Carbon and time: A study of the carbon implications of British adults' use of time

by

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RESOLVE Working Paper 01-12

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Acknowledgements

The authors would like to thank members of nef (the New Economics Foundation), and in particular Anna Coote, for the invitation to present this work at the Expert Colloquium "*About Time: Setting the Agenda for a Shorter Working Week*", held in London in January 2012. We thank the participants of the colloquium and also the following people for the highly informative conversations that have contributed to this working paper: Tracey Bedford; Jonathan Chenoweth and Carl Sofield.

The support of the Economic and Social Research Council (ESRC) is gratefully acknowledged. This working paper is published as part of the interdisciplinary research programme of RESOLVE - the ESRC Research Group on Lifestyles, Values and Environment.

ISSN 1755-7259

Abstract

In order to meet the UK's challenging greenhouse gas (GHG) reduction targets, behaviour change will be necessary in addition to changes in technology. Traditionally, this has been approached from the angle of shifting the goods and services people purchase towards lower impact options. But an equally valid angle is through changing the way people use their time. In order to devise policies that take this approach, it is first necessary to understand the GHG implications of different types of time use, and, to this end, this paper describes a study in which we explored the GHG emissions per unit time for different types of activities.

In this paper we focus on 'non-work' time, and examine how different activities, such as household chores and leisure pursuits, give rise to varying amounts of household carbon emissions. We do this first for an average person in a UK household. We then move on to look at how non-work time use varies within households, and how this impacts on resulting carbon emissions. We find, for example, that men generally have more leisure time than women, and that leisure activities are generally associated with lower carbon emissions. In the discussion that follows we explore the implications of our findings for the varying roles carried out within different types of household, we look at the constraints within which people operate, and investigate the concept of carbon as a potential marker for social justice. We also briefly consider the inter-relatedness of the economies of households with industry, the implications for work-time reduction policies, and the complexity of the modelling challenge required to support development of policies for a lower carbon future.

1 Introduction

In order to meet the challenging reductions in greenhouse gas (GHG) emissions set out in the Climate Change Act 2008 (HM Government 2008), it is becoming increasingly agreed that behaviour change by households will be necessary alongside technological and infrastructure innovations (Jackson 2009; Moriarty and Honnery 2010; OECD 2011). The challenge of how consumers can reduce their emissions is generally approached from the perspective of changing the basket of goods and services that they purchase. However, an alternative way to consider the problem is to consider how people might change their patterns of time use (Jalas 2002; Reisch 2001). Thus, rather than taking the more traditional focus of how people can spend their money differently, we can look through the lens of how they might use time differently.

A necessary precursor to exploring the potential GHG reductions that may be possible through changes in time use, is to understand the status quo: although many studies explore the relationship between how households spend their money and the GHG emissions that the expenditure gives rise to, there has to date been much less focus on the GHG implications of how people spend their time. This study aims to contribute to filling this gap. Accordingly, in this study, we investigate the carbon intensity of different uses of time[1]. In other words, are the GHG emissions per unit time higher for some activities, such as going to the theatre, than for others, such as staying at home and watching television? If so, how much?

We limit the scope of this study to understanding the time use behaviour of people in an average UK household outside of their time at work (paid and voluntary) and during routine daily life (holidays are excluded). However, the activities of people outside working time are inextricably linked to their working lives and roles in the wider economy: people play dual roles as both consumers and producers in the wider economy. Therefore our paper also discusses some of the complexities that this interconnection results in, and the implications for work time reduction policies.

This paper is organised as follows: In Section 2 we set out the methodology used in this study along with the assumptions and limitations. In Section 3 we present results, first looking at time use by an average British adult, followed by the GHG intensity of time use. We then look at differences between the GHG emissions of men and women with respect to their time use, and this Section finishes with a comparison between our results with those from other studies. In Section 4 we conclude the paper with a discussion of the insights that this work might bring in forming policies to move towards lower carbon lifestyles.

2 Methodology

This study draws on two major datasets: the GHG emissions of an average UK household, and time use data for an average British adult. In the following sub-sections we first briefly describe the two major datasets used (sections 2.1 and 2.2), and then describe the way in which they are combined in order to estimate the GHG emissions of different types of time use (Section 2.3). This gives the basic framework that underpins the study.

[1] In both cases GHG emissions arise due to expenditure on goods and services. However in this study we go one step further than general consumption studies and allocate consumption to categories of time use.

2.1 GHG emissions of an average household

There are essentially two types of GHG[2] emissions attributable to households: direct and indirect (or 'embedded'). Direct emissions are those that arise due to direct fuel use, such as gas for space and hot water heating, electricity for powering lights, appliances and gadgets, and fuel for personal transportation. Indirect, or 'embedded' emissions are emissions that arise along supply chains in the production and distribution of products and services purchased by households, such as GHG emissions embedded in food, clothing and vehicles. Embedded emissions that occur in the supply of products that are purchased by UK households are attributed to UK households whether they arise in the UK or overseas.

The carbon emissions of an average UK household are thus estimated separately as two categories: direct and embedded emissions, as described in the following paragraphs. The year of focus for the estimation is 2004.

Direct household GHG emissions are recorded in the UK Environmental Accounts (ONS 2008) in which they are recorded as emissions due to direct energy use in the home ('Consumer expenditure - not travel'), and those due to personal transportation ('Consumer expenditure – travel'). Non-travel emissions are allocated to space heating, water heating, lighting and electricity for powering appliances and gadgets according to DECC (2009). Emissions due to travel are allocated according to time spent travelling as recorded in Table 5.17 in the Time Use Survey (ONS 2006b). Further disaggregation is carried out based on National Travel Survey (DfT 2009a) Table 4.2, assuming that time travelled is proportional to distance travelled[3].

Estimation of embedded emissions is based on expenditure data combined with environmental data. In essence, it is calculated by combining the expenditure by an average UK household with information on the carbon emissions that are generated in the UK and abroad by every pound spent in various categories. In this study we used the Environmentally-Extended Input-Output (EEIO) sub-model within the Surrey Environmental Lifestyle MApping (SELMA), full details of which are given in Druckman and Jackson (2008b; 2009b; 2009a).

The output of the EEIO sub-model gives carbon emissions according to 122 Standard Industrial Classification (SIC) categories. This classification system tells us about the industry sectors in which emissions arise. As such it contains some very useful information, but in order to tell us more about how people use GHG emissions to support their lifestyles, and we re-allocated this to 41 Classification of Individual Consumption According to Purpose categories (COICOP) (UN 2005). This re-allocation is based on 'Households final consumption expenditure by COICOP heading' in the Supply and Use Tables ONS (2006a: Table 4)[4]. These categories are listed in Appendix 1.

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[2] In this study "GHGs" refer 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).

[3] The National Travel Survey allocates a small portion of travel distance to 'Personal business' which is visits to services, e.g. hairdressers, launderettes, dry-cleaners, betting shops, solicitors, banks, estate agents, libraries, churches; or for medical consultations or treatment; or for eating and drinking, unless the main purpose was entertainment or social (DfT 2009b). Therefore, in the absence of further data 50% of this is allocated to Personal Care and 50% is excluded from the study.

[4] One exception to this is the SIC sector 'Retail Distribution', as examination of this showed inconsistencies. For example in the 2006 version of the Supply and Use Tables, 51% of Retail Distribution is allocated to Other

2.2 Time use by an average household

A survey of how people in Great Britain use their time was carried out in 2005 by the Office for National Statistics (ONS 2006b). The aim of the survey was to find out how people spent their time during a typical day. The survey was an interviewer administered diary with 30 pre-coded activity descriptions. The respondents were members of the household aged 16 and over, and only one member of each household was surveyed. Data collection was done in four waves in February, June, September and November 2005, and thus intended to cover all seasons. The main holiday periods of Christmas, Easter and August were avoided as the aim was to capture time use during a typical day. Weighting has been applied to the responses to compensate for response rate, and adjusted to ensure that the days of the week were equally represented. More details can be found in ONS (2006b). The time use survey categories are shown in Appendix 2.

2.3 Estimating the GHG intensity of time use

It will be apparent from the discussion above that time use data and GHG emissions data are in different categories, and in this study we combine them into activity categories related to time use. Categories were selected to be representative of the household activities which incur both GHG emissions and time use. Details of the allocations used are presented in Appendix 3.

The GHG intensity of each activity category is defined as the GHG emissions that arise (both directly and indirectly) per unit time while carrying out the activity. It is estimated as follows. We estimate the total annual direct and embedded GHG emissions of an average UK household, which we call G, using SELMA. In each day we assume the average adult takes part in *n* activities. We assume that the average number of adults per household is *p*. Therefore each activity *k* gives rise to GHG emissions g_k such that

$$G = 365\, h\, p \sum_{k=1}^{k=n} g_k \tag{1}$$

where *h* is the number of households in the UK. The GHG intensity $\bar{i}_k$ of activity *k* is estimated as

$$\bar{i}_k = \frac{g_k}{t_k} \tag{2}$$

where t_k is the time allocated to each activity *k.*
The source of *p* and *h* is Table 5 in ONS (2011).

In the following paragraphs we give details of allocations, and the limitations are discussed in section 2.5.

As in other studies of this nature (see, for example, Jalas (2002; 2005)), it was necessary to exclude certain categories of GHGs emissions and time uses from the study due to a lack of available data and difficulties in allocation of time and/or GHG emissions. As this is a household study, time spent in work (paid and voluntary) is excluded as it is not included within the GHG data. Formal education outside the home is also excluded, although study-related travel time and the associated GHG emissions are included. The emissions due to

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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%. Carbon emissions due to Retail Distribution are therefore allocated according to distribution margins from 'Supply of Products' in the Supply and Use Tables (ONS 2006a: Table 4) following Jackson et al (2006) and Carbon Trust (2006).

holidays are also excluded as the Time Use Survey covers typical daily life, as described above. Financial services, housing rental services, furnishings and textiles, postal services and tobacco use have been excluded as it is not possible to match any specific use of time to them. Excluded categories are summarised in Appendix 4.

Emissions due to shopping in the study include emissions due to travelling to shops and, because 12% of shopping is done in the home (TUS Table 2.2) it also includes emissions due to heating, lighting and computer use for the relevant amount of time in the home. Emissions due to the purchase of items are allocated to the relevant category: thus emissions due to purchase of clothing is allocated to Personal Care, and those due to food products are allocated to Eating and drinking. In theory, these emissions include the upstream emissions incurred due to the production and distribution of the products purchased, but this excludes capital investment for, say, building new shopping malls or new food superstores.

The category 'Spending time with family/friends outside the home' includes only the time explicitly recorded for which this was the primary activity, plus the travel emissions allocated to Visiting friends at private home and elsewhere (DfT 2009a: Table 4.2). Therefore it does not include the emissions that arise in the main destination at which the time was spent. Hence these emissions may appear to be under-estimated here, but this allocation was necessary in order to avoid double counting. For example, in cases where the destination is another person's house then emissions for heating another person's house will be allocated to the other person's household carbon emissions.

The time spent on each indoor activity was used as a guiding factor for the distribution of direct emissions resulting from space heating and lighting. Sleep is one exception, which requires no lighting and little heating. In the absence of better data two hours of heating were deemed to be required for each night's sleep based on the assumption that, on average throughout the year, heating remains on for one hour after the household members go to bed, and comes on again one hour before household members wake. Space heating levels are considered to be constant regardless of the activity being carried out. However, in reality, heating is most effective if adjusted according to the activity being carried out: for example, a sedentary pastime requires a higher temperature for thermal comfort than more active pastimes (Hong et al. 2006; Summerfield et al. 2007).

The allocation of lighting according to the time spent on each indoor activity relies on the assumption that the use of lighting remains equal for each activity. However in reality use may fluctuate depending on the activity. For example, it may require more or less lighting to read than to watch television depending in which room the activity is being carried out or the type of lighting used. However, such discrepancies should have a minimal impact on the results given the relatively low GHG emissions resulting from lighting, which are less than 2% of households' total carbon footprint (Druckman and Jackson 2010).

In modern life, activities are carried out simultaneously, such as listening to music while preparing food, or having a meal while spending time with friends or family (Godbey 1996; Godbey et al. 1998). In the time use diaries, respondents were asked to record their primary and secondary activity. The data used in this study is the time spent on the primary activity for all cases except for 'Using the computer', as 87% of time attributed to using a computer in the Time Use Survey has a secondary activity related to it (ONS 2006b). Thus computer use is allocated to the relevant secondary activity based on ONS (2006b: Table 15), making

the assumption that the remaining 13% can be allocated proportionately in the same way (ONS 2006b).

2.4 Estimating GHGs due to men and women

In order to investigate the emissions due to an average woman or an average man for one day we assume that each activity *k* has the average GHG intensity $\bar{i}_k$ as estimated using equation 2. The Time Use Survey provides estimates of average time use for men and women from which we can calculate the time ${}_m t_k$ that an average man spends on each of the activity categories in our study, and also that for an average woman man ${}_w t_k$. We assume that the average intensity of each activity is constant; in other words, we assume, for example, that the emissions per hour due to a man watching television are the same as those for a woman watching television.

The average daily GHG emissions for a man ${}_m g_{day}$ can therefore be estimated:

$$ {}_m g_{day} = \sum_{k=1}^{k=n} {}_m t_k \, \bar{i}_k \qquad (3) $$

where *n* is the total number of activity categories used in this study. The emissions due to a woman are estimated in a similar manner.

2.5 Assumptions and limitations

Inevitably in a study of this nature that draws on different datasets intended for different purposes, many assumptions are required and the limitations of interpretation of the study must be made clear in the light of these assumptions.

The GHG emissions are estimated for the UK. These are divided by an estimate of the number of households in the UK and number of people per household to estimate the per capita GHG emissions. The Time Use Survey (ONS 2006b) gives estimates of average time use for a sample of the Great Britain population, and thereby, by using this dataset we assume that emissions and time use are the same in Northern Ireland as in the rest of the UK. In reality, emissions in Northern Ireland will be different as there is a greater proportion of rural households in Northern Ireland and also a greater proportion not connected to mains gas supply. Therefore the emissions associated with space heating and hot water are likely to be higher per capita in Northern Ireland than in the rest of the UK.

A further mismatch is that the GHG emissions data for this study are for 2004 whereas the Time Use Survey (ONS 2006b) reports survey data taken in 2005. We thus assume that the intensity of time use is the same for both years.

Another mismatch is that the Time Use Survey included only people 16 years and over, whereas the GHG emissions are on a household basis with children included in the per capita estimates. Furthermore, GHG emissions vary across different socio-demographic groups and geographical locations (Brand and Boardman 2008; Brand and Preston 2010; Druckman and Jackson 2008a; Druckman and Jackson 2009b; Gough et al. 2011), and these variations are not reflected in our study. Another factor to acknowledge is that many of the emissions, such as those due to space heating, are variable throughout the different seasons of the year, and this study presents an average for one year.

It is also important to note that the GHG emissions included in this study are those due to household expenditure. The study thus excludes emissions due to capital investment and government expenditure (Druckman and Jackson 2009b; Druckman and Jackson 2009a). This

is particularly important for some categories, such as personal care, as the vast majority of health care in the UK is carried out by the National Health Service which is government funded. Therefore the emissions due to Personal Care are underestimated. Similarly ,the category Study includes study at home and travel for purpose of studying, but excludes emissions due to formal study outside the home, such as those due to running schools and universities. This is because expenditure for this was, in 2004, generally carried out by government and is therefore outside the scope of this study (Druckman and Jackson 2009b; Druckman and Jackson 2009a).

The major limitations within this study arise from the aggregation of the two primary data sets of time use and GHG emissions into activity categories. Jalas (2005: p136), in a similar study, argues that there is *"no single 'right' categorization of activities,"* and therefore describes his household activity categories as *"a partly arbitrary attempt to decompose everyday life into sequences, towards which humans orient their attention"* (Jalas 2005: p136). These observations also apply well to this study and it is important to note that the activity categories used are built up of many activities which are often carried out in many different ways by different households. For example, one household member may watch television on a small-screen portable set in the kitchen, while another may use a larger set with amplified sound in the living room. The motivation may be essentially the same in both instances. But the associated GHG emissions could be considerably different.

Multi-tasking and multi-purpose goods can also reduce the credibility of set activity categories (Alcala and Antille 1999; Jalas 2009). Accounting for multi-tasking, except where noted, is outside the realms of this study, however it is clear that this occurs for many household activities. For example, according to the Time Use Survey (ONS 2006b) Eating and drinking was often carried out as a secondary activity while Going out with family/friends was recorded as the main activity. Furthermore, the use of multi-purpose goods presents problems for categorization if use of the goods spans different activities. This is becoming more relevant with the increasing use of 'smart' phones and tablet computers. Such devices can be used for accessing the internet, watching television or reading (Grossman 2010). Any future time use studies will need to account for the increased proliferation of such devices and their impact on the categorisation of activities.

Jalas (2005) argues that it is not possible to allocate the energy use of certain household services and goods to time using activities and this includes furniture and financial services, for example, as in our study (see Appendix 4). However Jalas (2005) excludes heating and lighting whereas in this study, GHG emissions relating to heating and lighting have been allocated according to the time spent on indoor activities. This, arguably, provides a clearer picture of the true GHG intensities of activities taking place within the home. While Jalas (2009) makes the point that this type of consumption does *"not require the active and direct participation of consumers in order to be consumed,"* this study takes the view that even if heating and lighting are being used while the household members are not present, the related emissions can still be allocated to the activities for which they are required. For example, if the heating is left on while the household members go to work, in order to provide a comfortable temperature in which to have dinner and watch television upon their return, then it stands to reason that the related emissions from the heating can be allocated to having dinner and watching the television. While similar deductions can be made regarding furniture and textiles, the vast differences between these items and their use in different households make any assumptions with regard to activity allocation problematic, therefore emissions associated with furnishings and textiles have been excluded from this study.

In light of the limitations presented here, the results offered in this study should be regarded as a first step towards analysing the GHG emission intensity of activities per unit of time for the UK. There is great potential for future research to provide more accurate and tailored results for households across the UK.

3 Results

In this section we first sketch a picture of how an average British adult spends their time. We then present the estimates derived in this study for the GHG intensity of time use.[5]

3.1 How an average adult uses their time

The way in which an average British adult uses their time is shown in Figure 1. Unsurprisingly, this shows that the highest single time-use category is Sleep and Rest, at nearly 9 hours per day, with Leisure and Recreation[6] being the next highest category, accounting for on average 5.7 hours per day. In this chart, the category Household, which accounts for an average of 2.7 hours per day, includes cleaning and tidying of the house, repairs, gardening, pet care, personal care, clothes care and caring for others. Food and Drink, which accounts for 2.1 hours per day, includes both eating and drinking (including alcohol and eating out) as well as food preparation and dishwashing.

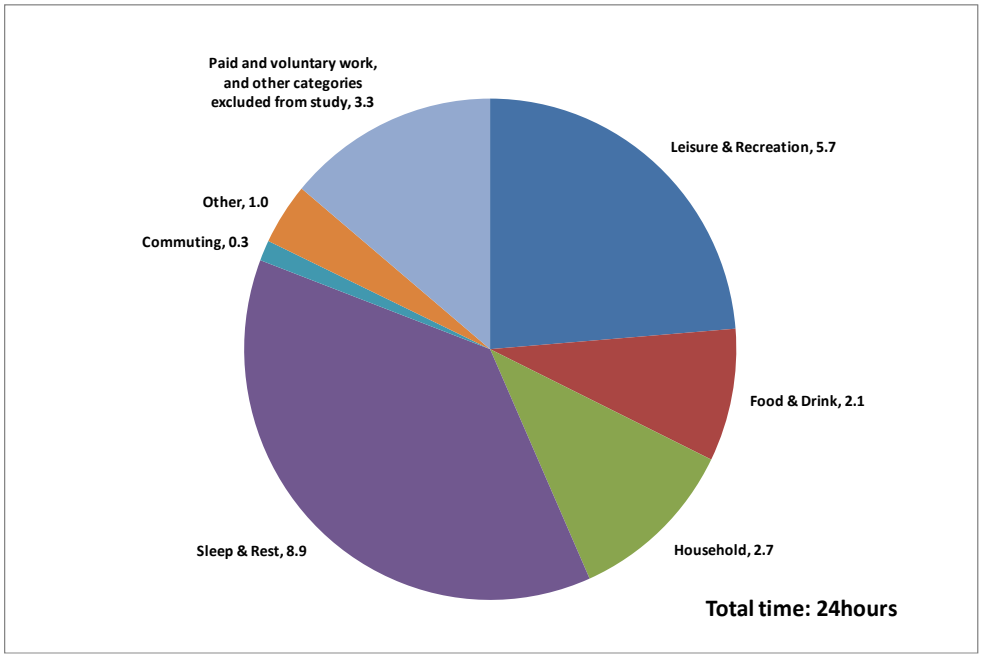


Figure 1: Time use of an average British adult. Source ONS (2006b)

[5] Readers who are interested in looking at detailed estimates of the GHG emissions of an average UK household allocated to high-level functional uses are referred to Druckman and Jackson (2010).

[6] Leisure and Recreation includes the following categories:

- Spending time with family/friends at home
- Spending time with family/friends outside the home
- Reading
- TV & Videos/DVDs, Radio & Music
- Hobbies & Games
- Entertainment & Culture
- Sport & Outdoor Activities.

In the results that follow we show the intensity (GHG emissions per unit time) of different time-use activities. As noted above, due to difficulties in relating certain activities to GHG emissions and *vice versa*, it was necessary to exclude several time use and GHG emission categories from the study. The time excluded from the study, which includes paid and voluntary work, is 3.3 hours per day. The GHG emissions excluded from the study account for around 5.2tCO_2e per household of the total carbon footprint of 26.1tCO_2e per household.

3.2 The GHG intensity of time use of an average adult

Figure 2 shows the GHG intensity of some broad categories of time-use. From this we can clearly see that Sleep and Rest, as expected, has an extremely low GHG intensity. The graph shows that leisure activities have a relatively low intensity, at around 1kgCO_2e/hr, compared to the daily average intensity of 1.2 kgCO_2e/hr. The most GHG intensive time use categories are Food and Drink, and Commuting, both giving rise to over 3.5kgCO_2e/hr. One notable feature of this graph is the striking difference in the time use intensities shown: for example time use associated with the category Food and Drink is over 42 times more GHG intensive than Sleep and Rest, and nearly 4 times as intensive as Leisure and Recreation.

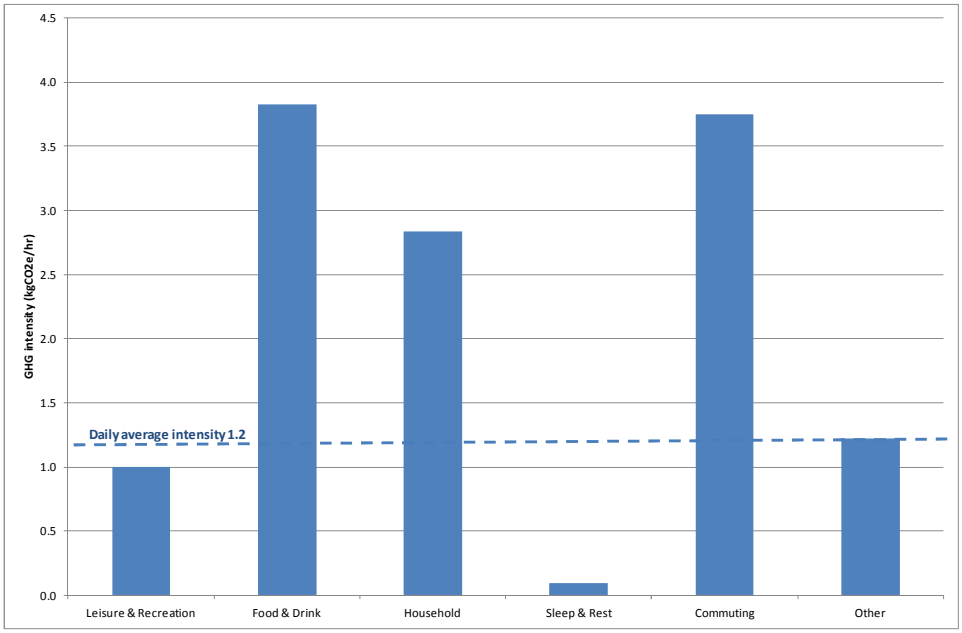


Figure 2: The GHG intensity of time use – broad categories

One particular aspect that is interesting to explore is the importance of travel in the GHG intensity of time use. Figures 3a and 3b show more disaggregated time use categories. In Figure 3a the contribution of emissions due to transport is shown separately within each category. Here, the GHG intensity of the travel component includes both direct fuels used for transportation, such as petrol and diesel, as well as embedded emissions attributed to travel, such as those from the production and distribution of cars, and those attributed to public transport. This graph demonstrates the importance of travel emissions in activities that take place outside the home such as Entertainment and Culture (which includes, for example, outings to the theatre) and Sport and Outdoor Activities (such as trips to football matches). These activities are dominated by travel emissions. Conversely activities that take place in the home have, in comparison, relatively low emissions per unit time.

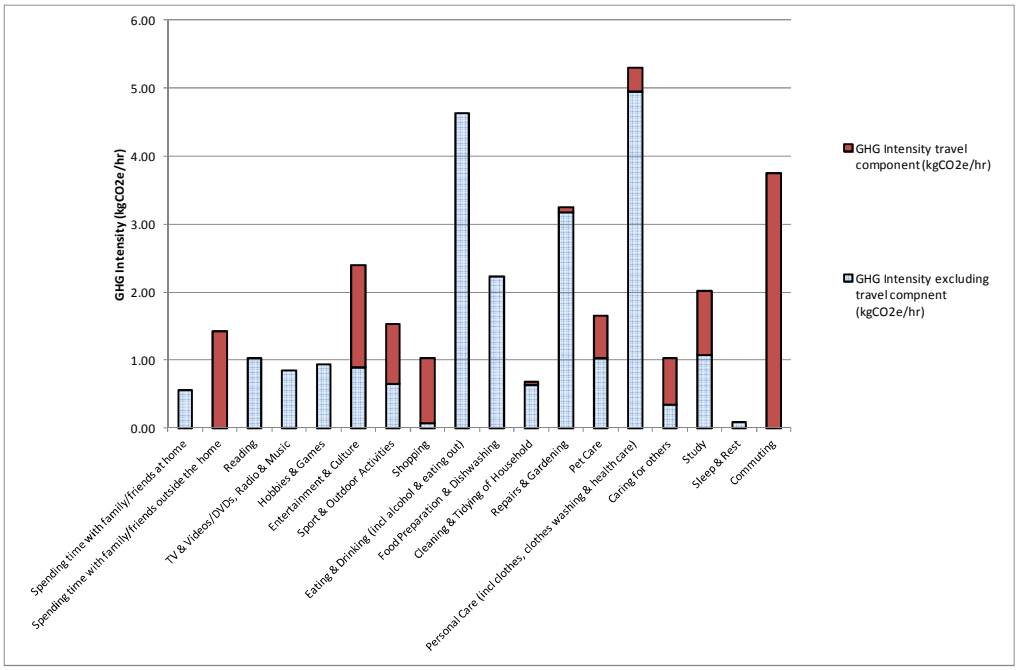


Figure 3a: The GHG intensity of time use – detailed categories with total travel disaggregated

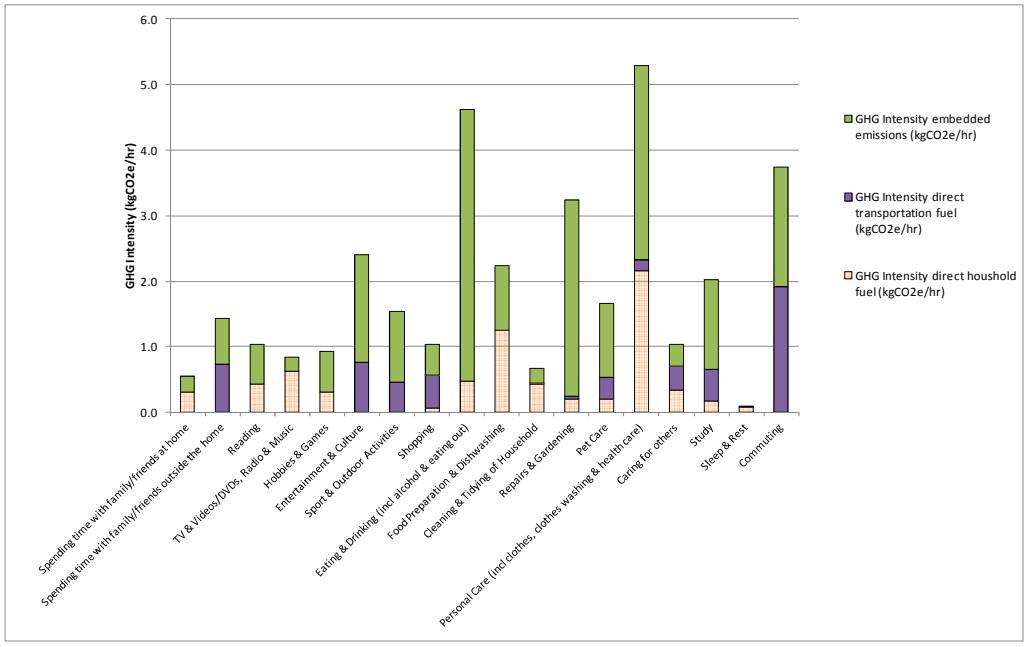


Figure 3b: The GHG intensity of time use – detailed categories showing direct and embedded emissions

Prominent exceptions to this are the GHG intensities of Eating and Drinking, Food Preparation and Dishwashing, Personal Care, and Repairs and Gardening which have high GHG emissions per unit time, but relatively low travel emissions. In order to understand these categories in more detail, Figure 3b shows the same categories of time use with the

emissions this time allocated to: direct household fuel (gas, other fuels and electricity); direct transportation fuel; and embedded emissions. This graph shows that embedded emissions account for around 90% of emissions due to Eating and Drinking. These are emissions that arise along the food supply chain, including, for example, emissions due to fertilisers, pesticides and transportation. Similarly around 93% of emissions due to Repairs and Gardening are embedded emissions. However in the time use category Personal Care, embedded emissions only account for around 56% with direct household fuels accounting for around 41% and the balance made up of a small portion of direct transport fuels.

Another feature that is clearly demonstrated in Figure 3b, is the importance of embedded emissions in travel. As can be seen in Commuting, only around half of the emissions due to transport are from direct fuel use in personal vehicles (petrol/diesel), with around half being embedded emissions. This is explored in more detail in Druckman and Jackson (2010).

These figures enable us to explore which type of leisure activities are less GHG intensive in more detail than in Figure 2. Spending time with family/friends at home is the least GHG intensive category apart from Sleep and Rest. This category includes both spending time with family and friends when family and friends are physically in the home and also spending time with them remotely, for example talking on the phone or by electronic means such as through email. At around 0.6kgCO_2e/hr, this time use category is composed of around 56% emissions due to direct household fuel use (which includes heating, lighting, and electricity for powering equipment) with the remainder being embedded emissions that arise during manufacture and distribution of equipment (such as telephone and computer).

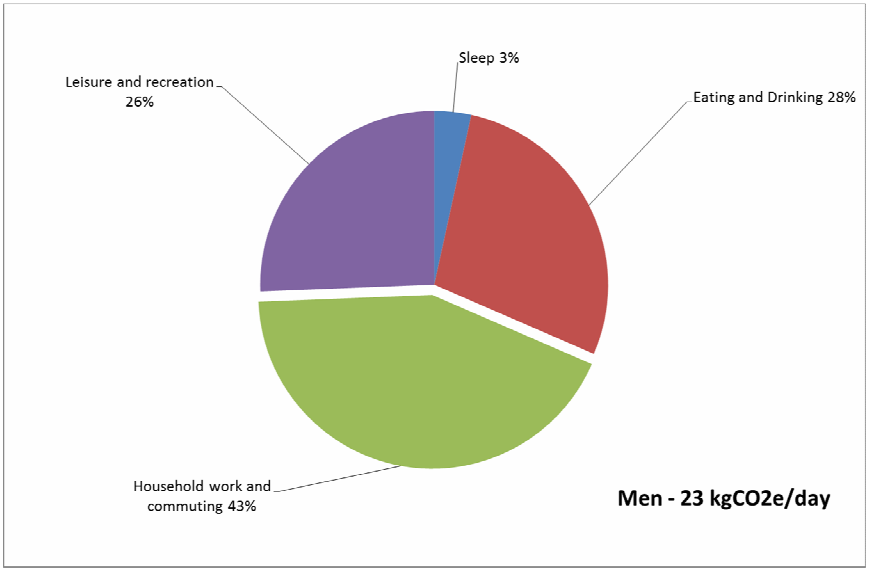
Entertainment and Culture is the most intensive leisure time use category, at around 2.4 kgCO_2e/hr. From Figure 3a we can see that the total (embedded and direct) emissions due to transport make up around 63%, again demonstrating the importance of travel emissions. The embedded emissions in this category include, for example, GHG emissions due to leisure services such as running theatres and cinemas.

In this study we chose to keep Shopping as a category of its own whereas in previous studies we have allocated emissions due to shopping to the category of items purchased (Carbon Trust 2006; Druckman and Jackson 2009b; Druckman and Jackson 2010). The reason for this choice is that we were interested in investigating shopping as a leisure activity. Interestingly the GHG emissions per unit time for shopping are estimated at around 1.0 kgCO_2e/hr which is less than the average intensity of 1.2 kgCO_2e/hr. This includes time spent shopping both in the home (such as internet shopping) and also time actually at the shops. Importantly, it should be noted that, as stated above, it excludes the GHGs due to either items purchased or to the infrastructure and running of shops and shopping malls. Thus the figure here may be considered an under-estimate.

3.3 Men, women, time and carbon

Using the time use data identified in Section 3.1 and the carbon intensities of time use shown in Section 3.2, we now allocate total carbon to different high-level time use categories for British adults. Figure 4 shows the average daily GHG emissions of British men and women allocated to high-level time use categories. A particular concern here is to differentiate household work (and associated activities) from what we might call discretionary time – time spent in leisure and recreational activities. Hence the categories shown in Figure 4 are slightly different from those used in Section 3 above. Specifically, the Household Work and Commuting category has been taken here to include the following

subcategories: food preparation and dishwashing; commuting, shopping and study. Other categories have been adjusted accordingly.



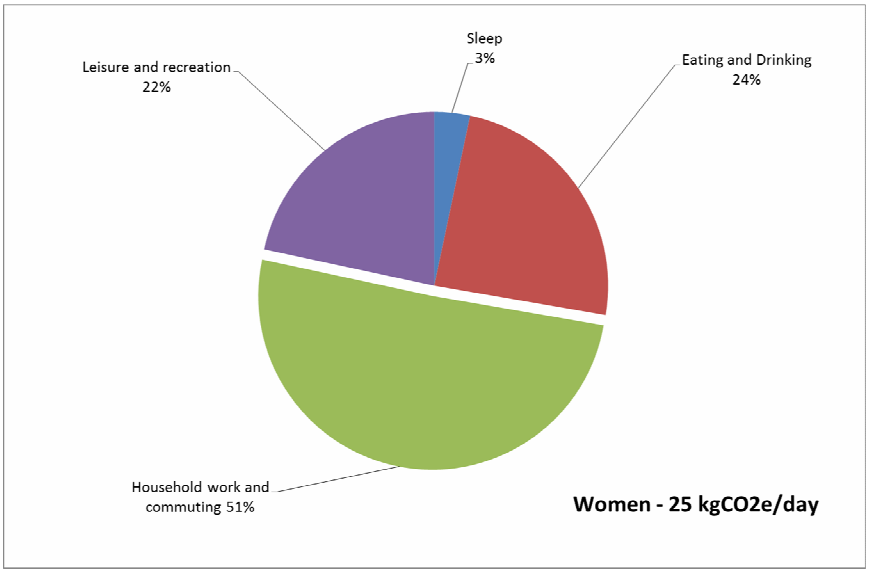


Figure 4: The average daily GHG emissions of British men and women

Figure 4 shows that the total GHG emissions for an average day are slightly higher for women than for men (around 25kgCO_2e for an average woman compared to around 23 kgCO_2e for an average man). This is perhaps not surprising since women have on average more 'non-work' time than men - 21.3 hours per day compared to 19.8 hours per day (ONS 2006b). Conversely men spend more time at work and it should be remembered that the carbon emitted from work (production) is attributed in this accounting system to consumption based activities. In fact, the overall carbon intensity of time use for an average woman is almost the same as that for an average man, at around 1.2 kgCO_2e/hr.

There are, however, some differences between men and women in terms of the carbon implications of the way they spend their time. First, it is of course already widely known that women spend more time in household work than men do. So it is perhaps not surprising to

find that the carbon associated with household work is higher for women than it is for men, slightly offset by the higher carbon attributable to men commuting to work. Conversely, men spend more carbon in leisure and recreation activities than women do. About 26% of men's carbon footprint is allocated to leisure, compared to 22% for women. This is partly because they spend more time in leisure and recreation than women. But it is also partly because they tend to engage in more carbon intensive leisure activities than women do, spending more time in out-of-home activities than women do.

The differences are admittedly not huge, and it is certainly not possible to draw hard and fast conclusions about sexual politics from these data. It should be remembered in particular, of course that, gender differences in this analysis can only be seen as proxies for role differences. Mary Douglas (1976) postulated that '*An individual's main objective in consumption is to help create the social world and to find a credible place in it*.' From the perspective of this paper, we might paraphrase Douglas to suggest that the main objective of *time use* is to help create the social world and to find a credible place in it. It is not revolutionary to suggest that men and women approach this task in different ways. The results here indicate that these differences will probably have carbon implications and may well have important ramifications when it comes to carbon emission reduction policies, or indeed to work-time reduction policies.

3.4 Comparison with other studies

There are very few comparable studies with which to compare the results of this study, and, in particular there are no studies, to our knowledge, which explore the difference in GHG intensity of time use between men and women. The most comparable studies are those carried out by Jalas (2002; 2005; 2006). Jalas studied the time use intensity of direct and indirect energy use by Finnish households 1987–1990. He used different categories of intensity to those selected in our study, but found similar patterns, with time uses that incur travel having generally higher intensities, and with leisure activities having generally relatively low intensities.

Similarly, in a study of the direct and indirect energy use associated with leisure activities by Norwegians in 2001, Aall et al (2011) found that the energy use per hour was lower for leisure activities within the home such as traditional games, and radio and television, and that activities requiring travel were in general more energy intensive per unit time. A notable exception to this was an exceptionally high energy intensity found for 'Redecoration.' This is similar to the high GHG intensity shown for Repairs and Gardening in our study (see Figure 3). Also in line with our results, Aall also found that reading was more energy intensive than listening to the radio and watching television.

Minx and Baiocchi (2009) studied the material intensity of time use in Western Germany in 1990. Again, the categories used were different to those in either Jalas's, Aall's or our study. They found that the highest material intensity categories were Household Production and DIY, with Leisure and Socialising having relatively low material intensities of time use.

4 Discussion and conclusion

We started this paper reminding readers that, in order to achieve the challenging reductions in GHG emissions required to meet climate change objectives, technology alone will not do the job: behaviour change is essential. And yet to date we are struggling to engage consumers in the behaviour change actions necessary. This is, in part, because consumers are to a large extent locked-in to the systems of provision within which they carry out their lives. But it is also because carbon emissions are driven by aspiration, by the search for luxury, status and influence, and by the pursuit of the 'good life' (Carrillo-Hermosilla 2006; Jackson and Papathanasopoulou 2008; Sanne 2002; Unruh 2002). Some of this is closely bound up with individual and collective identity and driven crucially by social norms (Gregson et al. 2007; Hamilton 2010; Jackson 2009).

This study recasts these discussions in terms of time use. For instance, it shows that a significant proportion of carbon is 'locked up' in basic systems of household provision: the way we cook, shop, commute, care for ourselves, our clothes, our homes, and for others. Women's carbon footprint tends to be slightly higher because they spend more time in these activities. But this division of carbon simply mirrors a 'division of labour' in the home. And beyond this division of labour there are some potentially more significant 'divisions of leisure'. Men spend more carbon in leisure and recreation than women do, partly because they spend more time in leisure and partly because they spend time differently in leisure, preferring for example to socialise outside the home.

Leisure activities generally have lower than average GHG emissions intensity, at around 1kgCO_2e/hr compared to an average of all activities of around 1.2 kgCO_2e/hr. Furthermore, our study has shown, for example, that activities in and around the home, such as reading, playing games, or simply spending time with friends and family, are all relatively low GHG intensity leisure pastimes compared to those that involve travel. So a possible strategy for reducing GHG emissions is to shift leisure activities towards those that take place in and around the home. But such a strategy would clearly have to navigate the subtle and sometimes not so subtle differences that characterise people's use of leisure time. Gender is one those differences. But identity – even within gender – is closely bound up with the way that we socialise and the activities we engage in.

This possibility raises interesting concerns about carbon allocation and social justice – concerns that are likely to be exacerbated by a consideration of wider social and demographic differences between people. For example, Nussbaum discusses the economics of 'tragic choices', where many must choose between leisure time and a decent standard of living, choosing to work longer hours to support their family while knowing that family relations will suffer (Nussbaum 2011). She considers the case of a single parent who may effectively have no choice over significant aspects of the use of her time.

Elsewhere Robert Goodin has reflected on our ability to control of the use of our time, or the 'capacity to spend time' as one wishes (Goodin 2010). He frames this discussion as a question of temporal justice. Goodin argues that there are increasing inequalities in particular over '…discretionary control over one's time'. Based on a review of six nations[7], he argues that the type of person with the greatest capability to exercise control over discretionary time is 'almost invariably' the person in a dual-earner household with no kids (so-called DINKs). By contrast the person with the least discretionary time is often the 'lone mother'.

[7] US, Australia, Germany, France, Sweden and Finland.

When we couple these concerns with the allocation of carbon between non-discretionary and discretionary time, we can see that carbon reduction policies may inadvertently invoke a dual set of injustices: temporal and carbon. As framed by Goodin and Nussbaum, this is generally a gender issue, however, with changing family structures (Allan et al. 2001; Godbey 1996; Godbey et al. 1998; Patterson 2000), it might increasingly be seen as an issue of household roles.

The complexity of this terrain should already warn us against simplistic expectations about behaviour change. Both household provisioning activities and the use of discretionary time are likely to be resistant to change, without appropriate changes in underlying and supporting physical and social structures. This is clearly true for policies aiming to change leisure practices. It is also true for policies aimed at work-time reduction.

Many observers have advocated a decrease in working hours as a way of enhancing well-being and improving the social, economic and ecological balance of Western economies (Coote et al. 2010; Gorz 1994; Hayden 1999; Jackson 2009; Reisch 2001; Schor 2005; Victor 2008). But this paper indicates that a simple transfer of time from paid work to the household may be employed in more or less carbon intensive ways. The actual carbon reduction achieved will depend on who works less and where that former work-time is allocated. The methodology employed in this paper could potentially be used to estimate these impacts. But simplistic prescriptions about associated carbon reduction are likely to fail. Much will depend on the whether reduced working time means reduced income, on whether reduced income leads to significant changes in non-working time allocation, and on whether the reduction in working time is shared equally between men and women, for example.

In principle, none of this detracts from the possibility that people could actually work less and still live better lives. But beyond the gender and income implications of this suggestion, it is crucial to identify the appropriate supportive structures that would allow us to lead 'slower' lifestyles, and spend more time (for example) to care for our children and the elderly; or simply to have fun in less carbon intensive ways.

For instance, the analysis indicates that travel infrastructure is key to lowering the carbon implications of both household work and leisure activities. Evidence from the past suggests that we have constant time budgets for travel: the amount of time we spend travelling has traditionally not changed whereas the distance we travel has vastly increased (Binswanger 2001; Hofstetter et al. 2006). With constrained income this may change, but may also lead to impoverished lives unless there are appropriate changes to planning and infrastructure provision.

Generally speaking, looking at time use by households without taking account of the interconnectedness of the economy is a heroic simplification. Households are both producers and consumers: in simplistic economic terms, households receive wages in return for working in industry to produce goods and services for consumption. They also invest their savings in industry, in return for dividends. The mix of goods and services that households choose to consume largely drives industry, and determines which sectors thrive[8].

[8] As different sectors have very different carbon intensities, this has important implications for supply-chain emissions carbon (Carbon Trust 2006).

From the point of view of time use, the amount of time that households work is, of course, directly related to their amount of non-work time, and this has knock-on effects (although not so straightforward) for wages, prices and spending, and the output of industry (Becker 1965). A reduction in working time may generally be expected to reduce incomes and increase non-work time. Traditional economics might say that the mix of goods and services that households choose to spend their resulting income on can be estimated using income elasticities. But this would ignore the issue of time use, as income elasticities for different goods and services are biased when the dimension of time use is omitted (Becker 1965). The change in the mix of goods and services consumed due to a change in time use and the associated carbon emissions are hard to predict and beyond the scope of this paper.

Nonetheless, the suggestion that reduced work-time will lead to lower carbon emissions must at least begin to address the possibility of time rebound. Everything depends on how the time freed up is re-spent. Under conditions of constrained income, people (and perhaps more particularly women) may spend more time in household provisioning and shift the balance away from less carbon-intensive leisure time. Not all of these changes lead to positive rebound of course. For example, if we had more time away from work, we may spend more time but less energy in shopping, cooking and eating, and be more careful with the food that we buy and waste. It is hard to project the carbon intensity of time use changes without further evidence. But the lesson here is that 'carbon rebound' from work-time reduction should be factored into policy analysis.

Thus a full analysis of the implications of changes in time use within the home for carbon emissions is intertwined with changes within the entire economy and any analysis must also recognise that some sections of communities may need additional support if they are to exercise their capability to use time in new, potentially less carbon intensive ways. Modelling this is a challenging task and outside the remit of this paper. Nevertheless, by developing a deeper understanding of how we use GHGs to support UK lifestyles using the time-use perspective as in this paper, it is hoped that we can help generate more successful strategies to aid the transition to a lower carbon future.

Finally of course the astute reader will not have failed to notice that there is considerable potential for carbon reduction to be achieved by both men and women – including the authors of this paper – by getting more sleep.

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Appendix 1: COICOP Categories

01.1	Food
01.2	Non-alcoholic beverages
02.1	Alcoholic beverages
02.2	Tobacco
03.1	Clothing
03.2	Footwear
04.1	Actual rentals for housing
04.2	Imputed rentals for housing
04.3	Maintenance and repair of the dwelling
04.4	Water supply and miscellaneous dwelling services
04.5	Electricity, gas & other fuels
05.1	Furniture, furnishings, carpets etc.
05.2	Household textiles
05.3	Household appliances
05.4	Glassware, tableware & household utensils
05.5	Tools and equipment for house & garden
05.6	Goods & services for household maintenance
06.1	Medical products, appliances & equipment
06.2	Out-patient services
06.3	Hospital services
07.1	Purchase of vehicles
07.2	Operation of personal transport equipment
07.3	Transport services
08.1	Postal services
08.2	Telephone & telefax equipment
08.3	Telephone & telefax services
09.1	Audio-visual, photo & info. Processing equipment
09.2	Other major durables for recreation & culture
09.3	Other recreational equipment etc.
09.4	Recreational & cultural services
09.5	Newspapers, books & stationery
09.6	Package holidays
10.	Education
11.1	Catering services
11.2	Accommodation services
12.1	Personal care
12.3	Personal effects nec
12.4	Social protection
12.5	Insurance
12.6	Financial services nec
12.7	Other services nec

Source: ONS (2006a)

Appendix 2: Time Use Survey categories

Sleep
Rest
Personal care ie wash/ dress
Eating & Drinking
Cooking, washing up
Cleaning, tidying
Washing clothes
Repairs and gardening
Pet care
Paid work
Formal education
Recreational study
Voluntary work
Caring for own children
Caring for other children
Caring for adults in own household
Caring for adults other household
Shopping, appointments
TV & videos/DVDs, radio, music
Reading
Sport & outdoor activities
Spending time with family/friends at home
Going out with family/ friends
Contact with friends/family
Entertainment and culture
Attending religious and other meetings
Hobbies
Using a computer
Other specified/not specified
Travel

Appendix 3: Time and GHG allocation table

Household Activity Categories	Time Allocation	GHG Emissions Allocation†
Spending time with family/friends at home	Spending Time with family/friends at Home. Contact with friends/family	Telephone & Telefax Equipment & Services (8.2 & 8.3) allocated according to Standard Industrial Classification (SIC) categories, expenditure data and data on use of ICT in the home[1]. Audio-visual, photo & info. processing equipment (9.1) allocated according to SIC categories with supplementary data from expenditure survey (ONS 2006c). Heating and lighting allocated according to time use. Direct 'brown goods' electricity use emissions allocated according to DECC 2009.
Spending time with family/friends outside the home *	Going out with family/friends. Travel time allocated according to Table 5.17 in Time Use Survey supplemented by National Transport Survey data (DfT 2009a).	Emissions from travel allocated according to National Transport Survey (DfT 2009a).
Reading	Reading	Newspapers, Books & Stationery (9.5). Assume GHGs due to stationary are negligible. Heating and lighting allocated according to time use.
Watching TV & Videos/DVDs, Listening to Radio & Music	TV & Videos/DVDs, Radio, Music Use of computer allocated according to secondary activity.	Telephone & Telefax Equipment & Services (8.2 & 8.3) allocated according to SIC categories, expenditure data and data on use of ICT in the home[1]. Audio-visual, photo & info. processing equipment (9.1) allocated according to SIC categories with supplementary data from expenditure survey (ONS 2006c). Recreational and Cultural Services (9.4) allocated according to expenditure survey. Heating and lighting allocated according to time use

Hobbies & Games	Hobbies Use of computer allocated according to secondary activity.	Telephone & Telefax Equipment & Services (8.2 & 8.3) allocated according to SIC categories, expenditure data and data on use of ICT in the home[1] Other Major Durables for Recreation & Culture (9.2) Other Recreational Items & Equipment, Gardens & Pets (9.3) allocated according to SIC categories supplemented by expenditure data (ONS 2006c) Recreational and Cultural Services (9.4) allocated according to expenditure survey. Audio-visual, photo & info. processing equipment (9.1) allocated according to SIC categories with supplementary data from expenditure survey (ONS 2006c). Heating and lighting allocated according to time use
Sleep & Rest	Sleep Rest	Heating and lighting allocated according to time use. Assumes heating is on for 2 hours per night.
Eating & Drinking (incl alcohol & eating out)	Eating & Drinking	Food and Non-alcoholic beverages (1) Alcoholic beverages (1.2) Glassware, tableware and household utensils (5.4), Catering service (11.1). Travel according to National Transport Survey (DfT 2009a).
Personal Care *	Personal Care ie Wash/Dress. Travel time allocated according to Table 5.17 in Time Use Survey supplemented by National Transport Survey data (DfT 2009a).	Clothing and footwear (3), Health (6) and Personal care (12.3). Household appliances (5.3) and Personal effects nec (12.3) allocated according to expenditure data (ONS 2006c). Medical Products, Appliances and Equipment. Travel allocated to Personal business according to National Transport Survey (DfT 2009a), of which 87% is attributed to personal care in line with Druckman and Jackson [2]. Heating, lighting and water use allocated according to time use
Study	Formal Education that takes place iside the home according to TUS Chart table 2.2. Recreational Study Travel time allocated according to Table 5.17 in Time Use Survey supplemented by National Transport Survey data (DfT 2009a). Use of computer allocated according to secondary activity.	Education (10) Telephone & Telefax Equipment & Services (8.2 & 8.3) allocated according to SIC categories, expenditure data and data on use of ICT in the home[1]. Audio-visual, photo & info. processing equipment (9.1) allocated according to SIC categories with supplementary data from expenditure survey (ONS 2006c). Emissions from travel allocated according to National Transport Survey (DfT 2009a). Heating and lighting allocated according to time use

Cleaning and Tidying of Household	Cleaning, tidying. Travel time allocated according to Table 5.17 in Time Use Survey supplemented by National Transport Survey data (DfT 2009a).	Glassware, tableware and household utensils (5.4) Goods and Services for Routine Household Maintenance (50%) (5.6) Household Appliances (5.3) allocated according to expenditure data (ONS 2006c). Travel allocated to Personal business according to National Transport Survey (DfT 2009a), of which 5% is attributed to cleaning and tidying in line with Druckman and Jackson[2]. Heating and lighting allocated according to time use
Repairs & Gardening	Repairs & Gardening.	Maintenance and Repair of the Dwelling (4.3) Tools and Equipment for House and Garden (5.5) Other Recreational Items & Equipment, Gardens & Pets (9.3) allocated according to SIC categories supplemented by expenditure data (ONS 2006c). Travel allocated to Personal business according to National Transport Survey, of which 5% is attributed to Repairs and gardening in line with Druckman and Jackson [2]. Heating and lighting allocated according to time use.
Pet care	Pet Care Travel time allocated according to Table 5.17 in Time Use Survey supplemented by National Transport Survey data (DfT 2009a) - assume 30% of Day trips are for pet care (dog walking).	Other Recreational Items & Equipment, Gardens & Pets (9.3) allocated according to SIC categories and supplemented with expenditure data (ONS 2006c). Heating and lighting allocated according to time use. Travel according to National Transport Survey (DfT 2009a) - assume 30% of Day trips are for pet care (dog walking).
Caring for others	Caring for Own/Other Children and Adults. Travel time allocated according to time spent travelling	Heating and lighting allocated according to time use. Emissions from travel allocated according to National Transport Survey (DfT 2009a).
Food Preparation & Dish Washing	Cooking, Washing Up	Glassware, tableware and household utensils (5.4) Goods and Services for Routine Household Maintenance (50%) (5.6) Household Appliances (5.3) allocated according to expenditure data (ONS 2006c). Heating, lighting and water use allocated according to time use
Entertainment & Culture	Entertainment and Culture Attending Religious and Other Meetings Travel time allocated according to Table 5.17 in Time Use Survey supplemented by National Transport Survey data (DfT 2009a) -assume 35% of Day trips are for entertainment and culture.	Telephone & Telefax Equipment & Services (8.2 & 8.3) allocated according to SIC categories, expenditure data and data on use of ICT in the home[1]. Recreational and Cultural Services (9.4) allocated according to expenditure data (ONS 2006c). Audio-visual, photo & info. processing equipment (9.1) allocated according to SIC categories with supplementary data from expenditure survey Heating and lighting allocated according to time use. Emissions from travel allocated according to National Transport Survey (DfT 2009a).

Sport & Outdoor Activities	Sport & Outdoor Activities. Travel time allocated according to Table 5.17 in Time Use Survey supplemented by National Transport Survey data(DfT 2009a) - assume 35% of Day trips are for sport and outdoor activities.	Other Major Durables for Recreation & Culture (9.2) Other Recreational Items & Equipment, Gardens & Pets (9.3) allocated according to SIC categories supplemented by expenditure data (ONS 2006c). Emissions from travel allocated according to National Transport Survey (DfT 2009a).
Shopping *	Travel allocated according to time spent travelling.	Telephone & Telefax Equipment & Services (8.2 & 8.3) allocated according to SIC categories, expenditure data and data on use of ICT in the home[1]. Emissions from travel allocated according to National Transport Survey (DfT 2009a). Heating and lighting allocated according to time use.
Commuting *	Travel allocated according to time spent travelling. Use of computer allocated according to secondary activity.	Emissions from travel allocated according to National Transport Survey (DfT 2009a).

Notes

† The numbers in the 'GHG Emissions Allocation' column refer to COICOP categories as used in ONS (2006c).

* Starred items are underestimated due to exclusion of emissions due to capital investment and government expenditure from the study.

[1] ONS (2007).

[2] Druckman and Jackson (2010) .

Appendix 4: Categories excluded from this study

Time	Paid work Voluntary work Formal education outside the home Other
GHG emissions (*COICOP Categories)*	Tobacco and narcotics (2.2) Rent paid for the housing (4.1) Rent paid by owners occupying housing (4.2) Furniture and furnishings, carpets and other floor coverings (5.1) Household textiles (5.2) Postal services (8.1) Package holidays (9.6) Accommodation services (11.2) Retirement homes, wet nurses, counsellors, adoption services etc (12.4) Insurance, financial and other services nec (12.5-12.7) Holidays: Aviation and shipping emissions. Expenditure by UK residents abroad.