The Ecological Footprint of UEA:

Calculation, Analysis and Strategies.

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Executive Summary

An Ecological Footprint for the University of East Anglia (UEA) has been calculated and used as a basis for recommendations to improve sustainability at UEA. The Ecological Footprint measures a population's consumption and waste, and compares this to the planet's biocapacity. Criticisms of the Ecological Footprint approach are evaluated in this report, and our approach to these shortcomings is presented. Furthermore, transparency and explicitness of methodology are emphasised when calculating and presenting the Ecological Footprint of UEA.

Currently, there is no standardised methodology for calculating an Ecological Footprint. The method utilised in this analysis was derived from conversion factors based on professional Ecological Footprint consultancy publications. A component analysis is used to calculate the contributions of energy consumption, transport, water use, built land and waste to the UEA's total Ecological Footprint.

The total Ecological Footprint of UEA is calculated to be 13,160.59 global hectares (gha) per year. This figure can be converted into an Ecological Footprint 0.88gha/year per full-time student. The most significant factors in UEA's Ecological Footprint are waste, which is 59.5% of the Footprint, energy, 29%, and transport, 10.3%.

The Ecological Footprint calculated in this study could be refined with additional data to remove the assumptions in the calculations, but this could only be achieved with improved data monitoring. The Biomass Plant currently under construction will reduce UEA's Ecological Footprint by approx. 6%. However, efforts should be concentrated on reducing waste, as this is by far the largest component of UEA's Ecological Footprint.

There are several groups currently working to reduce the University's ecological impact. This analysis provides a strong framework for combining efforts in a manner that can communicate the immediate priorities for improving the sustainability strategy of UEA.

Acknowledgments

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Contents

1. Introduction

The Ecological Footprint is a tool increasingly employed to quantify human use of natural capital and can be utilised at many scales, from the individual to the planet. This report utilises the Ecological Footprint approach to quantify the ecological impact of the University of East Anglia (UEA). This is achieved by applying an Ecological Footprint component analysis, quantifying five factors that contribute to the institution's Ecological Footprint.

The overall aims of the project were to:

1. Calculate an Ecological Footprint of UEA that is as inclusive as possible, given the time and data available.
2. Use the resulting Footprint analysis as a basis for recommendations to improve sustainability at UEA.
3. Evaluate how our Footprint analysis may be used as a communication tool at UEA, and how the analysis could be improved and expanded in the future.

In order to achieve these aims the report is split into 8 sections, beginning with section 2 that introduces the concept of the Ecological Footprint and outlines its key limitations. As the Ecological Footprint is a highly contested concept this section explains how this report will address the shortcomings. Section 3 provides a comprehensive explanation of the methodology used in this study to calculate the Ecological Footprint of UEA, and the detailed calculations involved are provided in appendix 1. Section 4 presents a summary of the results by component and the total Ecological Footprint of UEA, the results are also displayed in a pie chart which clearly illustrates the relative significance of each component. Section 5 provides a discussion and evaluation of the results, indicating the strengths and limitations of this study. The following section 6 provides some recommendations for how UEA could reduce its Ecological Footprint based on these results. Section 7 evaluates UEA's current environmental strategies and discusses how the Ecological Footprint could be incorporated as a valuable communication tool into future projects designed to increase the University's sustainability.

2. The Ecological Footprint

This chapter will introduce the Ecological Footprint, describing the need to quantify biocapacity and the principles outlining the concept. It will explain the basic methodology for calculating an Ecological Footprint, and will define some of the key criticisms of Footprint analyses.

2.1 Quantifying Biocapacity

The impacts of humans on the planet have reached an unprecedented level. Through our patterns of consumption and waste, we are dramatically altering biogeochemical cycles, the composition of the atmosphere, the number and distribution of species and the structure and functioning of both terrestrial and oceanic ecosystems (Vitousek, 1997). Along with the system changes that are observable now, the earth potentially faces irreversible and catastrophic system feedbacks (Alley *et al.* 2003). These environmental changes will continue to affect resource availability and human survival whilst the natural capital continues to be exploited beyond its regenerative capacity (Wackernagel *et al.* 2002).

The UN-mandated World Commission on Environment and Development pioneered the term ‘sustainability’, which has become the dominant rhetoric in national and international policy. We are increasingly aware of the need to live within the planet’s means, to practice development “*...that meets the needs of the present without compromising the ability of future generations to meet their own needs*” (WCSD 1987).
Such a challenge requires a means of quantifying our impact on the planet and its resources, and measuring this against the planet’s current ecological limits (Moran *et al.* 2008).

2.2 Ecological Footprinting

The Ecological Footprint is a resource accounting tool that measures how much biologically productive land and sea is used by a given population or activity, and compares this to how much land and sea is available (Kitzes and Wackernagel, 2009). It was developed in 1990 by Mathis Wackernagel and William Rees as a means of making our ecological constraints clear and our sustainability strategies more effective and livable (Rees and Wackernagel, 1996).

The Ecological Footprint is an aggregate index, incorporating all the materials consumed and the wastes generated by the unit in question. These materials and wastes demand ecologically productive areas to provide resource flows and waste sinks, such as cropland to grow potatoes or a forest to sequester carbon dioxide emissions (Kitzes and Wackernagel, 2009). The Ecological Footprint aims to determine the total amount of land required to support these consumption-related resource flows and waste sinks (Rees and Wackernagel, 1996). To accomplish this, an amount of material consumed by a population or activity is divided by the yield of the land or sea area from which is was harvested or where its waste material was absorbed. The hectares that result from this calculation are converted to global hectares (gha) using yield and equivalence factors (Kitzes and Wackernagel, 2009). The sum of global hectares needed to support the consumption and waste patterns of a population or an activity gives its Ecological Footprint.

2.3 Global Hectares

The translation of consumption and waste patterns into the equivalent area of ecologically productive land required to produce resources and absorb waste is central to the Ecological Footprinting method. This ecologically productive land is given a standardised unit: Global Hectares. Global hectares represent hectares with the potential to produce renewable biomass equal to the world's potential average of that year (Monfreda *et al.* 2004). The use of a common unit makes the results of Ecological Footprint analyses globally comparable (Kitzes and Wackernagel, 2009), similar to financial evaluations that use a single currency to compare financial flows throughout the world.

The concept of quantifying the earth's ecological limits is not restricted to Ecological Footprinting. There have been several attempts to quantify the planet's biocapacity using financial evaluations, such as Costanza *et al's.* (1997) monetary analysis that values the biosphere at US$33 trillion a year. The creators of the Ecological Footprint argue that whilst such monetary analysis is an excellent method of raising awareness, it is essentially misleading as it suggests substitutability (Wackernagel *et al.,* 1998; Rees and Wackernagel, 1996). The Ecological Footprint method of using bioproductive land as a proxy for waste and consumption patterns communicates the finite character of the planet in terms that are far more readily understood (Wackernagel *et al.* 1998).

2.6 Ecological Footprint: from individuals to the planet

One of the key strengths of the Ecological Footprinting method is its applicability across scales. Ecological Footprint accounts have been calculated for the planet (Wackernagel, *et al.,* 2002; Ewing *et al.* 2008), for nations (Wackernagel *et al.* 1999; Moran *et al.* 2008; Bicknell *et al.* 1998; Haberl *et al.* 2001), for cities and regions (Warren – Rhodes and Koenig 2001; Hanley *et al.,* 1999, Collins, *et al.* 2006), for businesses, activities and institutions (Chapagain and Orr, 2009; Rees and Wackernagel, 1996; Herva *et al.,* 2008) and for individuals (Redefining Progress, Global Footprint Network). Since its development in 1996, the Ecological Footprint methodology has been applied in thousands of contexts, and its flexibility and adaptability make it practicable at all scales.

2.7 Critiques of the Ecological Footprint

The Ecological Footprinting method has been utilized across the globe in many different contexts. Many scientists, policy-makers and activists have welcomed the advance of this sustainability index as an effective device for presenting human resource use in an easily communicable way (Costanza, 2000). However, as the popularity and use of the

Ecological Footprint has increased, so too has a body of criticism against its principles and method. Critics argue for a systematic appraisal of the shortcomings of the Ecological Footprint, particularly because its rapid rise to recognition has preceded any critical evaluation of the techniques underlying it (Fiala, 2008; van den Bergh, 1999). Several criticisms of the Ecological Footprint are considered here under five categories: its use as an aggregate index, its consideration of trade and also of technological advances, the arbitrary nature of boundaries and the factors that it does not include. This list of critiques is by no means exhaustive, but includes the key criticisms that have been raised over the last ten years.

2.7.1 The Ecological Footprint as an Aggregate Index

A recurrent criticism of the Ecological Footprint relates to how it provides a one-dimensional indicator by summing up all the ecological impacts associated with consumption in terms of land use. Its creators maintain that as an aggregate indicator the Ecological Footprint is a powerful decision-making tool (Rees and Wackernagel, p.17, 1996). It allows policy-makers to quickly monitor the sustainability of consumption patterns, and assess whether human demand is within the amount that nature can supply (Wackernagel *et al.*, 2002). However, critics of the Ecological Footprint argue that a single indicator cannot accurately reflect the dynamics and detail of consumption. Costanza (2000) and Opschoor (2000) both caution that policy-makers are usually too busy to consider the detailed information behind an aggregate index. The uncertainties, weights and assumptions involved in creating the Ecological Footprint are ignored, and without this information the Footprint can communicate very little. Rees and Wackernagel (p. 17-18, 1996) are familiar with this criticism, and agree that, like all ecological models, it is necessarily simplified and cannot include all interactions. They argue that it is an under-estimation of humanity's land and resource requirements, which, whilst not precise enough for managing nature, still provides challenging guidelines for managing ourselves in a more ecologically responsible way. Other authors remain sceptical of its use even as a communication tool, and call instead for the use of multiple, complimentary indexes to better represent resource consumption (den Bergh and Verbruggen, 1999; Opschoor, 2000).

2.7.2 Boundaries in Footprinting

One of the most common applications of the Ecological Footprint is at the level of a city or a nation (e.g. Warren – Rhodes and Koenig 2001; Hanley *et al.,* 1999, Collins, *et al.* 2006). Opponents to the method argue that from an environmental perspective, historical and administrative borders are arbitrary. Consequently, rather than measuring the sustainability of a region or nation, Footprinting at this scale measures the inequality of wealth distribution (den Burgh and Verbruggen, 1999; Fiala, 2008). For example, the difference in the per capita footprint of Canada and Benin is due to the differences in consumption between the two nations, which in turn is due to the differences in per capita income. Furthermore, even within one region or nation we are likely to find similarly large differences. This variance is ignored in the Ecological Footprint, which instead makes strong assumptions about which consumption level within a region to consider (Fiala, 2008).

2.7.3 Trade

Proponents of the Ecological Footprint tend to call for self-sufficiency over trade (Wackernagel and Silverstein, 2000), a view that has also riled critics. Proponents of Footprinting argue that the current economic strategies of countries like Singapore, the Netherlands or Switzerland can only operate by draining other regions ecologically (Wackernagel and Silverstein, 2000). The expansion of world trade and production accelerates global resource depletion, and as consumers are regularly spatially and psychologically disconnected from the resources that sustain them, they have little direct incentive to conserve these resources (Wackernagel and Rees, 2006, p.20-21). Wackernagel and Silverstein therefore argue that a healthy global economy should encourage development that does not depend on increasing imports of ecological capacity from elsewhere "*...for the pragmatic reason that we are running out of elsewheres*". (Wackernagel and Silverstein, 2000). Conversely, Costanza (2000) argues that trade can be sustainable, and a weakness of the Ecological Footprint is that it simply doesn't distinguish between 'fair' and 'unfair' trade, or between imports from sustainable and unsustainable land use. In rejecting trade, the Ecological Footprint neglects comparative advantages of regions related to resource distribution, space and population density (den Burgh and Verbruggen, 1999). Ayers (2000) notes that trade actually makes it possible for areas to increase their carrying capacity by exchanging one type of available ecological service with another that is locally inadequate.

2.7.4 Technological Advances

Another criticism of the Ecological Footprint is that it cannot predict future growth in consumption as it does not account for changes in technology (Fiala, 2008). Wackernagel and Rees (1996) argue that technology improvements could either reduce or increase our demand on the planet's resources, and that whilst Footprinting methods cannot predict this they serve as an important measuring rod of progress towards sustainability. However, Fiala (2008) questions the ability of the Ecological Footprint to monitor sustainability. Taking the example of intensive vs. extensive production, he shows that intensive production, facilitated by technological advances, is actually considered beneficial by the Ecological Footprint as it takes up a relatively small amount of land. However, intensive production tends to increase waste, land depletion and land degradation. Footprinting would show extensive production to be more environmentally damaging because it involves a greater land area, although it could in fact be far more sustainable that its intensive counterpart. Thus as a region moves towards increasing intensive production it could be seen under Ecological Footprinting to be moving towards sustainability, when in fact the impacts of intensive production are far from sustainable.

2.7.5 Exclusions from the Ecological Footprint

Through aggregating information into one index, critics of the Ecological Footprint argue that not only is the detail within this information lost, but several key factors are excluded. Biodiversity, along with associated values such as species scarcity and habitat uniqueness are not accounted for in Footprinting (Mcmanus and Haughton, 2006). As discussed above, the differences in sustainable and non-sustainable land use are not accounted for, so for instance the impact of organic vs. conventional farming on biodiversity is not considered under current Ecological Footprinting.

Land degradation through contamination of the atmosphere, water sources and soil are not addressed in the Ecological Footprint. Ayers (2000) argues that in focussing exclusively on carbon dioxide, methane, another important greenhouse gas, is ignored.

Sulphur and nitrogen emissions from fossil fuel consumption are similarly neglected in Footprinting, though both may have important ecological consequences such as eutrophication.

Holmberg *et al.* (1999) also noted that waste assimilation beyond carbon dioxide is not generally considered in Footprint assessments. They discuss in detail the possibilities of including waste in an Ecological Footprint, and conclude that where assimilation capacities in the ecosphere are known for certain substances, a Footprint for that substance could be calculated. However, for the majority of waste substances, an Ecological Footprint cannot be applied as the assimilation capacities are not known and so they would have to be accounted for some other way.

Some critics have expressed concern that water is not given sufficient attention in Ecological Footprinting, and it is regularly excluded from accounts despite its central importance to resource production and human survival (Mcmanus and Haughton, 2006, Holmberg *et al.*,1999).

Finally, since the Footprint considers only the flow of consumption and some waste, it does not account for many important qualitative aspects of resource use. For example, the impacts of slash-and-burn harvesting in the rainforest are not considered, nor is the killing of dolphins associated with tuna fishing (Holmberg *et al.*, 1999).

2.8 How will we address these shortcomings?

We consider that there is a need at UEA for a more inclusive focus on sustainability, and believe that an Ecological Footprint analysis could provide a powerful communication tool for raising awareness. We agree with Rees and Wackernagel (1996) that despite its shortcomings, the Ecological Footprint can provide a means of addressing consumption patterns and improving sustainability. However, we will address these criticisms as follows:

- We will endeavour to make all our calculations and the assumptions and weighting involved transparent, so that any policy or future calculations made using our work may consider the entire process, not just the end result.

- We have included this summary of criticisms leveled at the Ecological Footprint in order to make readers aware of both the strengths and weaknesses of the measurement.

- We will include water in the calculations.

- We will be explicit not only about what we have included, but also what is missing.

- We will suggest where future work could improve on our Footprinting, including the use of other indexes to supplement the Ecological Footprint.

3. Methodology for Calculating UEA's Ecological Footprint.

After several weeks of research it has been surprisingly difficult to determine a standardised methodology for calculating the Ecological Footprint of an organisation. This is because although there are many basic calculators available on the internet which claim to provide a personal Ecological Footprint and two global organisations who are competing to make their methodology for calculating a nation's Ecological Footprint the standard measure (namely the "Global Footprint Network" and "Redefining Progress"), there is little information regarding the calculation of an organisation's Ecological Footprint. It seems that due to the growing market for calculating an organisation's Ecological Footprint, and the greater utility of such an approach, the consulting company's who are now profiting from calculating Ecological Footprints for organisations have become more secretive with their techniques.

However, after contacting the Global Footprint Network and "Best Foot Forward" (an Ecological Footprint consultancy based in Oxford), I have been able to derive a methodology from their recommendations and from other Ecological Footprint studies for organisations. At this point we would like to thank Kevin Lewis at Best Foot Forward for his valuable guidance and advice with regards to calculating the Ecological Footprint for an organisation. He recommended two key texts which have been used as a basis for the calculation of the Ecological Footprint of UEA, these were "Sharing Natures Interest" by Chambers, Simmons and Wackernagel (2000) and "Stepping Forward: A resource flow and Ecological Footprint analysis of the South West of England" by Chambers, Child, Jenkin, Lewis, Vergoulas and Whiteley (2005) which was part of *The Stepping Forward Report Series* conducted by Best Foot Forward Ltd.

Without Kevin's help and the recommendation of these two texts it would have been very difficult to derive an Ecological Footprint for UEA as there is simply no standardised or freely available methodology for calculating the Ecological Footprint for an organisation. Although the Global Footprint Network defines standards for Ecological Footprint accounting, they do not freely provide any instructions for methodology. Unfortunately the tools that they do provide are only available at a significant cost (min €570 for the "project license" of their National Footprint Accounts, see: Global Footprint Network, 2009) which was beyond the financial resources available for this project. However, by using the texts mentioned above a reliable methodology for calculating the Ecological Footprint for UEA has been derived based on conversion tables used by the Ecological Footprint consultancy Best Foot Forward.

3.1 The Ecological Footprint Data Collection

An Ecological Footprint is a very broad concept (as described above in section 2) and can cover an almost infinite number of factors. Therefore any study needs to define its limits. The limits to this study are due to time constraints and data availability. Our group has worked hard to contact the relevant people who are working on similar projects across the UEA campus, and have being able to form some very useful relationships. We have collaborated with Elaine Colk, who runs an Environmental Sciences Masters course in "Environmental Management Systems" at UEA and has been working on collecting data that can be applied to an Ecological Footprint analysis for the past 10 years.

After several meetings with Elaine and her Masters groups who are working on collecting the most recent set of data, we acquired as much relevant data as possible and learnt how difficult they have found it to acquire the data. This is due to a complete inadequacy of the recording of various sustainability measures and a lack of communication between relevant departments at UEA. It seems that although UEA is making significant efforts to become a low Carbon campus, there is very little effort being put into recording waste production, transport use and sustainability of procurement. Therefore data for some of the factors that we initially wanted to include in our Ecological Footprint analysis of UEA were simply not available.

Although the majority of the data was derived from research carried out by Elaine Colk and her Masters course students, we have also used UEA's most recent transport survey, a report on transport at UEA carried out by Keith Tovey (UEA) and GIS analysis to calculate our results.

3.2 Calculating an Ecological Footprint

The Global Footprint Network publishes the "National Footprint Accounts" every year, using an Ecological Footprint methodology known as the "compound" approach. This approach captures all resource use, including trade, within a geographical boundary, and is measured at a national level (Chambers *et al.*, 2005). The National Footprint Accounts also provide equivalence factors, which enable the conversion of data into the international standardised unit of the global hectare (gha) (Chambers *et al.*, 2005).

Although the National Footprint Accounts represent the global Ecological Footprint "gold standard", they are not directly applicable to an organisation, or immediately relevant to national or regional policy-makers, as they do not relate to policy areas or activities such as waste or transport (Chambers *et al.*, 2005). In order to make the accounts relevant to an organisation, a component methodology can be employed. This involves the analysis of key activity and policy areas, such as the production and consumption of food, domestic energy and personal transport (Chambers *et al.*, 2005), and will be used in order to analyse the Ecological Footprint of UEA. Although this approach is the only feasible methodology for calculating the Ecological Footprint of an organisation it does have several disadvantages. This is mainly due to data availability and reliability, which makes national and international comparisons difficult (Chambers *et al.*, 2000). Furthermore, assumptions must be taken in order to fill in the gaps in the data and so even direct comparisons between organisations may be inaccurate. Another problem with the component methodology can be double counting when adding the component footprints together, although when calculating the Ecological Footprint for an organisation this is not a problem (Chambers *et al.*, 2000).

3.3 The Geographical Principle

Before an Ecological Footprint of an organisation can be calculated, the boundaries of the study must be defined. The boundaries can incorporate either be the organisation's footprint (geographical principle) or the total consumption associated with the organisation's population (responsibility principle) (Chambers *et al.*, 2005). For this study the geographical principle was employed, as it is the only feasible boundary that can be applied considering the limited data that is available for UEA and the infinite difficulties that would apply to collecting data for the total impact of the population of UEA in all aspects of their lives.

3.4 The Component Approach

In order to analyse the Ecological Footprint of UEA, this report has employed a component approach utilising the most accurate and up-to-date data currently available for UEA.

The components that will be analysed are:

- Transport
- Energy Use
- Water Consumption
- Waste
- Built Land

These components represent the main categories of impact of UEA on the natural environment, and the data that is currently available for UEA. In order to calculate the total Ecological Footprint for UEA the individual component Footprints will be added together, and then presented as a percentage of the total Ecological Footprint to illustrate their relative significance.

3.5 How UEA's Ecological Footprint was Calculated

The following sections show how the Ecological Footprint for each component was calculated.

3.5.1 Transport

To calculate the Ecological Footprint of the transport of staff and students at UEA the following conversion table will be used, which is derived from Chambers *et al.* (2000). The conversion factors are based on fuel consumption, uplift for construction, maintenance and infrastructure, an estimate for apportioned road/rail space and average passenger occupancy. For further details see p.86 and p.150 of Chambers *et al.* (2000).

Table 1: Conversion factors for Various Modes of Transport

Mode of transport	**Conversion factor (ha-year per 1000 passenger kilometres) (B)**
Car	0.09
Business flights by staff	0.08
Bus and train	0.03

(Source: Chambers *et al.*, 2000: 86).

The data used to calculate the amount of passenger kilometres travelled by car to UEA is based on a report by Keith Tovey (2009) "Carbon Dioxide Emissions associated with Commuting to UEA" which was funded by Carbon Connections.

To calculate the amount of passenger kilometres travelled by bus to UEA we have used the percentage bus use of UEA staff and students based on 2005 UEA transport survey (source UEA Travel Plan 2006) multiplied by the current population of UEA (source UEA, 2007) to calculate the total number of people using the bus to travel to UEA in one year. This figure was then multiplied by the average number of kilometres travelled per person per day, which was assumed to be approximately 11km. This assumption is based on the distance of a return journey from Castle Meadow in the centre of Norwich to UEA along the 25 bus route, which we feel is an accurate representation of the average bus journey taken by people commuting to UEA. See Appendix 1.1 for the complete calculations and section 4.1 for the results.

3.5.2 Energy Use

The energy use footprint accounts for only direct energy used by the buildings of UEA, which is split up into electricity use and heating.

Electricity

To calculate the Ecological Footprint of UEA's electricity use the conversion factors shown in table 2 (below) are used. These conversion factors are derived from Chambers *et al.* (2000: 83) who based them on many different sources, and the estimated amount of forest land required to grow the required fuel for biomass.

Table 2: The Conversion Factors for Electricity Production via Different Energy Sources.

Energy source (electricity generation)	**Conversion Factor (gha/GWh) (B)**
Coal	198
Oil	150
Nuclear	147
Natural gas	94
Biomass - woody	36

(Source: Chambers *et al.*, 2000:83)

Heating

Most of UEA's heating comes from the combined heat and power plant (CHP) on campus, and so to avoid double counting only the conversion factors for electricity production are used. Therefore the University Plain (which the CHP provides heating for) is assumed to have no Ecological Footprint for heating. However there are several buildings that are part of UEA and are not heated by the CHP. These have been accounted for individually and the relevant conversion factors applied from table 3 below.

Table 3: The Conversion Factors for Heating Production via Different Energy Sources.

Energy: Primary and Secondary Fuels	**Conversion Factor (gha/GWh)**
Natural Gas	45
Fuel Oil	59

(Source: Chambers *et al.*, 2000:82)

The complete calculations for the Ecological Footprint of UEA's energy use can be seen in appendix 1.2, and the results are summarised in Section 4.2.

3.5.3 Water Consumption

The supply and consumption of water is not identified in the National Footprint Accounts, so for this study the methodology used by Chambers *et al.* (2005) will be employed to calculate the Ecological Footprint of water use at UEA. Their calculations account for the energy used to supply, collect and treat water, as well as treatment of wastewater and release back into the environment (Chambers *et al.*, 2005). The methodology for calculating the water supply conversion factor (the Ecological Footprint of one megalitre of water use) is shown in Table 4 below:

Table 4: Chambers *et al.* (2005) Calculation of the water supply conversion factor

Water supply (1 Megalitre)		**Energy land**
A	Carbon per megalitre (tonnes)	0.1
B	Carbon responsibility	69%
C	World carbon absorption (tonnes C/ha/yr)	0.95
D	Equivalence factor	1.35
(A*B*D)/C	Ecological footprint conversion factor (gha/megalitre)	0.099

(Source: Chambers *et al.*, 2005),

So if UEA's total water use is multiplied by the Ecological Footprint conversion factor provided by Chambers *et al.* (2005), then UEA's water Ecological Footprint can be calculated. This calculation is shown in Appendix 1.3, and the results are summarised in Section 4.3.

3.5.4 Waste

The total amount of waste produce by UEA in 2007 – 2008 was:

Landfill = 3539.2 tonnes.

Recycled = 1786.4 tonnes.

(Source: Boardman, pers. Comm., 2009)

However, the composition of UEA's waste is not known, and would be very difficult to determine due to obvious logistical and health and safety reasons. In fact the composition of waste for most organisations and households is unknown. To get around this obstacle, the average composition of UK municipal waste will be used in order to provide a rough estimate of the Ecological Footprint of UEA's waste. However there is not even accurate data about the average composition of UK waste. According to Burnley (2006) the only component of the municipal waste stream where the results from several studies can be compared is the household-collected waste. He further states that more recent studies show a good agreement in terms of composition, with the main components being in the following ranges:

Paper and card: 23–25%

Kitchen and garden waste: 35–38%

Plastics: 8–10%

Glass: 6–7%

Metals: 3–5%

(Source: Burnley, 2006)

The mean percentage will be used for each of the components above to provide a rough estimation of the composition of UEA's waste. This does not account for all of UEA's waste and only provides a rough estimation, as a large university is likely to have a different composition of waste than an average household.

The conversion factors to be used are derived from Chambers *et al.* (2000) and are shown in table 5 below.

Table 5: The Conversion Factors for Various Types of Waste.

Waste	**(Average) Footprint Conversion Factor (gha/tonne)**	**Assumptions**
Paper- landfilled	3.4	Accounted for through the embodied energy and materials in the waste plus an allowance for the landfill impact.
Paper – recycled	2.45	Calculated by the energy "saved" by recycling compared to virgin production.
Glass – landfilled	1.05	Embodied energy of a virgin product plus the landfill land.
Glass – recycled	0.85	Based on energy savings from recycling glass.
Aluminium cans – landfilled	13.6	Estimate accounts for embodied energy, mining land and landfill land.
Aluminium cans –recycled	0.65	Accounted by the energy savings compared to virgin production
Plastic – landfilled	3.85	Embodied energy, based on 9 different plastics, and landfill land.
Plastic - recycled	2.2	Energy savings through recycling

(Derived from Chambers *et al.*, 2000: 95)

The calculations for the Ecological Footprint of UEA's waste are shown in Appendix 1.4, and the results are summarised in Section 4.4.

3.5.5 Built Land

In the National Footprint Accounts, built land is included as a separate component, but not distinguished by different uses. Therefore built land includes all areas that are built on, contaminated or degraded to the degree that they are rendered biologically unproductive (Chambers *et al.*, 2005).

To calculate the built land Ecological Footprint for UEA, the conversion factor calculated by Chambers *et al.* (2005) will be employed. In order to calculate the conversion factor Chambers *et al.* (2005) apply a yield factor provided by the National Footprint Accounts to convert built land area into hectares of global average crop area, and then a crop area equivalence factor to convert the data into global hectares. Table 6 below demonstrates this methodology and the resulting conversion factor calculated by Chambers *et al.* (2005).

Table 6: Calculation of the built land conversion factor

Built land (per hectare)		**Built Land**
A	Built land (ha)	1
B	Crop yield factor	2.44
C	Equivalence factor	2.18
A*B*C	Ecological footprint (gha/hectare)	5.32

(Source: Chambers *et al.*, 2005)

By estimating the amount of built-up area occupied by UEA using ArcGIS and Ordnance Survey data available form www.digimap.edina.ac.uk and multiplying this figure by the Ecological Footprint conversion factor provided by Chambers *et al.* (2005) the Ecological Footprint for built land of UEA can be calculated. All of the buildings belonging to UEA were included (inc. Earlham Hall, The Sainsbury Centre and all accommodation including the Village) along with any concreted areas, roads and paths. The calculations for the Ecological Footprint of UEA's built land are shown in Appendix 1.5, and the results are summarised in Section 4.5.

3.5.6 The total Ecological Footprint of UEA

The total Ecological Footprint of UEA = the Ecological Footprint of transport + the Ecological Footprint of energy use + the Ecological Footprint of water consumption + the Ecological Footprint of waste + the Ecological Footprint of built land.

4. Results

4.1 Transport

Mode of transport	Value (1000s passenger km/year) (A)	Ecological Footprint (gha) (A*B)
Car	13050.98	1174.5882
Business flights by staff	unavailable	n/a
Bus and train	5940	178.2
TOTAL Ecological Footprint for transport		**1352.79**

4.2 Energy

		Ecological Footprint (gha)
Electricity	Onsite Generation	1881.88
	Imported Grid	1779.71
	Total	**3661.59**
Total Heating		137.22
Total Oil		12.98
TOTAL energy footprint		**3811.79**

4.3 Water Use

	Total (Megalitres) (A)	Ecological footprint conversion factor (gha/megalitre) (B)	TOTAL Ecological Footprint (gha) (A*B)
UEA's Water Consumption	327.8115	0.099	**32.45**

4.4 Waste

The Ecological footprint of UEA's waste (recycled and landfilled) is **7830.45 gha.**

4.5 Built Land

The Ecological footprint of UEA's built land is **133.11 gha**.

4.6 The total Ecological Footprint of UEA

Component	Ecological Footprint (gha)	Ecological Footprint (%)
Transport	1352.79	10.3
Energy	3811.79	29.0
Water Use	32.45	0.2
Waste	7830.45	59.5
Built Land	133.11	1.0
TOTAL Ecological Footprint of UEA (gha)	**13160.59**	**100**
Total Ecological Footprint of UEA per person (Total footprint/18000)	0.73	
Total Ecological Footprint of UEA per student (Total footprint/15000)	0.88	

The UEA campus is 129.5 hectares (UEA, 2007), whereas the total Ecological Footprint of UEA is 13160.59 gha. Therefore the Ecological Footprint of UEA is 102 times the size of UEA's campus. It can be seen from fig. 1 that the largest impacts arise from waste (59.5%), energy (29%) and transport (10.3%).

An eco-efficiency indicator can be derived by comparing the footprint to the total population of staff and students at UEA (18,000), which equates to an ecological footprint of 0.73 global hectares per person. On the other hand, if we are trying to assess the creation of value, in UEA's case educating students, the footprint per full-time student should be compared. There are almost 15,000 full time students at UEA (UEA, 2007), and so the per-student footprint is 0.88 global hectares, inclusive of all the components measured by this study.

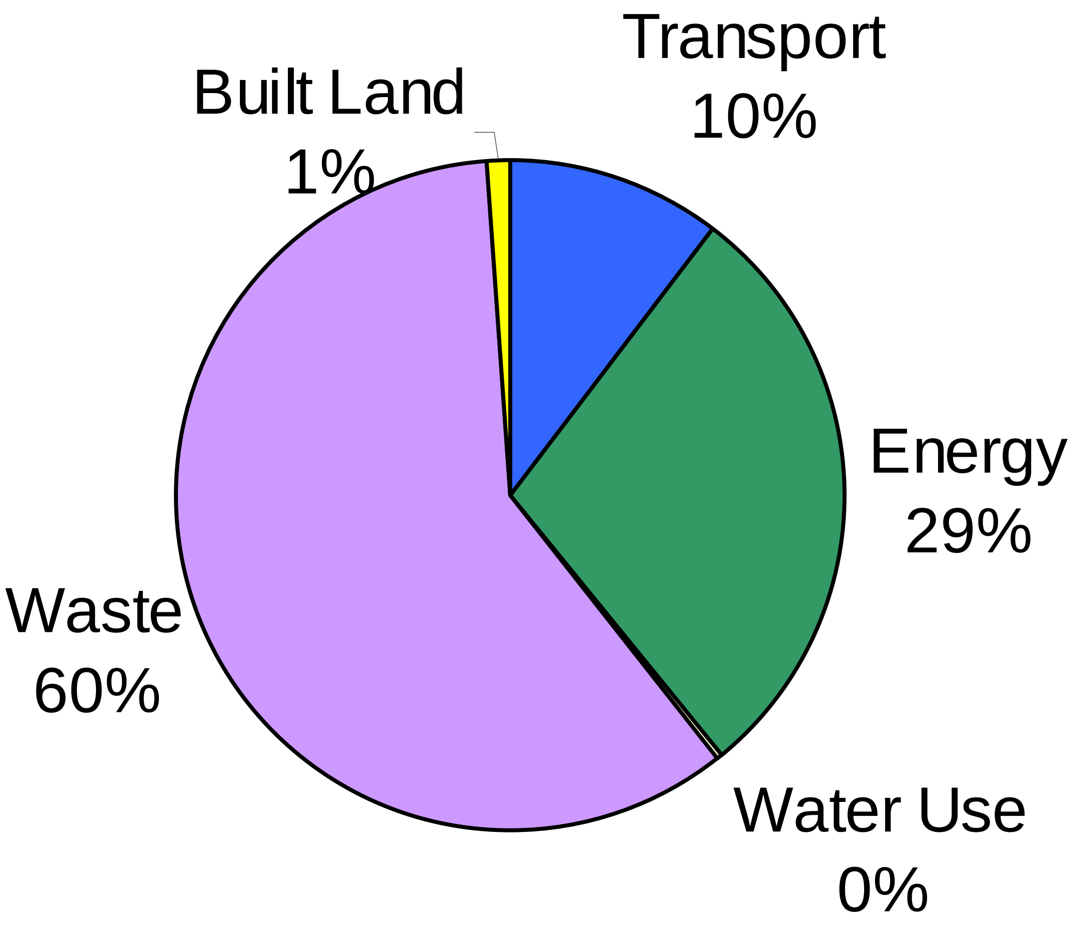

Fig. 1: The Ecological Footprint of UEA by component, rounded to the nearest whole percentage.

5. Discussion

5.1 Where to take an Ecological Footprint?

The Ecological Footprint (Ecological Footprint) calculated for UEA thus far is only an estimate. As discussed previously, the concept behind the Ecological Footprint tool is one that is inherently scaleable yet inherently impractical when taken to its theoretical limit. Given this situation and the desire to understand UEA's footprint as much as possible, which paths can we take to enhance our understanding and how far along them can we go? The answer to this is, perhaps frustratingly, as far as we are willing to spend the time and effort to go. Of course, this is not true *ad infinitum* and there will come a point at which our abilities to gather information and determine certain factors become insufficient to expand the Ecological Footprint calculation any further. Still, there are sufficient omissions and assumptions in the footprint previously calculated that any future workers will find their time easily filled. Future workers may choose take this study, note our limitations/omissions and work to refine or remove them. This is the nature of science and such a method is welcome to be applied to this study.

5.2 Where the Weaknesses Lie

The first limitation of the Ecological Footprint calculation carried out is simple to rectify and will better refine the final result. In using a component approach, we selected particular areas to study and, as a result, chose to omit other areas. This is perfectly reasonable given the time and personnel constraints but provides an immediate method to expand the Ecological Footprint. Purchased products represent perhaps the largest contributors to UEA's Ecological Footprint that was not examined in the context of this project. It was mainly omitted because of the challenge of dividing footprint responsibility between manufacturer and user. Even a rudimentary analyse of this area would give a more complete estimation of UEA's Ecological Footprint.

Moving beyond omitted components brings the discussion onto the subdivision of the chosen components. A component in an Ecological Footprint is calculated by the effect of a number of unique factors that define that component. Any limitations in measurement (perhaps for lack of time or funding) or assumptions made at this stage will cause the calculated component to be less true to the actual Ecological Footprint. The particular assumptions we chose, or were forced, to make are addressed in detail below.

5.2.3 Waste

The largest component of UEA's footprint (60% overall) contains the most assumptions and so has the greatest potential errors. The current monitoring strategy of waste is essentially non-existent and the only information that can be obtained is a bulk disposal quantity derived from the financial records of bin collection. These bulk figures do not give any indication of waste composition or relative 'fullness' of the bins. Further discussion of the waste calculations carried out is given in section 5.3.

5.2.4 Energy Consumption

As the second largest component of UEA's Ecological Footprint, the assumptions that were made in the energy consumption calculation have great potential to introduce inaccuracies. As mentioned previously, the lack of information on how the conversion factors for various fuels were calculated hamstrings accurate calculations for UEA. This is particularly evident for the electricity generation footprint.

In the case of the grid-produced energy, there is a complete lack of footprint conversion data for the nuclear component. The case for this, as set forth by Sharing Nature's Interest, is from the lack of risk assessment capability of the Ecological Footprint method. Their argument is that in the long-term the risk of ecological damage is as high as that of fossil fuels. For this reason, the authors suggest using a footprint equal to that of fossil fuels in order to avoid giving nuclear power a zero footprint value. The value used for this is an average of the coal, oil and natural gas values (198, 150 and 94 Ha/GWh respectively) and the calculated value is close to that of oil at 147 gha/GWh. The imported electricity is from Europe and is brought to the UK through the 2GW interconnection from France (LEG, 2001). Given that much of the power is likely to be sourced from French nuclear reactors, it is considered reasonable to use the same conversion for the imported power as for the nuclear component of the UK grid power.

Another weakness in the calculation is that there is no factor given for storage electricity. Without a conversion factor for this, the UEA Ecological Footprint is incomplete. Presumably the government table refers to pumped storage facilities such as Dinorwig power station (First Hydro, undated), which use excess grid electricity to elevate water and release it through turbine generators in times of higher demand. In this case, a future Ecological Footprint analysis may choose to calculate a relative proportion of each electricity generation source (Coal, oil, gas etc.) that is contributing to pumped storage and so generate an overall footprint contribution from this component.

By using the conversion factor of natural gas for the renewable energy fraction, the choice was made to produce an overestimate of the footprint component. This was done simply because of the limitations of the conversion factors available for the calculations. Given the lack of explanation and transparency in creating the conversions, assumptions must be made to account for the missing conversion factors. Erring on the side of caution was considered more prudent.

The gas electricity footprint for the UEA plain from the on-site power plant makes up the single largest component of the entire Ecological Footprint and, as such, deserves closer examination. A simple multiplication has been carried out based on the natural gas conversion factor. While this may seem reasonable at first glance, the oversimplification introduced into the Ecological Footprint from this may be significant.

As mentioned above, there is limited transparency in the calculation of the conversion factors. The author's of Sharing Nature's Interest carried out detailed calculations that are intended to best represent the footprint factors of different components. Without having access to the full documents, we can only assume that the factor produced represents some average value, hopefully representative. Of course, there are many different types of gas turbines for electricity generation and efficiencies can reach over 40% for a simple cycle or more than 55% for combined cycle (Langston, 2004). It is not evident which value was used to generate a conversion factor or whether there is some weighted world average that was calculated and used. In any case, with the combined cycle turbines operating at UEA and the on site use of most of the electricity (removing any transmission losses) the footprint calculation may well be an overestimation if the university is penalised by a more average factor.

5.2.5 Water and Transport

The water component suffers from some limitations of data. For example, there was no information available on the water consumption of the village launderette and so it was assumed to be the same as the medical centre launderette. In addition, limited sewerage quantities are recorded for the university plains and these may not even be required since the conversion factor claims to include the 'cost' of water cleaning. In this case, the water footprint would be approximately 10 Global Hectares less (~32 instead of ~42). Given that the water component represents only 1% of the total footprint, then this possible error of 0.25% is relatively minor and so we chose to err on the side of overestimation.

The transport component is one that is very complex and our calculations are deeply simplified. This is mostly due to lack of data but also due to complications of footprint division. For example, a member of staff travels 20km in their car to work at UEA. After their workday is completed they travel to a guest lecture on their subject in Norwich city centre, drive to the supermarket and then return home. The total distance travelled on the return journey is 40km for a total day's distance of 60km. In this case, how should the footprint be apportioned? Perhaps UEA can take on the basic distance to and from the person's home but should they include the mileage to the guest lecture? In the case of students riding on the bus, should this be included fully in the footprint? There is a case to be made for either side of the argument e.g. students probably represent most of passengers on the 25 & 35 routes but the buses would, and do, still travel these routes when there are no students present. This is discussed by Chambers *et al.* (2005) as the responsibility principle, where the impacts are assigned to the individuals creating them and the reasons behind the individual's activities. In the case of UEA the argument goes that the student's would not travel along these bus routes if the university did not exist and so the responsibility lies with UEA.

For the sake of carrying out the calculation with limited data we made some simple assumptions:

- The cars are single occupancy.
- The percentage of bus travellers from the Transport survey (2009) are all travelling an average of 11km i.e. from Castle Meadow in the City Centre to UEA campus (5.5km each way).
- The bus travels do not include any student journeys outside of term time.

The data for the car travel were obtained from an unpublished study by Dr. Keith Tovey (2009) and so details of the method are limited.

One major omission from the transport data available was that of flights associated with the university. Assessing this component brings many of the same issues discussed with respect to car travel and the relative 'responsibility' of such footprint contributions. The flight component may be relatively simple to calculate with respect to business travel by staff (if the appropriate records are made available), but there is also a large component from international student travel that should be at least addressed if not calculated.

5.3 Assessing the Footprint and Stepping Towards the Future

Given the large number of comments made above regarding the negative or limited aspects of the Ecological Footprint, one could be forgiven for thinking that there is nothing useful to be obtained. This is far from the truth as the relatively simple calculations carried out in this study have already ranked the contributors to the UEA's Ecological Footprint quite reasonably. Given the obscure factors that can appear to be behind such a footprint, it is important to act in full transparency when carrying out any analysis. If nothing else, it is critical for forming more accurate future estimates that the limitations of early work are well documented.

When this study's methodology is compared to that suggested by professional organisations, it holds up well. Using the component-by-component method suggested by Chambers *et al.* (2005), our report is complete with the exception of the omitted factor of purchasing. That an estimated footprint can be calculated in a relatively short time is a testament to the effectiveness of the technique and the data acquisition by key people at UEA (particularly Elaine Colk).

Overall, the Ecological Footprint is dominated by the energy consumption and transport components. These are not unusual in Ecological Footprint analyses (e.g. Oxford Brookes university Ecological Footprint in Chambers *et al.*, 2000) but UEA should be congratulated for having a much smaller energy footprint than other, smaller universities. A study carried out by Emily Wright in the Environmental Sciences Department of Colorado College in 2002 generated an energy component footprint of nearly 5000 gha. Given that the population of the college is listed as ~2100 (Colorado College Facts, 2008-2009), the per capita energy footprint is much higher than that of UEA's ~18000 students (~2.5 gha per capita vs.~0.19 gha per capita). Indeed, the progressive stance of UEA on energy becomes very apparent when the new biomass gasifier plant is considered. This plant is a 1.4MW capacity combined heat and power unit that has an expected return period of seven to eight years (UEA Estates and Buildings, 2008). According to Dr. Keith Tovey (Pers. Comm. 2009) in the school of Environmental Sciences, a conservative load factor (percentage of the time it will operate at full capacity) for the plant is 60%, possibly rising to near 70% as the operation becomes smoother. These numbers were used to generate a tentative estimate of the footprint reduction due to the biomass replacing grid imports.

1.4 (MW) x 31557600 (seconds per year) x 0.60 (load factor) = 26508384 MJ/year

26508384 / 3.6 (MJ/KWh) = 7363440 KWh = 7.36 GWh

So the biomass plant will replace 7.36 GWh of the 12.60 GWh of grid imports to leave a 5.24 GWh import.

Revised Imports (GWh)
5.24

Grid import mix with biomass plant operational

Fuel	Mix (% / 100)	GWh Imported	Ecological Footprint factor	Ecological Footprint contribution (Gha)
Coal	0.34	1.78	198	352.42
Oil	0.01	0.03	150	4.27
Gas	0.37	1.92	94	180.69
Nuclear	0.20	1.07	147	156.99
Renewables	0.05	0.24	94	22.75
Imports	0.03	0.16	147	23.02
Storage	0.01	0.04	0	0
			Total	**740.15**

Biomass plant footprint

Biomass (GWh)	Ecological Footprint factor	Ecological Footprint contribution (Gha)
7.36	36	264.96

Total new energy footprint (gha) = Gas CHP + Revised Imports + Biomass + Gas heating + Oil heating

= 1881.88 + 740.15 + 264.96 + 137.22 + 33.69

= 3057.90 gha

This new footprint of the energy component is 775.33 gha lower than the current estimate of the energy component (at 3057.9 gha). This represents an approximately 20% reduction in the energy component of the Ecological Footprint and an approximately 6%

reduction in the entire footprint. Of course, if the plant operates at the near 70% load factor that Dr Tovey suggests, these reductions will become greater.

So, given the previous discussion, where should future calculations of UEA's Ecological Footprint look to improve? Before looking to refine any of the current components, it is imperative that some kind of assessment is made for the omitted factor of purchasing. This is not a simple task however as there are many links in the supply chain (raw materials, transport, manufacturing, advertising etc.) for any product and the responsibility principle must be applied to each of them, and to UEA as the final purchaser. This is a very complex task but the waste component offers another possible method for dealing with this.

The waste component generated using the factors given in the method section is approximately twice the size of the next largest component (energy). This extremely high but the factors from Chambers *et al.* (2000) have been generated to include more of a complete embodied energy footprint than simply the 'cost' of disposing of an item. In this case, any calculations for a waste component actually represent (at least partly) the manufacturing and purchasing costs associated with the waste products. Using the waste products as a proxy for purchasing as well as disposal is not a perfect solution, but given the challenges of carrying out a purchasing footprint it may well be the best option.

Once the omitted components have been included, there is plenty of scope for fine-tuning the calculated components with more complete data or reduced assumptions. The individual component comments in section 5.2 give suggestions for these.

6. Recommendations: How to Reduce the Ecological Footprint of UEA.

There can be many possible ways to try and reduce the ecological footprint of UEA. Only once there is a clear idea and measurement of the current impact that UEA has on the environment can people begin to try and make necessary changes to reduce environmental impact and decrease the ecological footprint. There are many aspects to look at closely in order to decide how to reduce the ecological footprint of UEA. It is important to examine each aspect individually as well as together as a whole and how each is affected by one another. Different aspects that impact the environment must be analyzed and treated differently, and methods must be improved to reduce these impacts. Some of these measures used to calculate the ecological footprint of UEA are: transportation, consumption and waste, energy use, and water use. While all of these are significant, it is important to prioritize which impacts are most stressing on the environment and which issues need to be addressed and reduced immediately. While some improvements are already being made to the university to help reduce its impact on the environment, more changes and recommendations can be helpful when trying to reduce the ecological footprint of UEA and change its practices for the better.

6.1 Energy

One of the most important things to consider when looking at methods to try and reduce the ecological footprint of UEA is the energy use of the campus. The amount of energy used at UEA is one of the major contributing factors to the impact the university has on the environment surrounding it. Part of the energy use of the university has already been improved greatly and is seen as one of the most efficient in the country. For example, the combined heat and power plant that UEA uses is much more efficient than using separate plants that other businesses and universities use. UEA also plans to reduce its amount of carbon emissions in the near future. Also, a revolutionary biomass power plant is currently being planned and built, the goal being for it to be completed in 2009 and reduce carbon emissions by up to 8,000 tons per year. This plant is one of the first built in the country, and if all goes as planned, the target is to reduce emissions up to 80% by the year 2015 rather than the previous goal of 2050. UEA is also currently working to improve the energy efficiency of older buildings, as well as expanding district heating and cooling networks, which will increase efficiency from central generation (Newton pers. comm. 2009). Another important way to decrease energy use is by creating and participating in energy awareness campaigns and even competitions to reduce energy use, which help educate and involve students, staff, and others on simple ways to reduce energy use daily. UEA has participated in a few of these campaigns in the past, and plans to do more in the future (Newton pers. comm. 2009). These campaigns can help people become more aware of their own daily impacts on the environment and educate them on how to reduce it.

While all of these improvements are being made to UEA energy use to reduce emissions, more can still be done to help reduce the ecological footprint in terms of energy. Several buildings on campus are run on grid electricity and natural gas or oil, perhaps switching to more sustainable sources would further improve sustainability, which will help UEA in the long run. Even simple everyday things done by students and staff can help to reduce the amount of energy used on campus and around the university. Some easy things that UEA as a whole can do to reduce energy use include using energy saving light bulbs in buildings and making sure that all lights and computers are turned off in rooms around campus at night and even when they are not in use. Computers and screens can be programmed to go into a standby mode so they hibernate or turn off automatically when they are not in use to save power and reduce costs (Goodall, 2009). Also, turning off all computers, monitors, copiers, etc. is an easy and useful thing to do. These changes would significantly decrease the amount of energy that is used, and wasted, each year at UEA. Also, in dining areas such as the Blend, Zest, the Hive, and the Union Pub, the use of high power LED lighting reduces energy use and is much more efficient than regular lighting. It will be interesting to see how the upcoming biomass plant affects energy use and exactly what improvements will be seen once it is built and running properly (refer to section 5). In terms of buildings, however, simply turning thermostats down by a few degrees and only heating or air conditioning rooms that are in use can greatly reduce overall energy use.

6.2 Transport

Another important aspect of UEA that can be changed in order to reduce impact is transport. It is important to note that the scope of an ecological footprint is always changing, and can include outside factors, such as driving. While many students, teachers and staff members regularly take the bus, which is a great method of transportation, the majority still drive their cars to campus. Only about 20% of the total population at UEA takes the bus to campus every day, while 22% drive their own car (UEA Travel Plan, 2006). While many students do live on campus, a large number live off campus and do not choose public transport for their daily commute.

Taking the bus, riding bikes, and walking to campus are all great alternatives to driving separately, which is a waste of gas and also pollutes the environment around UEA greatly. Travelling by bus is much less carbon intensive than travelling by car. Even carpooling with others to campus is a good idea to help reduce carbon emissions and environmental impact. One idea to help encourage this would be an incentive plan for students and staff members to benefit from taking the bus, riding their bikes, carpooling, or walking to school to make it cheaper for students not to drive their own cars to campus every day. Even carpooling or choosing another alternative to driving just one or two days a week can help make a difference and reduce personal carbon emissions by up to 20% each year (epa.gov, 2009). There are many alternatives to driving your own car which can help reduce the ecological footprint of UEA. Another measure that could help would be for UEA to switch their vehicles to electric, saving the university money in the long run and improving sustainability. Transport is a big area to be covered and does not always only include the boundaries of UEA, but everyone that travels to and from campus everyday, making it difficult to measure and hard to make concrete changes and suggestions for improvement.

6.3 Waste

In terms of consumption and waste at the University of East Anglia, many recommendations for improvement can be made in order to help reduce the amount of materials that the university uses and wastes each year. Reducing the amount of waste produced and consumed by UEA is a top priority in reducing the ecological footprint, as even though it accounts for 60% of UEA's footprint, an enormous amount of waste is not accounted for in our analysis. Even so any changes or improvements that could be made to reduce waste would be a huge step in the right direction for the university.

Recycling is a major issue that can definitely be improved around campus. Many people feel recycling is an important way to help reduce waste and turn it into something useful again, yet the majority of people continue to throw away things that can be easily recycled such as paper, plastic, glass, and cardboard. The total amount of waste from UEA in 2007-08 that went into landfill was 3,537.24 tons, and the amount that was recycled was 1,786.4 tons (Boardman, pers. Comm.., 2009). Less than half the amount of waste on campus was recycled, while around 80% of all waste is recyclable (recycling-revolution.com). These numbers show potential for improvement if individuals as well as the university itself chose to recycle more of their waste. There are numerous benefits from recycling. For example, every ton of paper that is recycled saves 17 trees, and universities use and waste an incredible amount of paper. Also, it takes 95% less energy to recycle aluminium than it does to make it from raw materials. Making recycled steel saves 60%, recycled newspaper 40%, recycled plastics 70%, and recycled glass 40% (recycling-revolution.com, 2009). These savings far outweigh the energy created as bi-products of incineration and landfilling. An increase in recycling would not only benefit the environment, but would also cut costs at UEA. Well-run recycling programs cost less to operate than waste collection, landfilling, and incineration (epa.gov, 2009).

One way to possibly encourage recycling on campus is to put more bins across the university with clear labels so people know what exactly can be reused. Recycling campaigns are also a great way to get more people involved and raise awareness about the benefits that come from recycling. Also, UEA could change its purchasing practices by buying and use more recycled and reused materials such as paper and cardboard as opposed to using new virgin materials. Even switching a small percentage of purchases to recycled materials will begin to make a difference and eventually begin to save the university money as well. Because UEA produces so much garbage, recycling part of it is a way to reduce the amount of waste produced by the university. Every bit of recycling makes a difference. For example, one year of recycling on just one college campus, Stanford University, saved the equivalent of 33,913 trees and the need for 636 tons of iron ore, coal, and limestone (recycling.stanford.edu, 2000).

A significant amount of waste is produced by the dining establishments at UEA. While some places such as Zest and the pub do use washable plates, glasses and silverware, the Blend and other places do not. These disposable dishes cost a lot of money to produce and buy and they create large amounts of waste, for example, paper cups for drinks such as tea and coffee. Other universities and businesses have taken notice of this waste and started offering discounts for individuals who bring their own reusable mugs and cups. This would be a great idea for UEA and would not only reduce waste at these places, but also save money for the university overall.

Purchasing practices are another important aspect of how universities are run and the impact they have on the environment. Universities purchase large amounts of products, and it is important to know just where these products come from and how they are made. Making purchases such as natural and organic food and recycled products such as paper can help to reduce destruction of planet earth and shows that protecting the environment is important to the school as well. An earlier study done by a student society at the University of British Colombia states that the ecological footprint will be reduced by doing things such as purchasing organic food grown within 2km of the campus, which will also be beneficial for local farmers and companies (AMS, 2008). This university also seeks to reduce its footprint by composting 100% of pre-consumer food waste as well as some post-consumer food and paper waste, purchase at least 30% recycled paper, and create a natural food store on campus so students and staff have the option of shopping there (AMS, 2008). While natural and organic foods are a bit more expensive, the small added cost is worth the benefits for the surrounding natural environment as well as local businesses.

6.4 Water

While water use and conservation is sometimes overlooked, it is an important issue that is becoming increasingly pressing. Universities use an immense amount of water every day, and require the use of clean water for numerous systems all over campus. To reduce water use at the university, many important changes can be made that will reduce the amount of water used and wasted daily on campus. Water saving techniques and equipment are being installed to not only conserve water but also cut costs. Old equipment should be replaced with current energy-saving devices. Leaky sinks, showers, and toilets in buildings should be repaired, and sinks with automatic shut-off should be installed (epa.gov, 2009). It is also a possibility to use toilets that conserve water, which are becoming increasingly popular as they reduce water use and annual costs. Low-flow shower heads and toilets that use less water are also great ideas for alternative to be installed in dormitories to conserve water. These changes will save money for the university in the long run. To reduce outdoor water use, it is suggested that universities maximize natural vegetative cover, and limit the amount of lawn area provided. Maintaining playing fields using drought-tolerant grasses is also an environmentally friendly alternative to using grass that takes lots of water to sustain (epa.gov, 2009). These better management practices are economically beneficial to the university as well as the environment around it.

As it can be seen, making an effort to reduce consumption can not only benefit the environment but also individuals as well as the university itself. Making changes to transportation, purchasing and waste patterns will have an environmental and economic benefit for the university in the long run.

7. UEA: Commitment, Communication, Continuity

7.1 UEA: 'exemplar of best practice'?

> "*We value sustainability because we know that we can achieve nothing if our activities are not sustainable, both economically and environmentally*" (UEA Corporate Plan, 2008-2012).

The University of East Anglia is an internationally renowned university, well respected for its environmental credentials. These are exhibited through highest quality research and teaching, placing it as a global leader in the environmental sciences (UEA Corporate Plan 2008-2012). This is well represented by several impressive symbols of environmental aptitude, praised by the wider community. For example, UEA boasts the largest concentration of World Leading Low Energy Buildings (UEA, 2007), including the Elizabeth Fry Building, and the Zuckerman Institute for Connective Environmental Research (ZICER) building, which won the first ever Low Energy Building of the Year Award in 2005. The University is currently building a biomass fuelled gasification combined heat and power plant, which will be "one of the greenest power plants in the country" (UEA, 2007). It is predicted that the biomass power plant will reduce UEA's carbon emissions by 34% after two years in operation (UEA, 2007). Vice-Chancellor professor Bill Macmillan claims: "As you would expect from a university with a world-renowned School of Environmental Sciences, we take our energy efficiency seriously and are committed to practising what we preach in tackling climate change (UEA, 2007). UEA has set itself the goal of being an exemplar of good practice environmentally by becoming a 'Low Carbon Campus', which is just one of its core values for campus sustainability (UEA Corporate Plan 2008-2012).

7.2 UEA Environmental Policy

The University of East Anglia has stated provision for 'resourcing the vision' for facilities and environment, to enhance the campus, and become "an exemplar of good practice environmentally" (UEA Corporate Plan 2008-2012). Moreover, "we take our energy efficiency seriously and are committed to practising what we preach in tackling climate change" (vice-chancellor Professor Bill Macmillan, 2007). However, as Martyn Newton, the University's Risk and Sustainability Manager, astutely asserts, "our original 1960s and 70s buildings present challenges in energy efficiency" (UEA, 2007).This discrepancy is familiar of a wider concern that has arisen from research for this study. The symbols of environmental aspiration introduced above undoubtedly set a high standard that one hopes the University's campus environmental policy should exemplify. A comprehensive critique of UEA's environmental policy is unnecessary within the remit of this report. Suffice it to say that it reveals that the University of East Anglia is by no means unaware of its role in promoting "environmentally sympathetic" policy. It has been said that university implementation of an environmental policy portrays its "formal demonstration of intent regarding environmental performance improvement" (People & Planet, 2008). However, this optimism is not unanimous. For example, Wright (2006, in Watson-Brown, 2008) rightly criticises that these policies "rarely offer specific directives of action plans" and so remain "statements of intent". The first 'general operational objectives' in UEA's environmental policy is to *"create and implement mechanisms for understanding, controlling and reviewing UEA's significant environmental impacts"*. This study treats such claims with necessary caution given that no such comprehensive mechanism yet exists. The Ecological Footprint approach, if developed fully and sustained properly, could provide this such a mechanism.

7.3 Weaknesses

The question stands whether the underlying, everyday mechanisms operating at UEA support the high precedence set by the University's ambitious environmental policy and its multitude of low energy buildings, proudly illustrated in many UEA publications. This is not to criticise UEA's environmental achievements, which are undeniably great and well-recognised as such. Instead this report emphasises that always more can be done to reduce UEA's environmental impact. From the Ecological Footprint derived in this study it is clear that, despite the University's 'low energy strategy' (UEA, 2007), energy usage remains a large component (26%) of UEA's environmental impact. Moreover, the difficulty found during data collection for this study, because of inconsistent, inadequate, or inexistent monitoring of environmental impact data, often confounded by poor communication, reflects at fundamental weakness in UEA’s current sustainability strategy. Therefore, we suggest that the Ecological Footprint approach highlights important issues surrounding the environmental impact and sustainability of the UEA campus which are not acknowledged in any University publications, and should be used to enhance current communication of the UEA’s true environmental performance, as discrepancies evidently remain.

7.4 Sustainability at UEA

Research for this project has enabled our group an insight into the overall action towards sustainability taking place at UEA, aside from the low energy business ventures. We learned of groups and individuals who are each working towards improving UEA’s environmental performance. The work of Elaine Colk’s students had often been informed by meetings with members of staff listed below. This was useful to assess what level of environmental impact monitoring occurs within their University divisions, and indeed what data could be obtained. The assistance and data provided by Elaine Colk for this project negated meetings with the staff mentioned above as her MSc students had largely covered our intended lines of enquiry. Thanks to this cooperation, we were able to collate secondary data and limit our primary research to calculating the Built Land. This allowed us to collect far more accurate and comprehensive data than we would have been able to in the time available.

- Martyn Newton: Risk & Sustainability Manager
- Mel Pascoe: Energy Manager
- Dawn Dewar: Transport Co-ordinator
- Steve Boardman: Procurement Manager
- Janice Bone: Deputy Director of Waste and Recycling

In addition, the University of East Anglia features numerous well-renowned research departments, including some whose aims are specifically to monitor and reduce the environmental impact of the UEA campus (CRed at UEA). These include:

- The School of Environmental Sciences
- The Carbon Reduction (CRed) Programme
- The Tyndall Centre for Climate Change Research
- Climatic Research Unit
- The Low Carbon Innovation Centre including 'Carbon Connections'
- Centre for Social and Economic Research on the Global Environment (CSERGE)
- Zuckerman Institute for Connective Environmental Research
- Centre for Environmental Risk

7.5 Environmental Action

As well as the individuals and departments introduced above, I wish to draw attention to the activities of individuals and groups in the student community who are encouraging attention to environmental issues on campus. One such group is the UEA Go Green Campaign, represented by the Student Union Environment Officer and other members of the Student Community, which has communicated sustainability objectives for UEA (Fig.2).

Figure 2: UEA 'Go Green' objectives

1. Creating and implementing a carbon reduction strategy within 3 years to cut UEA's total carbon emissions by levels significantly ahead of government targets (currently at least 42% by 2020 and 80% by 2050 compared to 1990 levels).

2. Carrying out a comprehensive environmental audit by the end of 2009, to establish significant time-bound targets for improvement.

3. Employing by September 2009 at least one dedicated full-time member of staff responsible for coordinating the reduction of the university's environmental impact.

These laudable objectives are supported by a team of people with great enthusiasm for, and commitment to, environmental issues, and specifically the environmental impacts of UEA. The UEA Go Green Campaign is an innovation supported by People & Planet, a student campaigning network in Britain. The ‘Green League’ (People & Planet, 2008) has ranked UK universities by both their commitment to systemic environmental management and their performance. This document which considers the quality of UEA’s environmental policy, in terms of what it covers and whether it is reviewed, suggests that UEA has much work before it can become “exemplar of best practice” (People & Planet, 2008). Environmental initiatives currently engaged in by UEA students are convincing, and continue the success of other recent student-led environmental activities at UEA. These include Green Wing, Eco-campus society, and the Campus Sustainability Initiative society, each with the intention of improving student life at UEA through engagement in pertinent environmental issues such as climate change. These, and other campaigns, have each had successes and merit recognition.

7.6 UEA’s Ecological Footprint as a Communication Tool

It is hoped that the visual representation of UEA’s environmental impacts derived in this study should provide an excellent catalyst for communication amongst the University community, particularly by student groups, whose implicit intentions are made public by conspicuous campaigning, and thus require effective visual aids to portray salient points of supporting research. It is hoped that our Ecological Footprint should provide the basis for a new structure for auditing, involvement, and communication at UEA. It should improve on many of the weaknesses identified by Watson-Brown (2008) in her Development Studies dissertation, which uses UEA as a case study for evaluating sustainability initiatives in Higher Education. Watson-Brown (2008), provides a comprehensive overview of UEA’s sustainability and highlights weaknesses in the current system that hinder further progress at UEA (Figure 3). It describes critical ‘conditions for success’ in the sustainability strategy of UEA (Figure 4).

Figure 3 ‘Barriers to change’ at UEA, from Watson-Brown, 2008

- Economic
- Communication
- Institutional attitude
- Individual pressures
- Transient student population
- Conflicting priorities

Figure 4 Recommendations for UEA, from Watson-Brown, 2008

- Senior support
- Environmental policy
- Full-time environment officer
- Environmental auditing
- Communication and involvement
- Funding
- Leadership

These students at UEA, who clearly recognise the University’s potential in “leading the way in sustainability and the battle against climate change” (UEA Go Green, 2009), should be heartened that research into UEA’s environmental impacts is improving and should be rewarded for their commitment. However, a problem often cited as a barrier to change towards the sustainability of universities is the transience of the student population (Chang, 2004, in Watson-Brown, 2008), and this is indeed true for UEA. Only when there is continuity in the infrastructure available to students for pursuing environmental objectives, which is surely beneficial to a University claiming world leadership in the environmental sciences, can the aptitude of students and staff alike for instigating positive change, be fulfilled. The Ecological Footprint approach would go some way to providing this essential infrastructure upon which further research and student campaigns could be based.

7.7 Communication

Higher Education institutions such as the University of East Anglia have a considerable role in the promotion of, and commitment to, sustainability objectives, both within the institution and through external engagement (HEFCE, 2008). The Ecological Footprint approach has been recognised as a potential strategy for assisting the sustainability of higher education institutions in the UK and beyond (Clugston & Calder, 1999; Litten, 2005). As well as analysing the present situation, an institutional Ecological Footprint provides a framework for future sustainability planning, and can indicate priorities for improvement. The Ecological Footprint approach communicates the finite character of the planet in terms that are readily understood (Wackernagel *et al.* 1998). It quantifies environmental impact and thus translates abstract concepts into more readily understandable numbers, tables, and illustrations, lending it to "all kinds of potential exhibits" (Wackernagel & Yount, 2000).

However, "even the best Ecological Footprint analyses are ineffective if they cannot be communicated clearly to a variety of audiences" (Wackernagel & Yount, 2000). Therefore, developing a communication strategy to illustrate the main aspects of empirically-based footprint analysis is essential to promote action across all strata of the University institution. The Ecological Footprint approach should be used at UEA as a communication tool by those who endeavour to create positive change to the sustainability of the campus by reducing its environmental impact. The Ecological Footprint tool should benefit monitoring and analysis, and help to visualise, plan and act, on sustainability initiatives. Our Ecological Footprint could well be applied to UEA to better align its current practices with its ambitious environmental aspirations. UEA has undeniably made great progress towards becoming 'exemplar of best practice' environmentally, but critically needs to "portray understanding and commitment through more careful campus management" (People & Planet, 2008). The UEA divisions listed above need to be enhanced by a full-time sustainability officer, responsible for implementing an ongoing monitoring system across all sectors, so that the Ecological Footprint derived in this study can be enhanced and trusted to improve communication between currently somewhat disparate actors. The University should use the Ecological Footprint of UEA to support any projects initiated by these groups to provide outreach of knowledge to the whole university community, to ensure that UEA's environmental policy delivers actual, observable, and sustainable results.

8. Conclusion

This report is the synthesis of eight weeks of research, development of ideas, and communication, both within the group and externally. The methodology for calculating an ecological footprint was difficult to derive as no standardised calculations have been published. Confounding this was the complexity we encountered in collecting data for inclusion in UEA's Ecological Footprint. Nonetheless, this analysis provides a good representation of the relative weight of each component. The following conclusions address each of our initial research aims:

1. *To calculate an Ecological Footprint of UEA that is as inclusive as possible, given the time and data available.*

We have conducted an Ecological Footprint analysis for UEA that incorporates all the data available within this short space of time. Our approach and assumptions within it have been explicit and the resulting Footprint provides a good representation of the relative weight of each component. Compared to professional Ecological Footprint analyses that are often simplified due to time and data constraints, this was a very thorough investigation. Reliable and comprehensive data, professional conversion factors and good synthesis of results have contributed to a powerful Ecological Footprint of UEA.

The total Ecological Footprint of UEA, accounting for transport, energy, water use, waste and built land, is calculated to be 13,160.59 gha per year. This can be converted into an eco-efficiency indicator of Ecological Footprint per full-time student, which for UEA is 0.88 gha per student per year. This is a more useful figure for comparisons over time; as UEA's population grows inevitably so too will its total Ecological Footprint. Furthermore, the component approach utilized in this report has enabled the identification of the most significant factors affecting UEA's Ecological Footprint, which in descending order of significance are: waste (59.5%), energy (29%), and transport (10.3%).

2. *To use the resulting Footprint analysis as a basis for recommendations to improve sustainability at UEA.*

We have proposed a series of recommendations which are based on the results of the Ecological Footprint analysis. Waste, Energy and Transport account for approx. 99% of the Footprint and therefore should be the focus of future sustainability strategies at UEA.

The Biomass Plant currently under construction is a clear example of the University's aims to reduce its environmental impact. When in operation we expect the plant to reduce UEA's energy Footprint by approx. 24%, and its overall Footprint by approx. 6%. This will contribute to goals of campus sustainability. However, waste is the largest component in the Ecological Footprint derived from this study. Reducing the amount of waste produced at UEA is a priority if the Ecological Footprint is to be reduced. This will require new strategies and a holistic approach, as waste is an issue for all sectors of campus. Increasing recycling will be important, but reducing the amount of all waste produced should be given precedence.

Improved monitoring of Ecological Footprint components is an absolute priority. The difficulties found during the data collection for this project reflect a key problem in the sustainability strategy of UEA. Data needs to be easily accessible and recorded consistently in order to implement effective strategies to reduce the Ecological Footprint of UEA.

3. *To evaluate how our Footprint analysis may be used as a communication tool at UEA, and how the analysis could be improved and expanded in the future.*

The Ecological Footprint calculated for UEA has considerable potential as a tool to aid communications of sustainability strategies at the University. Whilst many investments are being made to reduce UEA's environmental impact, a reassessment is necessary to raise the profile of currently weaker areas in UEA's sustainability strategy. For example, very little is currently being done to monitor and reduce waste on campus, which our Ecological Footprint has shown to be a significant contributor to UEA’s environmental impact.

In conclusion, the key strength of the Ecological Footprint measurement is its value as a communications tool. It incorporates a variety of measures into a holistic indicator of environmental impact that highlights UEA's currently inconsistent sustainability strategy. This study has produced an Ecological Footprint that offers a clear visual representation of UEA’s current environmental impact. This could be used to greatly improve communication between those who are working towards calculating and reducing UEA’s environmental impact and the wider University community.

Appendix 1: Calculation of the Ecological Footprint Results

A1.1 Transport

Calculating the number of passenger kilometres travelled by bus to/from UEA per year:

Table A1: The Results of UEA's Most Recent Transport Survey (2005)

Mode of Transport	Percentage of UEA population
car	22%
bus	20%
walk	36%
cycle	19%
other (motorbike, park and ride)	3%

(Source: UEA Travel Plan, 2006)

Based on the results of UEA's most recent transport survey, conducted in 2005, the number of people who take the bus to/from UEA is 20% of the total population of 18000:
20% of 18000 = 0.2 x 18000 = 36000 **(A)**

Number of kilometres travelled per person per journey assumed to be 5.5km (based on distance from UEA to Castle Meadow along the 25 bus route). This should be multiplied by 2 in order to account for a return journey to UEA. So the number of kilometres travelled per person per day is assumed to be approximately 11 km **(B)**

Total distance travelled by bus per day (Km) is equal to the number of kilometres travelled per person per day multiplied by the number of people who take the bus per day:
Total distance travelled by bus per day = A x B = 39600 Km.

The number of working days in an academic year (assuming that this is when most of the travel to UEA will be conducted) is 150. This is based on subtracting the number of weekend days from a 30 week academic year.

Therefore the approximate total distance travelled by bus per year is:
39600 x 150 = 5940000 Km.

Before this figure can be inserted into the Ecological Footprint conversion table it needs to be converted into total 1000 passenger km per year by dividing by 1000:
Total 1000 km per year = 5940000/1000 = 5940.

Table A2: The total Ecological Footprint of transport at UEA

Mode of transport	Value (1000s passenger km/year) (A)	Conversion factor (gha per 1000 passenger kilometres) (B)	Ecological Footprint (gha) (A*B)
1000s passenger km/year in car	13050.98	0.09	1174.5882
Business flights by staff	unavailable	0.08	n/a
Bus and train	5940	0.03	178.2
TOTAL Ecological Footprint for transport			**1352.7882**

A1.2 Energy

A1.2.1 Electricity

The Ecological Footprint of UEA's electricity consumption: Imported grid electricity

The Net UEA Grid Import of electricity is produced by a variety of sources. In order to provide a more accurate measure of the Ecological Footprint of UEA's imported grid electricity the UK's average energy mix proportions (given in table A3) are used in table A5 below to calculate the approximate amount of electricity UEA derives from each fuel type and the corresponding Ecological footprint. Renewable energy is assumed as being equal to natural gas for simplification and because approximately 30% of renewable energy is produced from landfill or sewage gas (source: BERR, 2008). Nuclear energy is assumed to be equal to Fossil Fuels, due to the risk factor that it involves (Chambers *et al.*, 2000) and imports are assumed to be equivalent to nuclear because the majority come from France which utilises almost only nuclear energy for electricity production.

Table A3:UK Electricity Generation Mixture

	TWh	% of UK mix
Coal	125	33.97
Oil	2	0.54
Gas	135	36.68
Nuclear	75	20.38
Renewables	17	4.62
Imports	11	2.99
Storage	3	0.82
TOTAL	**368**	**100**

(Source: UK Energy White Paper 2007)

Table A4: Electricity use by UEA 2006/2007

Location	Amount Imported from Grid (KWh)	Amount Exported to Grid (KWh)	Net Grid Import of Electricity (KWh)	Net Grid Import of Electricity (GWh)
UEA Plain	11322300	57700	11264600	11.26
UEA village	910296	0	910296	0.91
NAM	363717	0	363717	0.36
Earlham Hall	68414	0	68414	0.07
UEA TOTAL	**12664727**	**57700**	**12607027**	**12.60**

(Source: Elaine Colk)

Table A5: Calculating the Ecological Footprint of UEA's Net Imported Grid Electricity

Fuel Type	% of UK energy mix (A)	GWh Imported (A/100* 12.60 = B)	Conversion Factor (gha/GWh) (C)	Ecological Footprint (gha) (B*C)
Coal	33.97	4.280	198	847.48
Oil	0.54	0.068	150	10.21
Gas	36.68	4.622	94	434.44
Nuclear	20.38	2.568	147	377.48
Renewables	4.62	0.582	94	54.72
Imports	2.99	0.377	147	55.38
Storage	0.82	0.103	0	0.00
TOTAL Ecological Footprint of UEA's net imported grid electricity				**1779.71**

The Ecological Footprint of UEA's electricity consumption: electricity produced on site

The footprint for the electricity produced on site is calculated by multiplying the GWh produced by the CHP (20.02) by the footprint factor for gas (94 gha/GWh).

Footprint of onsite generation = 20.02 x 94 = 1881.88 Global Hectares

The total Ecological Footprint of the UEA's electricity consumption

Total electricity footprint = electricity produced on site + imported grid electricity

UEA's Total electricity footprint = 1881.88 + 1779.71= 3661.59 Global Hectares.

A1.2.2 Heating

Table A6: The Ecological Footprint of Gas used for Direct Heating

Location	KWh	GWh (A)	Conversion Factor (gha/GWh) (B)	Ecological Footprint (Global Hectares) (A*B)
Village	2307467	2.307467	45	103.84
Dev Farm	332101.9	0.332102	45	14.94
NAM	293705	0.293705	45	13.22
WoodHall	116071	0.116071	45	5.22
TOTAL Gas direct heating footprint				**137.22**

Oil
Earlham Hall uses 0.22 GWh of oil for heating.
The Conversion Factor for fuel oil is 59 (gha/GWh)

Therefore the total Ecological Footprint for heating using oil is:
0.22 x 59 = 12.98 Global Hectares

TOTAL ENERGY FOOTPRINT
Total energy footprint = Electricity + Gas Heating + Oil Heating
Total energy footprint = 3661.59 + 137.22 + 12.98

Total energy footprint = 3811.79 Global Hectares

A1.3 Water Consumption

Table A7: The Ecological Footprint Conversion Factor For Water Consumption

Water supply (1 Megalitre)		Energy land
A	Carbon per megalitre (tonnes)	0.1
B	Carbon responsibility	69%
C	World carbon absorption (tonnes C/ha/yr)	0.95
D	Equivalence factor	1.35
(A*B*D)/C	**Ecological footprint conversion factor (gha/megalitre)**	**0.099**

(Source: Chambers *et al.*, 2005),

Table A8: UEA's Water Consumption for 2006 - 2007

Location	Water (m^3)
University Plain Total	288325
Village	27111
Earlham Hall	801
Colney Lane	2168
Dev Farm	106
Village Laundrette	1771.75
Street Launderette	5757
Med. Centre Laun	1771.75
TOTAL	**327811.5**

(Source: Elaine Colk)

Table A9: Calculating UEA's Ecological Footprint for water consumption

	Total (m^3)	Total water consumption (Megalitres) (A)	Ecological footprint conversion factor (gha/megalitre) (B)	TOTAL Ecological Footprint (gha) (A*B)
UEA's Water Consumption	327811.5	327.8115	0.099	**32.45**

A1.4 Waste

Table A10: Calculating UEA's Ecological Footprint for Waste and Materials

Waste	Average percentage composition of UK household waste (A)	UEA's total waste in tonnes 2007 -2008 (landfilled or recyled) (B)	Total amount of UEA's waste per component in tonnes (A * B/100) (C)	(Average) Footprint Conversion Factor (gha/tonne) (D)	Ecological Footprint (D * E)
Paper-landfilled	24	3539.2	849.41	3.4	2887.99
Paper – recycled	24	1786.4	428.74	2.45	1050.40
Glass – landfilled	6.5	3539.2	230.05	1.05	241.55
Glass – recycled	6.5	1786.4	116.12	0.85	98.70
Aluminium cans – landfilled	4	3539.2	141.57	13.6	1925.32
Aluminium	4	1786.4	71.46	0.65	46.45

cans –recycled					
Plastic – landfilled	9	3539.2	318.53	3.85	1226.33
Plastic - recycled	9	1786.4	160.78	2.2	353.71
TOTAL					**7830.45**

A1.5 Built Land

Table A11: Calculation of the built land conversion factor

Built land (per hectare)		**Built Land**
A	Built land (ha)	1
B	Crop yield factor	2.44
C	Equivalence factor	2.18
A*B*C	Ecological footprint (gha/hectare)	5.32

(Source: Chambers *et al.*, 2005)

UEA campus is 320 acres, which is 129.5 hectares (UEA, 2007).

By estimating the total area of land that buildings of UEA occupy using ArcGIS and multiplying this by the Ecological Footprint conversion factor provided by Chambers *et al.* (2005) above, the Ecological Footprint for built land of UEA can be calculated.

25.02 hectares x 5.32 gha/hectare = 133.11 gha

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