger's *International Trade Related Food Miles – The Case of Canada* (2012). Data is obtained from the Canadian CHASS (Computing in Humanities and Social Sciences) *Trade Analyzer Database*. The database tracks Canadian import totals based on *Harmonized System* (HS) 10-digit merchandise codes by origin (country or US state) and province of clearance.

Distance Calculations

Two types of distances were considered, land and sea. Where available, road distances were used for North American destinations and more specifically, the distance between the most populous city in each province and state were used. Road distances were taken from online North American Mileage Charts whereas all other imports were assumed to be transported by sea. The *Sea Distance/ Port Distances* online tool, available on Sea-Distances.org, was used to calculate distances between sea ports. Where available, the most major sea port was used for each origin or destination. Inland countries' imports were assumed to be trucked to the closest major sea port and shipped by sea. Accordingly, inland countries without a major sea port used the distance to the closest sea port in a neighboring country.

Percent Imports by Destination

Canadian imports for the latest available year, 2013, was exported and organized into broader food categories to align with food consumption data. Based on the total quantity of imports, the percent of food imports by category and origin destinations was calculated. For example, 4.32% of Canada's total wine imports were imported from Australia into Ontario. A matrix of food category import percentages by origin and province of clearance was created.

Average Food-Kilometers

An average food kilometer value was determined for each specific category, separated by road and by sea, using a weighted average. Each individual import percentage by food category, destination, and origin, was multiplied by the respective road or sea distance. Using the same example as above, the percent of total wine imports from Australia to Ontario was multiplied by the assumed sea distance (20 618 kilometers x 4.32% = 866 kilometers). The sum of each food category's distances by destination and origin was taken as the average food-kilometers distance.

Percent Scale for Imports

With an average import distance for food categories calculated, a percent import scale factor was applied which averaged out the imported sea and road distances across the entire food category population. Percent imports were calculated by analyzing data from *CANSIM Table 002-0011*, which documents the imports and total supply for food categories by year (Statistics Canada, n.d.).

Total Kilometers Calculation

Finally, the average food distance per food type was multiplied by the total food consumption recorded in the Embodied Energy [Food] subsection. Since the most recent available data year was 2013, the CHASS *Trade Analyzer Database* exports were used to estimate an average food-kilometer for each food category, which was then multiplied by total food imports to generate tonnes-kilometers per food type. These totals are then multiplied by emission factors for CO_2e per tonnes-kilometers by sea and truck to estimate total emissions.

Sources

Kissinger, M. (2012). International trade related food miles: The case of Canada. *Food Policy, 37*(2), 171-178. doi:10.1016/j.foodpol.2012.01.002

Mileage-Charts. (n.d.). Retrieved August 2017, from http://www.mileage-charts.com/chart.php?p=index&a=NA

SEA-DISTANCES.ORG. (n.d.). *Sea Distance/ Port Distances.* Retrieved September 2017, from https://sea-distances.org/

Statistics Canada. (n.d-a). Table 002-0010: Supply and disposition of food in Canada, annual (tonnes unless otherwise noted), *CANSIM*. Retrieved on September 17, 2017, from http://www5.statcan.gc.ca/cansim/a47

Statistics Canada. (n.d.-b). Table 002-0011: Food available in Canada, annual (kilograms per person, per year unless otherwise noted), *CANSIM*. Retrieved May 11, 2017, from http://www5.statcan.gc.ca/cansim/a47

Weber, C.L., Matthews, S.H. (2008). Food-miles and the relative climate impacts of food choices in the United States. *Environmental Science & Technology*, *42*, 3508–3513.

Challenges and Opportunities

Similar to food consumption, the biggest challenge concerning food-kilometers is the lack of readily available data sources. Quantifying food-kilometers can be difficult, and relies on the combination of several data sets to produce estimates. National Canadian import data was used to approximate average, representative distances for the entire food category which limits insights from food-kilometers to a national scale.

Using Canadian imports sorted on the 10-digit HS system, we were able to quantify imports and their origins and destinations at a granular level. Some of the fine-grained food-related items may not be associated with consumption (for example, wheat for sowing). It is assumed that the transported distances for food items are similar between food for consumption and production.

Another challenge was that this methodology only considers road and sea distances. Although the majority of food imports are by truck and sea, it is estimated that 7% of imports are by train (Kissinger, 2012). The associated emissions with air travel are significantly higher than those associated with truck or sea distances (Weber and Matthews, 2008) For this reason, air imports should be considered in food calculations even though they represent a small portion of total food imports.

Averaged road and sea distances for Canadian imports are scaled by percent import factors for each food category. This scaling to determine overall average distances introduces uncertainties in the last step of distance calculations.

The methodology only considers imported food distances whereas domestic food-kilometers between provinces and cities are not calculated; however, these distances and their associated emissions are partially included in the Transportation portion of the ecoCity Footprint Tool.

Buildings and Stationary Energy

Evaluates the materials, embodied and operational energy; and the built area associated with residential, industrial and commercial buildings in order to establish a material-flow analysis, assess the direct and embodied carbon, and evaluate the ecological footprint of buildings.

Embodied Materials and Energy [Buildings and Stationary Energy]

Methodology

The number of commercial, institutional and residential buildings as well as an estimated composition of each building type are required to evaluate the embodied materials and energy associated with the building stock. Residential units are divided into categories depending on building types (e.g., single family detached house, apartment, etc.). Commercial and industrial buildings are differentiated based on height as this is a significant indicator of their material composition.

The ecoCity Footprint Tool contains calculations and assumptions to derive the embodied materials and energy associated with the total materials contained within the buildings, which were developed through Dr. Moore's original ecological footprint study of the City of Vancouver, and are summarized in Dr. Moore's 2013 thesis. Specifically, for a prescribed set of building archetypes, building material composition is assigned while average lifespan and floor area can be altered to reflect local conditions.

The material composition estimates were derived using the Athena Impact Estimator for Buildings Tool. The archetypes created for the Vancouver 2013 study have been used in this inventory, as they are not likely to have changed significantly since the previous study. The average lifespan of buildings was assumed to be 40 years for residential buildings and 75 years for institutional/commercial buildings'.

Sources

National census data provides a detailed count of housing units. Most physical infrastructure data, including the number of commercial buildings, was available in GIS files through the engineering department.

Statistics Canada. (Feb 8, 2017). *Private Dwellings Profile, 2016 Census.* Retrieved from http://tinyurl.com/y82sb66z.

Moore, J., Kissinger, M., & Rees, W. E. (2013) An urban metabolism and ecological footprint assessment of Metro Vancouver. *Journal of Environmental Management, 124*, 51-61.

Operating Energy [Buildings and Stationary Energy]

Methodology

To calculate operating energy, data is required on the annual consumption of electricity, natural gas, and other heating fuels; broken down by sector. Energy lost through transmission and fugitive emissions is also collected or estimated. Carbon footprints are then calculated using provincially specified emissions factors.

Stationary Energy and Transmission Loss

Stationary energy-use data for Vancouver was collected from three main sources, BC Hydro, FortisBC, and existing reports on other fuels used in heating. BC Hydro's estimated transmission loss rate of 7.5% was applied to account for emissions associated with electricity transmission losses (Equation 1).

$$\text{(total energy in MWh) x (0.075) = energy loss through transmission} \quad (1)$$

$$\text{Where total energy in MWh = (energy used in boundary) / (0.925)} \quad (2)$$

Fugitive Emissions

Fugitive emissions estimates for Vancouver were obtained from the City's 2015 GPC GHG emission inventory.

Sources

Most operating energy data, including energy losses, fugitive emissions, and emissions intensity of electricity in BC, was available from energy utilities such as BC Hydro and FortisBC. Unfortunately, energy types like propane, and wood are not centralized and therefore their energy data must be either collected by a municipality or estimated using past studies. This study relied on data from Vancouver's GPC inventory, which obtained data from the Province of BC's Community Energy & Emissions Inventory (CEEI) to estimate energy and emissions associated with propane, and wood fuel use.

City of Vancouver's 2015 GPC Inventory

BC Ministry of Environment. (2016). *2016/17 B.C. best practices methodology for quantifying greenhouse gas emissions: Including guidance for public sector organizations, local governments and community emissions*. Retrieved from http://www2.gov.bc.ca/assets/gov/environment/climate-change/cng/methodology/2016-17-pso-methodology.pdf

Built Land Area [Buildings and Stationary Energy]

Methodology

Built area includes all non-road areas that have been paved for parking or built-up for residential, industrial, and commercial use. Estimates of built area of by sector were obtained from Metro Vancouver's Generalized Land Use by municipality fact sheet. Estimates of naturalized areas were obtained from City of Vancouver's biodiversity strategy.

Sources

Street area was obtained from municipal GIS available online

Metro Vancouver's 2011 Generalized Land Use by Municipality, by Metro Vancouver Policy, Planning and Environment on June 8, 2016.

Vancouver Biodiversity Strategy 2016, p. 15.

Consumables and Waste

Evaluates the materials, embodied energy and embodied materials, and land area associated with the production and disposal of products in the municipal waste stream.

Data is collected on:

- the type and quantity of solid and liquid waste generated in the greater Vancouver area by sector (residential, industrial, commercial and institutional) and by material type;
- the method in which these materials are managed (i.e., landfilled, incinerated, recycled or composted);
- the energy consumption and emissions associated with the waste management facilities, and the transportation of the waste; and
- the material composition and built area associated with waste management facilities.

The embodied energy of materials involved in the operation and delivery of waste is also included as an indirect impact of waste production.

The various outputs draw from different components of this data set:

- The GPC inventory includes direct GHG emissions associated with handling solid and liquid waste.
- The Consumption-Based Emission Inventory (CBEI) includes the embodied emissions associated with the production and transport of the materials that were consumed as represented by the disposed materials. It also includes the direct emissions associated with disposing the waste stream, but does not include the impact of the recyclables stream as this would be captured within the LCA of the consumed goods; which would result in double counting of impacts.
- The ecological footprint includes the CBEI emissions plus the impact of the built area associated with handling the waste stream.

Embodied Materials, Embodied Energy and Operating Energy [Consumables and Waste]

Methodology

Solid waste data is collected disaggregated by sector, material type, and destination (i.e., landfill, recycling, or composting). The Metro Vancouver Annual Report and Waste Composition Report for 2015 contain the total tonnage for the metro region and the breakdown of waste by source type (single- and multi-family residential, demolition, ICI) as well as by material type. These numbers were prorated by Vancouver's percentage of the metro population. While there was more local data available, it was not consistent with the total flows for the region and was therefore considered less reliable or less complete than the regional data.

Recycling tonnages data came from the Metro Vancouver Recycling and Solid Waste Management Annual Report for 2015. Compostion of the recyclable stream was based on regional averages, as presented in Metro Vancouver's Waste Composition Report for the same year.

Emissions associated with landfilling and composting were obtained from Vancouver's GPC Inventory for 2015.

The embodied materials and energy of consumables, meaning the material and energy used in the production and supply chain, is estimated using lifecycle assessment data that is built into the Tool.

Operating energy at the Vancouver South Transfer Station, Vancouver Landfill, and the WTEF at Burnaby was prorated based on Vancouver's percentage contribution to these sites for 2015. The North Shore Transfer Station, Cache Creek, and the Vancouver South Recycling Depot were not included due to lack of available data and the relatively small size of flows at these facilities attributable to the City of Vancouver.

Volume flows of liquid waste are used to calculate direct emissions from the liquid waste stream and material composition of facilities is used to calculate the embodied energy of this infrastructure. Data on the volume of liquid waste was available through the 2015 Greater Vancouver Sewerage and Drainage District Environmental Management and Quality Control Annual Report. City of Vancouver estimates that the proportion of waste treated at the Iona wastewater treatment plant that is attributable to City of Vancouver is 90.7%.[15]

The material composition of facilities, and the sanitary sewer and storm drain pipes was obtained from the 2011 ecological footprint assessment results, as they were assumed to have not changed since 2011.

Sources

Metro Vancouver Recycling and Solid Waste Management 2015. pdf.

Tetra Tech. 2015 Waste Composition Monitoring Program. Pdf. Jan 2016.

City of Vancouver GPC Inventory 2015. Excel spreadsheet.

WTEF Environmental Monitoring and Reporting, 2016 Update, doc July 7, 2017

[15] Personal communication, Lloyd Lee, City of Vancouver (email dated August 4, 2017)

Multi-Material BC. (2015). *Annual Report 2015.* Retrieved on July 2017, from https://Recycle BC.ca/wp-content/uploads/2017/02/MMBCAR2015.pdf

Challenges and Opportunities

Recycle BC, the province-wide recycling agency that handles collection of recyclables across the Province, is unable to provide composition data for recycled materials. The agency is currently reviewing its data collection and sharing protocols and if municipalities begin to express interest in the material composition of their recycled materials it is possible Recycle BC will make that data more widely available. The Province is currently re-negotiating its contract with Recycle BC so there is now an opportunity to request making the provision of this data a requirement in the contract renewal.

*Solid and Liquid Waste Built Area [*Consumables and Waste]

Methodology

Total area committed to landfilling, as well as that used for recycling transfer stations, was obtained from GIS files or directly from facilities operators. Built area data was readily accessible through GIS and staff resources. In-boundary waste transfer stations were not included in this data, partly because the data is spread out over a number of private contractors and partly because the surface area would be included in our estimates of paved surfaces. The area of the Recycle BC facility was also not included in this study as the facility serves all of BC and Vancouver's contribution would have been relatively minor.

Facilities included outside of Vancouver's boundary are the Vancouver Landfill, Cache Creek Landfill, Waste to Energy Facility (WTEF) in Burnaby, and the Coquitlam Resource ReCity of Vancouver plant.

Sources

Transfer & Landfill Operations Branch, City of Vancouver Engineering Services. Vancouver Landfill 2015 Annual Report (March 2016). Pdf.

Golder Associates. 2015 Annual Report Cache Creek Landfill, Cache Creek, BC (March 31, 2016). Pdf.

Challenges and Opportunities

In future, tracking in-boundary waste and recycling transfer stations may be of interest.

Transportation

Evaluates the embodied materials and embodied energy of physical transportation infrastructure and vehicles, operating energy (fuel consumed by vehicles), and physical built area occupied by transportation infrastructure.

Embodied Materials and Embodied Energy and Built Area [Transportation]

Methodology

Built area for transportation includes road length and paved right-of-way width. The quantity of roadway and the road material composition is used along with LCA data to evaluate the embodied energy of transportation infrastructure. Road land area was calculated based on road lengths available from the City of Vancouver GIS data. Railway lengths were also obtained from the same source. GIS data indicated road length only; widths used to calculate area were based on assumptions of lane width standards and guidelines by the City. Material composition was based on data from the 2011 ecological footprint assessment.

Sources

City of Vancouver GIS data available online

Challenges and Opportunities

Large portions of city surfaces are paved, yet their surface materials are not consistently, uniformly, or currently listed and tracked across jurisdictions. As previously mentioned, paved or impermeable surfaces represent a loss of important ecosystem services, represent a significant source of CO_2, and even reduce the esthetic qualities of an area.

Operating Energy [Transportation]

1. Road Transportation

Methodology

Private and Commercial Vehicles

Data requirements included Vehicle Kilometers Traveled (VKT), number of vehicles per class, average mileage for each vehicle class, and emissions factors for each vehicle class.

Data for 2012, including VKTs, was available through the Province of BC's CEEI. Average VKTs were multiplied by the total number of vehicles and average fuel consumption for each vehicle class.

Transit

Intraurban diesel rail was calculated using rail length from City of Vancouver GIS data and emissions were obtained from Metro Vancouver's 2010 GPC emissions models, forecast for 2015. Bus emissions (non-electric) came from the 2012 CEEI.

Off road vehicles

Emissions from off-road equipment (non-road pleasurecraft) for Port Metro Vancouver came from the Metro Vancouver 2010 Emissions Inventory, forecast by MV for 2015. The MV total was then apportioned by population to estimate use within city boundary.

Sources

Private Vehicles

The 2012 CEEI provided the number of vehicles, energy used, and VKT by vehicle type for the City of Vancouver.

Transit Data

Railway length was obtained from City of Vancouver GIS data available online.

Emissions factors came from the City's 2015 GPC inventory and are based on the 2014 BC Protocol for quantifying GHG emissions (Table 7).

Challenges and Opportunities

All pilot municipalities had difficulties collecting data on road transportation. Up-to-date ICBC data was difficult to access and VKT data is no longer being collected since the elimination of the AirCare Program. Several BC municipalities are now exploring digital options for calculating VKTs which could lead to more robust emissions calculations in the future.

2. Marine Transportation

Methodology

Marine transportation includes private vessels, passenger ferries, and cruise ship activities. Private vessel emissions require an estimate of the number of vessels registered and owned by residents of each municipality and their annual fuel use. Emissions are then calculated using the total amount of privately used fuel and emissions factors for marine gasoline and diesel. In this study, commercial vessel emissions calculations are similar. However, fuel use should be amortized based on the total population using the service and based on emissions factors specific to large marine diesel engines.

For Vancouver, commercial vessel data and analysis was retrieved from the CEEI and Metro Vancouver 2010 Emissions Inventory. The MV total was then apportioned by population to estimate use within the city boundary.

BC Ferries data was also limited. Information on passenger origin and destination was not available and subsequently, it is extremely difficult to allocate ferry use to any one region or population especially given the significant tourism use of the BC ferries service. Total fuel use was not available, and so a portion of the emissions was allocated based on Vancouver's proportion of BC's population.

Sources

Metro Vancouver 2010 Emissions Inventory, by Shelina Sidi at Metro Vancouver, forecast by MV for 2015. Excel spreadsheet.

Challenges and Opportunities

Public and private non-commercial waterborne transportation was not included due to lack of available information. The City of Vancouver does not claim waterborne vehicular emissions in its reports, though there is such activity in the city.

3. Air Travel

Methodology

Vancouver residential air travel was estimated using average per-capita values for Metro Vancouver based on a modified methodology described in *A Greenhouse Gas Emissions Inventory and Ecological Footprint Analysis of Metro Vancouver Residents' Air Travel* (Legg et al., 2013). These per-capita factors were multiplied by each pilot city's population to estimate greenhouse gas emissions.

Air travel data was provided by the Vancouver International Airport (YVR) organized by destination. The total number of inbound and outbound flights were sorted into four categories:

1. International
2. International – United States
3. Domestic – Flights within Canada
4. Commuter – Flights within British Columbia

Seat Class

YVR provided the total number of seats per flight. Where available, a breakdown of seat classes was provided. Using these numbers, average factors for seat class breakdowns were generated based off of flight type (International, International – United States, and Domestic) and plane size (total seats). These factors were then used to estimate the number of seats by class for flights that did not provide disaggregated seat data.

Average Load Factor

Since YVR does not collect passenger numbers per flight, average flight load factors were applied to the total number of seats per flight to estimate passenger movements. Based on YVR estimates, their average load factor in 2015 was 82%. For reference, this load factor was compared to national averages for major Canadian airlines listed as Level IA, which means the airline's transported passenger revenues were at least ten million. Air Canada's 2015 load factor was 84%, and WestJet's 2015 load factor was 80% (Statistics Canada, 2016).

Distance and Emission Calculation

The Great Circle Distance was used to estimate flight distances to and from each destination using the World Airport Codes web tool. For cities with multiple airports that did not specify the specific airport, the largest airport for the city was used. These flight distances were then multiplied by the number of passengers by seat class per destination to estimate total passenger-kilometers by flight and seat classification. Then, air emission factors based on flight distance and seat class from the United Kingdom Department for Environment, Food & Rural Affairs (UK DEFRA) were applied to convert passenger-kilometers to tCO_2e (UK DEFRA, 2016).

Metro Vancouver Residential Scale Factor

Finally, a load factor of 0.20 was used to scale YVR's total flights for Metro Vancouver Residents. YVR demographic analysis from 2015 indicates that approximately 20% of flights are attributable to Metro Vancouver residents (J. Aldcroft, Manager, Environment, YVR, personal communication, August 22, 2017). Total residential emissions were divided by Metro Vancouver's population to generate per-capita air emission averages, which are multiplied by the population for each pilot city to estimate tCO_2e associated with residential air travel.

Sources

Metro Vancouver 2010 Emissions Inventory, by Shelina Sidi at Metro Vancouver, forecast by MV for 2015. Excel Spreadsheet.

Legg, R., Moore, J., Kissinger, M., & Rees, W. (2013). A greenhouse gas emissions inventory and ecological footprint analysis of Metro Vancouver residents' air travel. *Environment and Pollution, 2*(4). doi:10.5539/ep.v2n4p123

Statistics Canada. (n.d.). Table 401-0043: Operational statistics for major Canadian airlines, level IA, by airline, monthly*, CANSIM.* Retrieved on October 14, 2017, from http://www5.statcan.gc.ca/cansim/a47

UK DEFRA. (June 2016). Greenhouse gas reporting: Conversion factors 2016. Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/526958/ghg-conversion-factors-2016update_MASTER_links_removed_v2.xls

Challenges and Opportunities

These estimates are limited by four main constraints.

YVR can only provide flight data to and from flights based off their first destination. This overlooks air emissions associated with Metro Vancouver residents on connecting flights, which is represented in the final results. For example, domestic flight emissions represent 32.4% of total air travel emissions, while international flights (excluding to the United States) account for 39.8% of air travel emissions. A number of these domestic flights are much more likely to be flights to Canadian cities connecting to international destinations, and as such the second leg of air travel is not estimated.

Second, these estimates do not account for Metro Vancouver residents who may drive to and from other airports (Bellingham, WA and Abbotsford, BC) for outbound and inbound flights. With high volumes of air traffic served by YVR, this may not represent a significant omission, but it does present an area for future research and consideration.

Third, the introduction of the 82% average flight load factor and 20% scale for residential emissions introduces scaling uncertainties into the last points of emission calculations.

Water

Evaluates the materials, embodied energy, operating energy, and built area impacts of the water purification and distribution system relied on by the municipality.

Embodied Materials and Energy [Water]

Methodology

Pipe length and material composition of pipes were obtained directly from Jen Bailey at the City of Vancouver. Total volume of water also came from the City. Reservoir land area, road area and pipes data were obtained from Metro Vancouver for the 2011 assessment. The water treatment materials of interest for embodied energy calculations include the length and material composition of pipes, the number of pump stations used for distribution, water catchment infrastructure (including intakes, tunnels, and dams), and access roads used to access the watershed area. Lastly, the total volume of water available through the reservoirs, as well as daily demand on those reservoirs, is important for material flow accounting.

The ecoCity Footprint Tool has built-in assumptions established from previous research (Moore, 2013) that enables the calculation of the embodied energy of materials utilized in the water system infrastructure.

Sources

Bailey, Jen at the City of Vancouver. Personal email communication.

Operating Energy [Water]

Methodology

Operating energy data was obtained from Metro Vancouver and pro-rated based on Vancouver's level of consumption.

Sources

Metro Vancouver staff (Conor Reynolds)

Built Area [Water]

Methodology

Area calculations for the watershed included roads (length and width) and protected area and reservoir area were obtained from the Metro Vancouver factsheets. Areas for associated buildings, and dams were obtained from the previous research data from 2011.

Sources

Metro Vancouver's 2011 Generalized Land Use by Municipality, by Metro Vancouver Policy, Planning and Environment on June 8, 2016

2011 ecoCity Footprint assessment.

IPPU and AFOLU

Industrial Products and Pollutants (IPPU) and Agricultural, Forest, and other Commercial land uses (AFOLU) are important dimensions of a GPC compliant BASIC+ inventory. The ecological footprint and CBEI output however does not include these sources, as energy use and emissions from these sectors are already captured in the evaluation of consumables and waste.

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[i] WWF (World Wide Fund for Nature). (2014). *Living Planet Report.* Gland Switzerland: World Wide Fund for Nature. Retrieved from: http://wwf.panda.org/about_our_earth/all_publications/living_planet_report/ (accessed on 12 November, 2015).

[ii] Rockström, J., et.al. (2009). Planetary boundaries: exploring the safe operating space for humanity. *Ecology and Society,* 14(2): 32. Retrieved from: http://www.ecologyandsociety.org/vol14/iss2/art32/ (accessed on 5 October 2015).

[iii] Wackernagel, M. and W. Rees. (1996). *Our Ecological Footprint: Reducing Human Impact on the Earth.* Gabriola Island BC: New Society Publishers. Retrieved from: http://cdn1.footprintnetwork.org/Living_Planet_Report_2014_summary.pdf (accessed on 26 October 2015).

[iv] WWF (World Wide Fund for Nature). (2014). *Living Planet Report.* Gland Switzerland: World Wide Fund for Nature. Retrieved from: http://wwf.panda.org/about_our_earth/all_publications/living_planet_report/ (accessed on 12 November, 2015).