Bhutan’s Ecological Footprint Report 2014

Gross National Happiness Commission,
Royal Government of Bhutan in collaboration with
Otago Polytechnic, New Zealand
July, 2014
Ecological Footprint of Bhutan and its Regions

6 July, 2014
Executive Summary

This report provides the first step in determining the amount of required data that is currently available so that a detailed Ecological Footprinting (EF) analysis can be carried out as and when required.

The Ecological Footprint tool has been shown globally to be effective at providing high-level guidance on resource consumption and trends in resource demand. The EF uses consumption data and EF conversions to provide a single unit for all the goods and services consumed and the waste created, by a given population. Until now Bhutan’s EF has not been interrogated in detail.

The following project uses two different sources of data to calculate Bhutan’s EF. The first results in an EF presented in local (Bhutan) hectares (bha), the second in global hectares (gha). The EF results of the following project show that Bhutan nationals are using less than half the country’s biocapacity. Of the total EF 70% is in energy land and a following 23% in crop land. The food EF is the largest component, totalling 40%, whilst services is close behind on 37%. The results are also compared to EF calculations for Bhutan provided by the renowned EF consultancy, Global Footprint Network (GFN). GFN also found that Bhutan is living within its biocapacity but there were stark differences with this report as it showed the firewood EF to be more than 50% of the available forested land biocapacity.

Further investigation by the Bhutan Government is recommended. Potential benefits include widespread communication and planning between the government and wider society through a common language of resource use and availability. Weaknesses in the current methodology are highlighted throughout the report and suggestions of how the data could be improved are made. It is emphasised that the development and use of the EF tool would be most effectively carried out by a specialist team within the Bhutan government. Training and template development is recommended with the help of the qualified EF experts and trained facilitators.
1. Introduction

The measurement and establishment of an EF baseline is one of the indicators for the 11th Five Year Plan - National Key Result Areas. Gross National Happiness (GNH) is Bhutan’s development philosophy and a development goal. ‘Sustainable and Equitable Socio-Economic Development’ and ‘Conservation and Sustainable Management of Environment’ are the two important pillars of GNH besides ‘Good Governance’ and ‘Culture’. GNH guides Bhutan’s development while trying to achieve its economic goals, poverty reduction and livelihood enhancement. GNH must, amongst other initiatives, also ensure that environmental and natural resource concerns and degradation are addressed to maintain their renewed state of being, and to ensure continuous availability of resource requirements on a sustainable basis. Sustainable development must meet the needs of the present generation without comprising the ability of the future generations to meet their own needs (Bruntland Commission Report, 1987). In the quest to pursue social and human development, resource use must aim to meet human needs while preserving the environment so that these needs can be met not only in the present but also for generations to come. 

Modern society is made up of a complex web of economic, social, environmental and political systems integrating at global and local scales. Appendix 1 introduces the drivers of unsustainability and the key influences on consumption. As society becomes increasingly urbanised the ability for communities to receive feedback in response to resource use becomes increasingly difficult. There is an increased mental separation between the resources people use and where these come from. Measurement tools are required to keep track of both the supply of available biocapacity and the demands that society is making on biological systems at a global, national and local levels. The EF provides these measures by using ‘land’ as a common unit of measurement and provides a clear understanding of what it means to be ‘sustainable’ or live within the planet’s biocapacity (Robèrt et al., 2002). The specific EF method required depends on the project.

The world’s available biocapacity has been quantified by Global Footprint Network (GFN) in terms of a measure of the biologically productive land and water available for human use (Lenzen, Borgström Hansson, & Bond, 2007). It is an aggregate of the productivity of various ecosystems within the area, for example, arable or crop land, pasture, forest and bioproductive sea, and built or degraded land. Biocapacity is dependent not only on natural conditions but also on prevailing farming and forestry practices (Chambers et al., 2005, p. 26). The equation for biocapacity is (GoodPlanet.info, 2012):

\[
\text{Biocapacity} = \text{Land area} \times \text{bioproductivity}
\]

Bioproductivity is the amount of biological production required to renew the biotic resources humans use (food, timber) and to absorb their waste (mainly carbon dioxide emissions from energy use). Bioproductivity is essentially the ability of a piece of land to produce biomass, and different ecosystems have different levels of bioproductivity (Chambers et al., 2005, p. 26). Biocapacity is therefore the measure for the bioproductive utility of land for humans. This unit of resource measurement is known as a ‘global hectare’ (gha) and GFN has calculated a total of 11.9 billion gha available on the planet (Ewing, Moore, et al., 2010; Global Footprint Network, 2011; WWF, 2010).

As the global population continues to increase, the ‘earth share’ of ecological goods and services available to all continues to decline (Wackernagel & Yount, 2000). Figure 1.1 shows this relationship. The global population increased from 3 billion in 1959 to 7 billion in 2011, resulting in the ‘earth share’ decreasing by more than half, from 3.96gha/person to 1.70gha/person. The global population
is projected to reach 10 billion by 2083, causing a further decrease in the ‘earth share’ to 1.2gpa/person (Ewing, Moore, et al., 2010; United Nations Department of Economic and Social Affairs Population Division, 2010).

![Figure 1.1: Change in ‘earth share’ as population increases over time.](image)

Currently the world’s communities are in ‘overshoot’; a condition in which ecological goods and services are consumed at a rate beyond the biosphere’s regeneration rate (Catton, 1980; Wackernagel et al., 2002). Humanity is exhausting the planet’s ecological capital, and is operating beyond the planet’s carrying capacity by 156% (Freeling, 2012). To function in overshoot, humanity continues to meet its ecological demand by liquidating resource stocks and accumulating carbon dioxide in the atmosphere (Freeling, 2012; Wackernagel et al., 2002).

As there is increasing demand for the planet’s limited resources and availability of land, the cost of those products and services with the biggest demands will continue to increase. The EF tool allows decision-makers to identify where there is the greatest threat of increasing cost and reduction in supply. It then encourages them to be pro-active in designing a more resilient low EF system for the future.

As discussed in appendix 1 and depicted in figure 1.2 below, how much people consume, their EF, is caused by a range of factors – the political and governance system under which they are operating and the urban form in which they live. These are largely aspects of resource consumption that individuals have little control over, except through their right to vote in a democratic system. On the other hand, those aspects that effect an individual’s lifestyle - their income, the amount of available time and values have the biggest effect on an individual’s EF (Lawton, 2013). The concept of lifestyle and urban form EF fits clearly alongside the aspirations of the Gross National Happiness Index and the plans of the 11th Five Year Plan.
The EF tool has been ‘road tested’ by a number of national governments, local and regional bodies and by business organisations worldwide including local authorities in Europe, South America, the USA and Australia. The tool has been used in a variety of ways. For example to:

- Provide baseline data regarding resource consumption valuable for monitoring progress towards resource goals;
- Determine the extent to which implementation of programmes and targets reduce a community’s pressure on ecosystems;
- Educate central and local government staff and community members about resource consumption and local and global resource constraints;
- Actively engage the community in urban sustainability initiatives, showing environmental impacts at the individual, community, national and worldwide levels;
- Identify activities and strategies with the largest EF and initiate programmes to engage the public and redesign to reduce resource dependency; and
- Develop impact scenarios for the future, i.e. 2020 and beyond, including analysis of how changes by the behaviour of the community would impact on the country’s EF.

The discussion chapter of this report outlines a number of ways the EF could largely utilise data already gathered by the GNH index. However, there is a recommendation that the EF framework and methodology is tailored to the Bhutan context and redesigned to provide a comprehensive EF analysis. This could be achieved by a team of EF experts working in collaboration with the GNHB. The EF team will ensure that the knowledge and ability to carry out EF calculations will remain with the GNHB who will continue to take the lead on EF research into the future.
2. Project Methodology

This research has contributed to basic science by providing fundamental data on the flow and use of resources within communities. The research is predominantly descriptive in nature, providing data sets that have previously not been available in a concise form. Use of the EF as an index provides an effective tool for consolidating large amounts of data into a comparable and easily communicable format. The fundamental data and assumptions required throughout the project is outlined below such as population figures, urban classification and lifestyles. A brief explanation regarding the GFN data is also included below.

This report aims to clearly show where data was sourced and what assumptions were made during its application. The following sub-sections highlight some key points of data that are used throughout the project and how and where the data was derived.

2.1. Data gathering

EF calculations at the national and regional level require a considerable amount of data. As noted throughout the project, this initial EF calculation was carried out in order to better understand the value of the EF tool to the Bhutan government and help establish the amount of data already available and what may still need to be collected. It must be noted that an increased understanding of Bhutan society would have been a benefit to support better informed assumptions about certain aspects of the EF calculations.

Bhutan has a large amount of valuable information that could be used for the EF calculations. Due to the lack of time and resources available not all the data that may have been useful was used. For example, the EF of food grown at home and bought from retailers is different, but just how different would depend on a more detailed look at the Bhutan food system.

2.3. Fundamental Data

The following is some of the fundamental data used in the following report. An aim of the research was that the data would primarily reference 2012. This was not always achievable, in part due to the time-lag of publishing data. The data that was not available for 2012 was substituted with data from any time back to 2010.

2.3.1. Population

Bhutan has not carried out a census since 2005. As a result all population figures are estimates. The population estimate for 2013 of 733,004 was used in the following report (NSB, 2011; p.3).

Reliable regional population data was difficult to attain. Population estimates for each region are provided in the Annual Dzongkhag Statistics 2012 books (NSB, 2012a & 2012b). However as shown in the first two columns on the left side of the table 2.1 below, when these regional population figures were added together, the total was much less (only 75% of the population was accounted for) than the national figure of 733,004.

Alternative population information was sourced through the NSB website (NSB, 2014) which provides a national and regional population clock for that given moment in time (May, 2014). This data was used to show the portion of the population living in each region, shown in the column second from the right. These portions were then applied to the 2013 figure to give the regional
populations in the right-hand column of table 2.1 above. The population percentages were used to provide the final estimated 2012 regional population data used in the following research.

Table 2.1: Proposed regional population data.

<table>
<thead>
<tr>
<th>Regional Comparison</th>
<th>Est. region population 2013</th>
<th>Est. regional population May 2014</th>
<th>% of total population</th>
<th>Proposed 2012 regional population data</th>
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</thead>
<tbody>
<tr>
<td>Bhutan - proposed</td>
<td>733,004</td>
<td>748,783</td>
<td></td>
<td>733,004</td>
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<td>Bumthang</td>
<td>12,707</td>
<td>18,629</td>
<td>2.5%</td>
<td>18,466</td>
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<td>54,861</td>
<td>86,766</td>
<td>11.6%</td>
<td>86,009</td>
</tr>
<tr>
<td>Dagana</td>
<td>19,352</td>
<td>21,643</td>
<td>2.9%</td>
<td>21,454</td>
</tr>
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<td>Gasa</td>
<td>3,049</td>
<td>3,602</td>
<td>0.5%</td>
<td>3,571</td>
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<td>8,691</td>
<td>13,223</td>
<td>1.8%</td>
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</tr>
<tr>
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<td>14,254</td>
<td>17,319</td>
<td>2.3%</td>
<td>17,168</td>
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<td>Monggar</td>
<td>38,284</td>
<td>43,238</td>
<td>5.8%</td>
<td>42,861</td>
</tr>
<tr>
<td>Paro</td>
<td>31,485</td>
<td>42,113</td>
<td>5.6%</td>
<td>41,746</td>
</tr>
<tr>
<td>Pema Gatshel</td>
<td>22,336</td>
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<td>20,663</td>
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<td>20,483</td>
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<tr>
<td>Samdrup Jongkhar</td>
<td>30,432</td>
<td>47,035</td>
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<td>69,470</td>
<td>9.3%</td>
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<td>120,428</td>
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<td>Trashigang</td>
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<td>57,522</td>
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<td>Trashiyanste</td>
<td>16,057</td>
<td>20,506</td>
<td>2.7%</td>
<td>20,327</td>
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<td>36,647</td>
<td>4.9%</td>
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<td>19,053</td>
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<td>20,970</td>
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<td>Actual total</td>
<td>553,630 (75%)</td>
<td>742,249</td>
<td>99.1%</td>
<td>735,772</td>
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</table>

2.3.2. Urban Form

There are a total of 127,942 households in Bhutan (NSB, 2013b; p.111-113) of which 43,515 (34%) were urban and 84,427 (66%) were rural.

It is understood that most regions are a mix of both rural and urban communities, however the percentage of urban to rural of each region could not be located. It seemed important that this information be available to analyse data and assess trends. Table 2.2 below is an attempt to categorise the regions by urban form - dense urban through to rural. Those regions whereby more than 80% of its residents lived less than an hour from ‘motor-roads points’ (RNR, 2013; table 103) were classified as ‘urban’. Regions where 80% of the population was within 3 hours of the nearest road were classified as ‘peri-urban’ and the final 4 regions were classified as ‘rural’.
Table 2.2: Classification of urban, peri-urban and rural regions.

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<th>Region</th>
<th>Rural</th>
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<th></th>
<th></th>
<th>Urban</th>
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<th>Peri-urban</th>
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<td></td>
<td>(-) 1 hour</td>
<td>1 to 3 hours</td>
<td>4 to 6 hours</td>
<td>(+) 6 hours</td>
<td>(-) 1 hour</td>
<td>1 to 3 hours</td>
<td>4 to 6 hours</td>
<td>(+) 6 hours</td>
<td>(-) 1 hour</td>
<td>1 to 3 hours</td>
<td>4 to 6 hours</td>
<td>(+) 6 hours</td>
<td>(-) 1 hour</td>
<td>1 to 3 hours</td>
<td>4 to 6 hours</td>
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<tr>
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</tbody>
</table>

2.5. Lifestyles
EF results would have benefited further from analysis alongside individual and collective lifestyle attributes from various regions. On the other hand, working with averages means that it is difficult to pick up on slight shifts in lifestyle trends. As noted above, an individual’s lifestyle has the potential to have a significant impact on their EF. For example, an individual’s shopping habits versus the ability for them to make it themselves. Further, if they do buy products are they inclined to source them locally or buy environmentally friendly products? It is recommended that further research be carried out at an individual level to highlight those actions that have the largest contributions to an individual’s EF. This could be done through structured surveys.

2.6. Global Footprint Network data
EF calculations require a considerable amount of data, not only related to what individuals and nations consume but also the embodied energy and resource conversions of whatever they are consuming, the data to develop these often being difficult to obtain. As mentioned above, GFN is an internationally recognised EF consultancy operating out of the USA. The opportunity to use internationally standardised data was considered important. GFN also provided the option to have the Bhutan EF calculated using internationally available standardised consumption data through Food and Agriculture Organisation of the United Nations (FAO) and the World Bank.
The GFN data was purchased as part of the current project contract, however if further use of the data is required, the license will need to be extended beyond the project research team.

2.7. Use of EF in relation to Bhutan

Some work has been carried out on the Bhutan EF over the past couple of decades. While 3 references were found, a comprehensive EF assessment has not yet been carried out.

The *Living Planet Report 2000* (Loh, 2000; p.25) was the first to publish EF material relating to Bhutan. The report showed that globally Bhutan had one of the lowest estimated EFs at 0.79gha/capita and a biocapacity of 2.6gha/capita suggesting that Bhutan was operating well within its biological limits. Although there were subsequent Living Planet Reports unfortunately Bhutan did not continue to be included in the publication.

In 1999 research was carried out by a Dutch organisation RIVM comparing the national EFs of Benin, Bhutan, Costa Rica and the Netherlands with the aim to 1) review the EF concept, 2) to gain insight into trends in resource use related to consumption in these countries over time in 1980, 1987 and 1994 and 3) discuss the applicability and usefulness of the EF (van Vuuren et al. (1999; p.7). The project methodology 1) focused on individual components of the EF (land and carbon dioxide emissions) instead of focusing on the aggregated EF and 2) the land use calculations were based on local yields instead of global average yields. The figures used in the research supported Bhutan’s low yield numbers, particularly for firewood and food. The Bhutan EF was calculated as 0.9bha and 0.6gha in 1994, very low EF figures.

Although per capita and total land use differed among the four countries, available data suggested increasing land use in all four countries while per capita land use decreased. The EF for CO2 emissions increased for all four countries both per capita and in absolute terms. The study concludes that the EF was successful in providing an interesting basis for discussion on environmental effects of consumption patterns - including those outside the national borders - and on equity concerning resource use. This report provides some valuable insights into Bhutan yields and EF methodology.

The only other mention of the EF tool in relation to Bhutan is on the website Go Green (2013). This website states that it provides Global Environmental statistics. However the data on this website is very out-of-date. The figures representing Bhutan’s EF are those from the Living Planet Report in 2000.
3. The Ecological Footprint

EF is used internationally and within NZ by governments, non-governmental organisations, businesses, schools and individuals as a way to measure, communicate and compare how individuals and communities use resources. Appendix 2 provides a further introduction to the EF tool and where and how it has been used previously. The following section discusses considerations for project and methodology design. It provides some background about the design of EF methodologies and the reasons for the current EF design.

The EF was first introduced by Wackernagel and Rees (1996) in *Our Ecological Footprint: Reducing Human Impact on the Earth*. EF accounting enables an estimate of the resource consumption and waste assimilation requirements of a defined human population or economy (Wackernagel & Rees, 1996). The EF also provides a baseline and comprehensive method for evaluating whether human populations meet a minimum condition for sustainability, namely that humanity’s demands on the biosphere remain within the biosphere’s regenerative capacity (Monfreda, Wackernagel, & Deumling, 2004; Wackernagel et al., 2005; Walsh et al., 2010). Initially developed for measuring national consumption, the EF is increasingly being used to support policy formation through scenario creation and communication (Collins et al., 2009; Cornforth, 2009; Monette, Colman, & Wilson, 2001; Monfreda et al., 2004; Moran et al. 2007; Wiedmann, Wood, et al., 2007; Wilson & Grant, 2009). Community planners, policy-makers and leaders see the EF as a tool for measuring the state of unsustainability in their communities, indicating society’s biggest impacts on the environment, raising awareness about sustainability issues, and assisting with defining sustainability goals (Best Foot Forward Ltd., 2002; Calcott & Bull, 2007; Collins & Flynn, 2005; Wilson & Grant, 2009).

Increasingly, research shows that at least a 50% reduction in resource consumption can come from an individual’s change in lifestyle. Further reductions could then come from changes in government procurement, urban form and infrastructure, and improvements in the eco-efficiency of products and services (Barrett et al., 2006).

3.1. EF Assumptions

The original EF indices created by Wackernagel and Rees in 1996 were based on six assumptions (Wackernagel et al., 2002, p.9266):

1. The majority of the resources people consume and the wastes they generate can be tracked.
2. Most of these resource and waste flows can be measured in terms of the biologically productive area necessary to maintain flows. Resource and waste flows that cannot be measured are excluded from the assessment, leading to a systematic underestimate of humanity’s true EF.
3. By weighting each area in proportion to its bioproductivity, different types of area can be converted into the common unit of gha, (defined as equivalent hectares of land area with world average bioproductivity).
4. Because a single gha represents a single use, and all gha in any single year represent the same amount of bioproductivity, they can be added up to obtain an aggregate indicator of EF or biocapacity.
5. Human demand, expressed as the EF, can be directly compared to nature’s supply, biocapacity, when both are expressed in gha.
6. Area demanded can exceed area supplied if demand on an ecosystem exceeds that ecosystem’s regenerative capacity. Humans can temporarily demand more biocapacity from forests or fisheries than those ecosystems have available. Alternatively natural systems can be saturated with waste beyond their ability to sequester it, e.g. the carbon cycle causing an increased concentration of carbon dioxide in the atmosphere. This situation, where EF exceeds available biocapacity, is known as ‘overshoot’.

All assumptions relate to each of the EF methods discussed below except, as in part of this research, where local yields are used in place of global yields. In the case where local yields are used, assumptions 3 and 4 do not apply. The implications of these assumptions and the various EF methods will be discussed below.

3.2. Consumption Categories and Land Types
As well as the scale and detail required to fulfil the aims of an EF project, consideration must be given to what will work in the Bhutan context.

The EF is calculated by compiling a matrix in which a land area is allocated to each consumption category (Lenzen & Murray, 2003). Consumption, as shown in table 3.1, is divided into nine categories: food, transport, consumer goods, holidays, household energy, housing, infrastructure, government, and services.

Table 3.1: EF Template: An individual’s EF is made up of three parts, each comprising a number of categories. A description of these categories specifies some of the data required.

<table>
<thead>
<tr>
<th>Parts</th>
<th>Category</th>
<th>Sub-categories</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The EF related to individual lifestyles</td>
<td>Food and drink</td>
<td>Food and drink at home and eating out</td>
</tr>
<tr>
<td></td>
<td>Travel</td>
<td>Car, bus, train and air travel</td>
</tr>
<tr>
<td></td>
<td>Consumer goods</td>
<td>Pets, clothes, computers, televisions, books, furniture, appliances</td>
</tr>
<tr>
<td></td>
<td>Holidays</td>
<td>Holidays at home and abroad</td>
</tr>
<tr>
<td>2. Household EF related to the urban form and built environment</td>
<td>Energy</td>
<td>Energy used in the home</td>
</tr>
<tr>
<td></td>
<td>Housing</td>
<td>House building, maintenance and repairs</td>
</tr>
<tr>
<td>3. Collective EF, related to central and local government and services</td>
<td>Infrastructure</td>
<td>Motorways, railways, bridges and stadia</td>
</tr>
<tr>
<td></td>
<td>Government</td>
<td>Consumables and durables for local and central government</td>
</tr>
<tr>
<td></td>
<td>Services</td>
<td>Water, phone, post, hospitals, education, finance, police etc.</td>
</tr>
</tbody>
</table>

In EF calculations land is divided into seven types: energy land, degraded or built land, gardens, crop land, grazing land and managed forests, ‘land of limited availability’ (considered to be untouched forests), and ‘non-productive areas’, defined as deserts and ice-caps (Wackernagel & Rees, 1996). The ‘non-productive’ areas are not included in the following analysis, but fishing land is included.
Thus seven land types are used in the EF calculations with data collected from disparate sources such as production and trade accounts, state of the environment reports, and agricultural, fuel use and emissions statistics. Bhutan land types and local yields are discussed below in section 3.7.

The final EF calculations are shown in a Consumption Land-Use Matrix (CLUM), a matrix combining the consumption categories with the land types. The CLUM is the most effective way of communicating the amount and types of land required to provide a population with the resources they consume. EF calculation results for each footprint category in the following chapter will be shown using a CLUM.

Carrying out calculations to achieve detailed result requires an EF methodology that can use both national ‘top-down’ and individual ‘bottom-up’ data. These options are considered below in project design considerations.

3.3. Project Design Considerations
The following section briefly describes EF methodologies, more info can be found in appendix 3.

Since its conception in the late 1990s the EF has undergone a number of methodological revisions, altering not only where the data comes from, but also the level of detail at which the EF can track changes in an individual or community’s resource consumption. Wiedmann and Barrett (2010), surveying over a decade’s worth of case studies, highlighted that there is no one-size-fits-all approach to projects using the EF. The footprint methodology should be adapted depending on:

1. Whether the aim of the project is to compare footprints locally, nationally or internationally;
2. Who the expected target audience is for the project results, i.e. individuals, local community groups, policy makers, international agencies;
3. The level of resource accounting detail required, i.e. at an organisational level, community wide level, national or international level;
4. Availability of data which must also be considered in association with required detail and
5. The skills of the project team and available resources including money and time.

Though it is generally acknowledged as a valuable education tool that enriches the sustainability debate, the original EF was limited as a regional policy and planning tool for ecological sustainable development, because it does not reveal where impacts really occur, what the nature and severity of these impacts are, and how these impacts compare with the self-repair capability of the ecosystem. In response to the problems highlighted, the concept has undergone significant modification. These modifications include the use of input-output analysis, renewable energy scenarios, land disturbance as a better proxy for sustainability, and the use of production layer decomposition, structural path analysis and multivariate regression in order to reveal rich EF details (Lenzen & Murray, 2003).

3.4. EF Methodologies
There are primarily three different overarching methods. These are the original compound method created by Wackernagel and Rees (1996), the input-output analysis (IOA) method developed by Bicknell (1998) and her team in NZ, and the component method, which is becoming increasingly successful with local EF projects. There are also variations within these methods which will be discussed below. Use of local NZha is less likely using the compound method than in input-output or
component based methods; however it could be used, as there are method options available. How the data is intended to be used is paramount to how the EF calculations should be carried out.

1. Compound method – There are two distinct parts to calculating EF using the compound method. The first is to find the embodied EF of the product or service and the second is to calculate the total consumption of the product or service in question.

2. Input-Output Analysis (IOA) - IOA is a macroeconomic technique that relies on data on inter-industrial monetary transactions (Lenzen & Murray, 2003, p. 8). In broad terms IOA tables show an industry’s output, i.e. what is sold by the industry to other industries (and to itself), and an industry’s inputs, i.e. what is bought by an industry in order for it to produce its goods or services (sometimes called its production recipe) (Murray & Lenzen, 2010, p. 7).

3. Component method - Recent case studies focused on the EF of sub-national populations have increasingly supported the component method for its suitability in the local context. The method was developed to connect with people through their daily activities (for example waste production and electricity consumption) (Barrett, 2001; Ryan, 2004; Simmons et al., 2000).

The component method was selected as the best-fit method for the following research. In the component-based model the EF values for certain activities are pre-calculated using data appropriate to the region under consideration (Simmons et al., 2000). For example, to calculate the impact of a ferry ride, local average data on fuel consumption, manufacturing and maintenance energy are calculated. These figures may then be converted to total EF per kilometre. The total kilometres travelled by a population are then multiplied by EF per kilometre to give a result of the final EF of an individual or community. Many of the original EF compound calculations aimed to capture indirect effects in a life-cycle context (Barrett, 2001; Simmons & Chambers, 1998; Simmons et al., 2000). The results are then put into a CLUM for both the results of the category EF and total EF.

3.5. Global versus Local Hectares

One of the important initial aims of the EF tool as developed by Wackernagel and Rees (1996) was to have the ability to compare different countries or populations. International comparison of footprints requires consideration of the differences in biological productivity. Gha are used for converting both the EF calculation and available biocapacity to an average land unit that can be compared internationally.

Differences in local yields are primarily due to environmental factors, including solar flux, soil type, climatic conditions and type of vegetation cover. This issue is addressed in EF calculations by relating consumption to global average yields, rather than to local yields (McDonald & Patterson, 2004). The GFN (2012) states the ‘gha’ is a productivity weighted area used to report both the biocapacity of the earth, and the demand on biocapacity (the EF). Using gha rests on the assumption that different types of biologically productive areas can be expressed in the same unit once they are scaled proportionally to their productivity (Sustainability Report, 2002). When using the gha the areas of forest, pasture and crop land do not represent real land, but are hypothetical areas that would be needed to support the consumption of the population if local farming and forestry was conducted at
'world average productivity' (Lenzen and Murray, 2003). In comparison, bha are those hectares of land actually used to produce resources in Bhutan.

The use of gha, initially created by Wackernagel and Rees, requires two scaling factors, the equivalence factor and the yield factor, in relation to the six different land types. Bhutan’s yield and equivalence factors are shown in table 2 below. The definition of each is explained by Klinsky et al. (2009):

1. Equivalence factors relate to land categories. The bioproductivity of each land type is unique, so all categories must be made comparable before they can be aggregated into the total EF. Consequently each land category is given an equivalence factor that is multiplied by the subtotal EF of that land category. The equivalence factor reflects the comparative bioproductivity of all land categories and converts hectares consumed per category into hectares of average bioproductive land, the final unit of the EF.

2. Yield factors relate specifically to a country. They estimate the productivity per hectare of a particular type of land for a particular country; a yield factor converts the use of a bha of cropland into a gha of cropland.

Table 3.2: Equivalence and yield factors as calculated in the National Accounts – Bhutan 2010 (GFN, 2014)

<table>
<thead>
<tr>
<th>Equivalence Factors</th>
<th>Yield Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cropland</td>
<td>2.51</td>
</tr>
<tr>
<td>Garden land¹</td>
<td>2.51</td>
</tr>
<tr>
<td>Grazing land</td>
<td>0.46</td>
</tr>
<tr>
<td>Forest land</td>
<td>1.26</td>
</tr>
<tr>
<td>Fishing grounds</td>
<td>0.37</td>
</tr>
<tr>
<td>Consumed land²</td>
<td>2.51</td>
</tr>
</tbody>
</table>

1. Garden land is considered to be the same as consumed land though it has more potential for subsequent uses in the future.

2. In the current methodology, hydroelectricity generation land is accounted for as consumed land.

After each land category subtotal has been converted into average bioproductive hectares, all categories are summed to a final EF figure (Klinsky et al., 2009). The equivalence and yield factors are both averages that generalise how much more or less productive one country or land type is compared to another. Thus, they help to provide a result that can be compared between countries because all calculations have been based on the same average.

However, using equivalence and yield factors means little to understanding how the variation in yields between different products can benefit Bhutan. In other words, if the transport energy is low enough, there is no incentive to consume local produce because the yield is assumed to be the same worldwide. Conversely, if the calculations are done in local hectares then the yields of different foods and crops can be compared for the adequacy of Bhutan specific conditions. If the yield of Bhutan-produced food is higher than elsewhere then there is an additional incentive for it to be grown in Bhutan because the EF of the product will be lower. Using local hectares also helps when deciding on the types of food that should be grown locally, rather than using an international
average yield which may not reflect local Bhutan growing conditions. Where Bhutan does benefit by using the equivalence and yield factors is when the biocapacity is calculated.

The following calculations are shown in both local and global hectares which are then compared and discussed in the results section.

3.6. Bhutan’s Biocapacity

The biocapacity calculations carried out for this research and those by GFN are dissimilar due to differences in how land has been categorised, both in bha and gha. As mentioned above yield and equivalence factors are used to calculate the available biocapacity for Bhutan. The way in which Bhutan land is categorised into ‘productive’ and ‘non-productive’ is important in allocating the amount of available bioproductivity.

The Statistical Yearbook of Bhutan 2013 (NSB, 2013; p.90) provides a breakdown of Bhutan’s various land-types. These figures are very different to the figures used in the GFN Land use Data (GFN, 2014) for Bhutan. NSB data was ‘categorised’ into crop, grazing, forest and consumed land. As shown in table 3.3, the 2010 GFN and NSB data showed Bhutan had a total of 3.9 million bha of productive land. However the land types were categorised quite differently which caused irregularities.

<table>
<thead>
<tr>
<th>Bhutan land</th>
<th>NSB</th>
<th>GFN</th>
<th>NSB</th>
<th>GFN</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bha</td>
<td>gha</td>
<td>Bha</td>
<td>gha</td>
</tr>
<tr>
<td>Crop land¹</td>
<td>112,550</td>
<td>113,000</td>
<td>234,037</td>
<td>234,973</td>
</tr>
<tr>
<td>Grazing land²</td>
<td>157,546</td>
<td>407,000</td>
<td>99,131</td>
<td>256,093</td>
</tr>
<tr>
<td>Forestry land³</td>
<td>3,105,816</td>
<td>3,249,000</td>
<td>3,600,321</td>
<td>3,766,303</td>
</tr>
<tr>
<td>Consumed land⁴</td>
<td>34,141</td>
<td>95,360</td>
<td>70,993</td>
<td>198,292</td>
</tr>
<tr>
<td>Degraded land</td>
<td>429,353</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>3,839,406</td>
<td>3,839,000</td>
<td>4,004,482</td>
<td>4,455,661</td>
</tr>
</tbody>
</table>

1. Crop land includes all ‘agricultural areas’
2. Grazing land includes ‘meadows (pasture)’
3. Forestry land includes all ‘forest areas’ and ‘shrubs’
4. Consumed land includes built-up areas, non-built up areas and water bodies (to include hydroelectric).

There are a number of irregularities shown between the NSB derived figures and GFN’s figures.

1. Estimates using the NSB data would suggest that 88% of Bhutan is ‘productive’ land and the remainder is ‘unproductive’ meaning it is covered in bare areas (1.2 million ha), degraded areas (20,645 ha), marshy areas (3,200) and snow cover (285,435 ha).

2. GFN data suggests that Bhutan has 3.2 million Bha of forestry land. The NSB dataset however shows that Bhutan only had 2.7 million Bha of forestry in 2010 (NSB, 2013; p.90), of which 54.4% is unsuitable for timber (MAF, 2011; p.28) totalling 1.2 million Bha of managed forests suitable for use. GFN have included all of Bhutan’s forests in their calculation and more. Other land categories that GFN may have included as forestry land are ‘shrubs’ (totalling 400,525 ha) bringing the total forestry area to 3.1 million Bha, closer to GFN’s 3.5 million. However,
land covered in ‘shrubs’ would likely have a much lower bioproductivity rate, otherwise the land would have been planted in forestry.

3. The GFN ‘consumed land’ figure is very high. In order to have such high figures a lot of Bhutan’s ‘degraded’ land is likely to have been categorised as consumed land. As shown in table 3.3 above the equivalence factor for consumed land is 2.51. As a result when the Bha is converted into gha, this makes a large impact.

4. GFN’s grazing more than 2.5 times higher than the NSB figure. It is difficult to assess from where this additional land may be interpreted.

Once the equivalence factors and yield factors were applied the total figures became 4 million gha (NSB) and 4.5 million gha (GFN), a difference of 0.5 million gha. The available biocapacity calculated by GFN is an over-estimate of available biocapacity caused by unrealistically high estimates of productive forest and grazing land.

3.7. Bhutan Land and Local Yields

Use of either gha or local hectares is hotly contested by those using the EF index (Klinsky et al., 2009; Wiedmann & Lenzen, 2007; Wiedmann, Wood, et al., 2007a). It seems that when and how the global or local hectare is used depends predominantly on the aims of the research and how the EF information is to be used. For this research it was decided that the majority of the EF results would be shown in local hectares. The use of local hectares has been supported by a number of case studies (Bicknell et al., 1998; Field, 2011; Huang, 2010; McDonald et al., 2006; McDonald & Patterson, 2001, 2003).

Bha are a more appropriate unit of measurement primarily because the level of detail required for the project to make good scenario decisions requires the ability to compare Bhutan-grown resources with each other. As discussed extensively by Weidmann and Lenzen (2007, p. 676), “footprint analyses measured and expressed in global hectares cannot answer research (or policy) questions related to the regional characteristics of (primary) production activities, at least not as a sole metric.” As a result Weidmann and Lenzen recommend the use of local hectares when EF data is being used at a local level. In addition, using bha is more meaningful to people when communicating the impact of resource use with communities and individuals. People can imagine an area of land approximately the size of a rugby pitch as one hectare, but when gha are used the actual land area is warped and the unit of measurement becomes less meaningful.

The challenge of using bha is that additional research to find local yields is required to carry out the EF calculations. If gha units were used, the ‘world average yield’ for various resources could be bought from the GFN. As there is very little guidance on the methodology for calculating local yields for use in footprint accounting, the remainder of this section will provide a discussion on the different land types, a brief description of how the footprint calculations are carried out for each, and the ‘local hectare’ workings for some of the more contentious local yields such as energy land.

Productive lands such as forest, grazing and crop lands produce raw resources that are often changed or transformed to produce a whole range of secondary products. The efficiency of this transformation is called the extraction rate. For example wood from trees, the parent product, could be used for making paper and card or for house framing. These secondary products could be a more or less efficient use of the raw material compared with directly using the parent product. This
depends on the amount of waste created during the transformation. For example the extraction rate for ‘newsprint paper’ is only 0.25m³ of derived product per m³ of parent product, and therefore the yield is only 0.45m³/gha, whilst the extraction rate for the parent product, ‘roundwood logs’ is 1.0 and the yield is 1.81m³/gha (GFN, 2011; forest_yield). Extraction rates have been used where possible for the current research although data was often very difficult to find. Where extraction rates have not been used, basic yields have been substituted, which would be higher. As a result the EF for some products may be slightly lower. A lack of data regarding extraction rates for processed food from crop and grazing land could also be a limitation of the EF calculations carried out here.

3.7.1. Consumed Land and Garden Land
Infrastructure for housing, transportation and industrial production occupies consumed land. Best estimates indicate a global total of 0.2 billion hectares of built-up land (Wackernagel et al., 2002). Built-up land is assumed to have replaced cropland, as human settlements are predominantly located in the most fertile areas. Areas occupied by hydroelectric dams and reservoirs, used for the production of hydropower, are also counted within consumed land.

Garden lands are areas covered in private gardens, urban parks and recreation spaces. These are often open areas or used to grow ornamental trees and flowers. Garden land is separate from crop, grazing or forest land as it is not used specifically for producing products, and it is also not consumed land as it still has potential biocapacity for future uses. The biocapacity of garden land is assumed to be the same as crop land.

3.7.2. Crop and Grazing Land
The National Footprint Accounts (Ewing et al., 2010) use FAO harvest and area data for more than 70 major crops to calculate the area of cropland needed to produce a given quantity of crop product. The accounts do not track activities that decrease the long-term productivity of cropland such as soil degradation, erosion or salination, even though these processes will be reflected in future decreases in biocapacity.

Crop and grazing land is a calculation of the physical area required to supply a primary resource such as wheat or apples from cropland, and beef and chicken from grazing land. Grazing animals often require crop land for the supply of supplementary food, such as corn-fed battery chickens. The yield, which is the amount of product from a hectare of land, differs considerably between products. As also explained for forest land below, parent products from grazing and crop land, such as milk or wheat, are used to make secondary products. For highly processed goods these extraction rates were not available and as a result the yield used on its own is likely to be higher than reality, causing the footprint to be slightly lower.

Growing crops for food, animal feed, fibre, and oils requires cropland, the land type with the greatest average bioprodutivity per hectare (Kitzes et al., 2007). In 2003 the Food and Agriculture Organisation of the United Nations (FAO) estimated there were roughly 1.5 billion hectares of cropland worldwide. This area is 13.4% of the total land but 30% of the biocapacity. In 2010 NSB (2013) reported that there were 1,125.5ha of land being used for ‘agriculture’, including ‘wetland’, ‘dryland’, ‘orchards’, ‘plantations’ and ‘other horticulture’, making up 2.9% of Bhutan’s total landmass.
Raising animals for meat, hides, fibre and milk can entail the use of feed products grown on cropland, fishmeal from wild or farmed fish, and/or range land area for grazing (Kitzes et al., 2007, p. 5). Worldwide there are approximately 3.5 billion hectares of natural and semi-natural grassland and pasture. To calculate the grazing land EF of a livestock product, diet profiles are created to determine the mix of concentrate feed, cropped grasses, and grazed grasses consumed by that type of livestock. Data specific to rearing and feeding animals in Bhutan was not available at the time of this research. Additional insights into Bhutan specific animal husbandry and care would reduce the number of assumptions made by the research team and produce better local EF calculations.

### 3.7.3. Fishing Land

The fishing land EF of a population is based on its fish and seafood consumption. According to Ewing et al. (2008, p. 12) the EF of fishing land is based on the amount of annual primary production produced in the area above a hectare of ocean floor required to sustain a harvested aquatic species. Initially the fishing grounds calculations were straightforward. Rees and Wackernagel (1996, p. 233) suggest the maximum sustainable yield from the oceans is about 100 million tonnes (t) of fish per year. To calculate the world-average yield per hectare the global fish catch is divided by the total productive ocean area. About 96% of the world's fish catch is produced in shallow coastal and continental shelf areas that constitute only 8.2% of the world's oceans (about 2,970 million hectares). Average annual production is therefore about 74.46kg of fish per productive hectare (0.07ha/kg of fish).

### 3.7.4. Forest Land

In 2004, 54.4% of Bhutan’s forest was unsuitable for timber due to technical, ecological and economic reasons. Of the remainder, 16.8% was managed for timber production, 8.2% was a commercially manageable area for timber production and 8.6% was suitable for local use (FIMS 2012; table 4.3).

The EF of firewood, wood products and paper and card is calculated using the amount of forest land required to grow them. Forest land in Bhutan is less productive than the world average though there is some discrepancy between data sources. GFN 2010 data shows Bhutan’s average yield is 1.67m³/bha/yr compared to the global average for wood is 1.82m³/ha/yr (GFN, 2014; constant_forest_increment). The research by van Vuuren et al. (1999; p.37) suggested that the forest yield for Bhutan was 5.0 (m³/ha).

**Table 3.4: Tree yields of a range of forest varieties grown in Bhutan, 2013.**

<table>
<thead>
<tr>
<th>Tree yields</th>
<th>Yield m³/bha</th>
<th>Rotation Age yrs</th>
<th>Amount per year m³/bha/yr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue Pine</td>
<td>358.88</td>
<td>120</td>
<td>2.99</td>
</tr>
<tr>
<td>Mixed Conifer</td>
<td>393.95</td>
<td>160</td>
<td>2.46</td>
</tr>
<tr>
<td>Fir</td>
<td>316.68</td>
<td>180</td>
<td>1.76</td>
</tr>
<tr>
<td>Broadleaf</td>
<td>298.79</td>
<td>100</td>
<td>2.99</td>
</tr>
</tbody>
</table>

In comparison, as shown in table 3.4 the productivity of forest land and species varies between 1.76 – 2.99m³/bha/yr. Broadleaf and mixed conifer plantations make up the greatest portion of the forest at 80% of the plantations with an average yield of 2.73m³/bha/yr and will be the calculation used for
the bha calculations. The differences between the GFN forest yield estimate and local information is considerable and suggests that the GFN yield is an underestimate.

The world average production of firewood is 3.35 m³/gha/year (GFN, 2011; forest_efp, Wood Fuel (NC)). This suggests that the whole tree can be used for firewood, rather than just the high quality wood for timber production, therefore resulting in a higher wood yield. No local data could be found to show the variances between timber yield and firewood yield and therefore the wood yield from above will also be used for the firewood yield.

The EF of paper is calculated using the amount of forest land required for growing trees used to produce paper. Additional energy land is also needed for the manufacture of the paper and the felling and milling of the wood, however these calculations have not been included. To calculate the number of hectares requires the following information. Four tonnes of wood are needed to produce 1.4t of paper (Paper Round, 2010). Therefore, 2.88t of wood are required to make 1t of paper. The average density value for wood is 440 kg/m³ (Energy Conversion Info; p.51). Using the world average recycled paper content of 38% (Abramovitz & Mattoon, 1999), the paper forest land conversion is 0.0556 bha/t of paper.

3.7.5. Energy land

The footprints of renewable and non-renewable energy sources require different types of land and use different energy to land values, so they need to be calculated separately. Non-renewable energy primarily emits CO₂ as a waste which needs to be assimilated (or the fuel needs to be replaced with a sustainable alternative) through the use of ‘energy land’. In comparison, renewable hydroelectricity energy emits much less CO₂ but requires physical or ‘consumed land’. The methods for calculating the energy EF is discussed in the following section.

Research by Wackernagel and Rees (1996) suggested that for most developed countries the energy land component can be up to 50% of the overall EF. Consequently the energy to land conversion method and ratio have a considerable impact on EF calculations (McDonald & Patterson, 2004, p. 52). Bhutan's total primary energy supply comes from a mix of renewable and non-renewable sources. In 2011 57.4% of Bhutan’s primary energy came from non-renewable energy including coal, liquid fuels (petrol and diesel), firewood, kerosene and LPG. The remaining 42.6% of Bhutan’s energy needs was fulfilled by hydroelectricity (Ernst & Young; p.30). Three methods are available to deal with non-renewable land calculations and are discussed in appendix 4. Based on that discussion this research will use the ‘CO₂ absorption method’. In order to calculate energy land in bha additional research into the rate of carbon sequestration by Bhutan trees is necessary.

The CO₂ absorption methods for energy land (forested land required to sequester CO₂) and forest land are based on similar calculations as that of forest land, using the number of trees per hectare of land. However GFN highlight that whilst being used for EF calculations, this land should be mutually exclusive. Energy land and forest land should not be the same land. In 2010 Bhutan had 2.7 million hectares of forested land (NSB, 2013; p.90).

The amount of carbon flowing through the carbon cycle changes slightly with the ability of the carbon sinks, particularly biomass and oceans, to sequester carbon dioxide from the atmosphere. Biomass includes both commercial forests and indigenous forests and carbon sequestration by the world’s oceans. When calculating a specific energy-to-land ratio a number of aspects are considered,
including the type and amount of biomass and energy used by the specific region. The energy per hectare conversion for world average forest requires calculating the CO₂ needed to create the carbon in wood, then the energy produced by that carbon. The world average energy-to-land ratio for non-renewable energy is therefore 73GJ/ha under the ‘CO₂ approach’. Oceans also sequester CO₂. Using the absorption rate of 35% as proposed by the IPCC, the energy-to-land and ocean ratio becomes 99GJ/ha, rounded up to 100GJ/gha or 6.6 tonnes CO₂/ha/yr. van Vuuran et al. (1999; p.46) compared two rates 5.2 tonnes and 11 tonnes CO₂/bha/yr.

The carbon sequestration rate for Bhutan varies and has been difficult to confirm. The Second National Communication to the UNFCCC Report states that in 2000 the total carbon uptake was 6,309.63 Gg (6.3 million tonnes) CO₂-equivalent (NEC, 2011; p.30). There was an estimated 2.9 million hectares of forest in Bhutan at the time (ibid.). The sequestration rate was therefore 2.15 tonnes CO₂/bha/yr or 33GJ/bha. This increases to 44GJ/bha when the ocean sequestration rate is applied. More research is required to confirm the energy-to-land conversion for Bhutan. The following report EF will present the energy EF using the sequestration of 44GJ/bha, whilst the calculations in gha will use the rate of 100GJ/gha.

Some research has been carried out into energy-to-land conversions for renewable energy sources, although this needs further investigation. The land use of hydro-electricity is estimated by dividing total energy production by the typical area required by hydro-dams and corresponding corridor spaces for transmission rows (Wackernagel & Rees, 1996, p. 69). The result is an estimated 1,000GJ/gha of land. This land is energy land for the embodied energy of the infrastructure and the physical space required by hydropower storage lakes. Calculations have also been carried out for a range of other renewable energy sources including wind and tides. The average conversion factor for these sources calculated by Chambers, Simmons and Wackernagel (2000) was 9,090GJ/gha per year. In 2010 42.6% of Bhutan’s energy needs was fulfilled by hydroelectricity (Ernst & Young; p.30) and will use the hydroelectricity conversion of 1,000GJ/bha of consumed land is used for the following calculations.

The energy EF of countries and communities makes up a large portion of the overall EF and therefore using an appropriate energy-to-land ratio for both renewable and non-renewable energies is important, hence the discussion of the assumptions made above. However the distinction between the use of renewable and non-renewable energy in the data sourced for the research was difficult. For example, the embodied energy of food includes its processing which may have been electricity used in ‘medium and light voltage’ industry or ‘commercial’ buildings rather than thermal energy combustion. More data is required to clearly show these instances. This is because 42.6% of Bhutan’s primary energy is electricity, however of that 80% is used in high-voltage industries which are mainly products that are exported (Ernst & Young, 2012; p.22) suggesting that a lot of the energy used within Bhutan is non-renewable. As a result the renewable conversion rate will only be used where the use of electricity is explicit, i.e. household energy which uses 10% of the electricity produced in Bhutan (Ernst & Young, 2012; p.16).

3.6. Man vs. Wild

As previously discussed, bioproductive lands are those areas that are classified as being of productive use to people and the economy. However there is also the question of the land required to support the other 7-14 million species with which humans share the planet (Wackernagel et al.,
There is an estimated 13 billion hectares of land available on planet earth. Of this, GFN estimates that 10.8 billion hectares is biologically productive land (Ewing, Moore, et al., 2010). The World Watch Institute suggests that the remaining 21% is unsuitable for crops, pasture, and/or forests because the soil is too infertile or shallow to support plant growth, or the climate and terrain is too cold, dry, steep, stony, or wet (Pimentel & Wilson, 2004). It is not possible to determine how much bioproductive area needs to be reserved (Wackernagel et al., 2002) although some ecologists and biogeographers have recommended at least 10% of the earth’s land surface (and a critical although undetermined amount of the marine realm) (McNeely, 1999). Other scientists propose at least 25% (Soulé & Sanjayan, 1998). The Brundtland Report, Our Common Future (Brundtland Commission, 1987) proposed protecting 12% of the biosphere (Wackernagel et al., 2002).

If 12% were needed in addition to the 21% that is currently not ‘useful’ to society, it would equate to 1.2 billion hectares, making the total area left for human use 9.56 billion hectares. The GFN supports the idea that the ‘biodiversity buffer’ should be enough to maintain representative ecosystem types and viable populations of species. How much needs to be set aside depends on biodiversity management practices and the desired outcome (GFN, 2012). The ‘fair earth share’ discussion in chapter 1 was based on the calculation that, in 2007, humans had 11.9 billion hectares of land to produce goods and services, providing 1.7gha/person. If the 2007 ‘fair earth share’ included land for other species it would decrease to 1.4gha/person, 0.3gha per global citizen. In order to move towards a sustainable future, society needs to balance out the supply and demand of biocapacity. As discussed earlier the planet is already in overshoot. If further land is to be set aside for ‘nature’ then society is in an even more unsustainable position.

Bhutan has the highest fraction of land under protected area system with the highest proportion of forest cover of any Asian country. Bhutan is distinctive among developing countries in that it has allotted 50 percent of its geographical area to national parks and wildlife sanctuaries and other conservation areas (FIMS, 2012; p.2). The National Forest Policy 1974 was one of the first policies in the country requiring that at least 60% of the country is maintained under forest cover for all time to come (ibid, p.5). This is the equivalent of setting aside 2.24ha per Bhutan national, well above the suggested global average above.

3.7. EF methodology limitations

The EF is a proven tool for communicating resource use and constraints to a diverse range of audiences (Hunter et al., 2006; Kooten & Bulte, 2000; Simmons & Chambers, 1998; Wiedmann & Barrett, 2010), however the EF methodology has been under scrutiny since its conception. A number of authors have focused on highlighting its perceived weaknesses (Beynon & Munday, 2008; Ferguson, 2001; Fiala, 2008; Lenzen & Murray, 2001; McDonald & Patterson, 2004; Paul, 2006).

Criticisms are numerous, including the generality of the equivalence and yield factors (McDonald & Patterson, 2004), the lack of specificity for local use (Paul, 2006), the inability to consider degraded land (Fiala, 2008; Lenzen & Murray, 2001), difficulties in finding reliable data (Ryan, 2004), and the energy land methodology (Fiala, 2008). As already discussed, the GFN’s ‘one-size-fits-all’ methodological design shows significant inaccuracies. A recent paper from the NZ Centre for Ecological Economics (NZCEES) shows that GFN’s attempt at using a generic methodology for over 120 countries and international datasets (Ewing et al., 2008) resulted in the New Zealand calculations being over-exaggerated. NZCEE’s recalculations dropped New Zealand ten places in the
world ranking from 6th to 16th place (Andrew & Forgie, 2009). The GFN has since amended parts of their method in order more accurately to reflect New Zealand’s EF (Ewing et al., 2010).

Many of these weaknesses are accepted because it is argued that even with these the footprint tool is the most effective way of providing high-level resource accounting for communities. There are a number of other tools and methods available that attempt to quantify the level of sustainability that is (or is not) being attained by any given community, including Green Globe (Green Globe, 2012), Visable Solutions (Community Matters, 2012), and Green Star Communities (Green Building Council of Australia, 2012). The majority of these are a tick-box assessment rather than a quantitative measurement. Many also struggle to communicate the impacts that highly consumer-oriented lifestyles are having on the natural environment. Kooten and Bulte (2000) assessed the ability of the EF to communicate complex messages to a range of audiences and found it to be successful, as have a number of other projects (Andrew & Patterson, 2008; Baldwin et al., 2008; Barrett & Simmons, 2003; Collins, Cowell, & Flynn, 2007; Collins et al., 2005; GFN, 2010; NZCEE, 2007; Redefining Progress, 2006; Simmons & Chambers, 1998).

The EF is one of many tools in the areas of resource accounting and environmental reporting. However, to get a complete view of current sustainability issues more than one tool is required in order to obtain multiple measurements. Research needs to continue in this field to find effective ways of both measuring societies’ demands on the natural environment as well as ensuring that the results can be used to influence individual, community, business and government decision-making and actions.

3.8. Tourist EF
Case studies show that the everyday EF of a tourist is often very different to that of nationals, due to having very different activity and consumption behaviour (Becken, 2009; Becken & Patterson, 2006; Collins et al. 2007; Lawton, 2013). Bhutan tourists EF will differ to Bhutan nationals due to their food, travel, accommodation and activity needs.

Visitor arrivals to Bhutan peaked at 105,407 in 2012, a figure that marked a record growth rate of +64.62% compared to the previous year (TCB, 2012; p.14). On average international visitors stay 6.9 days (ibid; p.27). This equates to an additional 1,993 people in Bhutan for the whole of 2012. It was explored how the tourist EF may be extrapolated from the EF of Bhutan nationals for the following EF calculations. Unfortunately in most situations this was too complex and outside of the scope of the research. It is recommended that further investigation be carried out to better understand the needs of tourists to Bhutan and how the calculations of this EF may be achieved in an efficient manner.

3.9. Export EF
An important point to be reaffirmed here is that the Bhutan EF should not include the resources and waste required for the export of goods and services. To calculate a population’s EF, the following equation is used (Wackernagel and Rees, 1996; p.65):

\[
\text{Consumption} = (\text{production} + \text{import}) - \text{export}
\]

This point only needs to be considered when dealing with top-down national data. For example, the total number of kilometres travelled by all freight is likely to include the travel required to transport
goods, bound for export. Ideally this part of the freight EF would be subtracted from the total food freight EF.

As with the tourist EF above, the export EF was often not available and as a result some of the following EF calculations may be a slight over-estimate. On the other hand, Bhutan is not a major exporter of goods (other than electricity) and therefore the impact should only be slight. It is suggested that these calculations could be completed if given the right knowledge and data, however more time is required.

3.10. Summary
The EF has been found to be an effective tool for making high-level assessments of the amount of land available to a population and the land that population is currently consuming. There are numerous methodologies used in EF projects, many of which have been designed to fulfil the aims and outcomes of this specific project. This variability causes confusion and makes it difficult to compare case studies. The current project has found a number of inconsistencies with the most commonly used data, the GFN National Accounts, particularly when converting bha into gha. Bha are more suitable for projects wanting to look at local conditions and have a detailed breakdown of EF data.
4. Bhutan EF Results

The following results are presented in a range of ways in order to provide a rounded perspective. The total Bhutan EF will be presented alongside the EF per capita and will be presented in both local Bhutan hectares (bha) and in global hectares (gha). A Cumulative Land Use Matrix (CLUM) will be used to show the Bhutan EF in consumption categories for food, transport, consumer goods, housing and services. References to where the data was gathered will be noted alongside the table and any assumptions will be discussed. Detail about how data could be improved is also included.

Please note: Further detail about the data discussed can be found in the accompanying excel sheets. Follow the instructions in italics ‘name of document, name of sheet/tab, line numbers’.

4.1. Food EF

The Food EF required an investigation into: 1) the amount of food consumed by Bhutan nationals; 2) the total area of land required to grow the food consumed by Bhutan nationals; 3) the embodied energy required for agricultural inputs and machinery during the growing of the food and 4) the embodied energy of the food assumed to be accumulated between where the food was produced and the purchase of the food.

The amount of food consumed by Bhutan nationals differed between two sources - the FAO stats (FAO, 2013) and Government data (NSB, 2013b; p.127). The FAO data (FAO, 2010) for the reference year 2010 was used as it provided data of relating to the raw food content consumed, and the associated food yields at that time. These FAO statistics used are the production plus import, minus export meaning the data includes not only food consumed by Bhutan locals, but also food that may be used to feed tourists and food wasted either during processing, transport or not-consumed (FAO, 2010). It is suggested that further information is required to assess both the amount of food produced that is then wasted and food consumed by tourists. The food consumed at the national level, is shown in table 4.1.1 below.

<table>
<thead>
<tr>
<th>FAO Data</th>
<th>Bhutan consumption</th>
<th>Average yield</th>
<th>Food EF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg/capita/year</td>
<td>kg/bha</td>
<td>bha/capita</td>
</tr>
<tr>
<td>Fruit Total</td>
<td>121.86</td>
<td>10,814</td>
<td>0.0163</td>
</tr>
<tr>
<td>Vegetable Total</td>
<td>141.99</td>
<td>6,893</td>
<td>0.0196</td>
</tr>
<tr>
<td>Grains and Pulse Totals</td>
<td>373.64</td>
<td>1,651.83</td>
<td>0.1384</td>
</tr>
<tr>
<td>Other Total</td>
<td>30.72</td>
<td>2,649.63</td>
<td>0.0192</td>
</tr>
<tr>
<td>Beverages</td>
<td>8.05</td>
<td></td>
<td>0.0011</td>
</tr>
<tr>
<td>Total Crop Land</td>
<td></td>
<td></td>
<td>0.1946</td>
</tr>
<tr>
<td>Poultry &amp; eggs</td>
<td>0.84</td>
<td>15.61</td>
<td>0.1049</td>
</tr>
<tr>
<td>Buffalo, beef and offal</td>
<td>10.82</td>
<td>328.97</td>
<td>0.0036</td>
</tr>
<tr>
<td>Pig, sheep, goat</td>
<td>1.78</td>
<td>577.06</td>
<td>0.0019</td>
</tr>
<tr>
<td>Dairy Products</td>
<td>55.77</td>
<td>5,214.22</td>
<td>0.0079</td>
</tr>
<tr>
<td>Total Grazing Land</td>
<td></td>
<td></td>
<td>0.1183</td>
</tr>
<tr>
<td>Total Fish Land</td>
<td>2.91</td>
<td>74.46</td>
<td>0.0391</td>
</tr>
<tr>
<td><strong>Total Food</strong></td>
<td><strong>748.38</strong></td>
<td></td>
<td><strong>0.3520</strong></td>
</tr>
</tbody>
</table>
On average each Bhutan national requires 748.38kg of food and beverage per year totalling 0.3520bha per capita of crop, grazing and fish land. Please refer to ‘Extra Calculations, FAO Food Calculations, lines 2-114’ for a detailed breakdown of the data.

Agricultural vehicles were added to the EF calculations using the required embodied and operational energy. Data from the *Agriculture Machinery Centre* (AMC, n.d.) showed that Bhutan requires approximately 115,687GJ of energy to power its agricultural machinery each year. The EF of agricultural vehicles is 0.0036bha/capita (*Bhutan and District Food EF, Bhutan Food EF, lines 41-49*) and 0.0016gha/capita (*Gha - Food EF, Bhutan Food EF, lines 41-49*).

Agricultural inputs are included in the energy land calculation. In 2011 Bhutan consumed a total of 3,297 tonnes of fertiliser and pesticide (RNR, 2013; p.76-77). The embodied energy of these products is 1.899GJ per tonne totalling 6,259GJ. The EF of agricultural inputs is 0.0002bha/capita or 0.0001gha/capita.

Expenditure data was used to provide an estimate of the embodied energy of food products consumed in Bhutan, assumed to include all processing, transport, associated retail and wholesale energy and packaging. There was no way of separating out the transport from the rest of the embodied energy, and as a result there may be double up from the freight energy in the following section. The conversion of 0.016GJ/NU$ (WB, 2013; figure 0.13) was used alongside ‘food consumption expenditure’ per household (NSB, 2013b; table A2.42). Calculations found that on average the people of Bhutan spend 1,450.68NU$ per capita on food. The EF of food embodied energy is therefore 0.5280bha/capita (*Bhutan and District Food EF, Bhutan Food EF, lines 55-69*) and 0.2320gha/capita (*Gha - Food EF, Bhutan Food EF, lines 41-49*). Previous research into the embodied energy of the food EF found that the conversion figures used for assessing the embodied energy of food are dubious. The complexity of the food system requires a more detailed analysis of the energy required by the processing, transport, and associated retail and wholesale energy and packaging and waste sectors as suggested below. The authors therefore suggest these calculations be used with caution, and only as an indication of the variances between regions as shown in table 4.2.4.

The following food EF information missing from this data is highlighted as:

1. The amount of the food consumed that is not bought but grown on private or public land for personal consumption. There is good data relating to the amount of subsistence farming carried out in Bhutan. However it has not been used to articulate what the impact of this is on the food system. The authors of this report have a limited understanding of the Bhutan food system and as a result find it difficult to identify the benefits that locally grown food have on the food EF. However, it could be assumed from New Zealand’s experience that a move toward more home-produced food, reduces the food EF considerably (Lawton, 2013). A more detailed analysis of the trends away from self-sufficiency will help to increase understanding of where Bhutan’s EF is likely to grow in the future but also where land could be used more efficiently now. Shifting land currently needed for production of food required for Bhutan locals to other available land such as backyards, increases the available land for exports.

2. The food EF for transport should be included here. However the ‘food transport’ portion of the ‘goods transport’ EF discussed in the following ‘transport section’ could not be extrapolated. The New Zealand EF breakdown showed that 5% of the total footprint was for
transporting food (Lawton, 2013; p.117). This was further broken down into understanding the transport required in order to get imported products from their place of origin to NZ, the internal transportation of food between the regions, from food producers to manufacturers, to and from wholesale and retail businesses, and finally from retail or growers to households.

3. The amount of food packaging and waste associated with food. Food packaging, particularly plastic has a high embodied energy and materials component which increases the food EF the more packaging required. The waste component is most important in relation to how the embodied materials of that waste can be retained within the system to be reused or recycled. This in turn retains the embodied materials in the system, rather than having it become ‘waste’.

4. Cardiff (Collins et al., 2009) and New Zealand (Lawton, 2013; p.128) case studies found that there was an increase in the EF of food consumed outside of the household. There was not sufficient information or understanding of Bhutan culture in order to carry out the calculations required.

Bhutan’s total food EF is 658,287bha (‘Bhutan and District Food EF, Bhutan Food EF, lines 77-82) and 0.89bha/capita (Gha - Food EF, Bhutan Food EF, lines 77-82). Majority of the food EF is related to the energy required to produce the goods (64%) and the crop land (22%) to grow food, with grains being responsible for 71%. A summary of the food EF findings in bha can be found in table 4.1.2 and in gha in table 4.1.3.

<table>
<thead>
<tr>
<th>Food EF</th>
<th>Energy</th>
<th>Crop</th>
<th>Grazing</th>
<th>Fishing</th>
<th>Total per capita</th>
<th>Bhutan Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruits, Vegetables, Grains</td>
<td>0.3234</td>
<td>0.1946</td>
<td>0.1183</td>
<td></td>
<td>0.6363</td>
<td></td>
</tr>
<tr>
<td>Animals Products</td>
<td>0.180</td>
<td>0.0391</td>
<td></td>
<td></td>
<td>0.2190</td>
<td></td>
</tr>
<tr>
<td>Agricultural Inputs</td>
<td>0.0038</td>
<td></td>
<td></td>
<td></td>
<td>0.0038</td>
<td></td>
</tr>
<tr>
<td><strong>Food EF</strong></td>
<td><strong>0.5070</strong></td>
<td><strong>0.2337</strong></td>
<td><strong>0.1183</strong></td>
<td><strong>0.0391</strong></td>
<td><strong>0.8981</strong></td>
<td><strong>658,287</strong></td>
</tr>
</tbody>
</table>

Table 4.1.2. Bhutan Food EF in bha.

<table>
<thead>
<tr>
<th>Food EF</th>
<th>Energy</th>
<th>Crop</th>
<th>Grazing</th>
<th>Fishing</th>
<th>Total per capita</th>
<th>Bhutan Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fruits, Vegetables, Grains</td>
<td>0.1423</td>
<td>0.5959</td>
<td></td>
<td></td>
<td>0.7495</td>
<td></td>
</tr>
<tr>
<td>Animals Products</td>
<td>0.079</td>
<td>0.0391</td>
<td>0.0413</td>
<td></td>
<td>0.2818</td>
<td></td>
</tr>
<tr>
<td>Agricultural Inputs</td>
<td>0.0017</td>
<td></td>
<td></td>
<td></td>
<td>0.0051</td>
<td></td>
</tr>
<tr>
<td><strong>Food EF</strong></td>
<td><strong>0.2230</strong></td>
<td><strong>0.6350</strong></td>
<td><strong>0.0413</strong></td>
<td><strong>0.0144</strong></td>
<td><strong>0.9137</strong></td>
<td><strong>669,735</strong></td>
</tr>
</tbody>
</table>

Table 4.1.3. Summary of the Bhutan Food EF in gha.

The national data above was used as a template to complete the following regional data set. The main component of the food EF data that changed between regions was the amount of money spent on food. The amount of agricultural inputs, such as fertilisers and pesticides, purchased by each
region also varied but the amounts are minimal and resulted in little effect on the regional EF. A summary of the regional footprints in both bha and gha are in table 4.1.4.

### Table 4.1.4. Regional Bhutan Food EF in bha and gha.

<table>
<thead>
<tr>
<th>Regional Comparison</th>
<th>Regional Food EF (bha)</th>
<th>Regional Food EF (gha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bumthang</td>
<td>1.0616</td>
<td>0.9885</td>
</tr>
<tr>
<td>Chhukha</td>
<td>0.7755</td>
<td>0.8626</td>
</tr>
<tr>
<td>Dagana</td>
<td>0.7725</td>
<td>0.8613</td>
</tr>
<tr>
<td>Gasa</td>
<td>1.4322</td>
<td>1.1515</td>
</tr>
<tr>
<td>Haa</td>
<td>0.8917</td>
<td>0.9137</td>
</tr>
<tr>
<td>Lhuntense</td>
<td>1.0724</td>
<td>0.9932</td>
</tr>
<tr>
<td>Monggar</td>
<td>0.7705</td>
<td>0.8604</td>
</tr>
<tr>
<td>Paro</td>
<td>1.1164</td>
<td>1.0126</td>
</tr>
<tr>
<td>Pema Gatshel</td>
<td>0.8912</td>
<td>0.9135</td>
</tr>
<tr>
<td>Punakha</td>
<td>0.9354</td>
<td>0.9329</td>
</tr>
<tr>
<td>Samdrup Jongkhar</td>
<td>0.8032</td>
<td>0.8748</td>
</tr>
<tr>
<td>Samste</td>
<td>0.7841</td>
<td>0.8664</td>
</tr>
<tr>
<td>Sarpang</td>
<td>0.9048</td>
<td>0.9195</td>
</tr>
<tr>
<td>Thimphu</td>
<td>1.0981</td>
<td>1.0045</td>
</tr>
<tr>
<td>Trashigang</td>
<td>0.8811</td>
<td>0.9091</td>
</tr>
<tr>
<td>Trashiyane</td>
<td>0.8653</td>
<td>0.9021</td>
</tr>
<tr>
<td>Trongsa</td>
<td>0.9383</td>
<td>0.9342</td>
</tr>
<tr>
<td>Tsirang</td>
<td>0.8109</td>
<td>0.8782</td>
</tr>
<tr>
<td>Wangdue Phodrang</td>
<td>0.9159</td>
<td>0.9244</td>
</tr>
<tr>
<td>Zhemgang</td>
<td>0.7386</td>
<td>0.8464</td>
</tr>
</tbody>
</table>

There are a few anomalies relating to the regional data. Thimpu and Paro represent 16% and 5.62% of the population respectively but consume 20% and 7.15% of the food EF in bha. On the other hand, Chhuka represents 11.59% of the population but only consumes 9.83% of the EF (bha). These variables are caused by the average amount of money spent on food by households in these regions. Paro spends on average 2,150NU$ per household whilst Thimpu spends 2,148NU$ and Chhuka spends 1,199NU$. The average is 1,574NU$ per person per year.

#### 4.2 Transport EF

The transport EF includes a breakdown of the embodied energy and land area required for transport infrastructure (including airports) and the operational and embodied energy of the all vehicles in Bhutan.

The Bhutan roading network comprises of 10,058km of sealed and unsealed road at an average width of 3.5m. Of the total network 35% is paved (1,214bha) and 66% is unpaved (2,306bha). Paved roads have an embodied energy conversion of 335MJ/km over a 50 year timeframe (Alcorn, 2003;
p.27), a total EF of 244bha or 0.0000bha per capita per year. Although unsealed roads are likely to require some maintenance, the embodied energy data could not be located and the EF impact is likely to be minimal.

Airports require a relatively large area of land and a considerable amount of asphalt. The only data that could be found regarding the size of airports in Bhutan was for Jakar Airport in Bumthang (GCMAP, 2014). It covers an area of 3.6bha, the asphalt embodied energy EF is approximately 5.4bha. The airport has a total EF of 9bha.

The remainder of the Transport EF was the operational and embodied energy of vehicles and is presented in table 4.2.1 (bha) and 4.2.2 (gha) below. The transport modes were divided into three categories, ‘Public transport’ including buses and taxis and ‘private transport’ including two wheeler, small and medium sized vehicles. The EF of ‘goods transport’ included all heavy vehicles. Government data (RTSA, 2013) was used to calculate the passenger distance travelled for buses and taxis. The daily data was multiplied by 365 days to provide annual averages (Bhutan and District Transport EF, Bhutan Transport EF, lines 20-27 & 36-42). Worldwide data was used for the operational and embodied energy data with Bhutan specific variables relating to the average passengers per vehicle and the average age of vehicles.

The following points highlight where improvements to the transport EF calculations could be made:

1. ‘Private transport’ could have included infrastructure for walking and cycling if data were available, though the EF impact would be extremely minimal.
2. ‘Goods transport’ could have been reassigned to either the food EF (for the transport of food related goods) or to consumer goods (for the transport of consumer goods) however there was not enough data about this EF to make an informed calculation.
3. As mentioned in the food section, the data for transporting food related to tourism and exports is included in the calculations above. The contribution from these groups should be removed.
4. Buildings related to transport use, including the physical land and operational and embodied energy of the buildings could also be included. There was not to follow this up.
5. The airport EF has been mentioned above. Unfortunately there was not enough data to carry out accurate calculations relating to flights taken by Bhutan nationals. Of the data available it was also assumed a large portion of these would be flights were by non-nationals visiting the country for work or pleasure.

Regional EF data (NSB, 2013a & 2013b) was provided giving the number of vehicles in each region, and the average distances travelled. The average passenger numbers and age of vehicles were the same as the national data. Note that data for some regions, such as Zhemgang, data was not available at the time of writing - see source for further detail (Bhutan and District Data, Zhemgang Data, lines 277-295).
Table 4.2.1. Transport EF in bha.

<table>
<thead>
<tr>
<th>Transport</th>
<th>Passenger distance travelled</th>
<th>Operational energy</th>
<th>Embodied energy</th>
<th>EF/capita per year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Km/pasenger per year</td>
<td>MJ/pkm</td>
<td>MJ/pkm</td>
<td>bha/capita per year</td>
</tr>
<tr>
<td>Bus</td>
<td>914.24</td>
<td>1.72¹</td>
<td>0.09¹</td>
<td>0.0368</td>
</tr>
<tr>
<td>Taxi</td>
<td>393.34</td>
<td>2.02²</td>
<td>0.53²</td>
<td>0.0164</td>
</tr>
<tr>
<td>Two-wheeler</td>
<td>146.17</td>
<td>2.30³</td>
<td>0.35³</td>
<td>0.0473</td>
</tr>
<tr>
<td>Small</td>
<td>1,172.97</td>
<td>1.68²</td>
<td>0.53²</td>
<td>0.0012</td>
</tr>
<tr>
<td>Medium</td>
<td>30.12</td>
<td>1.68⁴</td>
<td>0.66⁴</td>
<td>0.0490</td>
</tr>
<tr>
<td>Heavy vehicles</td>
<td>1,170.40</td>
<td>1.72⁵</td>
<td>0.73⁵</td>
<td>0.0081</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3,827.24</strong></td>
<td></td>
<td></td>
<td><strong>0.1588</strong></td>
</tr>
</tbody>
</table>

1. Assumed to be travelling at full capacity - 50 people, full distance, 15 year lifespan
2. Assumed to be transporting 4 people, 20 year lifespan
3. Assumed to be carrying 2 people, 17.5 year lifespan
4. Assumed to be transporting 3 people, 20 year lifespan
5. Assumed to be transporting 1 person and goods, 13.5 year lifespan

Table 4.2.2. Transport EF in gha.

<table>
<thead>
<tr>
<th>Transport</th>
<th>Passenger distance travelled</th>
<th>Operational energy</th>
<th>Embodied energy</th>
<th>EF/capita per year</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Km/pasenger per year</td>
<td>MJ/pkm</td>
<td>MJ/pkm</td>
<td>gha/capita per year</td>
</tr>
<tr>
<td>Bus</td>
<td>914.24</td>
<td>1.72¹</td>
<td>0.09¹</td>
<td>0.0162</td>
</tr>
<tr>
<td>Taxi</td>
<td>393.34</td>
<td>2.02²</td>
<td>0.53²</td>
<td>0.0072</td>
</tr>
<tr>
<td>Two-wheeler</td>
<td>146.17</td>
<td>2.30³</td>
<td>0.35³</td>
<td>0.0208</td>
</tr>
<tr>
<td>Small</td>
<td>1,172.97</td>
<td>1.68²</td>
<td>0.53²</td>
<td>0.0005</td>
</tr>
<tr>
<td>Medium</td>
<td>30.12</td>
<td>1.68⁴</td>
<td>0.66⁴</td>
<td>0.0215</td>
</tr>
<tr>
<td>Heavy vehicles</td>
<td>1,170.40</td>
<td>1.72⁵</td>
<td>0.73⁵</td>
<td>0.0036</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>3,827.24</strong></td>
<td></td>
<td></td>
<td><strong>0.0699</strong></td>
</tr>
</tbody>
</table>

1. Assumed to be travelling at full capacity - 50 people, full distance, 15 year lifespan
2. Assumed to be transporting 4 people, 20 year lifespan
3. Assumed to be carrying 2 people, 17.5 year lifespan
4. Assumed to be transporting 3 people, 20 year lifespan
5. Assumed to be transporting 1 person and goods, 13.5 year lifespan

The total EF of transport is 0.1588bha/capita and 0.0699gha/capita. The difference between the two results is significant due to the non-renewable energy rate, with a world average of 100GJ/ha, and the Bhutan local only 44GJ/ha.
The regional EF transport results *(Bhutan and District Transport EF, Bhutan Transport EF, lines 67-86)* range from 0.4261bha to 0.0081bha per capita. The results in table 4.2.3 showed three groups of regions with high, medium and low EFs:

- High - Thimpu, Chhukha and Paro
- Medium - Bumthang, Lhutense, Haa, Samste, Sarpang, Trongsa and Tsirang
- Low - Dagna, Gasa, Monggar, Pema Gatshel, Samdrup Jongkhar, and Zhemgang

Graph 1 below shows the results for each region breakdown into public transport, private transport and goods transport EF. The graph shows the three high EF regions have a combination of high goods figures (Chhukha & Paro), high personal transport figures (Chhukha & Thimphu) and high public transport figures (Thimphu).
4.3. Consumer Goods EF

Consumer goods account for the total land required for the production (and operation) of all the goods purchased and waste created for the households and individuals. This includes (but is not limited to) furniture, white wear, home wear, electronics and clothing and footwear.

Household ownership of consumer goods (NSB, 2013b; p.150 & 151) was used to calculate the EF of consumer goods in 2012. The percentage of households owning goods was multiplied by the total houses and the estimated weight per item. The weight was multiplied by the conversion factor provided in the Global Footprint Network worksheet (GFN, 2013; carbon_efe). The goods accounted for by weight and embodied energy is shown in table 4.3.1 below. Additional household expenditure data was used to calculate the EF of clothing and footwear, and general household furnishings as shown in table 4.3.2.

There were some limitations with the above EF calculations, whereby further investigation would improve their accuracy.

1. EF data regarding the embodied materials within these products makes it difficult to calculate the crop, grazing and forest land required. As a result many of the products and services consumed as consumer goods are accounted for through their embodied energy and accounted for in energy land. Two products were considered to be have been consumed in a high enough amount in order to attempt to calculate their embodied materials component, wool and daphne. Unfortunately, there was insufficient understanding of where these products come from and how they are used in order to calculate their associated EF.

2. The weight of the individual items in table 4.3.1 and the weight per NU spent in table x were estimates. More accurate weights for these items would be useful.
3. The list of consumer goods above is not exhaustive. There will be additional goods and services that should be included in this category that are not included. Further work could be carried out to firstly identify what they are and secondly, include their EF above.

Table 4.3.1. Ownership data - consumer goods EF in bha.

<table>
<thead>
<tr>
<th>Consumer Goods</th>
<th>Ownership</th>
<th>Weight conversion</th>
<th>Energy conversion</th>
<th>EF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td># items</td>
<td>kg/item</td>
<td>GJ/tonne</td>
<td></td>
</tr>
<tr>
<td>Refrigerator</td>
<td>55,527</td>
<td>50</td>
<td>57</td>
<td>0.0049</td>
</tr>
<tr>
<td>Microwave</td>
<td>125,383</td>
<td>15</td>
<td>57</td>
<td>0.0001</td>
</tr>
<tr>
<td>Modern stove</td>
<td>40,174</td>
<td>35</td>
<td>60</td>
<td>0.0026</td>
</tr>
<tr>
<td>Rice-cooker</td>
<td>106,448</td>
<td>6</td>
<td>60</td>
<td>0.0012</td>
</tr>
<tr>
<td>Curry-cooker</td>
<td>92,118</td>
<td>6</td>
<td>60</td>
<td>0.0010</td>
</tr>
<tr>
<td>Water-boiler (urn)</td>
<td>85,593</td>
<td>1</td>
<td>60</td>
<td>0.0002</td>
</tr>
<tr>
<td>Washing-machine</td>
<td>15,609</td>
<td>35</td>
<td>57</td>
<td>0.0010</td>
</tr>
<tr>
<td>Electric-iron</td>
<td>28,531</td>
<td>1</td>
<td>57</td>
<td>0.0001</td>
</tr>
<tr>
<td>Television</td>
<td>74,846</td>
<td>15</td>
<td>100</td>
<td>0.0035</td>
</tr>
<tr>
<td>VCR/DVD</td>
<td>46,443</td>
<td>7</td>
<td>100</td>
<td>0.0010</td>
</tr>
<tr>
<td>Camera</td>
<td>21,878</td>
<td>0.1</td>
<td>300</td>
<td>0.0000</td>
</tr>
<tr>
<td>Radio</td>
<td>49,641</td>
<td>1</td>
<td>100</td>
<td>0.0002</td>
</tr>
<tr>
<td>Watch</td>
<td>64,611</td>
<td>0.05</td>
<td>100</td>
<td>0.0000</td>
</tr>
<tr>
<td>Foreign hunting bow</td>
<td>90,839</td>
<td>1</td>
<td>100</td>
<td>0.0003</td>
</tr>
<tr>
<td>Mobile phone</td>
<td>118,730</td>
<td>0.5</td>
<td>100</td>
<td>0.0002</td>
</tr>
<tr>
<td>Computer</td>
<td>20,982</td>
<td>15</td>
<td>100</td>
<td>0.0010</td>
</tr>
<tr>
<td>Sofa</td>
<td>45,164</td>
<td>30</td>
<td>23</td>
<td>0.0010</td>
</tr>
<tr>
<td>Wood heater</td>
<td>29,043</td>
<td>30</td>
<td>57</td>
<td>0.0015</td>
</tr>
<tr>
<td>Electric heater</td>
<td>39,406</td>
<td>10</td>
<td>57</td>
<td>0.0007</td>
</tr>
<tr>
<td>Fan</td>
<td>29,171</td>
<td>2</td>
<td>57</td>
<td>0.0001</td>
</tr>
</tbody>
</table>

Table 4.3.2. Spending data - consumer goods EF in bha.

<table>
<thead>
<tr>
<th>Consumer Goods</th>
<th>Annual average expenditure</th>
<th>Weight conversion</th>
<th>Energy conversion</th>
<th>EF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nu</td>
<td>kg/NU$</td>
<td>GJ/tonne</td>
<td></td>
</tr>
<tr>
<td>Furnishings and equipment</td>
<td>2,374.68</td>
<td>0.1</td>
<td>23</td>
<td>0.0217</td>
</tr>
<tr>
<td>Clothing and shoes</td>
<td>16,791.72</td>
<td>0.01</td>
<td>70</td>
<td>0.0466</td>
</tr>
</tbody>
</table>

The total average consumer goods EF in 2012 was 0.0894bha/capita or 0.0399gha/capita. Refrigerators and televisions are a large component of the ownership data and clothing and shoes of the spending data.

The regional consumer goods EF used household spending data and is shown in table 4.3.3 below. Further detail about each region’s EF can be found in the supporting calculations Bhutan and Districts Consumer Goods, ‘region’, lines 33-55 and Gha - Consumer Goods, ‘region’, lines 33-55.
Table 4.3.3. Regional Bhutan Consumer Goods EF in bha and gha

<table>
<thead>
<tr>
<th>Regional Comparison</th>
<th>Regional Consumer Goods EF</th>
<th>Regional Consumer Goods EF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>bha</td>
<td>gha</td>
</tr>
<tr>
<td>Bumthang</td>
<td>0.1432</td>
<td>0.0630</td>
</tr>
<tr>
<td>Chhukha</td>
<td>0.0824</td>
<td>0.0363</td>
</tr>
<tr>
<td>Haa</td>
<td>0.2168</td>
<td>0.0954</td>
</tr>
<tr>
<td>Monggar</td>
<td>0.0977</td>
<td>0.0430</td>
</tr>
<tr>
<td>Pemagatshel</td>
<td>0.0800</td>
<td>0.0352</td>
</tr>
<tr>
<td>Samdrup Jongkhar</td>
<td>0.1038</td>
<td>0.0457</td>
</tr>
<tr>
<td>Sarpang</td>
<td>0.1014</td>
<td>0.0446</td>
</tr>
<tr>
<td>Trashigang</td>
<td>0.0940</td>
<td>0.0413</td>
</tr>
<tr>
<td>Trongsa</td>
<td>0.1104</td>
<td>0.0486</td>
</tr>
<tr>
<td>Wangdue Phodrang</td>
<td>0.0931</td>
<td>0.0410</td>
</tr>
</tbody>
</table>

The regional results in table 4.3.3 show some variation between the region’s EF ranging from 0.0517bha for Zhemgang, to 1.1939bha for Gasa. Gasa’s high EF is a result of high spending on clothing and shoes (31,542NU), over one and half times the national average. Gasa households also spend an additional 8,567NU per year on furnishings, three times higher than the national average.

4.4. Housing EF

There are multiple parts to the housing EF and shown in the total Housing EF table 4.4.1 (bha) and 4.4.2 (gha) below. These include:

1. timber for the housing structure construction and maintenance – forest land;
2. the firewood required for household cooking and heating – forest land;
3. other fuels are also used for cooking and heating purposes – energy land;
4. electricity required by domestic housing – consumed land; and
5. the physical land required for the house and garden - consumed and garden land.

There were approximately 127,942 private dwellings in Bhutan in 2012. A number of assumptions were made about these dwellings in order to provide the following EF calculations. Dwellings were assumed to be on average 2-storey - urban buildings are two-three storey whilst rural properties often house animals on the ground floor, with living quarters above (Lang et al., 2013). The average
dwellings therefore had a physical area of 149m², an EF of 0.01bha totalling 0.0013bha per capita. Additional garden land was also added however it is important to keep this land separate from the land that has been built on, because although it is part of an individual's EF it is still available for alternative uses. The average section size across the country is 371.61m². The garden area minus the house area is an average of 297.29m² or 0.0052bha per capita.

As noted in section 4.7.4 the average annual yield increment is 2.73m³/bha/yr. Data detailing the amount of embodied timber in a house could not be located. Information was found detailing that in 1991 annual consumption was 0.29m³/capita/year (FAO, 2000), an EF of 0.1064bha/capita. This wood consumption figure may not only include wood for household construction but for all timber uses such as furniture etc. If a house is assumed to last 50 years, with an average of 4.5 people per house each house has approximately 30.5m³ of embodied wood.

Firewood collection is controlled, whereby a permit system for felling trees is used to protect remaining forests. A report by the FAO (2000) noted that on average a family of 5.5 required 12m³, 10 trees per year or 0.8bha/capita/yr. More recent research suggests that firewood use is about 1.03GJ or 0.0316bha/capita per year (Ernst & Young, 2012; p.32). The cumulative data for each region (NSB 2012a & 2012b; p.52) showed the firewood for 2012 required 53,761m³ or 0.0269bha/capita/yr. The second of these two figures will be used in the following calculations.

The embodied energy of a house the energy needed for its construction, maintenance, demolition and disposal. There was no data specific to the whole-of-life embodied energy of the various housing types in Bhutan. An average figure of 1.8GJ/m² (Mithraratne et al., 2007; p.159) over the life of the building (assumed to be 50 years) for all buildings types is used. Previous research has found that 60% of the energy is required in the construction of the building, 34% in the maintenance and 6% in its demolition and disposal. There is a total of approximately 19 million m² of buildings totalling 1.1 million GJ or 0.04bha/capita per year.

The operational energy of residential dwellings includes electricity required to run electrical whiteware and lights, whilst kerosene or gas lamps and candles may also be used. Unfortunately there is not sufficient breakdown of the data to fully understand the amount of various fuels required by households, though it is assumed to be minimal (NSB, 2013b; p.141). The Statistical yearbook 2013 shows a total of 2,572.2kWh/capita (NSB, 2013a; 157) equivalent to 0.0093bha/capita/yr.

There were some limitations with the above EF calculations, whereby further investigation would improve the accuracy.

1. Section sizes are likely to vary across the country, particularly between rural and urban settings.
2. There are a range of materials that houses can be built out of. There was some suggestion that the data may not be too difficult to attain as there is already information relating to the material that a dwelling’s floor is constructed out of. Further discussions with Bhutanese architects and builders would provide valuable additional insight in order to more accurately calculate the embodied energy of these methods.
Table 4.4.1. Bhutan Housing EF in bha.

<table>
<thead>
<tr>
<th>Household EF</th>
<th>Energy Land</th>
<th>Forest Land</th>
<th>Consumed Land</th>
<th>Garden Land</th>
<th>EF/capita</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>bha</td>
<td>bha</td>
<td>bha</td>
<td>bha</td>
<td></td>
</tr>
<tr>
<td>Construction/Maintenance</td>
<td>0.0354</td>
<td>0.1064</td>
<td></td>
<td></td>
<td>0.1418</td>
</tr>
<tr>
<td>Operation</td>
<td>0.0093</td>
<td>0.0269</td>
<td></td>
<td></td>
<td>0.0362</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>0.0446</td>
<td>0.1333</td>
<td>0.0013</td>
<td>0.0052</td>
<td><strong>0.1844</strong></td>
</tr>
</tbody>
</table>

Table 4.4.2. Bhutan Housing EF in gha.

<table>
<thead>
<tr>
<th>Household EF</th>
<th>Energy Land</th>
<th>Forest Land</th>
<th>Consumed Land</th>
<th>Garden Land</th>
<th>EF/capita</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>gha</td>
<td>gha</td>
<td>gha</td>
<td>gha</td>
<td></td>
</tr>
<tr>
<td>Construction/Maintenance</td>
<td>0.0156</td>
<td>0.1064</td>
<td></td>
<td></td>
<td>0.1220</td>
</tr>
<tr>
<td>Operation</td>
<td>0.0093</td>
<td>0.0269</td>
<td></td>
<td></td>
<td>0.0362</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>0.0248</td>
<td>0.1333</td>
<td>0.0018</td>
<td>0.0027</td>
<td><strong>0.1716</strong></td>
</tr>
</tbody>
</table>

Table 4.4.3. Regional Bhutan Housing EF in bha and gha

<table>
<thead>
<tr>
<th>Regional Comparison</th>
<th>Regional Housing EF</th>
<th>Regional Housing EF</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>bha</td>
<td>gha</td>
</tr>
<tr>
<td>Bumthang</td>
<td>0.1756</td>
<td>0.1337</td>
</tr>
<tr>
<td>Chhukha</td>
<td>0.1801</td>
<td>0.1370</td>
</tr>
<tr>
<td>Dagana</td>
<td>0.1759</td>
<td>0.1342</td>
</tr>
<tr>
<td>Gasa</td>
<td>0.1753</td>
<td>0.1334</td>
</tr>
<tr>
<td>Haa</td>
<td>0.1764</td>
<td>0.1335</td>
</tr>
<tr>
<td>Lhutense</td>
<td>0.1739</td>
<td>0.1318</td>
</tr>
<tr>
<td>Monggar</td>
<td>0.1736</td>
<td>0.1311</td>
</tr>
<tr>
<td>Paro</td>
<td>0.1776</td>
<td>0.1358</td>
</tr>
<tr>
<td>Pema Gatshel</td>
<td>0.1737</td>
<td>0.1314</td>
</tr>
<tr>
<td>Punakha</td>
<td>0.1747</td>
<td>0.1324</td>
</tr>
<tr>
<td>Samdrup Jongkhar</td>
<td>0.1890</td>
<td>0.1475</td>
</tr>
<tr>
<td>Samste</td>
<td>0.1792</td>
<td>0.1370</td>
</tr>
<tr>
<td>Sarpang</td>
<td>0.1754</td>
<td>0.1334</td>
</tr>
<tr>
<td>Thimphu</td>
<td>0.1798</td>
<td>0.1381</td>
</tr>
<tr>
<td>Trashigang</td>
<td>0.1763</td>
<td>0.1346</td>
</tr>
<tr>
<td>Trashiyangste</td>
<td>0.1744</td>
<td>0.1328</td>
</tr>
<tr>
<td>Trongsa</td>
<td>0.1748</td>
<td>0.1325</td>
</tr>
<tr>
<td>Tsirang</td>
<td>0.1742</td>
<td>0.1321</td>
</tr>
<tr>
<td>Wangdue Phodrang</td>
<td>0.1780</td>
<td>0.1357</td>
</tr>
<tr>
<td>Zhemgang</td>
<td>0.1730</td>
<td>0.1301</td>
</tr>
</tbody>
</table>
Table 4.4.3 above shows the Housing EF of the various regions. There was not a lot of data available in order to identify the variances between the regional footprints and as a result the calculations vary little. Samdrup Jongkhar is highlighted as having the largest housing EF at 0.2014bha and 0.1475gha per capita per year. This is a result of requiring more electricity on average per household.

4.5. Services EF

The services EF is made up of all those parts of the economy provided to the citizens of Bhutan through their taxes, i.e. hospitals and schools. This includes the land required to put government and service buildings, the public ‘garden land’ such as the Royal Botanical Garden, the operational and embodied energy of these buildings and the day to day workings of these service sectors.

Parks and reserves also have an EF as the land is therefore ‘consumed’ by an activity and requires garden land. On the other hand, the land is available for a different use in the future and plays important alternative functions such as providing green corridors for wildlife and a place for people for recreation and to spend time in nature. Information was located regarding the Royal Botanic Park. This is a 4,700bha park that equates to 0.0064bha per capita.

Only estimates were available to calculate the land area consumed by government and service buildings. The average size of a building and the area of land required by commercial activities (*Bhutan and District Data, Bhutan Data, lines 396 & 397*) was multiplied by the number of businesses (NSB, 2013a; p.123). A two-story building was assumed to have a floor area of 222.67m² and that each of the 7,474 businesses had their own building. The total physical land EF was 83.32bha or 0.0001bha per capita (*Bhutan and District Services EF, Bhutan Service EF, line 9*).

The embodied energy was calculated for the construction, maintenance, demolition and disposal of buildings over a 50 year timeframe was an average of 3.15GJ/m² (MWHS, 2013). Compare this to the lower embodied energy rate of 1.8GJ/m² used in the housing EF above. As discussed above Bhutan has approximately 1.67 million m² of floor area for commercial business and government totalling 166.6bha (*Bhutan and District Services EF, Bhutan Service EF, lines 37-44*) or 0.00023bha per capita.

The operational energy of service buildings was calculated using data from the *Statistical Yearbook* (NSB, 2013a; p.110) showing a total of 1,171Gwh sold to industry. From the list of energy uses two were excluded from the following calculations - ‘high voltage’ as majority of this energy goes into producing goods that are then exported and ‘agricultural energy’ as this should have been picked up in the food EF calculations. Table 4.5.1 below presents the total EF of embodied operational energy of services in Bhutan was 0.0014bha (*Bhutan and District Services EF, Bhutan Service EF, lines 15-27*) per capita.
Table 4.5.1. Electricity EF in bha, sold to Bhutan Services.

<table>
<thead>
<tr>
<th>Services EF</th>
<th>Electricity sold</th>
<th>Energy</th>
<th>EF/capita</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>GWh</td>
<td>kWh/capita</td>
<td>bha</td>
</tr>
<tr>
<td>Commercial</td>
<td>43.44</td>
<td>59.26</td>
<td>0.0002</td>
</tr>
<tr>
<td>Industrial</td>
<td>10.18</td>
<td>13.89</td>
<td>0.0000</td>
</tr>
<tr>
<td>Institutions</td>
<td>46.44</td>
<td>63.36</td>
<td>0.0002</td>
</tr>
<tr>
<td>Street Lighting</td>
<td>2.59</td>
<td>3.53</td>
<td>0.0000</td>
</tr>
<tr>
<td>Power house auxiliaries</td>
<td>1.06</td>
<td>1.45</td>
<td>0.0000</td>
</tr>
<tr>
<td>Temporary connections</td>
<td>18.16</td>
<td>24.78</td>
<td>0.0001</td>
</tr>
<tr>
<td>Low Voltage Bulk</td>
<td>56.21</td>
<td>76.69</td>
<td>0.0003</td>
</tr>
<tr>
<td>Med Volt Industries</td>
<td>109.54</td>
<td>149.44</td>
<td>0.0005</td>
</tr>
<tr>
<td></td>
<td><strong>287.62</strong></td>
<td><strong>0.0014</strong></td>
<td></td>
</tr>
</tbody>
</table>

Other energy use by industry includes coal, fuel, kerosene and LPG totalling 56,205Mtoe (metric tonnes of oil equivalent) (UNDP, 2013; p.16). These figures were converted to energy land equivalents totalling 0.0730bha (Bhutan and District Services EF, Bhutan Service EF, lines 30-34) or 0.0335gha (Gha-Services EF, Bhutan Service EF, lines 30-34) per capita per year.

Lastly the embodied energy of services required calculated through ‘services expenditure’ (NSB, 2013a; p.197). The service sectors include social services, economic services, housing and public amenities, public order and safety services, religion and culture services and general services. Table 4.5.2 below shows the breakdown. The embodied energy EF by expenditure for the Bhutan services EF is 0.3959bha (Bhutan and District Services EF, Bhutan Service EF, lines 45-53).

Table 4.5.2. Embodied Energy by Expenditure EF in bha.

<table>
<thead>
<tr>
<th>Services EF</th>
<th>Expenditure</th>
<th>Energy</th>
<th>EF/capita</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>NU$/capita</td>
<td>GJ/capita</td>
<td>bha</td>
</tr>
<tr>
<td>Social services (Health and Education)</td>
<td>5,825.16</td>
<td>93.20</td>
<td>0.0932</td>
</tr>
<tr>
<td>Economic Services</td>
<td>11,800.89</td>
<td>188.81</td>
<td>0.1888</td>
</tr>
<tr>
<td>Housing and Public Amenities</td>
<td>1,042.48</td>
<td>16.68</td>
<td>0.0167</td>
</tr>
<tr>
<td>Public order and safety services</td>
<td>1,055.25</td>
<td>16.88</td>
<td>0.0169</td>
</tr>
<tr>
<td>Religion and Culture services</td>
<td>1,165.21</td>
<td>18.64</td>
<td>0.0186</td>
</tr>
<tr>
<td>General services</td>
<td>3,854.69</td>
<td>61.68</td>
<td>0.0617</td>
</tr>
<tr>
<td></td>
<td><strong>24,743.68</strong></td>
<td><strong>395.90</strong></td>
<td><strong>0.3959</strong></td>
</tr>
</tbody>
</table>
Limitations on this data include:

1. Literature suggests there are parks and sports fields located throughout towns and cities (NSB, 2012a & 2012b; p.60), however more detailed data regarding the size and area of this land could not be located.

2. The embodied energy of buildings will vary depending on the type and age of the building. Further detail regarding the range of buildings and their material make-up would provide additional insight into this part of the services EF.

3. It is likely that some of the commercial buildings included in the calculations are used specifically in relation to food, transport or consumer goods. As a result the operational and embodied energy EF of these categories should be attributed to these EF categories. Further investigation is required to better understand this demand.

Table 4.5.3 below shows a breakdown of Bhutan’s total services EF including the physical land required, and the operational, construction/maintenance of buildings and the embodied energy calculated through expenditure data. The total services EF for Bhutan was 0.4840bha (Bhutan and District Services EF, Bhutan Service EF, lines 62-67) or 0.4487gha (Gha – Service EF, Bhutan Service EF, lines 62-67) per capita per year.

<table>
<thead>
<tr>
<th>Services EF</th>
<th>Energy</th>
<th>Consumed land</th>
<th>Garden land</th>
<th>EF/capita</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational</td>
<td>0.0744</td>
<td>0.0014</td>
<td></td>
<td>0.0758</td>
</tr>
<tr>
<td>Construction/Maintenance</td>
<td>0.0057</td>
<td></td>
<td></td>
<td>0.0057</td>
</tr>
<tr>
<td>Expenditure</td>
<td>0.3959</td>
<td></td>
<td></td>
<td>0.3959</td>
</tr>
<tr>
<td>Physical land</td>
<td></td>
<td>0.0001</td>
<td>0.0065</td>
<td>0.001</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>0.4760</strong></td>
<td><strong>0.0015</strong></td>
<td><strong>0.0065</strong></td>
<td><strong>0.4840</strong></td>
</tr>
</tbody>
</table>

The regional ‘service EF’ is shown in table 4.5.4. The results suggest some variance between the regions. Pema Gatshel has the highest service EF of any region, 63% higher than the national average, due to the very high expenditure in hospitals, 241 million NU per year (NSB, 2012b).
Table 4.5.4. Regional Bhutan Services EF in bha and gha.

<table>
<thead>
<tr>
<th>Regional Comparison</th>
<th>Regional Services EF bha</th>
<th>Regional Services EF gha</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bumthang</td>
<td>0.2283</td>
<td>0.1929</td>
</tr>
<tr>
<td>Chhukha</td>
<td>0.2026</td>
<td>0.1671</td>
</tr>
<tr>
<td>Dagana</td>
<td>0.1763</td>
<td>0.1409</td>
</tr>
<tr>
<td>Gasa</td>
<td>0.3099</td>
<td>0.2806</td>
</tr>
<tr>
<td>Haa</td>
<td>0.4953</td>
<td>0.4660</td>
</tr>
<tr>
<td>Lhuntense</td>
<td>0.4953</td>
<td>0.4660</td>
</tr>
<tr>
<td>Monggar</td>
<td>0.1342</td>
<td>0.0988</td>
</tr>
<tr>
<td>Paro</td>
<td>0.1752</td>
<td>0.1398</td>
</tr>
<tr>
<td>Pema Gatshel</td>
<td>0.7668</td>
<td>0.7313</td>
</tr>
<tr>
<td>Punakha</td>
<td>0.5472</td>
<td>0.5118</td>
</tr>
<tr>
<td>Samdrup Jongkhar</td>
<td>0.4839</td>
<td>0.4485</td>
</tr>
<tr>
<td>Samste</td>
<td>0.1295</td>
<td>0.0940</td>
</tr>
<tr>
<td>Sarang</td>
<td>0.3348</td>
<td>0.2994</td>
</tr>
<tr>
<td>Thimphu</td>
<td>0.1340</td>
<td>0.1048</td>
</tr>
<tr>
<td>Trashigang</td>
<td>0.2046</td>
<td>0.1905</td>
</tr>
<tr>
<td>Trashiyanste</td>
<td>0.3024</td>
<td>0.2670</td>
</tr>
<tr>
<td>Trongsa</td>
<td>0.4860</td>
<td>0.4505</td>
</tr>
<tr>
<td>Tsirang</td>
<td>0.4839</td>
<td>0.4485</td>
</tr>
<tr>
<td>Wangdue Phodrang</td>
<td>0.4839</td>
<td>0.4485</td>
</tr>
<tr>
<td>Zhemgang</td>
<td>0.4839</td>
<td>0.4485</td>
</tr>
</tbody>
</table>

4.6. Total EF

Bhutan’s total EF per capita is shown in bha in table 4.6.1 and gha in table 4.6.2 below. Energy land (bha) makes-up 70% of the total EF. This percentage is particularly high because of the low sequestration rate of Bhutan forests. A following 23% is in crop land, forest land is 7% and grazing land 6.5%. Of the total energy EF 40% is required for food, 37% for services and 12% for transport, as shown in graph 4.2 below. Energy land (gha) makes-up 48% of the total EF, whilst crop land requires an additional 39%. Forest is 8%, grazing 2%, garden land 1.47%, consumed land 1% and fishing land is less than 1%. When divided into categories the food EF requires 55% of the total EF, whilst services require 27% and housing 10%. Those figures are also shown in graph 4.3.
Table 4.6.1. CLUM showing Bhutan’s EF in bha.

<table>
<thead>
<tr>
<th>Total EF</th>
<th>Energy land</th>
<th>Consumed land</th>
<th>Garden land</th>
<th>Forest land</th>
<th>Crop land</th>
<th>Grazing land</th>
<th>Fishing land</th>
<th>Total person</th>
<th>Bhutan Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>bha</td>
<td>bha</td>
<td>bha</td>
<td>bha</td>
<td>bha</td>
<td>bha</td>
<td>bha</td>
<td>bha</td>
<td>bha</td>
</tr>
<tr>
<td>Food</td>
<td>0.5070</td>
<td>0.2337</td>
<td>0.1183</td>
<td>0.0391</td>
<td></td>
<td>0.8981</td>
<td>658,287</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport</td>
<td>0.1588</td>
<td>0.0048</td>
<td></td>
<td></td>
<td></td>
<td>0.1636</td>
<td>119,955</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consumer Goods</td>
<td>0.0886</td>
<td>0.0008</td>
<td>0.0052</td>
<td>0.1333</td>
<td></td>
<td>0.0894</td>
<td>65,528</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Housing</td>
<td>0.0446</td>
<td>0.0013</td>
<td>0.1333</td>
<td>0.2337</td>
<td>0.1183</td>
<td>0.0391</td>
<td>1.8131</td>
<td>1,328,978</td>
<td></td>
</tr>
<tr>
<td>Service</td>
<td>0.4760</td>
<td>0.0015</td>
<td>0.0052</td>
<td></td>
<td></td>
<td>0.4775</td>
<td>350,007</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>1.2750</td>
<td>0.0085</td>
<td>0.0052</td>
<td>0.1333</td>
<td>0.2337</td>
<td>0.1183</td>
<td>0.0391</td>
<td>1.8131</td>
<td>1,328,978</td>
</tr>
</tbody>
</table>

Table 4.6.2. CLUM showing Bhutan’s EF in gha.

<table>
<thead>
<tr>
<th>Total EF</th>
<th>Energy land</th>
<th>Consumed land</th>
<th>Garden land</th>
<th>Forest land</th>
<th>Crop land</th>
<th>Grazing land</th>
<th>Fishing land</th>
<th>Total per capita</th>
<th>Bhutan Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>gha</td>
<td>gha</td>
<td>gha</td>
<td>gha</td>
<td>gha</td>
<td>gha</td>
<td>gha</td>
<td>gha</td>
<td>gha</td>
</tr>
<tr>
<td>Food</td>
<td>0.2230</td>
<td>0.6350</td>
<td>0.0413</td>
<td>0.0144</td>
<td></td>
<td>0.9137</td>
<td>669,739</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Transport</td>
<td>0.0699</td>
<td>0.0100</td>
<td></td>
<td></td>
<td></td>
<td>0.0799</td>
<td>58,552</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Consumer Goods</td>
<td>0.0391</td>
<td>0.0008</td>
<td>0.0108</td>
<td>0.1333</td>
<td></td>
<td>0.0399</td>
<td>29,249</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Housing</td>
<td>0.0248</td>
<td>0.0027</td>
<td>0.0108</td>
<td>0.1333</td>
<td></td>
<td>0.1716</td>
<td>125,815</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Service</td>
<td>0.4319</td>
<td>0.0032</td>
<td>0.0136</td>
<td>0.6350</td>
<td>0.0413</td>
<td>0.0144</td>
<td>1.6538</td>
<td>1,212,248</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>0.7887</td>
<td>0.0167</td>
<td>0.0244</td>
<td>0.1333</td>
<td>0.6350</td>
<td>0.0413</td>
<td>0.0144</td>
<td>1.6538</td>
<td>1,212,248</td>
</tr>
</tbody>
</table>
Table 4.6.3 compares the total available biocapacity and required EF. These results in ha show that in total Bhutan’s EF of 1.8ha/capita is well within their 4.7ha/capita biocapacity, with 61% of the biocapacity still available. The only consumption category not within the available land is cropland, with an EF of 0.2ha/capita and a biocapacity of 0.16ha/capita, an overshoot of 51%. It is suggested that society does not set aside land for carbon sequestration and therefore this category is in overshoot by 100%. According to the above calculations, if everyone lived like a Bhutan national we would require 1.04 planets. The Bhutan average EF is currently within 0.04 if the ‘fair earth share’ footprint of 1.74 (GFN, 2014; summary). Only minimal changes would be required to reduce the average EF by this amount.
Table 4.6.3. Comparison of the project EF figures (bha) with biocapacity figures.

<table>
<thead>
<tr>
<th>Total EF</th>
<th>Energy land</th>
<th>Consumed land</th>
<th>Fishing land</th>
<th>Cropland land</th>
<th>Grazing land</th>
<th>Forest land</th>
<th>Total per capita</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>bha</td>
<td>bha</td>
<td>bha</td>
<td>bha</td>
<td>bha</td>
<td>bha</td>
<td>bha</td>
</tr>
<tr>
<td>EF</td>
<td>1.2750</td>
<td>0.0085</td>
<td>0.0327</td>
<td>0.2337</td>
<td>0.1183</td>
<td>0.1333</td>
<td>1.8131</td>
</tr>
<tr>
<td>Biocapacity</td>
<td>0.0470</td>
<td>0.1550</td>
<td>0.2170</td>
<td>4.2780</td>
<td>4.6970</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>+81%</td>
<td>-51%</td>
<td>+46%</td>
<td>+97%</td>
<td>+61%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4.7. Regional EF Results

The regional EF results are shown in table 4.9.1 below. The region with the largest EF is Gasa as discussed in consumer goods mainly due to their high expenditure. Thimphu has the largest regional EF at 2.05bha.

The regions are also divided into their urban forms as shown in table 2.2. The aim was to identify some trends between urban and rural footprints. The summary suggests that peri-urban footprints are the lowest, whilst rural is the highest and urban somewhere in between.

Table 4.9.1. Final regional CLUM in bha.

<table>
<thead>
<tr>
<th>Regional EF</th>
<th>Food</th>
<th>Transport</th>
<th>Consumer Goods</th>
<th>Housing</th>
<th>Service</th>
<th>Total/person</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>bha</td>
<td>bha</td>
<td>bha</td>
<td>bha</td>
<td>bha</td>
<td>bha</td>
</tr>
<tr>
<td>Bhutan average</td>
<td>0.8981</td>
<td>0.1636</td>
<td>0.0894</td>
<td>0.1844</td>
<td>0.4842</td>
<td>1.8198</td>
</tr>
<tr>
<td>Bumthang</td>
<td>1.0616</td>
<td>0.0767</td>
<td>0.1432</td>
<td>0.1756</td>
<td>0.2283</td>
<td>1.6855</td>
</tr>
<tr>
<td>Haa</td>
<td>0.8917</td>
<td>0.0865</td>
<td>0.2168</td>
<td>0.1764</td>
<td>0.4953</td>
<td>1.8667</td>
</tr>
<tr>
<td>Paro</td>
<td>1.1164</td>
<td>0.2579</td>
<td>0.1746</td>
<td>0.1776</td>
<td>0.1752</td>
<td>1.9017</td>
</tr>
<tr>
<td>Punakha</td>
<td>0.9354</td>
<td>0.0669</td>
<td>0.1050</td>
<td>0.1747</td>
<td>0.5472</td>
<td>1.8293</td>
</tr>
<tr>
<td>Sarpang</td>
<td>0.9048</td>
<td>0.0876</td>
<td>0.1014</td>
<td>0.1754</td>
<td>0.3348</td>
<td>1.6041</td>
</tr>
<tr>
<td>Thimphu</td>
<td>1.0981</td>
<td>0.4685</td>
<td>0.1705</td>
<td>0.1798</td>
<td>0.1340</td>
<td>2.0510</td>
</tr>
<tr>
<td>Trashigang</td>
<td>0.8811</td>
<td>0.0620</td>
<td>0.0940</td>
<td>0.1763</td>
<td>0.2046</td>
<td>1.4180</td>
</tr>
<tr>
<td>Tsirang</td>
<td>0.8109</td>
<td>0.0827</td>
<td>0.0784</td>
<td>0.1742</td>
<td>0.4839</td>
<td>1.6300</td>
</tr>
<tr>
<td>Urban Average</td>
<td>0.9625</td>
<td>0.1486</td>
<td>0.1355</td>
<td>0.1763</td>
<td>0.3254</td>
<td>1.7483</td>
</tr>
<tr>
<td>Dagana</td>
<td>0.7725</td>
<td>0.0462</td>
<td>0.0746</td>
<td>0.1759</td>
<td>0.1763</td>
<td>1.2456</td>
</tr>
<tr>
<td>Trongsa</td>
<td>0.9383</td>
<td>0.1355</td>
<td>0.1104</td>
<td>0.1748</td>
<td>0.4860</td>
<td>1.8450</td>
</tr>
<tr>
<td>Mongar</td>
<td>0.7705</td>
<td>0.0217</td>
<td>0.0977</td>
<td>0.1736</td>
<td>0.1342</td>
<td>1.1978</td>
</tr>
<tr>
<td>Wangdue</td>
<td>0.9159</td>
<td>0.0515</td>
<td>0.0931</td>
<td>0.1780</td>
<td>0.4839</td>
<td>1.7225</td>
</tr>
<tr>
<td>Chhuka</td>
<td>0.7755</td>
<td>0.4261</td>
<td>0.0824</td>
<td>0.1801</td>
<td>0.2026</td>
<td>1.6667</td>
</tr>
<tr>
<td>Trashi Yangtse</td>
<td>0.8653</td>
<td>0.0677</td>
<td>0.1182</td>
<td>0.1744</td>
<td>0.3024</td>
<td>1.5280</td>
</tr>
<tr>
<td>Lhuentse</td>
<td>1.0724</td>
<td>0.0981</td>
<td>0.1385</td>
<td>0.1739</td>
<td>0.4953</td>
<td>1.9782</td>
</tr>
<tr>
<td>Pemagatshel</td>
<td>0.8912</td>
<td>0.0244</td>
<td>0.0800</td>
<td>0.1737</td>
<td>0.7668</td>
<td>1.9361</td>
</tr>
</tbody>
</table>
### The averages at the bottom of each section show that the ‘rural’ group have the highest EF, followed by urban then peri-urban. However, as mentioned above Gasa’s expenditure on food and consumer goods increases the average for this group of four regions considerably. If Gasa is excluded from the average, this figure decreases to 1.4344g/ha, considerably lower than either of the other groups. Depending on the specific drivers for Gasa’s high EF, this result would suggest that rural regions may have a lower EF than the urban or peri-urban.

#### 4.8. GFN results

According to the GFN (2014) figures Bhutan has an available biocapacity of 4.5 million g/ha and an EF of 2.9 million g/ha, of which about eighty three percent is produced in Bhutan (2.4 million g/ha). Bhutan exports another 494,591 g/ha. GFN therefore estimate 2.7 million g/ha of Bhutan’s available biocapacity is consumed locally and in exports, making the total resource consumption by the nation in surplus by 39%.

GFN calculations suggest that Bhutan requires a total of 4 hectares per capita. As a result if anyone in the world lived like a Bhutan national we would require 2.3 planets (GFN, 2014). However the results republished in table 4.9.2 shows that Bhutan is still within their biocapacity with approximately 35% availability. Crop land, grazing land and energy land are calculated to be in overshoot by 28%, 25% and 100% respectively.

#### Table 4.9.2. Comparing GFN EF figures with biocapacity figures.

<table>
<thead>
<tr>
<th>Total EF</th>
<th>Energy Land g/ha</th>
<th>Consumed Land g/ha</th>
<th>Fishing Land g/ha</th>
<th>Cropland Land g/ha</th>
<th>Grazing Land g/ha</th>
<th>Forest Land g/ha</th>
<th>Total per Capita g/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>EF</td>
<td>0.1065</td>
<td>0.2731</td>
<td>0.0327</td>
<td>0.4142</td>
<td>0.4426</td>
<td>2.7411</td>
<td>4.0101</td>
</tr>
<tr>
<td>Biocapacity</td>
<td>0.32365</td>
<td>0.35275</td>
<td>5.1877</td>
<td>6.1372</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difference</td>
<td>-28%</td>
<td>-25%</td>
<td>+47%</td>
<td>+35%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The GFN results highlight Bhutan’s considerable forest land requirements totalling 68% of the total EF. Of the forest EF, firewood represents 92% of the total wood products. This firewood figure comes from the FAO Forestat website (FAOSTAT, 2013). The FAO estimate shows Bhutan produced 4.89 million m³ of firewood in 2011 and 4.95 million m³ in 2012. Woodfuel, including wood for charcoal is defined as “roundwood that will be used as fuel for purposes such as cooking, heating or power production” (FAOSTAT, 2013; forest products definitions).
Unlike many other national EFs, Bhutan’s energy land requirements are minor at only 2.6% of the total.

4.8. EF Comparison

The EF results in of the bottom-up calculation in gha and the GFN results as shown in table 4.8.1. There are considerable differences, particularly in forest land and carbon land. The ‘bottom-up’ forest land result was only 0.1333gha, whilst GFN was 2.7411gha. As noted above this is a consequence of very different consumption amount and needs further investigation to calculate actual amounts. The ‘bottom-up’ energy land was 0.7887gha compared to GFN’s 0.1065gha.

Graph 4.8.1. Comparison of the EF provided by GFN vs the EF calculated above against each of the land types, in gha.

This suggest that the consumption data used by both of these parties are very different and some additional work is required to better understand the datasets and where the two can align.
5. Discussion

Increasingly society is increasing its understanding of the impacts it is putting on the natural environment. However the pressure to continuous grow and develop creates an uneasy tension. Ecological Footprint data provides an opportunity for country to pause and take stock; to consider the demand that it has on the finite planet upon which we rely reflect on whether ‘more, bigger, faster, higher’ is actually increasing our overall happiness and wellbeing.

“Not everything that can be counted counts, and not everything that counts can be counted.”

– Albert Einstein

EF research above tells a story, not only about what Bhutan consumes, and the potential productivity it has available, but also how much of the data needed to tell the full EF story is already available. As Bhutan’s living standards increase the aim to maintain and improve on their low EF. This data will also become increasingly valuable as the cost of high EF goods and services increase.

The following section will look at how Bhutan stands compares internationally, a brief look at how the EF is changing over time, and how the EF data in this report could be used to create scenarios and finally the strengths and weaknesses of this report. The final section will provide some recommendations for moving forward.

5.1. Global position

There are two reports published on a reasonably regular basis, comparing the EF of nations. Unfortunately, the most recent publication to include Bhutan was 2000 (Loh, 2000). The results found in the previous section have therefore been used to show how Bhutan compares to other nations using figures 5.1 and 5.2 from the GFN Atlas from 2010.

Figure 5.1 shows the EF of nations per person for 2007 data. The world average EF of 2.7gha is shown by the yellow arrow on the right hand side of the figure. Using the GFN results for 2010, Bhutan’s EF was 4gha/capita. This result puts Bhutan on-par to Slovenia (indicated by the yellow star) and next to Bulgaria and Turkmenistan.

Figure 5.2 provides some perspective on where Bhutan resides for biocapacity per person compared to other countries. The world average, again shown by the yellow arrow, is 1.78gha and Bhutan is currently sitting at 6.1gha per person. This is at about the same capacity as the Russian Federation (indicated by the yellow star) and between Latvia and Mauritania.
Figure 5.1. ‘EF per person’ results from the GFN (2007; p.19&20) showing where Bhutan would sit if they were included in the figure.
5.2. Scenarios
One of the strengths of the EF is to ability to take a very broad perspective on a range of systems and better understand their interconnection. Because of the common unit of measurement the calculations can be used to test assumptions about proposed policies and projects. For example, the effect of increasing trade with a particular country will allow the people of Bhutan with a greater variety of products. However it will also vastly increase packaging and waste, transport infrastructure for distribution and energy for operation. Having a detailed understanding of these impacts allows the decision-making to have a qualitative figure that could then be compared to an alternative option, such as the costs and benefits of producing more locally.

For example, computer ownership in Bhutan continues to increase (NSB, 2013b; p.147). This is likely to have positive effects allowing increased communication, commercial opportunities and knowledge building and sharing. However, on the other hand computers require a considerable
amount of materials and embodied energy during their production and electricity for their operation; they have an EF of 100GJ/tonne.

5.3. Changing EF

The results of van Vuuren (1999; p.40) research showed Bhutan’s EF changing little between the years 1980 and 1994. The net land-use results showed no increase in consumption, changes in the consumption pattern and a decrease is productivity (ibid; p.41). The report goes on to explain that Bhutan is limited in biocapacity, particularly in relation to grazing and crop land. As a result, to keep up with consumption Bhutan will need to increase the amount of imported food. One of the limitations of using local hectares is that, as shown in the research above, due to these imports the country is showing an overshoot in cropland. The calculations above suggest that the EF for each of the consumption categories have increased since 1994. The approximate carbon/energy land EF for Bhutan in across this same time period was about 0.2gha/capita. The results found in the recent review was 1.28bha or 0.78gha in energy EF alone.

5.4. Happiness

Table 4.7.1 provides a comparison of EF with urban and rural forms. This comparison of regions could also be used to assess happiness against EF. The Bhutan Living Standards Survey 2012 Report (2013b; table A3.98) is a ‘distribution of households by self-rated happiness level and by Dzongkhag’. After review of the data there was only a slight correlation between the EF results and the happiness levels. Some interesting points:

1. Haa, a mostly urban region, had the highest number of ‘very happy’ people and no ‘very unhappy people’ in 2013. Its overall footprint was one of the higher results and it had the highest level of expenditure on consumer goods.

2. Gasa, a mostly rural region, is the second highest number of ‘very happy’ people in 2013 and had the highest overall EF and a particularly high food EF.

3. At the other end of the scale there was no correlation between being the least happy region and having either a high or low EF.

There is some indication that the EF could help with insight into understanding Bhutan’s happiness. More work is required to build the correlations between EF and happiness.

5.5. Strengths and weaknesses of the research

The depth and level upon which a piece of research such as the ecological footprint is almost boundless. In every part of the research above a considerable more time could have been spent on delving deeper to get more accurate data.

Bhutan holds an extensive amount of data gathered through the Bhutan Living Standards Survey (NSB, 2013b). Much of this data is incredibly useful and could have been used in the EF calculations. On the other hand it is very difficult to assess whether the information required is available in the format needed. Unfortunately due to the minimal nature of the research contract there was not the time or the resources to delve in deeper. This would require a researcher on the ground to ask the questions in a way that achieve the data required.
6. Recommendations

Additional work is required to improve on the EF calculations in this report. On the other hand, through this research it has become clear to the research team that a great deal of the information required for the research may already be available through the likes of the Bhutan Living Standards Survey. However, wasn’t yet available in the correct format to be used for EF calculations.

State of the carrying or bio-capacity will inform the condition of the environment and natural resource, and ensure that Bhutan’s consumption, use and bio-capacity are accounted for through monitoring and managed well. This can be achieved through effective and regular surveys, data management, also through awareness raising, and sound policy, plan and decision making processes thereby ensuring that they are maintained sustainably and as pristine as naturally possible.

6.1. Local knowledge

As noted throughout the report there are currently weaknesses with the format in which data is received. This was primarily due to the researcher’s lack of first-hand experience and understanding of Bhutan society. Data was predominantly provided to the research by another non-resident (Michelle Olivier) who was not trained in EF methodology. This meant that information was often not delivered in a usable form.

These weaknesses would be drastically reduced if the research were carried out within Bhutan by Bhutan nationals. Data is most useful when those who need to use it, understand it and its potential. This point is highlight in a paper by Collins and Flynn (2007) who highlight the importance of developing and retaining institutional knowledge about EF to be used by government. This requires some expenditure of money and time upfront but the long-term benefits are worthwhile.

Training in using the EF template and inputting additional data, could be achieved with the assistance of a specialist EF team to assist a team of qualified nationals to design an EF template as discussed below.

6.2. Data Template

EF calculations require a great deal of data. However, once a data template has been created and the correct mathematical equations put in place, EF calculations are relatively straight-forward. EF template design, such as the one provided by GFN (2014) can be as simple or as complex as required to gain the specific insight into resource use required. Templates or calculators can also be used at the individual level.

6.2.1. Questionnaire

The process of undertaking research and data collection alongside individuals also provides the opportunity to support and educate those who take part (Hunter, Carmichael, & Pangbourne, 2006). As part of the larger research project, individual members of the communities were able to discuss the resource requirements of their lifestyles. Community members were invited to take part in a visioning exercise to discuss what their community might look like in a resource-constrained future.

The Bhutan Living Standards Survey (NSB, 2013b; appendix 4) could be used to collect additional data where required. An example of a footprint survey is available in appendix 5. This questionnaire would need to be designed to ensure that it does not repeat questions or gather data already gained through different questions. As noted above finding the correct data requires working closely with
the GNHB. Some examples of online surveys have also been developed and could be used for specific situations where internet access is assured, for example the WWF Calculators (WWF, 2014).

As discussed in appendix 1 there is a close correlation between income, time and EF. This concept fits alongside the Bhutan Living Standards Survey already carried out by the Bhutan Government. Including additional information which can then be used to align the

6.3. Information Dissemination

The strength of the EF tool is its ability to present a coherent picture of the total environmental impacts of an individual or group of people. The EF’s strength as a common means for measuring all goods and services consumed as well as waste produced, also creates an effective communication tool. The ‘language’ of the EF can be shared between government, business, civil society and the rest of the world.

6.3.1. Communities and individuals

As noted above one of the most powerful ways to create change is to start with a conversation. It is important that this information is communicated and disseminated to the broader public in an easy simple manner. Having material that is nice to look at and easy for people to read will encourage their interest in the topic. For example, upon completion of the New Zealand Footprint Project a ‘coffee table’ style book was produced (Lawton, 2013b) with the aim of talking to everyone, particularly those who did not know about ecological footprinting.

The authors of the report are unsure about the degree of community led action carried out in Bhutan by Bhutan community members, groups and NGOs. For any community groups who are interested, an EF calculator could be designed for their use. The calculator can be used as a measuring and monitoring tool for community led projects that may affect the EF of individuals. Training could be provided to those in the community who are interested in taking a lead.

6.3.2. Government officials

The above calculations and results provides the Bhutan government with another perspective upon which to base good policy decisions. As noted above the EF can play an important role in monitoring both the demand and supply of renewable resources.

Future development scenarios that result in varying EFs can be used by policy makers in order to better understand long-term trends and options. The impacts can be tested using various policy decisions and the proposals quantified. Specific measurable outcomes can be debated. WWF Wales did this extremely well in their document One Planet Wales – Transforming Wales for a prosperous future within our fair earth share of the Earth’s resources (Ravetz et al., 2007). Figure 6.1 shows the overall reduction required for Wales to move towards a ‘fair earth share’ footprint across all consumption categories. Figure 6.2 provides more detail into their food EF and actions required to reduce that footprint by 70% by 2050. This will be achieved through a combination of community education and engagement, and policy changes including. There are plenty of opportunities for Bhutan to carry out similar investigations with the support of an expert EF team.
Figure 6.1. Trends and targets in the UK EF (Ravetz et al., 2007; p.5)

Figure 6.2. The cumulative impact of strategies on the EF of food in Wales (Ravetz et al., 2007; p.7).
Research Team - Otago Polytechnic Centre for Sustainable Practice

Carmeny Field
Lead Researcher
Carmeny completed a Master of Building Science degree at Victoria University of Wellington in 2011. Her research focused on New Zealand housing; comparing timber houses and straw bale houses, and the occupants operation and energy use. Following on from this, her Masters research estimated the ecological footprints of Wellingtonians in 1956 and 2006. Surveying residents who lived in Wellington during both years. This research was conducted in order to understand the relationship between ecological footprints and quality of life. Carmeny’s research is available online here. Following her passion for skiing, she travelled for a couple of years working in North America in the ski industry and tourism before returning to New Zealand. While working and travelling, she got involved in sustainability committees in order to contribute to the operation of businesses. Now living in Wanaka, New Zealand where she continues to work in the ski industry and conducting research in her field.

Dr. Ella Lawton
Project Manager and Researcher
Ella led the Project’s South Island community engagement processes and facilitated the project’s partnerships on behalf of Otago Polytechnic Centre for Sustainable Practice. Ella was also responsible for the project design and footprint calculations as part of her PhD completed in January 2013. As an emerging researcher Ella has a multi-disciplinary background with undergraduate degrees in law and science from the University of Otago, New Zealand and a Masters in ‘Strategic Leadership towards Sustainability’ from Blekinge Institute of Technology, Sweden and a PhD in Architecture from the Victoria University of Wellington, New Zealand. For the past 5 years Ella has also taught on the Graduate Diploma in Sustainable Practice with the aim of supporting sustainability practitioners to create and action strategic plans towards achieving sustainability. In October 2013, Ella was elected as a Queenstown Lakes District Councillor and represents the Wanaka Ward. Ella looks forward to continuing to work with communities in order to find solutions that provide the opportunity for the highest level of wellbeing with minimal footprint.

Dr. Maggie Lawton
Reviewer
Maggie Lawton was the North Island Project Manager of the New Zealand Footprint Project. She has a PhD in Chemistry and has worked as a forensic scientist and led the New Zealand Forensic Science Service at ESR. Later as part of the Executive time at Landcare Research she oversaw a range of environmental and sustainability research projects. She then moved into policy development and worked in management positions in Manukau, Auckland and Queenstown Council/ Local Government. Her research and consulting includes land management, urban and infrastructure development and building design. Maggie now operates her consultancy “Future by Design” which focuses on strategic sustainable development and research transfer into policy and practice.
Appendix 1: Unsustainability

Overshoot is caused by two predominant trends (Robèrt, 2009) which interact in society’s unsustainable use of the planet’s finite resources. These are depicted in ‘the Funnel Metaphor’ (figure 1.2) (Holmberg, Lundqvist, Robèrt, & Wackernagel, 1999; Robèrt et al., 2002). The first of the trends is a decreasing supply of resources and decline in the health of natural systems. The second is the rising demand for resources from an increasing population with growing expectations. These trends are putting considerable pressure on society’s ability to create and sustain wellbeing for all. This raises the question of what a sustainable future might look like.

![Figure 1.2: The Funnel Metaphor showing trends resulting from unsustainable use of the Earth’s biocapacity (Boisvert et al., 2009).](image)

For humanity to live sustainably the supply of, and demand for, resources must be equal. The drivers of unsustainability need to be reversed and ecosystems returned to a healthy steady state for a sustainable future. The ability to renew resources and sustain the health of natural systems must be able to happen perpetually, for both current and future generations (United Nations Environment Programme, 1992). To achieve this goal it is necessary to understand the quantity of resources available, how quickly they are used, and for what purposes. It is important to compare how much of Earth’s resources society demands from nature’s supply. Measurement tools, such as the Ecological Footprint (EF) (Wackernagel & Rees, 1996), are therefore required to help guide humanity in a sustainable direction (Barrett, 2001; White, 2007; WWF, 2010).

The trends shown in figure 1.2 have created a state of unsustainability where society can no longer provide resources for current and future generations within the biocapacity of the Earth. The drivers of unsustainability—decrease in supply and increase in demand—are influenced by environmental, social and economic actions.
1.1. Decrease in Supply

The planet is finite; there is a limited amount of land for distribution amongst the growing global population (United Nations Environment Programme, 1992; Wackernagel et al., 2002). Land is the source of all renewable resources and provides a platform from which all ecological systems have to assimilate and recycle resources (Wackernagel & Rees, 1996). In 2010, arable land, both grazing and crop land, totalled 13.31% of the land surface. Crop land has the highest biocapacity of all land types but is only 4.71% of total land on the planet (United States Central Intelligence Agency, 2008). Overall global bioproductivity has increased. Widespread use of irrigation and nitrogen fertilisers, increased crop efficiency and clearing of natural forest has enhanced biocapacity, although “this often comes at the cost” (Laurance, Cook, & Verweij, 2012, p. 41) of requiring more resources and creating more waste elsewhere. In order to increase biocapacity humans remove natural systems and disrupt ecological systems, creating a feedback loop which in turn further decreases available biocapacity.

The decrease in supply of biocapacity is prompted by two pressures: the declining biocapacity of land and the declining health of the Earth’s ecosystems.

Declining Biocapacity of Land

Biocapacity is a measure of the biologically productive land and water available for human use (Lenzen et al., 2007). There are six types of biologically productive land, comprising five land types for production (crop, grazing, forest, fishing and consumed land), and one for assimilating waste (energy land). Bioproductive land excludes areas that are not defined as productive for human use such as deserts, glaciers, and the open ocean (Lenzen et al., 2007). Bioproductivity is the ability of a piece of land to produce biomass, which is the weight (or estimated equivalent) of organic matter, including animals, plants and micro-organisms (living or dead) above or below the soil surface. The amount of resource produced by a piece of land is measured in yields.

Maximising the immediate production of goods and services from land has long caused problems for cultures around the globe (Diamond, 2005). A piece of land is intricately connected to its surrounding ecological dimensions, including both environmental and societal systems.

The economic Theory of Production asks the question “what combination of inputs, known as factors of production, will generate the quantity of output that yields maximum profit” (Cobb & Douglas, 1928). Since the human race shifted to an agrarian lifestyle, people have altered the bioproductivity of land, largely in an attempt to increase potential biocapacity (Larsen, 1995). They have done this by manipulating the natural quantity of the key inputs. Altering water availability is perhaps the most obvious change, with the introduction of irrigation. The addition of chemicals such as phosphorus, nitrogen, and calcium carbonate to alter the pH, has also been common practice for centuries. More recently, however, synthetic inputs such as inorganic fertilisers and pesticides have also been used to increase land productivity. Many of the negative effects of these manipulating activities are not accounted for in the current economic system. They are described as ‘externalities’ and, as they are excluded from economic accounting, are not included in the price of the final product (Caplan, 2012).

For a while the biocapacity of land can be manipulated by using resources that have been moved from one place to another, and these may temporarily substitute for the decreasing health of land.
For example, as the natural availability of nutrients in soil is depleted by industrialised food systems, chemical-based substitutes are added (L. R. Brown, 2012). This allows for similar yields to be produced from a given area of land; however, the hidden total land required has increased because additional ‘energy land’ has been used to sequester the carbon dioxide emissions related to transport, production processes, fertiliser production and on-farm processes. The amount of currently available resources, particularly food, is reliant on this model of substituting cheap energy such as oil for natural systems services. It is estimated that half of the world’s food is provided using systems reliant on this substitution, which is clearly only a temporary measure (L. R. Brown, 2012; Erisman, Sutton, Galloway, Klimont, & Winiwarter, 2008).

**Health of the Earth’s Ecosystems**

Ecosystems are the planet’s life-support systems for the human species and all other forms of life (Corvalan, Hales, & McMichael, 2005), yet every year the natural systems at a planetary scale are in decline (Laurance et al., 2012, p. 12). The *Millennium Ecosystem Assessment* Working Group (Millennium Ecosystem Assessment, 2005) reported that approximately 60% (15 out of 24) of the ecosystem services it examined are being degraded or used unsustainably, including fresh water, capture fisheries, air and water purification, and the regulation of regional and local climate, natural hazards, and pests. The *Living Planet Report*, now in its 9th edition, shows a 30% global decline in biodiversity health since 1970 (Laurance et al., 2012, p. 8). This decline not only affects people but also the billions of other life forms that depend on these systems and each other. A decline in the health of ecosystems reduces the bioproductivity of the land and often has irreversible negative effects.

Brown (2012) highlights the importance of healthy soils and the impact that industrial farming has on natural systems. For example, overgrazing and bad agricultural management have caused extensive tracts of the world’s grain-producing areas to suffer desertification.

As the health of Earth’s natural systems declines, so does the potential biocapacity available to humans, and as the planet heads further into resource-use overshoot, the health of systems declines further. In order to overcome this trend, the current economic system encourages adding more inputs, which substitute for bioproductivity, by transporting it from one geographical location or ecosystem to another. This substitution generally reduces the health of all natural systems and, as with desertification, will lead to the eventual collapse of the system.

### 1.2. Increase in Demand

The second trend shown in figure 1.2 is the increasing demand for the earth’s resources. This has two drivers: the first is the increase in the world’s population, and the second is the increasing resource-linked expectations of people. Population increase is acknowledged as a serious global issue (Laurance et al., 2012), however for NZ, the major impact on consumption is increasing demand.

**Population**

The global population continues to increase, with a forecast of 9 billion by 2050 (DESAPD, 2009). Whilst some populations have plateaued, others continue to grow with the support of better health care and food availability. On the other hand, there are more people living in poverty than ever before (L. R. Brown, 2012; UNFPA, 2007). Increasing access to education and equity for women has
been shown to slow population growth; however, the most successful campaigns have been the widespread accessibility of birth control to women. In 2012 World Population Day promoted universal access to reproductive health care for “a world where every pregnancy is wanted, every childbirth is safe, and every young person’s potential is fulfilled” (United Nations Population Fund, 2012). The population explosion has been the unspoken ‘elephant in the room’ for some time, but it is finally being accepted as the issue that cannot be ignored (Crossette, 2011; TIME, 2011). Slowing the rate of population increase will lighten the pressure the human race puts on the natural environment (Biello, 2009), but only if consumption of resources first stabilises, then declines.

Consumption
Consumption is increasing as individuals require more resources to support their lifestyle demands (Assadourian, 2010). Consumption, the purchase of goods and services (Oxford University Press, 2010), has grown dramatically over the past five decades. In 2010 consumption was up 28% from $23.9 trillion spent worldwide in 1996 and up 600% from the $4.9 trillion spent in 1960 (in 2008 dollars). Some of the increase came from growth in population, but human numbers only grew by a factor of 2.2 between 1960 and 2006, meaning consumption expenditure per person almost tripled (Assadourian, 2010).

Consumer ‘lock-in’, a situation in which the buyer is more or less trapped in their purchases (Sodeman, 2008), demonstrates how factors such as convenience, habits and norms influence people’s behaviour (Lucy Brown, 2009; Sanne, 2002). Evidence also shows citizens are often ‘locked-in’ to unsustainable consumer practices due to social and institutional norms and even physical structures (Mont & Power, 2010; Power & Mont, 2010; Sanne, 2002). It is vital, therefore, that governments shift the institutional architecture of consumer ‘lock-in’ (Power & Mont, 2010).

On the demand side are three main spheres of influence. In terms of their individual control, these range from political and cultural systems (least control) through to community urban form and dwelling type, to personal lifestyle decisions (most control). Within the spheres of influence three different factors influence resource consumption behaviour in relation to lifestyle: values (Rhys Taylor & Allen, 2010), time (Fitt & McLaren, 2010), and income (Assadourian, 2010; Canadian Centre for Policy Alternatives, 2008; Clark, Frijters, & Shields, 2008). These spheres and factors are shown in diagrammatic form in figure 1.3.
Governance occurs not only through those with official power but also through the conscious transfer of power from individuals to an entity such as a religious or cultural group. The ability to change these overarching systems is virtually unavailable at an individual level and requires large-scale shifts involving many members of a population.

Spaargaren and Vliet (2000, p. 53) note that within ‘structuration theory’, rules and resources together constitute the structures that are involved in the reproduction of social practices. Governance, in relation to the availability of resources to individuals, could be viewed on an axis from capitalist freedoms, through to a restricted communist regime. For example, the rise in China’s middle class in an increasingly capitalist society, has shown consumption increase exponentially (L. R. Brown, 2012; Chen & Chen, 2006). Prioritisation of material consumption, the perceived source of stability in Western societies, means that the economy, political institutions, and even the popular media all serve the task of continuous economic growth (Lucy Brown, 2009). This economic requirement has taken governments and communities hostage, making it seem impossible to decouple economic growth from the increasing consumption of resources.

The drive to ‘maximise production’ within an economic paradigm that does not accept ‘limits to growth’ has created an increasing demand on common resources, creating a situation known as the
‘tragedy of the commons’ (Hardin, 1968). This tragedy develops when unregulated common land becomes overgrazed as each individual attempts to maximise their use of the land and associated economic output. The result is tragedy for all as the natural systems that support the land collapse. In some cases governance systems have created means for avoiding this, such as the NZ fisheries Quota Management System of the Ministry of Primary Industries (2012). Instances of other governing bodies creating a shift toward lower resource use are discussed below.

Ration/Quota Systems

Rationing was used by Britain in World Wars I and II as a way of fairly distributing the limited amount of resources available to the British public (Trueman, 2012). This government intervention was justified on the basis that it was for the ‘greater good’. More recently Lucy Brown (2009) investigated an Individual Carbon Quota System (ICQS) on the basis that limiting the amount of carbon dioxide (CO₂) each individual can emit limits the amount of environmentally harmful consumption that can take place. Brown’s (2009, p. 6) exploration of this concept from both a collective and individual perspective concluded such CO₂ limitation could be carried out as “government intervention may be justified on the grounds of being necessary for the citizen’s well-being”.

Sufficiency Economy

The Sufficiency Economy as defined by Krongkaew (2003) is a philosophy that guides the livelihood and behaviour of people at all levels, from the family to the community to the country, on matters concerning national development and administration. Krongkaew explains that the Sufficiency Economy theory was developed by His Majesty the King of Thailand after the 1997 economic crisis. Sufficiency means moderation and reasonableness, including the need to build a resilient system against internal and external shocks. In this way the King hoped to maintain balance and be ready to cope with rapid physical, social, environmental, and cultural changes from the outside world. The sufficiency economy premises that each person strives for ‘true happiness’, to be attained when a person is fully satisfied with what he or she has and is at peace with the self. A sufficiency economy would be an economy fundamentally conditioned by basic need, not greed, and restrained by a conscious effort to cut consumption.

Urban Form

The world is undergoing the largest wave of urban growth in history. In 2008, for the first time, more than half of the world’s population lived in towns and cities (UNFPA, 2007). By 2030 this number will be almost 5 billion, with urban growth concentrated in Africa and Asia. The trend in NZ is similar. Most New Zealanders live in urban areas, within 50 kilometres of the coast, and three out of four live in the North Island. While the national population density is low, it is high in major urban areas (Ministry for the Environment, 2007b, p. 35). Even though many New Zealanders identify with rural landscape or wilderness areas, 86% of the population lives in urban areas. This makes NZ one of the most urbanised nations in the world (Ministry for the Environment, 2007, p. 41). As the urban environment continues to increase, it is important to understand the effects that urban form has on NZ consumption patterns.

Infrastructure can be perceived as both a constraint and a driver of consumption (Mont & Power, 2010). Numerous authors have assumed that urban living reduces an individual’s EF because of an increase in shared infrastructure, smaller dwellings, and shorter distances to travel to work and the
shops. However, recent research has shown that this may not be the case (Rees & Wackernagel, 1996; Wiedmann, Wood, Lenzen, Tovey, & Moloney, 2007a; Richard Wood & Garnetta, 2009). Ghosh et al. (2007) show that low-density urban forms could have more potential to be resource-use efficient than more compact urban forms, due to an increased ability to be self-sufficient. On the other hand, with at least 50% of an individual’s EF dependent on lifestyle choices (Barrett, Birch, Baiocchi, Minx, & Wiedmann, 2006) lifestyle is as influential as urban form.

Urban infrastructure is long-lasting and influences resource needs for decades to come (Wackernagel, Kitzes, Moran, Goldfinger, & Thomas, 2006). It can ‘lock-in’ residents to high footprint activities. Sanne (2002) gives the example of the preferred low-density, one-family housing creating urban sprawl. This spurred a move away from public transport and made it easier to increase car ownership. Therefore designing or redesigning urban centres for a lower EF while retaining high “liveability” could also influence people’s behaviour.

**Lifestyle**

Lifestyle drives how individuals decide to fulfil their fundamental human needs and therefore the consumption of goods and services.

A lifestyle is a more or less integrated set of practices embraced by an individual, not only because they fulfil utilitarian needs, but also because they give material form to a particular narrative of self-identity (Cockerham, 2005; Giddens, 1991). Lifestyle is a characteristic set of behaviours specific to a given time and place (Assadourian, 2010; Spaargaren & Vliet, 2000). An individual’s lifestyle therefore determines the choice of satisfiers to fulfil the perception of needs.

Fundamental human needs are finite, few and classifiable. They are the same for all cultures and historical periods (Maslow, 1943; Max-Neef, 1991; Tay & Diener, 2011). Manfred Max-Neef (1991), a Chilean economist, proposes nine needs: subsistence, protection, affection, understanding, participation, idleness, creation, identity and freedom. Max-Neef and others (Spaargaren & Vliet, 2000; Walter, 2012; Zorondo-Rodríguez et al., 2011) suggest needs are expressed through satisfiers and it is the satisfiers that vary according to historical period and culture. Hence, satisfiers are what render needs historical and cultural, and economic goods are their material manifestation (Max-Neef, 1991). Max-Neef further proposes that needs must be treated as being equal rather than hierarchical, as suggested by Maslow. The importance of giving needs equal importance is emphasised by the media’s use of human needs to sell products and services, increasing society’s consumption. It seems that for many individuals the need for true subsistence (healthy food and drink) is much less important than other needs such as participation, identity and affection. An important step towards reversing consumption trends would be to increase people’s ability to disregard the media’s manipulation of these fundamental needs.

Certain satisfiers have a larger or smaller EF than others. Where and how they are produced, consumed and disposed of has a greater or smaller impact on local and distant environments and communities. Some people are choosing their satisfiers more carefully, either using ‘green’ credentials (Doerr, 2007; United States Environmental Protection Agency, 2004), or by questioning the ability of physical satisfiers to fulfil their fundamental needs (Becker, 2012; Mont & Power, 2010; Mortimer & Abrahamse, 2010).
There has been research into segmentation of society with respect to resource requirements. In 2008 DEFRA, the Department for Environment, Food and Rural Affairs in the United Kingdom, created a framework for pro-environmental behaviours. The framework pulls together evidence on public understanding, attitudes and behaviours; identifies behaviour goals; and draws conclusions on the potential for change across a range of behaviour groups (DEFRA, 2008, p. 3). The NZ Ministry for the Environment commissioned research using DEFRA’s framework. The results were somewhat similar to the UK though NZ had considerably more ‘waste watchers’ and fewer ‘stalled starters’, ‘side-line supporters’ and ‘cautious participants’ (M. Johnson, Fryer, & Raggett, 2008, p. 67; Rhys Taylor & Allen, 2010). DEFRA’s framework for pro-environmental behaviours specifically looks at an individual’s perceptions and actions that are ‘green’ or ‘environmental’. Therefore there is a danger of missing other actions that may not be seen as ‘green’ but have a considerable effect on lowering an individual or household’s EF.

Other research into NZ lifestyles also shows the distribution of resource consumption across a range of different lifestyles based on broader socio-economic values. Market research by Jill Caldwell and Christopher Brown (2007) attempts to overturn the idea of the ‘typical New Zealander’ by providing a snapshot of the varying cultural and socio-economic backgrounds that, in turn, cause distinct ways of thinking and living. The ‘8 Tribes’ outlined in their research cover a range of NZ lifestyles which are particularly focused on the resonant values of people, although, as with the pro-environmental behaviours framework above, individuals’ incomes and place of residence vary within each tribe. A summary of each tribe is provided in box 1.1. An indication of the average income is shown but this should be used with caution as some tribes, such as the Raglan tribe, have a large deviation around the mean income.

How individuals choose satisfiers to fulfil their fundamental human needs is a manifestation of lifestyle characteristics, but dependent on values, incomes and time.

**Values**

Values are the principles that guide and motivate attitudes and actions (Navran, 2010). They are informed by an individual’s cultural and socio-economic background, and influence behaviour as well as attitudes (Crompton & Kasser, 2009, p. 51). As a result, values are an important driver of lifestyle decisions, affecting the types of satisfiers chosen which, in turn affect the level of individual resource use (K. W. Brown & Kasser, 2005; Gatersleben, Meadows, Abrahamse, & Jackson, 2008; Kasser, 2005; Richins & Dawson, 1992). Brown & Kasser (2005) examined how the footprints of 400 North American adults were associated with their life goals. A relatively high focus on materialistic goals related to a higher EF arising from lifestyle choices regarding transportation, housing and diet.

**Income**

Income affects a person’s wealth and reflects their chosen lifestyle. Increasing or decreasing a person’s income can have both positive and negative effects on their lifestyle. For example, earning an income is not only a means of making money but also forms an important part of their social wellbeing for many. The amount of money an individual has affects their access to resources and what they choose to consume.

Employment is a source of income, social relationships, identity and individual self-esteem (Winkelmann & Winkelmann, 1998). The workplace provides a space to share ideas, feel empowered
Wilkinson and Pickett (2009, p. 13) found that rich people tend to be, on average, healthier and happier than poor people in the same society. However they also found that when comparing multiple ‘rich’ countries with each other it made no difference whether, on average, people in one society were twice as rich as people in another. What mattered was not the actual income level and living standard, but how one person compared to others in the same society.

In many countries the gap between the richest and the poorest people continues to increase (Wilkinson & Pickett, 2009). In the UK this is influenced by many factors, but wage inequality is critical. It is a corrosive, destabilising issue that is linked to a range of social problems (Lawlor et al., 2009). Research by Wilkinson and Pickett (2009) and Lawlor et al. (2009) suggests that individuals compare themselves with those around them. It is unlikely that individuals are comparing income directly but, rather, those goods and services that different incomes can afford. As the income gap increases individuals scramble to ‘keep up with the Joneses’ by increasing their income and/or by going into debt to buy things that they cannot really afford.

Being financially well-off is becoming the end goal. Assadourian (2010) (figure 1.4) found that, by the 1980s, 80% of first-year college students in the United States stated it was ‘essential’ or ‘very important’ to be financially well-off, whilst only 40% thought it was ‘essential’ or ‘very important’ to ‘develop a meaningful philosophy of life’.

The drive to ‘win’, rise up the pecking order, and out-do each other has created a situation where societies are destroying the environmental, social and economic systems they rely on in an attempt to achieve their desired lifestyles (Barrett et al., 2006). Individuals with sufficient income have gone beyond satisfying their fundamental needs. There seems to be a belief that the amount of money they possess gives them the right to satisfy their needs and wants however they can, with little or no concern for environmental or social consequences. Numerous case studies show that generally the more money a country or individual has, the more natural resources they consume, and the higher
their EF. In Canada “the ecological footprint of the richest 10% is nearly two-and-a-half times that of the poorest 10%” (Canadian Centre for Policy Alternatives, 2008, p. 1). One fifth of the global population, living in the highest-income countries, account for 86% of private consumption expenditure while the poorest fifth account for a little over 1% (Tilford, 2000).

If healthy land and water are not available to provide for people’s needs, such as food, then income is required in the place of land, which in turn helps to shape lifestyle. For the World’s increasing urban population (United Nations Population Fund, 2007), inequality of income correlates not only with growing social issues but also with inequality of access to natural resources (Tilford, 2000). The research by Wilkinson and Pickett (2009) shows that people not only feel they need to earn more money to fulfil their fundamental human needs, but they also compete with others through a type of ‘show and tell’ in an effort to keep up with the social norms set by their peers. It could be argued that with a smaller income gap, people would not have such strong desires to buy so much ‘stuff’ and would not feel the need to earn a large income. As a result people would have more time to do other things and possibly have a lower EF.

**Time**

Time is a finite resource and for many people it is a luxury that is sought after, in a similar way to other drivers such as gaining income (Robin & Dominguez, 1992). There is regular commentary about lack of time and increasingly ‘busy’ lifestyles (Kreider, 2012). However people are starting to resist such pressures: “I made a conscious decision, a long time ago, to choose time over money, since I’ve always understood that the best investment of my limited time on earth was to spend it with people I love” (Kreider, 2012, p. 1).

NZ men aged 25-44 spend 31% of their waking lives at work. Another 34% is spent engrossed in mass media and ‘free-time’ activities which include reading, writing, watching television (TV) and playing video games (Statistics New Zealand, 2011e). Data on time spent watching TV for this demographic are not available. However, statistics averaged over the whole population show that, of the time spent engaged in mass media and free-time activities, 70% is watching TV (Statistics New Zealand, 2011b). If the majority of their mass media and free-time activity is watching TV then, on average, young men spend two-thirds of their waking lives either earning an income or watching television (an effective tool for promulgating the types and amounts of satisfiers required to fulfil their needs in order to ‘keep up with the Joneses’). In turn this encourages people to work more, increase their income, buy more belongings and watch more TV.

Proponents of the ‘living lightly’ concept (Librova, 2008) argue that the consumer’s life is difficult because he or she must constantly make decisions. The consumer is a slave to never-ending pseudo-needs. The consumer strives for greater work productivity and higher financial rewards, obsessively studies product catalogues, drives between supermarkets, and makes Herculean efforts to get through the maze of advantageous offers and loans. All this clutters the mind, takes time, and complicates life, suggesting it is necessary to simplify life to make it easier (Librova, 2008, p. 1122).

The amount of money earned allows for the exercise of different types of lifestyles with varying levels of resource consumption. A case study using the ‘8 Tribes’ categories shows that, on average, income correlates with EF (Lawton, in press). Some reduction in footprint can be made by moving to ‘greener’ products and services but the general rule-of-thumb is that the more products and services
people buy, the bigger their EF (Vale & Vale, 2009b). Reducing components of the NZ footprint, such as food and transport, is likely to require time. A decision to change how people spend their time is dependent on what they value, the urban form in which they live, and finally the broader governing political and cultural systems.

These drivers of consumption—political and cultural systems, urban form and lifestyle—can therefore be used to identify why individuals and communities are consuming resources at such a fast rate, and also to identify some of the key changes necessary to help people to consume fewer resources and live within their ‘fair earth share’ EF. But the question remains open: what does a ‘fair earth share’ EF look like in the context of a NZ community?

1.3. A Vision of Sustainability

“A vision without a task is but a dream, a task without a vision is drudgery, a vision and a task is the hope of the world”—cited in Outhwaite (2009) from a church in Sussex, UK, 1730 A.D.

The first international report on sustainable development is more than 25 years old (Brundtland Commission, 1987) and there is still a lack of consensus about what sustainability looks like, how it might be governed, and how the economy would operate. Providing scientific and artistic visions for a sustainable future will help to provide direction for plans and policies to achieve this. In addition to a vision, measurement tools are required to track the progress of an individual or community in achieving the vision (Holmberg, 1998; Holmberg & Robèrt, 2000; Outhwaite, 2009).

The concept of ‘fair earth share’ can be used to provide a vision of sustainability, where a person’s lifestyle can be supported by a certain quantity of land in perpetuity. A number of communities and organisations have used the concept of a ‘fair earth share’, or ‘one planet living’, as a guide for creating scenario options for moving toward this vision. WWF Wales provides scenarios illustrating how a range of different Welsh sectors, including food, transport, governance and lifestyles, could achieve a ‘75% reduction in their EF by 2050’ (Ravetz, 2007a, p. 1). The One Planet Wales challenge is, “...for the people of Wales to lead healthy, prosperous lives within their fair share of the Earth’s resources” (Ravetz, 2007a, p. 1). Others have also adopted this concept for ‘one planet economy’ (One Planet Economy Network, 2010) and ‘one planet business’ (Beloe et al., 2007).

What has not yet been demonstrated is a picture of what life and communities could look like when operating within the constraints of a ‘fair earth share’ EF. Visions and strategies are generally at the national level rather than allowing for individuals to tailor their lifestyles within their own personal ‘fair earth share’. What people do with their share is up to them and is dependent on their own preferences. The ‘fair earth share’ is relatively small in comparison to most current Western lifestyles. Thus some activities, such as international flights, would require a considerable amount of ‘savings’ (a trade-off with other resource consumption) for the person to stay within their ‘fair share’ allocation. To create a plan for achieving a ‘fair earth share’, the vision must be created by back-casting to current time, and then a strategic plan created for reaching the vision. Back-casting is a process of starting from a vision of success then looking back to the present to identify the most strategic steps to success (Outhwaite, 2009). The method of back-casting increases the likelihood of handling the ecologically complex issues in a systematic and coordinated way, and foreseeing certain changes (Holmberg & Robèrt, 2000).
Unsustainability is being driven by decreasing availability and an increasing demand on the World’s resources. In order to achieve a sustainable future, society needs to realign all aspects of consumption to achieve a vision of ‘fair earth share’ communities. Governing organisations must provide political and cultural systems that support the creation of an urban form that reduces barriers to communities achieving sustainable consumption habits. Communication of the ‘fair earth share’ vision can be achieved through campaigns appealing to each of the ‘8 Tribes’, their values, and how they decide to spend their income and use their time.

This research proposes that a range of scenarios is required, showing how individuals with a range of lifestyles living in different urban forms might live within their fair earth share. The ultimate question is ‘in what urban form could an individual live, and what kind of lifestyle could they have, to maximise their wellbeing whilst living within a ‘fair earth share’ footprint?’ For large-scale change that supports individual capacity to live more sustainably, communities must work collectively in all spheres of consumption influence. Defining the constraints by which people need to live will inspire individuals and communities to think and act creatively.
Appendix 2: Ecological Footprint related research

This section provides background about the EF, the tool for analysing the data, the method, and specific Bhutan yields that will be used.

Modern society is made up of a complex web of economic, social, environmental and political systems integrating at global and local scales. Appendix 1 above introduced the drivers of unsustainability and the key influences on consumption. As society becomes increasingly urbanised the ability for communities to receive feedback in response to resource use becomes increasingly difficult. There is an increased mental separation between the resources people use and where these come from. Measurement tools are required to keep track of both the supply of available biocapacity and the demands that society is making on biological systems at a global, national and local levels. The EF provides these measures by using ‘land’ as a common unit of measurement and provides a clear understanding of what it means to be ‘sustainable’ or live within the planet’s biocapacity (Robert et al., 2002). The specific EF method required depends on the project.

The following section provides an introduction to the EF tool. EF is used internationally by governments, non-governmental organisations, businesses, schools and individuals as a way to measure, communicate and compare how individuals and communities use resources. An introduction to various EF methods is also provided, highlighting the method used by this research. EF calculations are carried out with Bhutan yields in order to calculate the Bhutan EF in local yields. The final section of this chapter discusses some of the limitations of the EF and how caution should be exercised regarding the role of the EF in measuring sustainability.

2.1. International use

International case studies, particularly from the UK and Canada, have shown that EF can successfully measure and communicate the complexities of resource flows through society (Barrett, Vallack, Jones, & Haq, 2002; Collins & Flynn, 2005; Hunter et al., 2006). The data have been used to inform individual purchasing decisions at the household level (BioRegional & WWF, 2008; Simmons & Chambers, 1998; Vale & Vale, 2009b) and at national level (Lenzen & Murray, 2001; McDonald & Patterson, 2003; Wackernagel et al., 2005; WWF, 2010), as well as to inform product producers and designers about the resource impacts of their products (Wiedmann & Barrett, 2010; Wiedmann, Barrett, & Lenzen, 2007). EF data is increasingly being used to support policy formation through scenario creation and communication (Collins et al., 2009; Cornforth, 2009; Monette et al., 2001; Monfreda et al., 2004; Moran et al., 2007; Wiedmann & Barrett, 2010; Wiedmann, Wood, Lenzen, Tovey, & Moloney, 2007b; Wilson & Grant, 2009).

An influential international case study was funded by Cardiff City Council in partnership with BRASS Research Centre at Cardiff University and the Stockholm Environment Institute. Initiated in January 2003, the aim of the project was to “show where Cardiff’s EF is heaviest, and highlight areas of concern for the future” (A. Collins et al., 2005, p. 1). The project report also showed that the fundamental challenge was to slow down the growth of Cardiff’s EF, even before plans were put in place for reducing it. The report stated that “in order to slow down the growth of the City’s EF, significant changes in forward planning and activities will be needed from the Council, and its partners in the public and private sectors” (Collins et al., 2005, p. 1). It also identified that Cardiff’s citizens and visitors have a key role in minimising their own EF and the City’s overall ecological impact.
The New Zealand Footprint Project, completed in 2013, created a tested the EF method that will be used in the current project. The project was a collaboration between Otago Polytechnic, Auckland Council and Victoria University of Wellington.

Use of the EF in NZ has been varied and ranges from official publications and journals through to demonstration on television for education and behaviour change purposes. At the national level, the EF has been used by the MfE as a way of communicating environmental limits and personal consumption (Ministry for the Environment, 2008a; Rowan Taylor & Smith, 1997). In 2003 the MfE also commissioned a technical paper entitled *The Ecological Footprint of New Zealand and its Regions* (McDonald & Patterson, 2003). The report compared NZ’s regions with their biocapacity in an effort to show resource overshoot at the local level as well as resource exchange between regions. However with regard to policy and plan development, the EF has not been used at the national level.

The EF has been used with success at the local and individual level as a communication and education tool. The EF has been tested with primary school children as a way of learning about resource limits and encouraging behaviour change (Baldwin, Becken, & Allen, 2008), as a baseline measurement tool to encourage households to reduce their overall resource consumption (Far North Environment Centre, 2011; Kapiti Coast District Council, 2011), and as a communication tool and calculator for the television series ‘Wa$ted’ (Andrew & Patterson, 2008). There are multiple research projects where the EF has been used to measure the resource consumption of specific places, activities, products or buildings, including: the EF of the NZ economy (Bicknell, Ball, Cullen, & Bigsby, 1998); the EF of Auckland’s transport system (Huang, 2010); a comparison of Wellington’s 1956 and 2006 footprints (Field, 2011); the EF of the Waikato Region (Market Economics, 2006; McDonald & Patterson, 2001); the EF of the University of Otago School of Business (Aporo et al., 2007); the total environmental impacts of NZ’s food and fibre industries (Andrew et al., 2005); the EF of NZ’s aging population (McDonald, Forgie, & MacGregor, 2006); and, to be completed in 2013, the creation of a template to calculate the EF of major NZ sporting and cultural events (Spearing, 2012).

The EF has been used in NZ to fulfil a range of aims from whole country analysis to calculators for individual footprints. The uses have been restricted to a top-down approach to ecological footprinting which does not include the detail required to understand the key drivers of people’s EF. The following section explains the differences between the EF methods used in the projects above and introduce the component based, top-down bottom-up method used in the current research.
Appendix 3: Ecological Footprint Methods

Since its conception in the late 1990s the EF has undergone a number of methodological revisions, altering not only where the data comes from, but also the level of detail at which the EF can track changes in an individual or community’s resource consumption. Wiedmann and Barrett (2010), surveying over a decade’s worth of case studies, highlighted that there is no one-size-fits-all approach to projects using the EF. The footprint methodology should be adapted depending on:

1. whether the aim of the project is to compare footprints locally, nationally or internationally
2. who are the expected target audience for the project results, i.e. individuals, local community groups, policy makers, international agencies;
3. the level of resource accounting detail required, i.e. at an organisational level, community wide level, national or international level;
4. availability of data which must also be considered in association with required detail; and
5. the skills of the project team and available resources including money and time.

Though it is generally acknowledged as a valuable education tool that enriches the sustainability debate, the original EF is limited as a regional policy and planning tool for ecological sustainable development, because it does not reveal where impacts really occur, what the nature and severity of these impacts are, and how these impacts compare with the self-repair capability of the ecosystem. In response to the problems highlighted, the concept has undergone significant modification. These modifications include the use of input-output analysis, renewable energy scenarios, land disturbance as a better proxy for sustainability, and the use of production layer decomposition, structural path analysis and multivariate regression in order to reveal rich EF details (Lenzen & Murray, 2003).

There are primarily three different overarching methods. These are the original compound method created by Wackernagel and Rees (1996), the input-output analysis (IOA) method developed by Bicknell (1998) and her team in New Zealand, and the component method, which is becoming increasingly successful with local EF projects. There are also variations within these methods which will be discussed below. Use of local Bha is less likely using the compound method than in input-output or component based methods; however it could be used, as there are method options available. How the data is intended to be used is paramount to how the EF calculations should be carried out.

3.3.1. Compound Method

The most established method of conducting EF Accounting is the compound method (Rees, 1992; Wackernagel & Rees, 1996). It has become increasingly standardised over the years and is typically used at the national level. Consumption of more than 200 resources is included in the calculation and the footprints of these resources are aggregated into one of six land categories required to support that consumption (Wackernagel et al., 2005). To understand this method in more detail the GFN have created standardised guidelines for reporting on footprints using both the compound and input-output method mentioned below (Global Footprint Network, 2009).
Aggregated forms of the EF make it difficult to understand the specific reasons for the unsustainability of a given population’s consumption, and to formulate appropriate policy responses (Lenzen & Murray, 2003, p. 4). However, the method provides a means for international comparison that can be replicated and therefore also provides a basis for comparing footprints over time.

There are two distinct parts to calculating EF using the compound method. The first is to find the embodied EF of the product or service and the second is to calculate the total consumption of the product or service in question.

3.3.2. Input-Output Analysis

IOA is a macroeconomic technique that relies on data on inter-industrial monetary transactions (Lenzen & Murray, 2003, p. 8). The calculations for the footprints of populations by Wackernagel and Rees (1996) were mainly those items and services directly required by households, and by the producers of consumer items. These producers draw on numerous input items themselves, and the producers of these inputs also require land. Generally speaking, in modern economies all industry sectors are dependent on all other sectors, and this process of industrial interdependence proceeds infinitely in an upstream direction, through the whole life cycle of all products, like the branches of an infinite tree (Lenzen & Murray, 2003). IOA is an accounting procedure that relies on national input-output tables. A country’s input-output tables document the flow of money to and from the various industry sectors, showing just how interdependent they are. In broad terms IOA tables show an industry’s output, i.e. what is sold by the industry to other industries (and to itself), and an industry’s inputs, i.e. what is bought by an industry in order for it to produce its goods or services (sometimes called its production recipe) (Murray & Lenzen, 2010, p. 7). In order to use IOA to calculate an EF of a given population, physical and economic data are integrated into a combined flow account which helps connect environmental and economic fields. The resulting tables reveal the flows from the environment to industry in the form of ecosystem inputs and natural resources (Murray & Lenzen, 2010). Since its introduction by Nobel Prize laureate Wassily Leontief (1936), IOA has been applied to numerous economic, social and environmental issues. It was first applied to EF by Bicknell et al. in 1998 to calculate an EF for New Zealand (Lenzen & Murray, 2003).

Wiedmann and Barrett (2010) found that the main advantage of IOA lies in its unambiguous and consistent accounting of all upstream life-cycle impacts and the good availability of expenditure data that allow a fine spatial, temporal and socio-economic breakdown of consumption footprints. Limitations with the IOA method relate to the availability of data on embodied energy and land, in relation to monetary flows through the population under assessment. There continue to be advances in this area of research (Wiedmann & Barrett, 2010).

3.3.3. Component Method

There are numerous case studies detailing multiple methods to calculate the EF at a local community level. These case studies aim to provide local EF calculations that are complete, capturing all resources used by a community or individual (Aall & Norland, 2005; Hunter et al., 2006; Klinsky, Sieber, & Merged, 2009; Monette et al., 2001; Paul, 2006; Wilson, 2001). Recent case studies focused on the EF of sub-national populations have increasingly supported the component method for its suitability in the local context. The method was developed to connect with people through their
daily activities (for example waste production and electricity consumption) (Barrett, 2001; B. Ryan, 2004; Simmons, Lewis, & Barrett, 2000).

In the component-based model the EF values for certain activities are pre-calculated using data appropriate to the region under consideration (Simmons et al., 2000). For example, to calculate the impact of a ferry ride, local average data on fuel consumption, manufacturing and maintenance energy are calculated. These figures may then be converted to total EF per kilometre. The total kilometres travelled by a population are then multiplied by EF per kilometre to give a result of the final EF of an individual or community. Many of the original EF compound calculations aimed to capture indirect effects in a life-cycle context (Barrett, 2001; Simmons & Chambers, 1998; Simmons et al., 2000). Problems involved a general lack of data, and methodological issues such as boundary selection and double-counting. In addition, many consider embodied energy but not embodied land (Lenzen & Murray, 2003, p. 9; Simmons et al., 2000).

The component method is time consuming in finding the data, and the data are not readily substituted, i.e. data do not originate from a regularly updated database. The component method was selected for this research due to the level of detail that could be gained and the insight this might provide into the relationship of the EF to lifestyle trends. The method could also be carried out through a bottom-up approach using a range of different data sources.

To calculate the EF using the component method, life-cycle data (for most forms of consumption), the output of non-productive waste, and the loss of productive land through building activities are combined into an overall EF (Chambers, Griffiths, Lewis, & Jenkin, 2004; Hunter et al., 2006; Simmons & Chambers, 1998). For example, to calculate the impact of car travel, data on fuel consumption, manufacturing and maintenance energy, land apportioned to road space, and average occupancy are sourced for the country in question. The total can be used as an average EF estimate derived for a single passenger kilometre (pkm), which can then be used to calculate the impact of an individual’s vehicle use (Simmons et al., 2000).

The second part of the component method deals with the collection of data to produce figures for ‘per person’ consumption for a given population. This requires information from a range of national datasets at the international, national, regional, community, household and individual level involving both a ‘top-down’ and a ‘bottom-up’ approach. A top-down approach uses secondary data, providing a population total for any given resource or service. The total is then shared equally amongst all members of that population, providing a population average. The bottom-up approach provides primary and secondary place-specific data—if available—which can be used to replace the ‘top-down’ modelled data above (Collins, Flynn, Wiedmann, & Barrett, 2006). This includes census data, primary interviews, questionnaire data and other local information.

There are limitations to both the top-down and bottom-up approaches. Often data required for calculating EF is difficult to acquire, either because it is too general, not available in the correct measurement, or is weak in its own methodology (Aall & Norland, 2005; Collins & Flynn, 2008; Hunter et al., 2006).
Appendix 4: Energy Land

The following section explains the methods for calculating the energy-to-land ratio for both non-renewable and renewable energy. The EF component approach method is preferred and is then used to explain the energy to land ratio for Bhutan, in both bha and gha for renewable and non-renewable energy sources.

Non-Renewable Energy

Three approaches for converting non-renewable energy to land equivalents were proposed by Wackernagel and Rees. For all approaches, the rate at which biomass grows and sequesters CO₂ varies depending on the type of trees and where they are growing (Wackernagel & Rees, 1996, p. 73), making it necessary to have a local Bhutan energy to land ratio. All three methods have their benefits and limitations.

The ‘ethanol approach’ calculates the land required to produce a biologically-produced fuel substitute, such as corn and wood biomass for ethanol or methanol. This approach reasons that a sustainable economy requires a sustainable energy supply, and should not be dependent on the world’s reducing fossil capital. Wackernagel and Rees (1996, p. 72) further note that for a carbon-based fuel it is preferable to use carbon already cycling in the ecosphere rather than carbon that has been stored for millennia in an inactive pool. This approach avoids further CO₂ accumulation in the atmosphere. The rate of growth depends on the type of vegetation and the geography where it is grown. Wackernagel and Rees’ life-cycle calculations showed that the most optimistic net productivity from herbaceous plants for this approach was 80GJ/ha of land and 150GJ/ha from wood. However methods for using more land-efficient substitutes for liquid fossil fuels, such as biodiesel, continue to develop. New technologies are emerging using waste products (Biofuel.org.uk, 2010) and algae (known as Oilgae) (Scientific American, 2009) to produce liquid fossil fuel substitutes. The lifecycle of these future fuels needs to be researched in detail to gain better insight into their energy-to-land ratios.

The ‘biomass replacement method’ estimates the land area required to rebuild natural capital at the same rate as fossil fuel is being consumed. This method is similar to the ethanol approach whereby as society consumes non-renewable resources, a portion of the profit made from the use of these is reinvested into the equivalent value of manufactured capital or renewable resource assets such as forest or plant materials. Therefore once the fossil fuel reserves dry up, society can start cropping the energy land. Calculations show that one hectare of average forest could accumulate about 80GJ of recoverable biomass per year in standing timber (Wackernagel & Rees, 1996, p. 73). The concept of creating ‘sustainable forests’ or ‘green energy’ also sits behind the idea of ‘carbon offsetting’ and ‘green investment’ (CarboNZero, 2011).

The ‘biomass approach’ continues to be debated; Kunstler (2005) highlights one of the potential dangers is that the method supports the argument for countries to convert land previously in food production or indigenous forests into liquid fuel production. He also suggests this approach supports society’s addiction to ‘easy energy’ by suggesting, through technological developments, that there is direct substitution of one cheap energy source for another, allowing society to continue to use as much or more energy as before. However as yet, these technologies have neither been developed nor are at the scale needed for a complete renewal of infrastructure to support current energy use. The benefits of using the biomass approach are that using only current technologies there are
definite sustainable limits. Bhutan only has so much land and the calculation of how much ethanol and methanol can be produced is simple. Using New Zealand (NZ) as an example, it has 26,900,000ha of land, of which 430,400ha (1.6%) is currently used for horticulture (Ministry for the Environment, 2009b). Vale and Vale (2009b, p. 90) calculated that if NZ attempted to replace its 2009 vehicle fuel requirements with an ethanol/vegetable oil mix this would require 1,050,000ha. This calculation shows that NZ would need almost 2.5 times the current area used for horticulture to produce liquid fuel using current technologies. Another benefit of the biomass approach is its potential to generate sustainable energy and therefore the method could be said to be a truer reflection of the amount of land needed in a sustainable scenario. As a result the biomass approach is likely to be an effective approach when calculating future post-peak-oil scenarios.

The third method is the ‘CO2 approach’ which estimates the additional biologically productive area needed to sequester atmospheric CO2 through afforestation (Wackernagel et al., 2005, p. 16). The argument is that to avoid possible climate change, fossil carbon (in the form of CO2) cannot be allowed to accumulate in the atmosphere. The energy footprint is calculated by estimating the biologically productive area of land and its biomass needed to sequester enough carbon emissions to avoid an increase in atmospheric CO2 (Loh et al., 2004). Land and biomass, such as forests, act as a ‘carbon sink’, which is a process, activity or mechanism that removes a greenhouse gas or a precursor to a greenhouse gas from the atmosphere (UNFCCC, 1990). Some CO2 approach methods also include the oceans’ capacity for emissions absorption by deducting as much as one-third of the anthropogenic emissions (Wackernagel et al., 2005, p. 16). The calculations required for this concept are the basis for ‘carbon offsetting’ where individuals and organisations ‘offset’ their carbon emissions by planting a certain area, or number of trees (carbon footprint, 2011). Data on typical forest productivities of temperate, boreal and tropical forests used by Wackernagel and Rees (1996) explain that average forests can accumulate approximately 1.8tC/ha/year. This means that annually one hectare of average forest can sequester the CO2 emission generated by consuming 100GJ of fossil fuels. As a result the world average energy to land ratio is 100GJ/ha.

The ‘CO2 approach’ is flawed because it assumes society can ‘fix’ the problem of greenhouse gases by growing more trees or creating additional carbon sinks. According to GFN’s latest figures, society’s energy/carbon EF is 9,633 million gha (Ewing, Moore, et al., 2010, p. 44). This is the equivalent of world-average productive land covering an area the size of Asia (4,457.9 million hectares), North and South America (4,207.5 million hectares) and Europe (993.8 million hectares) combined. In addition, the carbon cycle is very complicated. In support of the ‘CO2 approach’ this method is the most broadly used and supported. Wackernagel and Rees promote the use of the ‘CO2 approach’ as the one that ‘would enjoy the highest public acceptance’ (Wackernagel & Rees, 1996, p. 73), and acceptance by the biggest organisations using EF (Barrett & Simmons, 2003; Global Footprint Network, 2009; Simmons & Chambers, 1998; Venetoulis & Talberth, 2006). Due to its broad international acceptance, the ‘CO2 approach’ will be used in the following research.

The CO2 Approach for Bhutan

The amount of carbon flowing through the carbon cycle changes slightly with the ability of the carbon sinks, particularly biomass and oceans, to sequester carbon dioxide from the atmosphere. As a result the ‘world average energy-to-land ratio’ is not the best value to use for Bhutan. However a method for calculating energy-to-land conversions in Bha for the ‘CO2 approach’ is not available. When calculating a specific energy-to-land ratio a number of aspects are considered, including the
type and amount of biomass and energy used by the specific region. Biomass includes both commercial forests and indigenous forests and carbon sequestration by the world’s oceans.

The energy per hectare conversion for world average forest requires calculating the CO₂ needed to create the carbon in wood, then the energy produced by that carbon. The world average forest assimilation rate is approximately 1.8tC/ha per year (Wackernagel & Rees, 1996, p. 73; Wada, 1994) which is converted to CO₂ using a molecular weight conversion ratio of 3.67. Therefore 1.8tC equates to 6.6tCO₂/ha. The world average energy-to-land ratio for non-renewable energy is therefore 73GJ/ha under the ‘CO₂ approach’.

Oceans also sequester CO₂. In relation to preindustrial carbon reservoirs, as much as 80% is thought to be held in the intermediate and deep ocean. However the ability for the deep ocean to sequester and cycle CO₂ is thought to be extremely slow, as much as 1,000 years for a cycle, because of the sluggishness of the vertical exchange between the surface and interior of the ocean (Sarmiento & Gruber, 2002, p. 31). Recent calculations used by the Stockholm Environment Institute in the Cardiff Footprint Project use 31% absorption (Collins et al., 2005, p. 161). A number of other EF studies (Barrett et al., 2002; Loh et al., 2004; Wackernagel & Rees, 1996) have included provision for the world’s oceans to absorb 35% of anthropogenic CO₂-equivalent emissions from fossil fuel combustion (IPCC, 2000). Using the absorption rate of 35% as proposed by the IPCC, the energy-to-land and ocean ratio becomes 99GJ/ha, rounded up to 100GJ/ha.

The carbon sequestration rate for Bhutan varies and has been difficult to confirm. The Second National Communication to the UNFCCC Report states that in 2000 the total carbon uptake was 6,309.63 Gg (6.3 million tonnes) CO₂-equivalent (NEC, 2011; p.30). There was an estimated 2.9 million hectares of forest in Bhutan at the time (ibid.). The sequestration rate was therefore 2.15tCO₂/ha/yr or 33GJ/ha. This increases to 44GJ/ha when the ocean sequestration rate is also included.

This rate is much lower than what is found in many parts of the world, however not unrealistic. In comparison New Zealand has some of the more productive forests in the world. The main forestry species *Pinus radiata* (Hollinger, Maclaren, Beets, & Turland, 1993, p. 196) which can maintain a carbon sequestration rate of 3.6tC/ha/year (Hollinger et al., 1993). This is the equivalent of 13.2tCO₂/ha/year, which is double the world average. On the other hand Hall and Hollinger (1997) found that indigenous NZ forests have a much lower sequestration rate of 5.87tCO₂/ha/year. A more recent publication from the Ministry of Agriculture and Forestry (2011) found that in simulated even-aged stands of indigenous forest, mean carbon sequestration rates varied across species from 1.26tCO₂/ha/year for *Podocarpus hallii* to 6.47tCO₂/ha/year for *Dacrydium cupressinum* (Kirschbaum et al., 2011, p. 21). It was concluded that both the plantation estate and indigenous forest results vary greatly depending on the geographical distribution across NZ in terms of temperature and rainfall.

As mentioned above, the energy-to-land conversion is a very important calculation because of the difference it can make to total EF. Without clear guidance on a best method for calculating Bha different conclusions could be drawn depending on which modes of sequestration are included. More research is required to propose a comprehensive energy-to-land conversion for Bhutan for common use. The final Bhutan EF will present the Bha EF calculations using the sequestration of 33GJ/ha, whilst the EF in gha will use the rate of 100GJ/ha.
Bhutan’s Renewable Energy

In 2010 42.6% of Bhutan’s energy needs was fulfilled by hydroelectricity (Ernst & Young; p.30). Some research has been carried out into energy-to-land conversions for renewable energy sources, although this needs further investigation. The land use of hydro-electricity is estimated by dividing total energy production by the typical area required by hydro-dams and corresponding corridor spaces for transmission rows (Wackernagel & Rees, 1996, p. 69). The result is an estimated 1,000GJ/ha of land. This land is energy land for the embodied energy of the infrastructure and the physical space required by hydropower storage lakes. Calculations have also been carried out for a range of other renewable energy sources including wind and tides. The average conversion factor for these sources calculated by Chambers, Simmons and Wackernagel (2000) was 9,090GJ/ha per year.

The hydroelectricity conversion of 1,000GJ/ha of consumed land is used for the following calculations.

The energy EF of countries and communities makes up a large portion of the overall EF and therefore using an appropriate energy-to-land ratio for both renewable and non-renewable energies is important, hence the discussion of the assumptions made in this section.
Appendix 5: New Zealand EF Questionnaire

Also note the attached EF calculator for your interest.
Welcome and thank you for supporting our research by filling in this questionnaire. Please remember that unless stated, the questions should be considered on average for the ENTIRE HOUSEHOLD.

Please note: The following questionnaire is only concerned with your personal lifestyle, not those aspects that you consider as WORK. Those items/travel supplied by work, paid by work and predominantly for the purpose of your job should not be included in your answers.

1.  
   i. Are you: 
   
   Male  Female

   ii. What is your age:  
   
   a. Under 25  
   b. 25 to 34  
   c. 34 to 44  
   d. 45 to 54  
   e. 55 to 64  
   f. 65+  

   iii. What ethnic group do you identify with?  
   
   a. European / Pakeha  
   b. Maori  
   c. Pacific Island  
   d. Asian  
   e. Other

   iv. What is your highest educational qualification?  
   
   a. A tertiary degree or professional diploma  
   b. A trade certificate or diploma  
   c. No tertiary qualifications (only school or no qualifications)

   FOOD

2. How often do you eat animal-based products?

   i. Beef / Lamb  
   
   a. never  
   b. infrequently (once every few weeks)  
   c. occasionally (one-three times a week)  
   d. often (nearly every day)  
   e. all the time (most days most meals)

   ii. Pork  
   
   a. never;  
   b. infrequently (once every few weeks)  
   c. occasionally (one-three times a week)  
   d. often (nearly every day)  
   e. all the time (most days most meals)

   iii. Fish  
   
   a. never  
   b. infrequently (once every few weeks)  
   c. occasionally (one-three times a week)  
   d. often (nearly every day)  
   e. all the time (most days most meals)

   iv. Poultry (chicken, duck, turkey)  
   
   a. never  
   b. infrequently (once every few weeks)  
   c. occasionally (one-three times a week)  
   d. often (nearly every day)  
   e. all the time (most days most meals)
v. **Milk & dairy**
   a. never
   b. infrequently (once every few weeks)
   c. occasionally (one-three times a week)
   d. often (nearly every day)
   e. all the time (every day most meals)

vi. **Eggs**
   a. never
   b. infrequently (once every few weeks)
   c. occasionally (one-three times a week)
   d. often (nearly every day)
   e. all the time (every day most meals)

3. **How often do you eat fruits, vegetables and grains?**

i. **Vegetables**
   a. never
   b. infrequently (about once a week)
   c. occasionally (one-three times a week)
   d. often (nearly every day)
   e. all the time (every day most meals)

ii. **Fruit and nuts**
   a. never
   b. infrequently (about once a week)
   c. occasionally (one-three times a week)
   d. often (nearly every day)
   e. all the time (every day most meals)

iii. **Bread**
   a. never
   b. infrequently (once every few weeks)
   c. occasionally (one-three times a week)
   d. often (more than 3 times a week)
   e. all the time (every day)

iv. **Rice**
   a. never
   b. infrequently (once every few weeks)
   c. occasionally (one-three times a week)
   d. often (more than 3 times a week)
   e. all the time (every day)

v. **Wheat pasta**
   a. never
   b. infrequently (once every few weeks)
   c. occasionally (one-three times a week)
   d. often (more than 3 times a week)
   e. all the time (every day)

vi. **Pulses (such as beans and legumes)**
   a. never
   b. infrequently (once every few weeks)
   c. occasionally (one-three times a week)
   d. often (more than 3 times a week)
   e. all the time (every day)
4. How much of the food that you eat is organically produced (without the use of chemicals)?
   a. don’t know;
   b. none that I know of (I don’t purposefully buy organic)
   c. some (I occasionally buy organic milk and sometimes I buy from the organic market)
   d. most (I always aim to buy organic at the shop and do not use chemicals on my garden)
   e. all (I only eat food that I know has been organically grown)

5. Fresh, not packaged and local food
   
i. How much of your diet is based on fresh, unpackaged foods?
   a. don’t know
   b. none of it (the business of life means I have to eat quick)
   c. about a quarter of it (I very rarely supplement my baked beans with a home cooked meal)
   d. about half and half (sometimes I cook local food, sometimes I order pizza)
   e. most of it (I’m a farmers market fiend but I really like potato chips)
   f. all of it (I only eat fresh, unprocessed, unpackaged food)

   ii. How much of the food that you eat is locally grown or produced within the region that you live?
   a. don’t know (I never pay any attention to where it is grown)
   b. very little (most of the food I eat is not grown locally)
   c. about a quarter (I sometimes stop at roadside stalls to buy fruit)
   d. about a half (I try to get to the local markets every week to buy fruit and veges)
   e. about three-quarters (we buy from the market what we cannot grow ourselves but I don’t know where our meat/seafood comes from)
   f. all of it (all of the food I eat is grown/produced locally)

   iii. How much of the food that you eat has NOT been bought but either caught or gathered yourself, produced on your own land, or exchanged or bartered with others?
   a. none (I don’t know anyone who grows their own food and I don’t gather my own)
   b. very occasionally (my parents live on an orchard an send me a box of apples every month)
   c. occasionally ("recreational hunter" - I love collecting wild fruit and we often go fishing and/or hunting)
d. often ("the farmer" - we never buy meat and have a thriving vegetable garden in the summer)
e. always ("Off the Radar" - I am fully self-sufficient and only buy the bare essentials like sugar and flour)

6. i. Do you have a home garden?
   a. Yes
   b. No. Why not? (go to question 7)

   ii. Do you grow edible plants and fruits in your garden?
   a. Yes
   b. No. Why not? (go to question 7)

   iii. How much fruit and veges do you grow and consume?
   a. Not much - some herbs
   b. A bit - some salad greens from a summer garden (1m²)
   c. Some – we eat something from the garden each day during summer (1-3m²)
   d. A lot - we eat mostly from the garden in summer and some in winter (3-10m²)
   e. Most – we eat mostly from the garden in summer and have additional food that we store for winter (10-20m²)
   f. All – almost all our fruit and veges are from our garden (larger than 20m²)

   iv. Why do you have a garden? (you may tick more than one)
   a. Saves money
   b. Is therapeutic to get outside
   c. Enjoy eating my own food
   d. Convenience, fewer trips to supermarket
   e. Health, I know how it is grown
   f. Environmental – less impact on the environment
   g. Always have, it is what we do

7. Eating out and take-aways.

   i. How often do you grab a meal from a cafe or fast-food restaurant? (do not include coffee)
   a. never (I love to cook at home, and it saves me money)
   b. occasionally (once every few weeks on special occasions)
   c. every week (fish and chip Friday is my favourite)
   d. 2-3 times a week (I need my coffee fix and I never remember to make my lunch)
   e. every meal (I am too busy to buy food and cook at home)

   ii. How often do you go to a restaurant to have a sit-down meal?
   a. never (I love to cook at home, my food is always better)
   b. occasionally (once every few weeks on special occasions)
   c. every week (we go out for dinner or brunch every weekend)
   d. 2-3 times a week (I have a very busy social calendar which means I eat out a lot)
   e. every meal (I live at restaurants)
iii. Do you eat the same kinds of food when you eat out, as you do at home?
   a. No (I like to treat myself when I go out for dinner so I can have a steak or the seafood platter that I don't eat at home)
   b. most of the time (sometimes I splurge on a fancy meal)
   c. yes (when I eat out I would eat a similar size and type of meal that I would eat at home)

iv. What is your primary alcoholic drink of choice?
   a. Wine/Cider
   b. Beer
   c. Spirits
   d. Other
   e. None

v. What best describes your drinking frequency?
   a. Never - I don't drink or very rarely drink
   b. 1-4 glasses of wine/spirit or 1-6 stubbies a week
   c. 1-2 bottles of wine a week, 5-10 glasses of spirit/mixer, 7-15 beer stubbies
   d. More

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Your Household

8. i. How many people live in your household?
   a. 1
   b. 2
   c. 3
   d. 4
   e. 5
   f. 6
   g. 7+

ii. In what range is your household income?
   a. No comment
   b. $40,000 or less
   c. $40,001 - $60,000
   d. $60,001 - $80,000
   e. $80,001-$100,000
   f. $100,001-$120,000
   g. $120,000-$140,000
   h. $140,001+

iii. What best describes your spending and saving habits?
   a. I spend all my income and then some
   b. live within my means
   c. I am a frugal spender and save for the future

9. Your Property

i. How would you best describe where you live?
   a. Rural
   b. rural-residential
   c. suburban
   d. urban
   e. inner city

ii. Which best describes your property?
   a. High country station
   b. A working farm
   c. Lifestyle block (0.4-30 hectares)
   d. Free standing house on large section (1,000-4,000m²)
   e. Free standing house on small section (less than 1,000m²)

iii. What is the size of your house (not including the garage)?
   a. 50 m² or less
   b. 51-100 m²
   c. 101-150 m²
   d. 151-200 m²
   e. 201-250 m²
   f. 251-300 m²
iv. In addition to your house, how much of your land is covered with a solid (impermeable) surface? E.g. driveway, garage, pool etc.
   a. None
   b. 1-10m²
   c. 11-20m²
   d. 21-30m²
   e. 31-40m²
   f. 40m²+

   - Single garage (15-25m²)
   - Double garage (26-36m²)

v. Do you own your own home?
   a. Yes
   b. No, we rent privately
   c. No, it is state housing

vi. What would you say comes closest to the materials your house is constructed of? (you may choose more than one)
   a. Timber frame
   b. steel frame
   c. clay brick
   d. Mud brick / rammed earth/ straw bale
   e. I don’t know or other

10. Energy for your whole HOUSEHOLD (please average your bills for the year, or winter average plus summer average divided by 2)

i. On average what do you typically spend PER MONTH on electricity for your home?
   a. I don’t use mains electricity
   b. I don’t know
   c. $0-50
   d. $56-100
   e. $101-150
   f. $151-200
   g. $201-250
   h. $251+

ii. What do you typically spend PER MONTH on natural gas/LPG/diesel (please circle) for your home?
   a. I don’t use gas
   b. I don’t know
   c. Under $25
   d. $26 - $35
   e. $36 - $45
   f. $46 - $55
   g. $56 - $65
   h. $66 - $75
   i. $76+

iii. What do you typically spend PER MONTH on coal for your home?
   a. I don’t use coal
   b. I don’t know
   c. Under $100
   d. $100 - $150
   e. $151 - $200
   f. $201+

iv. How much wood do you use EACH YEAR? (average it over the whole year)
   a. I don’t use wood
   b. I don’t know
   c. 0-2 m³
   d. 3-5 m³
   e. 6-10 m³
   f. 11-15 m³
11. Water
   i. Do you rely on mains water?
      a. Yes
      b. No (Go to Q12)
   ii. How much water do you use?
      a. Not much (we conserve or don't need much)
      b. Average
      c. A lot (use it to top-up the pool, water a large area of garden, have many appliances that require water)

12. Compared with the typical New Zealander, how much waste do you think you generate?
   i. Electronics: How often do you buy new home entertainment, personal computer equipment and electronic gadgets including tools?
      a. Rarely (I do not have many electronic gadgets, except perhaps a mobile phone)
      b. infrequently (I generally only replace broken TVs, computers, etc)
      c. occasionally (I replace out of date models and occasionally buy a new gadget)
      d. often (I own many of the newest gadgets on the market)
   ii. Clothing: What would you say comes closest to the typical amount of NEW clothing, footwear and/or sporting goods that you purchase EACH MONTH?
      a. Not much (new socks and underwear every few months, majority of my clothes are second hand)
      b. a little (I buy high quality that lasts a long time so maybe a t-shirt and underwear)
      c. some (new pants and a new shirt most months)
      d. a lot (I’m up to date with all the latest fashion trends)
   iii. Furnishings: What would you say comes closest to the typical amount of new household furnishings you purchase EACH YEAR?
      a. None (everything I own is second hand / hand-me-down)
      b. very little (maybe some new bedding, pots and pans and some artwork)
      c. some (a new lamp or table just to spruce things up)
      d. a fair bit (a couch, new bedroom set, I change it up from time to time)
      e. a lot (I completely refurbish my living room with new furniture - it's an annual ritual)
   iv. Appliances: How often do you buy new household appliances such as toasters, dishwashers and toastie-pie makers?
      a. rarely (I don’t purchase major appliances for my home, but may buy small items like a blender)
      b. infrequently (We have most of the ‘typical’ household appliances, but only replace them when they break)
Reading material: How often do you buy new books, magazines, and newspapers?
- Very rarely (I buy a newspaper, magazine or new book a few times a year)
- Infrequently (I subscribe to a magazine I receive once every two months)
- Occasionally (I buy the weekend paper and buy the 'Women's Day' every week)
- Often (I receive the newspaper daily)
- Very often (I buy the newspapers daily and buy books or magazines multiple times a week)

Waste: How many standard sized rubbish bags does your household throw out EACH WEEK?
- Less than one (or 1-3 shopping bags)
- One or two (or 4-8 shopping bags)
- More than two (or more than 9 shopping bags)

Recycling: How much do you recycle?
- Everything (all electronics, paper, card, plastic 1-7, glass, aluminium/tin and food scraps)
- Most (I recycle all plastic and have a home compost bin)
- Some (I recycle my milk bottles and cardboard)
- I don't recycle anything (either because you don't want to or because recycling collection is not provided in your community)

When you buy clothing or paper products, how often do you select items labelled as recycled, natural, organic, or made of alternative fibres such as hemp or bamboo?
- Almost never (I would only buy them if they are exactly what I was looking for and didn't cost any more)
- Sometimes when I can (I search them out but sometimes the price tag gets in the way)
- Almost always (these are the only products/clothes I buy)

When you are in the supermarket/shop/market do you consider the amount of waste associated with the products you are buying?
- Never (I do not consider waste)
- A little (I sometimes try to limit the number of plastic bags I need)
- Often (I try to buy products in bulk and buy refills to limit waste)
- All the time (I do not buy products that are associated with a lot of waste)

Travel by personal vehicle

How often do you bicycle or walk to get around? (you choose to leave

How far do you travel by car EACH week (as a driver or passenger)?
- 0km or I never ride in the car
your car at home so travel somewhere)
   a. Almost never
   b. seldom
   c. occasionally (I walk to work most days but love a Sunday drive)
   d. almost always (except when it’s raining for example)

iii. What best describes the primary car that you travel in?
   a. Compact car (2 door)
   b. Hybrid car
   c. a small-mid size car (2 or 4 door hatch)
   d. a large car (4 door sedan)
   e. a van, ute or minivan
   f. SUV or performance car

iv. Type of fuel?
   a. Petrol
   b. Diesel
   c. LPG
   d. Biofuel

v. In your primary car, how much driving do you do in urban areas (where you have to brake and accelerate often)?
   a. 100% (I only drive in urban areas or sit in traffic)
   b. 80% mostly in town but do go for a Sunday drive in the country
   c. 50% (I spend half my time on urban roads stopping and starting and half on the motorway or open road highways)
   d. 10% (I almost never drive in the city)

vi. How often do you drive your car with someone else in it, rather than alone?
   a. Almost never
   b. occasionally
   c. often
   d. very often
   e. almost always

14. Motorbikes
   i. Do you own a motorbike?
      a. Yes
      b. More than one
      c. No (go to Q16)

   ii. What is the size of your motorbike engine?
       a. I don't know
       b. 1-50cc
       c. 51-250cc
       d. 251-649cc
       e. +650cc

   iii. How far do you travel by motorbike EACH WEEK (as a driver or passenger)?
        a. 1-15km
        b. 16-50km
        c. 51-100km
        d. 101-150km
15. Do you use an additional recreational vehicle?
   a. Sail boat? Yes / no
   b. Motorised boat? Yes / no
   c. Jet Ski? Yes / no
   d. Light aircraft/helicopter? Yes / no

16. Toys: Do you own 2 or more of the following or similar items?
   a. Yes
   b. No

<table>
<thead>
<tr>
<th>Mountain bike</th>
<th>Skis / snow board</th>
<th>Wind surfer</th>
<th>Para glider</th>
</tr>
</thead>
<tbody>
<tr>
<td>Road bike</td>
<td>Kayak</td>
<td>Surf board</td>
<td>Rock climbing gear</td>
</tr>
</tbody>
</table>

17. Public Transport
   i. Do you regularly travel on public transport (bus, train, ferry)?
      a. Yes
      b. No (go to Q19)
   ii. How far do you travel by bus EACH WEEK?
       a. 0km
       b. 1-10km
       c. 10-25km
       d. 25-100km
       e. 100km+
   iii. How far do you travel by rail EACH WEEK?
        a. 0km
        b. 1-10km
        c. 10-25km
        d. 25-100km
        e. 100km+
   iv. How far do you travel by ferry EACH WEEK?
       (22km one way btw Waiheke & Akd)
       (4.7km one way btw Devonport & Akd)
       a. I don’t catch ferry’s
       b. 1-19km ( rtn 2x Dvpt)
       c. 19-88km (rtn 5x Dvpt & 2x Whk)
       d. 89-176km (rtn 3-4x Whk)
       e. 177-264km (rtn 4-6x Whk)
       f. 265km+ per wk

18. Flying: How far do you fly EACH YEAR? (if you only fly once every 2 years, please average your flying over those two years and remember to calculate return flights – see below)
   i. Nationally:
      a. 0km (I never fly nationally)
      b. 1-800km
      c. 801-1,600km
      d. 1,601-3,000km
      e. 3,001-6,000km
      f. 6,001-12,000km
      g. 12,001-30,000km
   ii. Internationally:
       a. 0km (I never fly internationally)
       b. 1-9,000km (2x Sydney rtn)
       c. 9,001-15,000km
       d. 15,001-24,000km (Los Angeles or Vancouver rtn)
       e. 24,001-40,000km (Africa or Europe rtn)
h. 30,001km+

Flight distance estimates (one way): [www.mapcrow.info/]
- Auckland to Christchurch 760km
- Auckland to Wellington 640km
- Auckland to Rotorua 230km
- Wellington to Nelson 200km
- Wellington to Christchurch 440km
- Wellington to Dunedin 800km
- Auckland to Invercargill 1,600km
- Auckland to Queenstown 1,550km
- Auckland to Fiji 2,100km
- Auckland to Sydney 2,200km
- Auckland to Perth 5,300km
- Christchurch to Sydney 2,100km
- Auckland to Singapore 8,400km
- Auckland to Los Angeles 10,500km
- Auckland to London, Amsterdam, Paris 18,300km
- Auckland to Dubai 14,200km
- Auckland to Vancouver 11,400km

19. Holidays: A holiday is staying anywhere other than the family home.

i. How often do you go on holiday each year? (you can choose more than one)
   a. Never (go to question 21)
   b. One or two weekends away
   c. We save up for a long summer/winter holiday
   d. We like to go away often, once a month
   e. Multiple weekends away during the year

ii. How far do you travel to go on holiday? (you can choose more than one)
   a. We travel by car, less than 100km
   b. We travel by car between 100-400km
   c. We travel by car more than 400km
   d. We travel by plane nationally
   e. We travel by plane internationally (Australia)
   f. We travel by plane internationally (Europe)
   g. Other____________________

iii. What are your main activities when you go on holiday? (you can choose more than one)
   a. Camping
   b. Fishing, hunting, walking, relaxing
   c. Staying at ‘the bach’
   d. Visiting friends and family
   e. Road-tripping, seeing the sights
   f. Spending time on the boat or 4WDing
   g. Staying at hotels/backpackers & eating out
   h. Other____________________

iv. What are your reasons for going on holiday? (you can choose more than one)
   a. Spending time with family and friends
   b. Seeing new places, experiencing new things
   c. Relaxing – doing as little as possible
   d. Gathering /hunting food
   e. Sports event
   f. Changes every year

20. PETS

Do you have any pets? (this does not include animals you eat or that do work around the farm) YES, please answer this section; NO, please go to question 22.
i. **Very low resource pet** (goldfish, rabbit with all food and bedding produced onsite). How many animals? 1, 2, 3, 4, 5+

ii. **Low resource pet** (birds, hens, hamsters, guinea pigs etc). How many animals? 1, 2, 3, 4, 5+

iii. **Medium resource pet** (cats and small dogs – Chihuahua, Jack Russell etc). How many animals? 1, 2, 3, 4, 5+

iv. **High resource pet** (medium and large dogs). How many animals? 1, 2, 3, 4, 5+

v. **Do you own a horse, sheep or cattle as a pet?** Yes / no.

21. **What are the major barriers to having a less resource intensive lifestyle?** (you can choose as many options as you like)
   
   a. Not interested (I don't think about reducing the amount of resources I use)
   
   b. Responsibility (I feel I do my bit, the government needs to make it easier)
   
   c. Defiant (I think about it a lot but I wonder “what difference will my actions make”)
   
   d. Lack of support (I am a lone voice in a big household, I do what I can to influence my personal consumption)
   
   e. Cost (the cost of going green is a major barrier)
   
   f. Change of habit (I have a hectic lifestyle and I sometimes need to go with convenience)
   
   g. Community and housing (where I live is not conducive to using fewer resources because...)

22. **Your Tribe**

   i. **Please read through the list below and indicate the statements that seem most typical of you. You may tick more than one box.**

   a. Acting ethically is so much more important than financial gain

   b. Getting rich is one of my life goals

   c. I usually go off things I’ve liked when they become popular

   d. I am more at home in my own culture than in the general Kiwi culture

   e. I am part of a tight knit ethnic community

   f. I can make things for a fraction of the cost of buying them

   g. I don’t care about "getting ahead", I just need to be free

   h. I identify with my working class roots

   i. I identify with the down to earth people you find in country areas

   j. I seem to need to do things my own way, whatever the cost

   k. I strive to get the best house and car I can afford

   l. I would die if I had to live in the provinces - the inner city is my heartland

   m. If I did wrong it wouldn't just affect me, it would bring shame on my whole family

   n. It’s important to take responsibility for the social and environmental effects of your lifestyle choices

   o. It’s more useful to do practical things with your hands than it is to be a brain box

   p. I’ve grown up as part of a wealthy privileged class

   q. Most people haven’t heard the new music I’m into

   r. My appearance is always pretty under-stated
s. My family has a tradition of using our wealth to help people of lower classes

My family has a tradition of using our wealth to help people of lower classes

t. My private school education has connected me with important social networks

u. My sense of taste and style is obscure

v. Old money has class, new money is crass

w. People who shout about how good they are are heading for a fall

x. Possessions are pretty unimportant in the scheme of things

y. Buying new stuff is one of the great joys of life

z. The church is the centre of our community’s social life

aa. The older I get, the less I fit into the mainstream

bb. The things I own show what I’ve achieved so far

cc. There’s no point chopping and changing all the time, you should make a plan and stick to it

dd. There’s nothing better than a knotty intellectual issue to discuss

ee. We must change the way we live our individual lives, so we can change the world

ff. You don’t want to aim too high in life, just keep it simple

ii. **Now look back over the statements in the previous question you stated as being indicative of you and find the ONE statement you agree with most or that most resonates with you.**

a. Acting ethically is so much more important than financial gain

b. I am more at home in my own culture than in the general Kiwi culture

c. I can make things for a fraction of the cost of buying them

d. I identify with the down to earth people you find in country areas

e. If I did wrong it wouldn’t just affect me, it would bring shame on my whole family

f. It’s important to take responsibility for the social and environmental effects of your lifestyle choices

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l. We must change the way we live our individual lives, so we can change the world

Thank you for taking part in the Footprint Project.

From the Footprint Team.
References


AMC (n.d.) Farm machineries fuel use. Agriculture Machinery Centre, Paro.


monde/Indicateur/Biocapacité


