

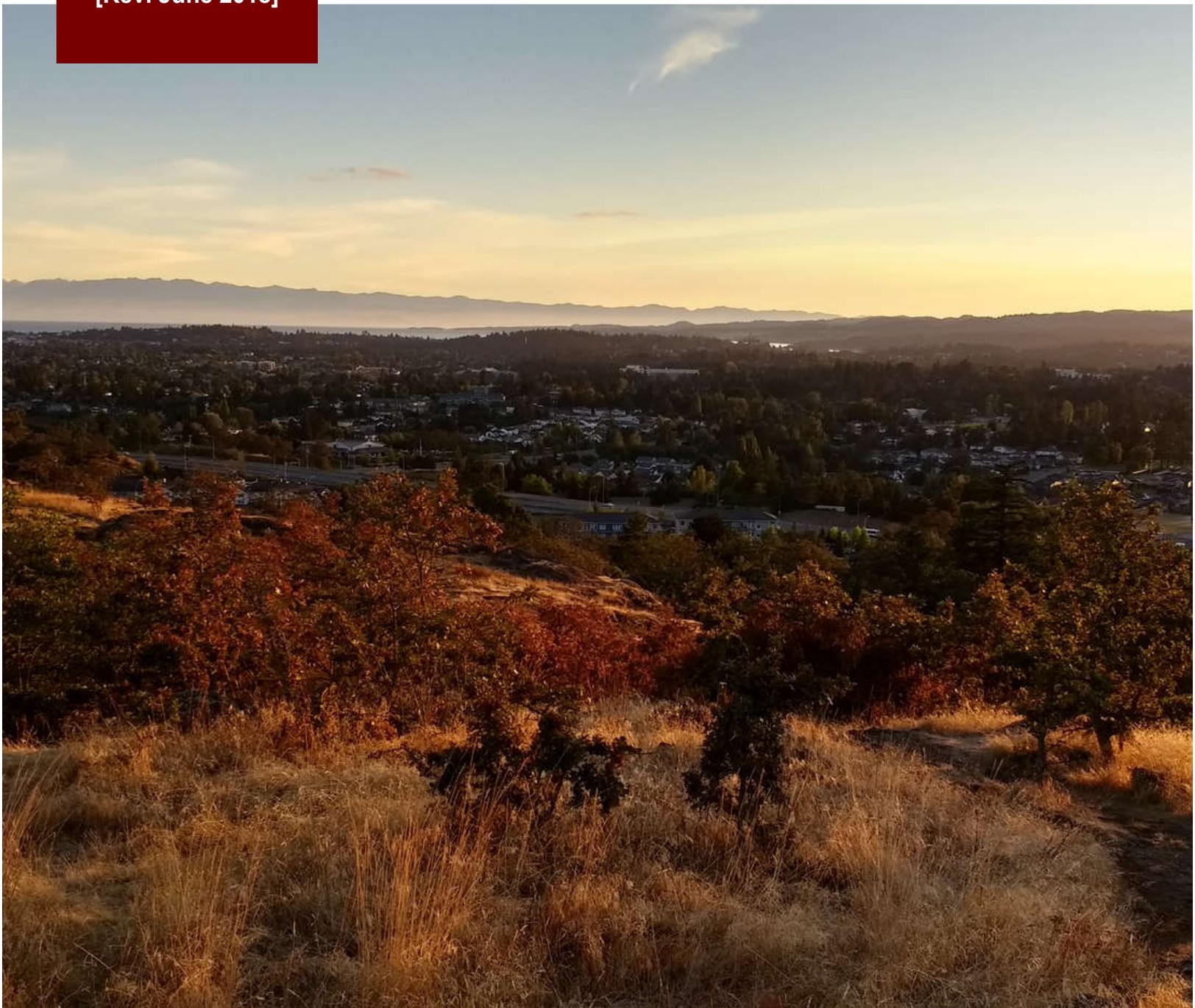
**DISTRICT OF
SAANICH**

**SUMMARY
REPORT**

**JANUARY 2018
[Rev. June 2018]**

ecoCity Footprint Tool Pilot

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



**FUNDED BY THE USDN
INNOVATION FUND**

PREPARED BY:



SUMMARY

In 2017, with funding from the Urban Sustainability Directors Network (USDN), BCIT and its partners pilot tested the ecoCity Footprint Tool (eF Tool) with five USDN members— District of Saanich, City of Victoria, City of Vancouver, City of North Vancouver, and Iowa City (US). The District was interested in this project because of its potential to inform and contribute to climate and sustainability planning efforts.

This *Summary Report* presents the results of Saanich’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 in 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 Saanich’s ecological footprint and consumption-based emission inventory results for 2015.

Ecological Footprint Assessment

The ecological footprint 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. It 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 global hectares is available for each person on the planet.

Results show that Saanich’s *per capita* footprint is 3.3 gha/person.¹ This means Saanich 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 Saanich resident.

Planets
Required by
Saanich

2.0



Territorial GHG Emission Inventory and Consumption-Based Emission Inventory

The Consumption-Based Emissions 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

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

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 Saanich are 881 kilotonnes of carbon dioxide equivalent (ktCO₂e), approximately double that of the territorial GHG emissions (see Figure 1).

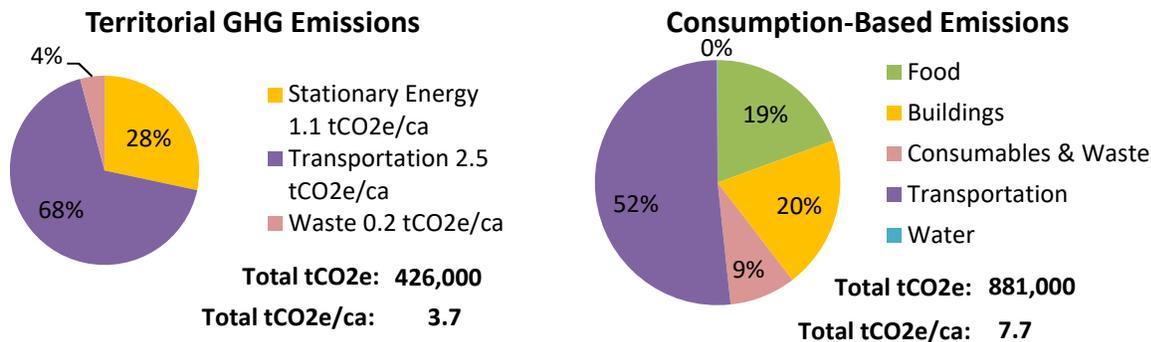


Figure 1: Comparison of Saanich's 2015 Consumption-Based and Territorial GHG Emissions

Inventory Highlights

- For the CBEI, the largest impact category is transportation followed by buildings; whereas for the EF, the largest impact category is food followed by transportation. Food impacts are the area in which these results vary most significantly. Food is a much higher portion of the CBEI, compared to 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 three-quarters of the food impacts are a result of animal proteins, particularly red meat and dairy products.
- Similar to the ecological footprint (EF), nearly three-quarters of the CBEI for food is a result of animal proteins and dairy. 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 Saanich'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 District of Saanich'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 Textiles and paper are a significant component of the consumables and waste footprint.
- The CBEI for consumables shows that the largest GHG impact is due to wood waste, textiles, and rubber. However, in contrast to the EF, consumption-based emissions are higher from plastics; and much less for paper. 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, in particular paper and textiles.**

TRANSPORTATION

- More than half of Saanich's transportation footprint is a result of fuel consumption for private vehicles, and adding the embodied energy of vehicles, private vehicle transportation represents two-thirds of the footprint. Similar to the EF, about three quarters of the consumption-based emissions for transportation are associated with private vehicle travel.
 - ↳ **A near-term priority is to continue to electrify the vehicle fleet (including the transit vehicle fleet); and to reduce the number of vehicles on the road by promoting active transportation, transit,³ 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 to promote compact communities that are designed for active transportation and transit.**

THE SUSTAINABILITY GAP

To achieve 'One Planet Living' Saanich's ecological footprint, as estimated with the ecoCity Footprint Tool⁴, would need to reduce from 3.3 gha per capita (including national and provincial services)⁵ to 1.7 gha per capita. This is a sustainability gap of 48% (see Figure 18). From a climate perspective, to achieve the target of maintaining global temperatures below a 2 degree Celsius in warming, GHGs must be reduced to 2 tCO₂e per capita. Given Saanich's current CBEI per capita emissions of 7.7 tCO₂e, GHG emissions would need to be reduced by 74%; and based on the GPC per capita emissions of 3.7 tCO₂e, they would need to be reduced by 46%.

This report presents a proposed One Planet Scenario, as an example of how Saanich could reduce its total ecological footprint to 1.7 gha per capita. It also presents a set of example policy and planning interventions to help close this sustainability gap.

² Operating energy for waste management facilities was not available, as discussed in Appendix A: Methodology, but would be negligible compared to the embodied energy and embodied materials impacts.

³ Promoting transit use over private vehicle use will shift a significant portion of the current emissions to transit, therefore it is particularly important to electrify the transit vehicle fleet.

⁴ As noted in the methodology, the bottom-up approach employed in the ecoCity Footprint Tool results in an underestimate of the footprint

⁵ Excluding national and provincial services Saanich's footprint is 2.8 gha per capita.

Acknowledgements

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Acronyms

AFOLU	Agricultural, Forest, and other Commercial Land Uses
BCIT	British Columbia Institute of Technology
CBEI	Consumption-Based Emission Inventory
CLP	Climate Leadership Plan
CMA	Census Metropolitan Area
CRD	Capital Regional District
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
tCO ₂ e	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 ₂ e	Carbon dioxide equivalent (CO ₂ e) expresses the impact of each 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.
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.
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.
Urban Metabolism	A study of the flow of energy and materials through the urban system.
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).

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 this eF Tool was used by the City of Vancouver. 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).

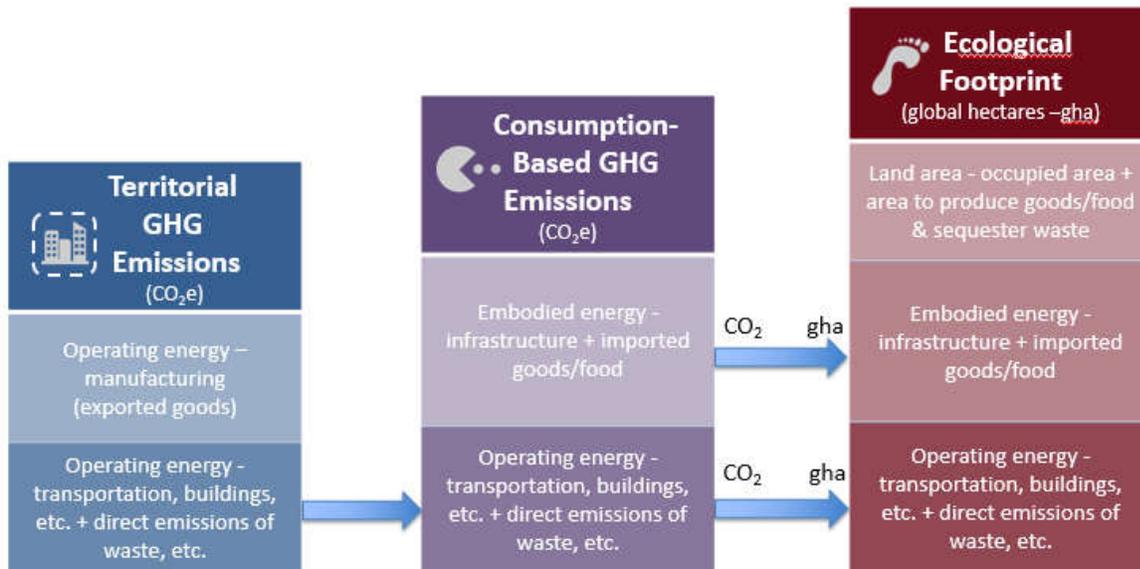
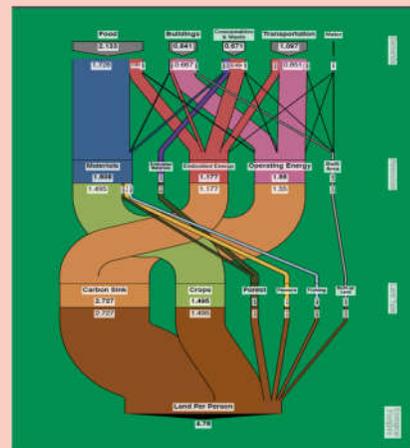


Figure 2 Comparison of the GHG Emission Inventories and Ecological Footprint Approaches

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 3, 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 a municipality 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.

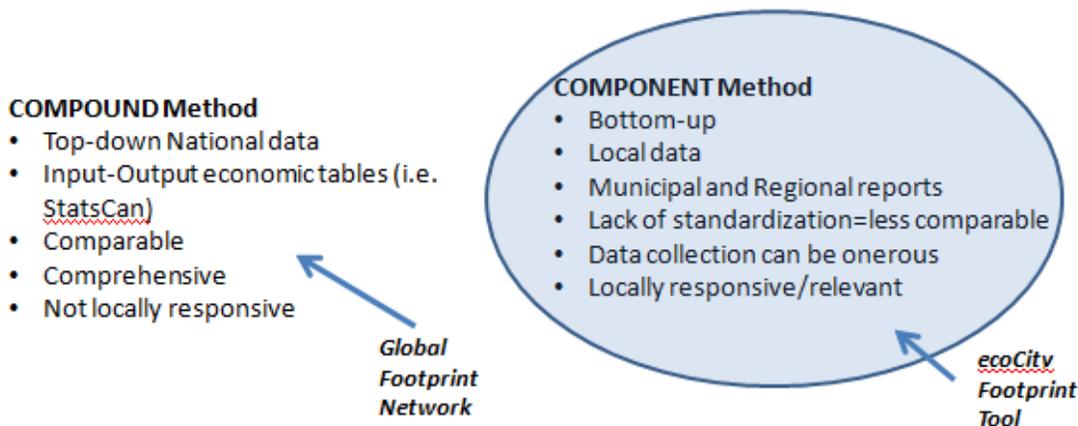


Figure 3 Two methods for calculating the Ecological Footprint

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– District of Saanich, City of Victoria, City of Vancouver, City of North Vancouver, 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 SAANICH

The District of Saanich was interested in this project because of its potential to inform and contribute to climate and sustainability planning efforts. The District is currently in the midst of renewing its climate-action planning efforts. The most recent Climate Action Plan (2010) contains GHG emission reduction targets for the community and for municipal operations (33% and 50% from 2007 levels by 2020, respectively).^v More recently, the District announced its commitment to using 100% renewable energy by 2050.^{vi}

Municipal Context

The District of Saanich expands across an area of about 110 km² (11,000 hectares) near the southern tip of Vancouver Island, and is within the Victoria Census Metropolitan Region. About half of its total area consists of urban development and the other half is rural, much of which is used for agricultural purposes. With a population of 114,000, Saanich has the largest population of the communities comprising the greater Victoria region (the region has a total population of 368,000).^{vii}

The District has a relatively moderate climate with summer highs at 23°C and winter lows of 2°C.^{viii} Heating is provided by a mix of electric baseboard, heat pump, natural gas, heating oil, and wood. Electricity is supplied by BC Hydro, 98% of which is from renewable hydro power. Natural gas is supplied by FortisBC and there are many distributors of home heating oil.

Saanich hosts the region's two largest institutions, Camosun College and half of the University of Victoria. Annually, the university enrolls 20,000 students.^{ix} Other major economical contributors are the tourism industry (\$1.19 billion), advanced technology industry (\$317 million), agriculture, government, oceans and marine space through the Victoria shipyard, construction, retail, and healthcare and retirement.

Saanich is a transportation hub to neighbouring areas with both major highways of the region passing through its borders. About 80% of public transportation is out of district travel with only 20% accounting for in-district travel. The majority of busses operating in the community are diesel-powered along with a few gas-powered buses. Plans are being developed to transition to a fully electric bus fleet by 2030.^x Currently, walking and biking make up 11% of total travel trips. The District of Saanich is aiming to increase active transportation rates to 22% by 2036 and to increase total trips on public transit from 7% to 14%.^{xi}

Approximately half of residents live in single-detached dwellings and half live in higher density dwellings such as apartments, row houses, or semi-detached homes.^{xii} Of these dwellings, the majority are shorter than five stories and made with wooden frames, and less than 1% of dwellings are taller, concrete-framed buildings. Saanich has numerous successes to build from. The Carbon Fund created by Saanich in 2007 was the first of its kind in North America.^{xiii} Each department contributes \$25 /tCO₂e^{xiv} to provide consistent funding for carbon-reducing projects in the municipality. Saanich also launched a composting program in 2014, called the Greener Garbage Collection, that has diverted over 50% of waste from landfills.

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 4). 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.

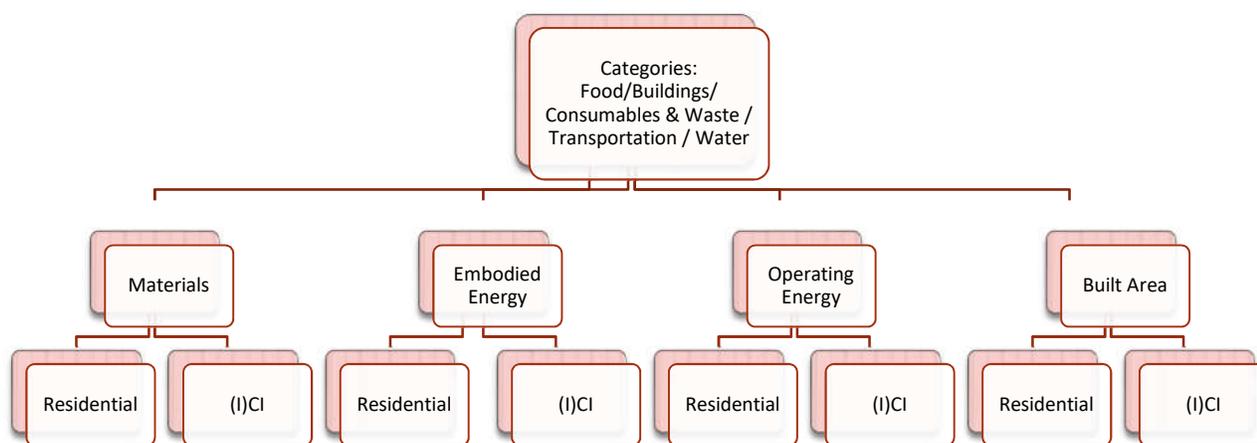


Figure 4: Data Inputs⁶

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 A.

⁶ (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 <i>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.</i>	Embodied energy and materials associated with food production (energy and materials used to produce and transport food)	✓	✓	x	<ul style="list-style-type: none"> Food consumption and 'food miles' statistics were not available at the local level; therefore national averages were used as a proxy. Vancouver is conducting a food survey this winter to derive local food estimates. Results from this study could be used as a proxy at a later date; or a similar survey could be conducted in the CRD.
	Land used to produce food	✓	x	x	
Buildings and Stationary Energy <i>The embodied materials, embodied energy, operating energy, and the built area associated with residential, industrial and commercial buildings are evaluated in order to establish a material-flow analysis, assess the direct and embodied carbon, and evaluate the ecological footprint of these buildings.</i>	Operating energy used by buildings and related infrastructure	✓	✓	✓	<ul style="list-style-type: none"> Built infrastructure data is comprehensive except that mixed-use residential-commercial buildings are listed and counted as commercial land area. Thus, there is an under-representation of residential multi-family buildings and an over-representation of commercial buildings. There is limited tracking of wood burning appliances, yet these technologies have a high impact on air quality.
	Embodied energy and embodied materials of buildings	✓	✓	x	
	Built area associated with buildings	✓	x	x	
Consumables and Waste <i>Data is collected on the:</i> <ul style="list-style-type: none"> 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	✓	✓	✓	<ul style="list-style-type: none"> Operating energy for waste (liquid and solid) facilities were not available, because some of this data is aggregated with other operational data from utilities. Composition data for recyclables was not provided by Multi-Materials BC (MMBC).
	Direct emissions from waste facilities	✓	✓	✓	
	Embodied energy and materials associated with consumables (as inferred by waste stream)	✓	✓	x	
	Built area associated with waste management	✓	x	x	

CATEGORY	INPUTS	EF	CBEI	TERRITORIAL GHG INVENTORY	KEY ASSUMPTIONS AND LIMITATIONS
Transportation <i>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.</i>	Operating energy associated with to transportation (fuel use for private and commercial vehicles; aviation; marine vessels and off-road vehicles)	✓	✓	✓	<ul style="list-style-type: none"> Private vehicle VKT data is no longer collected since the elimination of the AirCare Program; fuel consumption estimates are derived from ICBC vehicle registration data and travel surveys. Using data from the Victoria airport would provide a gross under-estimate of Victoria residents' total air travel since many residents travel to international airports for much of their aviation travel (i.e., Vancouver and Seattle). Therefore, residential air travel was estimated using average per-capita values for Metro Vancouver. Data for the MV Coho and the Clipper came from a study conducted in the early 2000s (more recent data was not available). 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 Saanich'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 personal vehicles and transportation infrastructure	✓	✓	✗	
	Built area associated with transportation	✓	✗	✗	
Water <i>Evaluates the embodied materials, embodied energy, operating energy, and built area impacts of the water distribution and purification system relied on by the municipality.</i>	Operating energy used in treating and conveying water	✓	✓	✓	Operating energy for water facilities was not available as it was aggregated with other regional government data.
	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 District of Saanich'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.

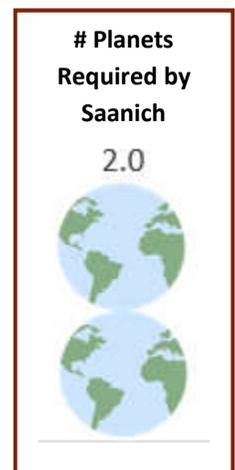
It is important to contextualize results with the knowledge that Saanich benefits from the services provided by the neighbouring City of Victoria. Many Saanich residents work in Victoria and utilize the cultural services in Victoria, generating waste and using energy while they do so. This would have a downward influence on Saanich's GHG emissions and footprint. 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 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 global hectares is available for each person on the planet.

Saanich's total ecological footprint is 319,000 gha,⁷ which is an area 30 times bigger than the municipal boundary. Saanich's current *per capita* footprint is 2.8 gha excluding the resource demands associated with national and provincial services such as the military. If we were to add these national and provincial services, Saanich's per capita ecological footprint increases by at least 18%, to 3.3 gha/person⁸. Although Saanich's footprint is significantly less than the Canadian and US average, it is still twice what is available (1.7 gha per person). Put another way, this means that approximately two earths would be required to support the global population if everyone had lifestyles comparable to a Saanich resident.

If we look at the various components of Saanich's footprint, as shown in Figure 5, consumption of food represents the largest impact (49%), followed by transportation (27%), buildings (15%), and consumables and waste (9%). As previously noted, some of Saanich residents' impact is being absorbed by the city of Victoria, which acts as a regional service centre. Thus, the energy used in commercial and institutional buildings, and the impact of consumables that result from Saanich residents working and recreating in Victoria is not captured in this footprint.



⁷ Excluding national and provincial services.

⁸ As noted in the methodology, the bottom-up approach employed in the ecoCity Footprint Tool results in an underestimate of the footprint.

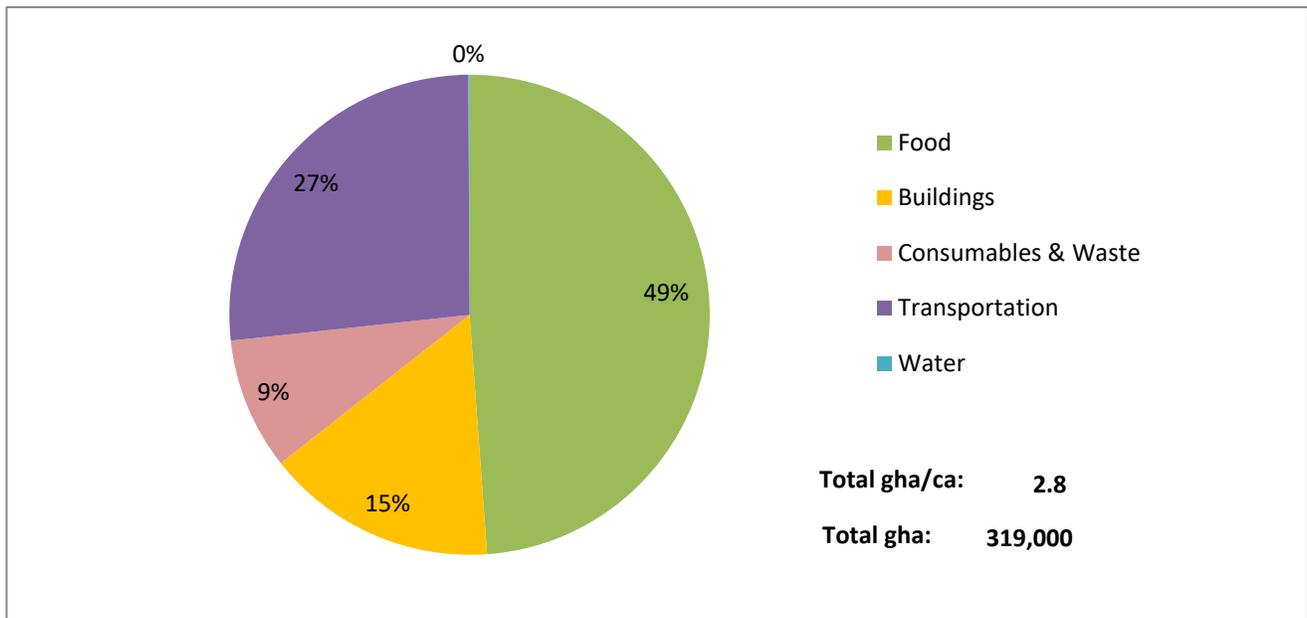


Figure 5: Summary of Ecological Footprint by Activity, 2015 (excluding national and provincial services)

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 6).

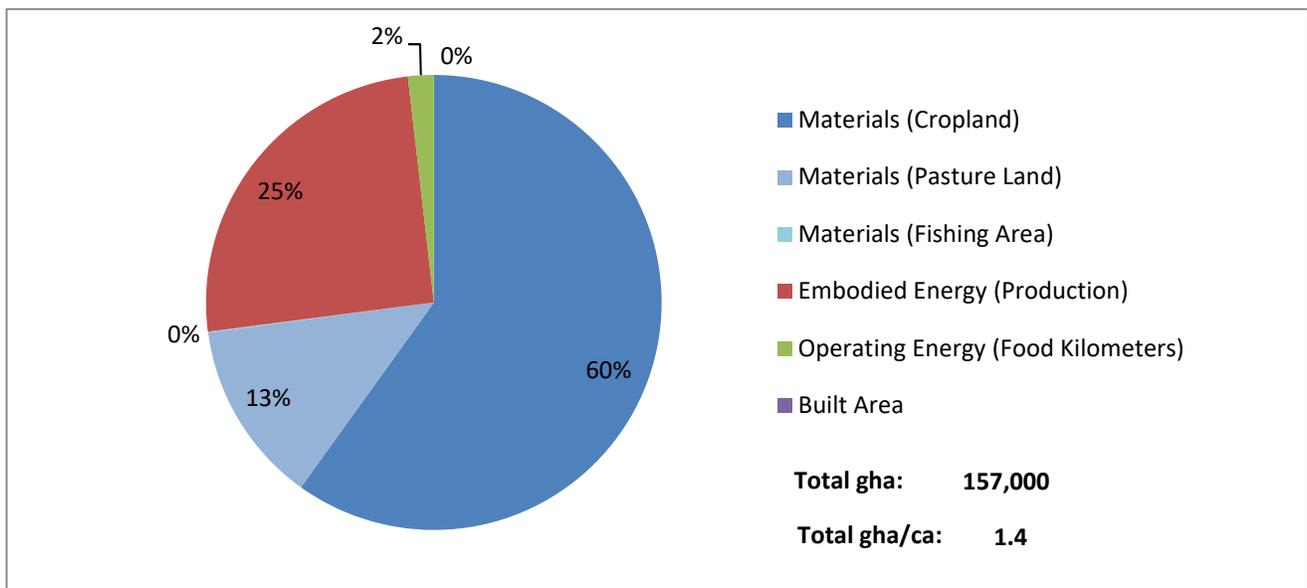


Figure 6: Food Footprint Summary, 2015

When we look at which types of food are having the largest impact on the footprint, nearly three quarters of the footprint is a result of animal proteins, in particular red meat and dairy products (see Figure 7). **These results demonstrate that the largest priority for reducing the Saanich'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.

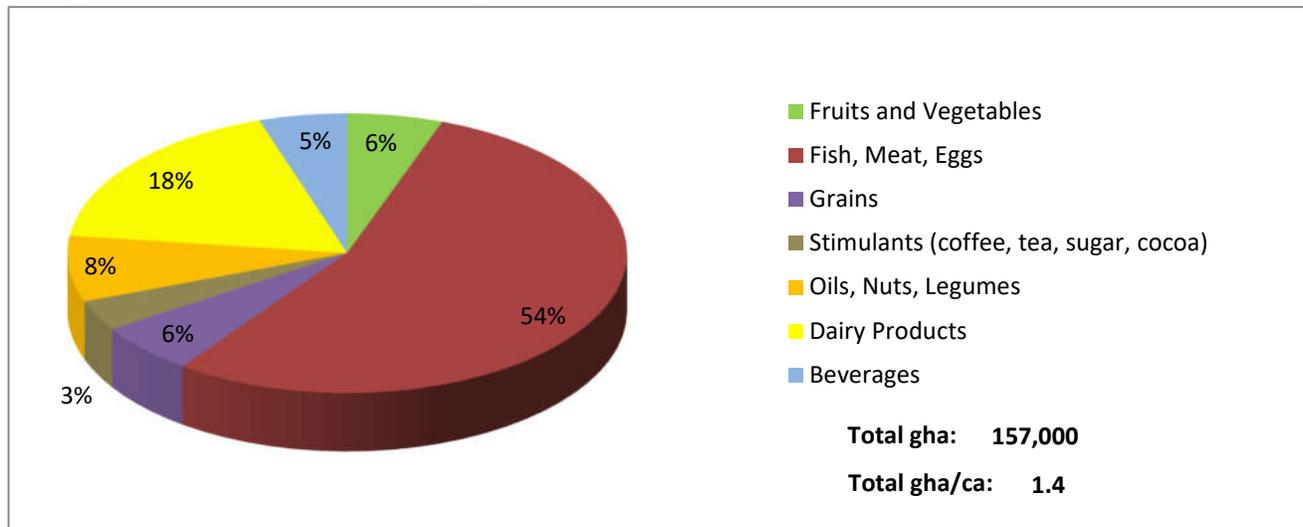


Figure 7: Food Footprint by Food Type, 2015

Buildings Footprint

As shown in Figure 8, nearly two-thirds of the ecological footprint of Saanich 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.⁹ As the municipality transitions 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 the District of Saanich’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.**

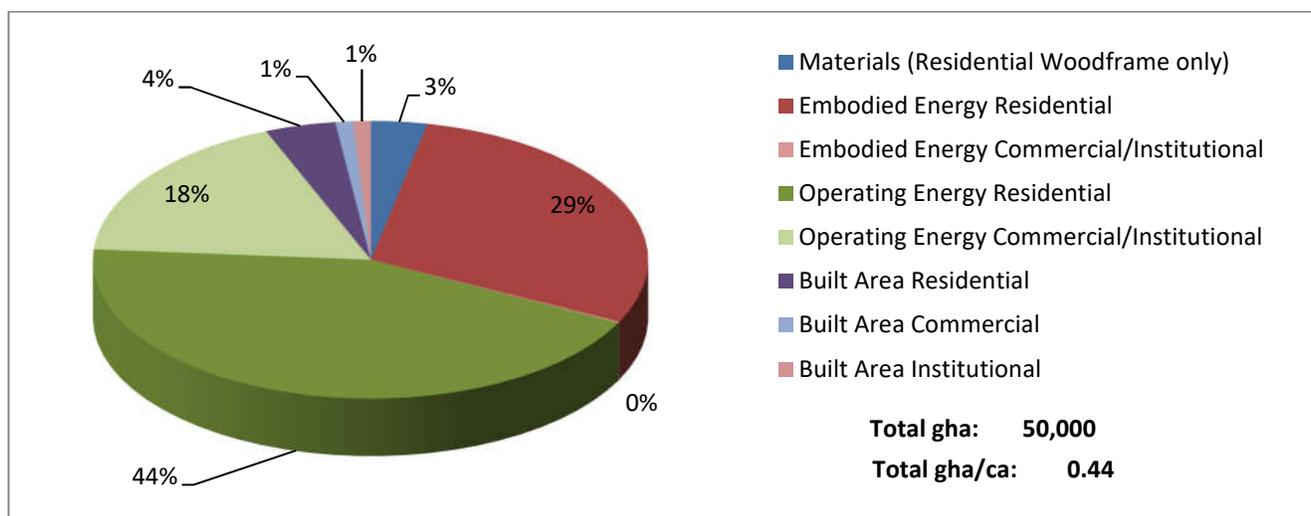


Figure 8: Buildings Footprint Detailed, 2015

⁹ 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.

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 municipality.¹⁰ As shown in Figure 9, these upstream impacts – the embodied materials and embodied energy associated with the consumables – represent 96% of the 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). **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, in particular paper and textiles.**

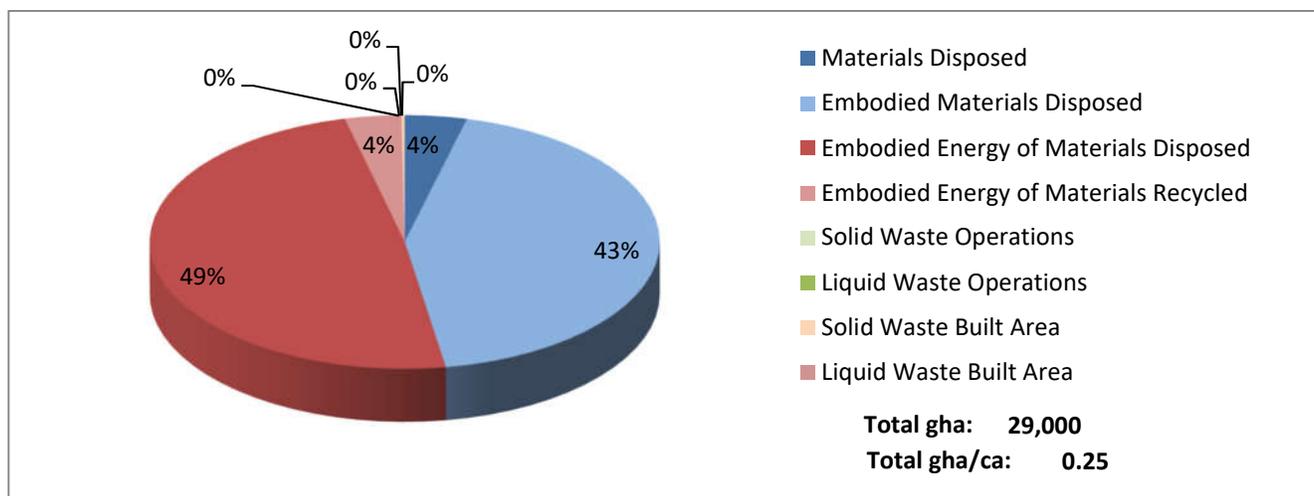


Figure 9: Consumables and Waste Footprint, 2015

It is also instructional to evaluate which consumables are yielding the largest impact on the footprint in order to develop targeted policy and communication measures. **As shown in Figure 10, the District of Saanich’s footprint is dominated by “wood waste, textiles, and rubber” and paper. These consumable types should be considered priority impact areas for footprint reduction. Within these components, it is also important to note that textiles typically comprise a small portion of the waste stream by weight, but their embodied energy and material are very high. Thus, textiles should be considered a particular priority.** Table 1 in Appendix A provides a detailed breakdown of footprint impacts by type (that is, by type of plastic, paper, etc.).

¹⁰ Operating energy for waste management facilities was not available, as discussed in Appendix A: Methodology, but would be negligible compared to the embodied energy and embodied materials impacts.

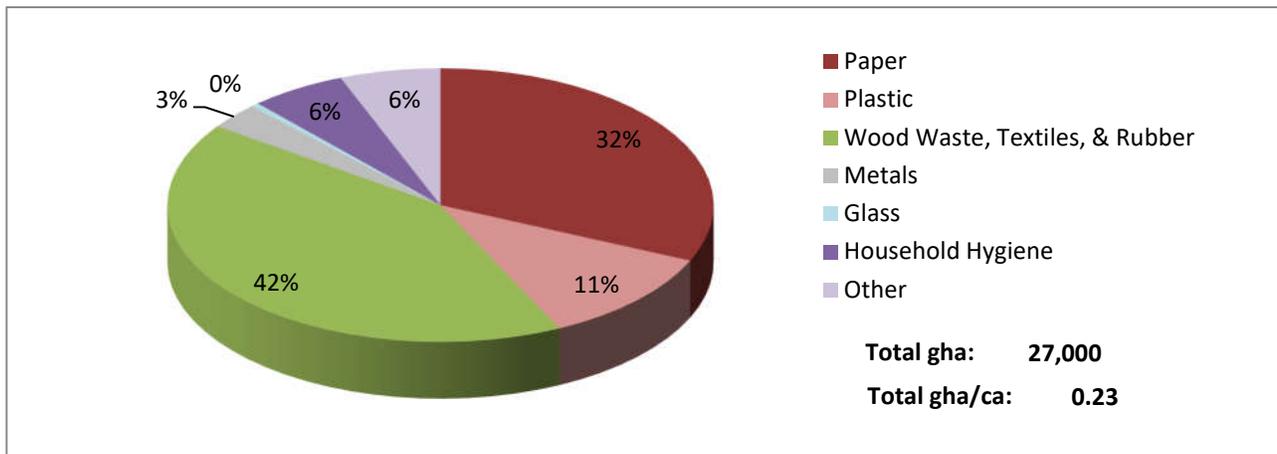


Figure 10: Consumables Footprint by Type, 2015

Transportation Footprint

Half of Saanich’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 two-thirds of the footprint. Air travel is also significant at 17%. **A near-term priority is 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.**

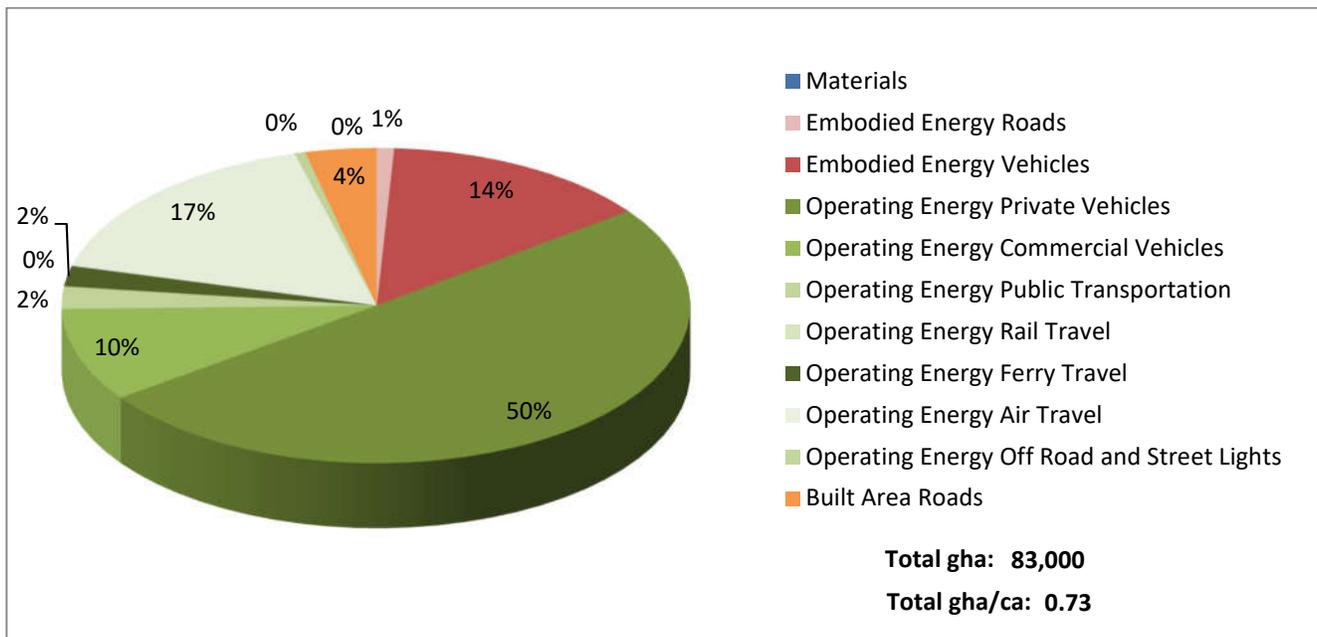


Figure 11: Transportation Footprint in Detail, 2015

Territorial GHG Emission Inventory

Through enhancements as part of the 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 is currently being prepared for the District by Stantec which will include updated transportation information collected as part of the 2017-2018 CRD Origin-Destination Survey. For this report, we therefore, present only summary information on the territorial emission inventory, for the purposes of comparison with the Consumption-Based Emission Inventory. The GPC inventory outlined in Figure 12, is based on 2012 CEEI data (grown by 2% to estimate 2015), which was the most up to date information available at the time. As shown the total territorial emissions for Saanich are 426 ktCO₂e,¹¹ or 3.7 tCO₂e per capita.

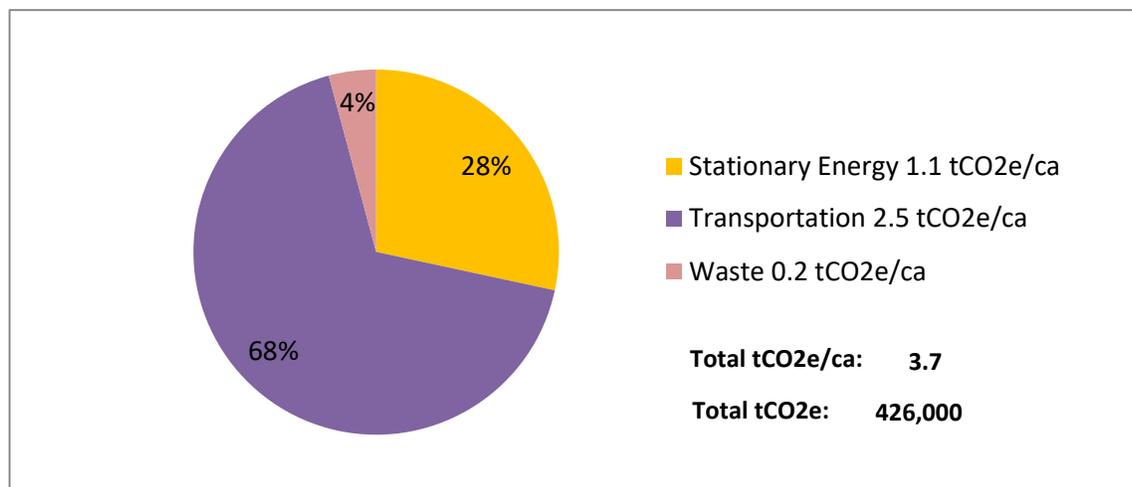


Figure 12: Territorial GHG Emissions Inventory (GPC Basic Inventory)

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; 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 Saanich were 881 ktCO₂e in 2015 (see Figure 13), more than double the territorial emissions (see Figure 12). 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 (52%) followed by buildings (20%); whereas for the EF, the largest impact category is food (49%) followed by transportation (27%). Food impacts are the area in which these results vary most significantly. Food is only 19% of the total for the CBEI, but 49% of the EF; the primary driver for this difference is the land intensity of food production.

¹¹ Carbon dioxide equivalent (CO₂e) expresses the impact of each different greenhouse gas in terms of the amount of CO₂ (carbon dioxide) that would create the same amount of warming. This enables reporting total greenhouse gas emissions in one measurement.

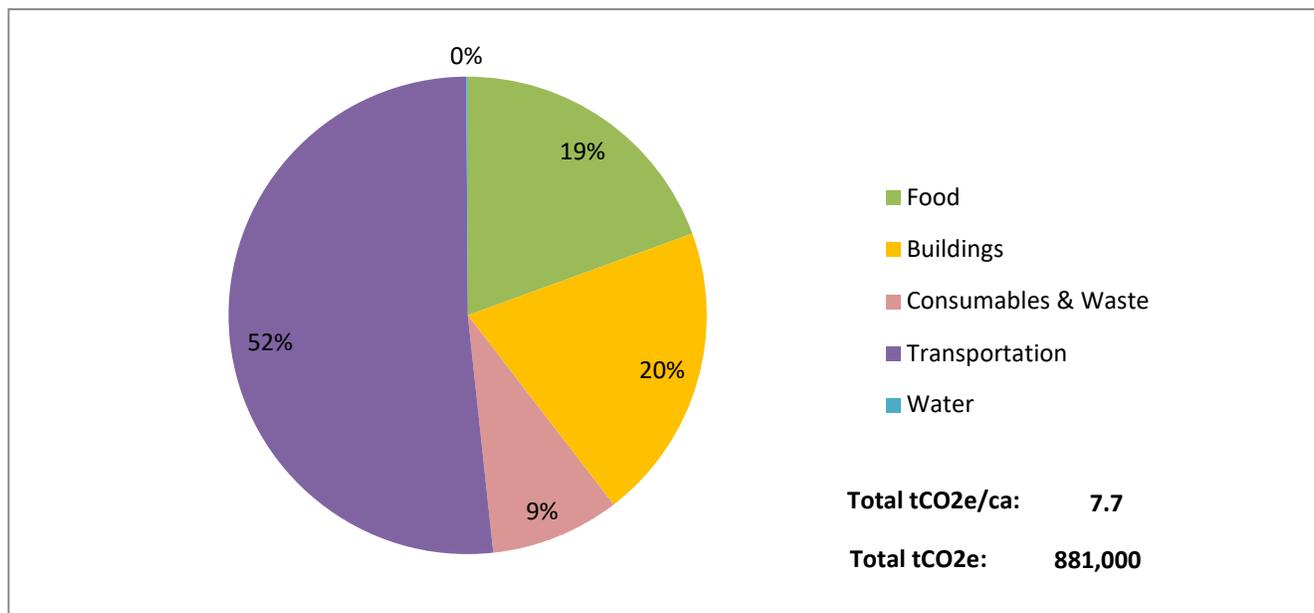


Figure 13: Summary of GHG Emissions from Consumption, 2015

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 14 shows that, similar to the ecological footprint (EF), the majority of the CBEI for food is a result of animal proteins and dairy (73%). 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.

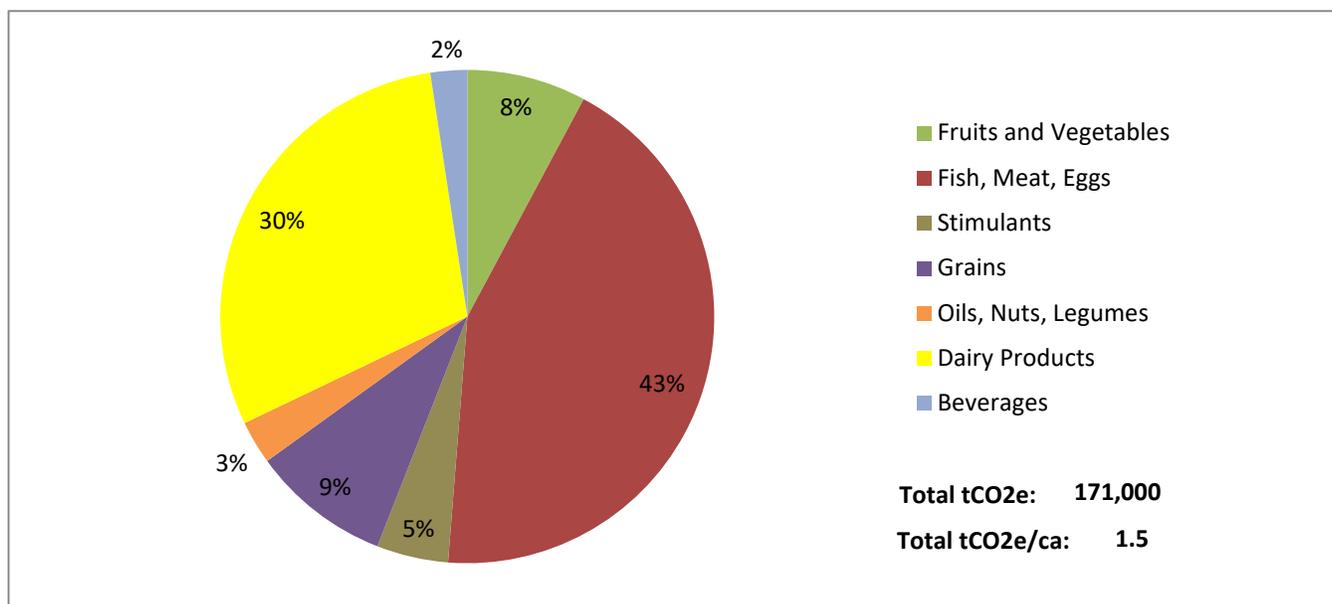


Figure 14: Greenhouse Gas Emissions Inventory of Food, 2015

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.

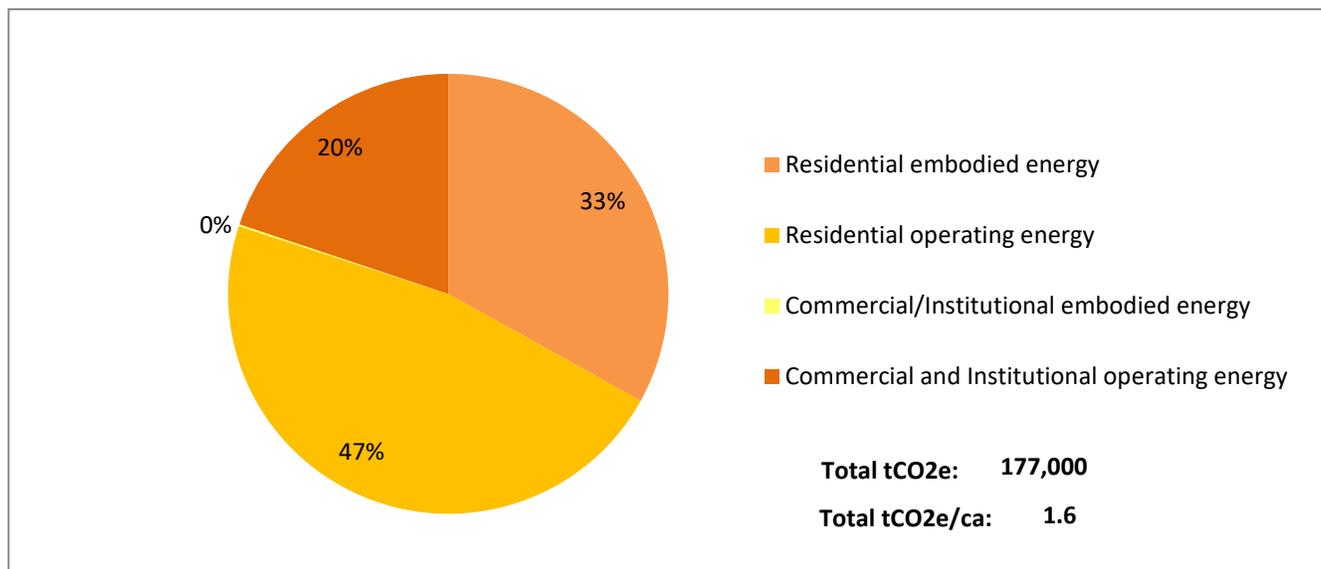


Figure 15: GHG Emissions Inventory of Buildings, 2015

CBEI of Consumables

The CBEI for consumables shows that the largest GHG impact is due to wood waste, textiles, and rubber (51%), as shown in Figure 16. However, in contrast to the EF, the consumption-based emissions are higher from plastics (26%, compared to 11% for the EF); and much less for paper (16%, compared to 32% 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 1 in Appendix A provides a detailed breakdown of GHG impacts by type (that is, by type of plastic, paper, etc.).

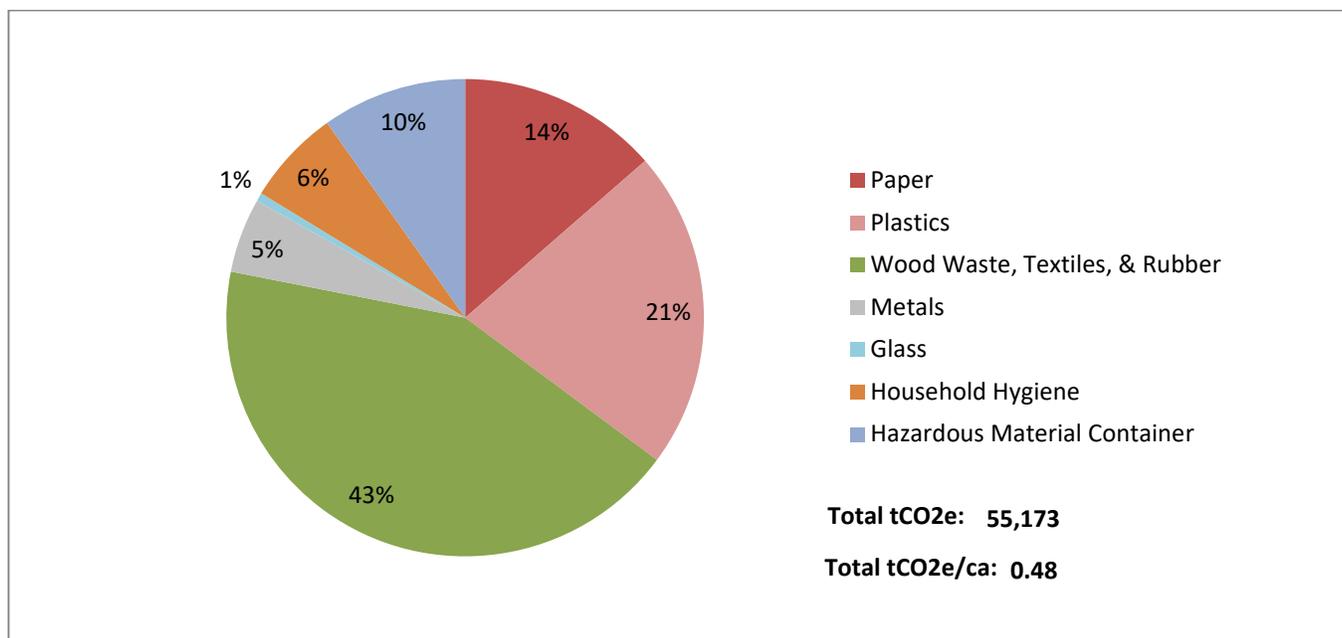


Figure 16: GHG Emissions Inventory of Consumables, 2015

CBEI of Transportation

Similar to the EF, the majority of the consumption-based emissions for transportation are associated with private vehicle travel (73%), as shown in Figure 17. Air travel also represents a significant component of the transportation CBEI (15%).

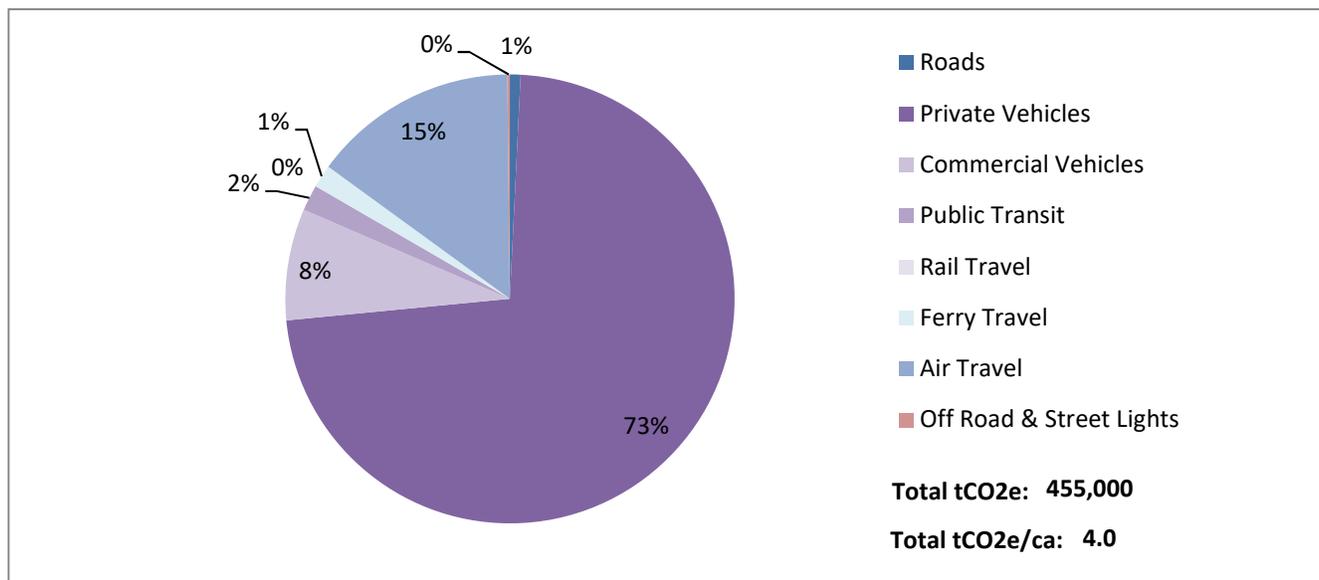


Figure 17: Greenhouse Gas Emissions Inventory of Transportation, 2015

THE SUSTAINABILITY GAP

To achieve ‘One Planet Living’ Saanich’s ecological footprint would need to reduce from 3.3 gha per capita (with national and provincial services)¹² to 1.7 gha per capita. This represents a sustainability gap of 48%. 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 tCO₂e per capita. Given Saanich’s current CBEI per capita emissions of 7.7 tCO₂e, GHG emissions would need to be reduced by 74%; and based on the GPC per capita emissions of 3.7 tCO₂e, they would need to be reduced by 46%.

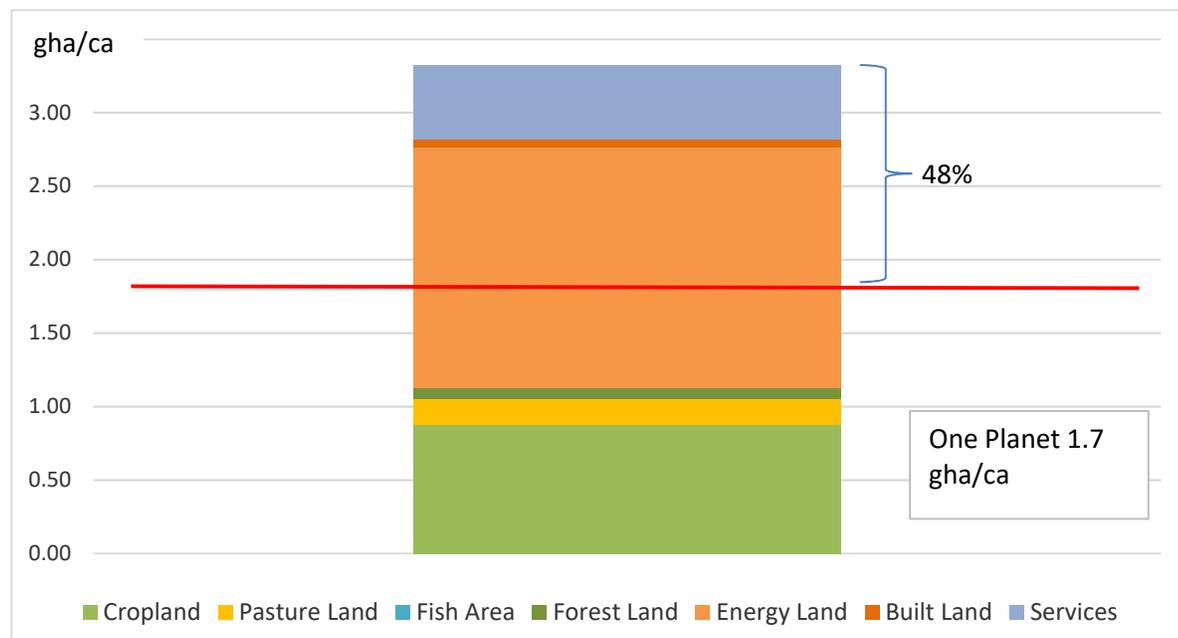


Figure 18: Sustainability Gap, 2015 (including national and provincial services)

¹² Excluding national and provincial services Saanich’s footprint is 2.8 gha per capita.

ONE PLANET SCENARIO

A One Planet Scenario for Saanich 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. The associated reduction in GHG emissions are also presented.

MEASURE	EF reduction (gha/capita)	GHG reduction (tCO ₂ e/capita)
Reduce beef (and substitute with chicken) and dairy (without substitution) by 50% ¹³	0.32	0.2
Reduce food waste post-purchase 25%	0.26	0.3
Eliminate heating oil	0.09	0.4
Reduce natural gas and propane consumption 66%	0.09	0.3
Improve electrical efficiency 40%	0.02	0.1
Reduce paper consumption 50%	0.03	0.02
Reduce textile consumption 40%	0.02	0.1
Reduce plastics consumption 30%	0.01	0.04
Reduce Municipal Solid Waste (MSW) 25%	0.04	0.11
Convert 50% of private vehicle fleet to electric	0.12	0.68
Reduce VkmT 25% in private vehicle fleet	0.08	0.5

The cumulative results of implementing these measures are shown in Figure 19. This chart compares Saanich's current ecological footprint, with the amount of resources that are globally available, and the One-Planet scenario.

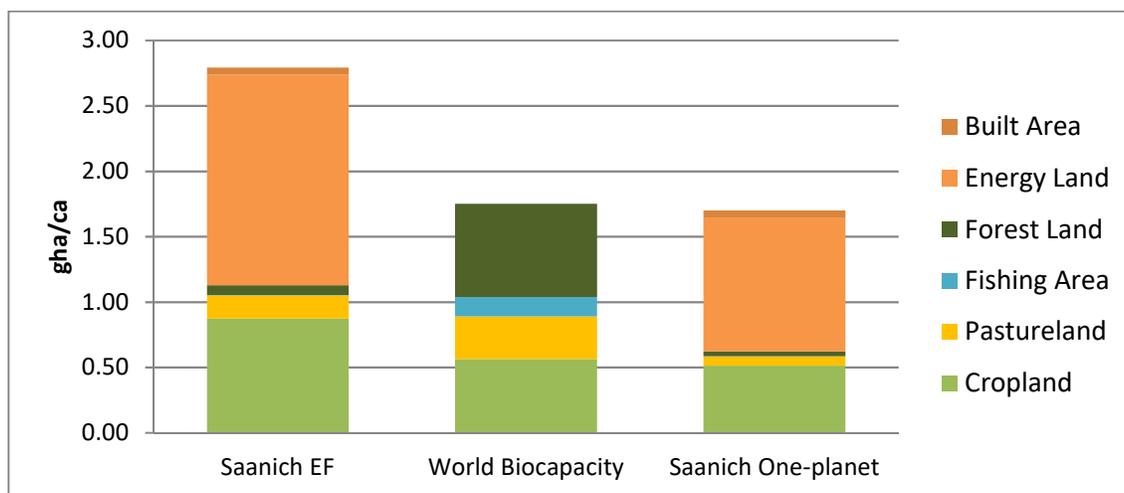


Figure 19: Saanich's Current Ecological Footprint Compared to a One Planet Scenario (excluding national and provincial services)

¹³ When one food item is reduced, essential calories will need to be replaced with calories from another food group.

POLICY RESPONSES AND INTERVENTIONS

While a typical territorial GHG inventory identifies the emissions that are occurring within a community's borders, the ecological footprint and consumption-based approach broadens the analysis to consider global ecological and carbon impacts. Local government staff can use data from the ecoCity Footprint Tool to identify activities and consumption habits that are having the greatest impact on their community's contribution to global climate change and ecological overshoot. They can then implement informed policy interventions to best reduce these impacts. 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.

CBEI and EF results highlight the need for the

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

municipality, and other levels of governments, to support a shift to a more sustainable pattern of consumption. This could include:

- Enacting policies and regulations to (1) influence consumers and (2) ensure that more sustainable options are available.
- Communicating the impact of purchasing decisions to residents, and encouraging their adoption of sustainable consumption behaviours.

Consideration of the CBEI and EF results can effectively shift some key areas of policy and planning decision-making. In particular, they highlight the necessity to:

- *Target the resource and climate impacts associated with food production and disposal.*
For Saanich, 19% of CBEI emissions and 49% of the EF are due to food consumption.
- *Decrease red meat and dairy consumption by substituting with legumes and white meat and reduce food waste.*
For Saanich, 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 Saanich, 98% of the food footprint is associated with energy and land requirements, while transportation represents only 2% of the food footprint.
- *Shift the focus from waste reduction to consumption reduction.*
For Saanich, 96% of the footprint associated with goods consumed is due to production and transport, rather than use and disposal.
- *Reduce the consumption and disposal of textiles, which have a very high ecological impact even though their portion of the waste stream is comparatively smaller.*
- *Reduce vehicle ownership and support this shift through effective land use planning.*
- *Eliminate emissions from oil, propane and natural gas usage in residential, commercial and institutional buildings.*

Potential Action Areas for District of Saanich

High-level actions for each sphere of municipal planning are presented below. This is not an exhaustive list, it is recommended that the District review results in detail and use these results to inform upcoming policy, planning and communication efforts.

Planning Sphere	Key Objectives	Instrument
FOOD	Reduce food waste	<ul style="list-style-type: none"> Promote sharing economy opportunities (e.g., community gardens). Promote diet shifts (e.g., ‘Meatless Mondays’ Oregon; Celebrate the Harvest campaigns).
	Reduce meat and dairy consumption	<ul style="list-style-type: none"> Adopt advanced purchasing standards (e.g., Emeryville Good Food Purchasing Program, EPA West Coast Forum on Materials and Climate’s Climate Friendly Purchasing Toolkit).
	Obtain local data on food consumption impacts	<ul style="list-style-type: none"> Implement food waste reduction campaigns (e.g., Canada’s Love Food Hate Waste; US EPA’s Food too Good to Waste; NRDC Save the Food Campaign). Undertake a food survey to gain knowledge about local food consumption and impacts so as to track progress toward goals.
BUILDINGS & INFRA-STRUCTURE	Increase efficiency (envelope 1 st approach)	<ul style="list-style-type: none"> 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.
	Use building materials with lower embodied energy	<ul style="list-style-type: none"> Building codes that promote energy and material efficiency
CONSUMABLES	Reduce the volume of individually owned goods	<ul style="list-style-type: none"> Promote sustainable consumption behaviours (e.g., Vancouver’s Green Bloc Neighbourhood Challenge). Promote sharing economy opportunities (e.g., clothes swaps). Promote ‘smart’ buying practices – focusing on durability and buying fewer clothes (e.g., Oregon DEQ’s Make Every Thread Count).
	Increase reuse	<ul style="list-style-type: none"> Support and promote Repair Cafés and Fix-it clinics and the local repair industry.
TRANSPORTATION	Reduce vehicle ownership	<ul style="list-style-type: none"> Increase electrification of fleet. Support and promote bike-sharing and car-sharing programs.
	Decrease vehicle travel	<ul style="list-style-type: none"> Continue to expand Active Transportation Initiatives.
	Improve efficiency of vehicle fleet	<ul style="list-style-type: none"> Ensure neighbourhood plans contribute to compact urban development, smaller homes and walkable neighborhoods.
	Better understand inter-urban transportation demand	<ul style="list-style-type: none"> Undertake an ‘Inter-urban’ Transportation Demand Survey to gain a better understanding of residents out of boundary transportation habits (e.g., ferry, cruise, aviation).

District Initiatives

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

- Update goal and target setting: consider adjusting emission reduction goals to reflect this new information (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).
- 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.
- 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.
- 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.

Green Bloc is an innovative ecological footprint challenge that is being piloted in four Vancouver neighbourhoods, using a streamlined version of the ecoCity Footprint Tool. Through Green Bloc, community members are measuring their household ecological footprint, developing neighbourhood action plans, and delivering neighbourhood enhancing, and footprint-reducing, projects in their communities. The first pilot neighbourhood – Riley Park – already reduced their footprint by 12% between 2013 and 2015. (See <http://greenbloc.lighterfootprint.ca/>)

In Vancouver, a collaborative group of non-governmental organizations are partnering with the City to actively bringing together a community of action around the Lighter Footprint goal. They are revealing and linking projects and partners across Vancouver, as well as encouraging new efforts in key impact areas, with the goal of helping Vancouver become a One-Planet City. (See: <http://lighterfootprint.ca/>)

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 2015, 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 a number of 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.

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 2: Life Cycle Assessment Data for Consumables by Material Type

Detail by Consumption	tCO2e/product	tCO2e	tCO2/t product	tCO2	LCA Factor	Embodied Energy Footprint	LCA FACTOR	LCA FACTOR	Embodied Materials Footprint
Paper		5,401		5,401	energy	gha	materials-crops	materials-forests	gha
Printed Paper	0.70	2,438	0.70	2,438	0.18	627		1.29	4,493
News Print	0.85	232	0.85	232	0.21	58		1.13	310
Cardboard and Boxboard	0.66	1,549	0.66	1,549	0.17	399		1.47	3,450
Telephone Directories	0.70	1,157	0.70	1,157	0.21	347		1.13	1,868
Other	0.70	25	0.70	25	0.21	8		1.29	46
Plastic		18,470		18,470					
Film (bags)	3.38	9,558	3.38	9,558	0.85	2,402			
PET	4.93	2,422	4.93	2,422	1.23	604			
HDPE	2.92	1,963	2.92	1,963	0.73	491			
PVC	1.99	3,312	1.99	3,312	0.5	833			
Other	3.38	1,216	3.38	1,216	0.85	306			
Organic Waste									
Food waste (not to include in the EF)		-		-		-			
Yard and Garden		-		-		-			
Wood Waste	0.72	1,319	0.72	1,319	0.18	330		0.41	751
Textile	15.00	34,900	15.00	34,900	3.76	8,748	3.14		7,306
Rubber	6.37	-	5.42	-	1.6	-	1.83		-
Other						-	0.05		4
Metals		5,026		4,272					
Ferrous Food/Drink Packaging not Recycled	1.80	331	1.53	282	0.45	83			
Ferrous Other	1.80	1,041	1.53	884	0.45	260			
Non-Ferrous and Bimetallic	12.82	3,654	10.89	3,106	3.21	915			
Glass		493		493					
Food/Drink Packaging	0.65	216	0.65	216	0.16	54			
Other	0.65	277	0.65	277	0.16	68			
Household Hygiene		5,917		5,029					
Diapers	3.20	5,917	2.72	5,029	0.8	1,479	0.36		666
Sanitary Napkins/Tampons	3.20	-	2.72	-	0.8	-	0.36		-
Other	3.20	2,734	2.72	2,324	0.8	684	0.36		308
Hazardous material Container		9,753		8,290					
Hazardous material Container	12.82	9,753	10.89	8,290	3.21	2,443			
Electronic waste		717		718					
Electronic waste	3.38	717	3.38	718	0.85	180			
TOTAL		84,730		78,175		21,317			19,201

APPENDIX B: DATA COLLECTION METHODOLOGY

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

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

Research Principles

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 is in contrast to 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.

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 (Capital Regional District) 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 2017, which will subsequently 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

In order to estimate distance travelled for Canadian food, food-kilometers use a similar methodology as outlined in Meidad Kissinger's *International Trade Related Food Miles – The Case of Canada* (2012). Similar to Kissinger's study, 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.-a, n.d.-b).

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 CO₂e 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, the 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 which was assumed to be 75 years for residential and 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 planning 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.

Challenges and Opportunities

We were unable to separate the number of apartments present in mixed-use buildings from the commercial building stock and as a result, there may be some double counting of embodied energy. The assumptions for calculating embodied energy impacts are unique for commercial buildings and residential buildings, therefore the embodied energy may not have been allocated accurately.

A specific challenge for Saanich data was the lack of resolution in files containing commercial infrastructure data, as well as data on building height.

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 Saanich 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).

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

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

Fugitive Emissions

Fugitive emissions estimates for Saanich were provided in tonnes of carbon dioxide equivalents (tCO₂e) by FortisBC in a memo from Wai Chi Kwan, Environmental Program Lead, April 17, 2017. FortisBC's approach is to estimate GHG emissions based upon the number of customer meter sets, at the

municipality, relative to the total system. This factor is then applied to the total vented and fugitive emissions in order to determine the fugitive- and vented-related emissions for a specific region.

Sources

Most operating energy data, including energy loss, fugitive emissions, and emissions intensity of electricity in BC, was available from energy utilities (BC Hydro, FortisBC). Unfortunately, data for heating oil, propane, and wood, is not centralized and must be either collected by a municipality or estimated using previous studies. The 2012 CEEI from the district of Saanich provided the most recent study year to have estimated wood and propane use.

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>

Challenges and Opportunities

There was limited tracking of wood burning appliances, yet these technologies have a high impact on air quality. Data on their use and number may help municipalities evaluate the importance of targeting these sources for reducing air contaminants and GHG emissions.

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. Calculations of total built area of homes and commercial structures were extracted from ESRI shape files using qGIS. However, this built area footprint does not include impermeable surfaces such as driveways, parking lots, and private laneways. Total built area for Saanich and Victoria was thus further amended using a permeability study that estimated total impermeable surfaces (i.e., paved surfaces) using satellite imagery.

The permeability study, commissioned by Habitat Acquisition Trust (HAT) in 2013 classifies impermeable surfaces in each of the CRD municipalities by percentage of area covered (e.g., area with less than 5% impermeable surfaces, area with between 5 and 10% impermeable surface, etc.). The report also contains a table with the total impermeable surface for each of the CRD municipalities. . In order to find the non-road paved area we took the difference between the total impermeable surface of each municipality, and the known paved road area and developed housing (Equation 3).

$$\text{non - road paved areas} = \text{HAT estimated impermeable area} - (\text{known}_{\text{built land area}} + \text{known}_{\text{area of paved roads}}) \quad (3)$$

The HAT land cover data set was found to be 94.4% accurate in its calculations of forested area and impermeable surfaces, and provide a relative approximation of the remaining paved area.

Sources

Built area was calculated using ESRI shape files provided by staff.

Supplementary data on impermeable surfaces:

Caslys Consulting Ltd. (2013). *Capital Regional District Land Cover Mapping: 1986, 2005, and 2011 Summary Report*. Prepared for Adam Taylor at the Habitat Acquisition Trust. Retrieved from http://www.hat.bc.ca/attachments/CRD_2011_land_cover_summary_report_final.pdf.

Challenges and Opportunities

The HAT land cover mapping effort and research was valuable to the completion of this research project however the most recent data was from 2011. Knowledge about land cover and land use change can inform public policy and help municipalities understand how development is affecting the type and availability of ecosystem services across the region. There is an opportunity to continue the work started by HAT and use this information to inform development standards that protect or seek to restore ecosystem services and ecological function to the many municipalities within the CRD.

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 Victoria 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). Landfill and organics tonnages were collected from CRD while the total volume of recycling data came from Recycle BC (formerly Multi-Material BC). Where the data was not available by municipality, we have pro-rated waste data based on a 2012 CRD Waste Study that attributed 23.2% of CRD waste to the District of Saanich. A CRD 2016 waste audit provided a breakdown of the waste composition by material type and provided an estimate of what portion of the waste stream was coming

from residential, multi-unit residential, and industrial/commercial sources. No estimate was available for the composition of recycled materials.

Emissions associated with landfilling and composting were obtained from Victoria's 2015 GPC Inventory, but were portioned out to each municipality based on estimated landfill contribution.

The embodied energy, of consumables, is estimated using lifecycle assessment data that is built into the Tool.

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 and the material composition of facilities for each municipality was available through the Victoria 2015 Community GHG report (Hegg, 2017).

The main components of the liquid waste infrastructure are the sanitary sewer and storm drain pipes. The length of sanitary sewer pipes and storm drains were extracted from GIS shape files.

Sources

Landfill waste volumes were available from CRD reports, and recycling volumes were available through Recycle BC (formerly Multi-material BC) annual reports. Additional data on waste apportionment by municipality, waste composition, and emissions from facilities came from CRD reports and the Victoria 2015 Community GHG report.

Data on the kilometer length of pipes and infrastructure included in the water distribution system within the District of Saanich were obtained from CRD reports, available online.

Capital Regional District. (2015). *Environmental Resource Management Annual Report*. Retrieved May 3, 2017, from <https://www.crd.bc.ca/docs/default-source/crd-document-library/annual-reports/solid-waste/SolidWasteAnnualReport2015.pdf?sfvrsn=10>

Tetra Tech. (2016). *2016 Solid Waste Stream Composition Study*. Prepared for the Capital Regional District. Retrieved from <https://www.crd.bc.ca/docs/default-source/recycling-waste-pdf/WasteCompositionStudy2016.pdf?sfvrsn=4>

Hegg, D. (2017). City of Victoria 2015 community greenhouse gas (GHG) emissions inventory report. Victoria, BC: Stantec Consulting Ltd.

Multi-Material BC. (2015). *Annual Report 2015*. Retrieved on July 2017, from <https://RecycleBC.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 Saanich's contribution would have been relatively minor.

Sources

Data on CRD waste facilities was obtained from CRD GIS technologist II: Jean-Paul Bezeau (June 27, 2017).

Data on Tervita Landfill came from a datasheet on the Highwest Facility, provided by staff (August 10, 2017).

Challenges and Opportunities

Currently, there is little liquid waste treatment in the CRD. Building a waste water treatment plant would increase built infrastructure and energy demands, effectively increasing the CRD's ecological footprint despite the numerous benefits to local ecosystems that are poorly captured in an ecological footprint framework.

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 lengths and material composition was accessed from the municipality.

Sources

Road area and length was extracted from existing GIS files received from Saanich staff. LCA data that identifies the embodied energy of paving materials was obtained from the Dr. Moore's previous ecological footprint assessment for Vancouver (Moore, 2013).

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 CO₂, 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.

ICBC registration data for 2012 and VKTs, were available through Hegg (2017). He grew the 2012 CEEI registration data by 2% to estimate 2015 registration rates as there were errors found in the 2015 data provided by ICBC. VKT data is from a 2009 Canadian Vehicle Survey completed by Natural Resources Canada. Fuel consumption rates are from the 2017 CEEI guidance documentation. Average VKTs were multiplied by the total number of vehicles and average fuel consumption for each vehicle class.

Additional data obtained from a 2012 CRD origin-destination study was used to evaluate what portion of travel is in-boundary versus out of boundary. This would be especially relevant for extending the ecoCity tool to cover a GPC BASIC+ inventory in the future.

Transit

Transit emission calculations for both Victoria and Saanich were estimated with the support of Allison Ashcroft, CUSP Coordinator. BC Transit provided total diesel fuel consumption for the regular bus service, as well as a GHG intensity by service hour that includes emissions from all BC Transit operations. Data on gasoline used by the HandyDART service in the CRD was not directly available. Instead, available service hours for HandyDART and Conventional and Community bus services were used to calculate emissions for the regional bus service. Using an emissions factor for diesel fuel, the portion of those emissions that came from diesel were extracted out in order to derive an estimate for the gasoline-based emissions directly related to the HandyDART service. Regional emissions were then pro-rated based on each municipality's portion of the regional population, for Saanich we used a population ratio of 0.31.

Off road vehicles

Off-road vehicle fuel consumption was not available for Victoria and Saanich.

Sources

Private Vehicles

Data on private vehicles relied on the same 2012 ICBC data used in:

Hegg, D. (2017). *City of Victoria 2015 community greenhouse gas (GHG) emissions inventory report*. Victoria, BC: Stantec Consulting Ltd.

Transit Data

Fuel Consumption data was provided by BC transit's Environmental Officer Geoff Huber.

Emissions factors came from:

BC Transit. (2017). *BC transit service plan: 2014/15 - 2016/17*. Retrieved from <https://bctransit.com/servlet/documents/1403640520031>

Service Hours were available from:

Victoria Regional Transit Commission. (2016). *2016/17 Annual service plan, budget and taxation regulation*. Retrieved from <https://bctransit.com/servlet/documents/1403645623601>

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.

A second opportunity lies in calculating bus emissions. In this study, the regional bus service emissions were allocated to municipalities based on population. In the future, it may be of interest to attribute emissions based on service hours. However, this data will be of lower importance in the future due to BC Transit's plans to electrify its fleet, which will reduce the GHG impact of transit.

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.

Private vessel data and analysis was already compiled for the CRD by Daniel Hegg (2017), boat emissions were attributed to Saanich by population. Of note is that data on larger ships, including the MV Coho and the Clipper, came from a study conducted in the early 2000s as more recent data was not available.

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 available, and we decided to allocate a portion of the emissions based on Saanich's proportion of BC's population.

Sources

Hegg, D. (2017). *City of Victoria 2015 community greenhouse gas (GHG) emissions inventory report*. Victoria, BC: Stantec Consulting Ltd.

BC Ferries. (2015). *Fuel Strategies Update Report*. Retrieved on June 29, 2015, from <http://www.bcferrycommission.ca/wp-content/uploads/2011/04/FY15-Fuel-Strategies-Update-Report-June-29-2015.pdf>

Challenges and Opportunities

Marine emissions from large private companies, including cruise ships and private ferry services, are difficult to find publicly. These emissions sources could be significant contributors towards a consumption-based emissions inventory. There is an opportunity for future transportation studies to investigate use of ferry services by Saanich's population. Travel demand studies would also enable accounting of cruise ship emissions.

3. Air Travel

Methodology

Greater Victoria has a local airport but calculating emissions associated with the Victoria airport would provide a gross under-estimate of Saanich residents' total air travel. In addition to travelling out of the Victoria International airport, many Saanich residents regularly use Vancouver and Seattle International airports.

Therefore, 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 tCO₂e (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

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 of their first destination. This overlooks air emissions associated with 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

Most water treatment materials are tracked and listed by the CRD. Saanich had supplementary GIS files on local water and sanitary pipes. 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

Municipal water authority data is comprehensive. In-boundary water distribution for Saanich was available through their open-data portal and CRD water distribution systems and watershed infrastructure was provided in GIS shape files by CRD staff.

Operating Energy [Water]

Methodology

CRD data on the operating energy used in operating municipal water utilities is currently aggregated with wastewater treatment infrastructure accounts. Given that CRD provides a varying level of services for different regions (i.e., sewage treatment is provided in the Saanich Peninsula), and that it was not possible to disaggregate this data, regional values would not provide a valid estimate for Saanich's portion of these emissions. However, the total amount of energy used for pumping is known to be negligible compared to Saanich's overall emissions profile.

Sources

Capital Regional District staff.

Built Area [Water]

Methodology

Area calculations for the watershed included roads (length and width), buildings, and dams; and protected area and reservoir area. These were available from the CRD website and from GIS files provided by Staff.

Sources

Water utilities provided most of the data on request especially for built infrastructure. Some data, such as reservoir area and protected area, was available through annual reports and online publications.

Capital Regional District. (2015). *Capital Regional District 2015 annual report*. Retrieved on May 4, 2017, from <https://www.crd.bc.ca/docs/default-source/crd-document-library/annual-reports/capital-regional-district-2015-annual-report.pdf?sfvrsn=4>

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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