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Worktime Reduction as a Solution to Climate Change: Five Scenarios Compared for the UK

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ABSTRACT

Reducing working hours in an economy has been discussed as a policy which may have benefits in achieving particular economic, social and environmental goals. This study proposes five different scenarios to reduce the working hours of full-time employees by 20% with the aim of cutting greenhouse gas emissions: a three-day weekend, a free Wednesday, reduced daily hours, increased holiday entitlement and a scenario in which the time reduction is efficiently managed by companies to minimise their office space. We conceptually analyse the effects of each scenario on time use patterns through both business and worker activities, and how these might affect energy consumption in the economy. To assess which of the scenarios may be most effective in reducing carbon emissions, this analytical framework is applied as a case study for the United Kingdom. The results suggest that three of the five scenarios offer similar benefits, and are preferable to the other two, with a difference between the best and worst scenarios of 13.03 $MTCO_2e$. The study concludes that there is a clear preference for switching to a four-day working week over other possible work-reduction policies.

1. Introduction

The option of choosing between working less and receiving a pay rise is not one that employees are often given. The trend in Western societies has been heavily focussed towards converting labour productivity gains into increased incomes over reducing working time, fuelling our consumption-driven economies. Although it is not yet high on the mainstream political agenda, there is a growing call in the academic literature and beyond to reverse this trend and move towards a society where we work considerably less. The focus of this discussion has to date largely been around the feasibility or impacts on health and happiness, and the macroeconomic consequences, such as employment creation (Antal, 2014; Böheim & Taylor, 2004; Kivimäki et al. 2015).

Recent research has also argued that, next to social and economic benefits, widespread adoption of such a policy could also have environmental benefits (Schor, 2005; Devetter & Rousseau, 2011; Rosnick 2013). This has largely been argued from the perspective that reduced working hours, through reduced incomes, will lead to a dematerialisation of our economies and thus lower energy use from the reduction in consumption. It has been suggested that a 20% reduction in work time could result in a decrease in national energy use by 16% (Nassen et al., 2009). Rosnick and Weisbrot (2007) calculate that the United States could reduce energy use by 20% through following the EU-15 work hours. With the majority of global energy use still coming from greenhouse gas emitting sources, reducing working hours may therefore help in keeping emissions low enough to limit global warming to 2 °C, as advised by the IPCC and accepted in the Paris climate agreement of December 2015.

The literature regarding the environmental impacts of reducing work hours has so far taken the perspective of reducing consumption, without considering the extent of how it could change the time use and energy consumption patterns in society. It also fails to capture the effects on energy use from business activities. A systems perspective is needed to undertake a reliable sustainability assessment. Pullinger (2014) offers practical considerations for designing working time reduction policy, recognising it can be implemented in a number of ways. However, this has not yet translated into systematic analysis of the potentially differing effects such designs could have on our energy (and time) use. If energy usage patterns differ between policy designs, then this means that associated greenhouse gas emissions will be different as well.

This paper tackles this issue by defining five different policy scenarios that could be implemented to reduce the number of working hours in society, and conceptually analysing the potential effects each could have on greenhouse gas emissions. The resulting conceptual framework

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is then applied to the case of the United Kingdom to quantitatively compare the relative impacts of each scenario. This is followed by a discussion of the results and policy insights.

2. Historical and Global Trends

Keynes (1933) famously predicted that due to gains in technical efficiency over the coming century we would all be moving to a dramatically reduced fifteen-hour workweek. Indeed, following World War II, the global trend was a considerable decline in working hours. In the period 1950–1973 the average decline in working hours per person was 0.57%, per annum, increasing to 0.7% from 1973 to 1980 (Schor, 2005). From this point on however, the trend started to become less steep, with the decline in working hours being only 0.3%. In the United States, working hours actually increased during this period, while others such as Australia remained relatively stable. Some countries, such as Germany continued to reduce working hours, and as can be seen in Fig. 1, German workers now work on average 77% of the hours worked by Americans. Fig. 2 shows the trend of average annual work hours in OECD countries from 1970 to 2013, which have progressively decreased from 2000 to 1780 during this period.

The United Kingdom has been chosen as a case study for the purposes of this paper's analysis. As shown in Fig. 1, its working hours are fairly average within the OECD countries, and its historical trend, shown in Fig. 2, follows the typical trend since 1970. An average UK worker, works around 20% longer hours than a Dutch or German worker, which is equivalent to the work reduction policy we are discussing in the paper. It could therefore be argued that such a policy is far from radical, as it moves the United Kingdom closer to otherwise similar economies of Germany and Netherlands.

Fig. 3 compares the changes in real average wages and work hours in the United Kingdom from 1990 to 2013. While working hours reduced by 5.8%, the increase in real average wages was far more significant at 35.3%. It is clear that the majority of gains in labour productivity over this period were prioritised towards increasing incomes rather than reducing working hours. Schor (2005) argues that this trend has primarily been due to firm-level incentives for longer hours alongside failure in the functioning of trade unions.

There has however been discussion in high income nations regarding whether we should now prioritise reducing work hours, as opposed to wage increases. From a social perspective, the literature has largely concentrated on the negative effect long working hours can have on psychological well-being and stress (Albertsen et al., 2008). It has also become a popular topic of discussion within economists debating our current paradigm of pursuing economic growth; arguably, greater happiness could be achieved by moving to an improved 'work-life balance', where more time is spent with family and friends, or leisure activities are pursued (Kallis, 2011; Van den Bergh, 2011). Through the consequent reductions in incomes, we could move towards a less consumption-driven economy. Under this premise, a small but growing body of literature has been analysing whether such a policy could also help us realise our environmental goals. (Schor, 2005; Nassen et al., 2009; Devetter & Rousseau, 2011; Rosnick 2013).

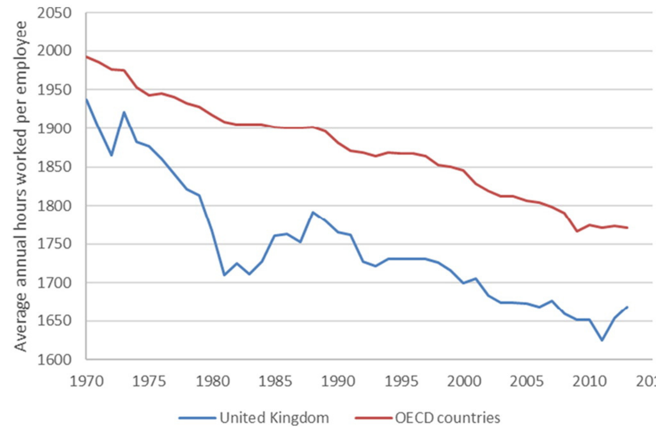

Fig. 2. Change in average annual hours worked in the UK and OECD countries 1971–2013 (Based on data from OECD Stat).

Modelling by Victor (2012) suggests that in a degrowth or low/no growth economy, worktime reduction may be a relevant factor in keeping unemployment and poverty low, while realising greenhouse gas reductions. The scale of the worktime reductions ranged from 15% for the low/no growth economy to 75% for the degrowth economy. However, a recent literature review on the topic concluded that it often does not capture the complexity of such policies, and ignores the second or third-level effects (Kallis et al. 2013).

Unfortunately, there are few empirical examples to assess the direct effects of a reduction in working hours on society. One case study of interest however is France, where in 1998 the government mandated a reduction in the working week from 39 to 35 h, aspiring to reduce unemployment. The evidence suggests that this was not significantly beneficial for employment or employee satisfaction (Estevão & Sá, 2006). Moreover, workers often work more than 35 h per work through overtime arrangements or second jobs. Despite this, of interest is the large effect the policy has had on social behaviours, particularly the broadening of the traditional peaks in transport and leisure activities.

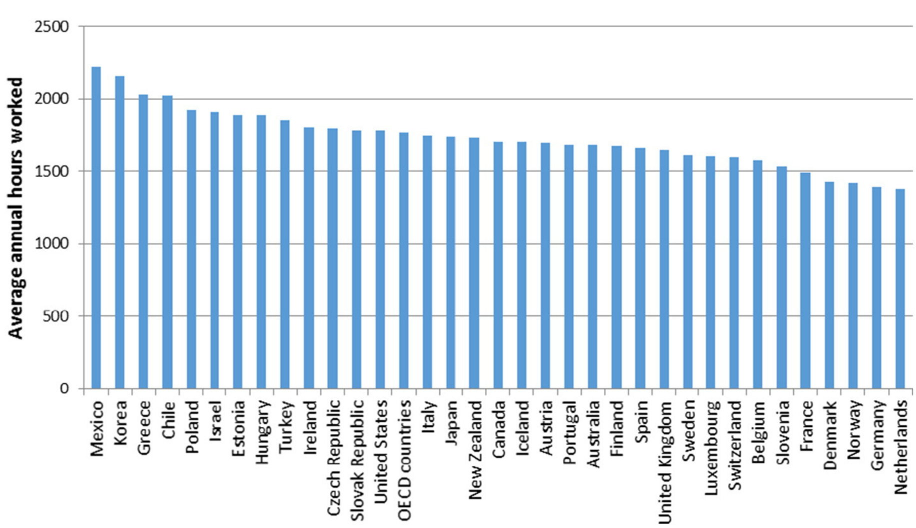

Fig. 1. Comparison of average annual hours worked in OECD countries for 2013 (Data: OECD Stat).

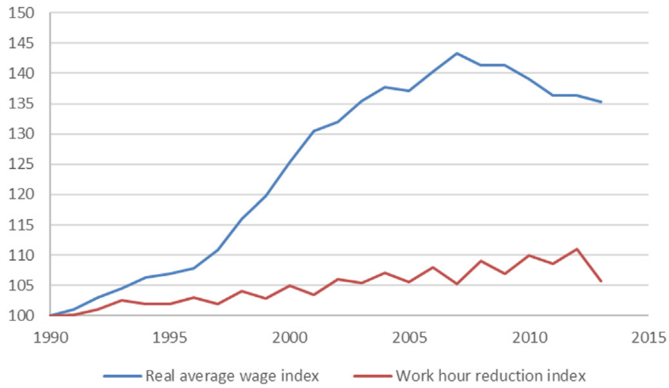

Fig. 3. Comparison of UK real average wages and reduction in average work hours 1990–2013 (Data: OECD Stat).

Survey findings also suggest that the shorter working week has moved France towards having less materialistic aspirations, with workers preferring to spend their extra free time with their families resting, or enjoying sport and cultural activities (Sanches, 2005).

Of further interest in the France case is the diversity of ways in which employees have arranged their weekly routines to adopt the reduced hours, as summarised in Table 1. These include reducing the number of hours worked per day, taking more holidays and having an extra day off every other week. This is consistent with our thinking of there being a number of different potential policy designs for reducing working hours. In practice, the French policy appears to have resulted in a blend of these different options. Given the potentially different effects on social behaviours and routines, it leads us to ask whether any potential arrangements for reducing work time could be more effective for society in achieving its environmental goals.

3. Formulation of Scenarios

A policy to reduce working hours could be implemented under a number of different practical arrangements, and could apply per week, month or annum. For our analysis we have considered five different potential policy scenarios to reduce per annum working hours. To this end we define the following scenarios:

(A) *Four-day workweek: Three-day weekend*
The most typical working arrangement throughout the OECD countries is the five-day workweek followed by a two-day weekend. Under this scenario, the workweek would be reduced to four days, giving an overall reduction in hours of 20%, provided working hours remain constant on the other four days. We assume that the extra free day is fixed on a Friday for all employees, providing an extended, three-day weekend during which businesses are closed and employees are not working in some sectors of the economy. However, we assume that companies in the hotel and catering, sports and leisure, and retail sectors, which currently operate during weekends, will decide to remain open on Fridays. Employees in these sectors will be given a free day off spread across the seven-day week in lieu of having Friday off.[1]

(B) *Four-day workweek: Free Wednesday*
An alternative application of a four-day working week would be to allocate the free day mid-week on a Wednesday instead of forming a three-day weekend. As with scenario A, the hotel and catering, sports and leisure, and retail sectors will not close on these days; individual employees' free days will be spread across the week in these sectors.

(C) *Workday reduction*
Typical work hours in the OECD countries are currently around 8 h per day. The average of a full-time employee in the UK is slightly lower at 7.5 h per day. Under this scenario, daily work hours would be reduced by 20%, meaning a 6-h workday in the UK, and 1.5 extra hours of free time every evening for each employee. Businesses in all sectors will remain open five days a week, but with the expectation of the offices closing earlier.

(D) *Increase in personal holiday entitlement*
Annual leave can fall into two subcategories; public holidays and personal holiday entitlement. In the United Kingdom, for instance, annual leave is typically around 25 days of paid holiday entitlement plus 8 public holidays. Under this scenario, we assume that personal holiday entitlement is increased to be consistent with a total 20% reduction in work hours, with public holidays held constant. For the United Kingdom this would involve an increase in the personal holiday entitlement to around 70 calendar days. An alternative sub-scenario would be the equivalent increase in national holiday. We will not analyse this, as it is effectively equivalent to the four-day workweek scenario, since all employees will be off work at the same time.

(E) *Workforce minimisation*
A potential scenario is for businesses to try to organise the reduction in working hours in the most efficient way; minimising their office space an overhead costs. To explore this scenario, we envision that firms have the ability to flexibly manage their workforce so that there are 20% fewer employees working at any given time. This could be achieved by keeping society's five-day workweek, but with each individual employee only working four days out of the five. This theoretically would result in a 20% reduction in office space and associated overheads if actively managed under a ‘hot desking’ arrangement to minimise a company's operational costs. This scenario could therefore also provide an incentive for employers to be more receptive to the idea of reduced working hours for their employees.

Table 1
Features of the implementation of the 35-h working week in France.

Arrangement	Percent
Reduction from 7.75 to 7-h working day	31
Extra days off per month	21
Extra half-day off per week	13
Extra day off every other week	7
Extra time “on account”	4
7.5-h working day plus extra weeks of holiday per year	7
Other (including a mix of the above)	35

Source: Sanches (2005).

Employees could also be given the freedom to decide which of the above options they would personally prefer, or mix the options depending on their needs. The complication of this is that it gives a wide scope for personal preference and as such the effects are difficult to conceptualise. A questionnaire would be needed to understand people's preferences in this aspect; regardless. However, these stated preferences may be different to revealed preferences. Most likely a blend of the above scenarios would occur, and thus would be unlikely to either be the most or least beneficial for the environment. For these various reasons, this is not subject to analysis in this paper.

There are also a number of other scenarios that could reduce the number of hours worked from the perspective of the total number of hours worked during an employee's lifetime rather than per annum. These could take the form of increased maternity and paternity leave, extended career break entitlement or a reduced retirement age.

[1] This assumption implies that there will be an increase in employment in such sectors, and the same will hold for the other four scenarios. While this will have environmental effects, the overall macroeconomic impact is difficult to predict. As it expected to be consistent for all scenarios due to the same 20% reduction in employee hours, this will not affect the comparative analysis presented in this article.

However, these, and particularly the latter, would be going against the current trend. Arguably, such alternative scenarios could provide environmental benefits similar in scope to the work-reduction scenarios (A) to (E). However, the behavioural consequences of these, particularly with regard to the impact on time use patterns within society, are more unclear than those in our five scenarios, making their environmental effects more uncertain and difficult to assess. This represents a potential area for further research.

There are two proposals on how working hours could be reduced in a society. Firstly, productivity gains could be translated into additional leisure time instead of increased incomes, in which case the trends we see in Fig. 3 would be reversed. Alternatively, working hours could fall at a greater rate than productivity increases, causing incomes to fall. To realise the greatest benefits for climate change, the latter is likely to be preferable. Modelling by Victor (2012) shows a much more rapid decline in greenhouse gas emissions under such a scenario. We therefore analyse our five scenarios, assuming reductions to be faster than productivity increases, for their potential to impact on society's carbon emissions. To allow for fair comparisons, we assume that each scenario represents a reduction in total working hours by 20% for full-time employees, which is consistent with the first scenario of a four-day workweek. This conceptual framework is then applied to the case of the United Kingdom.

4. Conceptual Analysis of the Effects of the Scenarios on Carbon Emissions

To conceptually analyse the effects that the scenarios to reduce working hours might have on carbon emissions, we separately evaluate two sides of society that will be affected; the impact through business activities, and that through employee activities. Although we now discuss all of the potential effects on carbon emissions from the scenarios, the focus of this paper's analysis is the relative effects of each one rather than the absolute effect, so it is only these that we later attempt to quantify. To aid our analysis we use the three-day weekend scenario as our reference scenario, against which expected carbon emissions are compared. This is sufficient to conclude about the most environmentally effective scenario and simplify the analysis by avoiding calculating the overall absolute values of carbon emissions.

Although all five scenarios involve a reduction of an employee's working hours of 20%, this does not necessarily entail that the total number of hours worked in an economy also reduces by 20%. In a country such as the United Kingdom, there are a significant number of employees that are working part-time, who would fall outside the scope of a policy to limit working hours. The average number of actual weekly hours worked by full-time employees was 37.5 in the United Kingdom for 2013, whereas the average for part-time employees was 16. Under our scenarios full-time employees would reduce their hours to 30, with part-time employees and self-employed workers, who have the autonomy to work the hours they desire, remaining the same. This together translates into a reduction in the total working hours in the United Kingdom of around 17.5%. This percentage would likely differ for other countries, depending upon the proportions of full-time, part-time and self-employed workers. In Section 5 we will evaluate the effects through business activities and in Section 6 the effects through employee activities, which is split into the 'time effect' and 'income effect'. The income effect will itself have several distinct impacts, which we subcategorise into *domestic energy use*, *the expenditure effect*, *commuting*, and *leisure and retail travel*.

5. Effects Through Public and Private Economic Activities

It is important to consider that the various sectors of the economy will respond in differing ways to the scenarios. We assume that essential economic sectors such as agriculture, health, education and waste management are outside the scope of the scenarios as the size of these industries is dependent upon various factors, particularly the size of the population, and hence would be difficult to contract. Additionally, retail and leisure services are also unlikely to reduce their opening hours, as they will want to take advantage of the extra free time of consumers. Indeed, we actually anticipate a growth in these sectors, which is discussed in Section 6. It is therefore foreseeable that there could be an increase in employment in the above mentioned economic sectors; such macroeconomic impacts however are beyond the scope of this paper and thus do not constitute part of our analysis.

5.1. Private and Public Sector Energy Use

Under some of the scenarios, businesses and public sector organisations will either be able to reduce office opening hours, or the size of their premises, therefore reducing energy consumption, such as for heating and lighting, and with it carbon emissions. The expected effects for each scenario are summarised in Table 2. Differences between scenarios depend upon how coordinated the working time reduction is among workers. When workers are coordinated to not be working at the same time, energy savings are made both in individual uses, such as catering, and pooled uses, such as heating. When work reduction is uncoordinated, for instance when workers can individually decide when to take holidays, energy reductions can only be made on individual uses. This effect would also vary between the industrial and service sectors. Some industries operate under continuous production with employees working in shifts rather than conforming to traditional daily working hours. These industries are very unlikely to reduce their operational hours, and will therefore not lower their energy consumption. Around 20% of male and 10% of female workers in the UK manufacturing sector are shift workers (McOrmond, 2004). However, the industries most likely to have shift patterns, such as metal and chemical industries, tend to be the among the most energy intensive. For this reason, we will make a conservative assumption that only 50% of industry is able to reduce their operations, and with it energy use. The industry sector therefore has proportionately lower reductions in energy use, namely half of those by the service sector (in each scenario).

5.2. Office Space

Scenario D is unique in that it would enable companies to reduce their office space by 17.5%, consistent with the reduction in number of hours worked. A secondary effect of this would be that there is reduction in the total office space requirement for the whole economy, resulting in less demand for new construction projects. To assess the impact of this reduction in construction, we consider the embodied carbon of a building, which aims to calculate all carbon emissions, from the energy required for every input into a building's construction. A 2011 report by construction consultancy company David Langdon estimated the average embodied carbon of thirty new office buildings to be 964 $kgCO_2e/m^2$ (Clark, 2013).

We therefore apply this reduction in embodied carbon to 17.5% of the new office building construction in the economy. The reduction could potentially be significantly more than this amount, as a contraction in the need for office space will mean a sizeable proportion of the existing office space is vacated. However, we are more concerned with the longer-term trend of greenhouse gas emissions, which we would expect to tend towards this 17.5% reduction. For industrial real estate buildings, we assume that 25% of the floorspace is for office-based or other activities dependent upon the number of employees at work each day and not production capacity. Industrial building construction will therefore see a 4.4% (25% $\times$ 17.5%) reduction in floorspace.

5.3. Output Effect

If the overall number of hours worked in the economy fell by 17.5%, it would be logical to assume that output per employee would also

Table 2
Effects of scenarios on energy consumption

	Reduction in total energy consumption		Notes and explanation of assumptions
	Industrial sector	Service sector	
(A) Three-day weekend	10%	20%	Work reduction is coordinated to fully close offices and some factories one day per week.
(B) Free Wednesday	10%	20%	Work reduction is coordinated to fully close offices and some factories one day per week.
(C) Work day reduction	5%	10%	Work reduction is coordinated so that offices and some factories are able to close earlier and reduce their daily operating hours. This is assumed to be less effective at reducing energy than the total closure of the offices as the system is not completely shut down for an extra day.
(D) Holiday entitlement increase	2.5%	5%	Uncoordinated work reduction enables energy reductions in personal uses such as catering, but no reduction in energy from pooled uses such as heating.
(E) Workforce minimisation	8.25%	17.5%	Work time reduction is coordinated to minimise the workforce at each moment, but office operational hours remain unchanged. A reduced daily workforce enables some offices and factories to be reduced by in size by 17.5% in proportion to the reduction in total worked hours.

reduce by 17.5%. However, it is likely that the hourly productivity of each worker would then increase, as a result of reduced fatigue and absenteeism; improved morale, and more focus due to the limited working time (LaJeunesse, 1999). A recent study showed that this was true for munitions workers during the First World War (Pencavel 2014). The relationship was nonlinear; above a threshold of 49 h, output rose at a decreasing rate as hours increased. Although it is difficult to draw general conclusions from this given the nature of the work that was studied, conceivably in modern service sector work the reduction in working hours would have a much greater effect on an individual's productivity as the work is more self-directed, with greater scope for procrastination. Motivation is an important factor of productivity on top of fatigue.

The overall effect on an economy's output is difficult to predict. Businesses may decide to compensate the reduction in hours worked per employee by hiring extra staff, which could even result in an overall rise in output if the productivity per worker increases. Output will also be influenced by changes in demand from the effects of the changes to employees' incomes and time, to be discussed in Section 6. These effects are therefore intrinsically linked together and difficult to completely separate from each other. Nevertheless, this is not considered in our analysis as any changes in output will likely be the same for all scenarios, given the identical overall reduction in work hours.

5.4. Business Transport

A significant proportion of the transport energy use in an economy is for businesses related activities, including business trips and logistical services. In the United Kingdom, 37% of transport energy consumption is allocated to Industry or Services sectors (DECC, 2015b). Business trips and logistical services would be expected to contract for all scenarios in line with the reduction of companies' output, reducing greenhouse gas emissions through less fuel use. However, our expectation is that there would be no significant differences between the five scenarios, as it would be proportionate to the reductions in output discussed in Section 5.3, which were equal for all scenarios.

6. Effects Through Employee Activities

The impact of reduced working hours on greenhouse gas emissions from employees can be divided into an 'income effect' and a 'time effect'. The income effect is the reduction in an employee's income and thus purchasing power from working fewer hours, and the time effect is the impact from employees having more time for activities other than work due to the change in their lifestyle patterns. Each scenario is likely to lead to different time use and behaviour of individuals within the economy. Other studies have illustrated the importance of considering time use analysis alongside energy use analysis (D'Alisa and Cattaneo, 2013). Some of these effects are likely to increase carbon emissions, and therefore negate some of the reductions seen in Section 5.

6.1. Time Effect

Although we have seen that reducing working hours can potentially lower energy consumption in several ways, work does have the advantage of being the least energy intensive use of time, as illustrated in Fig. 4. Instead of working, employees will spend a larger proportion of their time doing more energy intensive activities such as domestic work, cultural events and hobbies. A study based on Swedish time use data suggests that this effect alone could result in an increase in energy use of 0.06% per each percentage reduction in work hours (Nassen et al. 2009).

As employees spend less time at work they will inevitably spend the extra time either in their homes or consuming leisure activities outside of their homes; resulting in increased domestic and leisure energy consumption in the economy. Druckman et al. (2012) studied UK time use data to conclude that leisure is a relatively low energy-intensive use of time, particularly if it is spent in and around the home. However, some activities, such as eating and drinking, are more energy intensive than others, and energy intensity increases significantly if an element of travel is included. Certain discrepancies exist between the two studies; 'personal care' is considerably more energy intensive in the study by Druckman et al. This might be due to categorisation of activities, as energy intensive activities such as clothes washing could alternatively have been categorised as 'domestic work'. It is therefore pertinent to analyse leisure time use at a deeper level, accounting for where and how the extra free time is being spent.

To model how time use may change under the scenarios, we also employ the UK 2005 Time Use Survey, which is the most current available data of its type for the UK (Lader et al., 2006). For the purpose of our analysis we are treating time use effects as a thought experiment where

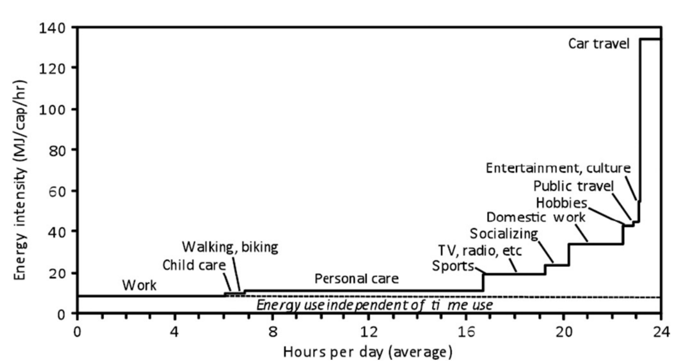

Fig. 4. The energy use of different activities on an average day (Nassen et al. 2009).

extra leisure time will be utilised in ways consistent with current time use patterns. We have re-categorised the data to include four 'free time' categories for analysis alongside the UK Energy Consumption data (Department of Energy & Climate Change [DECC], 2015a). This time is either assigned to being 'at home' or consuming in one of the three economic sectors 'Retail', 'Sports and Leisure' and 'Hotels and Catering', taken from the UK Energy Consumption data. Table 3 summarises the average time spent per person per day in these new categories.

As all five scenarios result in a 17.5% reduction in total paid work, they all result in an adjusted figure of 140 min spent per day on paid work. Additionally, we assume that domestic work, personal needs and sleep requirements are already being sufficiently met in society, and hence remain constant under the scenarios. Total travel time also remains constant (discussed in Section 6.1.4). This results in the time reduction in paid work being allocated to one of the four 'free time' categories, increasing overall 'free time' from 383 to 413 min; 7.8%. However, how and where employees decide to spend this extra free time is likely to differ between scenarios, depending on when in the week the extra free time is available. We estimate this on the basis that if extra free time is allocated to a weekend or as a holiday it facilitates a larger increase in trips, entertainment and cultural activities, whereas mid-week free time, or on a workday, is much more likely to be spent at home. Our envisaged proportions are summarised in Table 4, alongside the current proportions for comparison.

6.1.1. Domestic Energy Use

Time spent at home is likely to be less energy efficient than time spent in the office; in an office environment people are clustered together, sharing light and heat resources. Increased domestic energy consumption therefore has the potential to either partially or totally negate the business and public sector energy savings discussed in Section 5.1. Importantly however, domestic energy use is not only dependent on full-time employees. A large proportion of the population will be studying, working only part time, retired or unemployed; and for these sections of society there will be no change in domestic energy. Taking a societal perspective on domestic energy consumption, consistent with the Time Use Survey data, is therefore an appropriate approximation for the purposes of our analysis. We expect the impact from each scenario to vary somewhat due to the amount of time that employees will be spending in their homes, as shown in Table 4.

To estimate the expected increase in energy use under the scenarios we multiply the current domestic energy use taken from the UK Energy Consumption data by 7.8% (the increase in 'free time' under all scenarios) and the increase factors stated in Table 5.

The factors for space heating and cooling are equal to the 'at home' proportions from Table 4, as we expect space heating to proportionately increase with time spent at home. Cooking energy use is expected to similarly increase with 'at home' time, with the exception of scenario C, where we would not expect cooking habits to significantly differ from the present situation as individuals are still working a five-day week. Here a factor of 0 is applied. The factors for water heating are all assumed to be 0, as we would not expect the number of baths or showers taken to increase significantly under the scenarios. Other uses of hot water, such as for dish washing are unlikely to be significant enough, nor vary enough between scenarios, to affect the overall result. The factors for 'lights/appliances' are the 'at home' proportions from Table 4 multiplied by 0.6, to discount appliances that are always on, such as the refrigerator, and those unlikely to increase in use, such as washing machines.

A possible complication to the analysis is that any increase in holiday entitlement is more likely to be taken during the summer months, when heating and lighting consumption is considerably lower than in winter and at a time when they are likely to spend time outdoors; whereas the other scenarios could see more consistent increases throughout the year. Although this is what we expect in the United Kingdom with its temperate climate, the effect might be different in countries that use a large amount of air conditioning in the summer months.

Table 3
Re-categorised 2005 UK time use data (based on data from Lader et al. (2006))

Activity	Average minutes spent per day	Percentage time spent per day
Sleeping and resting	537	37.3%
Paid work	170	11.8%
Study, volunteering	14	1.0%
Domestic work	143	9.9%
Personal needs	106	7.4%
Free time - retail	34	2.4%
Free time - at home	267	18.5%
Free time - hotels and catering	48	3.3%
Free time - sport & leisure	34	2.4%
Travel - commuting	18	1.3%
Travel - leisure/shop	69	4.8%
Total	1440	100%

Table 4
Assumed proportions of extra free time under scenarios.

	At home	Retail	Hotels and catering	Sport and leisure	Total
Current average proportions	0.70	0.09	0.12	0.08	1.0
(A) Three-day weekend	0.50	0.15	0.20	0.15	1.0
(B) Free Wednesday	0.70	0.10	0.10	0.10	1.0
(C) Workday reduction	0.80	0.05	0.10	0.05	1.0
(D) Holiday entitlement increase	0.40	0.15	0.30	0.15	1.0
(E) Workforce minimisation	0.60	0.10	0.20	0.10	1.0

6.1.2. Expenditure Effect

As well as through the income effect (discussed in Section 6.2), employees' consumption habits will change through the availability of more free time. When exactly the extra free time is available will influence where the employees choose to spend their time and income; we therefore call this the 'expenditure effect'. To approximate the impact on carbon emissions from this effect, we envisage an expansion in the 'sports and leisure'; 'hotel and catering'; and 'retail' sectors of the economy, as more time will be spent on these activities. The increased time expenditure in these sectors result increased energy consumption, for which we calculate the carbon emissions. The increase in total free time of 7.8% is multiplied by our expected time proportions for the Retail; Hotels and catering; and Sports and leisure economic sectors, shown in Table 4, and then applied to the current energy consumption of these sectors.

6.1.3. Commuting

Daily commuting to and from work is a considerable proportion of all transportation energy consumption within a society. In the United Kingdom, commuting accounts for 14.4% of all transport energy use in the country (Lovelace, 2014). All scenarios, with the exception of the workday reduction scenario, would result in a 20% reduction in commuting energy use from each full-time employee, as each employee would work fewer days per annum. However, given that full-time employees only account for 63% of all workers in the United Kingdom, the overall effect on total commuting energy use is 12.5% (63% × 20%).

Table 5
Domestic energy increase factors for the different scenarios.

	Space	Water	Cooking	Lights/appliances
(A) Three-day weekend	0.50	0.0	0.50	0.30
(B) Free Wednesday	0.70	0.0	0.70	0.42
(C) Work day reduction	0.80	0.0	0.00	0.48
(D) Holiday entitlement increase	0.40	0.0	0.40	0.24
(E) Workforce minimisation	0.60	0.0	0.40	0.36

The reality however is likely to be more complex and difficult to predict, as commuter patterns may change given the extra free time. For example, if a worker is working fewer hours each day, they may decide they can commute by bicycle instead, lowering carbon emissions. On the other hand, they may see it as an opportunity to move to a more suburban location and spend their extra time commuting a longer distance. Due to the difficulty in predicting these secondary effects, they are not considered in our analysis.

6.1.4. Leisure and Retail Travel

In terms of distance, leisure is the largest purpose for travel in the United Kingdom at 41% of total travel distance. This is divided into 20% for visiting friends and 21% for other leisure, which includes holidays, day trips, sport and entertainment (DECC, 2015b). These activities are therefore significant contributors to the carbon emissions of a country. Under the scenarios, we expect to see an increase in these activities as employees will have more free time available to purse them. However, there has been academic discussion around the idea of a constant travel time budget; people have a fixed daily amount of time that is set aside for travel (Metz, 2012). If this holds true, then we expect the increase in leisure travel time under the scenarios to only increase by the reduction in travel time through commuting, discussed in Section 6.1.3. Using the 2005 UK Time Use Data, we can therefore calculate that the increase in travel for purposes other than commuting, such as shopping and leisure, would increase by 4.4% for all scenarios except for scenario C, where no reduction in commuting is expected.

We expect how employees spend this extra transport time to vary between scenarios. In scenarios A and D, we expect to see a greater increase in medium or long distance trips by road, rail or air as the free time is concentrated together to make weekend trips and extended holidays more feasible. In scenario B, there is less scope for doing these types of trips and any extra leisure travel is likely to be more local. Scenario E would be somewhere between scenarios A and B, as 40% of the employees will have an extended, three-day weekend. Considering these factors, we have estimated the proportions of the increased travel time which will be spent by road, rail, air or walking and cycling; as summarised in Table 6. Water transport is omitted from this analysis, due to it only accounting for less than 2% of UK leisure travel. To calculate the increase in carbon emissions, these proportions are applied to 4.4% of the current emissions for each transport mode attributable to purposes other than commuting and business.

A summary table showing a breakdown of the time effect from each of the five scenarios is included as Appendix A.

6.2. Income Effect

As a result of working fewer hours, we expect to see a proportionate drop in employees' incomes, although this could be partially offset by any increases in productivity per hour worked. In terms of take-home income, this effect is likely to be further offset due to progressive taxation systems common in the OECD countries. The reduction in incomes would translate to a reduction in the level of consumption in the economy, and with it lower greenhouse gas emissions. This effect on consumption has been the main area of interest in the environmental effects of working hours to date; for instance, a recent study estimates that a reduction of work hours by 10% could result in a 4.2% reduction in CO_2 emissions (Knight et al., 2013a, b). We therefore estimate that the 17.5% reduction of work hours under our scenarios could result in approximately a 7.4% reduction in greenhouse gases. However, this would overlap somewhat with the effects previously discussed.

Table 6
Leisure and retail travel time increase proportions under the different scenarios.

	Road	Rail	Air	Walking/cycling	Total
(A) Three-day weekend	0.5	0.1	0.2	0.1	1.0
(B) Free Wednesday	0.4	0.1	0.0	0.5	1.0
(C) Workday reduction	0.0	0.0	0.0	0.0	1.0
(D) Holiday entitlement increase	0.3	0.1	0.5	0.1	1.0
(E) Workforce minimisation	0.4	0.1	0.2	0.3	1.0

The income effect could also change the composition of consumption in society through reduced incomes. It is likely that we would see a greater than proportionate decrease in the consumption of luxury goods which have a greater carbon footprint, such as beef (Devetter and Rousseau 2011). Although the income effect is likely to be the largest of all effects in absolute carbon emissions, we anticipate that it would be the same for each of the scenarios, and therefore it is not pertinent to our comparative analysis. Nevertheless, it is important to note that some forms of consumption, such as leisure, will be partially influenced by changes in time use patterns, which is considered under the expenditure effect (Section 6.1.2). There is therefore an inter-relation between the time and income effects. If employees have more free time, but less income, they are less likely to spend their free time on trips abroad than if their income had remained stable, so from a climate change perspective there are likely to be positive synergies from the two effects. As the income effect is equal across scenarios, we do not factor in any changes in income in our analysis of time effects in Section 6.1, which avoids any double-counting between the two effects.

7. Comparison of Scenarios with Application to the United Kingdom

To compare the scenarios with regard to carbon emissions we use Scenario A, the three-day weekend, as a reference scenario and estimate the difference in emissions we expect the other scenarios have compared to this. The expected effects are summarised in Table 7, with a "+" representing greater emissions, a "−" representing lower emissions, and "0" representing no expected significant difference, based on the arguments in Sections 5 and 6.

Our expectation from this summary table is that the most likely result is Scenario A, B and E being the most beneficial scenarios at reducing carbon emissions, with Scenario D and E the worst. Nevertheless, each scenario has areas where it provides more benefits than the other scenarios. Therefore, to assess the relative merits of each scenario we need to estimate the expected size of each of the different effects, and the overall effect is likely to depend upon energy efficiencies and intensities of different time use. As the output effect, income effect and business transport effect are not expected to significantly differ between scenarios, they are omitted from the analysis.

To perform the study, we use UK DECC energy consumption data; applying the expected effects of each scenario described in Sections 5 and 6 to the most recent data, from 2013. The energy consumption amounts are converted to CO_2e using carbon conversion factors also supplied by the UK DECC. This approach is used for all effects except for 'office construction', where embodied CO_2e is used. The results, in reference to Scenario A, are summarised in Table 8, in million tonnes of CO_2e. The absolute values of our calculations are included in Appendix B.

7.1. Sensitivity Analysis

Our analysis is based on certain assumptions regarding human behaviour, which are uncertain without real-life behavioural studies to support them. To test the impact these assumptions have on our result, we perform sensitivity analysis on two of the behavioural assumptions; that there is no increase in the number of hours slept and that there is no net increase in travel time.

7.1.1. Sleeping Hours

In our analysis, we assumed that the extra free time would not be used for increasing employees' amount of sleep, as they are already meeting their weekly sleep requirement. However, it is also likely that employees are not currently get as much sleep as they desire if they

Table 7
Expected greenhouse gas emissions compared to reference scenario A.

Expected effects relative to Scenario A		(B) Free Wednesday	(C) Shorter working day	(D) Holiday entitlement increase	(E) Workforce minimisation
Business and public sector effects	Output effect	0	0	0	0
	Service sector energy use	0	+	+ +	+
	Industrial sector energy use	0	+	+ +	+
	Office construction	0	0	0	−
	Business transport	0	0	0	0
Employee effects	Income effect	0	0	0	0
	Expenditure effect	−	0	+	−
	Domestic energy use	+	+ +	−	+
	Commuting	0	+ +	0	0
	Leisure and retail travel	−	− −	+	−

had more free time available; we see in the UK Time Use Survey that people get on average 51 min extra sleep during the weekends. The significance of this is that sleep is a very low energy intensive activity, where little domestic or business energy is being consumed. To test this, we change the assumption, so that scenarios A, B, D and E have a sleep pattern equivalent to a current weekend day, consuming no extra energy during this time. The exception to this could possibly be space heating; the current UK government's BREDEM model assumes that no heating is on during sleeping hours of 11 p.m.–7 a.m., however these assumptions are disputed due to the need for better data (Shipworth et al., 2010).

Adjusting for this change would give an average increase of 7 min of sleep time per day in the applicable scenarios, thus reducing the amount of 'free time' to be spent on other activities by 7 min. This results in a smaller percentage of 'free time' increase of 5.9%, as opposed to 7.8% used in the analysis in Section 7. The changes this makes to the overall results are summarised in Table 9.

Under this test, our policy conclusions are reinforced; the difference between the most desirable scenario, A, and the least, C, increases by 1.28 $MTCO_2e$. Carbon emissions of scenarios B and E move closer towards Scenario A, furthering our conclusion that we would expect roughly similar results in the three top-tier scenarios A, B and E.

7.1.2. Leisure Travel

Our analysis in Section 7 also assumed that total travel time would be constant under the reduced worktime scenarios, due to the constant travel time budget theory. However, it is feasible that this assumption may not hold true and that employees may increase their leisure travel more than they reduce their commuting travel, as more opportunities for holidays and trips become available with their new schedules. We therefore change the leisure travel increases by the percentages in Table 10. The percentages for each scenario vary by how much we would consider extra opportunities for trips to occur.[2] Note that any increase in leisure travel reduces the amount of extra 'free time', which is also summarised in Table 10.

These factors were applied to our analysis, with the changes to carbon emissions in reference to scenario A, with the outcomes summarised in Table 11.

Under these changed assumptions, Scenario D has become the worst scenario, increasing the extra carbon emissions in comparison to scenario A to 13.85 $MTCO_2e$. The three other scenarios have improved relative to scenario A. As with the sleeping hours sensitivity test, our conclusion that there are three similar, more desirable scenarios (A, B and E) and two less desirable scenarios (C and D) is supported. Although our two sensitivity tests show that our analysis is somewhat sensitive to behavioural differences, we would not expect our overall result of a four-day workweek being preferable to be significantly challenged.

[2] We assume that extra holiday days give the most, free days around the weekend second most, mid-week free days the third most, and working days the least opportunities for extra leisure travel.

8. Policy Insights and Limitations

8.1. Implications for Policy

Our analysis shows that when energy consumption is reduced in one area of the economy, there is often a partial offset in a different area. This can be linked to the research into the rebound effect, where expected improvements in energy efficiency are reduced due to behavioural or systemic factors (Greening et al., 2000; Polimeni, 2012). If employees are spending less time in the office, reducing energy consumption in this location, there will invariably be an increase in energy consumption in a different location; in a household or leisure location. However, due to differences in energy intensities and efficiencies in distinct areas of the economy and time uses, we do not see a complete compensatory effect. The results therefore suggest there could be significant environmental differences between the designs of policies to reduce working hours. The difference between the two extreme scenarios is 13.03 $MtCO_2e$, over 2% of total UK greenhouse emissions, which were 568 $MtCO_2e$ in 2013 (DECC, 2015b). It is important to note that these figures represent a comparative range, not absolute values, and this is in addition to the expected carbon emission reductions from the income effect, output effect and business transport reduction, which were not part of our analysis.

Predicting absolute values of the effect of the scenarios on emissions is difficult to do given the degree of complexity involved in the effects. Nevertheless, Nassen et al. (2009), look at both the income and time effect on greenhouse gas emissions, and arrive at a reduction of −0.85% for each 1% reduction in work hours. Reducing work hours by 17.5% could therefore lower emissions by an order of magnitude of 15%. Our analysis provides a range around this figure, depending upon which scenario was chosen.

There is a clear two-tier ranking of scenarios, with scenarios A, B and E expected to have the greatest environmental benefits. The advantage of these three scenarios over the other two principally comes from the reductions in office energy use, from either closing the office completely for one day or from reducing the size of the office, combined with the reductions in commuting. The reduction in emissions due to reduced office construction had a far smaller effect than anticipated at only 0.30 $MtCO_2e$, meaning that scenario E was unable to distinguish itself from the two four-day working week scenarios. Perhaps the foremost lesson from this analysis is that it clearly illustrates how the particular design of a policy is an important consideration when aiming to reduce an economy's energy intensity, on top of the primary effects of the overall policy.

8.2. Political Feasibility of the Policy Scenarios

Despite the desirability of reducing work hours from an environmental perspective, there is likely to a lot of political debate in its realisation. The principal economic focus of almost all countries is GDP growth, despite its many recognised weaknesses as a measure of

Table 8
Relative reduction in greenhouse gas emission compared to reference scenario A (all figures in $MtCO_2e$ per year).

Effect on greenhouse gas emissions ($MtCO_2e$) per year		(B) Free Wednesday	(C) Shorter working day	(D) Holiday entitlement increase	(E) Workforce minimisation
Business and public sector effects	Service sector energy use	0.00	3.36	5.04	0.84
	Industrial sector energy use	0.00	5.35	8.02	1.34
	Office construction	0.00	0.00	0.00	−0.30
Employee effects	Expenditure effect	−0.19	−0.28	0.09	−0.10
	Domestic energy use	1.92	2.55	−0.96	0.96
	Commuting	0.00	3.37	0.00	0.00
	Leisure and retail travel	−0.43	−1.31	−0.12	−0.22
	Total of effects	1.30	13.03	12.07	2.51

Table 9
Results of sleeping hours sensitivity test.

Comparison to reference scenario A	Overall reduction in $MTCO_2e$ - before variable change	Overall reduction in $MTCO_2e$ - after variable change	Net change resulting from sensitivity test
(B) Free Wednesday	1.30	0.91	−0.39
(C) Workday reduction	13.03	14.31	+1.28
(D) Holiday entitlement increase	12.07	12.28	+0.21
(E) Workforce minimisation	2.51	2.30	−0.21

societal well-being (Van den Bergh, 2009). Due to the likely negative impacts on GDP from reducing work hours across society there is likely to be political reluctance unless there is a change to measuring social progress with happiness or other subjective well-being indicators. Reduced incomes will also inevitably result in reduced tax receipts which could challenge a government's ability to meet its other social objectives such as education, health and security.

An even greater challenge may come from public acceptance of the policy despite their support for greater leisure time. In the case of the 35-h workweek in France, there was an increase in dual-job holdings and a transition from larger to smaller firms, unaffected by the legislation, potentially motivated by a desire to work more hours (Estevo & Sa, 2006). In economies based on material aspirations, it may be difficult for employees to accept a reduction in income; employee preferences seem to mostly favour maximising income over minimising working time (Tijdens, 2003). There may also be practical obstacles for people who have mortgages and other forms of debt to accept reduced incomes as this would diminish their ability to repay.

A solution to make the scenarios more feasible would be an incremental transition rather than an immediate 20% reduction in hours, enabling employees to adjust to the conditions. This could be more difficult to achieve for the four-day workweek, unless the extra day off is initially compensated by working extra hours on the other days. This could also be achieved by first taking one extra day off per month and gradually adding more until a 4-day workweek was reached. There is also uncertainty over whether the scenarios preferable for reducing carbon emission would coincide with the preferences of employees, unions and employers.

8.3. Limitations and Future Research

The main limitation of this study is that although the analytical framework is able to successfully compare the scenarios, it inevitably fails to capture some aspects of the real-world complexity inherent in real economic systems and human behaviour. For example, under Scenario E we assume that commuting reduces by 12.5% as fewer workers are working each day. However, a secondary effect of this could be that congestion on roads reduces, and hence journey times. This may provide an incentive for an employee to move house to a location further from their workplace, negating the energy savings from not commuting once a week. These types of secondary and tertiary effects are very difficult to predict and quantify, which creates a degree of uncertainty in the analysis.

Our study has also only analysed the scenarios using the example of the United Kingdom. It is possible that the scenarios may have different relative merits in countries that have different energy use patterns in their societies. For example, in a country such as Denmark, where cycling is far more popular than in the United Kingdom, the carbon emission reductions attributable to commuting are likely to be less. Similarly, a large proportion of domestic and service sector energy use in the United Kingdom is for space heating. In countries with warmer climates, this effect is likely to be significantly less. Moreover, the majority of electricity production in the United Kingdom is produced from coal and natural gas; in countries where the share of renewable sources is much greater, we could see very different results. Similarly, differences would be expected in countries with differing population demographics, such as the proportions in retirement. A comparison with such countries is an area for future research.

Table 10
Assumptions for leisure travel sensitivity test.

	(A) Three-day weekend	(B) Free Wednesday	(C) Shorter working day	(D) Holiday entitlement increase	(E) Workforce minimisation
Original leisure travel increase	4.4%	4.4%	0.0%	4.4%	4.4%
Sensitivity test: leisure travel increase	9.8%	6.9%	0.0%	12.7%	8.4%
Original free time increase	7.8%	7.8%	7.8%	7.8%	7.8%
Sensitivity test: free time increase	6.8%	7.4%	7.8%	6.3%	7.1%

Table 11
Results of leisure travel sensitivity test.

Comparison to reference scenario A	Overall reduction in $MTCO_2e$ - before variable change	Overall reduction in $MTCO_2e$ - after variable change	Net change resulting from sensitivity test
(B) Free Wednesday	1.30	0.85	−0.45
(C) Workday reduction	13.03	12.09	−0.94
(D) Holiday entitlement increase	12.07	13.85	+1.78
(E) Workforce minimisation	2.51	2.40	−0.11

Reducing work hours across the whole of society is also likely to have a number of uncertain longer-term effects which could either compound or negate the environmental benefits. For example, with more time for leisure and community activities, it is conceivable that health in society will increase due to reduced stress levels and more active lifestyles. This could reduce the use of health care services and related carbon emissions, which account for 8% of the carbon footprint of the United States (Chung & Meltzer, 2009). However, with improved health we would expect longer life expectancies, and thus population growth could counteract the reduced consumption per capita. As well as affecting the death rate of society, the birth rate could also change. Although reduced incomes may dissuade some from having children, others may see the reduced working hours as an opportunity to dedicate more time to parenting, and needing to spend less on expensive childcare. Such demographic changes are difficult to predict, but could be significant in the longer term.

Part of our analysis involved a thought experiment on the behavioural changes resulting from reduced working hours, and how that may affect leisure time use. Although some of these assumptions were tested as sensitivity analysis, there is potential for such behavioural changes to influence the result, and therefore they deserve further attention and research.

9. Conclusion

The purpose of this study was to explore different design scenarios for implementing a policy to reduce working hours, and compare their impacts on greenhouse gas emissions. As few empirical examples of such a policy exist, we decided to conceptually analyse the effects of five different scenarios, each resulting in different energy patterns within society. Using the case of the United Kingdom, we estimated the expected changes in energy consumption we would expect under the scenarios, to produce a ranking of preference with regards to their impact on climate change.

The three best performing scenarios were those that involved employees working a four-day week as they enabled companies to reduce energy use, and employees to reduce commuting. Without achieving these reductions, the shorter working day and holiday increase scenarios performed worse as the other changes in energy use in the economy were not sufficiently compensatory. The range between the best and worst performing scenarios was 13.03 $MTCO_2e$, over 2% of total UK greenhouse gas emissions, which were 557.3 $MTCO_2e$ in 2013. This figure excludes the income, output and business transport effects, as these were not part of our comparative analysis (being assumed to be rather similar in scope across scenarios). Although difficult to predict with any degree of certainty, the absolute effect on emissions is likely to be considerably greater; an order of magnitude of 15% was argued to be realistic based on previous academic studies. The choice of scenario could therefore contribute more than 15% of the total environmental benefit (13.03/total emission reductions of around 84 $MTCO_2e$). Ultimately, we face a huge challenge in reducing net greenhouse gas emissions to zero over the coming decades, to limit climate change to 2 °C of warming. Although worktime reduction can only be part of the solution, any option with potential for such significant emission reductions should be strongly considered.

When implementing a policy which has the potential to significantly alter societal patterns and behaviour, environmental effects are likely to be complex. Our study presents just one example of this, and demonstrates how the particular design of such a policy can itself have a multitude of primary and secondary effects, each with their own impact on greenhouse gas emissions. Careful consideration should therefore be given to its specific design as this has the potential to either reinforce or negate the environmental benefits the overall policy is aiming to achieve.

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Appendix A. Changes to time use patterns under the scenarios

Activity	Difference from current situation					
	Current average minutes per day	Scenario A	Scenario B	Scenario C	Scenario D	Scenario E
Sleeping and resting	537	0	0	0	0	0
Paid work	170	−30	−30	−30	−30	−30
Study, volunteering	14	0	0	0	0	0
Domestic work	143	0	0	0	0	0
Personal needs	106	106	106	106	106	106
Free time - retail	34	+4.5	+3	+1.5	+4.5	+3
Free time - at home	267	+15	+21	+24	+12	+18
Free time - hotels and catering	48	+6	+3	+3	+9	+6
Free time - sport & leisure	34	+4.5	+3	+1.5	+4.5	+3
Travel - commuting	18	−3.6	−3.6	0	−3.6	−3.6
Travel - leisure/shop	69	+3.6	+3.6	0	+3.6	+3.6
Total	1440	0	0	0	0	0

Appendix B. Absolute values of greenhouse gas emission for all scenarios in $MTCO_2e$

Effect on greenhouse gas emissions ($MtCO_2e$) per year		(A) Three-day weekend	(B) Free Wednesday	(C) Shorter working day	(D) Holiday increase	(E) Workforce minimisation
Business and public sector effects	Service sector energy use	−6.72	−6.72	−3.36	−1.68	−5.88
	Industrial sector energy use	−10.69	−10.69	−5.35	−2.67	−9.36
	Office construction	0.00	0.00	0.00	0.00	−0.30
Employee effects	Expenditure effect	0.47	0.28	0.19	0.56	0.37
	Domestic energy use	4.79	6.70	7.34	3.83	5.75
	Commuting	−3.37	−3.37	0.00	−3.37	−3.37
	Leisure and retail travel	1.31	0.88	0.00	1.19	1.09
	Total of effects	−14.21	−12.91	−1.18	−2.14	−11.70

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