CITY OF POWELL RIVER

SUMMARY REPORT

NOVEMBER 2018

ecoCity Footprint

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

PREPARED FOR:
CLIMATE ACTION POWELL RIVER (CAPR)

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SUMMARY

This project was initiated in 2018 by the non-profit organization Climate Action Powell River (CAPR) with funding from the City of Powell River and the Pacific Institute for Climate Solutions (PICS).

This *Summary Report* presents the results of Powell River's Consumption-Based Emission Inventory and Ecological Footprint for 2016, 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 Powell River's ecological footprint and consumption-based emission inventory results for 2016.

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 Powell River's *per capita* footprint is 6.0 gha/person.[1] This means that residents are consuming 3.5 times more of the Earth's resources than what is currently available. Put another way, this means that approximately 3.5 Earths would be required to support the global population if everyone had lifestyles comparable to a Powell River resident.

 # Planets Required by Powell River

3.5

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 produced. This form of inventory is generated using the data typically collected for a territorial inventory,

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

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 Powell River are 166 kilotonnes of carbon dioxide equivalent ($ktCO_2e$), nearly double that of the territorial GHG emissions (see Figure 1).

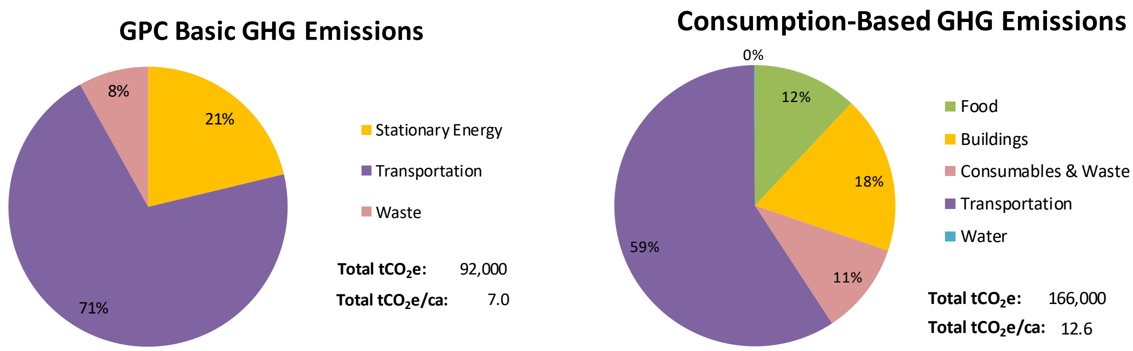

Figure 1: Comparison of Powell River's 2016 Consumption-Based and Territorial GHG Emissions

Inventory Highlights

- For the CBEI, the largest impact category is transportation followed by buildings; whereas for the ecological footprint (EF), the largest impact categories are transportation and food. Food impacts are the area in which these results vary most significantly. Food is a much higher portion of the EF, compared to the CBEI; 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 (cheese).
- Similar to the 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 Powell River'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 implement renewable energy, with a longer-term objective of ensuring footprint impacts are considered in decisions about building materials*** **and new housing types*.***

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 in contrast to the EF, consumption-based emissions are higher for 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, plastics and textiles.***

TRANSPORTATION

- Half of Powell River's transportation footprint is a result of fuel consumption for private vehicles, and adding the embodied energy of vehicles, private vehicle transportation represents nearly two-thirds of the footprint. Similar to the EF, 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' Powell River's ecological footprint, as estimated with the ecoCity Footprint Tool[4], would need to reduce from 6.0 gha per capita (including national and provincial services)[5] to 1.7 gha per capita. This is a sustainability gap of 72% (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 tCO_2e per capita by 2050. Given Powell River's current CBEI per capita emissions of 12.4 tCO_2e, GHG emissions would need to be reduced by 84%; and based on the more standard 'territorial' GHG emissions per capita of 7 tCO_2e, they would need to be reduced by 71%.

This report presents a proposed One Planet Scenario, as an example of how Powell River 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.

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[2] Operating energy for waste management facilities was not available, as discussed in Appendix B: 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 Powell River's footprint is 4.0 gha per capita.

Acknowledgements

We would like to acknowledge that the City of Powell River is on the traditional land of the Tla'amin Nation.

This report has been prepared by Cora Hallsworth (Principal, Cora Hallsworth Consulting-CHC), Ryan Mackie (CHC) and Dr. Jennie Moore (Director, Institute Sustainability, British Columbia Institute of Technology (BCIT)); with contributions and research provided by Arynn Keane (SFU) and with contributions and edits provided by Climate Action Powell River.

The authors would like to thank and acknowledge the many individuals who contributed time to this project. Special thanks to: Climate Action Powell River, staff members at the City of Powell River and qathet Regional District.

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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
qRD	qathet Regional District (formerly Powell River Regional District)
tCO_2e	Metric Tonnes Carbon Dioxide
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 ecocity Footprint (eF Tool), Built Area is the total municipal boundary excluding natural areas, where a natural area is a non-serviced area. For example, a treed park would be excluded, but agricultural land is included. In the eF Tool, the Built Area for the transportation sector is reported separately.
CO_2e	Carbon dioxide equivalent (CO_2e) expresses the impact of each 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.

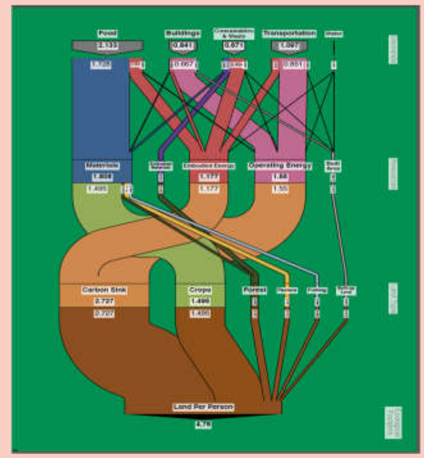
ECOCITY FOOTPRINT TOOL OVERVIEW

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).



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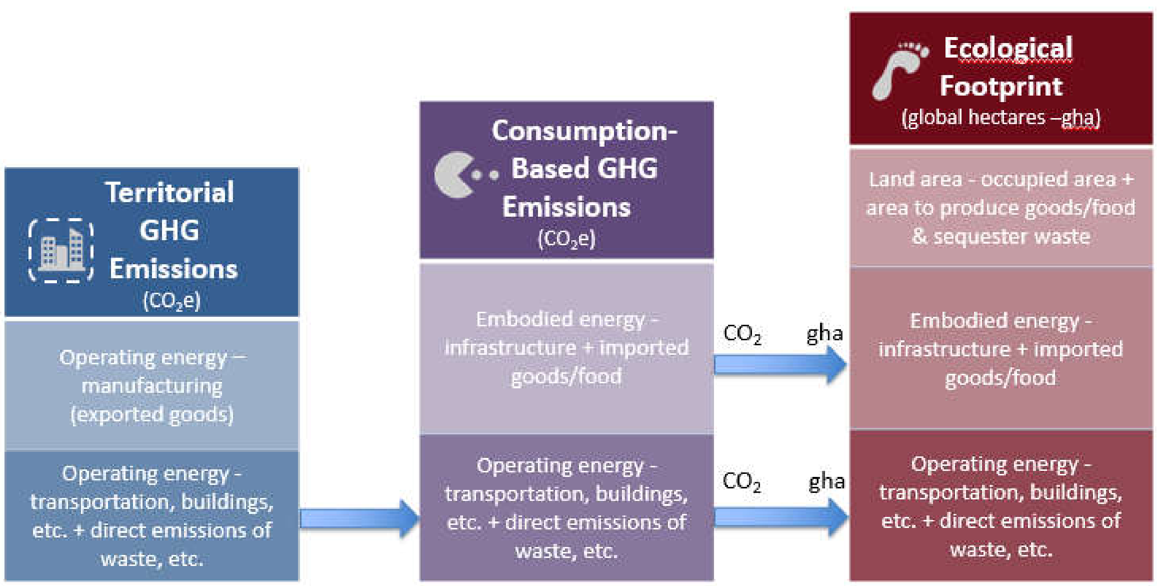


Figure 2 Comparison of the GHG Emission Inventories and Ecological Footprint Approaches

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.

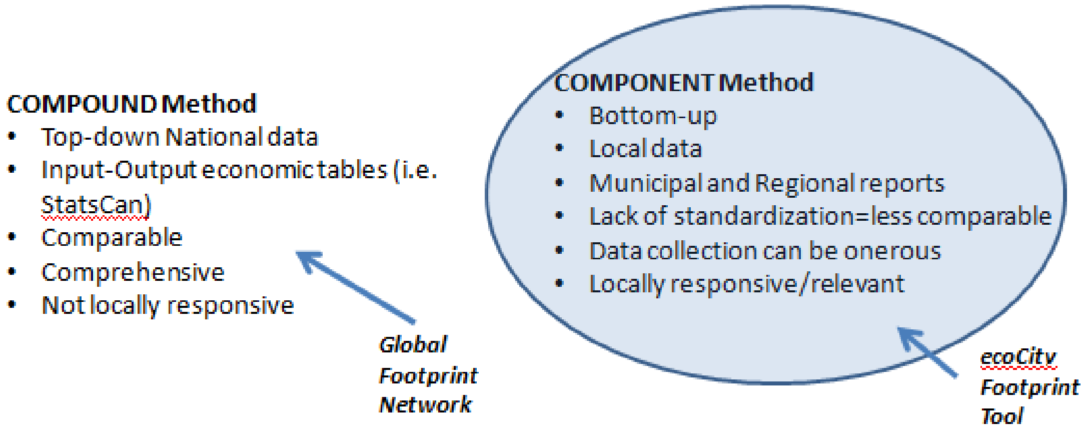


Figure 3 Two methods for calculating the Ecological Footprint

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.

ECOCITY FOOTPRINT IN POWELL RIVER

Climate Action Powell River (CAPR) initiated this project to inform and contribute to climate and sustainability planning efforts in the community, and in particular to advance their goal of creating a carbon-neutral city. Through the calculation of Powell River's ecological footprint, CAPR hopes to identify priorities for reducing the community's contribution to climate change and global overconsumption. The hope is that this information can inform policy and planning at the local level, and also be used to educate and engage stakeholders throughout the community. The project was funded by the City of Powell River and the Pacific Institute for Climate Solutions (PICS).

Municipal Context

The City of Powell River is a small community on the lower mainland of British Columbia that comprises approximately 30.6 km^2 within the qathet Regional District River on the traditional land of the Tla'amin Nation. The community has a population of 13, 157 individuals and a population density of approximately 450 individuals per square kilometer (Sources). The City of Powell River has limited public transportation and is spread out enough that walking and biking to destinations is often not practical. Despite being on the mainland, there are no highways to connect Powell River to other cities, and it is surrounded by mountains, forest, and ocean. This, combined with the low amounts of local industry, requires that the City of Powell River import much of its resources and ship out its waste.

Powell River has a warm and temperate climate with an average low of 0.3℃ in the winter and an average high of 22.1℃ in the summer, thus heating and cooling demand are not as significant as other locations in Canada.[v]

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, and natural gas is supplied by FortisBC.

Just under 25 percent of Powell River's working individuals are employed in goods production, both in primary and secondary sectors. This is mainly composed of forestry (the leading private sector for the economy), the pulp and paper mill, and aquaculture. The remainder of Powell River's workers are involved in the service sectors.[vi] The population of the City of Powell River has been stable, but may see an increase with projects such as the development of an aviation industrial park.[vii]

Some of the city's facilities are aging, and necessary changes are hard to make given the community's small tax base. Powell River is currently updating its sewage treatment plant and is in the final stages of an organics collection pilot program.

Powell River has undertaken a number of recent sustainability initiatives including the creation of a Sustainability Charter for the Powell River Region in 2010,[viii] a "Quick Start" Community Energy and Emissions Plan in 2012,[ix] an updated "Sustainable" Official Community Plan that incorporates sustainability principles in 2014,[x] and an Integrated Community Sustainability Plan in 2015.[xi] Recently the Sustainability Committee that was originally formed to drive development of the Charter back in 2010 has been re-established and continues to work on local policy and initiatives.

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 should align with the national census reporting year, therefore 2016 was selected as the reporting year for this study.

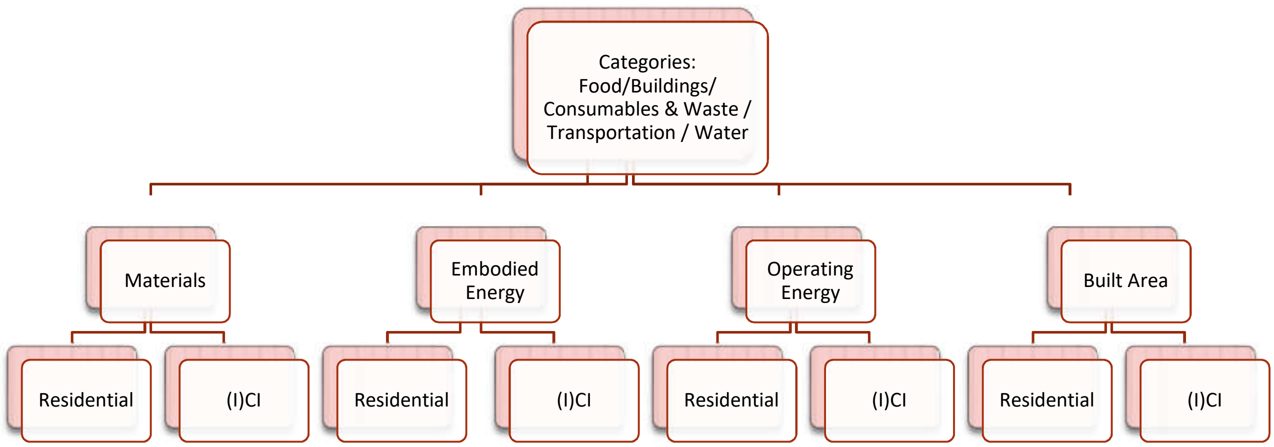


Figure 4: Data Inputs[6]

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 1.9 gha to account for these sources, which is a conservative estimate).
ii. The bottom-up approach does not fully capture all life-cycle impacts of materials and energy used in what is being measured in the footprint components (e.g., embodied energy of fuel and airplanes are not currently included).

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

[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 *Food available is measured as a proxy for food consumption and import distances are used to estimate food-miles travelled. Energy associated with the production and transportation of imported food is then estimated.*	Embodied energy and materials associated with food production (energy and materials used to produce and transport food)	✓	✓	✗	· Food consumption and 'food miles' statistics are not typically available at the local level; therefore, national averages were used as a proxy. Vancouver is currently conducting a food survey to derive local food estimates. Results from this study could be used as a proxy at a later date.
	Land used to produce food	✓	✗	✗	
Buildings *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.*	Operating energy used by buildings and related infrastructure	✓	✓	✓	· Commercial building count is estimated based on a ratio of residential to commercial total building numbers of other jurisdictions. · Built area is estimated using Google Maps. · 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	✓	✓	✗	
	Built area associated with buildings	✓	✗	✗	
Consumables and Waste *Data is collected on the:* · *quantity of solid and liquid waste generated by sector (residential, industrial, commercial and institutional) and by material type;* · *method in which materials are managed (i.e., landfilled, incinerated, recycled, composted);* · *energy consumption and emissions associated with waste management facilities, and transportation of waste;* *material composition and built area associated with waste management facilities.*	Operating energy used in waste management facilities and hauling waste	✓	✓	✓	· Operating energy for waste (liquid and solid) facilities were not available.
	Direct emissions from waste facilities	✓	✓	✓	
	Embodied energy and materials associated with consumables (as inferred by waste stream)	✓	✓	✗	
	Built area associated with waste management	✓	✗	✗	

CATEGORY	INPUTS	EF	CBEI	TERRITORIAL GHG INVENTORY	KEY ASSUMPTIONS AND LIMITATIONS
Transportation *Evaluates the embodied materials and embodied energy of physical transportation infrastructure and vehicles, operating energy (fuel consumed by vehicles), and physical built area occupied by transportation infrastructure. Data is collected for private and commercial vehicles; transit; aviation travel; marine travel and off road vehicle use.*	Operating energy associated with transportation (fuel use for private and commercial vehicles; aviation; marine vessels and off-road vehicles)	✓	✓	✓	· Relying solely on data from the Powell River airport would provide a gross under-estimate of residents' total air travel since many residents travel to international airports for much of their aviation travel (Vancouver). Therefore, air travel was estimated using average per-capita values for Metro Vancouver in addition to local flight data. · BC Ferries fuel usage attributable to Powell River residents was based on an estimate of annual fuel consumption for the standard winter schedule. This method assumes that the majority of travellers in the winter months are local (qathet Regional District). Results were apportioned based on Powell River residents' proportion of the regional population. · 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 *Evaluates the embodied materials, embodied energy, operating energy, and built area impacts of the water distribution and purification system relied on by the municipality.*	Operating energy used in treating and conveying water	✓	✓	✓	· 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 City of Powell River'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 the qathet Regional District (qRD) benefits from the services provided by the City of Powell River. Many residents work in the city and utilize the cultural services, generating waste and using energy while they do so. This would have an upward influence on Powell River's GHG emissions and footprint.

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.

 # Planets Required by Powell River

3.5

Powell River's total ecological footprint is 54,000 gha,[7] which is an area 17 times bigger than the municipal boundary. Powell River's current *per capita* footprint is 4.1 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, Powell River's per capita ecological footprint increases by at least 1.9 gha, to 6.0 gha/person.[8] Although Powell River's footprint is significantly less than the Canadian and US average, it is still 3.5 times what is available (1.7 gha per person). Put another way, this means that approximately 3.5 Earths would be required to support the global population if everyone had lifestyles comparable to a Powell River resident.

If we look at the various components of Powell River's footprint, as shown in Figure 5, transportation and the consumption of food represents the largest impact, followed by buildings, and consumables and waste. As previously noted, some of the qRD residents' impact is being absorbed by the city of Powell River, which acts as a regional service centre. Thus, the energy used in commercial and institutional buildings, and the impact of consumables that result from qRD residents working and recreating in Powell River is also 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. The estimation of the impact of national and provincial services was recently reviewed by Dr. Moore, with total impacts being higher than previously reported. As such, the results presented here (including these senior government services) are not directly comparable with results generated for Vancouver, Saanich, Victoria and North Vancouver (until these community's reports are updated).

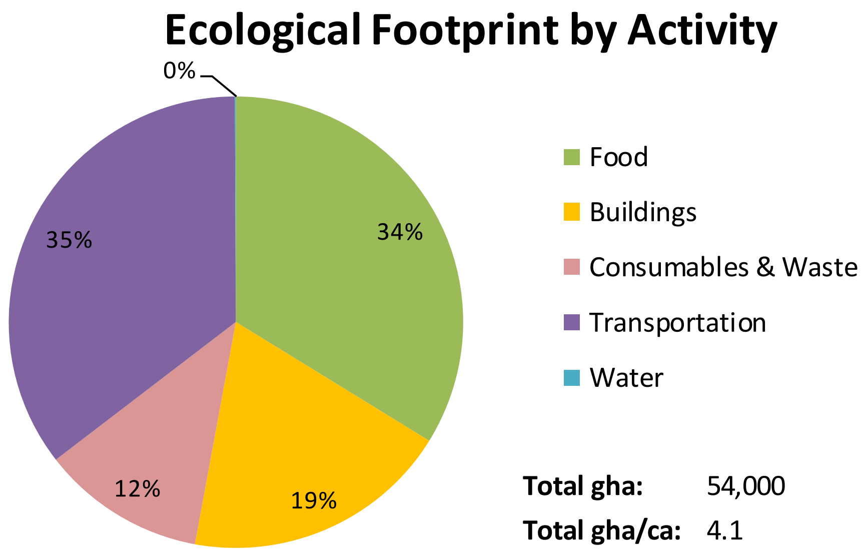


Figure 5: Summary of Ecological Footprint by Activity, 2016 (excluding national and provincial services)

Food Footprint

In considering the food footprint we see that only a small proportion of the impact is associated with transport of food, whereas 98% of the footprint is a result of the amount of land and energy that are utilized in growing food (see Figure 6).

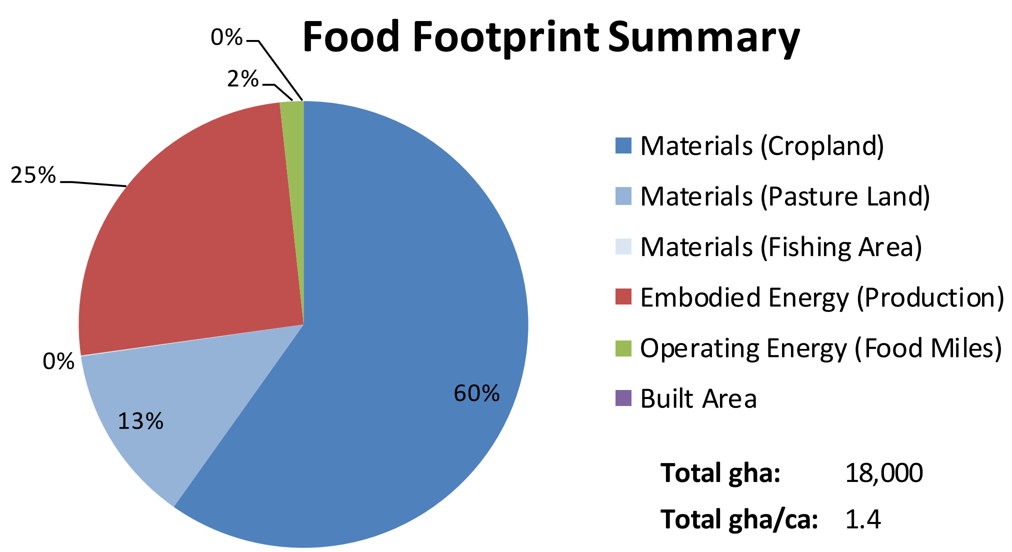


Figure 6: Food Footprint Summary, 2016

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, in particular cheese (see Figure 7). **These results demonstrate that the largest priority for reducing Powell River'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.

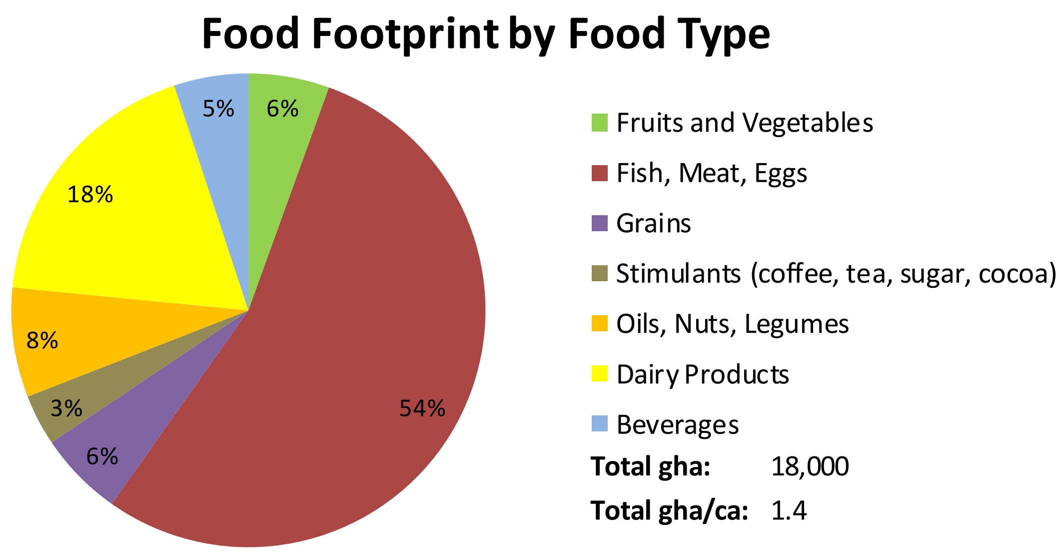


Figure 7: Food Footprint by Food Type, 2016

Buildings Footprint

As shown in Figure 8, nearly half of the ecological footprint of 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 buildings, the impact of material choices will make up a greater percentage of the footprint. In addition, the embodied energy impact of Powell River buildings is higher than that of other BC jurisdictions that have used the ecoCity Footprint Tool because Powell River has a much higher percentage of single-family homes, and fewer people per home. **The near-term priority should be to improve the efficiency of buildings and accelerate action to implement renewable energy, with a longer-term objective of ensuring footprint impacts are considered in decisions about building materials over their lifecycle and new housing types.**

[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.

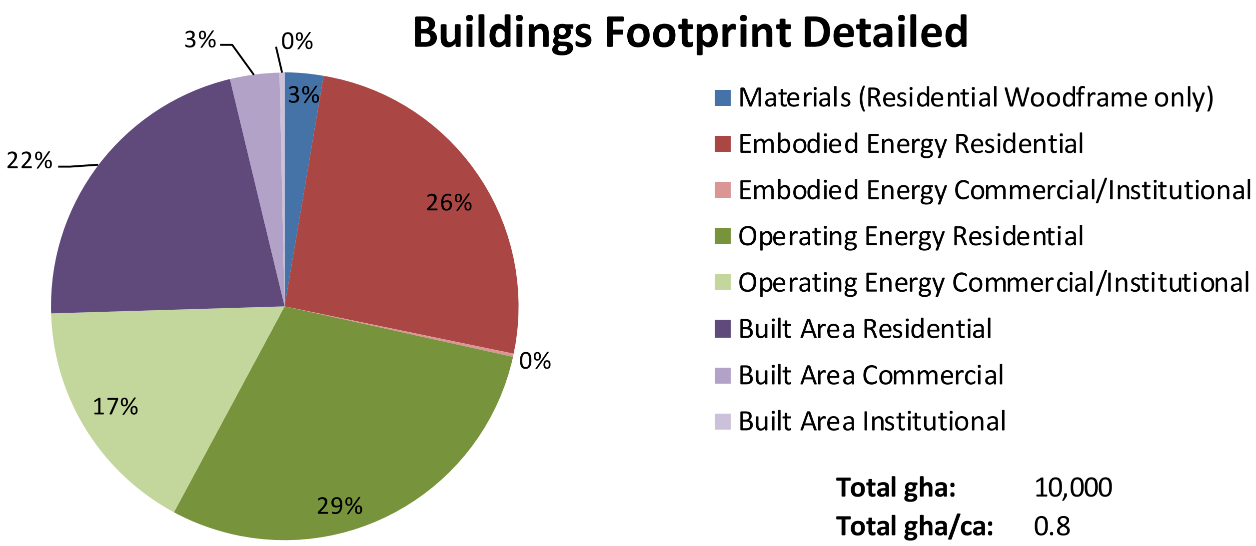


Figure 8: Buildings Footprint Detailed, 2016

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.**

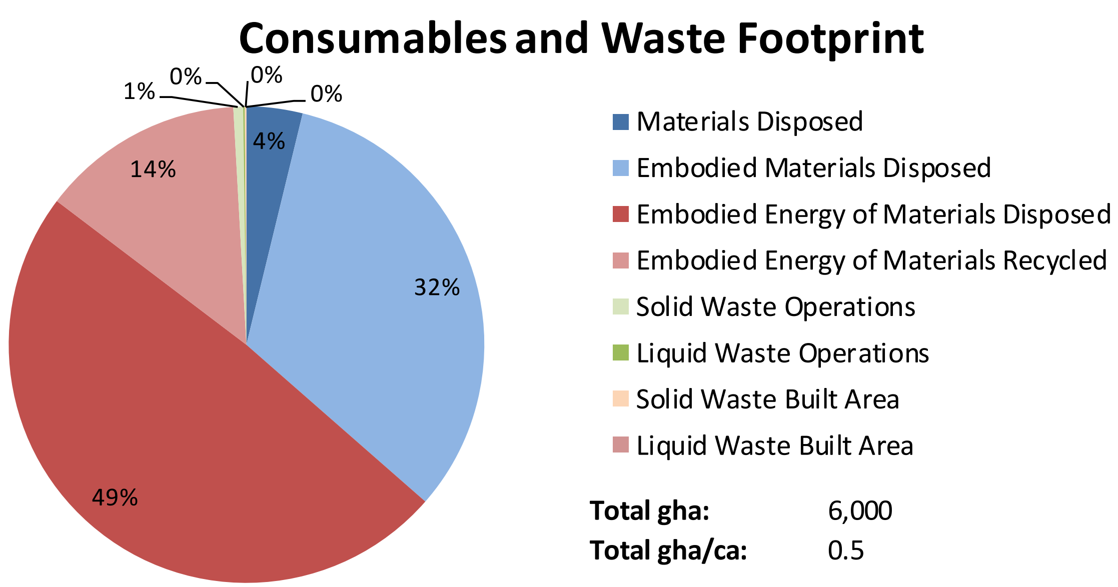


Figure 9: Consumables and Waste Footprint, 2016

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

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 consumables footprint is dominated by textiles, followed by paper, plastics and metals. 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.).

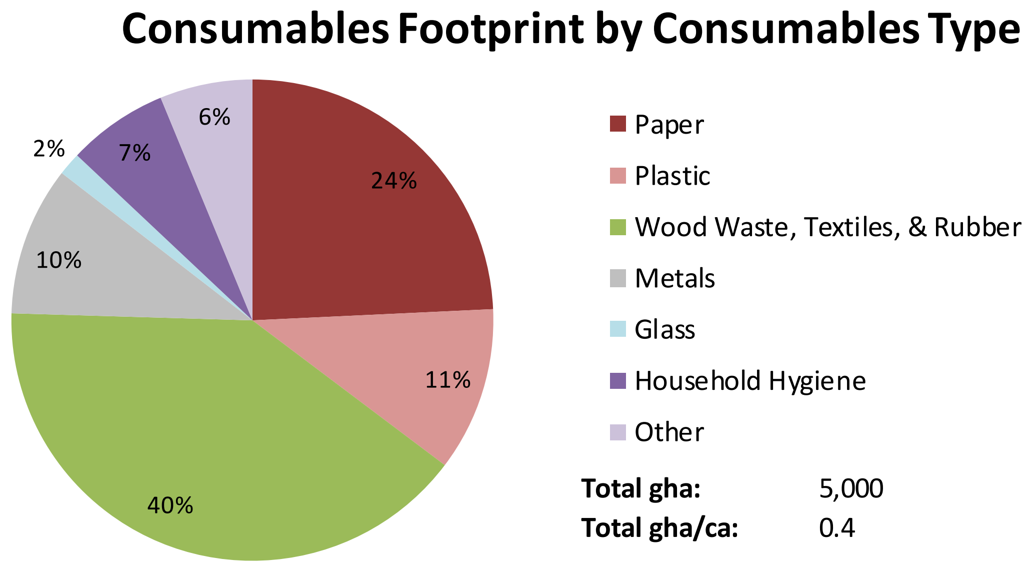


Figure 10: Consumables Footprint by Type, 2016

Transportation Footprint

Half of Powell River's transportation footprint is a result of fuel consumption for private vehicles, and if we add in the embodied energy of vehicles, private vehicle transportation represents nearly two-thirds of the footprint. Powell River has a much higher proportion of trucks in the private fleet then other jurisdictions studied which not only use more fuel, but also require double to triple the material (and embodied energy) to make. Air travel is also significant. **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 promoting compact cars over trucks, car sharing and transit. The long-term priority should be promoting compact communities that are designed for active transportation and transit.**

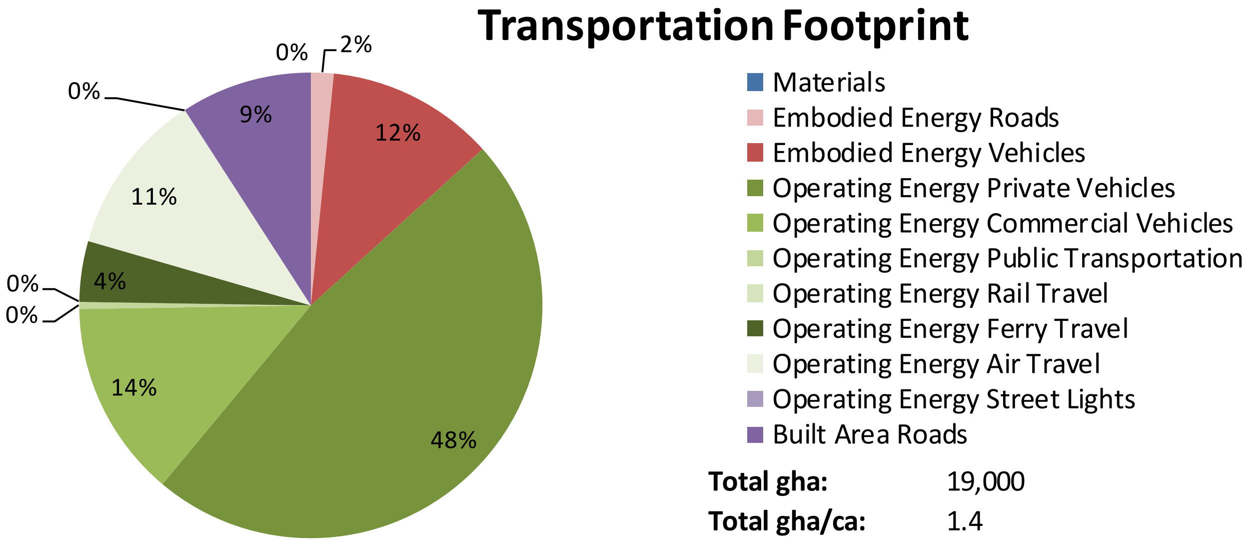


Figure 11: Transportation Footprint in Detail, 2016

Territorial GHG Emission Inventory

Through enhancements as part of a 2017 pilot project, the eF Tool now provides a territorial GHG emission inventory which is compliant with GPC[11] reporting protocols. For this report, we present only summary information on the territorial emission inventory for the purposes of comparison with the Consumption-Based Emission Inventory. As shown, total territorial emissions for Powell River are 92 ktCO_2e,[12] or 7 tC02e per capita.

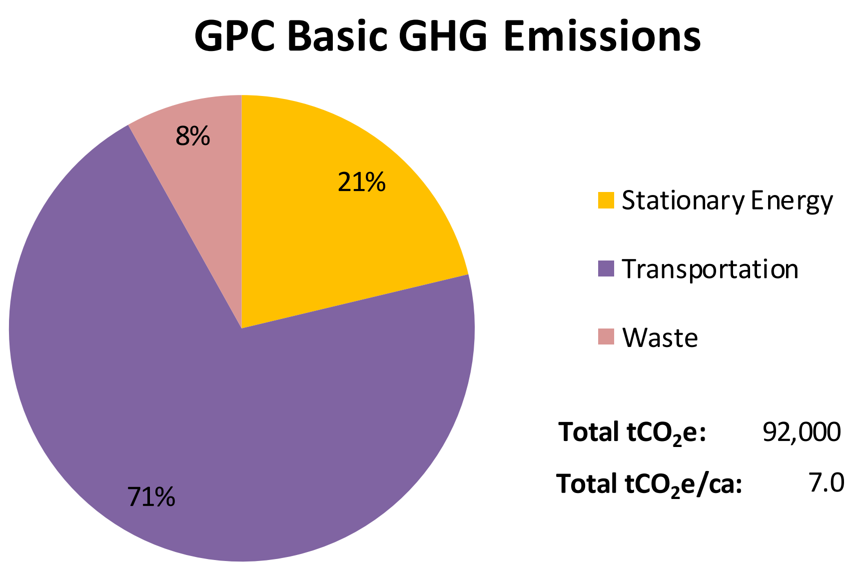


Figure 12: Territorial GHG Emissions Inventory (GPC Basic Inventory)[13]

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 Powell River were 166 ktCO_2e in 2016 (see Figure 13), nearly 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 (59%) followed by buildings (18%); whereas for the EF, the largest impact category is transportation (35%) followed by food (34%). Food impacts are the area in which these results vary most significantly. Food is only 12% of the total for the CBEI, but 34% of the EF; the primary driver for this difference is the land intensity of food production.

---

[11] 'Global Protocol for Community-Scale Greenhouse Gas Emission Inventories', a new international standardized approach to conducting territorial emission inventories at the community level.

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

[13] Stationary Energy is made up of emissions from fossil fuel and electricity use in buildings

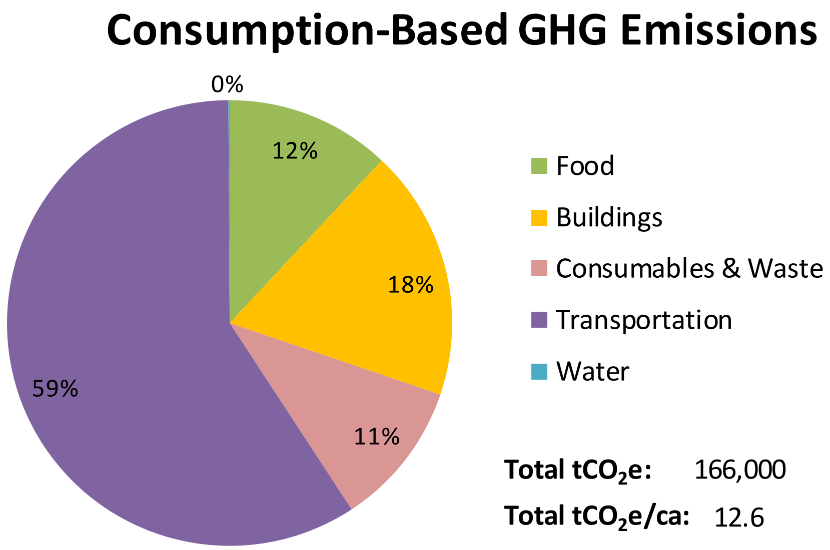


Figure 13: Summary of GHG Emissions from Consumption, 2016

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 (red meat) and dairy (cheese). 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.

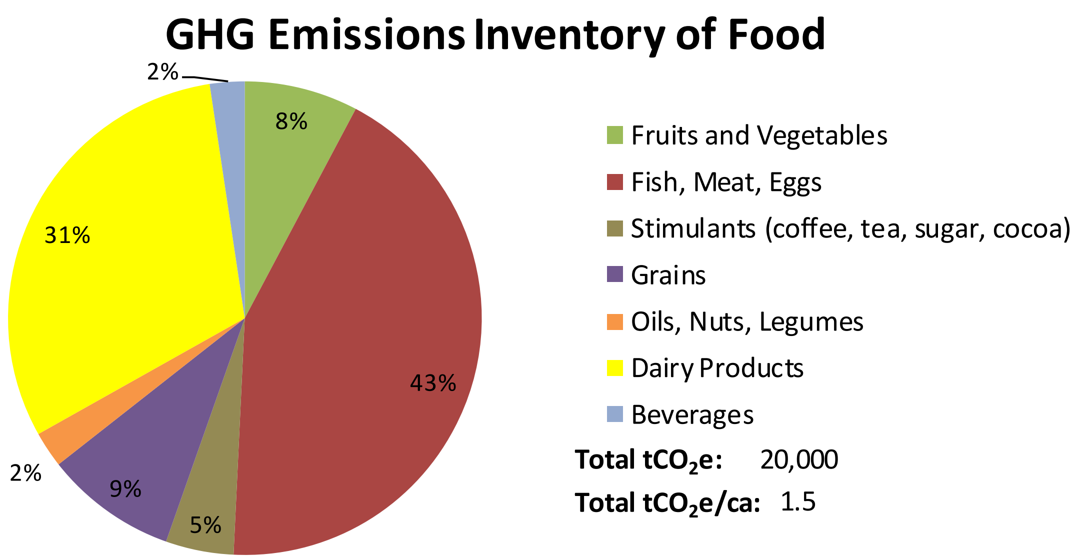


Figure 14: Greenhouse Gas Emissions Inventory of Food, 2016

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.

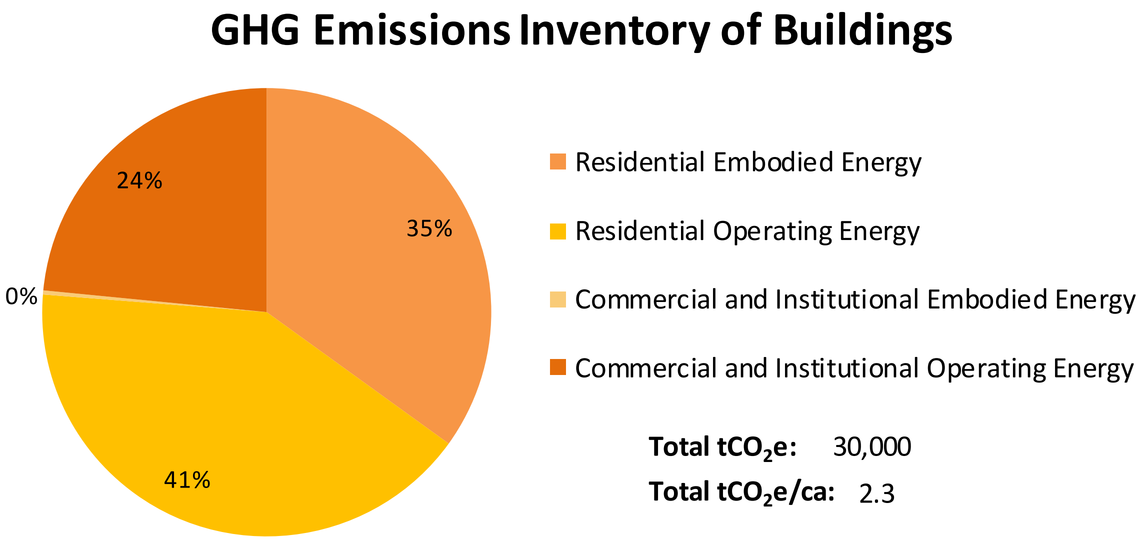


Figure 15: GHG Emissions Inventory of Buildings, 2016

CBEI of Consumables

The CBEI for consumables shows that the largest GHG impact is due to textiles, as shown in Figure 16. The impact on consumption-based emissions are higher from plastics then their impact on the footprint (17%, compared to 11% for the EF); and much less for paper (15%, compared to 24% 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.).

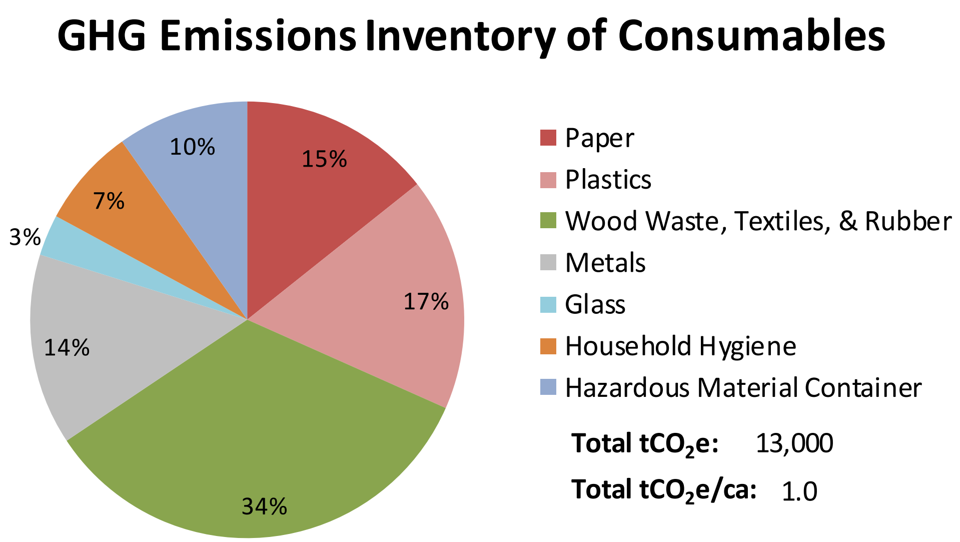


Figure 16: GHG Emissions Inventory of Consumables, 2016

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.

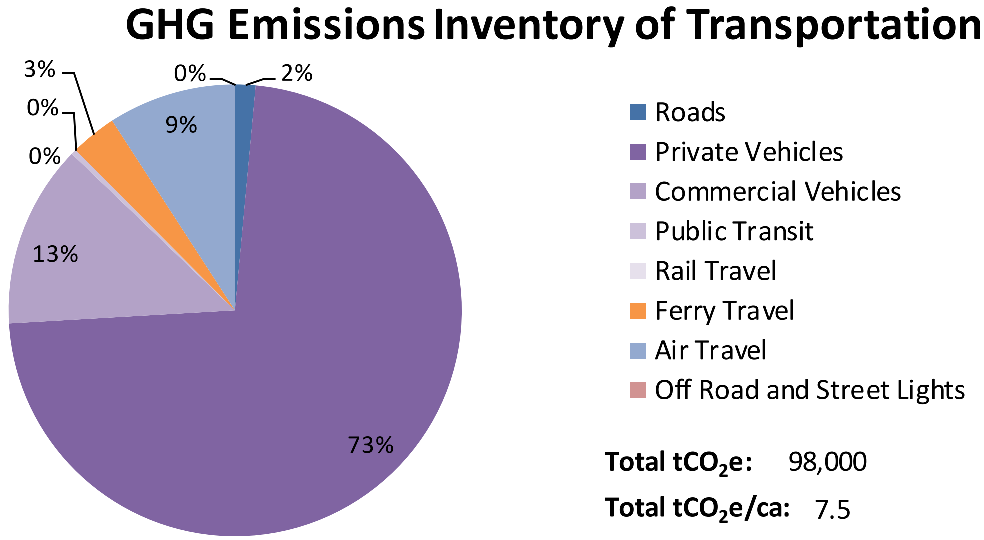
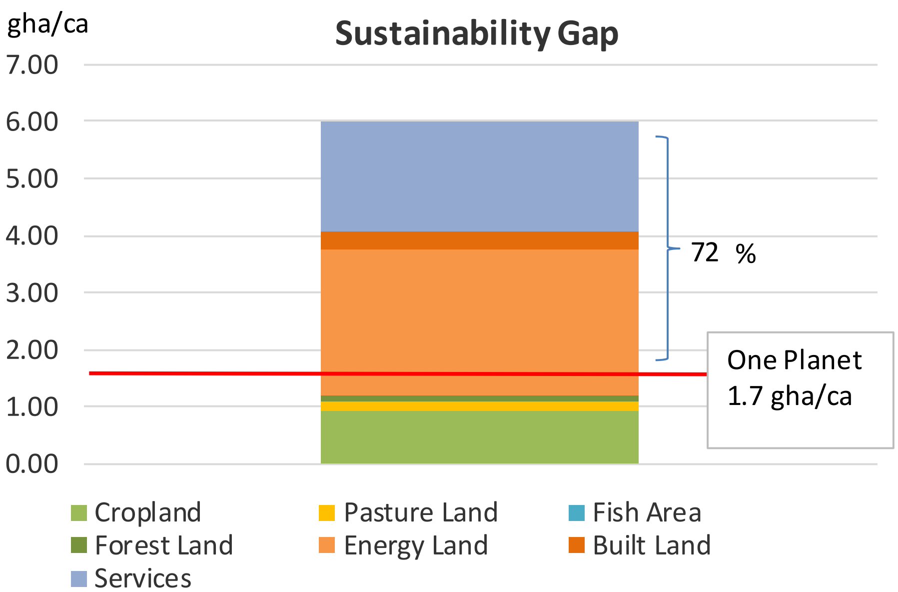


Figure 17: Greenhouse Gas Emissions Inventory of Transportation, 2016

THE SUSTAINABILITY GAP

To achieve 'One Planet Living' Powell River's ecological footprint would need to reduce from 6.0 gha per capita (with national and provincial services)[14] to 1.7 gha per capita.[15] This represents a sustainability gap of 72%. From a climate perspective, in order to achieve the target of maintaining global temperatures below a 2 degree Celsius in warming, GHGs must be reduced to 2 tCO_2e per capita before 2050. Given Powell River's current CBEI per capita emissions of 12.6 tCO_2e, GHG emissions would need to be reduced by 84%; and based on the GPC (territorial) per capita emissions of 7 tCO_2e, they would need to be reduced by 71%. Net GHG emissions would need to reach zero before 2075.



Cropland, Pasture Land, and Fish Area
- Refer to the area used for these activities

Forest Land
- Refers to the area of forest harvested

Energy Land
- Refers to the area of forest needed to absorb CO_2 emissions

Built Area
- Refers to the area covered by infrastructure such as roads and buildings

Services
- Refers to the area needed to absorb the impact of national and provincial services

Figure 18: Sustainability Gap, 2016 (including national and provincial services)

[14] Excluding national and provincial services Powell River's footprint is 4.1 gha per capita.

[15] Currently an average of 1.7 global hectares is available for each person on the planet

ONE PLANET SCENARIO

A One Planet Scenario for Powell River 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_2e/capita)
Convert 70% of vehicle fleet to electric & the remaining 30% to hybrid, also converting 50% of Light Trucks/SUV hybrids to Small/Compact Car hybrids**	0.92	5.58
Reduce VKT 25% in private vehicle fleet	0.03	0.17
Convert 100% of ferries and transit to electric	0.07	0.27
Eliminate fossil fuel use in buildings	0.29	1.40
Reduce beef/lamb by 75% (and substitute with fish, chicken and legumes) and reduce dairy (without substitution) by 50%[16]	0.53	0.29
Reduce food waste post-purchase 30%	0.25	0.37
Reduce Municipal Solid Waste (MSW) 50%	0.15	0.42

**These reductions can also be achieved by including mode shift to active transportation and transit which has the added benefit of reducing the total vehicle fleet size and its embodied energy.

This scenario lowers the footprint below the 1.7 gha per capita threshold, lowers the GPC (territorial) GHG emissions to 1.1 tCO_2e per capita, and lowers the CBEI GHG emissions to 3.9 tCO_2e per capita. Further emissions reductions would need to target aviation, vehicles, consumption of consumables, farming practices and the materials used for buildings and infrastructure such as roads.

What might a one planet lifestyle look like…[17]

Meet Brenda. Her family has recently moved into a new home in Westview that is certified zero carbon. This means that all building materials and construction equipment are carbon neutral. Most of the windows in the home face southwest overlooking Malaspina Strait. This design results in certification as a passive home with very little space heating and cooling requirements. A programmable thermostat maintains a comfortable room temperature by controlling window shading and a solar thermal heat/cooling pump system. The roof space is leased to one of Powell River's increasing number of urban farmers and to BC Hydro for renewable electricity generation.

In addition to weekly visits to the Farmers' Market, the family orders grocery deliveries from the network of local farmers and distributors, based on a meal plan she has entered online. She and her family eat a largely vegetarian diet high in fresh vegetables and legumes with small portions of white meat, local wild fish and local cheese, all of which is tracked in their personal carbon emissions budget. They collect all food scraps and yard waste for

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

[17] To enable residents to achieve a one planet lifestyle, governments and corporations that provide goods and services must also adopt one planet operations.

composting at the qathet carbon sequestration plant for use in local farms and community or private vegetable gardens.

The family owns a small electric car that is certified zero carbon. It is easily and quickly charged at the large number of charging stations throughout the city. They belong to the local car co-op for times when they need an electric truck or second vehicle. As often as possible, family members bike or walk to work or school. On inclement days, they use the electric car or make use of electric transit. It is a short trip to Westview Elementary for Brenda’s daughter, but her son takes transit to Brooks.

Brenda and her family hold periodic clothing swap parties. They also frequent local thrift and consignment stores. They have taken courses at the Powell River campus of VIU to learn about repurposing fabric and apparel. For DIY projects, they go to the Resource Recovery Centre to find what they need.

Brenda, her partner and children all like to participate in the Powell River sports and culture scene. When they do so, they can now rest assured that the events are all required to be carbon neutral. In the past they donated to the “Offset the Carbon Cost of this Event” receptacle, a long-time feature of all Powell River concerts and games.

The family keeps in touch with relatives and friends online. When they do travel, they make use of the electric shuttle bus and electric ferries to Vancouver Island and the Vancouver train terminal. The high-speed electric trains now only take 6 hours to reach Toronto. Usually they spend vacation time in the surrounding Powell River area.

Whenever the city or regional district hold public meetings to update residents on One Planet Living, the family attends.

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

> *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*

- 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 Powell River, 12% of CBEI emissions and 34% of the EF are due to food consumption.
- *Decrease red meat and dairy (cheese) consumption by substituting with legumes and white meat and reduce food waste.* For Powell River, meat and dairy consumption is responsible for nearly three quarters of the food component of the EF, and CBEI emissions.
- *Ensure that local food production has low resource intensity (in terms of fossil energy use and land area).* For Powell River, 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 Powell River, 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 City of Powell River

High-level actions for each sphere of municipal planning are presented below. This is not an exhaustive list, it is recommended that the City 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 Reduce meat and dairy consumption Obtain local data on food consumption impacts	· Promote sharing economy opportunities (e.g., community gardens). · Promote diet shifts (e.g., 'Meatless Mondays' Oregon; Celebrate the Harvest campaigns). · Adopt advanced purchasing standards (e.g., Emeryville Good Food Purchasing Program, EPA West Coast Forum on Materials and Climate's Climate Friendly Purchasing Toolkit). · 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 1st approach) Use building materials with lower embodied energy	· Implement government purchasing policies to favour recycled content/reused building materials. · Provide incentives for smaller and more energy efficient homes, and renewable technology incentives for homes and business. · Building codes that promote energy and material efficiency
CONSUMABLES	Reduce the volume of individually owned goods Increase reuse	· 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). · Support and promote Repair Cafés and Fix-it clinics and the local repair industry.
TRANSPORTATION	Reduce vehicle ownership Decrease vehicle travel Improve efficiency of vehicle fleet Better understand inter-urban transportation demand	· Increase electrification of fleet. · Support and promote bike-sharing and car-sharing programs. · Continue to expand Active Transportation Initiatives. · Ensure neighbourhood plans contribute to compact urban development, smaller homes and walkable neighborhoods. · Undertake an 'Inter-urban' Transportation Demand Survey to gain a better understanding of residents out of boundary transportation habits (e.g., ferry, cruise, aviation).

City Initiatives

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

- Update goal and target setting: consider adjusting 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).

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	12.82	**9,753**	10.89	**8,290**	3.21	2,443			
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 Powell River'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 population was also required to allocate regional impacts to the municipality.

Sources

Statistics Canada. (April, 2018). *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.

However, City of Vancouver plans to undertake a localized food survey in 2018, 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 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 CO_2e per tonnes-kilometers by sea and truck to estimate total emissions.

Sources

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

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

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

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

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

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

Challenges and Opportunities

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

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

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

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

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

Buildings

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]

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. The number of commercial buildings was estimated using ratios of residential to commercial building counts for other BC jurisdictions and scaled for Powell River's population.

Statistics Canada. (April, 2018). *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

The number of commercial buildings was not available and was estimated using ratios of residential to commercial building counts for other BC jurisdictions and scaled for Powell River's population.

Operating Energy [Buildings]

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.

The most recent building operating energy was provided by the province for 2017. However, BC Hydro and Fortis BC have both changed their methodologies from what was done in previous years. Until the new methodologies are back-casted and compared to the old methodologies it is unknown if the data is comparable. Therefore, the building operating energy data used for this analysis is from Powell River's 2012 CEEI, and those numbers were multiplied by the population change percentage of Powell River from 2011 to 2016 to adjust to the 2016 reporting year.

Transmission Loss

BC Hydro's estimated transmission loss rate of 7.5% was applied to account for emissions associated with electricity transmission losses (Equation 1).

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

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

Fugitive Emissions

Fugitive emissions estimates for Powell River were estimated by scaling the fugitive emissions for other BC jurisdictions by the amount of gas used.

Sources

The 2012 CEEI from the City provided the most recent study year to have reliable estimated energy use. This was scaled by population change to estimate 2016 energy 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

Government of BC (2012). 2012 Community Energy and Emissions Inventory (CEEI). Retrieved from https://www2.gov.bc.ca/gov/content/environment/climate-change/data/ceei

Challenges and Opportunities

The CEEI data combines commercial and institutional data sets, therefore commercial operating energy was over-represented and institutional data was not expressed in its own category.

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]

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 completed with rough estimates using Google Maps. Streets, lanes, and sidewalks could not be separated, so were included in total numbers and extracted later using data from other BC jurisdictions that shows roads to make up 40% of the built area on average.

Sources

Built area was roughly calculated using Google Maps.

Challenges and Opportunities

Built area is often available through GIS data, however smaller communities such as Powell River typically do not have the resources for GIS mapping. The methodology used is likely resulting in an overestimate of built area for Powell River as its impact is significantly higher then for other BC jurisdictions that have used the ecocity Footprint Tool.

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 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 (territorial) 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 tonnages, an estimate waste composition by material type and what portion of the waste stream was coming from residential, commercial/institutional, and construction/demolition sources were all available from the Powell River Regional District Solid Waste Management and Resource Recovery Plan. The volume of recycling and its composition was not available from Recycle BC (formerly Multi-Material BC) and was partially available from Let's Talk Trash who also provided data on organics collection. Waste and recycling data were for the qathet Regional District and apportioned based on the population of the City of Powell River.

Powell River's solid waste is shipped by barge to Vancouver, where it is then transported by train to the Roosevelt Regional Landfill in Washington, but data on this transportation process was not available. Emissions estimates were made using Google Maps to estimate distances and emission factors for barge and rail transport were available in literature (ECTA, 2011).

Roosevelt Regional Landfill generates energy from methane gas (Judd, 2012). In 2012, the Roosevelt Regional Landfill produced 17.6 Megawatts of energy from 2.1 million tonnes of waste. This data was used to back-calculate the methane collected at the landfill apportioned to Powell River's waste contribution.

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

Powell River's liquid waste system currently has three plants: the Westview System, the Townsite System, and the Wildwood System. They each discharge their effluent into Malaspina Strait (Opus Daytonknight, 2015). Structural information on the facilities was not available. Volume flows of liquid waste were available from the Liquid Waste Management Plan. However, this data includes storm water flows and therefore data from other jurisdictions was used to estimate the portion of flow attributed to liquid waste.

Operating energy for liquid waste treatment was available from personal communication with City staff, however, data on the liquid waste infrastructure and the solid waste operating energy and infrastructure were not available.

Sources

Landfill waste volumes and estimates of composition were accessed from the qathet Regional District and recycling volumes and composition were partially available from personal communication with Let's Talk Trash representatives. Volumes of liquid waste were available from the City.

Maura Walker & Associates. (2017). *Powell River Regional District Solid Waste Management and Resource Recovery Plan*. Retrieved from http://www.powellriverrd.bc.ca/wp-content/uploads/FINALSWRMP_17Nov2017-FINAL.pdf

ECTA. (2011). Guidelines for Measuring and Managing CO_2 Emission from Freight Transport Operations. Retrieved from https://www.ecta.com/resources/Documents/Best%20Practices%20Guidelines/guideline_for_measuring_and_managing_co2.pdf

Opus DaytonKnight. (2015). CITY OF POWELL RIVER LIQUID WASTE MANAGEMENT PLAN - STAGE 3. Retrieved from https://powellriver.civicweb.net/document/34493

Judd, R. (August 3, 2012). What a big bunch of garbage: but Roosevelt Landfill turns it into power. The Seattle Times. Retrieved from https://www.seattletimes.com/pacific-nw-magazine/what-a-big-bunch-of-garbage-but-roosevelt-landfill-turns-it-into-power/

Klickitat Public Utility District (2011). H.W. Hill Landfill Gas Project. Retrieved from http://www.klickitatpud.com/topicalMenu/about/powerResources/hwHillGasProject.aspx

Republic Services (2018). Roosevelt Regional Landfill. Retrieved August 2018, from http://local.republicservices.com/site/roosevelt

Challenges and Opportunities

Agencies that handle collection of waste and recyclables across the Province, are not providing full access to data. The Province and cities can make this data access a requirement in contract renewals.

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

Methodology

Data on built area was not available and estimates were made using data from other jurisdictions and scaling for population.

Sources

N.A.

Challenges and Opportunities

Smaller communities typically do not have the resources to track this type of data

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 area was not available and data from other BC jurisdictions was used to apportion the amount of the total built area from roads at 40%.

Sources

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

The methodology to calculate built area is likely resulting in an overestimate for Powell River as its impact is significantly higher then for other BC jurisdictions that have used the ecocity Footprint Tool.

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

Operating Energy [Transportation]

1. Road Transportation

Methodology

Private and Commercial Vehicles

Data requirements include 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 2016 and VKTs from Climate Action Powell River's carbon calculator could not be provided in time for this study. The latest data was 2010 CEEI data which was adjusted for population change to estimate 2016 data.

Transit

Transit emissions were provided from personal communications with City staff.

Off road vehicles

Off-road vehicle fuel consumption was not available.

Sources

Private Vehicles

Data on private vehicles relied on the same 2010 data used in:

City of Powell River (2012). City of Powell River Community Energy and Emissions Plan. Retrieved from https://powellriver.civicweb.net/document/2723

Challenges and Opportunities

All BC municipalities have difficulties collecting data on road transportation. Up-to-date ICBC data takes time to access and VKT data is no longer being collected by the province. The carbon calculator being hosted by Climate Action Powell River provides an opportunity to collect local VKT data for future studies.

2. Marine Transportation

Methodology

Marine transportation includes private vessels, passenger ferries, and cruise ship activities. Only limited data from BC ferries was available. Ferry fuel efficiency was estimated using the 2016 B.C. Best Practices Methodology for Quantifying Greenhouse Gas Emissions. The average fuel efficiency of Powell River's routes is likely much lower then this BC average since the smaller ships use more fuel per person and the minor routes have a lower average loading. This means emissions from ferry travel are likely under reported for this study. Total distances were calculated using the winter route numbers, assuming that extra runs during the summer were attributable to tourism. The removal of runs for holidays or weather and the addition of runs for predicted busy days were not accounted for. The ferry from Langdale to Horseshoe Bay was included in the total distance data because most individuals exiting Powell River in the southern direction take both ferries, rather than stopping in the Sechelt area. Emissions were apportioned based on average loads on the Comox and Earls Cove routes adjusted for the City of Powell River's proportion of the regional population.

Sources

BC Ministry of Environment. (2016*). 2016 B.C. BEST PRACTICES METHODOLOGY FOR QUANTIFYING GREENHOUSE GAS EMISSIONS*. Retrieved from https://www2.gov.bc.ca/assets/gov/environment/climate-change/cng/methodology/2016-17-pso-methodology.pdf

BC Ferries route and distance information retrieved from https://www.bcferries.com/

BC Ferry Services. (2017*). Annual Report to the British Columbia Ferries Commissioner*. Retrieved from http://www.bcferrycommission.ca/wp-content/uploads/2017/08/2016-2017_Annual_Report_to_the_BC_Ferry_Commissioner.pdf

Challenges and Opportunities

Marine emissions from other sources are difficult to find publicly, but these sources could be significant.

3. Air Travel

Methodology

Powell River has a local airport, but calculating emissions associated only with the Powell River airport would grossly under-estimate residents' total air travel. In addition to travelling out of the Powell River airport, many residents regularly use other international airports such as YVR in Vancouver.

Therefore, 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 Powell River's population to estimate greenhouse gas emissions in addition to the emissions from the Powell River airport. Emissions from Powell River airport were based on the average number of flights per year at an approximate distance of a flight (120km) apportioned to the City of Powell River's proportion of the regional population.

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

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

Seat Class

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

Average Load Factor

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

Distance and Emission Calculation

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

Metro Vancouver Residential Scale Factor

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

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

Flight information for Powell River airport from https://www.pacificcoastal.com/

Fuel consumption of Beechcraft 1900 calculated using information from https://www.globalair.com/aircraft-for-sale/Specifications?specid=282

Challenges and Opportunities

These estimates are limited by three 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 Powell River residents who may drive to and from other airports (Seattle, WA, Victoria, BC, etc.) 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

Other than some outdated pipe information, there was little structural information available. Water pipe lengths were added together to get a rough estimate of the total network, but there was no information on whether new pipes have been added. The water sources (lakes) have few structures associated with water collection, and are accessed by dirt logging roads and trails.

The available data indicated that 90 percent of Powell River's water was provided by Haslam Lake, which is a completely gravity fed system (Dayton & Knight, 2006). Powell Lake uses three pumps and provides the remainder of the community's water (Dayton & Knight, 2006). The average daily consumption was determined by adding average daily volumes consumed by the Haslam areas and the Powell Lake areas. Powell River has had a small population drop since that time which was not accounted for.

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

Dayton & Knight Ltd. (2005). Water Network Model Upgrade. Retrieved from https://powellriver.civicweb.net/document/378

Dayton & Knight Ltd. (2006). City of Powell River Drinking Water Protection Act Implementation. Retrieved from https://powellriver.civicweb.net/document/339/Drinking%20Water%20Protection%20Act%20Implementa.pdf?handle=91A96267FD97494CB0804C277E5B0158

Operating Energy [Water]

Methodology

The water system is mainly gravity fed, with a few hydraulic zones, and therefore does not use a lot of energy (Dayton & Knight, 2006). Electricity data was provided by city staff through the 2017 City Buildings Electricity Use.

Sources

Personal communication with City of Powell River staff

Built Area [Water]

Methodology

Area calculations for the watershed included roads (length and width), buildings, and dams; and protected area and reservoir area. Built area was not estimated for Powell River as there are few known structures associated with the water collection, and accessibility is through dirt logging roads and trails.

Sources

N.A.

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.

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