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Time, gender and carbon: A study of the carbon implications of British adults' use of time

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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 people purchase towards lower impact options. But an equally valid angle is through changing the way people use their time. This study explores the GHG emissions per unit time for different types of activities. It focuses on 'non-work' time, and examines 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 British adult, and then examine how time use varies within households, and how this impacts on resulting carbon emissions. We find, for example, that leisure activities are generally associated with lower carbon emissions than non-leisure activities, and that a higher proportion of an average man's carbon footprint is due to leisure than an average woman's. In the discussion we explore the implications of our findings for the varying roles carried out within different types of household, we investigate the concept of carbon as a potential marker for social justice, and discuss the implications for work-time reduction policies.

Keywords: Time use; sustainable consumption; gender; carbon emissions; leisure.

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 (Ropke and Godsken 2007).

An important distinction between how people spend their money on goods and services (and the associated carbon emissions) and how they spend their time is that all of us, rich and poor, those who are always time-strapped and those who cannot find enough to do, all have an equal allocation of just 24 hours per day. In contrast, average UK incomes and per capita carbon emissions both vary by more 1000-fold (Gough et al. 2011; Jin et al. 2011). We can (and must) cut our carbon emissions per capita; but we cannot cut our 24 hours per day time allotment. All we can do is reduce one activity, and transfer the time to another activity.

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 time¹. 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 British 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

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.

complexities that this interconnection results in and explores the complexity of modelling future scenarios.

This paper is organised as follows: In Section 2 we set out an overview of the methodology. In Section 3 we present results, first looking at time use by an average British person, 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. We conclude with a discussion (Section 4) 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: time use data for an average British person, and the GHG emissions of an average UK household. We commence with descriptions of the two datasets followed by an explanation of how they were combined.

Time use data were obtained from ONS (2006a). The aim of the Time Use survey was to find out how people spent their time during a typical day: data collection was done in four waves in February, June, September and November 2005, and thus intended to cover all seasons, with the main holiday periods of Christmas, Easter and August being avoided.

The GHG² emissions of an average household can be divided into two distinct categories: direct and indirect (or ‘embedded’) emissions. 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.

In this study we obtain direct emissions from the UK Environmental Accounts (ONS 2008). Non-travel emissions are then 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 2006a), and further disaggregation was carried out using the National Travel Survey (DfT 2009b) Table 4.2, assuming that

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 (CO₂e) (OECD 2005).

time travelled is proportional to distance travelled³. Embedded emissions were estimated using the Surrey Environmental Lifestyle MApping (SELMA) framework. This framework combines the expenditure of 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. Full details of SELMA are given in Druckman and Jackson (2008a; 2009a; 2009b).

Time use data and GHG emissions data are in different categories and in this study were combined into activity categories selected to be representative of the household activities which incur both GHG emissions and time use. 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.

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.

A further limitation of the study is that several time use and GHG emission categories are excluded, as in other studies of this nature (Jalas, 2002; Jalas 2005a; Minx and Baiocchi, 2009). For instance, paid and voluntary work-time is excluded, since household GHG emissions cannot be allocated to this use of time. Emissions due to furnishings, rent and financial services are excluded due to the difficulty in allocating specific time uses to them. GHG emissions due to holidays are excluded as the focus of this study is time use during routine daily life. A full list of exclusions is shown in Appendix 2. Due to these exclusions it is important to note that the relative intensity of time use activities is of more importance in our analysis than absolute values⁴.

A more detailed account of the methodology, assumptions and limitations of the study is presented in Appendix 1.

³ This is based on the premise that the distribution of travel modes is the same for all journey purposes.

⁴ It is however interesting to note that the average daily intensity of a British adult of 1.2kgCO₂e/hr estimated according to this study is in fact only very slightly lower than the average intensity of 1.3kgCO₂e/hr if no exclusions in either time or GHG are made.

3 Results

In this section we first sketch a picture of how an average British person 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 adult⁶ 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 Recreation⁷ 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.

In the results that follow we show the intensity (GHG emissions per unit time) of different time-use activities. As explained above, several time-use and GHG emission categories are excluded from the study. Time excluded from the study, which includes paid and voluntary work time, 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-use⁸. 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

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 The Time Use Survey excludes children under 16 years old.

⁷ 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.

⁸ In Figure 2 'Other' is Shopping and Study.

and Drink is over 42 times more GHG intensive than Sleep and Rest, and nearly 4 times as intensive as Leisure and Recreation.

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.

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 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 the 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.

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 $0.6\text{kgCO}_2\text{e/hr}$, 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 kgCO₂e/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.

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 shows that the total GHG emissions for an average day are slightly higher for women than for men (around 22kgCO₂e for an average woman compared to around 20 kgCO₂e for an average man). This is perhaps not surprising since women have on average more ‘non-work’⁹ time than men - 21.3 hours per day compared to 19.8 hours per day (ONS 2006a). 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 kgCO₂e/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

⁹ By ‘non-work’ time we refer to time outside (formal) paid and voluntary work.

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. This might be partially a matter of preferences, but it might also be related to the different nature of men's leisure time. This is because men's leisure time is generally more 'usable' than women's, as it is more likely to be in predictable and clearly demarcated blocks, while women's leisure time is less predictable, more fragmented and more likely to be interrupted and/or combined with caring responsibilities (Bryson 2007).

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

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 1kgCO₂e/hr compared to an average of all activities of around 1.2 kgCO₂e/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 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 nations¹⁰, 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'.

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; 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

¹⁰ US, Australia, Germany, France, Sweden and Finland.

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 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.

One potential way forward that might be considered a trail-blazer for future lifestyles in which deep cuts in energy use and GHG emissions might be achieved is the concept of the “twenty minute neighbourhood”. This is a neighbourhood where all basic needs, such as shops, workplaces, health facilities, libraries and recreational facilities can be met within a twenty minute walk or cycle (Larabee 2008; McNeil 2010). Natural areas such as parks are included within the area and, because people are no longer in their cars and live more locally based lives, community spirit and social capital are increased, resulting in improved levels of well-being (Benfield 2009; Costanza et al. 2012).

These more ecologically sustainable types of developments offer two particular benefits that are relevant to our time use study. First, GHG emissions will be lower due to reduced use of motorised transport. Second, importantly, with such a radical change to infrastructure, our constant travel-time budgets (as discussed above) will almost certainly be disrupted, triggering other changes in daily time allocations¹¹. Our study importantly gives guidance concerning preferred changes from a carbon

¹¹ In 2005 British adults spent on average 82 minutes per day travelling (ONS 2006a) which translates to an average of around two twenty minute return trips per day. The actual time spent travelling in a “twenty minute neighbourhood”

perspective. By looking at the chart in Figure 3a, which separates emissions (direct and embedded) associated with transportation from other emissions, we can clearly see that leisure activities are the preferable form of time use, and that even trips to local entertainment centres are likely to have emissions below 1kgCo2e per hour, assuming current technologies. Of course, the actual numbers will change, as (for example) renewables are further introduced into the energy mix and the thermal efficiency of dwellings is improved. But this example demonstrates how the approach used in our study can give insights into the time uses that might be envisioned in a future low carbon society.

Looking at time use by households without taking account of the interconnectedness of the economy is however, generally speaking, 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 thrive¹².

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).

Nonetheless, the suggestion that reduced work-time will lead to lower carbon emissions must at least begin to address the possibility of time rebound. Much depends on how the time freed up is 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.

would depend on how many trips are made per day, whether they are multi-purpose or not, and the location of each destination within the twenty minute range.

¹² As different sectors have very different carbon intensities, this has important implications for supply-chain carbon emissions (Carbon Trust 2006).

Estimation of time rebound effects relies crucially on the availability of data, and in particular data that indicates how people would spend time freed up. However, the availability of time use data is generally scarce: in the UK it is limited to data collected by BBC Audience Research in 1961 and 1974/5, ESRC funded studies in 1983-4 (winter) and 1986 (summer), and Office for National Statistics surveys carried out in 2000 and 2005 (Gershuny 2011; ONS 2006a). Hence obtaining a time-series of data from which to estimate 'time-use elasticities' (analogous to income elasticities used in mainstream rebound work¹³) is problematic. An alternative approach would be to conduct surveys to ask how people might use any spare time. However, observed changes in time use allocation have shown that this approach is also problematic. For example Jalas (2009) reports that people have generally replaced saved time by watching TV, even though this is not on their list of desired activities when asked what they would do if they had more free time. Nevertheless, despite these difficulties, it is important that some allowance for time rebound is factored into policy analysis concerning work-time reduction.

Thus we can see that 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 help us move towards 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.

¹³ See, for example, Druckman et al (2011).

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Appendix 1. Detailed Methodology

GHG emissions of an average household

As explained in the main text of this paper, the carbon emissions of an average UK household are estimated separately as two categories: direct and embedded emissions. 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'). As stated in the main text, 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 2006a). Further disaggregation is carried out based on National Travel Survey (DfT 2009b) Table 4.2, assuming that time travelled is proportional to distance travelled¹⁴.

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 (2008a; 2009a; 2009b).

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 (2006b: Table 4)¹⁵. These categories are listed in Appendix 1 of Druckman et al (2012).

¹⁴ The National Travel Survey allocates a small portion of travel distance to 'Personal business' which includes visits to hairdressers, dry-cleaners, libraries, churches, medical appointments and so on (DfT 2009a). In the absence of further data these are allocated as follows: Personal Care 85%; Cleaning & Tidying of Household 11.5%; Repairs & Gardening 2%; Entertainment & Culture 1%; Reading 1%; Watching TV & Videos/DVDs, Listening to Radio & Music 1%.

¹⁵ 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 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

Time use by an average household

The Time Use Survey 2005 (ONS 2006a) 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 (2006a). The time use survey categories are shown in Appendix 2 of Druckman et al (2012).

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 of Druckman et al (2012).

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

$$G = 365 p \sum_{k=1}^{k=n} g_k \quad (1)$$

The GHG intensity $\bar{i}_k$ of activity k is estimated as

$$\bar{i}_k = \frac{g_k}{t_k} \quad (2)$$

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

In the following paragraphs we give details of allocations.

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 2006b: Table 4) following Jackson et al (2006) and Carbon Trust (2006).

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 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 2.

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 2009b: 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 2006a). Thus computer use is allocated to the relevant secondary activity based on ONS (2006a: Table 15), making the assumption that the remaining 13% can be allocated proportionately in the same way (ONS 2006a).

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 ${}_w t_k$. 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:

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

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.

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 household¹⁶ to estimate the per capita GHG emissions. The Time Use Survey (ONS 2006a) 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

¹⁶ Both taken from Table 5 in ONS (2011).

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 in particular 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 2006a) 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 2008b; Druckman and Jackson 2009a; 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 2009a; Druckman and Jackson 2009b). 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 2009a; Druckman and Jackson 2009b).

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 2006a) Eating and drinking was often carried out as a secondary activity while Going out with family/friends was recorded as the main activity. Caring for children, the elderly or disabled is frequently a secondary activity during various household activities

such as Food preparation and dishwashing, particularly in the case of women (Bryson 2007). 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 2). 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.

Appendix 2. Categories excluded from this study

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

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

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

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.

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