ecoCity Footprint Analysis

for

Oxfordshire County

Part of Oxfordshire One Planet initiative with BioRegional

By Dr. Jennie Moore

April 10, 2019

For Bioregional

Ecological and carbon footprint analysis for achieving one planet living.

Summary

This report presents an ecoCity footprint analysis for Oxfordshire County for the year 2015. It includes: i) territorial and consumption-based greenhouse gas emissions inventories, ii) detailed ecological footprint, iii) per capita sustainability gap, meaning the difference between the ecological footprint and global ecological carrying capacity measured on a per capita basis, iv) identification of actions that could reduce the per capita footprint in-line with global per capita ecological carrying capacity, commonly referred to as one-planet living.

Data for this study were collected with assistance from Bioregional and Oxfordshire County staff and processed using the ecoCity Footprint Tool. Results support the One Planet initiative within Oxfordshire that is being coordinated through BioRegional, an international not-for-profit agency.

Oxfordshire's territorial and consumption-based greenhouse gas emissions inventories are presented in Figure a. The territorial emissions inventory, measured at 6.7 tCO_2e/ca, counts emissions generated within the County including those associated with industrial manufacturing as well as those associated with grid-supplied electricity and treatment of waste. The consumption-based inventory, measured at 10.0 tCO_2e/ca, includes emissions generated anywhere in the world that are associated with the consumption and lifestyle practices of the local population. This includes food and embodied energy in the supply chain of goods and services consumed within Oxfordshire as well as infrastructure located in the County.

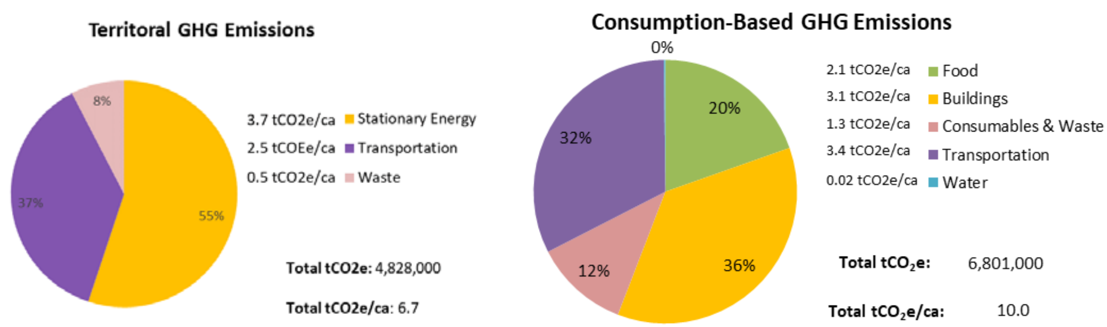

Figure a: Comparison of territorial and consumption-based greenhouse gas emissions inventories, 2015

Oxfordshire's ecological footprint is conservatively estimated at 3.56 gha/ca excluding senior government services and capital infrastructure formation outside the county. If these were added to the footprint the estimate would likely increase by 18-33%.[1] If everyone were to consume at a level equivalent to that of an average resident of Oxfordshire, it would require the resources of at least three Earth-like planets.

[1] The Global Footprint Network provides top-down footprint estimates for many cities and most countries. Cross-referencing the outcomes of this bottom-up analysis with such a top-down assessment can help identify the impact of senior government services. For example, in Canada, the impact of senior government services on Vancouver, a relatively low-footprint city in that country, revealed that senior government services and gross capital infrastructure formation contribute an additional 15% and 34% respectively.

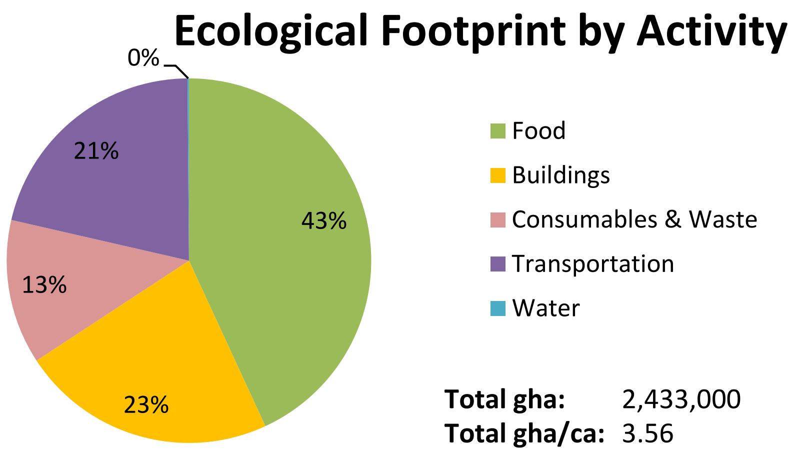

Figure b: Oxfordshire's ecological footprint (excluding senior government services), 2015

Consumption of dairy and meat, in particular red meat, account for the largest share of the food footprint. Reliance on coal and natural gas in grid-supplied electricity and for heating accounts for the largest share of the buildings footprint. Consumption of paper and textiles accounts for the largest share of the consumables and waste footprint. Private motor vehicle travel accounts for the largest share of the transportation footprint. Built area accounts for the largest share of the water footprint. (NB: In this study, the term "water footprint" refers to demand on nature's services to provide drinking water to urban residents.)

A One Planet Scenario is presented comprising a:

- 50% substitution of red meat with poultry; 50% reduction in fluid milk consumption;
- 75% building energy efficiency improvement, and substitution of 50% of fossil energy in grid-supplied electricity with zero-emission, renewable energy;
- 50% reduction in paper, plastic, textile, and household hygiene consumption;
- 30% reduction in other consumables;
- 75% reduction in air travel, commercial vehicle travel, and private vehicle travel.

It is important to note that averages can mask disparities in actual consumption among rich and poor in a given community. Therefore, it is possible that those who are more affluent and live with a higher than average ecological footprint may find more opportunity to reduce their impacts than those already living at subsistence levels.

The cumulative results of implementing these measures could reduce Oxfordshire's ecological footprint to 1.6 gha/ca (down 1.93 gha/ca from 3.56 tCO2e/ca). This is the recommended footprint conducive to living within global ecological carrying capacity, known as one planet living. The corresponding impact of these measures on the territorial GHG inventory could reduce emissions to 1.81 tCO2e/ca (down 4.89 tCO2e/ca from 6.7 tCO2e/ca). The impact of these measures on the CBEI would reduce it to 3.89 (down 6.11 tCO2e from 10.0 tCO2e/ca). This is still 2.89 tCO2e/ca above a recommended climate stabilization target of 1.0 tCO2e/ca (IGES, Alto, D-mat 2019).

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1.0 Introduction

Scientists suggest that we have entered the era of the Anthropocene in which humanity is the greatest force shaping earth's terrestrial systems. Currently, 50% of global, ecological net primary production is appropriated for human use. This figure climbs to 80% when indirect effects are considered (WWF 2014). As a result, humanity is in a state of ecological overshoot. This means that global consumption of energy and resources coupled with the associated pollution these activities generate, e.g., in the form of carbon dioxide emissions, exceeds what nature can produce and assimilate in a given year (Wackernagel and Rees 1996). As a result, we are bumping up against important planetary boundaries for water, nutrients, atmospheric loading of carbon dioxide, etc. (Rockstrom et al. 2009).

Simply stated, it would take at least 1.5 Earth-like planets to provide the ecological services we use year-over-year on a sustained basis.

Climate change is one of the most critical issues facing humanity as a direct result of ecological overshoot. Recently, Nation States from around the world, including England, 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 impacts of a changing climate.

Cities account for only 3% of global land use, but with over half the global population living in cities, they account for the majority of global resource consumption. Although cities can provide an efficient use of space, and in themselves are not a problem, the energy and resources intensity of urban lifestyles require vast resource areas outside the city. The discrepancy between the small amount of land occupied by cities and the extensive amount of land required to resource urban lifestyles is at the heart of the urban sustainability challenge. A city can require 50-200 times more land than is contained within its geographic area to provision the energy and materials needed to support its urban residents.

Consumption-based emissions inventories and ecological footprint analyses, aided by the ecoCity Footprint Tool, have the capacity to equip communities with the information needed to act on global climate change and ecological overshoot in an effort to operate within planetary boundaries.

1.1 Acknowledgements

Data for this study was collected by Majonne Frost, Program Manager, and Marina Goodyear, Project Officer, BioRegional Oxfordshire. Much of the

What is an Ecological Footprint?

An ecological footprint estimates 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. The ecological footprint measures demand on nature's services. It is measured in global hectares (gha) representing the global average bio-productivity of Earth's land and sea area.

What is a Consumption-Based Emissions Inventory?

A consumption approach includes emissions released to produce goods consumed within a region, regardless of where they originated. With globalization and economic integration, a significant amount of the emissions associated with the production, disposal, and transport of a region's goods occur in other places. A consumption-based emissions inventory illustrates the scale to which we are offloading emissions associated with our lifestyles onto other jurisdictions. This helps encourage strategies that maximize global, and not just local, emission reduction efforts. 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 a Territorial Greenhouse Gas Emissions Inventory?

A territorial emissions inventory includes only emissions from sources within a given region's borders.

information in this report was obtained directly from staff at Oxfordshire County whose time and effort is gratefully acknowledged.

This study was undertaken in support of the One Planet initiative within Oxfordshire, coordinated through BioRegional, an international not-for-profit agency.

1.2 Background

Since the late 1990s, governments have created GHG emissions inventories using an in-boundary or territorial approach that identifies emissions from sources within a particular region. However, this form of inventory does not provide a complete picture of a community's impact on global climate change. It misses the climate impacts associated with the many goods a community consumes, because many of these goods are produced in other regions, often on other continents.

By the early 2000s, a consumption-based inventory was introduced to address the so-called off-shored emissions associated with the production of goods and services in other countries being imported to meet the consumption demands of populations in predominantly service economies. The wider scope of emissions in the consumption-based inventory accounts for food, consumable goods and related embodied energy in the supply chain, as well as the embodied energy of buildings and infrastructure located in the municipality. This approach introduces consideration of a life cycle approach to address the hidden emissions associated with a variety of aspects of urban living and attributes them to the final consumer, regardless of where in the world they were originally produced.

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 assimilate the wastes it generates. Based on current global population and biological productivity levels, the Global Footprint Network reports an average of 1.7 global hectares is available for each person on the planet.[2] Like the consumption-based GHG emissions inventory, the ecological footprint is a consumption-based metric that attributes responsibility for resource demand to the final consumer.

[2] This is an approximate estimate. For example, assuming total global biocapacity of 11.96 billion hectares and a population of 7.4 billion people, the global average hectares available is 1.6 gha/ca.

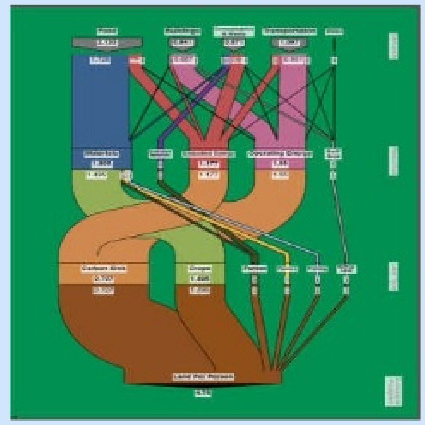
1.3 ecoCity Footprint Tool Overview

The ecoCity Footprint Tool enables a community to evaluate the demand on nature's services associated with its energy and material flows, also known as a residential urban metabolism, its 'territorial' greenhouse gas (GHG) emissions, its community-wide GHG emissions, its consumption-based GHG emissions, and its ecological footprint (See Figure 1). These inventories provide critical data to inform sustainable consumption and climate mitigation efforts.

Dr. Jennie Moore created the ecoCity Footprint Tool (eCF Tool) as part of her PhD under the supervision of Professor Emeritus William E. Rees, founder of the ecological footprint concept. The goal in creating the eCF Tool was to support local government in policy-related decision-making aimed at reversing global ecological overshoot. The tool generates a community-scale ecological footprint using predominantly locally sourced data. A prototype of the Tool was used by the City of Vancouver to inform its Lighter Footprint Goal and related efforts to achieve one-planet living through its "Greenest City 2020 Action Plan." The outputs from the Tool are highly valued by the City and continue to inform the strategies, actions, and monitoring methods to track progress.

What is an Urban Metabolism?

An urban metabolism, visualized here using a Sankey diagram, traces the flow of energy and materials through an urban system to inform the ecological footprint and consumption-based GHG emissions inventory. (see example below).



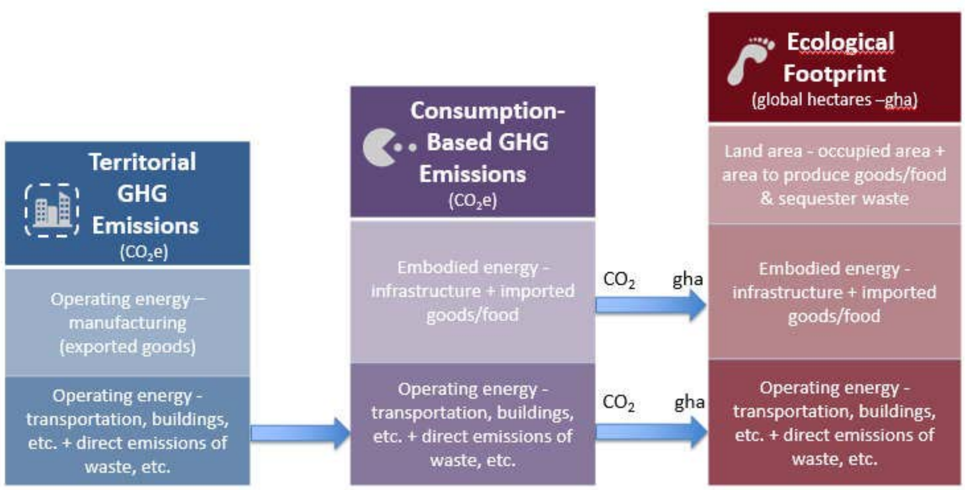


Figure 1: Comparison of GHG Emissions Inventories and Ecological Footprint Approaches

Many ecological footprint and consumption-based greenhouse gas (GHG) inventory assessments use the 'compound method' that is a top-down approach to data collection and assessment, relying on national, econometric data. The eCF Tool uses a 'component method' that relies on a bottom-up approach relying on local, community-generated data.[3] Dr. Moore's approach, informed by her background as both a climate action and demand-side management planner, aligns data with the way it is organized at the local government level (see Figure 4, below). Real consumption data, collected through an urban metabolism study, provides the utility needed to link policy intervention to directly observed energy and material flows and resultant emission outputs at the local government scale. This provides a clear and transparent understanding of how city functions, across all sectors and service areas, affect the footprint. It also enables scenario analyses to forecast which policy interventions and changes could enable reductions in the city's energy and material flows, greenhouse gas (GHG) emissions, and ecological footprint.

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 eCF Tool also has the potential to help streamline data collection and reporting due to its capacity to create multiple outputs: an urban metabolism, a territorial GHG inventory, a community-wide GHG inventory, a consumption-based GHG inventory, as well as an ecological footprint analysis.

2.0 Methodology

A detailed overview of the methodology by which the ecological footprint is generated in the ecoCity Footprint Tool, including the territorial and consumption-based GHG inventories, is provided in Dr. Jennie Moore's PhD dissertation (Moore 2013). Excel data sheets providing a synopsis of data inputs and outputs specific to this study are provided with this report as APPENDIX A.

The ecoCity Footprint Tool aligns with the typical spheres, or categories, of municipal planning and operations addressing: buildings, transportation, waste and water. A fifth category – food - is added, along with expanded scopes of impact associated with the life cycle of embodied energy and materials in buildings and infrastructure, as well as production of consumer goods. Data collection is organized according to materials, embodied energy, operating energy, and built area within each category (see Figure 2).

[3] In the case of data gaps, a top-down approach can be used as a supplementary method.

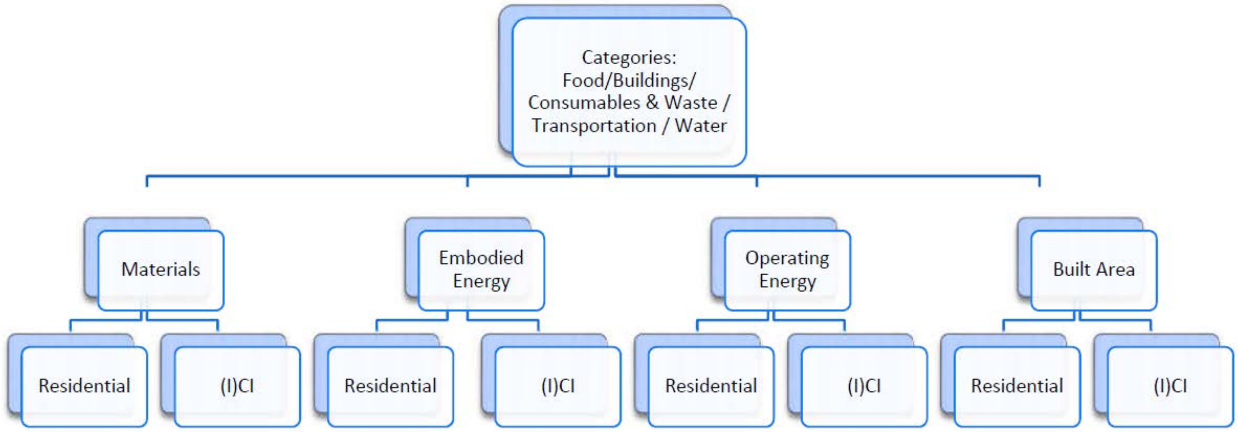


Figure 2: Data organization by category, component and sub-component (excerpt from Moore 2013).[4]

Data are then organized by sector, e.g., residential, institutional, commercial, and light industrial, noted by the bracketed "I" in Figure 2. Heavy industrial activities associated with production of goods for export are not counted in the consumption-based GHG inventory and ecological footprint. However, light industrial activity that serves the local economy, e.g., warehouse outlet stores, are included. Although a bottom-up approach to data collection that relies on community- and regional sources is prioritized, verifiable assumptions or proxy data can also be used in limited circumstances. It is important to note when proxy data is used in order to draw attention to gaps in local data collection capacity.

The bottom-up, component approach to data collection 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.

ii. The bottom-up approach does not fully capture all life-cycle impacts of materials and energy 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 territorial and CBEI GHG inventories and ecological footprint, as well as key assumptions and limitations, are presented in Table 1.

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

Table 1: Overview of data inputs required to generate the ecological footprint, CBEI and territorial GHG inventories

CATEGORY	INPUTS	EF	CBEI	TERRITORIAL GHG INVENTORY	KEY ASSUMPTIONS AND LIMITATIONS
Food *Food available is measured as a proxy for food consumption and import distances are used to estimate food-*kilometers *travelled. Energy associated with the production and transportation of imported food is then estimated.*	Embodied energy and materials associated with food production (energy and materials used to produce and transport food)	✓	✓	✗	• Food consumption statistics for food available at the local level (DEFRA 2018a) supplemented by national average data used as proxy (FAOSTAT 2013). • Food distances measured from primary source location to Oxford. For locally produced food, an estimated distance of 433 km is assumed. For imported food, a sea route distance via London as primary international receiving port is estimated using Ports.com. Distance from London to Oxford estimated at 94 km (Google Maps).
	Land used to produce food	✓	✗	✗	
Buildings and Stationary Energy *The materials, embodied energy, operating energy, and built area associated with residential, institutional and commercial buildings are measured.*	Operating energy used by buildings and related Infrastructure	✓	✓	✓	• Dwelling count and area (Oxfordshire County Council 2012). • Average household size (Oxfordshire County Council 2018a). • Commercial building count and area (UK Government 2009). Institutional building data not available. • Energy use data (DBEIS 2018a). • Emissions coefficients (DBEIS 2018b). • Total county area (Wikipedia 2018).
	Materials and related embodied energy of buildings	✓	✓	✗	
	Built area associated with buildings	✓	✗	✗	
Consumables and Waste *The materials, embodied materials and energy, operating energy, and built area associated with consumable goods represented in municipal waste streams is measured along with the quantity of solid and liquid waste generated by sector (residential, commercial and institutional), diversion rates (e.g., recycled, composted) and method of materials disposal (e.g., landfilled, incinerated, recycled, composted).*	Operating energy used in waste management facilities and hauling waste	✓	✓	✓	• Waste management and recycling data (DEFRA 2018b). • Waste composition (DEFRA 2015). Commercial waste by materials type not available. Estimate is based on total percentage of commercial waste disposed, resulting in an anticipated underestimate. • Assumed 4% of waste disposal in Oxfordshire is by landfill and 96% by incineration (DEFRA 2018b).
	Direct emissions from waste facilities	✓	✓	✓	
	Embodied energy and materials associated with consumables (as inferred by waste stream)	✓	✓	✗	
	Built area associated with waste management	✓	✗	✗	

CATEGORY	INPUTS	EF	CBEI	TERRITORIAL GHG INVENTORY	KEY ASSUMPTIONS AND LIMITATIONS
Transportation *Evaluates the embodied materials and embodied energy of physical transportation infrastructure and vehicles, operating energy (fuel consumed by vehicles), and physical built area occupied by transportation infrastructure. Data is collected for private and commercial vehicles; transit; aviation travel; marine travel and off road vehicle use.*	Operating energy associated with to transportation (fuel use for private and commercial vehicles; aviation; marine vessels and off-road vehicles)	✓	✓	✓	• Data for road widths and lengths (Oxfordshire County Council 2018b) • Data for motor vehicle fleet (DTS 2017), fuel consumption, and emissions from all transportation modes (DBEIS 2018c, 2017). • Data for air travel fuel consumption (Bioregional 2018). Note that because this data is exclusively available to Bioregional staff it is unverifiable by author. A publicly accessible data point is recommended in future studies.
	Embodied energy and embodied materials associated with private vehicles and transportation infrastructure	✓	✓	✗	
	Built area associated with transportation	✓	✗	✗	
Water *Evaluates the embodied materials, embodied energy, operating energy, and built area impacts of water distribution and purification systems relied on by the municipality.*	Operating energy used in treating and conveying water	✓	✓	✓	• .Drinking water volumes and infrastructure data (DEFRA 2018c; Thames Water 2018a, 2018b, 2017a). • Infrastructure renewal (Thames Water 2017b). • Energy use and associated greenhouse gas emissions (Thames Water 2018c). • Water reservoir and associated built areas (Thames Water 2018d).
	Embodied energy and embodied materials associated with water infrastructure	✓	✓	✗	
	Built area associated with water management	✓	✗	✗	

3.0 Results

The study is for the year 2015 and assumes a population for Oxfordshire of 683,200 (Oxford County Council 2018c) people distributed across a municipal area of 260,500 hectares (ha) (Wikipedia 2018).

3.1 Territorial and Consumption-based Greenhouse Gas Emissions Inventories

A territorial emissions inventory counts emissions generated within a particular city or region as well as emissions associated with provision of grid-supplied electricity from remote power stations. These are generally referred to as scope 1 and scope 2 emissions respectively. The data collected for this inventory is informed, in large part, by national government estimates for Oxford prepared for the study year 2015 (DBEIS 2017). The dominance of stationary energy in the territorial emissions inventory is due in part to the industrial load that is almost equal to the combined load of residential, commercial and institutional buildings. By contrast, the consumption-based inventory excludes industrial loads and includes emissions that are generally referred to as Scope 3 emissions, i.e., associated with the lifecycle of consumer goods, as well as emissions associated with the full range of lifestyle activities that support the resident population (see Appendix A). Carbon dioxide equivalent (CO2e) expresses the impact of each different greenhouse gas in terms of the amount of CO2 (carbon dioxide) that would create the same amount of warming. This enables reporting total greenhouse gas emissions in one unit of measurement that is used across both inventories.[5]

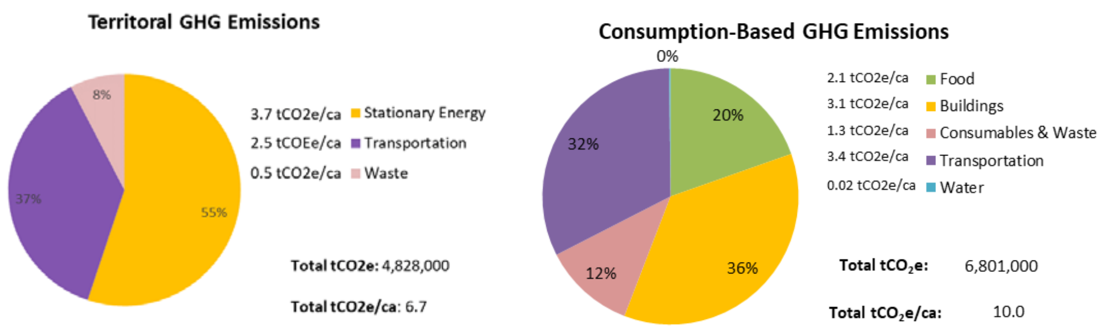


Figure 3: Comparison of Oxfordshire's Consumption-Based and Territorial Greenhouse Gas Emissions, 2015

The Consumption-Based Emissions Inventory (CBEI) presents the GHG emissions resulting from the production and consumption of goods and services delivered to a region, regardless of where those goods and services originated. This form of inventory is generated using the data typically collected for a territorial inventory, specifically 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 Oxfordshire are 6,801 kilo tonnes of carbon dioxide equivalent (ktCO2e), over one-third larger than that of the territorial GHG emissions of 4,828 kilo tonnes (see Figure 3).

3.1.1 Food Consumption-based GHG Emissions

A total 826,174 tonnes of food was consumed. Although only 20% of gross consumption by weight, dairy products account for almost half (45%) of the CBEI food component. To inform policy and planning decisions it is important to consider the varying contributions of each of the food types to the overall emissions profile. Figure 4 shows that following dairy, the next largest contribution of emissions results from consumption of meat. Meat only accounts for a tenth of food consumed, but it contributes 33% to the Food CBEI. Together, dairy and meat products account for 78% of the food CBEI. By contrast, grains also account for a tenth of food consumed, yet they contribute 9% to the Food CBEI.

[5] The ecoCity Footprint tool has the capacity to produce a greenhouse gas emissions inventory that could be compliant with the General Protocol for Cities (GPC) greenhouse gas emissions reporting protocol. However, because the focus of this study is on ecological footprint analysis, only summary information for the territorial emissions inventory is provided for purposes of comparison to the consumption-based emissions inventory in this report (see Figure 3 and Appendix A for details).

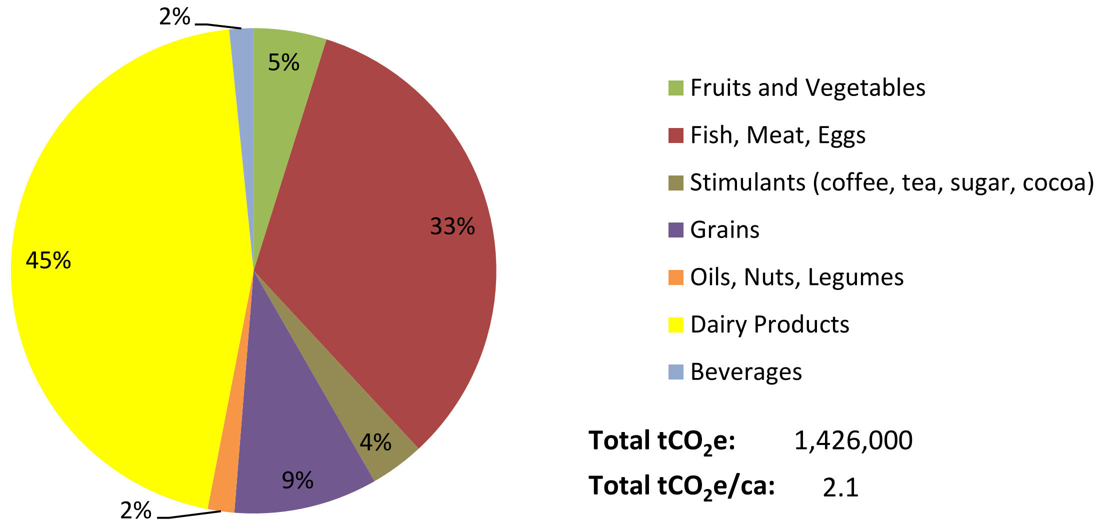


Figure 4: Food Consumption-Based Greenhouse Gas Emissions Inventory, 2015

3.1.2 Buildings Consumption-Based GHG Emissions Inventory

Operating energy dominates the impact on the Buildings CBEI, with residential buildings accounting for 54% and commercial and institutional buildings 35%. Buildings are assumed to be predominantly brick or concrete. The embodied energy of buildings is amortized over a building's lifecycle, accounting for a smaller annual impact. At 223,143 dwelling units, the embodied energy in residential buildings accounts for approximately 11% of the Buildings CBEI whereas the 5,573 commercial and institutional buildings account for less than 1%.

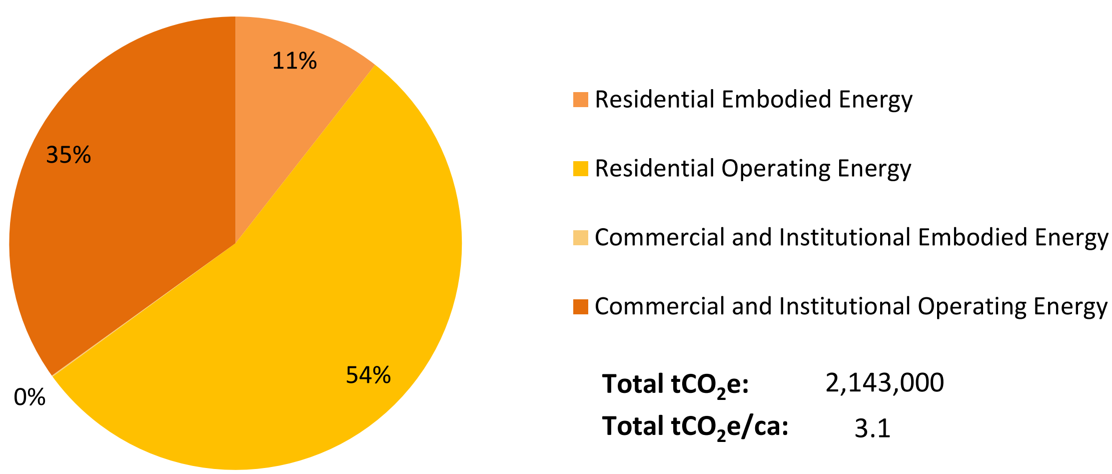


Figure 5: Buildings Consumption-Based GHG Emissions Inventory, 2015

3.1.3. Consumables and Waste Consumption-Based Greenhouse Gas Emissions Inventory

The CBEI for consumables shows that the majority of GHGs are associated with "Other," which means that the precise material properties were not distinguishable from the data collected. The next largest category is textiles (16%), as shown in Figure 6, followed by paper (9%), plastics (7%), metals (5%) and household hygiene (5%). Although textiles comprise a small amount of total wastes disposed (5,000 tonnes), they have a high carbon intensity (15 tCO2e/tonne of product). Similarly, plastic constitutes a slightly larger share of total wastes disposed (9,165 tonnes), but has a lower carbon intensity (3.32 tCO2e/tonne of product). By contrast, paper, which was consumed in large quantity (34,840 tonnes) has a relatively low carbon intensity (0.7 tCO2e/tonne of product).[6] Post consumption, the largest GHG impact is due to the landfilling of materials found in the residential (61%) and commercial (15%) waste streams, most notably food, followed by treatment of liquid waste. (NB: Although food waste and biosolids collected through liquid waste treatment are generally associated with food consumption, and although wastewater management is part of the water consumption metabolism, they are presented here to align with the municipal operations that often tie solid and liquid waste management functions together under joint utility services).

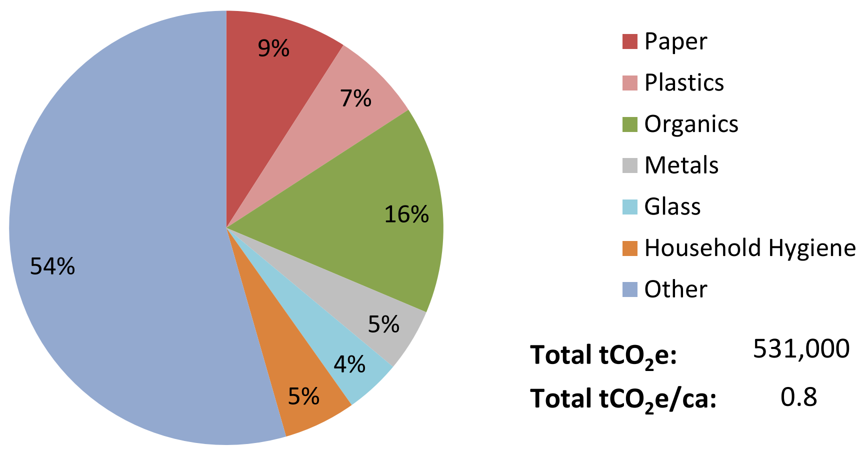


Figure 6: Consumables Consumption-Based GHG Emissions Inventory, 2015

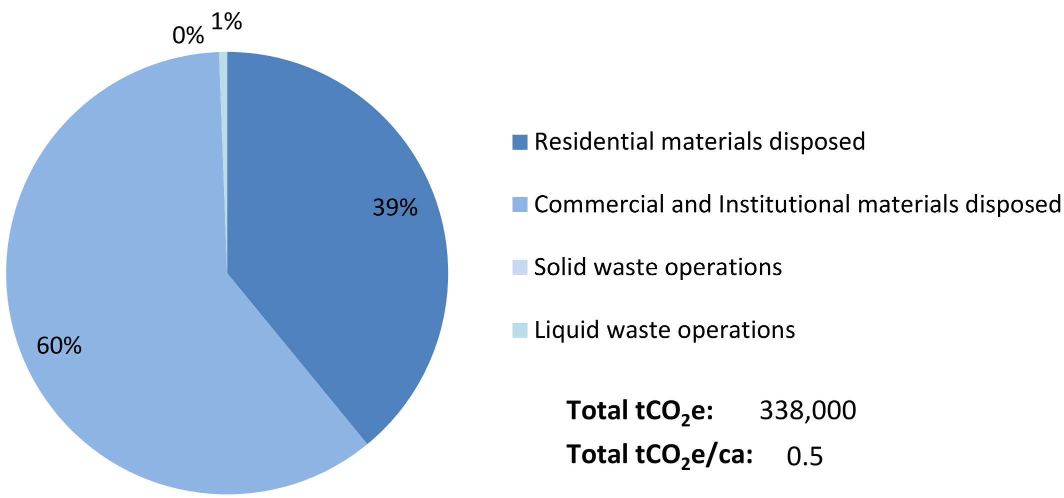


Figure 7: Waste Consumption-Based GHG Emissions Inventory, 2015

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[6] Life Cycle Assessment Data for Consumables by Material Type is presented in Appendix A and provides a detailed breakdown of supply-side GHG impacts by material type used for this analysis.

3.1.4 Transportation Consumption-Based GHG Emissions Inventory

The majority of the consumption-based emissions for transportation are associated with private vehicle travel (41%), followed by commercial vehicle travel (24%) and air travel (18%)(see Figure 8). The private vehicle fleet is estimated at 388,387 vehicles, accounting for the larger share of embodied energy (8%), compared to 54,905 commercial vehicles with embodied energy accounting for less than 1%. At a ratio of 0.57 vehicles per person, there appears to be a high incidence of motor-vehicle ownership.

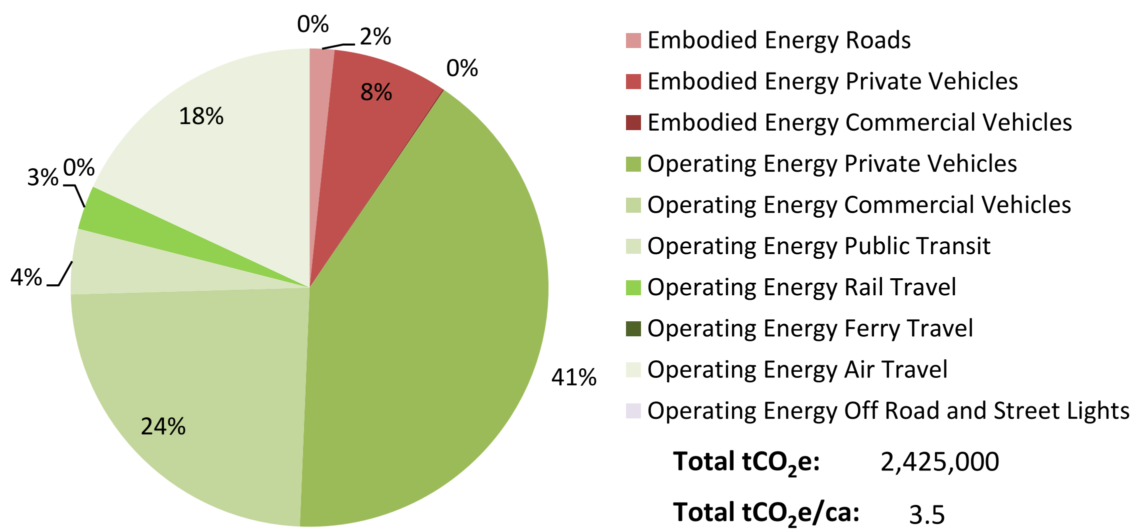

Figure 8: Transportation Consumption-Based GHG Emissions Inventory, 2015

3.1.5 Water Consumption-Based GHG Emissions Inventory

The majority of the consumption-based emissions for drinking water is associated with the operation of treatment facilities.

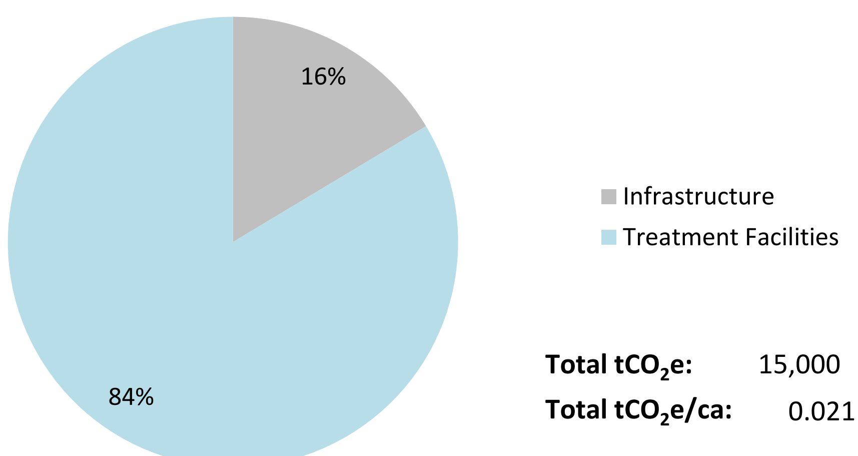

Figure 9: Water Consumption-Based GHG Emissions Inventory, 2015

3.2 Ecological Footprint

Oxfordshire's ecological footprint is conservatively estimated at 3.56 gha/ca excluding senior government services and capital infrastructure formation (see Figure 10). If these were added to the footprint it would likely increase by 18-33% (4.20 – 4.73 gha/ca). If everyone were to consume at a level equivalent to that of an average resident of Oxfordshire, it would require the resources of at least three Earth-like planets.

Oxfordshire's footprint, as estimated with the ecoCity Footprint Tool, is three times what is globally available (1.6 gha per person). Put another way, at least three Earths would be required to support the global population if everyone had lifestyles comparable to an average Oxfordshire resident.

Oxfordshire County's ecological footprint is conservatively estimated at 2,432,506 gha, an area 9 times larger than the county's total geographic area. As previously noted, these estimates exclude the resource demands associated with national services. A minimum additional 18% included in the footprint to account for these senior government services would increase the estimate to 2,870,357 gha, an area almost 11 times larger than the county.

Figure 10 represents Oxfordshire's ecological footprint by activity. Food comprises the largest share (43%), followed by buildings (23%), transportation (21%), consumables and waste (13%) and water (less than 1%). Each component of the footprint is described in further detail below.

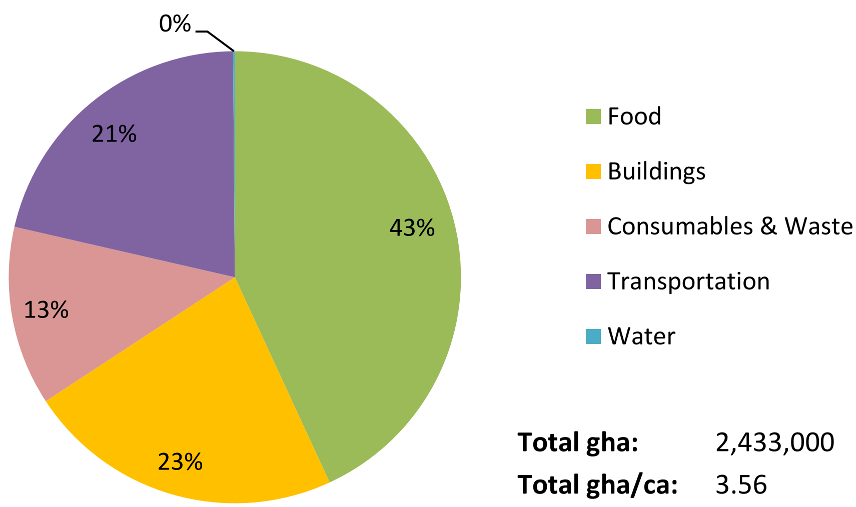

Figure 10: Ecological Footprint by Activity (excluding senior government services), 2015

3.2.1 Food Footprint

In considering the food footprint, one sees that 66% is associated with the amount of land required to produce crops and animal feed. The remaining 34% is predominantly associated with energy utilized in growing food, e.g., fertilizers and pesticides, and transportation of the food from farm to plate (see Figure 11).

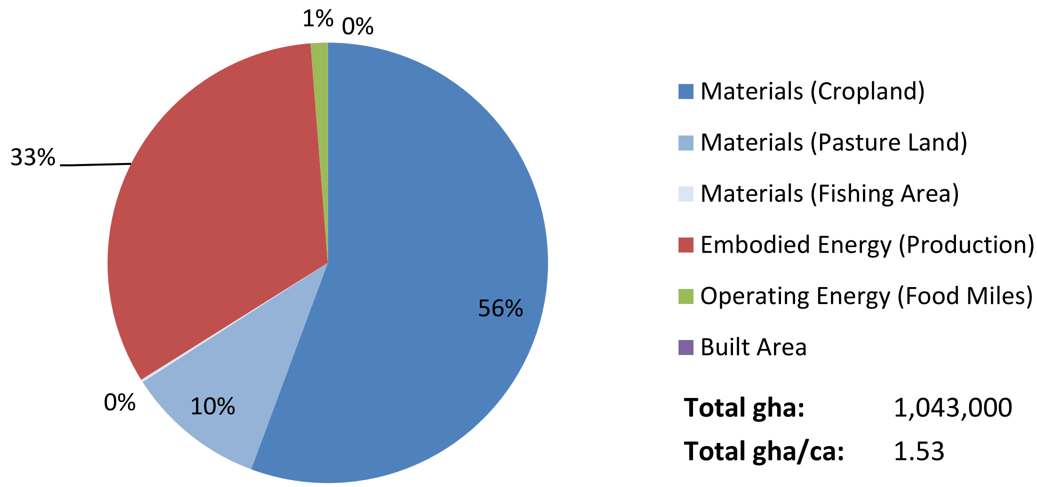

Figure 11: Food footprint Summary, 2015

When one looks at which types of food are having the largest impact on the footprint, almost half of the footprint results from consumption of meat (47%), in particular red meat, followed by dairy products (21%) (see Figure 12). These results indicate that the largest priority for reducing Oxfordshire's food footprint is to target consumption of animal proteins, both in terms of reducing overall consumption levels and in terms of reducing the land and energy demands associated with their production.

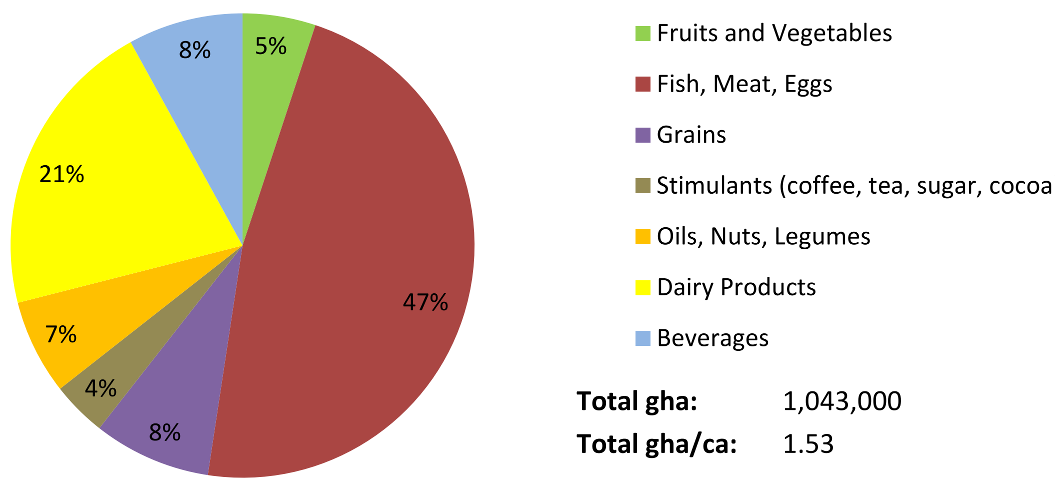

Figure 12 Food Footprint by Food Type, 2015

3.2.2 Buildings Footprint

As shown in Figure 13, 81% of the ecological footprint of Oxfordshire buildings result from operating energy and this is split relatively equally between the residential (47%) and commercial/institutional stock (34%). The embodied energy in the building materials is amortized over the lifespan of the buildings resulting in a lower annual impact compared to annual fuel and electricity consumption. Built area accounts for 9% implying a lower density built environment comprising predominantly low-rise structures. A near term priority on improving the operating efficiency of buildings and effort toward reducing fossil content (e.g., coal and natural gas) in electricity while moving to less carbon intensive fuels is recommended, with a longer term objective aimed at increasing the density, or intensity of use, of the existing built environment.

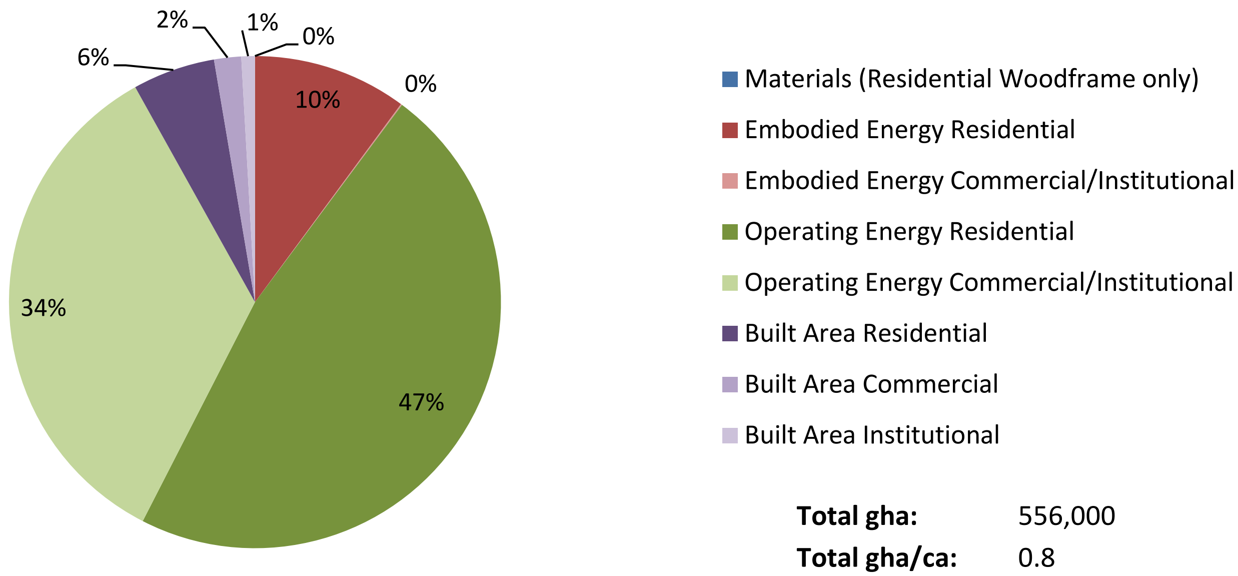

Figure 13: Buildings Footprint Summary, 2015

3.2.3. Consumables and Waste Footprint

The footprint of consumables and waste is dominated by upstream impacts, namely the energy and materials that go into producing the goods that are consumed in the city. As shown in Figure 14, these upstream impacts – the embodied materials and embodied energy associated with consumables – represent 70% of the consumables footprint. Embodied materials are those that are utilized in the manufacture of a consumable product, or infrastructure, but do not end up in the finished product. Embodied energy is the energy used in creating and delivering a particular material used in a consumable good. An additional consideration in the consumables footprint is the embodied energy of recycled materials that refers to the energy used in the remanufacturing of products using post-consumer materials. It constitutes the majority of the re-supply chain. Materials disposed refers to the footprint associated with materials that comprise consumer goods. The footprint associated with waste management services is usually very small compared to that of the footprint in the supply chain, often comprising less than 3%.

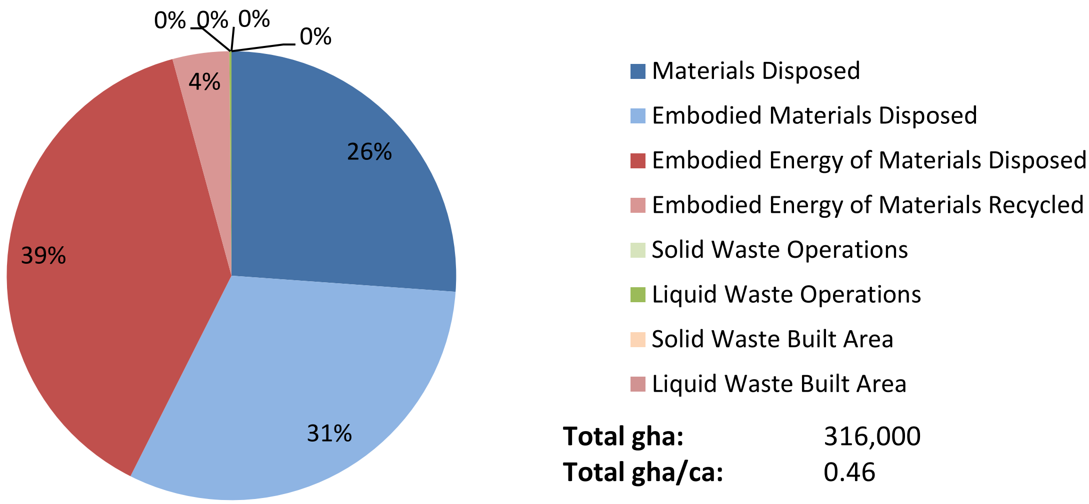

Figure 14: Consumables and Waste Footprint Summary, 2015

These results emphasize the need to prioritize reducing consumption over efforts to increase recycling that divert materials form the waste stream. With that said, there appears to be significant opportunity for materials recycling improvements as well.

It is also instructional to evaluate which type of consumable materials have the largest impact on the footprint in order to develop targeted policy and communication measures. As shown in Figure 15, the majority of Oxfordshire's consumables footprint is attributed to other waste (44%) referring to materials that were undefinable in the waste stream, but probably comprise a mixture of the other streams. (Hazardous material containers and e-waste is also included and each accounts for 1% of the total.) Paper (43%), followed by textiles (32%) and to a lesser degree plastics (8%) and household hygiene (8%) also contribute significantly. In contrast to the CBEI for this component, paper takes a larger share because of the land associated with growing the wood fibre used in paper production.[7] Note that total global hectares is lower in Figure 15 than it is in Figure 14 because Figure 14 also captures the impacts associated with waste management (operating energy and direct emissions from waste management).

[7] Table A-1 Life Cycle Assessment Data for Consumables by Material Type in Appendix A, provides a detailed breakdown of footprint impacts by type (that is, by type of, paper, plastic, etc.).

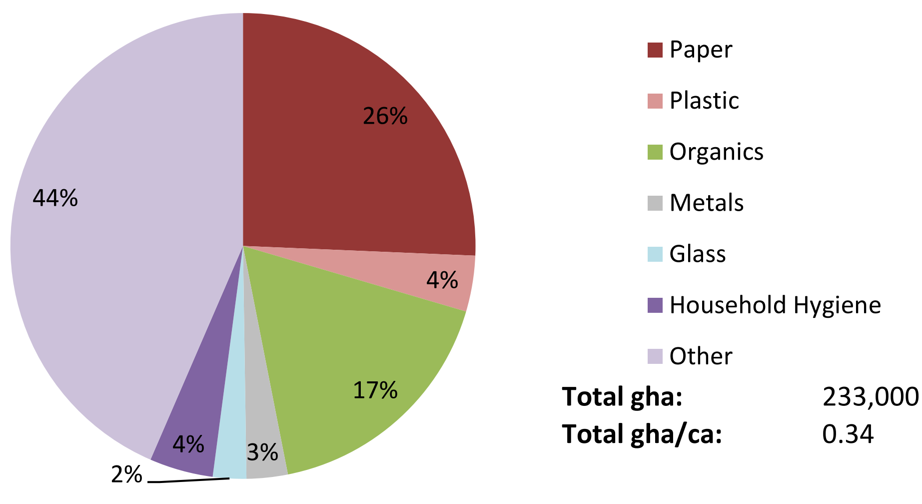

Figure 15: Consumables Footprint by Consumables Type, 2015

3.2.4 Transportation Footprint

Similar to the CBEI, three-quarters of Oxfordshire's transportation footprint results from fuel consumption associated with private vehicle travel (39%) and commercial vehicle travel (27%). Air travel (17%) is also significant. footprint. A near term priority could be to support a mode-shift away from private vehicle travel and to electrify the vehicle fleet 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 associate with private vehicle transportation through car sharing and transit. The long-term priority to complement these objectives should be promoting compact communities that are designed for active transportation and transit.

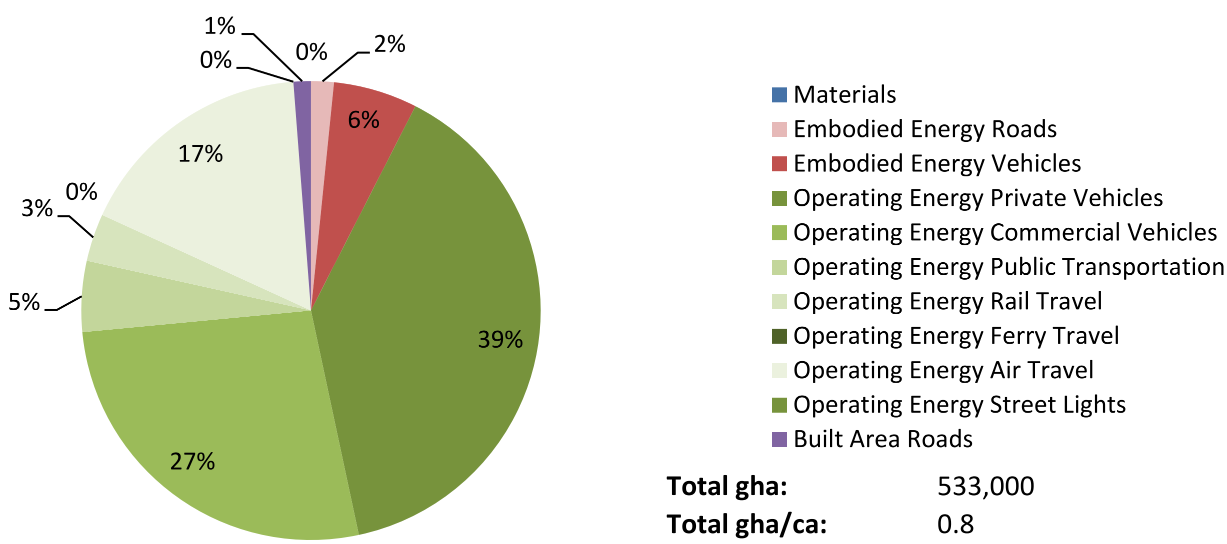

Figure 16: Transportation Footprint Summary, 2015

3.2.5 Drinking Water Footprint

Half of Oxfordshire's drinking water footprint comprises the land area associated with drinking water provisioning which is no longer in a natural state, e.g., concrete-lined reservoirs. The remaining half comprises energy associated with the operation of drinking water facilities and distribution systems (40%) and the embodied energy within that same infrastructure (10%).

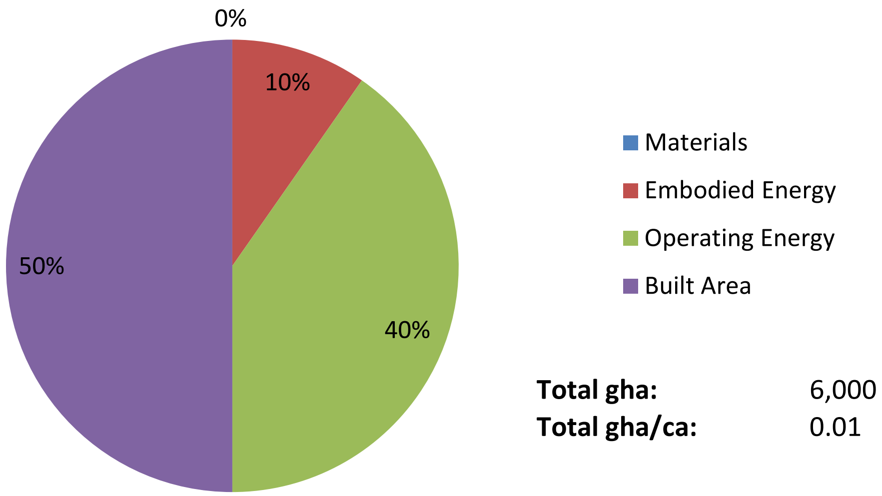

Figure 17: Drinking water footprint, 2015

4.0 Analysis

4.1 Sustainability Gap

Figure 18 represents Oxfordshire's ecological footprint at 3.56 gha/ca by land-type, including the threshold for one-planet living at 1.6 gha/ca, and the sustainability gap representing the difference between these two values. To achieve one-planet living, Oxfordshire's ecological footprint would need to reduce 55%, down 1.96 gha/ca from its current level at 3.56 gha/ca. Because the impact of senior government services is not accounted for in this analysis, the actual reduction would probably need to be greater still.

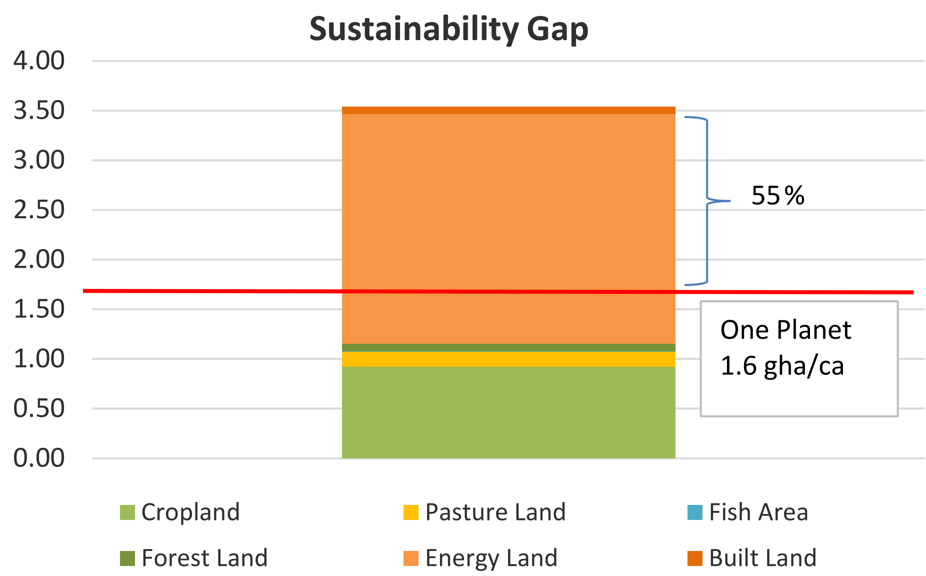

Figure 18: Sustainability Gap (excluding senior government services), 2015

It is important to note that averages can mask disparities in actual consumption among rich and poor in a given community. Therefore, it is possible that those with a higher than average ecological footprint may find more opportunity to reduce their footprint than those already living at subsistence levels.

4.2 One Planet Scenario

A One Planet Scenario for Oxfordshire is proposed based on measures listed in Table 3. They address that portion of the county's footprint that is directly associated with local consumption activity. However, to achieve the 1.6 gha per capita target, the actual reductions would likely need to be even greater in order to account for national and provincial services impacts, those components not included in this bottom-up analysis.

Table 3: Measures to Achieve a One Planet Scenario

Measure	GHG reduction (tCO2e/ca)	EF reduction (gha/ca)
Reduce beef (substitute with chicken) and reduce milk (without substitute) 50%	0.50	0.29
Reduce food waste post-purchase 45%	0.70	0.51
Improve building operating energy efficiency 75%	2.64	0.49
Reduce carbon intensity 50% in grid-supplied electricity (substitute with zero-emission, renewable energy)*	0.24	0.05
Reduce paper consumption 50%	0.02	0.04
Reduce textile consumption 50%	0.05	0.02
Reduce plastic consumption 50%	0.02	0.01
Reduce household hygiene (e.g., diapers) consumption 50%	0.02	0.01
Reduce other consumable purchases 30%	0.11	0.04
Reduce air travel (no substitutes) 75%	0.48	0.10
Reduce commercial vehicles travel 75% (substitute electric if over 50% renewable)	0.64	0.15
Reduce private vehicle travel 75% (substitute electric if grid over 50% renewable)	1.29	0.26

*The impact of this measure is muted by above noted building efficiency improvements; on its own this measure is estimated to generate a .94 tCO2e/ca and 0.18 gha/ca reduction.

The cumulative results of implementing these measures could reduce Oxfordshire's ecological footprint to 1.63 gha/ca (down 1.93 gha/ca from 3.56 tCO2e/ca). The corresponding impact of these measures on the territorial GHG inventory could reduce emissions to 1.81 tCO_2e/ca (down 4.89 tCO_2e/ca from 6.7 tCO_2e/ca). The impact of these measures on the CBEI would reduce it to 3.89 (down 6.11 tCO_2e from 10.0 tCO_2e/ca). This is still 2.89 tCO_2e/ca above the recommended climate stabilization target of 1.0 tCO_2e/ca (IGES, Aalto, D-mat 2019).

5.0 Conclusions

This report provides a brief overview of Oxfordshire's territorial GHG emissions inventory, consumption based GHG emissions inventory, and ecological footprint along with suggested measures to reduce that footprint to a level commensurate with global ecological carrying capacity, known as one planet living.

Oxfordshire's territorial GHG emissions inventory is estimated at 6.7 tCO_2e/ca and counts emissions generated within the county including those associated with industrial manufacturing as well as those associated with grid-supplied electricity and treatment of waste. The consumption based emissions inventory is estimated at 10.0 tCO_2e/ca and includes emissions generated anywhere in the world that are associated with the consumption and lifestyle practices of the local population. This includes food and embodied energy in the supply chain of goods and services consumed within the county as well as local infrastructure.

Oxfordshire's ecological footprint is conservatively estimated at 3.56 gha/ca excluding senior government services and capital infrastructure formation outside the city. If these were added to the footprint the estimate would likely increase by 18-33%. If everyone were to consume at a level equivalent to that of an average resident of Oxfordshire, it would require the resources of at least three Earth-like planets.

The results reveal that consumption of dairy and meat, in particular milk and red meat, account for the largest share of the food footprint. Operating energy in buildings coupled with reliance on fossil-based fuels in grid-supplied electricity accounts for the largest share of the buildings footprint. Consumption of paper and textiles and disposal of organics in solid and liquid waste streams account for the largest share of the consumables and waste footprint. Private vehicle travel accounts for the largest share of the transportation footprint. Although a small component overall, built land area followed by operating energy accounts for the largest share of the footprint associated with production of drinking water.

A One Planet Scenario is presented comprising a:

- 50% substitution of red meat with poultry; 50% reduction in fluid milk consumption;
- 75% building energy efficiency improvement, and substitution of 50% of fossil energy in grid-supplied electricity with zero-emission, renewable energy;
- 50% reduction in paper, plastic, textile, and household hygiene consumption;
- 30% reduction in other consumption;
- 75% reduction in air travel, commercial vehicle travel, and private vehicle travel.

The cumulative results of implementing these measures could reduce Oxfordshire's ecological footprint to 1.6 gha/ca, the territorial GHG inventory to 1.81 tCO_2e/ca (or lower), and the Consumption Based Emissions Inventory to 3.89 tCO_2e/ca. Other scenarios are possible

Other scenarios are possible and warrant further research. Ultimately, the cultural and political preferences of the community will influence decisions to adopt an appropriate path forward.

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