The Impact of Transport

Sustainable Transport Report

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BioRegional Consulting is a subsidiary company of BioRegional Development Group, an independent environmental organisation creating sustainable products and services that work in the mainstream

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Executive summary

Personal transport accounts for 16% of the UK's ecological footprint and domestic transport currently represents around 23% of the UK's carbon dioxide emissions, excluding those associated with international air travel (which in 2004 accounted for over ten million tonnes of carbon). Transport demand, particularly for road and air travel is increasing every year, as are the associated environmental impacts.

This report analyses the UK's current personal transport patterns and examines potential strategies for reducing this impact. The report examines a variety of strategies including increased efficiency of current transport modes, public transport and biofuels. Scenarios, based on transport patterns in the South East are also modelled to highlight potential strategies.

The report concludes that whilst the environmental impact of transport may be reduced through a range of strategies including efficiency gains, technology and to a lesser extent alternative fuels; given the increase in demand, efficiency savings alone are not going to significantly reduce energy use in the transport sector. Therefore the longer term aim has to be a reduction in the energy used / distance travelled by powered transport. This can only be done through a greater localisation, reducing the need or desire for people and goods to regularly move long distances.

For any sustainable community, ensuring that there are attractive, affordable local facilities and services; along with safe, accessible walking and cycling routes and facilities, is vital to enable us to work towards a One Planet lifestyle.

1 Introduction

Ecological footprinting tells us that if everyone on the planet consumed resources the way we do in the UK, we would need three planets to support us.

Figure 1: The Three Planet problem

BioRegional and our partners have been working to provide practical solutions and initiatives to make it easy for communities and individuals to reduce their ecological footprints in order to live sustainably within the carrying capacity of one planet. One of these initiatives is Z-squared: a concept design[1] for a 2000 home, zero carbon zero waste (hence Z-squared) community in the Thames Gateway, an area earmarked for substantial growth over the next few decades. The project aims to meet high sustainability targets and act as a demonstration for the many other communities that will be created in this area.

One of the Z-squared targets is to reduce the transport impact of the community. There are two key strategies to enable this:

1) reducing travel demand through providing facilities on site
2) encouraging and facilitating sustainable transport patterns, for example, through incentives for walking and cycling, public transport, car sharing and alternative fuels.

The report will focus primarily on personal transport i.e. the movement of people for work and leisure, rather than the transport impact of goods as this is included in the ecological footprint calculations for other elements such as materials and food.

The report will examine current transport patterns, their environmental impact and potential strategies to facilitate sustainable 'One Planet' transport patterns. The report will use the London Borough of Sutton as a primary case study and will highlight potential transport impacts for a range of scenarios.

[1] The Z-squared concept design has been developed by BioRegional and its partners: Foster and Partners Architects, KBR Infrastructure, Fulcrum Engineering and Cyril Sweett Cost Consultants. Z-squared has been supported by a number of agencies.

2 Current transport patterns in the UK

In 2005 the population of Great Britain made 61 billion trips, spending a total of 2.5 million years travelling. An average resident of Great Britain makes over 1,000 trips a year, travelling over 7,000 miles[1], and according to the Family Spending Report 2006, personal transport accounts for the highest proportion of household expenditure (approximately 14% of the average household income, an average of £61.70 a week) [2].

Figure 2 illustrates the main journey purposes for personal transport. As can be seen, most personal travel falls under visiting friends at private homes, commuting and shopping.

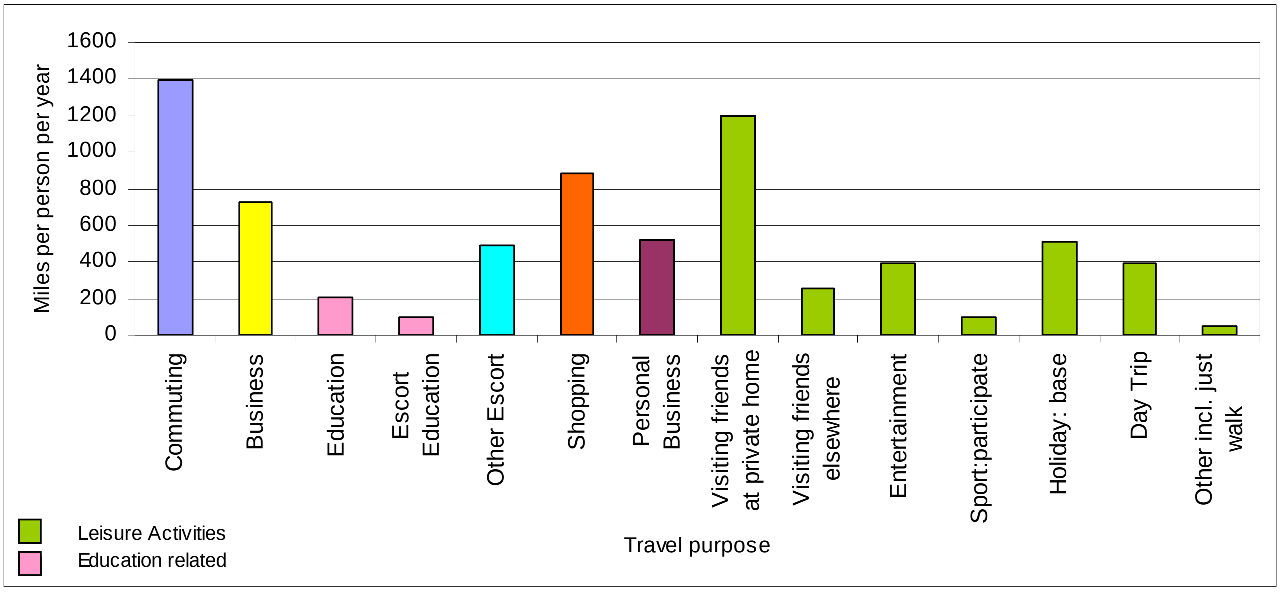


Figure 2: Average miles travelled per person in the UK by purpose[3]

Figure 3 details the average trips by purpose and main mode, illustrating that the car is currently the dominant mode for all purposes, with car drivers being higher than passengers, indicating that for the majority of journeys cars are solely occupied. This significantly contributes towards the ecological impact of personal transport.

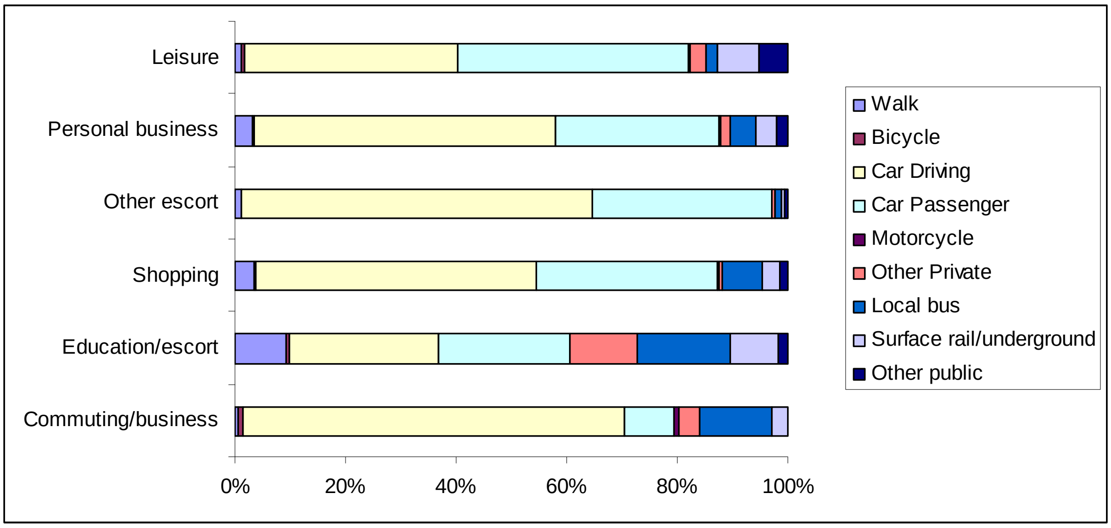


Figure 3: Trips by purpose and main mode[4]

Figure 4 shows the transport mode used by UK residents for different travel distances. The most striking feature is over half of journeys between one and two miles are made by private motorised vehicle. This implies that amenities need to be very convenient to reduce car use and a range of other incentives may still be required to reduce peoples' reliance on the car. This may also be partly attributable to high car ownership, once a vehicle has been purchased to maximise perceived value the car is often used for the majority of journeys, even if they are relatively short (see discussion on car clubs in section 4.2.3).

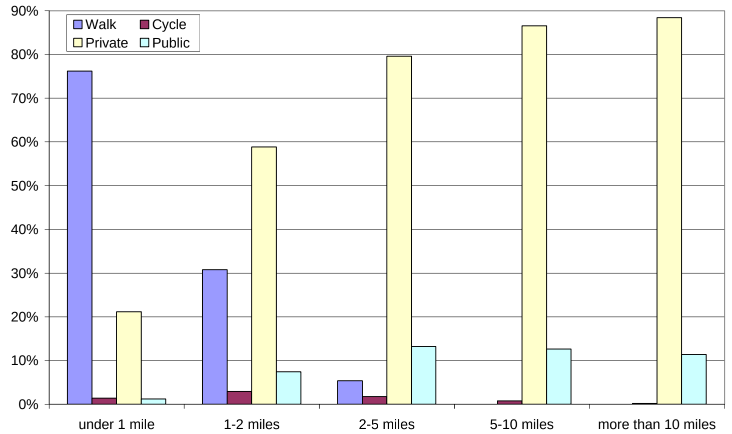


Figure 4: trips by mode by UK residents

Dispersed land uses, increased travel distances and increased car dependency have developed over the last three to five decades as a result of economic growth, and increased quality of life expectations, supported by[5]:

- people exercising choice and opting for rural rather than urban surroundings, where housing is cheaper, and the average pricing of utilities and other services provides an effective subsidy to rural residents;
- reduced job security and more females in the workforce, discouraging house relocation to be nearer a job which may change in the near future, and increased likelihood of a household location serving more than one employment location; greater influence of other factors such as schooling;
- a decline in traditional manufacturing industries in inner city areas, and growth of employment in the service and light industrial sectors; the latter have tended to locate in business parks and out of town developments adjacent to the trunk road network, not well served by public transport;
- stable (and recent decline) in real car prices over a long period and falling real fuel prices, encouraging the growth in car ownership as a more affluent population seeks the mobility to serve an enhanced quality of life;
- a generally good motorway and trunk road system which despite congestion hotspots has increased accessibility by road.

The main transport purposes are examined in further detail below.

2.1 Commuting

Commuting trips accounted for just under a fifth of total UK personal transport in 2005 (Figure 2). Of the 29 million people in employment an estimated 11% work from home at least some of the time, whilst 89% always travel to work. In 2001, 49% of commuting trips originated in, and 55% were destined for, the largest urban areas. Whilst economic activity and households are concentrated in urban areas, people often choose to live away from their workplace.

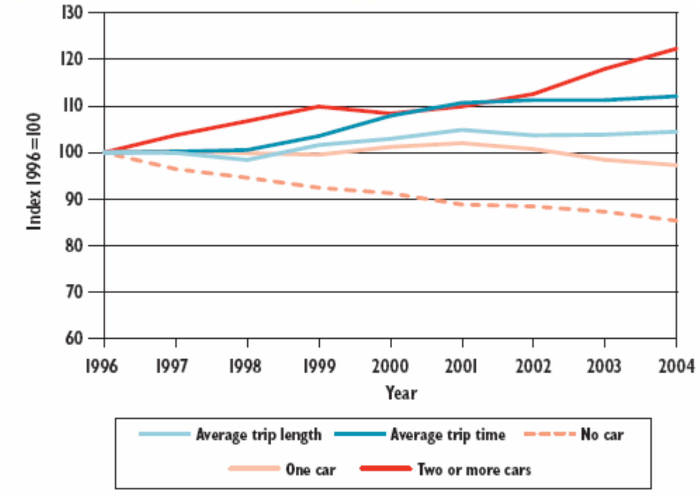


Figure 5 illustrates trend changes in commuting trip length, commuting journey times, and household car availability. The chart demonstrates that commuting trip lengths and commuting journey times have both increased over the last decade. Although there has been a large increase in car availability, and more people are choosing to travel to work by car and rail, the data suggests that there has been a decline in the average speed of travel for commuters – on average they are travelling more slowly than in 1996, primarily due to congestion.

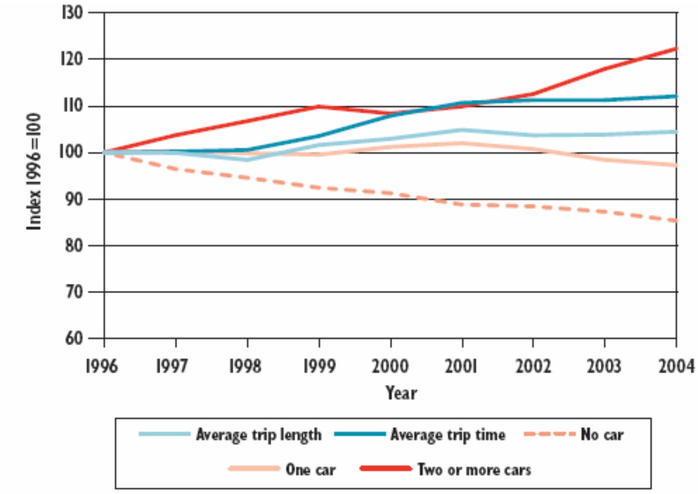


Figure 5: Commuting Trip trends by length, time and household car ownership, 1996-2004

Commuting trip length is strongly associated with the mode of transport chosen and the type of infrastructure used. Whilst walking and cycling are ideal for very short trips, and public transport can offer competitive journey times for longer trips to urban areas, in most instances the car is the mode of choice for commuters (Figure 3). In addition, it would appear that very few people are car passengers, indicating that the vast majority of people drive themselves to work and there is little in the way of lift sharing to the work place. Figure 6 shows the distribution of commuting trip lengths and mode choices for Inner London, Outer London, metropolitan areas and the rest of the UK.

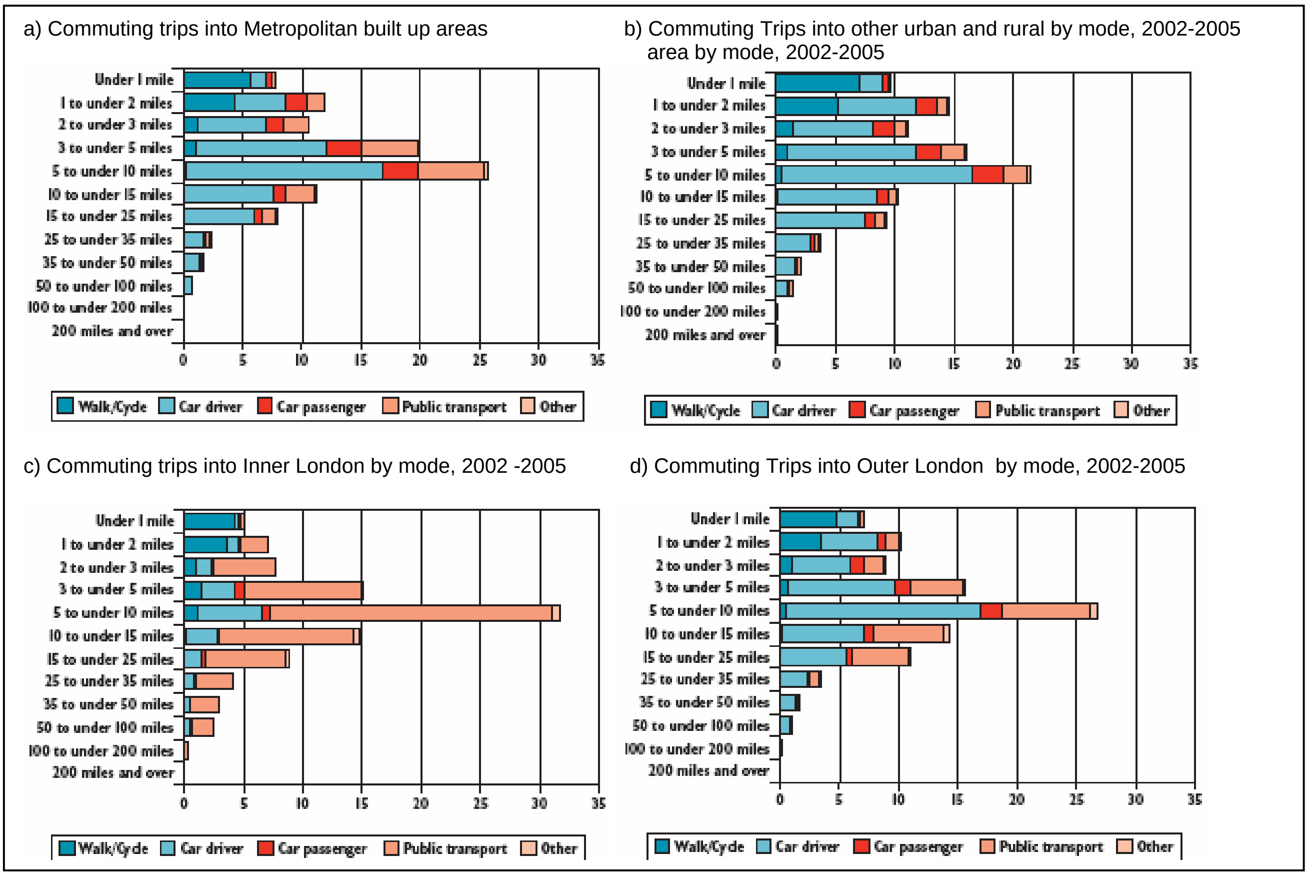


Figure 6: Commuting mode choice by destination and length of trip, 2002-2005[6]

Outside of London and the metropolitan areas, 64% of commuting trips are undertaken as a car driver. Indeed, even Outer London does not benefit from the same high levels of public transport service as the heart of the city. Commuters destined for Inner London tend to favour public transport. In part this is a result of the high levels of service offered by London public transport services and radial heavy rail routes, and in part a result of the long journey times by road through Inner and Outer London, alongside limited opportunities to park in the centre and other associated costs such as the congestion charge. London's density is such that public transport is often a more efficient way to supply transport.

2.1. Leisure

'Leisure' accounted for 40% of the distance travelled for personal transport in the UK in 2005. Reliance on cars for these journeys can be attributed to many of the factors highlighted previously, including concerns over safety and inadequate infrastructure for accessible walking and cycling. Sustrans emphasise that urban transport policy needs to be well integrated with land use, development and zoning policy, so that journey distances are not made longer than they need to be. Wherever possible, the goods and services which citizens need should be accessible by walking or cycling from their residential neighbourhoods.[7]

It should be noted however, that only holiday trips within Great Britain are included in this data;[8] the distance and impact of 'leisure' is likely to be significantly higher if international travel is included. The environmental impact of different transport modes for leisure and holiday activities is examined in further detail in the following section.

2.2. Shopping

Shopping accounted for 20% of trips made in 2005 and 12% of mileage (Figure 2). Whilst the average number of shopping trips per person has fallen, the average length increased by 10% since 1995/1997 from 3.9 miles to 4.3 miles in 2005. These trends are indicative of a switch from more frequent, short shopping trips on foot to local shops, to longer, less frequent car trips to large supermarkets. 63% of shopping trips are made by car and a high proportion of these (34% in 2005) are made as car passengers. The high proportion of shopping trips that take place at the weekend (33%) and the high concentration of these trips in the weekend lunchtime periods leads to considerable congestion around retail centres.[9]

Research suggests that retailers often over estimate the importance of the car to their customers and consequently focus their efforts on increasing the provision of car parking and resist measures to promote walking, cycling and public transport use – although pedestrian shopping areas tend to be commercially most successful. Research by Sustrans has highlighted that retail vitality would be best served by traffic restraint, public transport improvements, and a range of measures to improve the walking environment.[10]

2.3. Education Trips

'Education' trips have the highest proportion of journeys by modes other than the private car, however car use still represent 50% of journeys. The demand for education trips, like the demand for commuting trips, is very peaked with almost three quarters of education trips starting in the periods 8am-9am and 3pm- 4pm.[11] Between the early 1990s and the turn of the century there was a marked increase in the number of children being taken to school by car. Trips to school by car represent 13% of the total number of car trips on the road in urban areas between 8am and 9am.[12]

Over the past 20 years, there has been an increasing reliance on car use for school journeys, bus use has remained fairly constant and the number of journeys made by bicycle or foot has decreased. Many parents now integrate taking children to school with going onto work and therefore the school run is the first part of their commute. Many pupils travel to school by bus: the law requires Local Education Authorities (LEAs) to provide free travel to pupils who live more than three miles from school (two miles for the under eights). Some parents believe that these 'statutory walking distances' are out-of-date, while others have concerns about high fares, bullying, vehicle quality, or arrangements which do not cater for the needs of younger pupils.[13] Many parents fear both traffic and 'stranger danger', although the likelihood of being killed in a traffic accident is about 40 times greater than the risk of death following abduction by a stranger. Nonetheless, more needs to be done to make walking and cycling to school safe and easy for children.

3 Environmental Impacts of the Transport Network

Personal travel accounts for 16% of the UK's ecological footprint.[14] This is calculated by combining a number of important activities that have an impact on the environment. These include:

- The direct emissions of carbon dioxide, methane and nitrous oxide from the combustion of fuels for personal transport;
- The emissions of carbon dioxide from the manufacture as well as the maintenance of vehicles; and
- The direct land use for transport (e.g. road space, car parks).

To calculate the ecological footprint, all of these various transport impacts are converted into a land figure, measured in global hectares or global square meters. This is done for all forms of transport and therefore allows comparison between different impacts of transport.

The impact of transport on the environment is felt in many different ways. Transport can damage quality of life and in some cases, as shown by the Stern Review, the growth prospects of the economy as well. The main impacts on the environment are emissions of greenhouse gases, air pollutants, noise, and damage to both the natural and built environments.

Whilst the environmental impact of transport may be reduced through a range of strategies (discussed in more detail in Section 4) including efficiency gains, technology and alternative fuels, given the huge predicted growth of transport, the overall impact is set to increase significantly in future, particularly if aviation and international travel are included in the analysis. For example, road transport is predicted to grow by a further 33% in the next 20 years, along with a threefold increase in demand for air travel by 2030. Whilst there is some debate as to the true impact of aviation (see section 3.8 below), the government expects that national transport emissions (not counting international flights) will rise by 3.8 million tonnes between 1990 and 2020[15] (and others have predicted the increase to be between 7 and 13 million tonnes)[16].

The main environmental impacts relating to transport networks are discussed in further detail below.

3.1. Climate Change

Climate change is the most important long-term challenge facing the global community. The impact of greenhouse gas emissions on the global climate is scientifically well-established, and as the Stern Review has shown, climate change could have very significant impacts on the UK and global economy.

Domestic transport currently represents around 23% of carbon dioxide emissions, excluding those associated with international air travel.[17] This proportion is expected to grow to around 42 million tonnes of carbon by 2010 and then start to fall back to 2000 levels by 2050 (Figure 7). The rise in emissions in the short term is a result of the very strong historical relationship between transport demand and economic growth. In the longer term however, this relationship is expected to weaken as a result of demographic changes. In addition continued fuel efficiency improvements may also help to reduce emissions despite increases in transport demand.[18] It is important to note however that this does not include aviation.

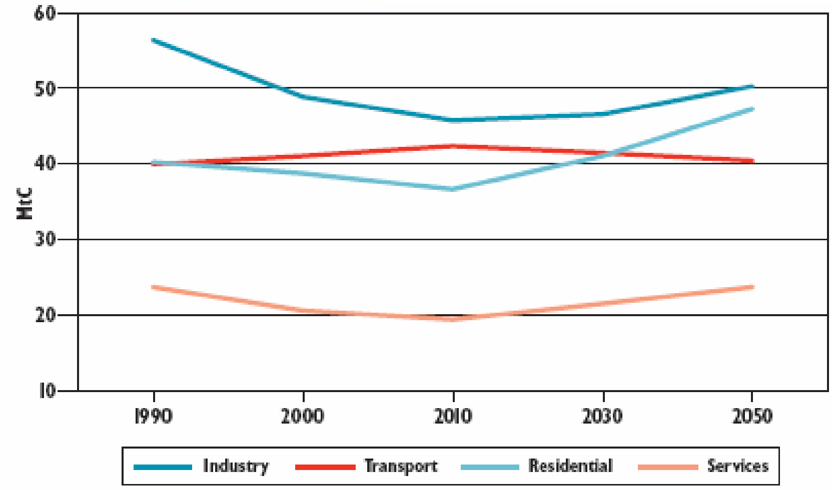


Figure 7: Greenhouse gas projections by sector

There is currently no international agreement on how to allocate emissions from international aviation and shipping. However, if they were counted on the basis of departures, UK carbon emissions from transport rises from 23% to 28%. If the aviation sector is defined as all domestic services plus all international departures from the UK aviation alone would contribute about 6% of the UK's CO_2 emissions and approximately 11% of the UK's total climate change impact, including an assumption for non-carbon emissions from aviation.

Figure 8 below outlines CO_2 emissions from transport by mode. As can be seen passenger car use is the main contributor to CO_2 emissions.

Mode	Emissions in Million tonnes of carbon dioxide (MtC)		
	Total	As a per cent of total domestic transport	As per cent of total UK CO_2 emissions
Road Transport:[a]	**32.6**	**93.1**	**21.4**
of which:			
Passenger cars	19.4	55.5	12.8
Light duty vehicles	4.4	12.4	2.9
Buses	1.0	2.8	0.6
HGVs	7.6	21.6	5
Mopeds and motorcycles	0.1	0.3	0.1
Railways	**0.7**	**1.9**	**0.4**
Civil Aircraft	**0.6**	**1.9**	**0.4**
Shipping	**1.0**	**2.9**	**0.7**
All domestic transport[b]	**35.0**	**100.0**	**23.0**
Total UK emissions	**152.5**		**100.0**
Memo items:			
International aviation	9.0		5.5
International shipping	1.6		1.0
All transport emission (incl. International)	**45.7**		**28.0**
Total UK CO_2 emissions (inc. International)	**163.1**		**100.0**

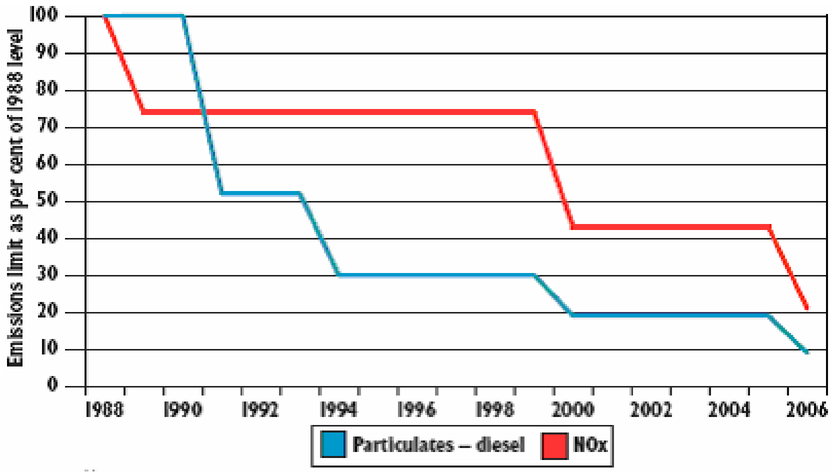
a. Total road transport includes a small amount of emissions from LPG vehicles and from engines
b. Total includes a small amount of emissions from other mobile sources of machinery

Figure 8: CO_2 emissions from transport by mode, 2004[19]

Transport is also the source of other greenhouse gas emissions (around 6% by weight of total transport greenhouse gases).[20] These include methane and nitrous oxide, present in very small amounts in exhaust emissions, and also gas emissions from refrigerants used in car air-conditioning systems. These gases both have a higher global warming potential than carbon dioxide.

3.2. Air Quality

Transport can have an impact on air quality. However, although still significant, despite increases in traffic emissions of key air pollutants from road transport have been reduced by about 50% over the last decade, as shown in Figure 9. This is largely due to a progressive tightening of European emissions standards, which have helped force improvements to vehicle engineering and design.



Notes

a Emissions of oxides of nitrogen and particulate matter remain generally higher for diesel vehicles than for petrol vehicles.

b Until 1992 NOx limits for petrol and diesel cars were based on a combined limit for both NOx and Hydrocarbons.

Figure 9: Air Quality – EU emissions standards for cars[21]

Despite this decline, there are still 'hot spots' in some city centres and along motorway corridors where concentrations of nitrogen dioxide and particulates from road vehicles exceed mandatory limits set by the EU and above the objectives set in the Government's Air Quality Strategy. The Department of Health estimates that there are between 12,000 and 24,000 early deaths each year resulting from poor air quality in UK cities.[22]

3.3. Noise

Traffic noise can be a concern for communities living close to the road networks, airports and flight paths. Noise from construction and maintenance work can also cause nuisance. Traffic noise from the trunk road network can be tackled through measures such as using appropriate materials and designs in both construction and maintenance. Quiet surfacing materials have been required to be used as a matter of course since 1999 in all new road construction and also in the maintenance of existing ones. Measures such as noise barriers on motorways also help reduce traffic noise to acceptable limits in residential areas and have recently been used to relieve the most severe noise problems experienced by communities living close to the existing trunk road network.

Technological progress means modern jet aircraft are typically 75% quieter than their 1960s counterparts and the number of people around the UK's major airports who live within higher noise contour areas has decreased over the past ten years. Nevertheless, aircraft noise remains a key local environmental impact for people living near airports and flight paths and can cause significant disturbance and annoyance; according to MORI in 2004 approximately 14% of UK residents were moderately or extremely bothered by aircraft noise.[23]

3.4. Landscape, heritage and biodiversity impacts

Transport infrastructure can also have a negative impact on landscape, heritage and biodiversity. The severity of such impacts varies considerably according to the specific location of a particular development. The diversity and complexity of environmental concerns can lead to competing challenges for surface infrastructure: for example, bypasses removing heavy traffic from town and village centres improve air quality and are popular with benefiting communities, but create a new or changed impact on the landscape and in the long run tend to lead to increased traffic growth.

Both new and existing roads, rail, ports and airports can have serious implications for wildlife, biodiversity and nature conservation. New infrastructure can cause direct loss of habitats if care is not taken over route planning, construction and maintenance. In addition, plants, animals and habitats are sensitive to the vehicle pollutants. For example, nitrogen oxides from exhausts form acid rain in the atmosphere that can damage the trees and soil. It is also estimated that at least 50,000 badgers, 100,000 foxes and 10 million birds are injured or killed on our roads each year in the UK by road transport.[24] On the other hand, road and rail estates can also support a wide range of plant and animal species otherwise under threat from urban expansion and land-use changes in the countryside.

Roads and related infrastructure also leads to an increased area of impermeable surfaces, interrupting natural water flow and exacerbating problems on flood plains. Run off from roads may include pollutants such as fuel oils and seasonal road treatments that can pollute nearby water courses. Paving over gardens to create driveways also means there is less green space available for wildlife.

3.5. Health

Vehicle emissions release potentially harmful substances such as nitrogen oxide, carbon monoxide and fine particles into the air. These pollutants can reach high levels of concentration in our towns and cities and related air pollution can trigger asthmatic attacks. Fine particles in particular may have long-term health effects especially for those with heart and lung problems.

Road transport also has a direct impact on health, for example, 3,201 people were killed on Britain's roads in 2005 (almost 9 people a day) and 28,954 were seriously injured; in total there were 271,017 road related casualties.[25]

In recent years, growth in car use has lead to increasingly sedentary lifestyles. 23% of the UK population is now obese, a threefold increase since 1980; obesity is associated with life threatening diseases including coronary heart disease, type 2 diabetes, osteoarthritis, many cancers, and respiratory disease, as well as social stigma and related mental health problems.[26] In addition, it is estimated that physical inactivity now costs the UK over £10 billion a year[27]. The Institute for European Environmental Policy recently published a report that makes a link between car use, obesity and carbon dioxide emissions. It estimates that if a typical British adult were to walk just an hour more a week equivalent to the difference between a typical driver and a non-driver, it would stop us putting on two stone in weight in over a decade[28]. In addition, this extra walking could potentially displace over 15% of the total carbon dioxide emissions from passenger cars.

Exercise is also vital to the health of children in the UK. One in 10 six-year-olds is obese. The total number of obese children has doubled since 1982. On present trends half of all children in England in 2020 could be obese[29]. Currently 29% of boys and 43% of girls under 16 have less than 30 minutes of physical activity on most days (the daily minimum level of activity as recommended by the Health Education Authority). As well as helping to improve health and decrease congestion, teachers in schools across the UK have reported that pupils who walk or cycle to school are more alert and concentrate better than those who travel by car. A recent US study showed a positive link between physical activity and performance in school tests[30].

It has been recognised that the built environment has a key role to play in facilitating and promoting active transport. Following a consultation in July 2007, The National Institute for health and Clinical Excellence (NICE) is expected to release guidance relating to the promotion and creation of physical environments that support increased levels of physical activity in January 2008.[31] CABE[32] has also released a briefing document that recognises how the built environment can be designed to maximise the potential for walking and cycling including traffic free walking and cycling paths, and the design and management of street networks that connect spaces in a manner that makes walking and cycling safe and attractive.

Impacts of Passenger Transport Modes

Clearly, the environmental impact of personal transport depends on the transport mode chosen. Figure 10 presents a comparison of the ecological footprint per passenger-km for the different modes of transport in the UK.

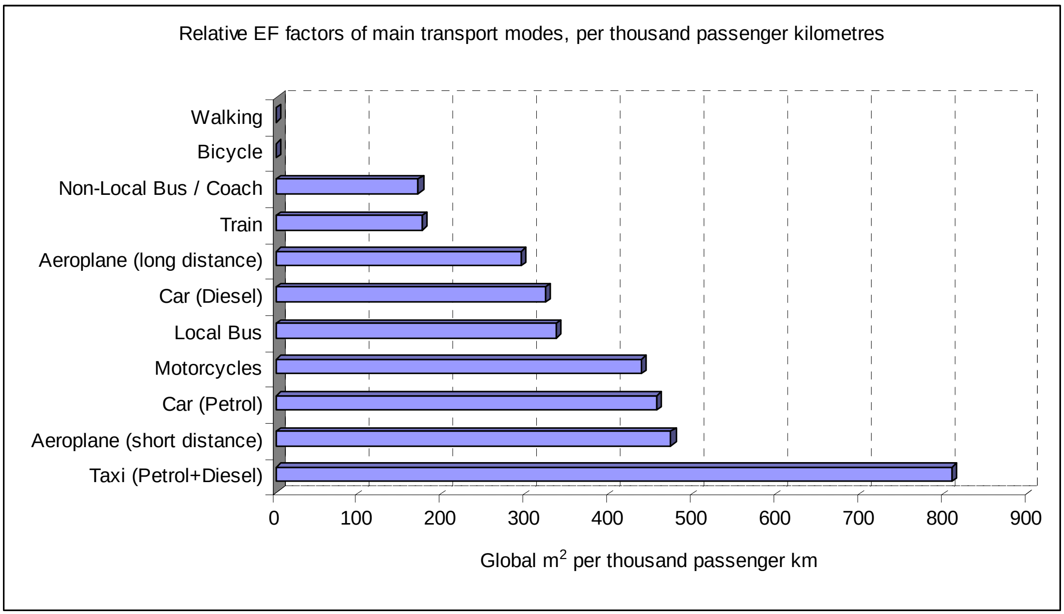


Figure 10: Relative Ecological Footprint factors of main transport modes, per thousand passenger kilometres[33]

A transport calculator has been provided in Appendix A which shows the estimated CO_2 emissions and ecological footprint for each transport mode. As can be seen from Figure 10, the use of petrol cars (including taxis) and motorcycles as well as short aeroplane trips have a larger impact per passenger kilometre than travelling by bus, bicycle or train. This is due to the CO_2 emissions from direct fuel combustion, manufacture and maintenance of vehicles as well as low occupancy rates of some individual travel modes (such as taxis). Cycling has the lowest impact, apart from walking which has a zero footprint, and has 0.3 per cent of the impact of a car for every kilometre travelled.

3.6. Cars

The average carbon emissions per kilometre for an 'average car' are 0.17 kg of CO_2 per km, with an associated ecological footprint of 0.46 global m^2. For an average diesel car kg of CO_2 emissions per kilometre are approximately 0.12, or 0.32 global m^2.[34]

Other important factors to consider are the embodied energy of the vehicles and the related infrastructure such as roads and motorways. A lifecycle energy analysis in the 1970s showed that making a typical automobile from virgin materials used about as much energy as each year's driving: i.e., the ratio of embodied energy to total lifecycle energy, assuming a 12-year product life, was ~1/13. A 1995 assessment by Ford's Scientific Research Laboratories found little change; the embodied materials and manufacturing energy was equivalent to 1.2 years' driving (or 1.4 years counting the "energy overhead" of petrol production).[35] It is also estimated that one kilometre of motorway consumes more than 100,000 tonnes of aggregate.[36]

3.7. Aviation

Between 2004 and 2005, CO_2 emissions from domestic aviation increased by 7.1 per cent, while international aviation emissions increased by 5.7 per cent, due to an increased number of flights. Between 1990 and 2005, emissions from aviation fuel use more than doubled.[37] In 2005 aviation was responsible for 5.5% of the UK's CO_2 emissions[38]. The government's 2003 Aviation White Paper predicts that air travel will treble by 2030: an increase in annual plane journeys from 180 million to 501 million.[39]

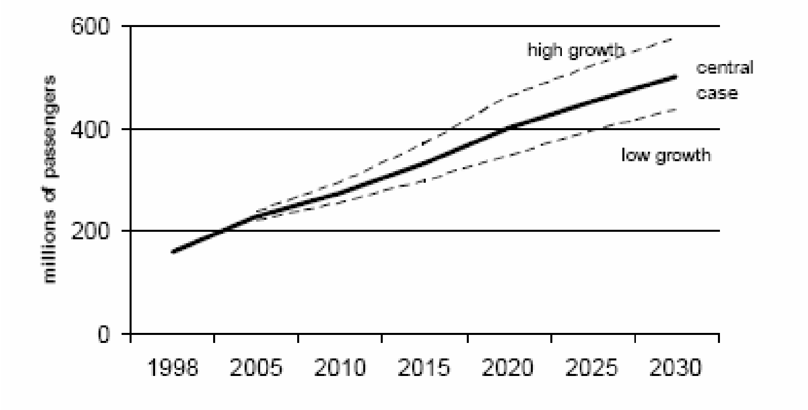


Figure 11: Forecast growth of aviation in the UK[40]

The Royal Commission on Environmental Pollution states that the carbon emissions per passenger mile for a fully loaded cruising airliner are comparable to a passenger car carrying three or four people. However while the mean distance travelled by car in the UK is 9200km a year, in a plane this is possible in one day. For a return flight from London to New York, every passenger emits approximately 1.2 tonnes of CO_2, the amount we will each be entitled to emit in a year once a 90 per cent cut in emissions has been made (see discussion in section 5). In addition the climate impact of flying is not confined to carbon; planes also release other gases and particles, which according to the Intergovernmental Panel on Climate Change (IPCC) have a warming effect 2.7 times that of CO_2.[41]

Calculating the emissions resulting from flying is not a simple process and as mentioned above there are many other factors, such as the global warming potential of other gases that should be included in impact assessments. However, even for carbon alone, there are a range of emissions figures; as can be seen in the table below, the carbon offsetting companies use different emission data.

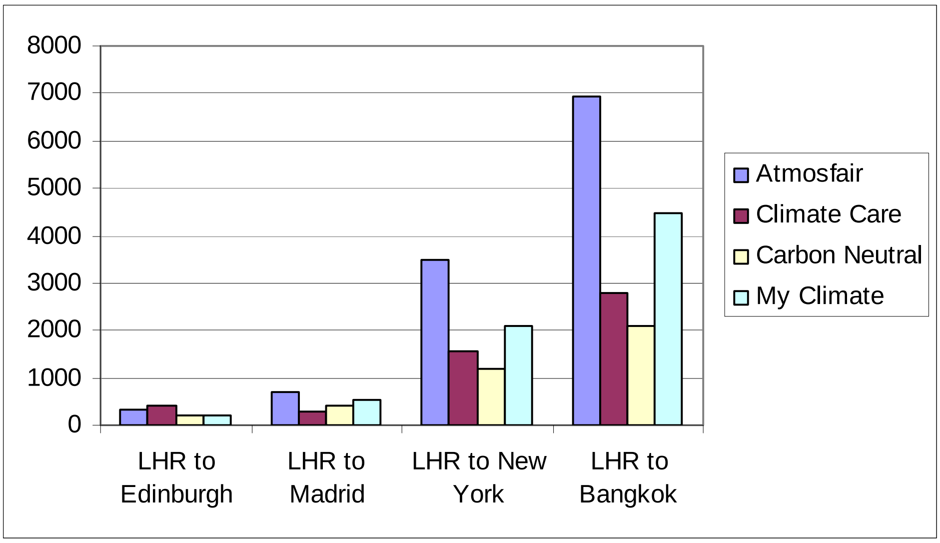


Figure 12: Return flights from London Heathrow, kg CO_2 per passenger.[42]

If this is translated into estimated kilograms of CO_2 per passenger kilometre it is easy to see that there is a substantial difference in emission rates (for example, ranging from 0.11 to 0.36 for the flight to Bangkok!).

For the emissions calculator provided in Appendix A we have used figures from Taking Stock and assumed:

- short haul: 0.18 kg CO_2 per passenger km
- Long haul: 0.09 kg CO_2 per passenger km

3.8. Trains

Rail travel in the UK produced approximately 0.7 million tonnes of Carbon in 2004, accounting for 1.9% of the UK's total transport emissions. The impact per passenger of rail travel depends on the energy used (for example diesel, or electric) and the number of passengers; currently there is limited data available on this. For the purpose of the transport emissions calculator, an average of 0.06 kg CO_2/passenger km and a footprint of 0.17m^2 per passenger km were assumed.

A recent transport study[43] compared emissions per passenger for rail and air, assuming 100% occupancy and for average occupancy (approximately 30% on Eurostar and 80% on Ryan Air). As can be seen (Figure 13), train travel has significantly lower emissions per passenger, especially when occupancy rates are increased.

Mode	CO_2 emissions per 100 seat-km	CO_2 emissions per 100 passenger-km
Class 91 East Coast train at 200 kph	1651	5504
Eurostar at 300 kph	2580	8600
Ryan Air	6165	7707
757-300	7045	8807
Fokker F28	17761	22201

Figure 13: Comparison of the emissions associated with 100% and average occupancy of journeys by rail and air

Whilst this report focuses on the transport of people, it is worth mentioning that rail also has an important role to play in transporting goods, for example, Network Rail estimate that one average freight train can remove 50 HGVs journeys from our roads, as well as producing significantly less emissions.[44]

3.9. Buses and coaches

As with all transport modes, the emissions and footprint per passenger directly depends on occupancy rates. It is worth noting however that local diesel buses are generally more polluting than, for example, inter city coaches (see table below). Even given the often relatively low occupancy rates however, emissions per passenger kilometre are still generally less than for the average car.

	Kg CO_2/ passenger km	EF (m^2) / passenger km
Local bus	0.128	0.334
Non-local bus	0.065	0.170

Research outlined by George Monbiot highlights the efficiency in terms of emissions and occupancy of coaches compared to private vehicles. For example, on a mile of roadway coaches can carry nearly five hundred people whilst cars can carry thirty. On an area of M25 examined, the carrying capacity of cars was found to be 15,000-20,000 whilst in coaches this increased to 260,000. Monbiot concludes that an intercity network of coaches could significantly reduce the amount of roads needed, as well as moving people more efficiently and reducing emissions. In addition, coaches are also more efficient in terms of cost. For example, a coach costing £150,000 can carry people on nearly 100,000 substantial person journeys per year, whereas ten cars costing £15,000 each (i.e. £150,000 in total) would on average do approximately 10,000 similar journeys[45]. CO_2 per passenger km are consequently much lower due to higher occupancy rates and efficiency savings.

3.10. Ferries

A study by Best Foot Forward calculated the footprint of ferry travel from Portsmouth to the Isle of Wight and found that it equated to approximately 0.93gha per passenger km. This is extremely high (short haul flights for example are estimated to need approximately 0.18 gha) due to very low occupancy rates of that specific route. Co2care estimate that average ferry emissions are approximately 0.11 kg of CO_2 per passenger kilometre. This figure has been used in the CO_2 calculator provided in Appendix A. More research is needed on the impact of passenger ferries.

3.11. Cruise liners

Calculations made by Climate Care found that cruise liners have a very high carbon impact. They found that a cruise liner, such as Queen Mary 2, emits 0.43kg of CO_2 per passenger mile. It also has a high cost to the ocean as 'the cruise industry has a poor record in terms of waste water treatment and disposal'. The size of the industry is also crucial: cruising is the fastest growing sector of the travel industry; in 2003, 9.3 million passengers took a cruise while the International Eco-tourism Society projects that 17 million passengers will do so in 2010.

It is worth noting, however, that cruises are not directly comparable to other holiday travel modes as the cruisers also provide food and accommodation for the customers for their entire holiday. So to compare, for example, a cruise from London to New York to a flight for the similar amount of time, all accommodation and food impacts would also potentially have to be included.

3.12. Holiday impacts

UK residents are making more trips abroad each year than ever before, over three times as many in 2002 as in 1981. In 1981, holidays accounted for 60 per cent of all trips taken abroad, but by 2002, this figure had risen to 74 per cent. Conversely, the relative importance of sea travel has declined, from 41 per cent of all holiday trips in 1981 to just 17 per cent in 2002, at the same time aviation is increasing.[46]

The table below outlines the potential CO_2 emissions associated with a trip from London to Paris by different modes. As can be seen, flying has the highest CO_2 emissions and Eurostar or ferry and coach have the lowest impact. It is worth noting that for the car emissions, occupancy is key. The scenario assumes two people are travelling, if it was only one person the emissions per person would double.

Mode	Carbon dioxide emissions per passenger (kg)	Time (each way)
Plane	92	1 hour 15 (plus 1 hour check in)
Ferry (Dover to Calais) **Plus car**	6 43 Total: 49	1 hour 30 mins 6 hours Total: 7 hours 50
Ferry (Dover to Calais) **Plus Coach (510 miles)**	6 33 Total: 39	1 hour 30 mins 6 hours 30 Total: 7 hours 50
Eurostar / train	40	2 hours 45
Cruise ship[2] **Plus car**	41 43 Total: 84	3 hours 6 hours Total: 9 hours

'Plus car' assumption: (medium sized engine, driving from Paris to Calais (178 miles), Dover to London (77 miles) return, i.e. 510 miles total) – assuming two people in the car. 29 miles Dover to Calais

[2] http://travel.guardian.co.uk/article/2006/dec/20/cruises.green

4 Reducing the Impact of Transport

There are a range of strategies proposed to reduce the ecological impact of current transport patterns, some of which are outlined below. Before examining sustainable alternatives, it is vital to first of all minimise transport demand as much as possible.

4.1. Reducing Transport Needs

As discussed above, whilst some savings are possible, as we live on a finite world and need to reduce our ecological footprint by two thirds in the UK, reducing the need for transport is fundamental. This can be done through a variety of ways.

4.1.1. Local Facilities

Transport impacts due to shopping and personal business could be reduced by making use of local facilities and shops to eliminate the need to travel by car. This may involve reverting to smaller, more frequent trips by public transport or walking, as opposed to travelling further by car and buying all goods from one source such as an out of town supermarket. Multi purpose trips can also help to reduce the overall distance travelled. Alternatively using online shopping and banking facilities can eliminate the need to travel altogether for these purposes. Ocado allows customers to view deliveries that are already planned in the local area and co-ordinate their own delivery time to tie in with this, reducing the number of separate trips made by delivery vehicles.

4.1.2. Educational trips

Over the past 20 years the proportion of children travelling to school by car has almost doubled, yet many live close enough to school to walk. Research conducted by Sustrans found that 45% of children would prefer to walk or cycle to school than be driven. The health benefits of this kind of daily exercise are undisputed. There has been an alarming rise in childhood obesity over the last ten years, a problem which would be largely eradicated if children undertook an hour's exercise each day.

For younger children, initiatives such as walking busses (whereby groups of children walk to school together with parental supervision) can help to reduce carbon emissions and time spent by parents delivering their children to school. For older children, ensuring there are safe walking and cycling routes and facilities is vital and will also have positive social benefits.

4.1.3. Leisure

Travelling for leisure and shopping purposes accounted for 50% of personal trips made in the UK in 2005, with the vast majority of journeys made by car.[47] In addition, nearly a quarter of all car journeys are under two miles; a 30 minute walk at most. There are many facilities to assist people in planning journeys by public transport, walking, cycling and eliminating the need to travel altogether. Promotion of these facilities and increased provision of safe pedestrian and cycle routes could help to encourage more sustainable transport use. A few examples include: http://journeyplanner.tfl.gov.uk www.traveline.org.uk and www.walkit.com http://www.bikely.com/listpaths

4.2. Providing and promoting sustainable transport options

Clearly it will not be possible to eliminate all transport needs, ensuring that more sustainable alternatives to private car use are easily available and promoted is therefore vital.

4.2.1. Walking and Cycling

Walking and cycling are the most sustainable transport options and have almost no ecological footprint (the embodied energy of the bicycle does have a small impact, calculated to be 0.00006 kilograms of CO_2 per passenger kilometer or 0.00030 global m^2 per passenger kilometer). Ensuring that there are safe accessible walking and cycling routes and facilities should therefore be a top priority. Whilst approximately 90% of children have bikes and over 30 per cent would like to cycle to school, only one per cent currently do. Ensuring that there are safe walking and cycling routes to all schools is vital in reducing the environmental, health and congestion impacts of the school run. In some cities (see case studies in Section 7), a pay as you go rental service is available for bikes, enabling residents to pick up a bike where they need it and drop it off when they are finished using it, allowing for much more flexibility in transport modes.

4.2.2. Public Transport

As can be seen from Figure 6, in high density cities such as London which has good public transport provision, people are prepared to reduce their car travel. For a community to be sustainable there is therefore the question of density in order to facilitate public transport provision and support for local facilities.

However, a direct shift from current transport patterns to the current public transport system in the UK is not the solution. The scenarios in Section 5 compare the impacts of a car dominated transport pattern to a more public transport orientated pattern. Whilst a shift from private vehicles to public transport would help to reduce emissions and ecological footprint, the impact will still be above the sustainable level. An overall reduction in all forms of motorised transport modes is needed to facilitate sustainable transport patterns.

4.2.3. Car Clubs

A car club offers members quick and easy access to a hire car, for periods as short as half an hour. Members book the car over the telephone or internet either in advance or at a few minutes notice, subject to availability and often use an electronic card to gain access to the vehicle. Where journeys by public transport modes are not practical, car clubs offer a more sustainable alternative to private car use. Research has found that each car club vehicle displaces 6-10 privately owned vehicles, reduces parking needs and that the longer members (particularly those who sell their own vehicle) belong to car clubs, generally the less they drive.

Car clubs also bring transparency to the cost of a vehicle, often leading to more economical use of the car and to taking full advantage of the alternatives such as public transport and local facilities. Car club members often take better advantage of public transport, cycle more often, or combine several trips into one. City Car Club's member survey in 2006 found that 11% of their members use their bicycle more since joining the car club and 16% walk more. Members also increased their use of public transport by 15%.[48] There are also potential financial savings, for example, it is estimated that if a member's annual mileage in their private vehicle is less than 6,000 miles per year, then a car club will save £1000 to £1500 a year in running costs alone.

4.2.4. Vehicle efficiency

The UK government has recently launched the 'Smarter Driving' campaign and estimate that if simple tips, such as ensuring tyres are inflated to the correct pressure, were adopted this could result in a national saving of more than 5.5 million tonnes a year of carbon dioxide and would also save motorists over 2 billion pounds in fuel costs.[49]

Whilst there is still a long way to go before all motorists ensure their vehicles are running at maximum efficiency, there is increasing awareness of the impact of vehicle transport. For example, two studies by the Office for National Statistics (ONS) for the Department for Transport show that more people are prepared to pay more to purchase an environmentally-friendly car and are in favour of driving less than a year ago. The research showed 75 per cent said they would pay more for a greener car in 2006 (compared to 71 per cent a year earlier) and 62 per cent said they were in favour of people cutting back on car use (compared to 59 per cent in 2005).[50]

However, this should be compared to the fact that in sales of larger, less fuel efficient vehicles are still increasing, for example, sales of 4x4s grew by 12.8 per cent in 2004, to 179,000, more than double the number sold a decade ago.[51]

4.2.5. Carbon offsetting

An increasingly popular proposed ‘solution’ to reducing the impact of transport, particularly aviation, is carbon offsetting. This involves paying a company to invest in projects, generally abroad, which aim to reduce carbon emissions by the same amount as produced by the journey being offset.

In spring 2007, the Intergovernmental Panel on Climate Change (IPCC) produced its latest compilation of scientific evidence on climate change[52]. The report concludes that keeping the average global temperature increase to 2°C - 2.4°C requires stabilisation at 445 - 490 parts per million of CO_2 equivalent in the atmosphere. This in turn requires global yearly emissions to be reduced by between 50 to 85% by 2050, based on current levels. The UK emits more than double the worldwide average CO_2 per person, and consequently must reduce emissions by between 80 and 90% by 2050, on current levels. This translates into a 40% cut by 2020.

Whilst carbon offsetting does, in some cases, provide funding for useful carbon reduction programmes, it does not reduce total global carbon emissions. In addition, as Figure 11 illustrates, the carbon offsetting companies use different CO_2 emission rates and there has been some debate concerning the effectiveness of some offsetting projects. Whilst offsetting does go some way towards raising awareness, the danger is that this may also encourage people to continue flying as they believe their impact is being negated by these projects.

4.3. Alternative vehicles

Reducing CO_2 emissions from UK transport is likely to require a combination of measures, including increased energy efficiency, new technology introduction, and fuel switching. The main alternative technologies for motorised transport can be divided into vehicles and fuels.

Key vehicle technologies are:

- Battery electric vehicles for niche markets such as urban journeys
- Hybrid vehicles, replacing conventional petrol and diesel vehicles
- Fuel cell vehicles, potentially able to replace all conventional vehicles

4.3.1. Electric Vehicles

At present, battery electric vehicles (BEVs) are the most common zero emission vehicle, producing no vehicle tailpipe emissions in the course of their operation. BEVs that are recharged using energy sourced from renewable energy technologies are as close to being zero emission as possible (there are emissions associated with their manufacture). Even when BEVs are charged using standard grid electricity, they are still cleaner than all other cars on the road.[53]

Battery electric vehicles consist simply of a large rechargeable battery which stores electrical energy and this coupled to an electric motor which drives the wheels. This combination is far more efficient than internal combustion engine powered cars and is the reason for their lower emissions.

However, battery electric vehicles still face significant barriers which are likely to prevent mass production and major market diffusion in the medium term. In the longer term, these barriers could potentially keep BEVs within niche applications such as urban commuting, rather than allow them to enter the mass market. Currently the major limitation with BEVs lies in their short range. Many of the smaller commuter BEVs have ranges of around

30 to 60 miles (50 to 100 km), while some higher performance examples have ranges of 150 miles (240 km).[54] Improvements in the energy to weight ratio of the battery would enable BEVs to have a range comparable to internal combustion engines and increase their marketability. In addition battery charging time is still high for most customer expectations, unless fast charging is used which would require more complex and considerably more costly charging stations.

In the past 12 months, interest in EVs has gathered momentum, with new high performance models being unveiled in the United States. In the UK, and especially in London, the growth in short range commuter EVs has been very strong. Westminster Council has recently installed 50 free electric charging points in the borough[55], including two on street points. There are three makes of EV currently on sale in the UK: the Reva G-Wiz, the NICE MEGA City and the Sakura Maranello4. These three vehicles are quadracycles which comfortably seat two and cost between around £8,000 and £10,000. Additionally, Smart has launched the Smart EV which is available for companies to lease.[56]


G-Wiz

While these costs are high when compared with conventional cars, large savings can be made through the operating costs (about 1p per mile), free or reduced rate parking offers, vehicle excise duty exemption and for driving in London, a Congestion Charge discount. However the battery is not cheap and after a while, its capacity to hold its charge reduces until it becomes unusable and needs replacing. The time this takes depends on the battery technology, how often it is used and how deeply it is charged and discharged. This also raises questions over how these batteries need to be disposed and whether elements can be recycled.

Another question over switching to cars powered by electricity as opposed to liquid fuel is whether our existing grid could cope with this added demand. Forecasts for the timing of peak oil[3] range from now until 2030[57]. This emphasises the immediacy of needing to reduce our reliance eon fossil fuels. Hence, when considering alternative fuels for transport, it must be recognised that while the emissions associated with supplying vehicles with electricity is lower compared to petrol or diesel; our priority should be eliminating our reliance on fossil fuels. Whilst, as highlighted, supplying electricity produced by renewables would eliminate the need for oil, it is going to be many years before renewables can meet transport and other demands of our society. This again emphasises the need to reduce the need to travel in the first instance.

4.3.2. Hybrid electric vehicles

Hybrid electric vehicles use an electric motor in conjunction with a conventional internal combustion engine (or fuel cell) to improve drive cycle efficiency and hence reduce fuel use. Hybrid vehicles, and potentially plug-in hybrid vehicles, may well prove a better alternative than battery electric vehicles for widespread market diffusion, as the challenges they face are less onerous. They can also use biofuels in the same way as conventional vehicles.

For high levels of emissions reduction, hybrids need battery technology to reach greater power density and energy density than is currently the case, at an acceptable cost. Unless a significant breakthrough occurs soon in battery technology, and if fuel cells can overcome their technology issues, hybrid systems may end up being a 'transition' technology in Europe. If fuel cells do not become successful then hybrid vehicles using biofuels could make a significant contribution to CO_2 emissions reduction.

It is also important to consider the environmental impacts attributed to the full life cycle of these vehicles including manufacture. These impacts were assessed in a study by Kiyotaka Tahara and several of his colleagues at Seikei University in Tokyo.[58]

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[3] Peak oil or 'Hubbert's peak' refers to a singular event in history: the peak of the entire planet's oil production. After Peak Oil, according to the Hubbert Peak Theory, the rate of oil production on Earth will enter a terminal decline.

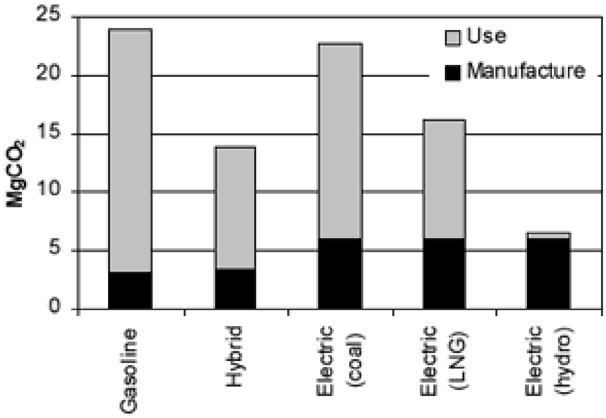


Figure 14: Total carbon dioxide emissions over the lifetimes of gasoline, hybrid, and electric cars.

Figure 14 reveals that gasoline cars are responsible for the least CO_2 emissions during manufacture, but the most during use, and therefore the most over the vehicle's total lifetime. Hybrid cars demand slightly higher CO_2 emissions during manufacture, and electric cars the most. Electric cars' high emissions during manufacture are most likely related to their very large batteries. But certainly the most important lesson of this LCA is the importance of the source of electricity used to power an electric car. Coal-based electricity leads to CO_2 emissions nearly as high as for a gasoline-powered car. Yet hydropower (or solar) results in dramatically lower emissions.

4.3.3. Fuel cell vehicles

Fuel cell vehicles are in demonstration in several countries worldwide. They still face technical barriers to introduction, including lifetime and durability concerns. However, significant progress has been made over the past decade and modelling suggests that mass-production costs will be fully competitive with conventional vehicles, if the technical challenges can be overcome. Storage of hydrogen is also a key issue, as fuel cell vehicle range is still limited to 350 miles at best.[59]

Fuel cell vehicles offer possibly the best long-term potential given the extremely wide range of possible hydrogen sources, including for example, biogas (see case studies in Section 7), but require support in research, development and demonstration in the short term, and in the initial stages of commercialisation. Monitoring and careful policy are required to ensure that low-carbon hydrogen is used, once appropriate.

4.4. Alternative fuels

Road transport in the UK and elsewhere relies almost exclusively (~98%) on oil for energy. This results in significant emissions of greenhouse gases, which are rising as a function of an increased vehicle fleet and higher annual mileage. Although different grades of fuel are available, almost all fuel used in the UK is either petrol or diesel. Alternative fuels occupy only a small portion of the market (1-2%).

There are a range of fuels that could potentially be used to power vehicles:

- As already discussed, battery vehicles and some hybrids known as plug-in hybrids require electricity
- Biofuels can be introduced either as blends in current fuels and used in current vehicles and hybrids, or potentially as pure fuel with small vehicle modifications
- Hydrogen is required for fuel cell vehicles and could also be used in internal combustion engines

This section examines each of the main alternative fuels in turn.

Biodiesel
Primary Material: Crop oils including oilseed rape, sunflowers and soybeans, as well as from waste cooking oils. **Emissions:** For 5% blend - marginal increase in NOx, decrease in PM and CO. Life cycle emissions of greenhouse gases from biodiesel are 24% those of diesel when processing is fired by straw and 30% those of diesel when gas is used to fire the processing. **Environmental Benefits:** Depending on the production method and source, it is generally accepted that biodiesel gives a maximum of 60% carbon dioxide reduction (well to wheel), which means a 3% reduction in a 5% blend.[60] Use of waste oil also reduces the amount going to landfill / clogging up the sewage system, in London alone over 1,000 tonnes of fat and oil enter the sewer network every year, causing 60,000 blockages.[61] **Potential Impacts:** Any fuel that does not conform to the recognised standard for biodiesel EN 14214, and meet the current diesel specification EN590 (maximum 5% biodiesel blend) may compromise the vehicle warranty.[62] In particular, using 100% biodiesel can potentially create problems with engine performance, unless the vehicle has been modified to use this fuel. Switzerland's Jean Ziegler[4] has said the conversion of arable land for plants used for green fuel has led to an explosion of agricultural prices which was punishing poor countries forced to import their food at a greater cost. Ziegler's submitted a proposal to the UN General Assembly, proposing a five-year moratorium, aiming to ban the conversion of land for the production of biofuels. Ziegler said he hoped that by the time the moratorium was lifted science would have made sufficient progress to be able to create "second generation" biofuels, made from agricultural waste or from non-agricultural plants such as jatropha, which grows naturally on arid ground.[63] **Current Use:** Biodiesel is currently in use in the UK and production is primarily from esterification of waste vegetable oil and rapeseed. Britain's first large-scale biodiesel plant opened in Scotland in March 2005, with the capacity to produce 50 million litres of biodiesel per year from waste cooking oil and animal fats.[64] There are currently 138 refuelling stations in the UK supply fuels containing 5% to 100% biodiesel in the fuel composition.[65] **Outlook:** In the longer term, biofuels are likely to come from sources such as wood, grass, straw and even organic waste materials (food waste and so on) in the form of second generation biofuels (see below).

Bioethanol
Primary Material: Generally produced from starchy crops like wheat, sugar beet, sugar cane etc. As with potable alcohol, it can be made from virtually any organic substance (grass, wood, green bits of municipal solid waste), but the technologies for doing so are not proven at commercial scale. Bioethanol is generally used as an additive (up to 5%) in petrol. As with biodiesel, it can be used at higher blends (in Brazil virtually all cars run on 30% or higher blends), but not without some, relatively cheap, vehicle modifications. **Emissions:** Emissions from bioethanol blends are generally slightly lower than from petrol, except for NOx emissions, which may be slightly higher because of the higher combustion temperature of oxygenated fuels. Hydrocarbon evaporation from the fuel system may be higher with ethanol blends. ETBE is also increasingly used as an octane enhancer in the place of MTBE, which is a reason for concern due to its toxicity. **Environmental Benefits:** Carbon dioxide savings can be achieved through the use of biofuel, with ethanol from wheat straw giving the biggest savings of up to 90% compared to petrol.

4 Jean Ziegler is The United Nations Special Rapporteur on the Right to Food

Potential Impacts: As with biodiesel, there are growing concerns that a drive to increase the production of bioethanol worldwide will lead to increased deforestation, reduced food stocks and land converted from food to fuel production. This would have devastating impacts in countries already experiencing food shortages and environmental degradation. Critics of bioethanol have also argued that the energy used in its production—by machinery, fertilisers, transport and the fermentation process—can be greater than the energy actually contained in the resulting fuel.

Current Use: Ford and others are already producing 'E85 flex-fuel vehicles' which can run on any petrol containing anything from zero to 85 per cent ethanol. In March 2006, bioethanol sales amounted to 8 million litres in the UK (about 0.4 per cent of total UK petrol sales).[66] Currently most bioethanol sold in the UK is imported. The supermarket chain Morrisons opened the first 10 bioethanol refuelling stations in March 2006.

Outlook: Plants to supply a total UK annual capacity of over 450 million litres of bioethanol— equivalent to 1.75% of 2005 total petrol sales—are either already under construction, or in the planning process

Pure Plant Oil

Primary Material: Pure Plant Oils are made by crushing and filtering oil-based crops such as rapeseed, palm or nuts. The neat oil is then ready to be used in some diesel engines.

Emissions: All emission levels are generally lower than for fossil diesel.[67] The only parameter which in general is unchanged is the NOx emission, because it is related to the combustion technology (high temperature and surplus air), and not directly to fuel composition.

Environmental Benefits: Depending on the production method, Pure Plant Oil (PPO) gives a greater carbon dioxide reduction (well to wheel) than biodiesel.[68] PPO contains no traces of carcinogens (benzene) and heavy metals, such as in conventional diesel fuels.[69] PPO is a fuel that UK farmers can grow and refine to fuel grade quality and therefore has potential benefits for the economies of rural areas [70]

Potential Impacts: The impacts of increased crop production for PPO are likely to be similar to those outlined for bioethanol. Currently in Europe however, the majority of PPO adapted vehicles use rapeseed oil which is produced in Europe and are therefore not relying on crops such as palm oil or soya which are often grown in cleared areas of biologically diverse tropical forest. In addition, the by products of PPO production can be used as high protein animal feed, thereby reducing the need to import protein from abroad.

Current Use: Pure plant oil technology is used all over the EU but most specifically in Germany, where many cars are converted to run on PPO and there is also an established refuelling network.

Outlook: Pure Plant Oil is highlighted as a potential contributor to the Renewable Transport Fuel Obligations. In 2005, the UK exported 280,000 tonnes of rape seed that would have yielded well over 90 million litres of locally grown fuel if the PPO model was adopted. [71]

Second Generation Biofuels – Biogas
Primary Material: Biogas is made from landfill gas and other organic material such as agricultural waste.
Emissions: In Linköping (Sweden), each bus running on biogas fuel reduces nitrogen oxide emissions (NOx) by 1.2 tonnes and carbon dioxide emissions (CO_2) by 90 tonnes per year. [72]
Environmental Benefits: Biogas can offer life-cycle CO_2 savings of up to 95% compared to conventional fossil diesel, although the savings may actually be greater than this estimate because capture of the waste gas prevents the emission of methane into the atmosphere.
Potential Impacts: Using biogas as a transport fuel may not be as efficient as using liquid biofuels, owing to additional infrastructure requirements.
Current Use: Sweden has the largest fleet of biogas-fuelled vehicles in the world, with around 7,000 vehicles in the country and plans to increase this number to 80,000 by 2010.[73]
Outlook: One biomethane plant using organic waste as the feedstock is under construction in the UK, with a second plant, using landfill gas, planned.[74] Several biogas refuelling stations linked to the HGV industry are planned for the next 5 years. [75]

Second Generation Biofuels – Lignocellulosic biodiesel
Second Generation biofuels encompass those fuels produced from lignocellulosic biomass such as wood, straw and components of municipal solid waste.[76]
Primary Material: Lignocellulosic feedstocks (e.g. wood or straw) are gasified and then converted to a mixture of kerosene, diesel and naphtha in a Fischer-Tropsch (FT) process. [77]
Emissions: Second generation biofuels are estimated to give greater environmental savings than primary source biofuels, with potential carbon dioxide savings of up to 94% compared to diesel. [78]
Environmental Benefits: Using these sources will lead to greater carbon savings at lower cost with less environmental impact compared to bioethanol and biodiesel from primary crop sources. Furthermore, second generation biofuels do not necessarily compete with food production unlike first generation biofuels as they are waste agricultural materials such as straw.
Potential Impacts: Currently, there are very few commercial cellulosic refineries in the world and the technology is still under development. The cellulosic refinery run by Iogen Corporation in Ottowa currently uses more energy than it produces, and, in terms of energy use and output, performs considerably worse than first-generation corn ethanol. The different processes needed to refine cellulosic ethanol, including pre-treatment and distillation, are extremely energy-intensive. [79]
Current Use: Biomass gasification technology is currently at demonstration stage, while FT process technology is mature. However, the integration of biomass gasification with the FT process is not yet fully developed. In Europe, a single pilot plant in Germany produces FT-biodiesel. The FT process is currently about twice as efficient at making biofuels from solid biomass as cellulosic ethanol.
Outlook: With significant effort it is estimated that second generation biofuels will have substantial market impact by 2015.[80]

Hydrogen

Hydrogen is produced using primary energy and is then stored and transmitted before it can be converted to an energy service in an end-use technology such as a vehicle. Producing pure hydrogen from water via electrolysis is not sustainable as the electricity used would be from power stations, which mainly burn fossil fuels, and the stations would then effectively be powering the country's transport vehicles as well as having to cope with its current loads. For example, it has been indicated that to satisfy all present transportation energy needs in the city of Los Angeles with hydrogen would double the water consumption rate of the city and require the continuous output of the equivalent of about 100 nuclear power plants.[81] This highlights that, as with electric vehicles, in a world of energy scarcity, it is crucial to address how current demands for transport fuel can be met, when electricity demands are already high across many other sectors. It is important to address that the current electricity supply may not be able to cope with the extra demands of producing hydrogen fuel for transport.

The electricity required for electrolysis can alternatively be provided from renewable sources such as wind, tidal, wave, hydro, or solar energy. The greenhouse gas emissions of hydrogen produced from renewably generated electricity are negligible, arising primarily from transport of the fuel and the embodied energy of renewable generation technologies. In addition however, hydrogen has a very low density and must therefore be compressed or liquefied for transport. Both of these processes require energy. Compression requires 10% of the hydrogen's energy content; liquefaction consumes 30-40%. Twenty-two tube trailers loaded with hydrogen at 3500 psi would be needed to match the energy contained in a single petrol tanker truck.[82] This adds greatly to the environmental impacts of this fuel.

There are techniques other than electrolysis that can produce hydrogen. The hydrogen for the London bus trials is produced by steam reforming of natural gas. The hydrogen gas is then liquefied by cooling it to a very low temperature. The liquid hydrogen is delivered to BP's filling station at Hornchurch in east London where it is stored underground. When the buses are being refuelled, the liquid is first vaporised into a gas before it is dispensed onto the bus and into pressurised cylinders.

It is important to note that as this process uses natural gas this does not alleviate our reliance on fossil fuels and producing hydrogen for all road transport from natural gas in the UK could increase consumption by about 41% over 2004 figures.[83]

The trials in London are part of the European HyFLEET:CUTE project which allows a direct comparison between hydrogen fuelled ICE (Internal Combustion Engine) and FC (Fuel Cell) buses. The project will examine the ecological and economical advantages and disadvantages of both technologies. The results of the trial will be important in determining part hydrogen fuel cells will play in achieving reduction in emissions from transport.

Biomass is another potential hydrogen source. Biomass energy crops, such as short rotation coppice and miscanthus, have been identified as being one of the major potential renewable energy sources for the UK. There are however greenhouse gas emissions associated with the use of nitrogen-based fertilisers used on crops dedicated for transport fuel production. However, several other sources could contribute to the biomass energy potential, including straw, forestry wastes, sewage sludge, landfill gases and municipal solid wastes (MSW). All these sources have some potential for distributed hydrogen production.

Scenarios that address how ultra low carbon road transport might be achieved suggest that if hydrogen is to be produced from renewable resources in the UK, both offshore wind and photovoltaics will be important technologies for the long term as a large requirement could emerge.[84] In practice, photovoltaics are likely to be widely distributed, often at single building scale, and so may not be well-suited to volume hydrogen production. In the shorter term a wide range of biomass resources can be used for producing liquid biofuels, but in the longer term biomass resources may be increasingly dedicated to hydrogen production. However, technology development and demonstrations will be required in order to determine the most viable routes.

Hydrogen may be more suitable as a fuel for trains than cars. Fuel cells are more efficient when they are bigger, and the rail refuelling infrastructure would be simpler than that required for road vehicles.[85]

The UK Renewable Transport Fuel Obligation and land capacity to produce biofuels

A Renewable Transport Fuel Obligation (RTFO) is being considered as an instrument to increase the use of renewable transport fuels by road transport in the UK. The short term objective of an RTFO will be to ensure that biofuels constitute 5% by volume of all fuel being sold on UK forecourts by 2010. The RTFO expects to reduce the carbon emissions from road transport in 2010 by about 1 million tonnes which is equivalent to a 2-3% reduction in the current levels of carbon emitted from road transport.[86]

For biofuels to have a significant impact on reducing carbon emissions, domestic production is critical yet there is debate as to whether UK agriculture's spare land capacity is sufficient to supply for the forthcoming biofuel demand. The National Farmers Union (NFU) figures below illustrate the feedstock (crop for biofuel production) required and land use involved in supplying for 5% of the projected UK fuel demand in 2010.

	Petrol	Diesel
Estimated 2010 Demand	19 million tonnes	22.5 million tonnes
5% by volume (RTFO)	1.2 billion litres of bioethanol	1.35 billion litres of biodiesel
Feedstock Required	3 million tonnes of wheat	2.7 million tonnes of oilseed rape
Land Involved	375,000 ha (8t/ha)	840,000 ha (3.2t/ha)

Figure 15: Illustration of land involved in supplying RTFO for 2010[87]

Note – these calculations use high estimates for fuel demand and conservative average yield estimates. These figures are for land involved in supplying feedstock for biofuels demand, not necessarily extra land required.

If 100% of the UK obligation were to be produced domestically it would involve approximately 20% of UK arable land - 1.2 million ha of 5.9 million ha (UK arable land 2004). This figure does appear high and such figures have been used to undermine UK ability to supply for this market and raises concerns that biofuel production will divert agricultural production away from food crops. However, it is important to look at these figures in further detail.

Dual purpose crops

One important factor is that the crops used in production of biofuels are dual purpose –

- In wheat bioethanol production, approximately one third of the crop is retained as distillers grains, a high quality animal feed
- In oilseed rape biodiesel production, approximately half the crop is retained as high protein animal feed.

Both of these co-products can be used as high quality animal feed that will replace some of the protein crops imported to the UK for animal feed and some of the UK crop area needed for feed. Biofuel co-products can also be used to supply biomass for heat and power production, so helping to reduce carbon emissions further. With these benefits, it is therefore important that co-product yields are taken into account in land requirement calculations.

Existing spare land capacity
The UK agriculture market is currently not at productive capacity. The projected extra land required to meet the 5% RTFO (net of co-product) is in the region of 900,000 ha. The UK has a current average exportable wheat surplus of 375,000 ha (or 3 million tonnes) and mandatory set-aside of 559,000 ha. If this land was used for biofuel production (934,000 ha in total) it could provide more than the 5% required as well as producing a significant amount of animal feed / biomass.

In addition, these calculations take no account for the current production of biodiesel from waste cooking oil (WCO) and tallow, such as the 50 million litres from Argent Energy in Motherwell, or the possibility to utilise more of the estimated 300,000 tonne per year stocks of WCO and tallow in the country.[88]

Future UK capacity for biofuel production
The NFU therefore concludes that UK farming can supply for the 5% RTFO required and in addition, it may also be possible to produce sufficient to meet the EU biofuel target of 5.75% by energy, equating to 7.5-8% by volume. The NFU estimate that achieving the UK RTFO target through UK grown biofuels will reduce CO2 emissions by two million tonnes (the equivalent to taking one million cars off the road).[89] In addition, with technological advances, a greater range of biomass feedstock, traditional waste and co-products will be available to increase the domestic supply of biofuel. However, further regulation is needed if biofuel production is to be truly sustainable, as currently under WTO rules, the UK and Europe would not be allowed to restrict the import of biofuels, such as palm oil, produced on deforested lands.

5 Scenarios for reducing UK personal transport emissions

This section identifies the reductions in UK CO_2 emissions that are required to prevent dangerous climate change and more specifically, the reductions that will be required in our personal transport emissions. A series of scenarios have been developed using baseline travel data is from research conducted for TfL as part of the Smarter Travel Sutton campaign. This is used to illustrate how our travel patterns will need to be modified to ensure targets are achieved. The baseline travel data did not include international travel and so one holiday has been added to the scenarios.

5.1. The One Planet Living Targets

Research published by scientists at the Met Office, predicts that the biocapacity of the Earth for absorbing carbon dioxide emissions is decreasing and by 2030 will have reduced from the current 4 billion tonnes of carbon to 2.7 billion tonnes of carbon by 2030[90]. The reduction in biocapacity coupled with a projected growth in global population means that carbon emissions per person should be no greater than 0.33 tonnes carbon per year (1.2 tonnes CO_2). Given that the average UK footprint is 11.9 tonnes CO_2 per capita per annum, a 90% reduction in carbon dioxide emissions will be required. Transport accounts for 20% of the average persons' carbon footprint (2.5 tonnes CO_2 per capita per annum), and so the UK target for transport is a maximum of 240kg of $C0_2$ per capita per annum.

In summary, the fair share CO_2 emissions for UK transport are:

	Transport kg CO_2 per capita per annum
UK current average	2523
2030 global fair share	240

Figure 16 illustrates two trajectories for reducing carbon emissions down to 240kg per person by 2030.

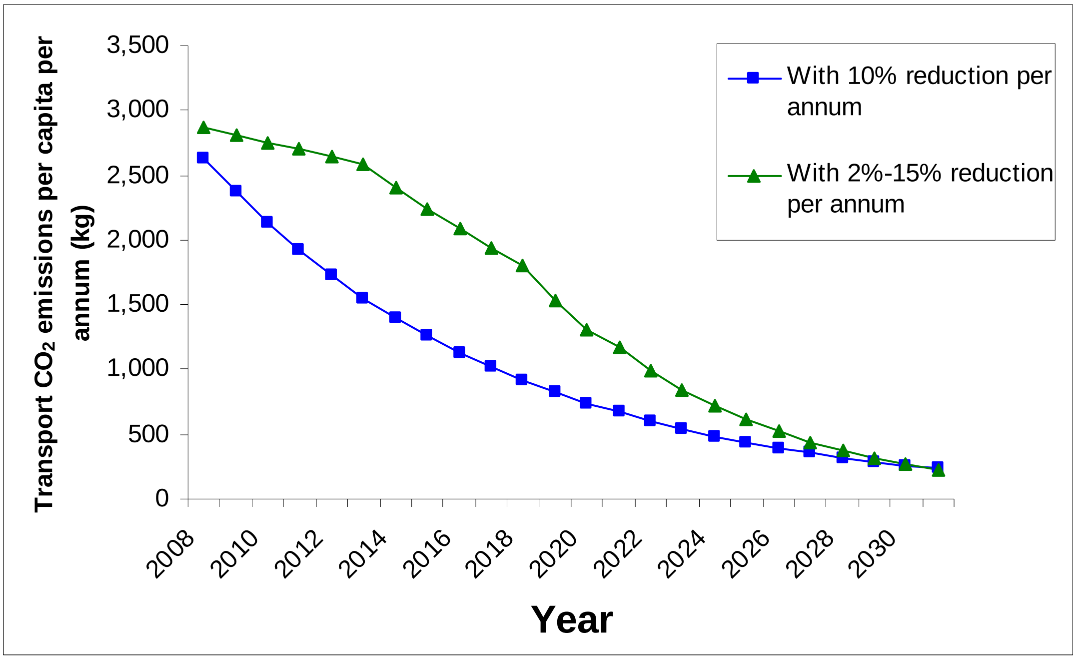
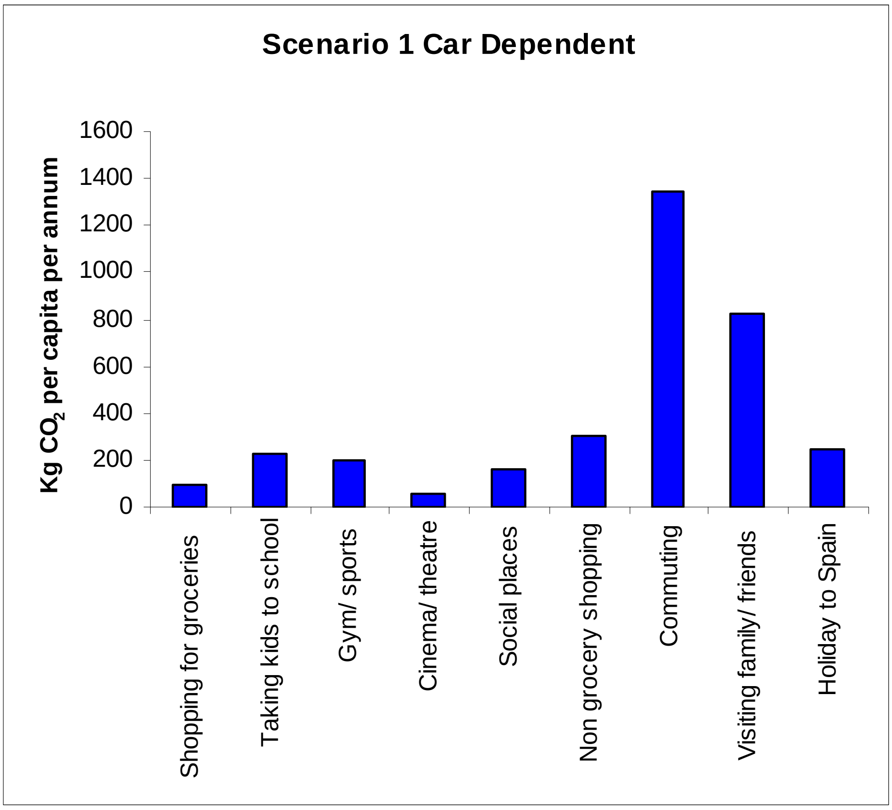


Figure 16: Towards a fair share for transport emissions by 2030

5.2. Scenario 1 – Car Dependent

From the transport research conducted by TfL it appears that Sutton is highly car dependent, with the vast majority of respondents claiming that the car was their primary transport mode for the majority of their trips. The first scenario therefore assumes high car use for each purpose. A holiday to Spain by plane is also included. The related carbon dioxide impacts associated with each purpose are highlighted below.



In total **21,436** kilometres were travelled in Scenario 1. The following table compares the total impacts to the UK current average and global fair share targets.

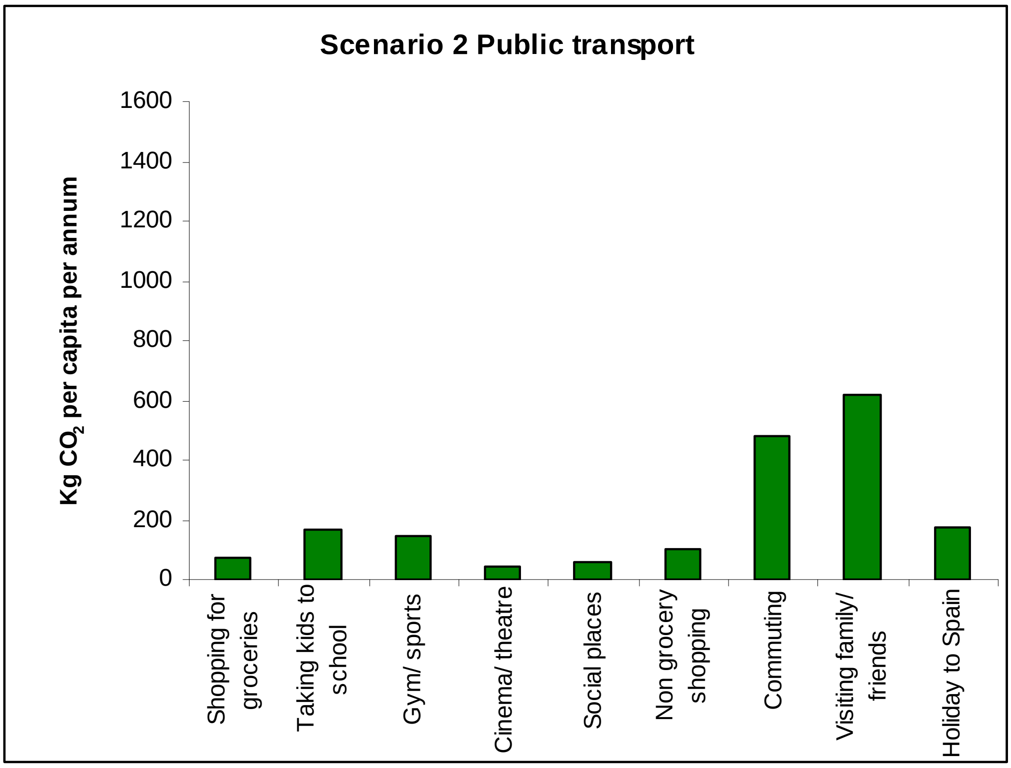
	Transport CO_2 kg per capita
Scenario 1 – Car dependent	**3455**
UK current average	2523
2030 target	240

As can be seen CO_2 emissions are over 14 times higher than required for a 90% cut in the UK's emissions

Clearly a significant change in transport modes and demand are needed. The following scenarios will assess ways to reduce this impact, including public transport, biofuels and demand reduction.

5.3. Scenario 2 – Public Transport

In the second scenario all journeys were transferred to public transport; 62% of journeys were transferred to train and 38% were transferred to bus. Instead of flying, the trip to Spain is done by train. As can be seen in the graph below, this helps to reduce CO_2 impact quite significantly.



In total **21,436** kilometres were travelled in Scenario 2. The following table compares the total impacts to the UK current average and global fair share targets.

	Transport CO_2 kg per capita
Scenario 2 – Public transport	**1840**
Scenario 1 – Car dependent	3455
UK current average	2523
2030 target	240

Transferring the all journeys from private car to public transport results in a CO_2 reduction of 53% yet CO_2 emissions are still over 7 times more than the 90% cut required in the UK.

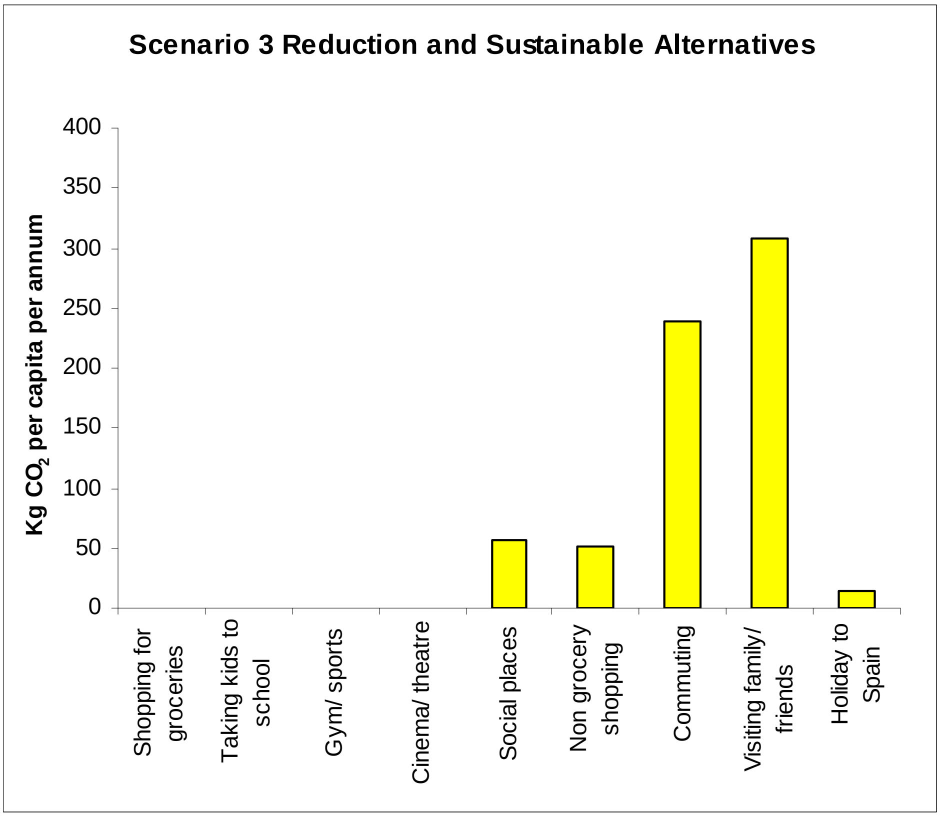
A similar study by Paul Mobbs found that a 60% shift of the UK's total personal transport demand from private vehicles to public transport (30% train, 30% bus) would result in a net energy saving of 17% per year of the energy currently used in the road transport sector and an energy saving of nearly 13% for transport as a whole.[91] He concludes that 'the fact that such a major shift in the way transport operates would produce such as a small saving in energy use illustrates one of the key issues… we travel too far by mechanised transport'. In order to work towards a sustainable transport pattern it is therefore necessary to reduce transport demand and switch to sustainable alternatives where possible, such as walking and cycling. The next scenario examines this impact in greater detail.

Scenario 3 – Reduction and Sustainable Alternatives

In this scenario overall transport demand is reduced by 46%. This is achieved through all groceries being ordered on line and delivered directly (whilst this will still have some impact, it can potentially significantly reduce emissions, for example, of the 20 people who are delivered to who would normally drive to the supermarket) and half of all non-grocery shopping trips are replaced through on line ordering and increased use of local facilities;

commuting is halved through increased home working or relocation nearer to work; the distance travelled to visit friends is also halved, potentially through socialising more locally; a holiday is taken in Cornwall (by train) instead of Spain, resulting in an 88% reduction in transport demand. 23% of the remaining journeys are done by walking or cycling and 72% are done by public transport.

The graph below illustrates the combination of travel reduction and increased use of sustainable alternatives such as walking and cycling leads to a significant decrease in CO_2 emissions.



In total **12055** kilometres were travelled in Scenario 3. The following table compares the total impacts to the UK current average and global fair share targets.

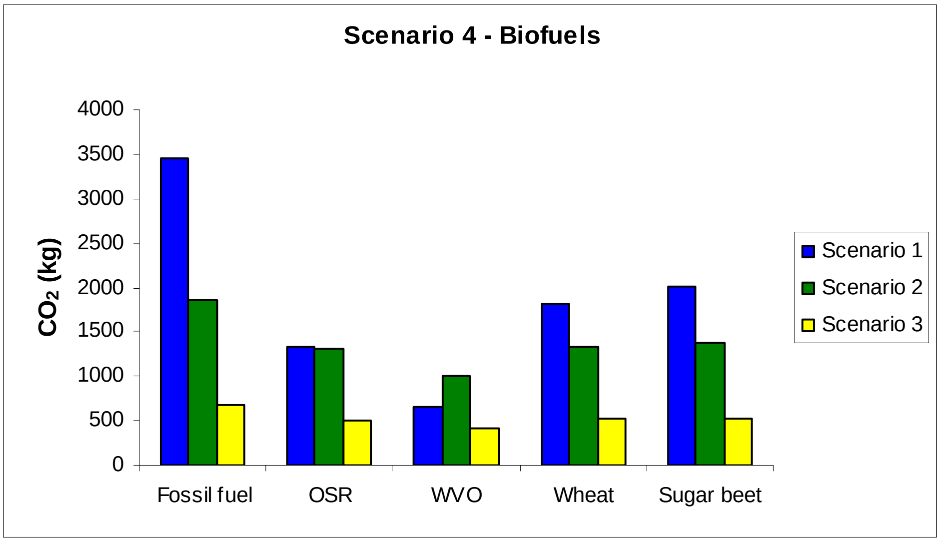
	Transport CO_2 kg per capita
Scenario 3 – Reduction and Sustainable Alternatives	**687**
Scenario 2 – Public transport	1840
Scenario 1 – Car dependent	3455
UK current average	2523
2030 target	240

As can be seen although this scenario results in a significant decrease in emissions and footprint, CO_2 emissions are almost 3 times more than the 90% cut required in the UK.

5.4. Scenario 4 - Biofuels

Whilst data on the ecological footprint of biofuels is not currently available and more research is needed in this area, some data on potential CO_2 emissions is available.

In the following graph all vehicle use has been replaced with biofuels. As can be seen, waste vegetable oil seems to give the greatest saving. However, it is worth noting that there is only a limited amount of waste vegetable oil in the UK. With other biofuels such as oil seed rape there is also only a limited amount of agricultural land available in the UK for their production. Therefore although UK grown biofuels can help to reduce emissions, transferring all current journey patterns to biofuels is not possible or sustainable as a large amount would have to be imported, potentially resulting in increased deforestation in countries such as Indonesia and Brazil. One potential solution could be to use electric vehicles powered by renewables. The embodied energy of the vehicles, batteries and required infrastructure would need to be included in the analysis of this option.



Key: OSR = Oil Seed Rape, WVO = Waste Vegetable Oil, Wheat and Sugar Beet are used for ethanol production.

5.5. Scenario 5 – One Planet Transport

Reaching the CO_2 reduction targets needed is very challenging. In the following scenarios the total transport CO_2 targets required for a 90% UK cut is used and broken down by mode to illustrate the **maximum travel allowance for any one transport mode**, assuming no other motorised mode of transport is used, to ensure the target emissions level is not exceeded.

2030 target (CO_2 kg)	Travel allowance						
	Car - km pa	Car - km per day	Train - km pa	Train - km per day	Local Bus - km pa	Km - km per day	Plane - km pa
240	1398	3.8	4004	11.0	1875	5.1	1328

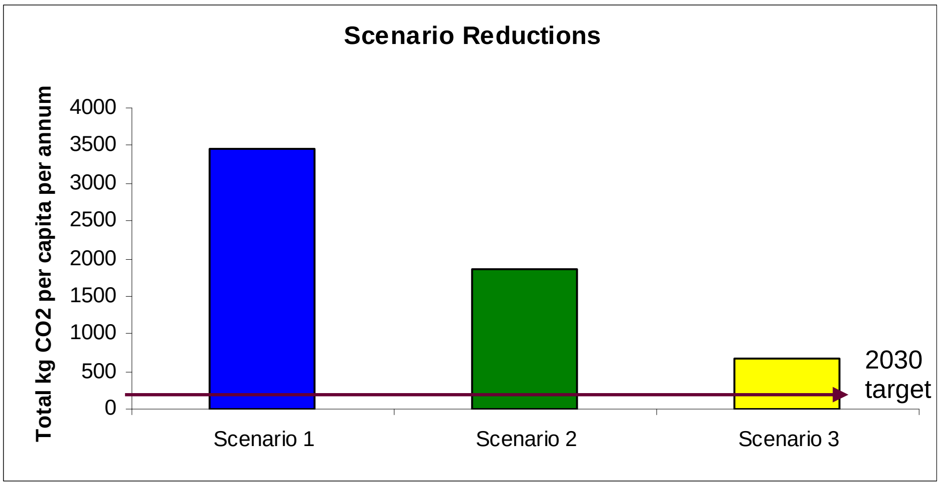
This has shown for example that if we are to meet these targets then we can only drive 932 kms a year (or 2.6 kms a day), without using any other energised transport modes. Even if all car journeys were switched to the rail which has lower CO_2 emissions per km than the car, this would permit a maximum distance of 2669kms to be travelled per year, equivalent to 7.3kms per day to meet the UK's 90% reduction target assuming a population of 9 billion.

While some efficiency may be achieved through technological development it is unlikely that the distances will increase significantly. It is also worth noting that in other areas of our ecological impact, such as food, it may not be possible to make sufficient cuts to reach the carbon and ecological footprint targets needed, therefore additional savings will need to be made in other sectors such as transport.

This scenario has illustrated that if we are to meet the targets needed we will need to radically shift our transport patterns away from fossil-fuel based transport modes towards more localised, sustainable patterns such as walking and cycling.

5.6. Scenario Conclusions

It is clear from the scenarios outlined above that although transferring current transport patterns from predominantly car orientated to public transport reduces CO_2 to some extent, in order to create a truly sustainable One Planet Living community there will need to be demand reduction as well as a switch to sustainable transport modes such as walking and cycling.



Whilst the use of biofuels could help to reduce the impact of powered transport it is important to note that there is only a limited sustainable supply currently available and production of some biofuels may compete with food and biomass (for energy generation) production.

6 General Conclusions

From the conclusions above it is clear there is no easy answer to providing sustainable transport options. The first priority for any sustainable community must be transport reduction, through the provision of local facilities, home working, co-ordinated home deliveries and promotion of local leisure and holiday activities. As Paul Mobbs concludes, efficiency savings alone are not going to significantly reduce energy use in the transport sector. Therefore the longer term aim has to be a real-terms reduction in the energy used / distance travelled by powered transport. This can only be done through a greater localisation of the economy, eliminating the need for people and goods to regularly move long distances.

However, it is clear that even in a localised economy people will still want to travel. The first priority here should be to promote sustainable alternatives such as walking and cycling, ensuring that there are safe routes and adequate facilities.

For those journeys which are too far for cycling or walking, public transport should be promoted and public transport providers should be encouraged to use alternative fuels and technologies such as biogas and electric vehicles powered by renewable energy (see case studies in following section). For journeys that are not possible by public transport, car clubs using electric vehicles charged from renewable sources could be one potential solution. However, the battery life and time needed to recharge the vehicles is an important element to consider.

Alternative fuels may also have a role to play, providing that they are sustainably produced and sourced. As technologies such as biogas develop, the amount of alternative fuels available will increase. However, this needs to be weighed up against other uses for example, agricultural land for food or biogas for heating and powering homes and further research is needed in this area.

It is clear that if we are to reach a sustainable footprint and the required reduction in carbon dioxide, flying should be avoided if at all possible. This can partly be done through the promotion of local leisure facilities and communication channels such as Skype / webcam and teleconferencing. If international travel is unavoidable, more sustainable alternatives such as coaches, trains and ferries should be promoted. As a last resort all flights should be offset.

It is worth noting that in some areas, such as food, the 66% footprint reduction needed to bring the UK to a sustainable level may not be achievable. Whilst food is vital to human survival, personal transport is not and additional savings could potentially be made in the transport related footprint. This is however, dependent on whether people are prepared to reduce their transport patterns.

Further research is also needed; there is currently a lack of robust data on the impact of transport, which partly explains the huge difference in CO_2 emission calculations used by the offsetting companies. Additional research is also needed in alternative fuels, such as pure plant oil as robust emission data is not currently available. It is also worth noting that the amount of emissions or footprint per passenger kilometre is also directly dependent on the number of people travelling / occupancy rates (which explains high passenger CO_2 emissions for taxis and the Isle of Wight ferry), for example, if a car transports two people rather than one then the emissions per person are halved, even if the passenger would otherwise have travelled by train, or not travelled at all! It is therefore also necessary to look at total transport energy demand for the UK as well as emissions per passenger.

Another possible area for research in the context of Z squared is the impacts of freight transport. With commercial buildings and services onsite, it is critical that the associated transport is dealt with and that provisions are made in this sector to minimise the use of road vehicles. It is also highly probable that people will be travelling to Z squared to work and consequently there must be a strong communication strategy to ensure that both residents and non residents travelling to and from the Z squared site all look to minimise the impacts of their journey.

7 Case Studies

Throughout Europe and elsewhere sustainable transport options are being developed and successfully delivered, some of which are outlined below.

7.1. Demand Reduction

Tele working in California
A detailed travel diary study of 40 participants in the State of California Telecommuting Pilot Project found that on average, telecommuters made 27 per cent fewer trips in total on days when they worked at home, made up of a reduction in car trips to work and a slight increase in car trips for other purposes.

UK
SocialData and Sustrans used individualised marketing to encourage sustainable transport patterns in Frome, Somerset and Gloucester. These resulted in net reductions in car trips of six per cent (Frome) and nine per cent (Gloucester). In Gloucester, total car mileage for the target population fell by nine per cent. About half the car trips were replaced by a walk, a quarter by cycling, and a quarter by public transport (Sustrans 2002b)

7.2. Sustainable Alternatives

Cycle Hire in Lyon

In Lyon the city is now littered with cycles for hire, by buying a card, similar to an oyster card you can hire a bike from anywhere in the city and return to any other registered location. With the first 30 minutes of a journey being free you could in theory never pay for cycling and never have to have the hassle of owning a bike. There are also different types of cards for 'heavy' or 'light' users.[92]

Cycling in Denmark
From 1999 to 2002, the city of Odense (population: 150000) was the official National Cycle City of Denmark. The project developed 50 pro-cycling initiatives, which included physical improvements of bicycle infrastructure, changes in regulations and awareness campaigns. During the project period, the citizens of Odense made 35 million new cycle journeys (about 25000 per day); half of which were previously made by car. The project shows that cycling policy can provide a rather cost-effective way to reducing car traffic in cities.[93]

Car clubs
Several studies have evaluated "before" and "after" levels of car use amongst people who join car clubs. Briefly, these studies demonstrate that car-sharers who give up their car on joining a car club are able to reduce their car mileage by 60 – 70 per cent. Car club members who do *not* give up a car (either because they never had one or because they are treating car club membership like a second household car) seem not to significantly alter their travel patterns.

7.3. Public Transport

Bike n Ride, Denver
Denver's bike-n-Ride program combines bicycles with public transport. All buses are equipped with bike racks on the front of each bus. The easy-to-use bike racks can hold two bikes and are available on a first-come, first-served basis. On Regional buses, bikes can be put on the bike racks or the luggage hold. Bikes can be loaded at all bus stops except those marked "non-bicycle stop." Bikes are also allowed on light rail. A free permit is required to ensure there is sufficient capacity.[94]

Biofuels for trains, France
SNCF operates on 15,000 km of non-electrified track. Improving the environmental performance of diesel traction by using biofuels is a key goal. Biofuels will supply 10% of the power for locomotives with recent engines as of 2007. In the OZONE project, SNCF Research is looking further ahead with the aim of developing “zero oil” technologies.[95]

Biogas buses and methane trains in Sweden
In Sweden many buses run on biogas and methane fuelled trains are also being trialled. In Linkoping, the 65-strong bus fleet is powered by biogas. Indeed the city boasts that it was the first in the world to try running buses on methane. Taxis, rubbish trucks and a number of private cars also fill up at the biogas pump. A high-grade biofuel mix is also available at the pumping station and Saab has started selling a biopowered version of their 95 model. The trains, introduced in 2005 Sweden are powered by methane produced by the waste from slaughter houses.[96]

7.4. Alternative Fuels

Waste Oil in London
SELTRANS project in South London collects waste cooking oil from catering establishments in Bromley and turn it into biodiesel for use in council fleets. Biodiesel Initiative for Sustainable Transport from Recycled Oil (BISTRO) offers a free collection service for restaurants, canteens, fast-food outlets and takeaways in the area. Over 100 businesses in Bromley have already signed up to the trial. The project not only helps to reduce greenhouse gas emissions but also helps to prevent the dumping of used oil down drains which accounts for more than half of the 100,000 blockages Thames Water clears from its sewers every day.[97]

Blooming Futures, Pure Plant Oil Conversions in Brighton

Blooming Futures is a small independent organization based near Brighton, specializing in converting diesel vehicles to use pure plant oil. They are also working with local farmers to source locally grown vegetable oil for use in converted vehicles. They claim that pure plant oil is ‘the lowest impact road fuel available today’. The energy footprint of PPO according to a respected agricultural report (the Levington report) shows that PPO actually has an energy foot print 25 times smaller than biodiesel – meaning it is far better for the environment to use the unprocessed oil rather than biodiesel and a footprint well over 50 times smaller than bio-ethanol.[98]

Alternative Fuels in Sweden
Over the last thirty years Sweden has been supporting the development of renewable transport fuels. Initially the impetus for this was energy security and the environment, however, more recently, as concern grows over the peak oil crisis, this has also been a major driver in development. Today, around 15 percent of all new cars sold are environmentally friendly cars that run on ethanol or biogas. Carbon dioxide neutral fuels are exempt from both carbon dioxide tax and energy tax. Environmental cars are also exempt from congestion charges and have access to free parking in some municipalities. Sweden is also working actively in the EU to permit a higher blend of ethanol in petrol. In addition, a legal framework is being developed to make it mandatory to have a least one fuel pump for renewable transport fuel at every gasoline and diesel oil filling station.[99]

Organic Power, UK biogas cars
Organic Power Ltd is a British company formed in 1997 to develop and license the patented Maltin® System. The multi-tank process treats a wide range of organic materials, either solid or liquid, particularly industrial wastes, energy crops, food processing residues and agricultural slurries. Adopting a completely natural process and without additional chemicals, the organic materials are degraded by naturally occurring aerobic and anaerobic bacteria. The process eliminates the pollution normally associated with organic residues and produces high quality methane gas, food grade carbon dioxide and clean fertilizers with no waste products. Naturally occurring bacteria are used to digest a wide range of organic materials which include most organic wastes and energy crops.[100]

8 Appendix A - Emissions Calculator

Mode of Transport	CO_2/km (kg)	EF (m^2)/km	Distance travelled (km)
Air International	0.089850	0.293000	
Air domestic	0.180663	0.472000	
Walking	0.000000	0.000000	
Bicycle	0.000060	0.000300	
Car petrol	0.171665	0.455000	
Car diesel	0.120424	0.322000	
Motorcycle/moped	0.164968	0.436000	
Van / lorry petrol	0.171617	0.455000	
Van / lorry diesel	0.120642	0.322000	
Local bus	0.128022	0.334000	
Non-local bus	0.065245	0.170000	
Surface Rail	0.059940	0.174000	
Taxi/minicab	0.302956	0.808000	
Ferry*	0.107000	N/A	
Cruise liner**	0.690000	N/A	
Total			

Source: Taking Stock
*Ferry = http://www.co2balance.com/
**Cruiseliner = Climate Care, http://travel.guardian.co.uk/article/2006/dec/20/cruises.green

Internal link: Emissions calculator final.xls

This information is taken from a data set that was put together by Taking Stock.[5]

Except for air and rail transport, emission data were derived from the UK National Atmospheric Emissions Inventory (NAEI) which contains the UK Emission Factors Database (EFD)[6]. Fuel consumption of airplanes was derived from CO_2 emission data provided by DEFRA[7]. For passenger railway transport total energy carrier consumption was calculated on a passenger-kilometre basis using both direct fuel consumption and fuel consumption via electricity[8]. The share of consumption due to passenger transport, in contrast to freight transport, was derived from the proportion of CO_2 emissions allocated to each category according to emission factors given by DEFRA. The 'hidden flow' factor for petroleum is 1.016 and for hard coal 4.87, i.e. for each tonne of petroleum 16 kg and for each tonne of hard coal 3.87 tonnes of additional material have to be moved[9].

5 Taking Stock – Managing our Impact Chapter 3: Consumption of Goods and Services in the South East, 2003

6 http://www.naei.org.uk/emissions/index.php

7 http://www.defra.gov.uk/environment/envrp/gas/10.htm

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