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AN EXPLORATION INTO THE CARBON FOOTPRINT OF UK HOUSEHOLDS

By

Angela Druckman and Tim Jackson

RESOLVE Working Paper 02-10

UNIVERSITY OF SURREY

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Abstract

If the UK is to achieve a reduction in greenhouse gas (GHG) emissions of at least 80% by 2050 on 1990 levels in line with the nation's Climate Change Act, it is imperative that policy-makers understand the drivers of UK emissions. In this paper we explore emissions that arise as a result of UK household expenditure, which is responsible for over three quarters of UK emissions when measured from the consumption perspective.

Accordingly, the aim of this paper is to look at the composition of the carbon footprint of an average UK household. This provides a basis for untangling the complex interplay between the material, economic, psychological, sociological and cultural forces that drive the emissions attributable to UK household consumption. The figures presented here will provide a foundation for academics, policy-makers and anyone interested in reducing household carbon emissions.

We explore in detail the carbon footprint of an average UK household (26tCO_2e), focusing on the activities that drive emissions. Our results show, for example, that around 10% of the carbon footprint is due to holidays, with total recreation and leisure activities (including holidays) accounting for well over a quarter (27%) of all household emissions. Other notable results are that food and catering accounts for nearly a quarter (24%) of emissions, and that the GHG emissions due to a meal eaten out are around 71-83% higher than for a meal eaten in the home.

This Working Paper presents results that have been estimated using the Surrey Environmental Lifestyle MApping (SELMA) framework. The baseline results presented here will be used as a foundation for further analysis and interpretation in future papers to be produced by RESOLVE.

1. Introduction

The UK has a formidable challenge to meet its legally binding target to reduce greenhouse gases (GHGs) by at least 80% by 2050 on a 1990 baseline (CCC 2009; HM Government 2008). It is becoming increasingly evident that all consumers in the UK must play a part in achieving the required reductions (Halpern et al. 2004; Jackson 2008), and in this paper we focus on the contribution that can be made by households.

The underlying assumption in our study is that carbon emissions are associated with all goods and services purchased by households (Carbon Trust 2006; Daly 1996; Daly and Cobb 1989; HM Government 2005; UN 2002; UNCED 1992). Based on this, our study takes the expenditure of an average UK household and estimates the carbon emissions that are emitted during the production, distribution, use and disposal of the goods and services purchased. By taking this perspective, known as the 'consumption perspective', we include, in theory, all emissions that occur along supply chains, whether the emissions arise in the UK or abroad.

Households are the focus of this study as they are the drivers of over three quarters of UK carbon emissions (76% on average for years 1990-2004), when measured from the consumption perspective (the remainder is due to government expenditure (11%) and capital investment (13%) (Druckman and Jackson 2009a)). There is an argument that all government and capital investment expenditure is made in support of households (Carbon Trust 2006; Jackson et al. 2007; Peters and Hertwich 2004) and therefore analyses sometimes allocate these expenditures to households. However, in order to draw direct policy implications with regard to households this allocation has not been carried out in this study.

There are two basic components of a carbon footprint. One component is carbon emissions from 'direct' energy use, such as for space heating, hot water and lighting. The other component is 'embedded' or 'indirect' carbon emissions, which are the emissions that arise in supply chains in the production and distribution of goods and services purchased by households. Embedded emissions may occur in the UK, but also, due to the globalisation of supply chains, many arise outside the UK. Embedded emissions account for around two thirds of the total average UK household carbon footprint, and therefore it is important that they are included. Our study contrasts with many carbon footprint tools available on the internet which are prone to omit embedded emissions.

The starting point for the analysis in this paper is that the carbon footprint for an average UK household in 2004 was around 26tCO_2e, as estimated by earlier work using the Surrey Environmental Lifestyle MApping (SELMA) framework (Druckman and Jackson 2009a)[1]. In this study we attribute GHG emissions to functional uses to give us information on the activities that the GHGs are used to support.

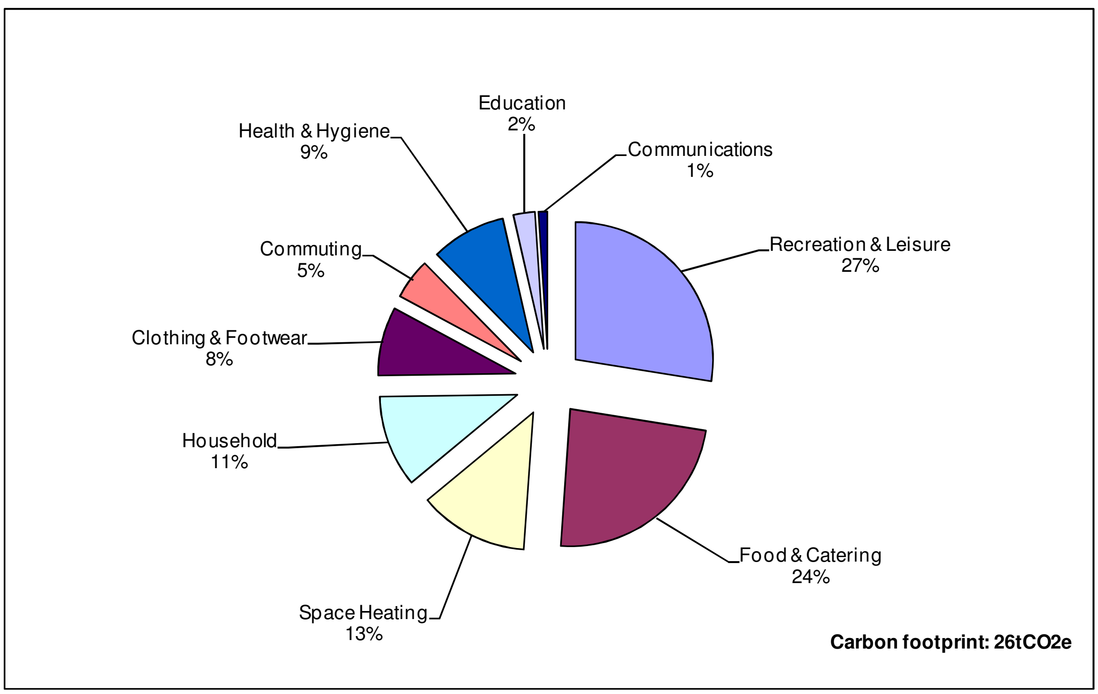

Figure 1: The carbon footprint of an average UK household (2004): high level functional uses

[1] There is, of course, a wide variation in the carbon footprints of different socio-economic groups. See Druckman and Jackson (2009b) for some analysis on this matter.

Accordingly, Figure 1 shows the carbon footprint of an average UK household disaggregated according to major high level functional use categories, in terms of greenhouse gases (GHGs)[2]. By allocating to functional uses, all emissions that arise due to, for example, eating are allocated to Food and Catering. Hence, Food and Catering includes emissions due gas and electricity used for cooking, and also personal transport fuels used for food shopping trips.

The aim of this paper is to look at the composition of the carbon footprint in greater detail than shown in Figure 1, to provide a baseline of current UK household GHG emissions for 2004 [3]. A particular focus is Recreation and Leisure: this includes holidays and 'everyday' activities, and as shown in the pie chart, this category accounts for over a quarter (27%) of the footprint. The other major categories we investigate are Food and Catering (which accounts for 24%), Household[4] (11%), and Clothing and Footwear (8%). We address questions such as:

- What proportion of the carbon footprint is embedded in paraphernalia purchased in the pursuit of hobbies?
- How much carbon is associated with holidays?
- How much is emitted through meals eaten at home? Is a meal eaten in the home more or less carbon intensive than one eaten out of the home?
- What is the relative amount of emissions due to care of clothing compared to emissions embedded in garments?

This will be of use as a basis for untangling the complex interplay between the material, economic, psychological, sociological and cultural forces that drive the emissions that arise from UK household consumption. The figures provided here will provide a foundation for academics, policy-makers and anyone interested in reducing household carbon emissions.

This paper is organised as follows: Section 2 presents the Methodology used for disaggregating the average UK household carbon footprint into functional uses. Section 3 presents the results for the footprint as a whole and includes a sub-section on travel emissions, whereas the following section (Section 4) examines in detail key high level functional use categories that are major drivers of UK households' carbon emissions. In the Discussion (Section 5) we elucidate the difference between production and consumption figures, before considering the global nature of supply chains that provide goods and services for UK consumption. In the Conclusion we highlight a few of the findings and emphasize that the results here will be used as a basis for future more interpretive papers.

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[2] This is an updated version of the footprint published in terms of GHG emissions in Druckman and Jackson (2009a) and, in terms of carbon dioxide only, in Druckman and Jackson (2009b).

[3] This is a "working" paper in the sense that to some extent it presents work in progress: during further work analysing and interpreting the footprint, refinements may be made to the analysis presented here.

[4] Excluding space heating.

2. Methodology

The estimates of carbon emissions used in this paper are produced using the Surrey Environmental Lifestyle MApping (SELMA) framework. This has been developed as part of the ESRC Research Group on Lifestyles, Values and Environment (RESOLVE) project in order to provide quantitative estimates of the environmental impacts of UK lifestyles. The year of focus for the study is 2004.

In this study 'carbon emissions' refers to a basket of six GHGs: carbon dioxide, methane, nitrous oxide, hydro-fluorocarbons, perfluorocarbons and sulphur hexafluoride (ONS 2008). The unit of measurement is carbon dioxide equivalent (CO_2e) (OECD 2005).

The household basis is considered preferable to a per capita basis because many emissions arise at a household level, such as those from energy used for space heating. Household estimates may be simply divided by the number of people in the household to give per capita emissions. However this approach is questionable, particularly in the case of infants and children. Should each child take full responsibility for an equal share of the emissions from petrol used to drive to the supermarket for a weekly food shop? Or should the emissions be allocated according to the weight of food consumed by each member of the household? Such problematic questions are the reason why, in general, it is more meaningful to estimate the carbon footprint on a household basis. It should be noted that the data sources used in SELMA are for the UK at a national level. In order to estimate results on an average per household basis, national emissions are divided by the estimated total number of dwellings in the UK (DCLG 2008a), adjusted for the number of vacant properties (DCLG 2008b).

We base our analysis around nine major high level functional uses categories of activities for which households use their carbon. This categorisation has been used in previous studies (Carbon Trust 2006; Druckman and Jackson 2009b; 2009a; Jackson et al. 2006). In this study we investigate the major categories of Recreation and Leisure, Food and Catering, Household, and Clothing and Footwear in greater depth, and to aid the analysis we add sub-divisions as shown below:

1. Recreation and Leisure
    - Holidays
    - Non- holiday recreation and leisure
2. Food and Catering
    - Eating in
    - Eating out
3. Clothing and Footwear
    - Embedded emissions in items of clothing and footwear
    - Care of clothing
    - Travel to shops for clothes shopping
4. Household
    - Fabric of household and furnishings
    - Household services
    - Lighting
5. Space Heating

6. Commuting
7. Health and Hygiene
8. Education
9. Communications

By allocating emissions to functional use categories we aim to shed more light on the drivers of carbon emissions, by looking at the relative amounts of carbon that various activities give rise to. The rationale for our choice of categories is in part to reflect the range of material, social and psychological needs that are associated with modern lifestyles (Jackson and Marks 1999; Jackson and Papathanasopoulou 2008). Some of these are basic functional needs for material subsistence, protection and health. Others are associated more with social needs such as communication and education. Others cover a range of social and psychological motivations for leisure, relaxation, and interacting with friends and family.

Through using high level functional use categories our study differs from other footprint studies, which tend to analyse emissions according to the Classification of Individual Consumption According to Purpose (COICOP) (UN 2005). COICOP assigns carbon emissions to categories such as 'electricity, gas and other fuels' but gives no indication of the end-purpose for which these energy services are used. In this study we attribute GHG emissions to functional uses to give us information on the activities that the GHGs are used to support. For example, rather than reporting carbon emissions due to gas use, we allocate the emissions to the activities that it supports, such as cooking, space heating, hot water for bathing or washing clothes. Similarly, emissions due to car travel are attributed to the purpose if the journey, such as commuting, escort travel (such as the school run) and food shopping.

As noted above, there are two fundamental parts to the carbon footprint of a household. The first is 'direct' emissions: these emissions arise from fuel used directly by households such for space heating and fuelling private motor vehicles. The second part is 'embedded' or 'indirect' emissions. These are the emissions that arise along supply chains in the production and distribution of goods and services purchased by households. We look at how embedded and direct emissions are allocated in turn separately, commencing with allocation of direct emissions.

2.1 Allocation of carbon emissions from direct energy use

Direct household GHG emissions are recorded in the UK Environmental Accounts (ONS 2008). Emissions due to direct energy use in the home ('Consumer expenditure - not travel'), and those due to personal transportation ('Consumer expenditure – travel') are presented separately. We look at direct energy use in the home first.

'Consumer expenditure - not travel' covers emissions from all types of fuel used directly within households for, for example, space heating and water heating. To this we add emissions due to electricity use within households, even though electricity is not, in reality, a fuel that is burnt directly by households. Electricity is, in fact, an energy carrier, and emissions from its production arise upstream at, for example, power plants where coal, gas or nuclear fuel are burnt. Emissions from electricity used by households are therefore, technically, embedded emissions. However, it is separated from the category of embedded emissions and included here as a direct household fuel because this is how it is commonly perceived by consumers, and it is subject to direct household decisions concerning use and savings. We obtain the emissions from domestic electricity consumption using figures from DUKES (DTI 2006), with adjustment for losses taken into account.

Non-travel emissions for each fuel type are allocated to 'Space Heating', 'Water Heating', 'Cooking', and 'Lights and Appliances' according to DECC (2009: Table 3.7). Electricity use for 'Lights and Appliances' is further disaggregated into electricity for 'Lighting', 'Cold Appliances', 'Brown Goods', and 'Wet Appliances' according to DECC (2009: Table 3.10).

The Allocation Chart (Table 1) shows how these categories are then allocated to functional uses. This shows that electricity for lighting is allocated 100% to 'Household'. Electricity used for 'Cold Appliances' (which is refrigerators, freezers and fridge/freezers) is allocated to 'Food and Catering'. Because 'Space Heating' is such a significant category in terms of GHG emissions, it is allocated a dedicated high level functional use category.

Brown Appliances include consumer electronics (such as televisions, DVD players and games consoles) and home computing. Emissions due to electricity consumption in this category are allocated according to DECC (2009: Table 3.10). In the absence of further data we assume that 50% of Home Computing is for communication purposes and 50% for recreation and leisure.

Water is used for many functions in daily life, such as for bathing, cooking, and toilet flushing. We use information from Waterwise (2010) as a basis for disaggregation of direct emissions due to water heating[5]. This is also used as a basis for disaggregating electricity used for powering 'wet appliances' (which include clothes washing machines, dishwashers, and power showers) assuming that electricity use in these machines is proportional to water use.

Direct emissions due to personal transportation is obtained from 'Consumer expenditure – travel' emissions as reported in the UK Environmental Accounts (ONS 2008). This includes emissions from transportation fuels, such as petrol and diesel, purchased by households for use in personal transportation. Direct carbon emissions due to travel are allocated according to DfT[6] (2008: Table 4.2). In the absence of further data, emissions due to Personal business, which includes visits to hairdressers, dry-cleaners, libraries, churches, medical appointments and so on (DfT 2009), are allocated 10% to Household; 10% Clothing and Footwear; 77% Health and Hygiene and 3% Recreation and Leisure. Emissions due to shopping are allocated according to the proportion of trips for food and non-food shopping estimated from DfT (2007a). In the absence of other data, non-food shopping is allocated 70% to clothing and footwear, 15% household furnishings, 15% to electrical appliances. Emissions due to shopping for electrical appliances is further disaggregated according to average household weekly expenditure on these items (ONS and Defra 2004-2005). Use of expenditure data assumes that travel emissions incurred in shopping for appliances are proportional to expenditure on the items themselves.

[5] We adjust this to account for increases in the efficiency of appliances and the increase in the volume of water used for personal washing (Zygmunt and Walker 2008). Water uses such as toilet flushing and drinking water are excluded in this as, of course, water is not heated for these purposes.

[6] The category Business is excluded and re-allocated pro-rata.

2.2 Allocation of carbon emissions embedded in goods and services

Estimation of embedded emissions is less straightforward than estimation of direct emissions. It is done using an Environmental Input-Output sub-model that is incorporated within SELMA. The Environmental Input-Output sub-model attributes all resource use and associated emissions that arise along supply chains to final consumers. Details of SELMA's Environmental Input-Output sub-model are published extensively elsewhere (see Druckman and Jackson (2008; 2009b; 2009a)) and are therefore not repeated here.

The output of the Environmental Input-Output analysis gives carbon emissions according to 122 Standard Industrial Classification (SIC). Categories. This is converted into 41 Classification of Individual Consumption According to Purpose (COICOP) based on 'Households final consumption expenditure by COICOP heading' in the Supply and Use Tables (ONS 2006: Table 4). One exception to this is the SIC sector 'Retail Distribution', as examination of this showed inconsistencies[7]. Carbon emissions due to Retail Distribution are therefore allocated according to distribution margins from 'Supply of Products' in the Supply and Use Tables (ONS 2006: Table 4) following Jackson et al (2006) and Carbon Trust (2006).

The Allocation Chart shown in Table 1 is used to allocate emissions according to COICOP categories into high level functional use categories. The next paragraphs explain some of the assumptions used in composing rows of the Allocation Chart.

'Household Appliances' includes items such as cookers, refrigerators, freezers, clothes washers, vacuum cleaners, and heaters; it excludes televisions and audio equipment which are classified as recreational goods. Upstream (embedded) emissions due to the production and distribution of 'Household Appliances' are disaggregated into the appropriate functional use categories according to average household weekly expenditure on these items (ONS and Defra 2004-2005). Use of expenditure data assumes that embedded emissions are proportional to expenditure.

'Other Personal Effects' includes purchase of jewellery, clocks, watches, leather and travel goods, sunglasses and baby equipment. The allocation of emissions in this category based on the carbon attributed to the SIC sectors.

Transport services are allocated on the same basis as personal fuel consumption. Carbon emissions due to aviation (which include emissions from, for example, heating and lighting airports in addition to emissions from aviation fuels) are attributed wholly to 'Recreation and Leisure'.

'Delivered fuel (indirect)' is the upstream carbon associated with the delivery of direct fuels to households. The results from the Environmental Input-Output model show that the majority of this (84%) arises in the Gas Distribution industry, and this portion is therefore allocated to functional uses in the same way as direct gas use. The remainder arises in the sectors 'Coal Extraction and Coke ovens' and 'Coke ovens, refined petroleum & nuclear fuel' and this is allocated according to information in DECC (2009: Table 3.7). Upstream emissions

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[7] For example in the 2006 version of the Supply and Use Tables, 51% of Retail Distribution is allocated to Other Personal Effects. In the 2009 version this is reduced to 25%, and furthermore, the percentage given for the year 2007 in the 2009 version of the tables is 17%.

due to 'Water Supply & Other Misc Services' are allocated based on information from Waterwise (2010)[8].

In the absence of further data, embedded emissions due to brown goods are allocated according to DECC (2009: Table 3.10). This allocation assumes that the carbon embedded in these goods is proportional to the carbon emitted during their use.

2.2.1 Assumptions concerning holiday emissions

In order to allocate emissions in the category 'Recreation and Leisure' between holiday and non-holiday emissions, we assume that all emissions due to aviation and accommodation services are attributable to holidays. We also assume that emissions due to water transport services are dominated by emissions from ferries, and therefore allocate all water transport emissions to holidays. Based on information from DfT (2008: Table 4.2) we assume that 7% of land travel (personal vehicles, railways and other land transport) is for holiday purposes ('holiday (base)', excluding day trips) and therefore is allocated to holiday emissions. Expenditure by UK residents abroad is allocated to its relevant categories such as food and clothing.

2.2.2 Aviation

In some studies an uplift multiplier factor is applied to GHGs emitted from aviation fuels to account for further radiative forcing caused by the creation of high clouds and emissions of other non-Kyoto GHGs (CCC 2008). In this study an uplift factor has not been used for aviation emissions. The reason for this decision is that the science concerning the contribution of aviation to climate change is as yet not well understood, therefore uncertainties are very high, and the issue is controversial (CCC 2008)[9] . However, in order to assess the implication of this decision, a sensitivity analysis[10] is carried out by applying uplift factors of 1.9 (based on DfT (2007b)) and 3.0 (based on RCEP (2007)).

2.3 Methodology for comparison of carbon emissions due to eating in and eating out

Little evidence is available concerning the relative benefits with respect to carbon emissions of eating at home or out in, for example, a restaurant, pub or canteen (Garnett 2010; Vaze 2009). To fill this gap we attempt to address this here.

The emissions associated with eating at home include: emissions embedded in the production and distribution of food and non-alcoholic drinks; emissions embedded in appliances such as cookers, freezers and dishwashers; direct emissions from heating water and running appliances; embedded emissions due to water usage; and emissions due to travel for the purposes of food shopping.

The emissions associated with eating out are included in the output of the Environmental Input-Output model in the sector 'Hotels, catering and pubs'. According to 'Household final consumption expenditure by COICOP heading in ONS (2006) 77% of these emissions are

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[8] This is adjusted account for increases in the efficiency of appliances and the increase in the volume of water used for personal washing (Zygmunt and Walker 2008).

[9] For a concise summary of the discussion concerning uplift factors, see CCC (2008) Box 8.1 pages 310-311.

[10] For the purposes of this sensitivity analysis we assume that all emissions attributed to aviation are from burning of aviation fuels, thus assuming that the contribution of emissions attributable to aviation from other sources are negligible.

due to catering services. These emissions include, in theory, all emissions that arise due to the production, storage, preparation cooking and services of meals served in these establishments. Other emissions that are associated with eating out are those from transportation to eating places such as restaurants. In our categorisation shown in the Allocation Chart (Table 1) these emissions are allocated to 'Recreation and Leisure'. But for the purposes of the eating in/eating out analysis only we include half of these emissions as part of eating out, assuming that the other half are associated with visits to pubs and so on when meals are not eaten and therefore remain as part of 'Recreation and Leisure. [11]

Having estimated the total carbon emissions associated with eating in and eating out for the average UK household in 2004 as described above, the next task is to estimate the relative quantity of emissions per meal for each case. This requires two assumptions: First, we assume that roughly 15% of all meals consumed are eaten out as estimated by Defra (2007: page 12). Second: we assume that a household eats 3 meals per day. From this we estimate the emissions from an average meal eaten in the home and for a meal eaten outside the home.

2.4 Limitations

The major limitations within the study arise in the use of the Environmental Input-Output sub-model to estimate embedded emissions. The major assumptions in this methodology include the assumption that each industry sector is assumed to be homogenous, and economies of scale are not taken into account. Moreover, the data problems associated with the methodology are considerable. Discussion of the shortcomings of the methodology and data are covered in Druckman et al (2008) and Druckman and Jackson (2008; 2009b; 2009a) and so not repeated here. Nonetheless, it is important to stress that they are considerable.

The focus of this paper concerns the division of the categories of emissions within the footprint, not the size of the footprint per se. Happily, the situation with regards this disaggregation is relatively robust. First, our results show that around 34% (8.9tCO_2e) of the footprint is from direct emissions: estimation of both the absolute quantity of these emissions, and the data sources used for disaggregation are predominantly straightforward government accredited sources, and hence is relatively robust.

Embedded emissions, as noted above, are estimated using the Environmental Input-Output sub-model. Within these results, the proportions allocated to each Standard Industrial Classification category are assumed to be of more reliability than the absolute value, as they are generated from within consistent datasets.

Thus although the specific size of the footprint of an average UK household might be subject to a fair degree of uncertainty, its disaggregation is a great deal less uncertain. Bearing this in mind, the results that follow are generally given in terms as percentages, with absolute values being given for completeness and clarity.

Another limitation worthy of mention here is that the study is based on household expenditure data from the Food and Expenditure Survey carried out by the Office for National Statistics (ONS and Defra 2004-2005), and from the UK National Accounts (ONS

[11] The travel emissions originally included under 'Food and Catering' are only those for shopping trips (DfT 2008).

2006). Therefore the carbon associated with items purchased through informal markets, or through non-market mechanisms, such as fruit and vegetables grown in gardens and allotments are excluded from this study.

3. The footprint as a whole

The carbon footprint of a household can be divided up in many different ways, and before looking at each of the major high level functional use categories illustrated in Figure 1 in detail, we first consider some more fundamental categorisations[12].

The footprint (26.1tCO_2e) is composed of essentially two types of emissions: 'direct' emissions and 'embedded' (or 'indirect') emissions, as explained earlier. The direct category includes household fuel use such as gas and electricity[13], and emissions due to fuels such as petrol and diesel used in private vehicles. Embedded emissions include all the emissions that arise in the production and distribution of goods and services purchased by UK households. At this simple level, we find that approximately two thirds (66%; 17.2tCO_2e) of emissions are embedded emissions, with the remaining 34% being direct emissions[14]. Decomposing the direct emissions further, our results show that 24% (6.2tCO_2e) are due to direct household fuel use, and 10% (2.6tCO_2e) due to personal transport fuel use.

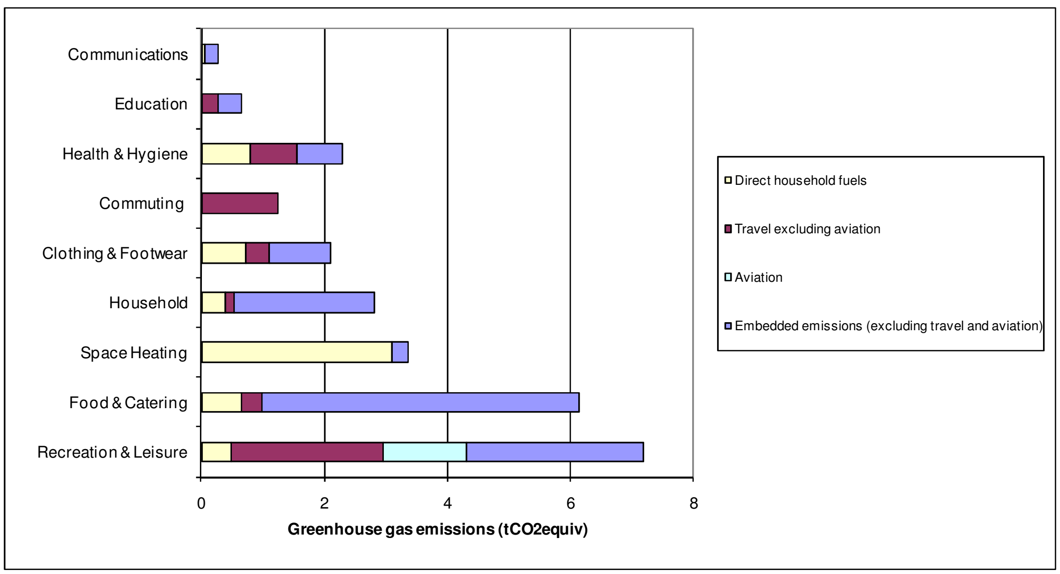

Figure 2: UK household greenhouse gases attributed to high level functional uses (2004).

Figure 2 illustrates the differences in composition between the high level functional use categories with specific focus on travel emissions. In this particular graph the carbon footprint of an average UK household categorised by high level functional uses is decomposed into sub-categories: 'direct household fuel', 'travel excluding aviation',

[12] Please note that discrepancies in results presented in the following sections are due to rounding errors.

[13] As mentioned previously, we include electricity use., in the category of direct fuel use by households. See Section 2.1.

[14] This is in line with other studies of developed countries which generally find that embedded impacts outweigh direct impacts (Bin and Dowlatabadi 2005; Munksgaard et al. 2005; Vringer and Blok 1995; Weber and Perrels 2000; Wiedmann and Minx 2007).

'aviation' and 'embedded carbon emissions (excluding travel and aviation)'[15]. Thus in this categorisation 'travel excluding aviation' is a mixed category of direct and indirect emissions: it includes direct emissions due to petrol and diesel used in personal cars as well as embedded emissions associated with private cars, and also emissions from public transport services. The graph shows that there is a component of travel emissions in all high level functional use categories except 'Space Heating'.

At a glance, it can be seen that whereas 'Food and Catering' emissions are dominated by embedded carbon emissions excluding travel and aviation. 'Space Heating' emissions are, as expected, predominantly due to direct household fuel use, with a very small upstream (embedded) component associated with the delivery of gas and other fuels to households. In contrast to these, 'Recreation and Leisure' has considerable components of all four categories of emissions.

3.1 Emissions attributed to travel

Travel is an important driver of carbon emissions and it is a category that households have a degree of control over, and a moderate awareness of its environmental implications. Therefore before considering each of the functional use categories in more detail we next explore travel emissions.

Travel emissions (excluding aviation) account for around one fifth (21%; 5.6tCO_2e) of the total carbon footprint, with aviation emissions accounting for a further 5% (1.4tCO_2e). Thus travel emissions, including aviation, make up 7.0tCO_2e which is over a quarter (27%) of the average UK household's footprint[16].

There are essentially three type of travel related emissions: (a) those that arise directly as a result of fuel burnt in personal vehicles; (b) emissions embedded in capital goods and in services; (c) those due to fuel burnt in public transport, which, in our categorisation are termed embedded emissions because, from a household point of view, they are 'embedded' in the price of a travel ticket. Category (b) includes emissions that arise during the manufacture and distribution of personal vehicles and public vehicles such as buses, trains and ferries. It also includes the emissions associated with the provision and running of petrol stations and garages, and the provision and distribution of motor fuels.

Figure 3 illustrates the major sources of transport emissions, classified according to embedded emissions and direct emissions due to personal transportation fuels. It shows that when no uplift factor is applied to aviation emissions, travel emissions are dominated by emissions associated with running and owning personal vehicles (66% of transport emissions): this includes both direct fuel use and embedded emissions. Aviation emissions (without uplift) account for around 1.4CO_2e (19% of travel emissions), and public transport services (comprising rail, water and other land transport) are small in comparison, being responsible for the remaining 14% of transport emissions.

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[15] In this categorisation, with embedded travel emissions removed from the general 'embedded' emissions category, embedded emissions now account for just 50% of the carbon footprint, with direct household fuels making up the remaining 24% as before.

[16] Please note that apparent discrepancies in results presented here and in the following sections are due to rounding.

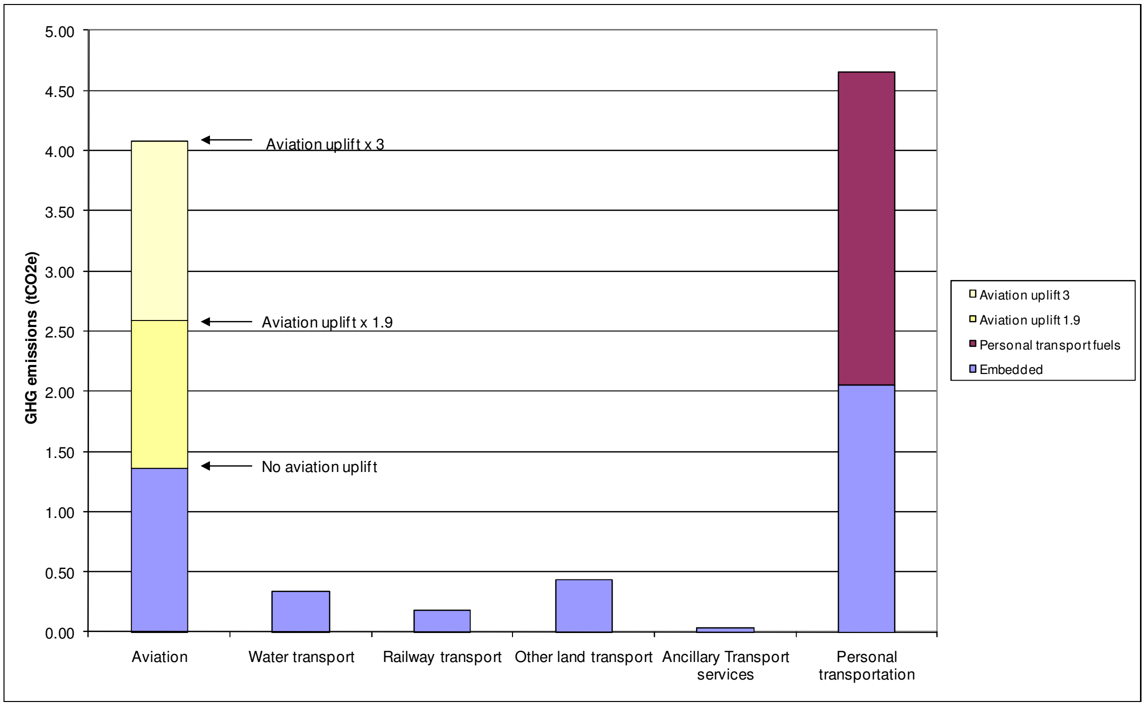

Figure 3: Travel emissions

3.1.1 Aviation

Aviation emissions are classed as embedded emissions. As mentioned above, without an uplift factor, they account for around 1.4tCO_2e of an average UK household footprint, which is 5% of the entire footprint, or 19% of total travel emissions. These emissions include those from burning aviation fuels as well as emissions associated with manufacture of aircraft and running air passenger services (which include, for example, the emissions produced in heating and lighting airports and airline administration).

As explained in Section 2.2.2, in this study an uplift factor has not been used for aviation emissions. However, the sensitivity analysis shows that if an uplift factor of 1.9 (DfT 2007b) is applied then aviation emissions rise to 2.6mtCO_2e which is nearly 10% of the total carbon footprint. If an uplift factor of 3.0 (RCEP 2007) is applied then aviation emissions rise to around 4.0mtCO_2e which is nearly 16% of the total carbon footprint. Figure 3 illustrates the difference that applying varying uplift factors makes. It is interesting to note that, even with the higher uplift factor, travel emissions are still dominated by personal transportation when all upstream emissions due to private vehicle ownership and use are included.

3.1.2 Personal vehicle use

As noted above, emissions associated with running and owning personal vehicles dominate travel emissions making up 4.7tCO_2e, which is 67% of transport emissions[17], and 18% of the entire carbon footprint (this includes both direct fuel use and embedded emissions). The majority of emissions associated with running and owning personal vehicles are direct

[17] With no aviation uplift.

emissions from burning fuel (2.6tCO_2e which is around 56% of emissions due to personal vehicles). However, this illustrates that a significant quantity (around 2.1tCO_2e or 44%) arise from the upstream emissions associated with personal car ownership and use. These comprise emissions associated with the manufacture of vehicles (around 0.7tCO_2e), and emissions associated with distribution and maintenance of vehicles, running garages and service stations (around 0.4tCO_2e). Other emissions arise upstream in, for example, refining petrol, tyre production and distribution, and running membership organisations such as the Automobile Association.

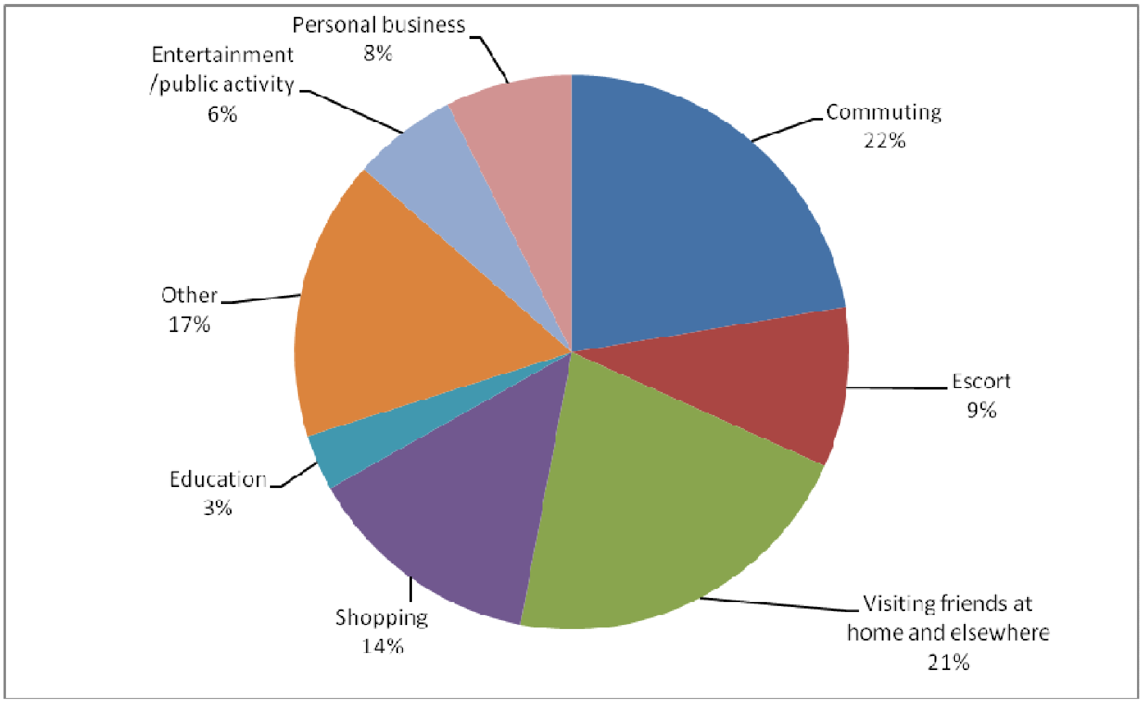

Figure 4: Percentage of average personal travel emissions from different activities. Source DfT (2008)

Figure 4 illustrates the activities that these emissions support. Commuting, and Visiting friends at home and elsewhere each account for over one fifth of personal transport emissions (around 1.0tCO_2e each). Around 14% (0.6tCO_2e) of personal travel emissions are for shopping trips. Personal business accounts for around 7%; as noted earlier this includes visits to hairdressers, dry-cleaners, libraries, churches; and medical appointments (DfT 2009). Escort travel includes 'Escort Education', otherwise known as the school run and 'Other Escort' which includes escort trips to services, such as the bank, doctor or library. Escort travel accounts for 9% or around 0.4tCO_2e, of which escort education is less than one fifth.

3.1.5 Public transport

Public transport (excluding aviation) accounts for a relatively small proportion of emissions: we estimate it at around 1.0tCO2e which is less than 4% of the entire carbon footprint, and around 14% of total travel emissions[18]. Public transport is comprised of: 'Other land transport' which is assumed to be predominantly buses, coaches and taxis, and makes up approximately 6% of total transport emissions; 'Water transport' which is assumed to be mostly ferries (5% total transport emissions); and railways which account for around only 3% of total transport emissions.

[18] Including aviation emissions in this total.

In this section we have looked at travel emissions in their own right. In the remainder of the paper travel emissions are allocated to functional uses.

4. Footprint breakdown by high level functional uses – the major categories

We now consider the main high level functional use categories in turn in more detail. The categories we cover are 'Recreation and Leisure', 'Food and Catering', 'Clothing and Footwear' and 'Household'. Together with 'Space heating', these categories over four fifths (83%) of the footprint. The remaining 17% comprises 'Commuting' (5%), 'Health and Hygiene' (9%); 'Education' (2%) and 'Communications' (1%). Detailed analysis of these categories does not mean, however, that valuable carbon emissions reductions could not be made: in particular one area that may be of interest to explore in future is 'Health and Hygiene'.

4.1 Recreation and Leisure

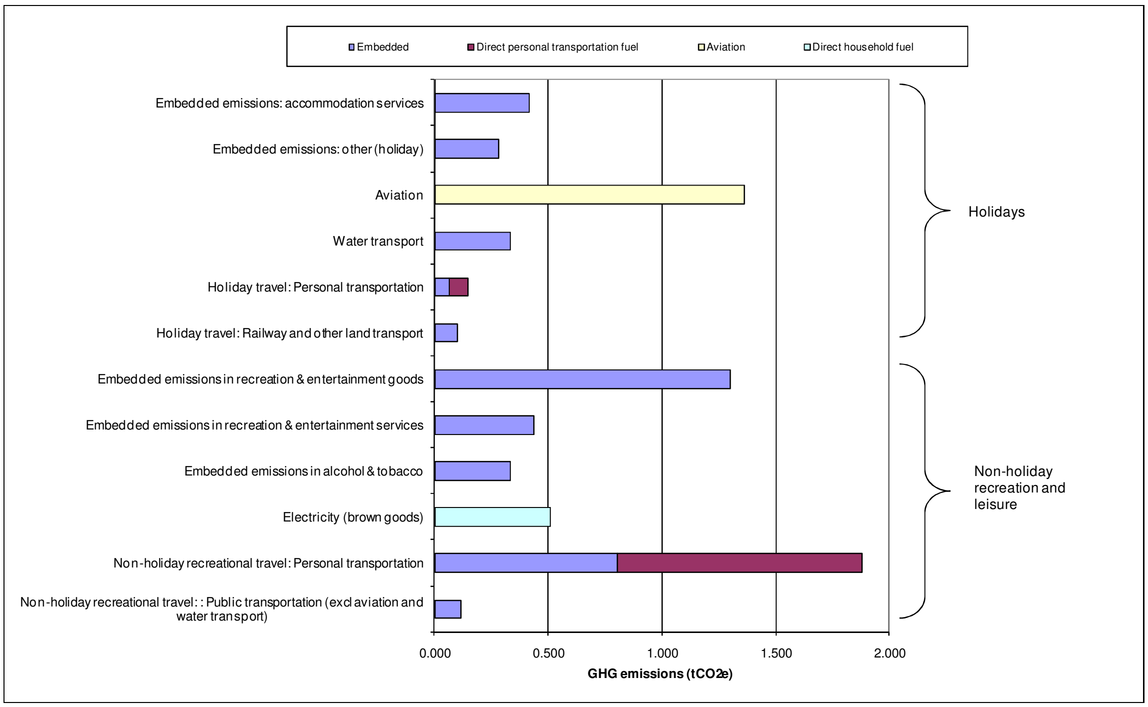

Figure 5: Recreation and Leisure

As stated above, over a quarter (27%) of the entire carbon footprint is attributed to 'Recreation and Leisure'. Within this category around 19% is due to aviation and 34% to other transportation, meaning that recreation and leisure emissions are dominated by transportation (53%). Of the remainder, 40% are embedded in goods and services (excluding travel services) and 7% is due to direct household fuel use[19]. Figure 5 shows Recreation and Leisure emissions sub-divided into holiday and non-holiday emissions.

[19] This figure includes a small portion of small portion of upstream embedded emissions associated with the delivery of household fuels. This practice is followed for the remainder of the paper, as this makes sense for the analysis in terms of functional uses.

4.1.1 Holidays

Our estimates show that emissions due to holidays are responsible for around one tenth of the entire carbon footprint (10%; 2.6tCO_2e). This is 37% of 'Recreation and Leisure' emissions.

Figure 5 shows that over half (52%) of holiday emissions are due to aviation (1.4tCO_2e), and when this is added to other holiday-related transport emissions, transportation accounts for nearly three quarters (74%) of 'Holiday' emissions. This includes water transport (13% of 'Holidays'; 0.3tCO_2e), personal transportation (6%; 0.2tCO_2e), and a small quantity of rail and other land transport emissions. As noted previously, travel emissions included here do not include day trips, and therefore may be underestimated. Furthermore, if an aviation uplift factor were to be applied to aviation emissions (see Section 2.2.2) then the emissions due to holidays would, of course, be increased further.

Emissions due accommodation services in hotels are estimated to be 16% of 'Holiday' emissions (0.4tCO_2e). Other embedded emissions include 'alcoholic beverages' and 'recreational services' purchased by residents abroad, which each account for around 2% of 'Holiday' emissions. Emissions due to recreational services may be underestimated here, as it is based on a general basket of recreation services, rather than services specifically purchased by tourists which may have a higher element of travel within them. This is an area for further research.

4.1.2 Non-holiday recreation and leisure

Non-holiday 'Recreation and Leisure' emissions make up around 4.5tCO_2e which is 17% of the total carbon footprint (63% of 'Recreation and Leisure' emissions). These are emissions that arise due to our recreational activities in everyday life. In the next paragraphs we look at these in more detail.

Our estimates show that emissions embedded in goods and services account for around 1.7tCO_2e which is 24% of 'Recreation and Leisure' and 7% of the entire footprint. We can separate this further into emissions due to purchase of goods, and those that arise due to provision of services as shown in Figure 5. Around 0.4tCO_2e (6% of 'Recreation and Leisure'; 2% of entire footprint) is due to recreational services. Such services include, for example, emissions associated with running gyms, swimming pools, and entertainment venues such as theatres and cinemas. It also includes upstream emissions incurred by, say, the television and film industries, such as running studios.

Embedded emissions in goods purchased for recreation and leisure purposes account for the around 1.3tCO_2e (18% of 'Recreation and Leisure'; 5% of entire footprint). Analysis of these emissions highlights that some activities that are generally regarded as 'green' have embedded emissions associated with them. This is illustrated by emissions of 0.3tCO_2e (25% of recreation goods; 4% 'Recreational and Leisure') due to purchases from the agriculture sector: this is assumed to be due to purchases for gardening, and purchase of house-plants and flowers. Other emissions embedded in recreational goods include, for example, books and newspapers (10% of recreational goods), sports toys and goods (11%), and animal feed (6%).

Approximately 0.9tCO_2e of non-holiday 'Recreation and Leisure' emissions are due transport (13% of 'Recreation and Leisure'; 3% of entire footprint). This includes, for example, travel to football matches, concerts and day trips to places of interest such as National Trust properties. Indeed it might be argued that the majority of leisure activities incur an element of travel, even if it simply comprises a short journey to the local gym or the village hall for a choir rehearsal.

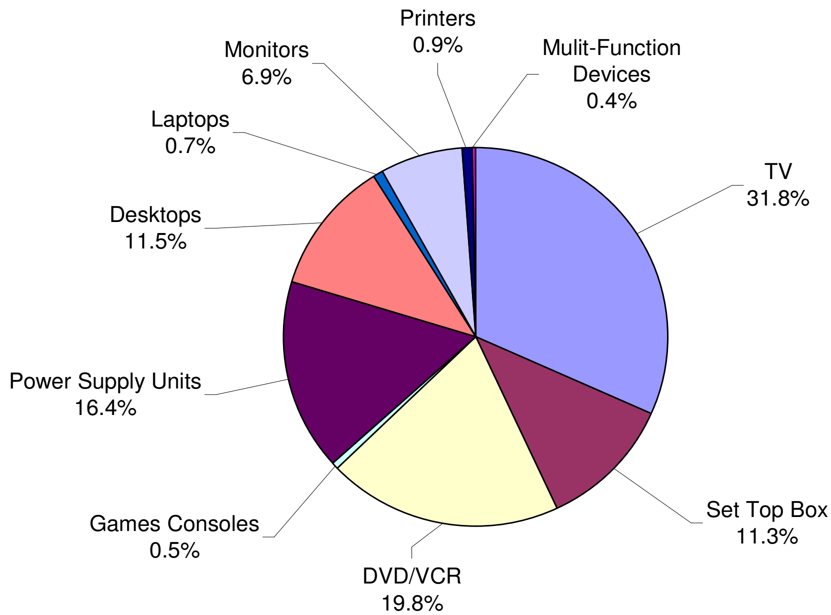

Figure 6: Electricity use, brown appliances breakdown. Source (DECC 2009: Table 3.10)

Electricity used for 'brown' goods is responsible for approximately 0.5tCO_2e making up 7% of emissions attributed to 'Recreation and Leisure'. Brown goods include electrical and electronic devices used in the home such as televisions, computers and games consoles. The pie chart in Figure 6 illustrates that use of televisions is responsible for around one third of these emissions, and DVD players and VCRs are responsible for another 20%. Emissions due to desktops, laptops, printers and monitors make up a further 20% of brown electricity consumption emissions.

Interestingly, embedded emissions due to alcohol and tobacco consumption are relatively low at 0.3tCO_2e which is around 5% of 'Recreation and Leisure' emissions and 1% of the entire carbon footprint. A word of warning is appropriate here, as our model does not include the carbon related to some of the wider side-effects associated with alcohol and tobacco consumption, such additional healthcare and policing.

4.2 Food and catering

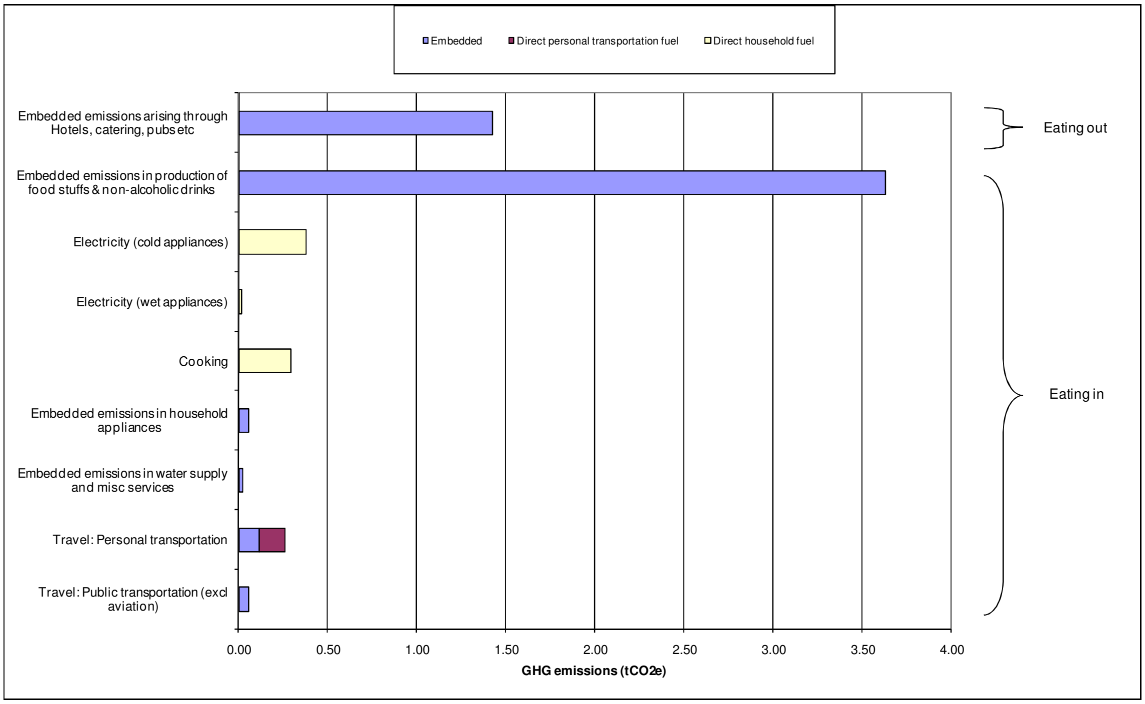

Figure 7: Food and Catering

'Food and Catering' accounts for around 6.1tCO_2e (24%) of the carbon footprint, when the footprint is measured in terms of GHGs. We consider emissions due to eating in the home, and eating out separately in the following sub-sections.

4.2.1 Eating in

Around 77% of 'Food and Catering' emissions (4.7tCO_2e; 18% of the entire carbon footprint) is due to eating in the home. As shown in Figure 7 a substantial portion (59%) of 'Food and Catering' emissions (78% of 'Eating In'; 3.6tCO_2e) are due to embedded emissions in the production of food and non-alcoholic drink that is eaten within the home. These emissions include, for example, methane from gestation of livestock, and nitrous oxide from agricultural soil management using synthetic nitrogen fertilizers and from animal manure management[20].

Other emissions that arise in association with food eaten at home include those involved with food preparation, storage and hygiene (such as cooking, refrigeration and washing) which account for around 18% (1.1tCO_2e) of the 'Food and Catering' emissions. This figure includes the carbon embedded in the production and distribution of household appliances (0.1tCO_2e) in addition to the emissions due to energy and water use associated with running them (0.7tCO_2e). The emissions associated with travel such as driving to supermarkets accounts for just 5% (0.3tCO_2e) of total 'Food and Catering' emissions.

This shows that for a meal eaten at home, the emissions embedded in the production and distribution of food and non-alcoholic drink are well over three times the emissions

[20] http://www.epa.gov/nitrousoxide/sources.html

associated with travelling to shops for food shopping, for storage, preparation, cooking, and for washing up after meals (3.6tCO_2e compared to 1.1tCO_2e).

4.2.2 Eating out

Around 1.4tCO_2e (which is 23% of all 'Food and Catering' emissions; 5% of entire footprint) is attributed to meals eaten out in establishments such as restaurants, cafés, canteens and takeaways[21]. This figure includes the upstream emissions due to the production and distribution of food and non-alcoholic drink, as well as those associated with food and non-alcoholic drink preparation, storage, hygiene and the general carbon emissions associated with the establishment such as heating and lighting.

Personal transportation included under 'Food and Catering' is for food shopping trips only. In our study, travel to pubs and restaurants, which comes under 'Visiting friends elsewhere' (DfT 2008) is included within 'Recreation and Leisure', and therefore emissions due to eating out may be slightly underestimated here. If however we include travel due to 'Visiting friends elsewhere' then the emissions due to eating out would rise to 1.5tCO_2e which is around 6% of the entire footprint.

4.2.3 To eat in, or to eat out?

Based on the assumptions outlined in Section 2.3, we estimate that a meal eaten out produces around 83% more greenhouse gas emissions than a meal eaten at home, if travel to the restaurant or canteen is included[22]. If the travel to the restaurant or canteen is not included, then we estimate that a meal eaten out produces around 71% more greenhouse gas emissions than a meal eaten at home. This includes non-alcoholic drink but not alcoholic drinks. It must be remembered in these comparisons that we have, in theory, included, all the embedded emissions both for eating in and out of the home. In particular, for meals eaten in restaurants, pubs and canteens, we include, in theory, all upstream emissions associated with the establishment and the service provided, and this explains why emissions due to eating out are higher than those associated with eating in.

4.3 Clothing and Footwear

'Clothing and Footwear' accounts for around 8% (2.1tCO_2e) of the carbon footprint of an average UK household. As shown in Figure 8, the carbon attributed to care of clothing is approximately equal to the carbon embedded in products (both around 41% of 'Clothing and Footwear', 3% of entire footprint). It should be noted here however, that the balance between these two categories is particularly dependent on the assumptions made concerning water use. It is likely that with the advent of 'fast fashion' and the 'Primark effect' clothing items are increasingly seen as disposable (Claudio 2007). Therefore the proportion due to production and distribution of clothing may have increased significantly since the date of our study. Hence while it is imperative that policies address the mechanisms used for cleaning clothes, they should also focus on improving the carbon intensity of production technologies.

[21] A small amount of food and non-alcoholic drink that cannot be classified as either 'Eating in' or 'Eating out' is purchased by UK residents abroad, accounting for around 0.1tCO2e. This is not taken into account in the analysis that follows.

[22] Travel for food to be purchased at home is included in both cases here.

The remaining 18% of 'Clothing and Footwear' emissions (0.4tCO_2e) are travel emissions due to shopping trips. These have been kept in a separate category, as clothes shopping is an activity in its own right, whether or not each outing results in purchase(s)[23].

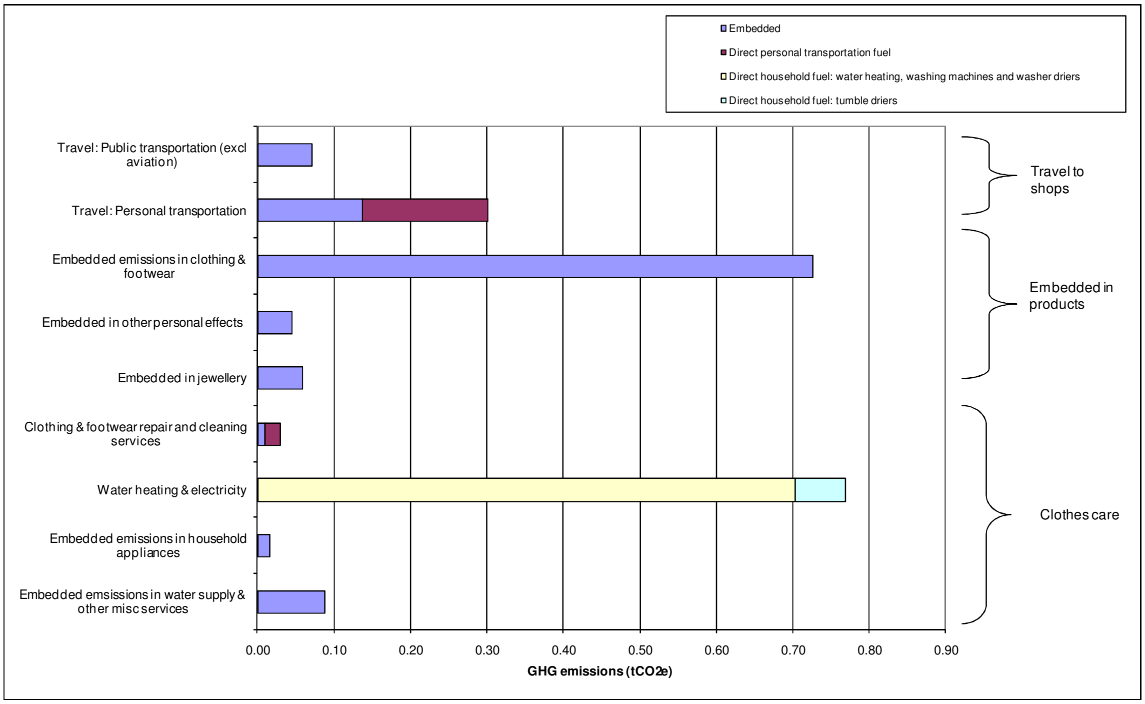

Figure 8: Clothing and Footwear

4.3.1 Embedded emissions in items of clothing and footwear

The majority of embedded emissions in the 'Clothing and Footwear' category are due to the production of clothing and footwear, with just small amounts (less than 0.1 tCO_2e) being due to the production and distribution of jewellery, and other personal effects (which includes accessories such as sunglasses and handbags).

4.3.2 Care of clothing

The vast majority (97%) of emissions due to clothes care takes place within the home, and of these around 88% are direct emissions for water heating and electricity to power appliances. The proportions of electricity use that are due for washing and tumble drying clothes are shown in Figure 9. Embedded emissions that arise during the manufacture and distribution of clothes washing and drying machines account for around just 2% of emissions due to care of clothing. These figures underline the importance of improving the efficiency of appliances used in UK homes.

[23] Items purchased by residents abroad are included in 'Clothing and Footwear' but travel emissions associated with these purchases are not included here.

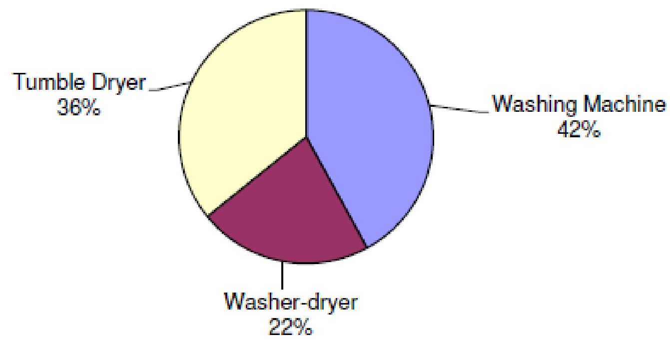

Figure 9: Proportions of direct carbon emissions in electricity used for clothes care. Estimated from DECC (2009: Table 3.10)

4.4 Household

The Household category is responsible for around 2.8tCO_2e for the average UK household which is around 11% of the entire carbon footprint. It comprises the carbon emissions that are associated with constructing, occupying and running a dwelling. Importantly, this category excludes emissions associated with 'Space Heating', which is placed in a category of its own, as it gives rise to such a significant quantity of carbon emissions.

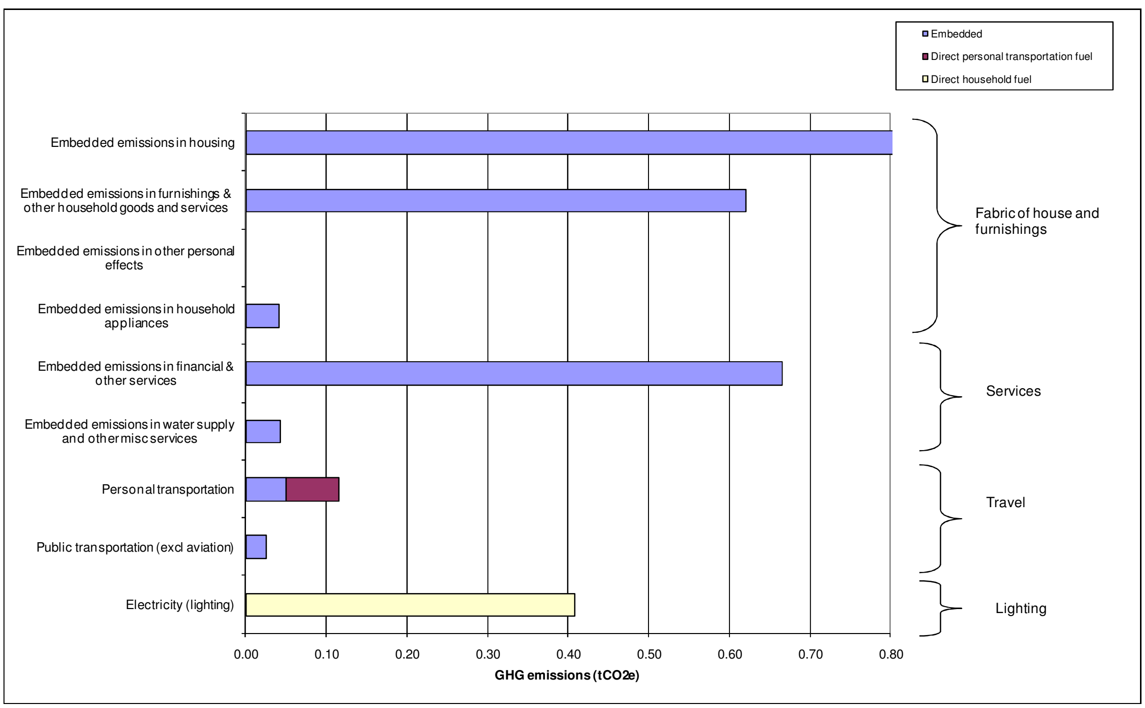

Figure 10: Household

In the Household category, embedded emissions account for around 82% of emissions (Figure 10). This mainly comprises emissions associated with the fabric of the household and furnishings, and those associated with various services. The remainder of emissions include direct electricity use for lighting and a small amount of personal transportation fuels used in shopping for household effects.

4.4.1 Fabric of the household and furnishings

The fabric of an average UK household and its furnishings account for over half of 'Household' emissions (55%; 1.6tCO_2e). This is just 6% of the entire footprint. Within this the highest proportion, as shown in Figure 10, is 'emissions embedded in housing' (around 0.9tCO_2e; 31% of 'Household' emissions): this refers to the emissions associated with construction, owning and renting of dwellings.

Emissions embedded in 'Furniture and Other Goods and Services' account for around 0.6tCO_2e or 22% of 'Household' emissions. 'Emissions embedded in 'Household Appliances' applies to relatively few appliances such as vacuum cleaners, as appliances associated with food (such as dishwashers) or clothing (such as tumble driers) are allocated to their respective high level functional uses, as explained earlier. This explains why the emissions embedded in 'Household Appliances' accounts for less than 2% of the 'Household' category.

4.4.2 Financial and other services

Not many householders will be aware that financial services, such as household insurance, have upstream carbon associated with them, but Figure 10 shows that emissions embedded in financial and other services account for around a quarter (24%) of 'Household' emissions (0.7tCO_2e; 3% of entire footprint). This category includes many different types of services: the highest carbon emissions in this category emanate from insurance and pension funds (0.3tCO_2e), and this is the upstream emissions associated with household payments into these industries. Other service industries in this category include social protection services, such as the emissions associated with social work activities ,and also banking and finance.

4.4.3 Lighting

Light is responsible for around 14% (0.4tCO_2e) of 'Household' emissions, which is under 2% of the entire household carbon footprint.

4.5 Comparison of results with other studies

Our study, as explained above, is based on Environmental Input-Output analysis (EIO), which is a top-down methodology, based on national datasets. An alternative way to estimate the carbon footprint of a household is to take a bottom-up approach, in which a picture of emissions is built up, item by item, by looking at the different sources of carbon emissions. This is formally known as Life Cycle Analysis (LCA). A review of studies that included EIO, LCA and hybrid EIO-LCA studies was carried out by Tukker and Jansen (2006). They found that some 70% of impacts occurred in the areas of housing, transport and food. Our study fits well with this general finding, with GHG emissions in these three areas making up 74% of emissions according to our study (housing: 24%[24]; transport 27%; food 24%[25]).

Francis (2004) carried out a study of UK household emissions for 2001, using broadly similar Environmental Input-Output methodology as used in this study. Differences between the two studies include the methodology used for estimating the number of occupied households in the UK[26], and treatment of the electricity sector in the Input-Output models[27].

[24] This includes 'Space Heating'.
[25] Apparent inconsistencies here are due to rounding.
[26] Francis used the figure provided in the Expenditure and Food Survey (ONS various years) which

Another important difference is that Francis assumes that the carbon footprint of imported goods and services are produced using UK technology, whereas our study attempts to model the different GHG intensities in 12 overseas regions by use of the Quasi-Multi-Regional Input-Output (QMRIO) model (Druckman and Jackson 2009b; Druckman and Jackson 2009a). Furthermore, it is not clear in Francis's methodology whether he converted final demand expenditure published in purchasers' prices into basic prices for use in the Input-Output model. Conversion between these different price bases is problematic (see Druckman et al (2008)). If he did not, as seems likely, this would cause an over-estimation of GHG emissions. The total footprint in 2001 estimated by Francis was 24.6tCO_2e compared to the estimate of 26.1tCO_2e in this study for 2004. This reflects an increase over time, but not as high as expected. The studies estimate very similar proportions of embedded emissions (67% Francis: 66% Druckman and Jackson). Francis allocated embedded emissions to the broad categories of 'Food, drink and tobacco', 'Clothing and footwear', 'Household and personal goods, and 'Leisure goods and services', however, comparison of results is difficult as Francis does not state how indirect emissions due to personal transportation are allocated[28]. Taking account of these factors, it can be concluded that, within the accuracy of the methodologies, the studies agree relatively well.

Nijdam (2005) carried out a comparable study of households in the Netherlands using a four region Multi-Regional Input-Output model. Comparison of results suggest that a Dutch household has broadly the same distribution of the main categories of consumption as a UK household, with around 26% of the footprint due to Household and furnishing (24% this study), 21% to Leisure (27% this study), and 8% to Clothing and footwear (8% this study). The primarily difference of relevance between the two countries is that the carbon intensity of electricity production is substantially lower in The Netherlands due to greater use of renewables than in the UK[29]. This explains why the proportion of the footprint due to food is higher in the Netherlands (30%) compared than in the UK (24%), as the majority of emissions due to food are not energy related. It also accounts for other differences: for example, whereas our study finds that emissions from care of clothes are approximately equal to those embedded within their production and distribution, Nijdam's study finds that the embedded emissions in production and distribution outweigh those from care. The reason for this difference is supported by the findings of a review of studies relating to the lifecycle emissions of UK clothing, which concluded that for '*non-synthetic fibres, energy use and therefore GHG emissions are predominant during the use stage, which includes heating water for washing and tumble drying. For synthetic fibres, GHG emissions are most prevalent in the raw material acquisition and production stages'* (ERM 2007: page 53).

As noted by Vaze (2009) it is difficult to get a definitive result to the question "Is it better to cook food at home, ….or to eat out?" Vaze comments that restaurants may have the advantage of efficiencies of scale, but also have large quantities of food waste. It is evident from this study that the majority of emissions from food and catering arise due to food production, which is intensive in terms of non-carbon dioxide emissions. Thus our result that

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is consistent with the Labour Force Survey, but not consistent with published population projections such as those provided by DCLG as used in this study (Dunstan 2007).

[27] The methodology used in our study pays special attention to emissions from the electricity production and distribution sector, which is the most critical sector with regards to GHG emissions. For details see Druckman and Jackson (2008).

[28] In our study these emissions make up over 6% of the entire footprint; they are not specified by Francis.

[29] Carbon intensity of electricity production: Netherlands 103.7gCe/kWh; UK 135.5gCe/kWh (2006) (WRI 2009).

a meal eaten out produces around 71-83% more greenhouse gas emissions than a meal eaten at home is not surprising. Our result is supported by findings of other studies: Engström and Carlsson-Kanyama (2004) report that about one-fifth of food is lost in food service institutions in Sweden, with plate waste being the largest source of loss (11-13% of the amount of food served). Alfredsson (2000) reported that the estimated energy requirements of a meal at home was 2.5-3.3 kWh compared to 3.5-5.3 per meal at a restaurant[30]. Using these figures it is estimated that a meal eaten out is between 6% to 112% more energy intensive than a meal at home. These studies together indicate that, in general, there is no beneficial effect of economies of scale in eating out compared to eating at home.

5. Discussion

Before highlighting some of the main results of this study, which will be done in the Conclusion, it is useful to briefly stand back and think about what a carbon footprint is. In this Discussion, we first discuss the difference between estimating footprints from two different accounting perspectives. We then move on to consider the global nature of embedded emissions within the footprint of UK households.

5.1 Consumption versus production accounting

We started this paper with the underlying assumption that there are carbon emissions are associated with all goods and services purchased by households. Our study takes the 'consumption perspective', which estimates all emissions generated during the production, distribution, use and disposal of the goods and services purchased by an average UK household to estimate its carbon footprint (Aalbers et al. 2008; Lenzen et al. 2007; Peters 2008).

It is important to point out that there are two specific ways of looking at the 'per household' or 'per capita' emissions of a country, and confusion can arise when the distinction is not made clear. Estimations can take the 'consumption perspective' (as used in this study) or the 'production perspective'. In the production perspective all emissions that arise within the UK are included, regardless of the destination of the final goods and services in the production of which they arise. Thus the production perspective includes emissions embedded in exports but excludes those in imports. The difference between production and consumption emissions are therefore the emissions associated with UK international trade.

Production perspective emissions are therefore not an appropriate basis for carbon footprint studies, and carbon emissions estimated on a production basis are not the same as the carbon footprint calculated using the consumption perspective. For UK households the carbon footprint estimated using the consumption perspective is higher than production perspective emissions because the UK has exported many of its carbon intensive industries overseas (Druckman et al. 2008; Wiedmann et al. 2008). The reverse is true for countries such as China, where emissions arising in the production of carbon intensive goods for export are higher than the carbon emissions embedded in their imports (Li and Hewitt 2008; Weber et al. 2008).

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[30] These figures are taken by Alfredsson from Uhlin, H-E. (1997): Energiflöden i livsmedelskedjan, Naturvårdsverket. No English translation is, to our knowledge, available.

5.2 The global nature of embedded emissions

In this study, as explained earlier, there are two fundamental categories of emissions: direct emissions and embedded emissions. Our results estimate that in 2004 approximately two thirds (66%) of emissions attributable to households were embedded emissions. When UK advisory bodies such as the Energy Savings Trust and the 'ActOnCO_2 campaign'[31] advise on ways for households to reduce their carbon footprint, they commonly target reductions in direct emissions, such as installing loft insulation, turning down the thermostat, and reducing car journeys. This is because these emissions are generally perceived to be more within the control of households. However, our results show that embedded emissions make up a substantial proportion of the total footprint, and therefore, to make meaningful progress, reductions in embedded emissions must also be made.

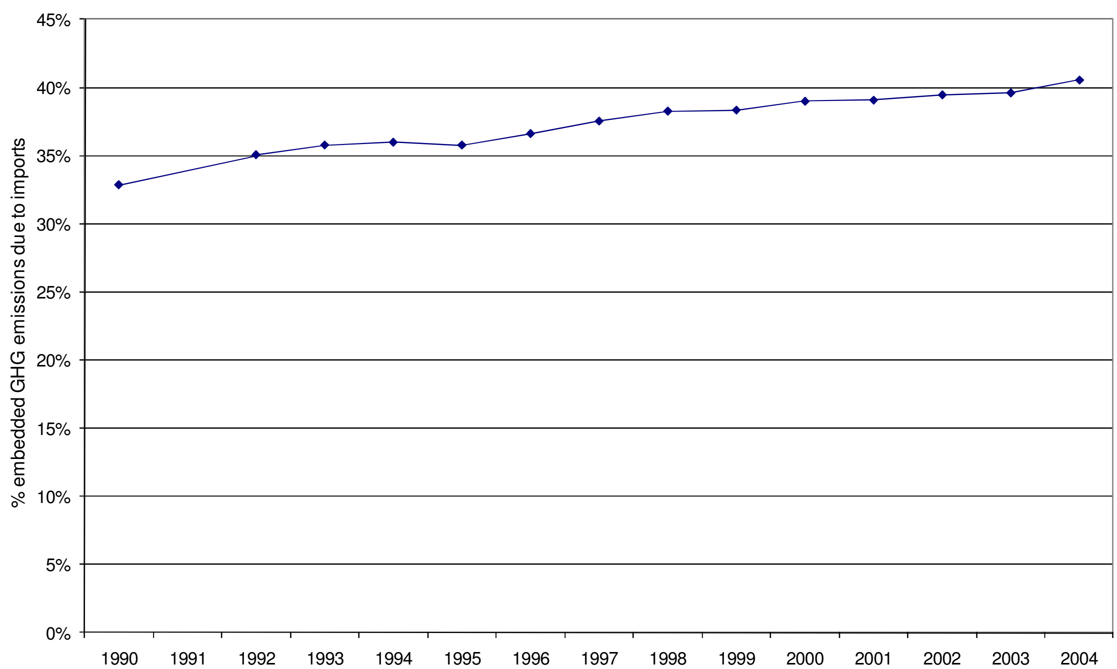

Figure 11: Trends in the percentage of imported embedded GHG emissions[32]

One reason that reducing embedded emissions is rarely suggested, is that it is conceptually harder to relate embedded emissions to personal responsibility for purchases made. Taking responsibility relies on appreciation that it is end consumers who are ultimate drivers of carbon emissions that occur in industry. It is particularly problematic for UK consumers to take personal responsibility because a substantial portion of GHG emissions embedded in goods and services purchased by UK households arise outside of the UK. This problem is growing with the increasing globalisation of supply chains: our estimates (see Figure 11) show that the proportion of embedded emissions that occur outside the UK have risen from 33% in 1990 to 41% in 2004. This demonstrates the interconnectedness between the emissions of UK households with the fields and factories in countries such as China, India and the USA.

[31] http://actonco2.direct.gov.uk/actonco2/home.html Accessed 21.10.10.

[32] This graph is based on figures produced as part of Druckman and Jackson (2009a) by running SELMA for years 1990 and 1992-2004.

Therefore, although it is hard for consumers to directly influence the quantity of carbon emissions embedded in their purchases, it is important that households become increasingly aware of these embedded emissions, and where possible reduce their purchase of carbon intensive goods. The rising percentage of imported embedded emissions also underlines the importance of reaching international agreements concerning reductions in carbon emissions.

6. Conclusion

In this paper we have carried out a detailed exploration into the activities that drive the carbon emissions of an average UK household, and our results present many varied opportunities for further analysis, interpretation and discussion. In the paper we have presented the major results of the study only, with the intention that it will be used as a basis for subsequent, more discursive papers. Therefore we conclude this paper by highlighting just some of the results of particular interest, adding a few pointers towards their policy implications.

Our findings show that, of the average UK household footprint of 26tCO_2e, around 10% is attributed to holidays. This means that although UK households only take a few weeks holiday per year, the footprint of holidays is disproportionately high compared to the time spent. Holidays are generally viewed as a reward for hard work throughout the year, and many people regard it as appropriate (or even 'deserved') to relax their environmental principles for the duration of their holidays (Barr et al. 2010; Holden 2007). The disproportionate portion of the average carbon footprint due to holidays shown in our study suggests that more effort should be focused on making holidays less carbon intensive, and, in particular, on reducing emissions from flying, which account for more than half of all holiday emissions.

Travel emissions (direct and embedded) make up over a quarter (27%) of the entire carbon footprint of the average UK household. Also worth commenting is that the emissions associated with running and owning personal vehicles dominate travel emissions, accounting for nearly one fifth (18%) of the entire carbon footprint. This includes emissions from both direct fuel use such as petrol and diesel and the embedded emissions associated with owning and running a motor vehicle. The potential for reducing travel emissions by, for example, encouraging use of public transport such as buses and trains, and placing sustainable transport at the heart of the town and country planning process, is thus considerable.

Food and catering is responsible for around nearly a quarter (24%) of the carbon footprint of an average UK household. Of this, meals eaten at home account for over three quarters of emissions (77%), with meals eaten out accounting for the remainder. For meals eaten in the home, over three-quarters of emissions (77%) arise in the production and distribution of food and non-alcoholic drinks purchased, with emissions due to shopping, storage, preparation and cooking being responsible for the remainder. Recent studies have found that around 22% of the food and drink purchased is wasted (WRAP 2009) and so this suggests that, by reducing waste, the carbon footprint of an average UK household could be significantly reduced. Furthermore, our results also show that a meal eaten out produces 71-83% more GHG emissions than a meal eaten at home. This suggests that there may be opportunities to reduce emissions of restaurants, pubs, hotels and canteens through efficiency measures, such as by reducing food waste, addressing the carbon efficiency of the establishments themselves, and through active supply chain management.

The results presented in this paper provide a basis for rich discussions into the drivers of carbon emissions of UK households, the potential for reductions, and possible policy options for bringing this about. These topics will form the basis of future papers.

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Table 1: Allocation Chart

		Functional Needs										GHG
	COICOP Categories plus Direct Use of Domestic Fuels	**Household**	**Recreation & Leisure**	**Space Heating**	**Food & Catering**	**Commuting & business**	**Health & Hygiene**	**Clothing & Footwear**	**Education**	**Communi cations**	**Total**	**emissions (tCO2e)**
Embedded emissions	Food & Non-alcoholic drink				100%						100%	5.1
	Alcohol & Tobacco		100%								100%	0.3
	Clothing & Footwear							100%			100%	0.7
	Housing	100%									100%	0.9
	Water Supply & Other Misc Services	12%			7%		57%	24%			100%	0.4
	Furnishings & Other Household	100%									100%	0.6
	Household Appliances	37%			48%			15%			100%	0.1
	Health & Hygiene						100%				100%	0.5
	Transport Services (excl avaition and personal vehicle fuels)	2%	44%		6%	30%	8%	6%	5%		100%	3.0
	Post & Communication									100%	100%	0.2
	Recreation & Entertainment		100%								100%	1.7
	Books & Newspaper								100%		100%	0.3
	Other Personal Effects	22%						78%			100%	0.1
	Holidays (excluding avaition)		100%								100%	0.8
	Aviation		100%								100%	1.4
	Education								100%		100%	0.1
	Financial & Other Services	100%									100%	0.7
	Delivered Fuels (indirect)	2%	3%	64%	6%		13%	12%		0%	100%	0.4
Direct emissions	Space Heating			100%							100%	3.1
	Water Heating				5%		50%	45%			100%	1.3
	Cooking				100%						100%	0.2
	Electricity (lighting)	100%									100%	0.4
	Electricity (cold appliances)				100%						100%	0.4
	Electricity (brown goods)		90%							10%	100%	0.6
	Electricity (wet appliances)				5%		50%	45%			100%	0.3
	Personal transportation fuel	2%	44%		6%	30%	8%	6%	5%		100%	2.6
	Total carbon footprint of an average UK household											**26.1**