ENERGY, CARBON DIOXIDE

AND CONSUMER CHOICE

Discussion paper

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1. EXECUTIVE SUMMARY

1.1.1 Analysis of need

If the threat of climate change because of anthropogenic greenhouse gas emission is accepted, then important economic, technological and social adaptations will be needed to avert the threat. Numerous studies have looked at the technological and economic strategies for the control of one of the principal greenhouse gases, carbon dioxide: few look at how control might be achieved through social adaptation in terms of changes in behaviour or lifestyle. This study is an attempt to look at the potential reduction in energy use and carbon emission due to relatively minor changes in lifestyle.

1.1.2 The global carbon problem

The scientific consensus is that to limit the rate and final increase in global temperature, annual carbon dioxide emission will have to be reduced by 60% to 80% as compared to 1990 by around the end of the next century. During this time, the world population may more than double. If it is assumed that equity in terms of per capita carbon emissions will eventually be achieved, then the per capita carbon emissions of most rich countries have to fall by over 90% from current levels.

1.1.3 The limits of technical measures

Conservation, energy efficiency and renewable energy sources are vital elements in strategies which aim to reduce carbon dioxide emissions. However, these technical measures run into increasing marginal economic and environmental cost with increasing levels of implementation. In practical terms, this makes it difficult to reach reductions of over 90% with these means, at least with known technologies. It is therefore necessary to appraise how changes in people's behaviour and lifestyle might contribute to carbon emission control.

1.1.4 Lifestyle change

Certain aspects of lifestyle are predicated on the consumption of goods and services, the provision of which has a physical impact on the environment. The enjoyment of warm buildings and private transport are examples of such. An analysis of the UK shows that minor lifestyle changes including wearing better clothes and buying smaller slower cars could reduce carbon emission by around 25% quite rapidly. A proportional reduction of this order may be made even if quite high levels of energy conservation are assumed. When such lifestyle changes are applied to other rich countries, similar emission reductions may be made, and lifestyle takes on global significance in terms of an element in carbon emission control strategies. A separate study is needed to detail how people's lifestyle and general patterns of consumption might be influenced. This study does however identify some of the approaches which might be taken.

2. INTRODUCTION

The provision and use of energy for services has a large impact on the environment in most populated parts of the world. This is a feature of rich industrialised countries and of poorer industrialising countries. The scope of the environmental impacts ranges greatly in space and time and effect; from the relatively localised and short-term impacts due to the emission of noise from cars, to the global and long-term impact of projected climate change induced by the anthropogenic introduction of trace gases into the atmosphere.

The focus of this study is on the limitation of climate change by the control of carbon dioxide emission from fossil fuel combustion. Carbon dioxide emission from this source is thought likely to be responsible for about 50% of global warming: the other 50% arises from carbon dioxide emissions due to deforestation, and from a mix of other trace gases (IPCC, 1990). Although the focus here is on carbon dioxide abatement, most of the measures studied in this report also reduce other pollutants such as acid chemicals.

There are many technical improvements and substitutions which can lessen the impacts of the multifarious uses of energy. Energy conservation through technical means must be a central policy measure: it can bring great cost savings, and reduces the 'upstream' environmental impacts of energy systems - carbon and acid emissions, radioactive waste, the ecological impact of hydroelectric schemes and so forth. There are however limits to the energy conservation.

Low impact energy sources, such as thermal solar heating, can also play a part in reducing emissions. Unfortunately, globally, there is no mix of energy supply options available now, or in the near future, which can provide <u>all</u> the energy needed economically without incurring significant environmental impacts. It may be that the production of cheap and efficient photovoltaic solar collectors <u>and</u> electricity storage or transmission will change this view.

Thus, these technical measures will not alone be sufficient for the development of environmentally benign and equitable futures. All human activities make the environment different from what it would otherwise be. Ultimately, continual increases in the demand for services and commodities from a world population which is projected to double over the next century can not be sustained without significant increases in environmental impact. Lifestyles incorporating activities such as unlimited private motoring and the high and increasing consumption of commodities will overwhelm technical improvements.

The structure of the report is as follows. The remainder of this chapter lays out the motivation and objectives of the study. After this chapter 3 gives an overview of global carbon emission and possible target reductions, and the consequences of this for the per capita carbon emission for different country groupings. Chapter 4 summarises the human needs for essential and other services, and how the provision of those requiring energy impacts generally on the environment. In chapter 5 the scope and limits of various energy strategy elements is briefly described, and an argument is made for including lifestyle change as an element of strategy. Following this, chapter 6 assesses the possible impact of limited lifestyle change on UK carbon emission in quantitative terms. This analysis is applied in broad terms to a selection of other countries in chapter 7. Chapter 8 raises some issues relating to the implementation of policies incorporating lifestyle change. Conclusions and recommendations are given in Chapter 9.

2.1 Study motivation

The motivation for this study, as for many others, is to minimise climate change which could cause great changes to natural ecosystems, and to human populations. In brief:

Certain species of flora and fauna, and ecosystems, will not be able to adapt to a rapid change in climate, or to a particular final change in climate. There are great uncertainties as to the future level and pattern of climate change regionally, and the response of living systems to such change. However, the consensus is that climate change will occur, and that it will lead to overall species loss, or loss of biodiversity.

Climate change and alterations in natural ecosystems will also impact on agricultural systems. Alterations to the geographical pattern of production and to the mix of products is likely to occur. Food is produced from agrosystems more or less tuned to current environmental conditions in terms of weather (rainfall, soil moisture, temperature, wind speeds etc.) and natural pests. It seems probable that food production will significantly change, and possibly fall overall, at least in the medium term whilst agrosystems are adapted to new conditions as far as possible. Alterations in food supplies are likely to threaten some human populations with food shortage, at least in some parts of the world. In addition some human settlements will be subjected to flooding through sea level rise and increases in violent weather. The geographical range of some human diseases and pests will probably increase.

2.2 Study objectives

The principal aims of this study are:

- to widen the range of energy policy options which might contribute to the control of climate change through reducing carbon dioxide emission by the inclusion of what may be called lifestyle change;
- To quantify the effects of certain lifestyle changes on UK carbon emissions in detail, and for other countries more generally;
- To provide an indication of how policies might influence lifestyle change.

3. GLOBAL CARBON, POPULATION AND EQUITY

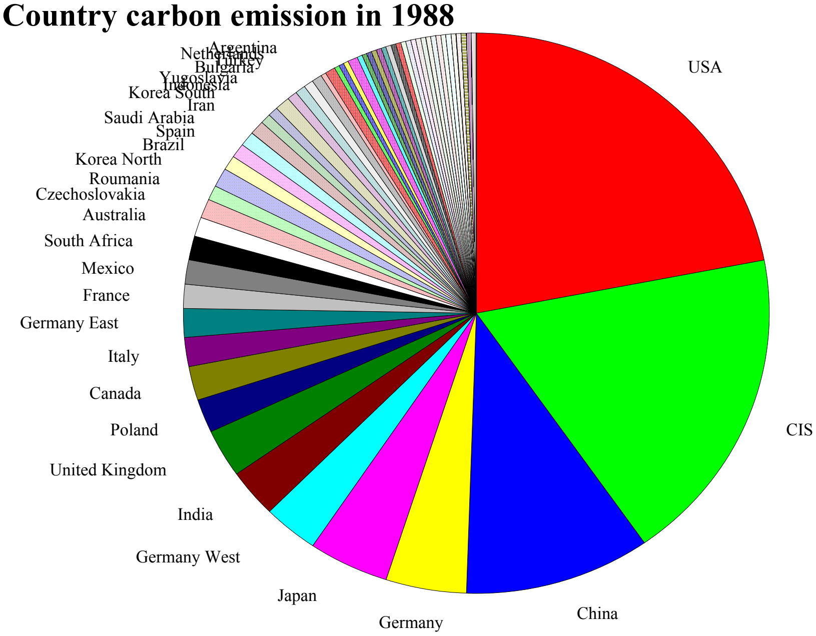
This chapter illustrates the present pattern of carbon emission and then proposes assumptions concerning ethical principles, population projections and the level of carbon emission control which might be desirable. The consequences of these assumptions are explored. Although this analysis refers solely to emissions of carbon from the combustion of fossil fuels, the ethical principles used would apply to certain other trace gases responsible for environmental damage and climate change.

The following analysis incorporates much inter country comparison. The terms Industrialised Country (IC) and Non-Industrialised Country (NIC) are used as labels for rich industrialised countries and poor non-industrialised countries.

3.1 The picture now

Carbon emission from fossil fuel combustion and flaring has been calculated by the Oak Ridge National Laboratory from UN fuel consumption statistics. The most recent data pertain to 1988. Figure 3-1 shows a breakdown of carbon emission by country. It is apparent that three countries or agglomerates - the USA, the CIS and China -account for over 50% of global carbon emissions. The twelve highest emitting countries together emit more than 75% of global carbon. The USA, with 5% of the world's population, emits 26% of the carbon; while China with 22% of the population emits 9%.

Figure 3-1: Country carbon emission in 1988



The United Nations have made estimates of population for 1990, and have projected these up to 2025. Figure 3-2 shows the population and carbon emissions of the major sub-continental groupings ordered in decreasing carbon emissions per capita. The area of each rectangle is proportional to the total carbon emission. This graph shows how the more populous regions such as East and South Asia emit very much less carbon per capita than North America, the CIS and Europe. In general, however the regions with lowest per capita emissions have the fastest growing populations.

Figure 3-2: Carbon emission (1988) and population (1990)

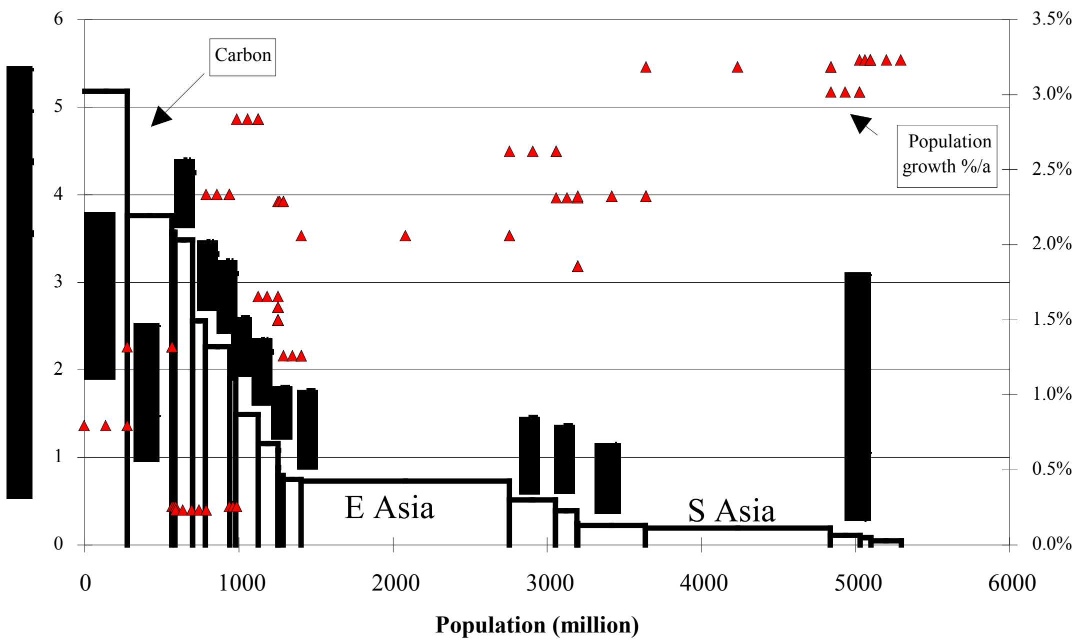
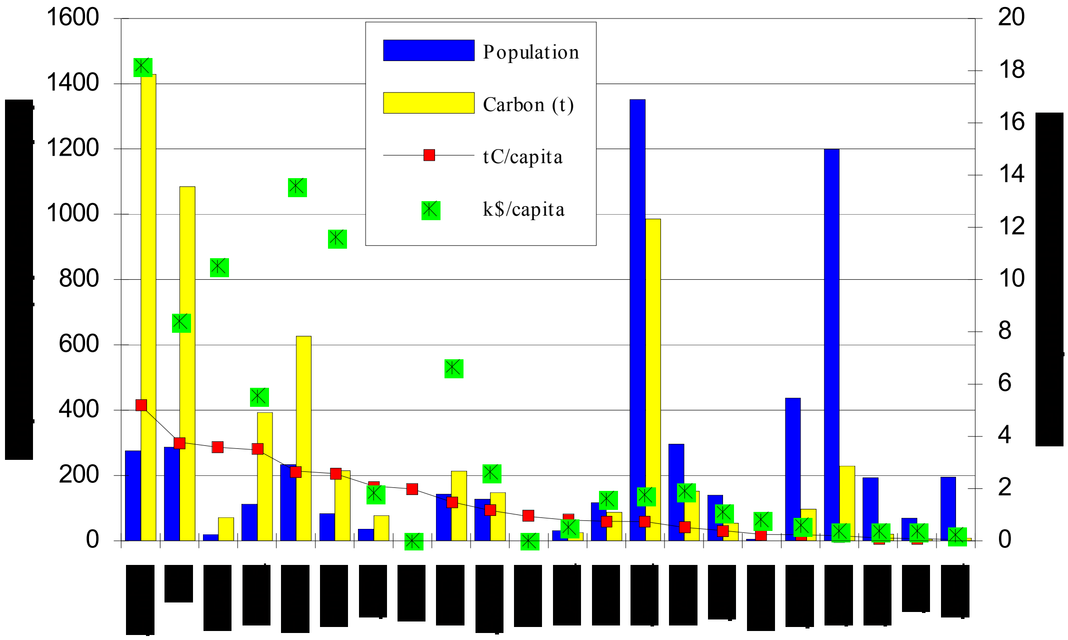


Figure 3-3 is an alternative representation of the information portrayed in the previous Figure except that GNP per capita for 1987 (from WRI, 1990) is shown rather than population growth rates. There are drawbacks to using GNP as an indicator of wealth: perhaps the most serious is that it does not account for differences in purchasing power in different countries. Nonetheless, it serves as crude indicator of wealth in terms of services and commodities purchased. The Figure shows that per capita wealth is roughly correlated with per capita carbon emission. However, the correlation is not very high. This is because of differences in the energy efficiency, fuel mix and output mix of the countries' economies; and because of geographical and climatic variations.

The codes for the geographical area are by continent and part of continent. The continental groupings are Am<u>erica</u>, Oc<u>eania</u>, Eu<u>rope</u>, Af<u>rica</u>, As<u>ia</u> and Latin America (LA).

Figure 3-3: Carbon emission (1988), population (1990) and GNP (1987)



3.2 Projecting carbon emissions

If current trends are continued, then carbon emissions are likely to increase from ICs and NICs because of economic and population growth. The increase in carbon emission from NICs is likely to be large for two basic reasons. First, their populations have low average ages and hence population growth is likely to be large. Second, they consume little energy per capita because they are poor, and as and if wealth increases so will energy use and carbon emission.

In this analysis, there is not attempt to make a projection of future global carbon emissions based on detailed assumptions and modelling. Instead, the consequences of making three types of assumption are explored. The first is an ethical postulate. The second relates to the population projections. The third concerns a scientific assessment of what should be the future limits to carbon emission if climate change is to be limited. These assumptions are briefly described below.

3.2.1 An ethic

An ethical basis for the global control of carbon emission is required. This is not merely a matter of philosophy. If a well-defined ethic is not agreed to, then it is probable that the political negotiations addressing the issue of carbon control will founder.

One may suggest an ethic, and a measure of it, as follows:

Each human being has an equal right to globally common goods. The use of the environment as a sink for pollutants should therefore be allocated equitably. A simple measure of this is the amount of a given trace gas emitted per capita by a certain country.

A number of difficult questions can be asked of this ethic, including the following:

- Should per capita emission limits be set individually for each gas, or should the contributions of each gas towards, say, global warming or ozone depletion be aggregated?
- Should limits only apply to future emissions? If so developing countries would be disadvantaged because the current trace gas concentrations in the atmosphere are largely due to emissions from developed countries. Perhaps it would be fair to allow developing countries higher per capita allowances precisely because they are developing and parts of development involve heavy industry with its concomitant emissions.
- Should the emission per capita take account of the age structure of the population? For example, should it only apply to adults? If so, developed countries with a higher proportion of adults would be advantaged.
- Some countries have geographies and climates which reduce the potential demand for energy. For example; countries where populations are concentrated will have a low potential demand for internal transport; countries with a temperate climate will require less space heating than a cold country, and less air conditioning than a hot one. Even in the UK, a country with a temperate climate, space heating gives rise to some 15% of carbon emissions.
- Certain countries are well endowed with resources which facilitate trace gas emission limitation. Some countries have abundant non-fossil (non-carbon) energy resources in the form of hydropower, wind, biomass and so on; others have very little of these.
- How rapidly should per capita emissions converge on a common level? Plainly, there is inertia in all spheres (political, economic, social, technical) which limits the rate at which countries can reduce their emissions.

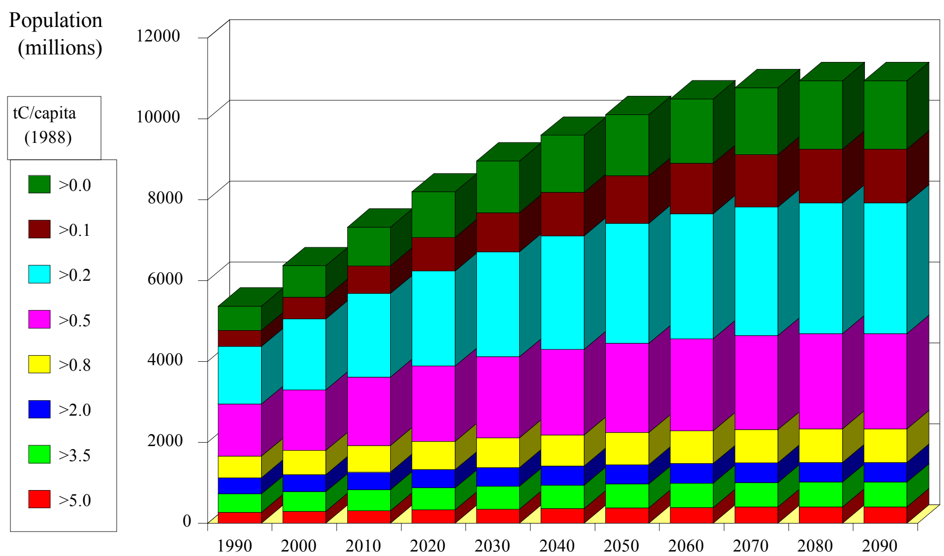
It may be that there is a transitional phase during which resources are transferred from high emitting countries to low emitting ones. A global limit to emissions would be agreed and this would be expressed as a per capita allowance. A market could then develop in which allowed emission quotas are traded for resources such as capital or technologies. Certain of these issues have been discussed previously by a number of authors (e.g. Krause et al, 1990; Grubb, 1989).

Ultimately, despite difficulties such as those outlined above, it is difficult to see a workable scheme which aims at other than a substantial convergence of countries on a common and agreed level of emissions per capita. This then, is taken as the ethical base.

3.2.2 Population

In this analysis, the rates of population growth between 1985 and 1990 have been taken and, by assuming these dwindle to zero by 2090, they have been projected into the future. The projections more or less accord with those made by the United Nations (1990) and the World Bank. More recent projections made by the UN suggest that the population is growing faster than previously expected, and that it will exceed 10 billion by 2050. The population has been aggregated according to per capita carbon emission ranges (tonnes of carbon per capita per year) for 1988: these ranges and the projection are shown in Figure 3-4. The projection shows clearly the greatest population growth occurring in the low emission countries.

Figure 3-4: Population projection, 1990 - 2090



3.2.3 Future carbon emission limits

A central problem is estimating the degree to which trace gas emission, and thence climatic change, should be controlled. First, the effects of a changing physical and climatic environment on ecosystems are not known with any precision. Secondly, there are great uncertainties in the response of global physical systems to different profiles of trace gas emissions.

The impact of climate change on biodiversity is extremely difficult to quantify for many reasons. Many species of flora and fauna have yet to be discovered, let alone described in biological terms. The interactions between species in ecosystems are understood well only for a few ecosystems. The response of individual organisms, of species and of ecosystems to environmental changes is largely unknown. It is difficult to enough to speculate on changes given some new environmental equilibrium; it is even more difficult to understand how biological systems will respond to a dynamically changing environment. How far and how fast will existing living systems adapt? It is therefore not yet possible to precisely quantify the biological effects of climatic change either during a period of rapid change, or once in an equilibrium state. Nonetheless, efforts have been made to estimate targets for the rate and ultimate change in average global temperatures which would allow many of the present systems to adapt... A consensus of views proposed in a number of reports (e.g. Rijsberman, Swart; 1990: Krause et al 1990) and by a number of bodies including the FRG Inquete-Kommission suggests a rate limit of 0.1 ^{o}C per decade; and absolute targets of 1 ^{o}C (lower risk) or 2 ^{o}C (high risk) increase over pre-industrial global mean temperatures.

How does the emission of trace gases have to be constrained in order to attain these targets? There is no simple answer, both because of the uncertainty of the effects of the gases, and because of the dynamics of climate change. The earth warms up slowly because of its thermal capacity. Consequently, even if trace gas concentrations were kept constant, the earth will continue to heat up to a new equilibrium temperature. Furthermore, CO_2 remains in the atmosphere for an average of 100-200 years on average, and so its concentration would fall very slowly even if emissions were to instantly cease. Even if emissions were kept at current levels from now on, the global temperature would rise at some 0.2 ^{o}C per decade for several decades. The profile of emissions year by year is important, as is the total emission over a period of (say) a century. Krause et al (1990) explore the issue of emission profiles and climate change. The long residence time of CO_2 means that, in terms of time scales less than 100 to 200 years, a rapid small reduction in emission is as effective in meeting targets for climate change as a slower but larger reduction. This observation is important because lifestyle change can, in principle, deliver significant emission reductions over short time periods as compared to technical change which is limited, inter alia, by stock turnover rates.

The IPCC scientific assessment of estimates that a reduction in carbon emissions of more than 60% is required to stabilise the concentration of carbon dioxide in the atmosphere at current levels (IPCC, 1990). To meet targets for climate change similar to those used above, Krause et al (1990) use a global emission target of 300 Gt for the period 1985-2100; because of the inertia in the socioeconomic and energy systems, the global emission scenario consistent with this limit show a rise in emission in the short term, followed by an eventual reduction in 2000 of total emission at 20% of 1985 levels - an 80% reduction. For the purposes of this analysis, the 300 Gt limit has been taken and it has been assumed that annual carbon emissions from fossil fuels will be reduced to 20% of 1990 levels by 2090.

3.2.4 Future carbon emissions

We may now combine our three assumptions to make some projections. It is assumed that by 2090:

- Per capita carbon emissions will have converged to global equity;
- The population will have grown as indicated above;
- Global fossil carbon emissions will be reduced to 20% of 1990 emissions.

Using these assumptions, we may employ simple arithmetic to make the projections. Assumptions about the rate at which high carbon emitting countries can reduce their per capita emissions have been made. In general, it has been assumed that it will take some years before a significant reduction can be achieved. These schematic curves have been used in order to illustrate the inertia of the political and economic systems involved. A discussion of the inertia to change is discussed elsewhere.

Figure 3-5 shows the evolution of carbon emissions from the countries within in each per capita emission band. It can be seen how the dominance of the high per capita emitting developed countries declines as equity is approached and populations grow. At the same time, the low emitting countries increase emissions proportionately, in line with their populations.

Figure 3-5: Global carbon emission profile, 1990 - 2090

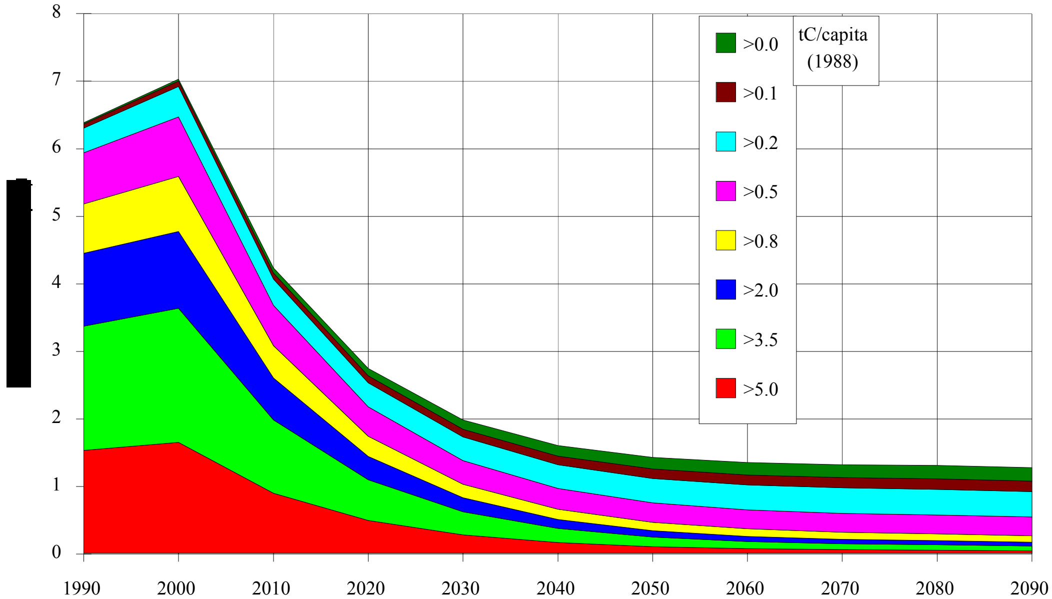


Figure 3-6 illustrates the interplay of global and per capita carbon emissions with population growth. The per capita emission bands are as previously set out. The complete convergence of per capita emissions by 2090 is illustrated. Given the assumptions made, per capita emissions have to converge on 0.12 tonnes of carbon per year in 2090. This represents an enormously difficult target for the high emitting industrialised countries. The per capita emissions of countries currently exceeding 2 tC have to be reduced at between 4% and 6.5% per year throughout the first half of the next century. Even then, as the graph illustrates, global emissions would dip under the Toronto ceiling about five years late. The integrated total global emission over the period is just over 300 GtC.

Figure 3-6: Carbon and population projection, 1990 - 2090

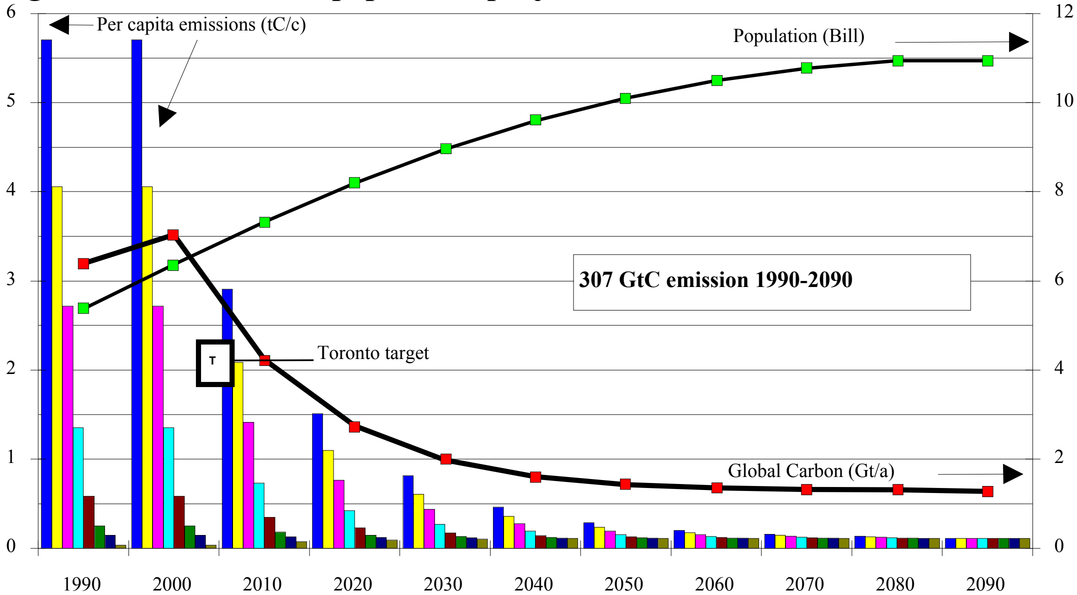


Table 3-1 quantifies the minimum reductions in per capita emission and lists the countries with populations greater than 20 million which lie within the per capita emission ranges. Of great significance is the immense reduction in per capita carbon emissions that the high emitters would have to make in order to attain equity. For example, the USA would have to reduce its current per capita emissions by over 98%.

Table 3-1 : Country reductions

1988 per capita emission	>5	>3.5	>2	>0.8	>0.5	>0.2	>0.1	>0
Reduction by 2090	> 98%	> 97%	> 94%	> 85%	> 77%	> 42%	> -17%	
	USA	Germany	Poland	Spain	Turkey	Egypt	Nigeria	Ethiopia
		Canada	Romania	Yugoslavia	Algeria	Morocco	Philippines	Kenya
		CIS	UK	Italy	China	Indonesia	Pakistan	Tanzania
			Germany	France		Thailand		Zaire
			South Africa	Korea North		India		Sudan
			Japan	Korea South		Brazil		Myanmar
				Iran		Colombia		Viet Nam
				Mexico		Peru		Bangladesh
				Argentina				

3.3 Discussion

It is assumed in the above analysis that a reduction to 20% of current emissions is achieved by 2090. Although this is a very substantial reduction by 2090, the assumed resistance to changes in trends coupled with the rapid population growth in the first few decades, has the consequence that global carbon emissions do not fall below current levels until after 2005 - more than 15 years hence. It may be that scientists come to the conclusion that this is too slow both because the world would be committed to climate change to great and too fast for enough species to adapt. Plainly, the faster and further climate and other aspects of the physical environment change, the greater the difficulties species will have in adapting. Conversely, it may be that scientific understanding of climate change and ecosystems will lead to the view that emission reduction does not have to be so rapid or great. At present, the probability of large relaxations of the proposed emissions targets looks low.

The population projections used will doubtless be changed as the years pass. However, it seems unlikely that they will be substantially lowered unless some important new factor comes into play - such as a pandemic, acute and massive food shortage, or new contraceptive methods. Indeed, as noted, the most recent UN projections are higher than previous ones.

Therefore, the likelihood is that if ICs do not radically reduce per capita emissions, and NICs follow similar development paths to the ICs, global carbon emissions will rise rapidly. For example, if the average global emission per capita were to reach 70% of current USA emissions, then with the projected population increases, global carbon emission would rise sevenfold. If emissions were assumed to be 20% of current US levels, global emission would double.

The conclusion must therefore be, given the assumptions made, that very large reductions in per capita carbon emissions must be made by the industrialised countries. Studies of ICs indicate that the use of improved energy efficiency and renewables alone would reduce carbon emissions by a large fraction, but one generally less than that implied by the analysis above as being necessary. However, these studies in the main assume continued trends in terms of lifestyle.

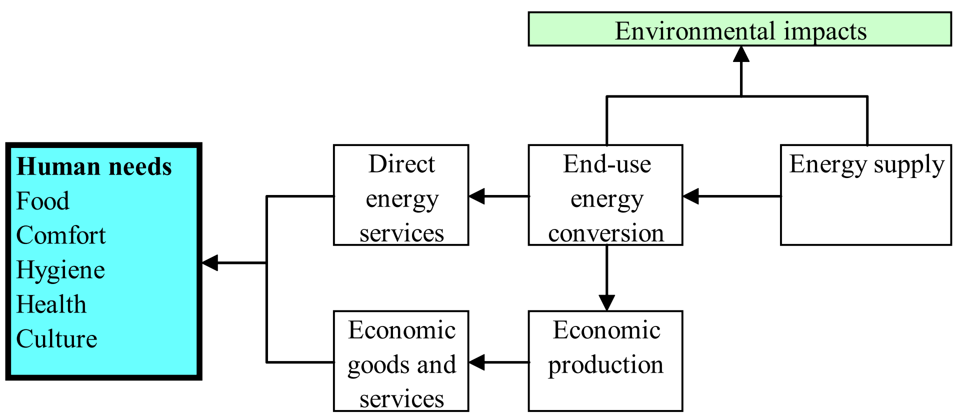
If global carbon emissions are to be controlled significantly, a two-pronged strategy will be required. First, ICs will have to implement quite radical energy strategies which, it is argued, will involve perceptible changes in behaviour and lifestyle. This is the area of detailed study of this report. Second, NICs will have to leapfrog certain of the stages that the ICs have passed through, and progress to highly energy efficient economies.

Especial effort is expended here on studying the potential for radical reductions in emissions from ICs rather than NICs. This is for a number of reasons: ICs have the resources and expertise to accomplish the requisite changes; ICs have more control over the world economy and its evolution; and ICs must take a lead if there is any hope of the NICs following a different path. ICs are largely responsible historically for the current excess atmospheric stock of carbon.

4. NEEDS, ENERGY SERVICES AND THE ENVIRONMENT

Many human needs are met with services dependent on the use of energy, and the provision of energy impacts on the environment. The satisfaction of human needs is the basic driving force. Figure 4-1 is a schema of the chain whereby energy in various forms is extracted from the environment and converted through a chain of technologies into energy services and goods which meet human needs. The extraction, conversion and distribution of energy gives rise to physical and chemical change to the environment which affect, generally adversely, humankind and ecosystems. This chapter gives an overview of the parts of this chain.

Figure 4-1: Energy service provision chain



4.1 Needs and energy services

What is energy for? Fuels of themselves are no use to man or beast. Lumps of coal, barrels of oil, pipes of gas and kWh of electricity provide us with nothing of utility. The energy content of fuels has to be transformed and applied in various technologies to provide what may be called energy (based) services. The question then is: what energy services do people require? Table 4-1 lays out some of the more obvious human needs which are met, at least in part, by the use of energy at the point where the service is provided. (The energy needs of the economy providing technologies, fuels and external services for private consumption are not discussed here). The form of energy required for meeting particular tasks depends on the nature of the task (e.g. heat cannot be used for lighting), and on the technology used to perform the task.

The basic types of needs and their associated tasks are determined by the basic physical and mental nature of human beings, and since this nature does not change except over evolutionary timescales, neither do the types of needs. But the levels of need do.

The levels of needs for energy services are influenced by the prevailing social, technological and economic context. For example, in the UK the generally accepted minimum standards of home heating and hygiene have increased enormously over the past century with increasing wealth and technological innovation. The development of relatively efficient central heating systems has occurred in parallel with the wherewithal to purchase these systems and fuels to run then. The needs of a society as a whole will be influenced by demographic change in terms of factors including total population, age structure and household size.

Table 4-1 : Human needs and energy services

NEEDS	Task	Energy form	Technologies
Food	storage	heat (cold)	refrigerator
	cooking	heat	cooker
Comfort	shelter	materials	buildings
	thermal	heat (hot/cold)	heater/air conditioner
	lighting	light	light bulb (/daylight)
Hygiene	personal	heat	shower & boiler
	clothes	heat	washing machine
	dishes	heat	dishwasher/hands!
	house	power	hoover
Health	miscellaneous	miscellaneous	medical services
Culture	travel	power	vehicles
	telecommunications	electricity	telephone, internet
	electronic media	electricity	TV, hi-hi etc.
	miscellaneous		

The minimum amounts of energy required to meet many of the needs outlined above are often hard to determine or even define, but generally they are very small. For example, the actual energy required to separate dirt from clothing or the human body is tiny in comparison with the energy actually used in washing machines or showers. Certain technological innovations more closely approach the minimum energy needed for tasks.

Cooking food brings about small physical and chemical changes the energy requirements of which are a tiny fraction of the energy in the fuels used in cookers: this fraction is less than 1%.   Much cooking consists of heating up food to boiling point, or some way beyond, and keeping it there until cooked. Conventionally much of this is done by putting food in boiling water in an uninsulated pan. Microwave cookers rapidly and directly heat food without the need to heat up water and saucepan, and they cook much faster reducing heat losses whilst at boiling point: they are therefore relatively energy efficient as compared to conventional cookers although they still use greatly more than the minimum. The point being made is that detailed analysis of needs and end use technologies and techniques can lead to large savings at this stage in the system, and that these savings will be multiplied down through the energy chain. Other needs such as thermal comfort do not necessarily require any non-human energy at all. Thermal comfort is achieved when the body is enveloped by a layer of air at an appropriate temperature. This can be accomplished with clothing and heat from the human body.

It is only possible to speculate what levels of need might be in the future. Potentially there is virtually no limit to the levels of certain of the needs of human beings. For example, the possible growth in long distance holidays or electronic entertainment is limited only by the time available for these things. Typically normative forecasts of future levels of need are made by assuming that people who become rich in the future will want what those presently rich want now, and that those presently rich will want more of the same, and start to consume novel goods or services. For example, some households now have <u>exterior</u> air conditioning in California. Such potential growth in consumption may be counterbalanced to some degree by the fact that some needs are more or less fully met in richer countries and the scope for growth there is probably small. The provision of lighting and refrigerated food storage are examples of this. (Even here, one can find examples of people lighting their gardens and the outside of their houses, or using a second refrigerator for cooling beer.)

The later analysis of lifestyle change and carbon emission deals only with relatively small lifestyle and need changes, and in this respect, it is not radical.   Nonetheless, this can lead to a deeper questioning of the nature of needs and the consumption of goods and services resulting from those needs. It can also bring into doubt the degree to which increased consumption is driven by increased needs. Occasionally these fundamental questions are addressed by those whose area of work is based on the meeting of human needs through production - economists. There is no room for a comprehensive look at such analysis here, but two quotes from one source, <u>The Affluent Society</u> by JK Galbraith (Galbraith, 1958) illustrate such questioning - and lack of it.

> *The theory of consumer demand, as it is now widely accepted, is based on two broad propositions, neither of which is quite explicit but both extremely important for the present value system of economists. The first is that the urgency of wants does not diminish appreciably as more of them are satisfied...When man has satisfied his physical needs, then psychologically grounded desires take over. These can never be satisfied or, in any case, no progress can be proved. The concept of satiation has very*

little standing in economics. It is neither useful nor scientific to speculate on the comparative cravings of the stomach and the mind. *[Page 141]*

A high level of production has become the keystone of effective economic security. There remains, however, the task of justifying the resulting flow of goods. Production cannot be an incidental to the mitigation of inequality or the provision of jobs. It must have a raison d'etre of its own. At this point economists and economic theory have entered the game... The result has been an elaborate and ingenious defence of the importance of production as such. It is a defence which makes the importance of production largely independent of the volume of production. In this way economic theory has managed to transfer the sense of urgency in meeting consumer need that was felt in a world where more production meant more food for the hungry, more clothing for the cold, and more houses for the homeless to a world where increased output satisfies the craving for more elegant cars, more exotic food, more erotic clothing, more elaborate entertainment - indeed, for the entire modern range of sensuous, edifying and lethal desires. *[Page 138]*

This illustrates the view that current economic objectives and their accompanying rationale will result in ever-increasing consumption. Should it not be possible to accommodate such increasing consumption within environmental constraints, then a radical revision of this conventional view will be required. The extent to which it is possible to have unlimited growth depends principally on two factors. Firstly, the type of goods produced and consumed is important. The resources used to produce a painting worth £5000 are less than those required for a foreign holiday of the same value. The other factor is the technologies available for producing the required goods.

4.1.1 What is consumption?

Consumption is a word with many meanings. Here we discuss its meaning in physical terms and in economics.

Physical consumption is the degradation of energy and order:

- The original consumption is eating food. The energy and nutrients in food are absorbed and utilised by the body, and waste with low energy content is excreted.

- Energy is degraded. This means that high quality energy, such as in fossil fuels, or solar energy, or hydroelectric potential, is used and degraded to a low quality (usually low temperature heat) which cannot be used for practical tasks like powering machines, or electrical equipment, or heating buildings or water.

- Order and information are degraded. Fabricated objects and materials are broken up and energy is required to replace them.

- There is an overarching technical definition of physical consumption, which is that entropy is always increased in any process. Entropy is common measure of the energy degradation and disorder

Economic consumption is generally related to the expenditure on goods and services.

- Public consumption consists of government spending on services, such as education, health, defence, etc.

- Private consumption is money spent by individuals on nondurables, such as food and drink, durables, such as cars and washing machines, and services, such as entertainment.

There is an overlap between the physical and economic concepts of consumption, but there are important differences.

- Economic consumption always results in physical consumption, but not vice versa. For example: eating free wild mushrooms constitutes physical consumption, but not economic because the mushrooms have no price attached.

- Economic consumption is quantified through price and quantity, and is not simply translated into physical consumption. For example: spending £100 on air travel has quite different physical impacts from spending £100 on books.

Ultimately, in this report, we are interested in the physical impacts on the environment and resources, so we need to convert economic consumption into physical consumption.

4.1.2 The energy chain

The needs described need minimum amounts of energy for them to be met. The technologies used at the point of service (lights, washing machines etc.) convert delivered fuels (gas, oil, electricity etc.) into energy forms which will accomplish the task required. These fuels are delivered by energy supply systems incorporating elements of distribution and production. Each link in this energy chain typically involves losses of energy. Energy savings made near the point of need reduce energy flows at all stages upstream.

We may take as an example cooking with an electric cooker. Over a year, the actual energy required for changing the food chemically and physically might be 10 MJ, and the energy required to heat the food to a palatable temperature might be about 100 MJ: therefore the minimum energy to meet the need is 110 MJ. A conventional electric cooker in the UK uses about 3600 MJ of delivered electricity and therefore has an efficiency of less than 3%. About 8% of electricity is lost in transmission from power station to consumer, so the station has to generate 3900 MJ of electricity. Assuming the power station efficiency to be 33% 12000 MJ of coal are burnt to produce the electricity.

This example emphasises the importance of making energy savings at or near the point of need. Savings made are multiplied as one passes upstream. A 1 MJ reduction in cooking need results in 110 MJ less coal burnt - a multiplier of over 100. Doubling the efficiency of the cooker would reduce delivered electricity requirements by 1800 MJ, and coal burn by 5900 MJ.

4.2 Characterisation of environmental impact

It is beyond the scope of this report to give details of the how energy service provision can impact on the environment. The purpose here is to illustrate that all current energy technologies have impacts of some kind — there is no panacea.

The conversion of energy in the energy chain, and the physical presence of energy technologies, gives rise to environmental impacts at all stages. The starting point is the first introduction of pollutants into the environment. These may be called primary inputs. Table 4-2 gives a categorisation and examples of these.

These primary inputs are transported and transformed in the environment. Ultimately, they arrive at a point where the actual impacts of concern occur. Many of the primary inputs have more than one type of impact, and their effects are often moderated synergistically with other inputs. The impacts may act directly or indirectly on human and non-human systems. Human and biotic health may be damaged directly such as by certain of the chemicals listed in the Table, and radioactivity. Alternatively, the impact may be more indirect: carbon dioxide modifies the global climate and so alters many facets of the environment conducive to particular human economies and natural ecosystems flourishing.

Table 4-2 : Primary environmental inputs

IMPACT	EXAMPLES	TECHNOLOGY SOURCE	CLASS
Chemical	Sulphur dioxide, nitrogen oxides Carbon monoxide, hydrocarbons, Carbon dioxide, methane	Power stations, refineries Boilers, vehicles, aircraft	Acid rain Toxic Global warming
Radioactive	Nuclear waste and accident	Nuclear power stations	Toxic
Biological	GM material	Energy crop	Biodiversity
Mechanical	Hydrological change, loss of habitat	Hydroelectric schemes	
Noise	Traffic noise	Vehicles	
Visual		Power stations, aerogenerators	
Dislocation	Roads	Transport system	
Thermal	Heat from cooling systems	Power stations	

The impacts have very different characteristics in terms of their extension in space and time. The impacts of most energy technologies falls with increasing distance from the technology because of the way in which pollutants are dispersed and deposited in the atmosphere and hydrosphere. Some examples may be given. Noise pollution is limited spatially, and is an instantaneous impact in that as soon as the primary input ceases, so does noise (although human health will not generally recover immediately). Acid rain acts at a regional scale. After reduction in primary input through emission control, the impact slowly diminishes as soils and biota recover, although its impact may never dwindle to zero. Carbon dioxide has a global impact which will extend over a century and more even if emissions were to cease now, but its direct local impacts are minimal. The impacts of a nuclear accident or waste spillage are concentrated spatially, but they extend over many hundreds of years albeit at declining levels. These examples illustrate how impacts extend from seconds to centuries in time, and spatially from a few metres to the whole world.

Some primary inputs are, from a human perspective, irreversible. Some of the radionuclides in nuclear waste have half-lives of many thousands of years, and the only way of minimising their impact is to isolate them from the biosphere over such a time period. The impacts of the primary inputs may be absolutely or practically irreversible. Species loss is irreversible if the requisite genetic information is not stored in banks, and the techniques for breeding from this information are not available. On a human time scale, some impacts of global warming or even large hydroelectric schemes may also be regarded as irreversible.

All energy technologies produce one or more primary inputs, and therefore have one or more environmental impacts. It is therefore not possible to have an energy system with no environmental impact - there is no panacea. Often the suppression of one input, such as reducing sulphur dioxide emission with flue gas desulphurisation, results in the creation of other inputs, such as the mining of limestone and the creation of wastes. In practical terms, it is a matter of weighing up impacts against each other arriving at what is considered the best compromise. There is no way of doing this objectively because the impacts are generally incommensurable and unvalued monetarily. As outlined above, the impacts are different in terms of type of impact, and their extension in space and time. How is the impact of ***x*** tonnes of acid emission from a coal power station to be compared with the impact of the production of ***y*** tonnes of nuclear waste from a nuclear power station, or to the loss of ***z*** km2 of wading bird feeding grounds due to the construction of a tidal power station? Decisions between such options arise from more or less complex political processes which use, to whatever degree, analyses of the impacts and technological and economic analyses of the options involved. Different factions participate in the political process, each typically having different views as to the importance of the impacts, although these views may not be formulated into precise policies or recommendations.

In the current context, there is no obvious best mix of energy technologies which may be deployed so as to meet carbon reductions of the order described in chapter 2 without incurring significant environmental impacts. There are however some technologies which are generally regarded as having a negligible or small environmental impact when deployed to moderate levels. Many energy conservation technologies such as low energy appliances have a negligible impact in operation. Some of these have to be used with care however. Some forms of insulation are made of materials carrying a health risk especially in installation. Reducing heat losses through ventilation control can increase levels of indoor air pollutants such as radon and organic chemicals. On the supply side, the technologies with the least impact are generally distributed solar thermal and photovoltaic systems. These may be installed fairly unobtrusively on rooftops and otherwise have a generally negligible impact in operation.

5. CARBON EMISSION REDUCTION STRATEGIES

This chapter briefly reviews the general elements of energy strategies aimed at carbon emission control. It describes the limits to technical measures. The notion is advanced that the non-technical element of lifestyle change should be included as an extra element in such strategies.

5.1 Energy strategies - conventional and radical elements

Before the late 1960s, energy problems were seen mainly as pertaining to difficulties in obtaining sufficient quantities of primary fossil fuels at a reasonable price: that is, problems of supply. The strategic and economic importance of maintaining secure and cheap commercial energy supplies to industrialised countries had long been exercising political minds. Powerful nations attempted to control the production and distribution of fossil fuels, particularly oil, by means ranging from economic pressure to military action.

This narrow conventional perspective was considerably broadened and altered during the 1970s. The politically induced oil supply crises during this period flagged the loss of control of production by major importing western nations. At the same time, there was a rapidly increasing perception of the environmental impacts arising from energy use, partly brought about because of the increased magnitude of some impacts, and partly because of a better understanding of environmental systems. The environmental impact of oil spills, nuclear wastes and accidents, and acid rain became important public issues. These crises of supply and environment led to more elaborate appraisals, and in some cases exploitation, of alternative sources and forms of fossil energy such as North Sea oil and gas, and oil shales. A few countries developed significant nuclear generating capacity. New programmes investigating modern approaches to exploiting renewable energy resources were initiated by most industrialised countries, although the investment in these was relatively small.

Contemporaneous with the search for supply alternatives was a trend towards a more refined understanding of how energy is transformed and used near or at the point of use. Thus, we have seen an increase in the detailed knowledge of how energy is transformed and used in buildings, vehicles, industry and so on. This approach is often called the 'bottom-up' approach and signalled an extension in energy analysis in the 70s. The approach led to a better appreciation of what might be accomplished economically and environmentally by relatively simple cheap technologies like insulation and low energy light bulbs. Several quantitative bottom-up studies were carried out around this time (e.g. Leach et al, 1979) which showed that significant energy savings were possible whilst maintaining economic growth and improving general living standards (however these may be defined). These studies were considered radical at the time, especially by energy supply concerns. To a small degree, the policy elements arising from their analysis have been incorporated in the energy policies of some governments, at least temporarily. However in general it is true to say that energy policies generally remain supply dominated, and therefore the economically optimal levels of energy efficiency are far from being realised.

Some works of this period (e.g. Lovins, 1977) raised more radical questions about lifestyle and the extent to which it is desirable for the consumption of goods and services to carry on growing. A few produced scenarios which included alternative views of concerning lifestyle. For example, in a supremely comprehensive bottom-up analysis of UK energy futures, Olivier et al (1983) talk of 'conserver societies' and of ".. scenarios [which] take as their starting point the possibility of greater changes in attitudes, lifestyles and economic structure over the period. ...It is assumed that the UK moves towards a post-industrial society". In practical terms, the main quantified difference between the conserver scenario and the 'technical fix' ones seems to be that a greater proportion of GDP arises from service sectors in the former than the latter.

To a large degree, the radical analysis of the basis of the demand for goods and services which require energy has faded over the past two decades. The studies mentioned above were children of their time. Since their publication the energy import security and price for the big industrialised countries has generally improved, thus diminishing the 'energy problem' in most people's minds. Also, the general political trend of the last decade and a half has had an effect. This is exemplified by the manifold changes in the UK: central energy planning is greatly diminished; less subsidy is given to both energy supply and conservation; there is a continued lack of progress in improving energy efficiency; and there is a general apparent belief of government that the energy markets will get it right. There have been gains and losses here, but on balance, the prospects for 'technical fix' solutions to environmental problems may have been diminished. The earnings from privatising gas and electricity would unquestionably have been less if the outlook had been for the sharp reductions in demand necessary if carbon emissions are to be reduced significantly and rapidly. There is also perhaps less questioning of the general 'way of life' manifested in richer countries than twenty years ago.

For these reasons most recent energy scenarios and their associated policies focus on technical measures and technological innovation as the principal means of solving the environmental problems caused by energy supply. The human and social factors which fundamentally determine the demand for services which require energy are not given as much analysis as technical matters. In particular, many scenarios are predicated on normative assumptions about people's demand for services and goods in the future, and many include rather simple extrapolations from the recent past. A common assumption is that GDP will grow steadily in the long term. This means the consumption of services and goods will grow, and the pressure on environment will remain. The nature of this pressure depends of course on the types of goods and services consumed, and the technologies used to provide them.

There are many reasons for using the growth assumption. It coincides with the common notion that GDP growth equates with progress, and that this is a good thing - a good future. 'Alternative' energy strategists often adopt such normative forecasts so that their scenarios are not dismissed as being 'hair shirt and sandals'. They can demonstrate that large reductions in environmental impact and cost are practicable even within an orthodoxy concerning demand. Not least, it means that the problem of understanding what the needs for services are can be set aside, and simple assumptions and equations can be used for projecting demand.

However, such simple extrapolations can obscure potential and 'abnormal' alterations in certain trends which may significantly affect energy demand and carbon emission. These may be largely involuntary, such as the permanence of a large number of unemployed people, or the gradual ageing of the population. Alternatively, voluntary social changes may occur which could be significant: people might work at home more, a consequence of which is reduced transport needs; or they might even adopt some of the lifestyle changes described in this report in order to reduce their living costs or diminish environmental impact. On the other hand, they may choose to adopt more energy intensive lifestyles by living further from work, purchasing larger cars or having more long distance holidays.

The elements of a carbon emission strategy advanced here are radical in the sense that they involve some visible changes in lifestyle, and this is a departure from many scenarios. This study aims to quantitatively assess the effect on carbon emissions of a small number of lifestyle changes. Most of the changes explored here are not of themselves radical in any social or political sense. Choosing a more economical car, going by bus or wearing a sweater can hardly be described as revolutionary activities: but, as will be shown, they nevertheless have a potentially significant effect on pollution emission. The analysis is confined to physical and quantitative aspects of behaviour, and does not attempt to look at the individual and social psychological processes which might drive human behaviour.

5.2 Technical means of emission control

Most energy strategies aimed at reducing carbon emission include the elements of energy conservation and efficiency, renewable energy, nuclear energy and switching to gas from coal and oil.

Energy conservation and efficiency

Energy efficiency is a central policy measure, and this reduces almost all environmental impacts of energy systems - acid emissions, radioactive waste, ecological impact of hydroelectric schemes and so forth. Energy conservation includes the reduction in energy losses, the recycling of energy, and the development of alternative processes which use less energy. Energy efficiency is here taken to mean the efficiency with which an energy input (such as gas) is converted into one or more useful energy outputs (such as electricity and/or heat). In most developed countries the potential for reducing energy demand economically with energy conservation and efficiency is large - typically of the order of 30% to 70% overall.

Zero carbon energy supply

Renewable energy sources produce no carbon during operation. The potential for these is large in some countries. However, some, such as hydroelectricity, can have substantial environmental impacts. Others, such as tidal or photovoltaic electricity are expensive. Low impact energy sources such as thermal solar heating can also play a part. The potential contribution of these sources is highly country specific but globally the potential is large. The development of certain key technologies could transform the outlook for renewable energy supply. Perhaps the key ones are the development of cheap and efficient photovoltaic collectors, electricity storage and electricity transmission.

Nuclear power brings the certainty of nuclear waste, and the possibility of catastrophic accident. There is at present no proven way of removing either of these threats to the environment and human health. Furthermore, nuclear power is very expensive in many countries. However, the potential output from nuclear power is very large.

Low carbon energy supply

Switching from coal and oil to gas can bring about a certain reduction since the latter produces less carbon emission per energy than the former. However, the degree to which this can occur is limited by the availability and cost of natural gas. A careful eye also has to be kept on the global warming effect of the anthropogenic methane emission resulting from the exploitation of natural gas. Currently a large switch to natural gas is an important element in the official carbon emission control strategies of many rich European countries.

5.3 The limits of technical measures

The technical measures listed above will not alone be sufficient for the speedy development of environmentally benign and equitable futures. The reasons for this centre on technical limitations, constrained rates of implementation, environmental impacts, and economics.

5.3.1 Technical limits

All energy conservation and supply technologies are subject to the physical laws of thermodynamics. These express themselves in the performance of energy technologies either by imposing trends of diminishing return, and by setting absolute limits.

There is a range of constraints imposed on the technical improvements that may be made in terms of energy conservation. Many energy conservation measures are subject to the law of diminishing returns in the sense that the incremental energy saving per extra investment diminishes. For example, to a first approximation the heat loss through the wall of a building is halved for every doubling of insulation thickness. It is therefore not possible to eliminate heat losses entirely, and other practical social and architectural factors limit the practicable thickness. Other conservation measures, such as heat recovery in ventilation systems are limited in efficiency for similar reasons.

The efficiency with which technologies may convert energy from one form to another is fundamentally constrained by thermodynamic laws. For energy technologies which convert energy in one form (chemical in the case of fossil fuels) into a lower grade form such as heat without the utilisation of a heat pump, the maximum efficiency is 100%. That is to say it is not possible to extract more than 1 GJ of heat output if 1 GJ of fuel is input. In principle, it is possible to put high-grade energy into a heat pump and upgrade environmental heat from the atmosphere, lithosphere or hydrosphere. For example in the UK, 1 GJ of electricity put into a heat pump typically upgrades about 2 GJ of environmental atmospheric, and produces 3 GJ of useful heat for water or space heating - an overall 'efficiency' of 3-400%. It is difficult for practical reasons to get performance much better than this. Energy technologies which convert energy into higher grade forms of energy are also limited: the efficiency of converting primary energy into power (e.g. electricity) is limited to around 50-60% because of the properties of available materials and other practical engineering constraints.

5.3.2 Rates of implementation

Technologies have typical 'economic' lives. The economic life of a technology depends on the society using it, and the economic costs and values appertaining to that society. In practice most energy consuming or supplying technologies last from 5 to 15 years (electric appliances, cars) through to 30 to 50 years (power stations and other energy facilities) up to 100 years and more (buildings). These long lifetimes constrain the rate at which devices leading to lower carbon emissions can economically be introduced. This inertia constrains the rate at which technical measures may economically be introduced. The importance of reducing carbon emissions rapidly has been discussed in the section describing the global warming problem.

5.3.3 Environmental impact

As has been shown, most, if not all supply technologies have a significant environmental impact of some kind. This is also true of some energy efficiency measures. In general as the contribution from any particular type of energy technology increases, it becomes more difficult to limit the marginal environmental impact. For example, sites with low impact may be found for the first tranche of economically sited aerogenerators, but as the capacity installed increases, the marginal sites can have more impact in terms of visual intrusion or noise.

5.3.4 Economics

All of the technical measures ultimately exhibit increasing marginal production costs. For most technologies, there are economies of scale which may lead to the marginal cost declining over the first units brought into operation. Economies of scale can apply to both technology production and to installation. Ultimately, however the next PJ of energy saved or produced will come more expensive than the previous one. This applies to all energy technologies whether they are efficiency technologies, or conventional or renewable supply technologies. The shape of the marginal cost curves varies greatly according to the technology.

The limits summarised above constrain the rate, and the ultimate degree, of deployment of technical measures. Recent assessments of the contributions of these measures have been made for EC countries (COHERENCE, 1991), the USA (Union of Concerned Scientists, 1991; Grubb et al, 1991) and Japan (Grubb et al, 1991) For these rich countries the total reduction in carbon emission thought to be achievable through mainly technical measures over the next 40 years or so lies in the range 30% to 70% as compared to 1990 emission levels. A certain proportion of these savings are due to certain lifestyle changes such as a switch from the private car to public transport systems. The studies indicate that some further savings may be made but that this would be increasingly difficult because the measures would be suffering rapidly increasing technical, environmental and economic penalties. Chapter 2 showed that reductions of the order of 90% in emission are required of the industrialised countries by 2030 if the targets are to be met whilst abiding by the ethic of per capita emission equity.

5.4 Lifestyle change

The technical studies of the type mentioned show that large reductions in carbon emission may be made economically using present technologies. However, over the scenario periods explored, the reductions fall short of the target reductions indicated in the chapter on global carbon analysis: emission does not fall fast enough or far enough. The scope for further reduction by technical means beyond 2030 is largely unknown. On the one hand, further technical developments for the better control of carbon emission may be expected; on the other if increased consumption trends continue over this very long time period there will be pressure for carbon emission to grow.

As expected the emissions of fossil fuel related pollutants other than carbon are reduced in the scenarios produced by the type of study mentioned above. There is however little or no detailed appraisal of other environmental impacts arising from the alternative technologies deployed, such as those due to the extended use of hydropower or biomass. The scenarios in these studies incorporate large increases in supply from a range of renewable and alternative fossil sources (mainly gas) which will increase other environmental impacts. A judgement is made (implicitly in many cases) that the value of the various impacts increased is less than that of the impact of that which is reduced (carbon dioxide and global warming). This may or may not be a judgement which is eventually confirmed.

Technical measures seem likely to ultimately fall short in two respects. First the levels of reduction brought about by these measures, although large, fall short of those targets indicated by the analysis of global carbon control. Second the levels of impact other than that due to carbon emission, may be presumed to have increased, and to be rapidly increasing at the margin. It seems improbable that reductions of the order of 80-90% and more in carbon emission can not be realised sufficiently rapidly within economic, environmental and social constraints with any combination of the technical measures. This is unless of course some improbable technological developments occur. Lifestyles based on a high and increasing consumption of commodities in activities such as unlimited private motoring will almost certainly overwhelm technical improvements.

There is therefore an argument that lifestyle change should be appraised for its possible contribution to carbon emission control. This is not to suggest that it is an alternative to the technical measures. Rather it should be seen as another complementary element in control strategies.

Most conservation measures are more or less invisible to the consumer. Outwardly there is little difference between a low energy versions of light bulbs, refrigerators and houses and their high energy brethren. Similarly different energy supply options are 'out of sight' of most consumers, although there are of course major local exceptions. The consumer satisfies a given need through the energy services these devices provide and, provided that they are not too costly, and notices little about the technologies involved. It may be said that such technological options are in a sense 'lifestyle neutral'.

Carbon emission reduction may also be brought about by visible changes in lifestyle. These changes can vary in degree. This can be exemplified by personal transport: a small change would be buying a slower car; a medium change would be travelling by bus or bicycle rather than car; a large change would be reducing travel altogether. In this study we are only interested how lifestyle manifests itself physically in terms of energy consumption and carbon. That is to say the study of how altered patterns of behaviour (lifestyle) might result in lower energy service needs and carbon emission. Lifestyle elements which do not have significant implications for energy use are ignored. For example, the literary contents of a magazine are not important from the energy point of view, but its size and method of production and distribution are.

Lifestyle changes which may significantly affect energy consumption and carbon emission may be divided into four categories: alteration of need; selection of technologies; use of technologies; and reduction of need. The UK case study in chapter 5 makes quantitative estimates of the effects of certain lifestyle changes and generally expands on some of the changes summarised below.

5.4.1.1 Reducing or altering the need and consequent level of energy service

The heating and cooling of buildings generally constitutes some 20% to 40% of primary energy use in rich countries. Energy services providing thermal comfort can be reduced by people wearing clothing more appropriate to the climate in which they live. Transport needs can be reduced in a number of ways. Choosing to live near work, school, shops and so on means less essential travel in terms of distance (rather than number of trips). Working at home reduces the number of commuting trips. Leisure travel is to a degree optional and choosing to visit nearby locations rather than distant ones reduces distance travelled. Especially important here is the choice of near rather than far holiday locations since the rapid growth in travel to distant locations by air is causes a significant increase in global warming.

5.4.1.2 Selecting efficient energy using technologies

Consumers can significantly affect their energy use by selecting efficient energy using technologies which will provide a similar but not exactly comparable service. In general the energy consumption of houses increases with their size and detachment: a small terraced (row) house will use less energy than a large detached house. Shorter trips can be made by zero carbon travel modes walking and cycling, longer ones by efficient public transport systems. Less powerful cars which use less fuel can be purchased but they will in general be slower and smaller.

5.4.1.3 Using energy technologies efficiently

Energy and carbon savings can be made by changing the way technologies are used. The careful and economic use of technologies can bring significant savings in the energy requirement of services. The careful control and use of lighting, hot water and space conditioning systems can bring about significant reductions in energy consumption. Cars may be used efficiently by minimising speed and acceleration to whatever degree feasible, by planning car trips efficiently, and by sharing cars with as many passengers as possible.

5.4.1.4 Purchasing different or less goods

The production and distribution of material goods such as furniture and services such as air transport requires energy. Consumers can therefore reduce energy use and carbon emission by purchasing less or different goods and services. This could mean buying less of the more transitory commodities such as newspapers. It could also mean replacing the stock of a more durable commodities such as a sofa less rapidly: to a first approximation increasing the lifetime of the sofa by 10% will reduce the energy cost of the service that furniture provides by 10%. But of course the service is not quite comparable in that the sofa is older on average and may satisfy requirements of style or good condition less well. Energy may also be saved by purchasing different types of a commodity. For example, it is possible that a sofa made of steel and artificial fibres requires more energy for manufacture and distribution than one made of wood and natural fibres. This last category of lifestyle change is the most radical in that it raises the question of how much is enough.

5.4.2 Discussion

The marginal difficulty of lifestyle change increases with the degree of deployment, just as for technical measures. This is because large lifestyle changes would be more difficult to implement than small ones, and because there are practical limits to lifestyle changes. Convincing people to purchase slower cars might not be too difficult; cajoling them into making all trips less than 30 km by bicycle would be difficult indeed. Small changes in clothing levels might be relatively acceptable, but wearing clothing levels which would eliminate all space conditioning requirements would in many countries not be a practical objective.

Most lifestyle changes bringing about reduced carbon emission would bring financial savings for consumers for that service. In the UK the energy efficient cars commercially available are smaller and slower than the average purchase and typically cost 40% less than the averaged sized car to buy. Running costs in terms of petrol and insurance and so forth are less by a similar proportion. The annuitised cost of wearing a sweater is certainly less than the cost savings realised through reduced fuel use. Of course these financial savings are made through a visible change in lifestyle, and a different level or quality of service, and so it may be said there is a reduction in consumer satisfaction. Given that such savings are made, an important question arises as to what the money is spent on instead - the respending effect. If the money saved through having a slower car is spent on flying to Bangkok rather than driving to Bognor Regis, then a net addition to carbon emissions and global warming will have been made. In this study no attempt has been made to asses the cost savings of lifestyle changes, or of the respending effect.

One advantage of changing lifestyle is that certain elements (such as those mentioned above) of it can potentially be changed quite rapidly. This is in contrast to technical fixes involving energy efficiency, renewables and so on. One of the observations of the IPCC is that of the many climate system feedbacks, the majority appear to be positive. That is to say that the warming effect of trace gases may in all likelihood be magnified by the response of certain of the earth's physical systems. This increases the importance of reductions in carbon emissions being realised as soon as possible. Certain lifestyle changes (e.g. travelling by bus instead of car, or wearing a sweater) could in principle have a rapid effect on emissions at low or zero cost.

6. UK CASE STUDY

This chapter gives an overview of the pattern of carbon emission from the UK, and proceeds to assess how a limited number of lifestyle changes and consumer choices might reduce this emission. The building services and passenger transport sectors are analysed in some detail in order to assess the scope for reducing carbon emission through lifestyle change. The results of this analysis are then collected together in a concluding section to give an assessment of how much emission could be controlled overall. The case study is a technical analysis of the potential reduction through lifestyle change. Ways in which lifestyle might be influenced are discussed in a later chapter.

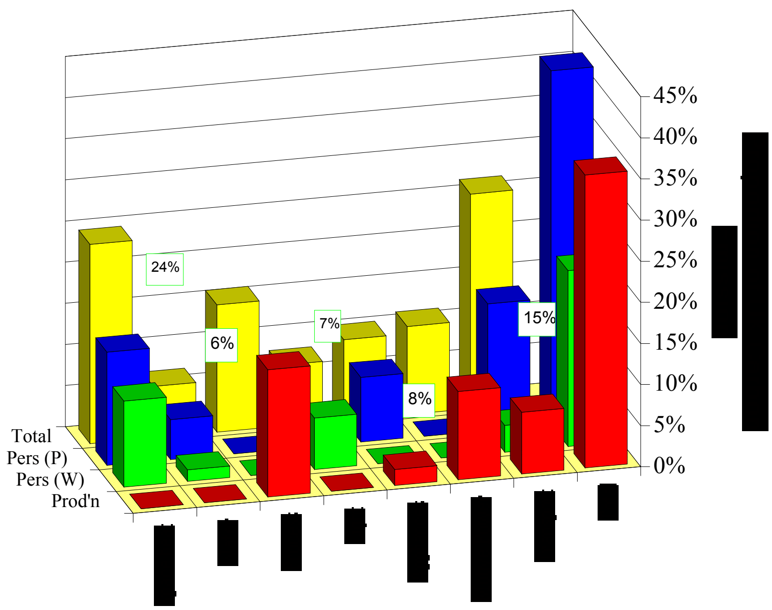
6.1 Current pattern of emission

Studies have detailed, inter alia, how delivered fuel was used in three major sectors: the industrial sector in 1980 (DEn, 1984); the commercial sector in 1985 (DEn, 1988); and the domestic sector in 1985 (DEn, 1990). Fuel use in the transport sector, and other statistics, are provided by the Transport Statistics of Great Britain (DTp, 1991). The Digest of UK Energy Statistics (DEn, 1991) provides data for 1990 on primary energy inputs to the UK economy, and the deliveries of fuels to the various sectors. These statistical sources may be used to estimate the allocations of energy use and concomitant carbon emissions to end uses and sectors in 1990.

The estimates of carbon emission have been aggregated by end use and by three rather unusual headings. These headings have been chosen in order to delineate how carbon emission arises from the provision of services to people, and to highlight those areas in which moderate lifestyle changes might have a substantial and calculable effect. The first heading or sector, called Production, includes the carbon emission arising from heavy industry, manufacturing industry, services and agriculture, and the emission due to freight transport. This may be seen as the emission due to the manufacturing and distribution of commodities, but it excludes that due to servicing people working in this sector. The second and third sectors include what may be called personal services, and includes space heating, hot water, certain electric appliances, lighting, and passenger transport. The second sector called Personal Work includes all emissions arising from personal services provided in the course of work. The third sector, Personal Private, includes personal services provided in people's homes or as passenger transport for private purposes.

Figure 6-1 depicts the breakdown of carbon emission by these three headings, and by end use. We see that about 36% of carbon emissions arise Production. Some 21% of emissions arise from personal services at work, and 43% from private personal services: thus about 64% of UK carbon emissions arise from the provision of personal services. We may also break the emission down by type of personal service or end use. The largest emission is due to space heating (24%) and passenger transport (18%): together these two give rise to 42% of UK emissions. Domestic appliances (8%), lighting (7%), and hot water (6%) are of secondary importance but not negligible.

Figure 6-1: Carbon emission and service : UK 1990



6.2 Building energy services

The principal purpose of most non-industrial buildings is to establish a comfortable microenvironment for people, and to provide a range of personal services such a lighting, cooking and hot water. In providing these facilities, UK buildings consume some 40 to 50% of total UK primary energy, and bring about the same proportion of total carbon emission. Even in the temperate maritime climate of the UK, a large proportion of the total energy delivered to buildings (about 30%) is used for heating and air conditioning such that thermal comfort is afforded.

The following section on buildings analyses the services provided in buildings in the order of magnitude of carbon emission.

6.2.1 Thermal comfort

Some 37.5 Mt of carbon are emitted in the process of providing a layer of warm air next to the skin of British people. It is important to understand why this is so even in a temperate climate. This section gives a brief introduction to the need for thermal comfort, and follows this with an analysis of how thermal comfort might be achieved with less emission by the wearing of more clothes.

6.2.1.1 Introduction

Human beings themselves consume energy in the form of food. This energy is used for driving a number of complex biochemical systems in the body which meet human needs such as movement, growth and nervous activity. The amounts of energy required for these functions depends on a number of factors including level of activity, age and sex. Most of the energy used in the body ends up as heat. Loss of heat occurs from the surface of the body and from respiration. Heat loss must over time balance the heat produced by the body otherwise the body temperature would rise or fall, and body temperature must be maintained within a fairly small range. The body has a number of systems which regulate the generation and loss of heat by the body. Heat losses from the body are reduced by diminishing the flow of warm blood to the surface. If the body temperature is very low, energy is fed to the muscles and shivering occurs and this otherwise useless activity generates extra heat to warm the body up. If the body temperature is getting too high, a number of processes act to increase heat losses including increased blood flow to the surface and sweating.

Feelings of comfort and discomfort companion these physiological processes. When the heat losses from the body balance the heat generated without the need for a significant effort at thermoregulation, a person feels comfortable. The greater the effort put into increasing heat generation, or altering body heat losses the more uncomfortable a person feels.

Given an adequate supply of food and water thermoregulation enables human beings to survive without clothing or heating in a wide range of climates. Physiological thermoregulation was the only means of temperature control until the invention of clothing in prehistoric times. The use of clothing to reduce the heat losses form the body had two effects. First, it enabled people to live in lower temperature climate zones. Second, in cold climates the food need in terms of calories would be reduced thus lessening the problem of survival.

Rather than providing an immediate environment for the body with clothing, a trend of the last two millennia or so has been towards achieving comfort by controlling the thermal environment within buildings. The culture dependent siting and design of buildings offered some limited passive control of the internal thermal environment.

As time passed, and knowledge accumulated, increasingly sophisticated and active technologies for controlling the internal environment were developed. Fire was used to provide increasingly extended provision of thermal comfort. With the invention chimneys and flues of increasing sophistication, the heat from fires could contribute to thermal comfort without at the same time drastically increasing draughts and augmenting heat losses from buildings. Initially people had to congregate around fires in cold weather since the comfort afforded did not extent far into the building because of the limited range of radiative and convective heating. Gradually however the zone of thermal comfort from such heating was enlarged first by the provision of more fireplaces, and by the development of a means of distributing heat from a central fire around the building. Accompanying these developments was increasing sophistication and automation of heating systems.

The emphasis gradually shifted from a focus on personal thermal comfort for people to the heating (or cooling) of buildings such that people are presumed to be comfortable. This change of focus has meant that other means or approaches to providing comfort have been rather forgotten. It has also lead to the overheating and overcooling of buildings being a common phenomenon: partly because of the focus on heating buildings, and partly because the control systems are not sophisticated enough.

There has been an increasing internationalisation and convergence of lifestyles and working patterns, designs and standards in clothing, building and environmental control, at least amongst wealthier people. Office workers down town wear much the same dress indoors the world over. It is often hard to tell in which country an office block were located purely from its external design. The designs of clothing and building originally tailored for local environments are increasingly forgotten, and these designs are rooted in a time when as much comfort had to be provided as much as possible by means which did not require anything but renewable energy.

Thus, without active energy consuming environmental control systems, the highly glazed office block overheats in Kuala Lumpur and freezes in Toronto. Similarly, people are typically overdressed in jacket and tie in Kuala Lumpur, and underdressed with the same in Toronto. On top of this, when active heating or cooling is applied, it is often excessive and badly controlled. In overheated buildings, people will open the window to cool it; in overcooled buildings they do the same to heat it up!

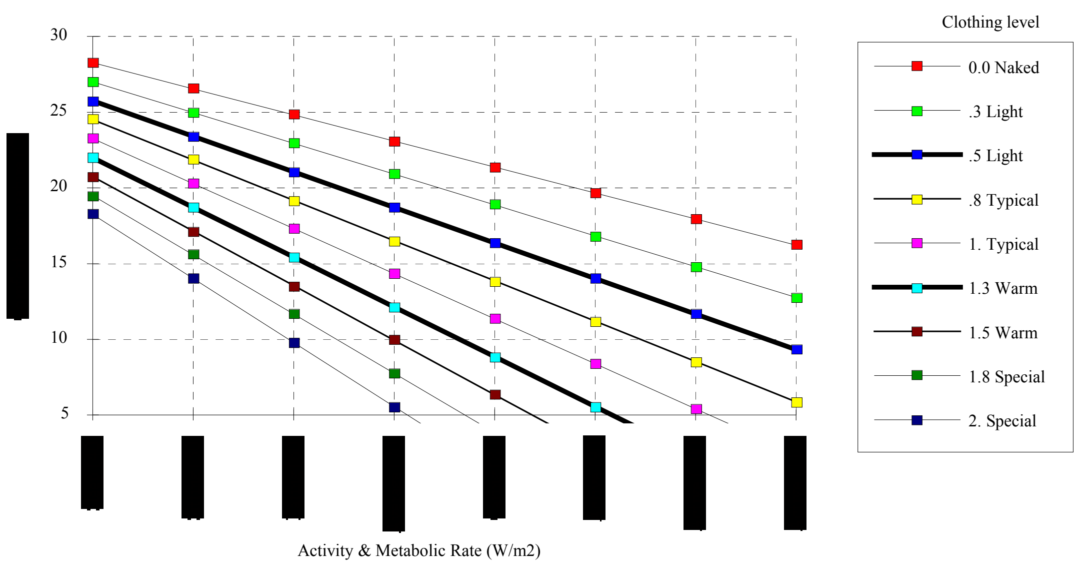
Thermal comfort, activity and clothing

In order to estimate the potential effect of higher clothing levels on temperatures we need to know the relationship between comfort, activity, clothing and temperature; and the current clothing levels people adopt at home and at work.

Fanger (1970) suggested that thermal comfort depends on six variables. Four of these (mean radiant temperature, relative air temperature, relative air velocity, water vapour pressure) relate to the internal environment of the building, and two (activity level, clothing) relate to people. As reported by Oseland and Raw (1990), the air temperature can be taken as the significant building parameter since this is closely correlated with the mean radiant temperature, and in typical UK conditions air velocity and vapour pressure are not greatly significant. Therefore one can usefully relate one building parameter (air temperature) to a combination of two person related parameters (activity level and clothing). Humphreys (1976) gives an equation which describes the form of this relationship. This has been adapted for this study.

Oseland and Raw (1990) analysed data taken from a study of small modern starter homes constructed between 1980 and 1985. The standard index of insulation due to clothing is called the clo . They found that the mean living room temperature was 19.2 ^{o}C, with an average clo value of 0.54, and that most of the people reported as being comfortable, or even a little warm. This finding reveals temperatures some 5 ^{o}C less than those expected from the experimental work of Fanger, and some 2 ^{o}C less than those expected from the findings of Humphreys. The parameters of Humphreys equation have been adjusted so as to approximately track this recent empirical evidence. Figure 6-2 depicts the resulting calculated variation of comfort temperature with activity and clothing level. The two dense lines bracket the usual range of clothing found in the UK. It can be seen that the comfort temperature for sitting or eating is reduced by some 6 ^{o}C per clo.

Figure 6-2: Comfort temperature, clothing and activity



The clo is a measure of the resistance to heat flow (1 clo = 0.155 m2.^{o}C/W). The greater the clo value, the more insulation clothing affords. As Oseland and Raw (1990) describe "the basic dress for a man, e.g. a shirt and trousers (0.54 clo) has a similar clo value to the basic dress for a woman e.g. skirt and shirt (0.50 clo)." (This is unsurprising since they share the same buildings.) They found in their survey of people at home that this was the typical insulation level of clothing worn.

Indoor air temperature and home energy use

A thermal model of a house has been used in order to estimate the effect of lowering indoor temperatures, and to study the effects of other changes including better heating controls. A typical uninsulated terraced house in the UK climate has been used as the base case. The model matches quite accurately the results of other models, but nonetheless it is probably not accurate to better than 10%. This is accurate enough for assessing the <u>differences</u> on energy use because of changes to certain parameters: besides, the effect of people's behaviour is large, and there is no beast such as an average family.

Figure 6-3 shows the assumed profile of demand for heating: this would correspond to a household the members of which are all out during the day. The bold lines show the target temperatures (Tt) for the three main zones: kitchen, sitting room, and bedrooms. The faint lines show the actual realised temperatures (Tr) reached in the case where zoned heating control applies. Thus the sitting room is only heated in the evening, which would not be the case if a typical non zoned control system were used. The snaking realised temperature curves illustrate the dynamics of building heating: temperatures take time to rise when heating is applied, and some time to fall when heating ceases. Temperature rises occur outside of heating periods because of incidental heat gains from solar energy and appliances and people.

Figure 6-3: House temperature profiles

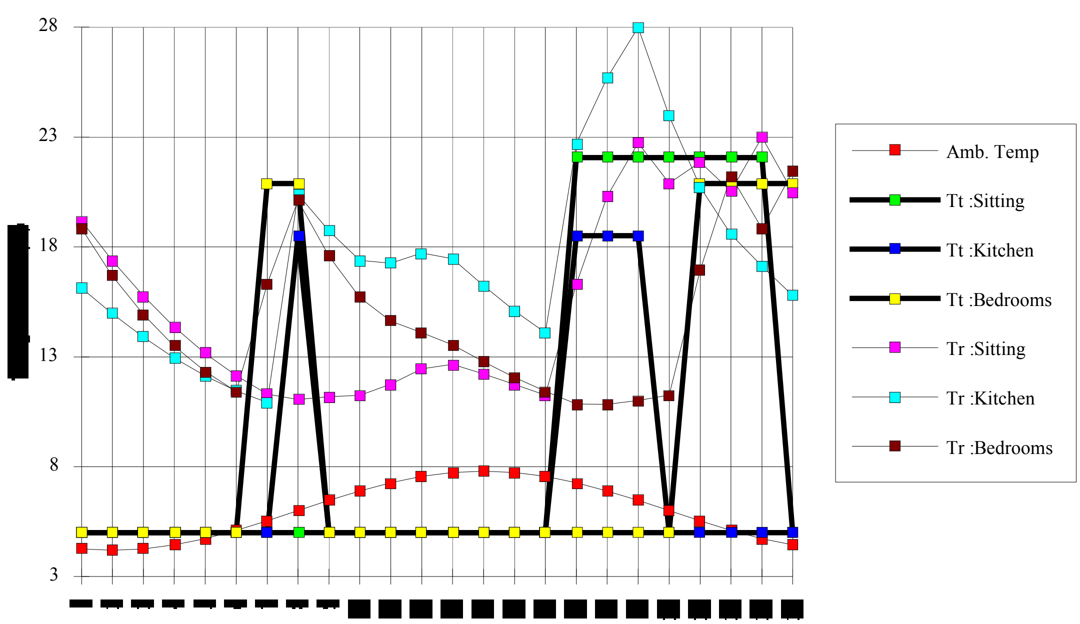


Figure 6-4 shows how the demand for space heating energy varies with different values for four parameters: clothing, insulation, unzoned or zoned heat controls, and low thermal mass construction.

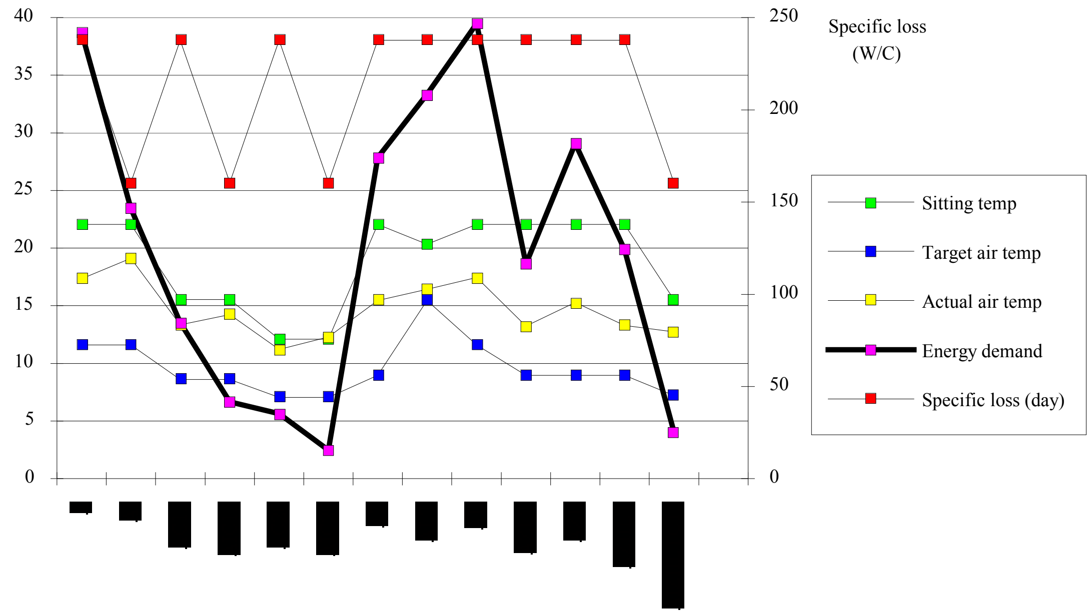
The key for the cases analysed is as follows:

A	average family occupancy
I	insulated
C15	clo value 1.5
Z	zoned
LT	low thermal mass

Of most interest here is the variation in energy need with clothing level and insulation. Insulation reduces space heat demand by 40%, whereas increasing clothing from 0.55 clo to 1.5 clo reduces energy consumption by 65%. A model run, not shown in the Figure, shows a reduction in energy demand of 31% is achieved by increasing clothing to 1.0 clo.

In controlling a heating system, the optimum results is obtained when each space heated only when required. In most UK houses, central heating systems are simply controlled by a timer which usually allows for one or two heating periods per day. However, the central heating heats the whole house during these periods, or at least all those rooms with radiators. Typically there is no point in heating the whole house at any particular time: bedrooms are often unused when the kitchen or sitting room is in use, and so on. The modelling results show that separately controlling the sitting room, kitchen and bedrooms (zoning) brings about savings of 30%. This is the maximum potential: in reality people vary their use of rooms and the transfer of heat from one part of the house depends greatly on internal construction and whether doors are left open.

Figure 6-4: House space heat needs



It takes some time to raise the temperature of a house, and for the house to cool when unheated. Usually this heating and cooling occurs outside of occupied periods, and the heat lost in these periods is wasted. The thermal mass of a building is the amount of heat needed to raise or lower its temperature by some specified amount, say 1^{o}C. Lowering the thermal mass makes the building heat up and cool quicker, and less heat is wasted. The model indicates that reducing the thermal mass of a house by 50% reduces energy consumption by 14%.

The national potential for savings through better clothes

It has been beyond the scope of this work to separately model a range of different dwelling types and occupancy patterns, or to model the effects of clothing levels on space heat use in commercial and industrial buildings. The estimates of national savings due to increased clothing levels have been made by generalising from the individual house analysis above. A number of important qualifications must be made when generalising - the most important of these are :

i. The comfort relationships assumed are for healthy adult men and women. Special consideration has to made for people who are ill, very old or very young. In such cases minimum temperatures may be higher than for the 'norm'.

ii. As studies have found, there is a wide spread of temperatures sustained in people's homes. Data are sparse, but it is clear that in the UK a substantial number of people have inadequate heating, and that this is mainly due to poverty (Boardman, 1991). As this author stresses, underheating leads to miserable conditions, and to ill health and death. The UK has a greater seasonal variation in mortality than most comparable countries, and the clear inference is that this is due to low temperatures because of inadequate heating. It is also clear however, that a substantial amount of overheating also occurs. According to analysis by the DoE (DoE; 1991) 28% and 10% of houses are warm and very warm respectively; and 13% and 2 % are cold and very cold. Plainly the energy savings possible due to clothing depend on the base temperature. The view is taken here that the underheating which occurs, is approximately balanced by over heating, and therefore the estimates of savings using averages will be reasonably accurate.

iii. Clo values can act only as a guide to the comfort afforded by clothing. A warm sweater and jacket will not do much for comfort if one has no trousers on. At low temperatures it becomes difficult to keep uncovered extremities such as hands and face comfortable. The author found that below about 12 to 14^{o}C it was necessary to wear fingerless gloves to keep fingers warm enough for typing.

iv. Everett et al (1985) and Lowe et al (1985) report the whole house temperatures recorded in low energy houses in Milton Keynes. The high insulation levels coupled with high thermal mass and incidental gains effectively set a minimum to indoor temperatures. Apart from this, there were ranges similar to those found by Oseland and Raw, and to those found in other studies, with the exception that very low temperatures were not found. These studies of low energy houses found that a 1^{o}C change in average house temperature changed house space heating requirements by 10-15%. This relationship is confirmed by the author's modelling experiments and so the importance of clothing in terms of proportionate savings remains even under the assumption that the future UK housing stock has high conservation levels.

v. People often share spaces at home and at work. The indoor temperature in shared spaces is usually set to make the least clothed or least active people comfortable. This in turn means that the majority of people have to wear less clothes than perhaps they would wish in order to be comfortable.

vi. There is little information about clothing levels of people at work rather than at home.

These issues require further detailed work.

The modelling results indicate that clothing might save between 30% and 65% of energy for clo values of 1.0 and 1.5 respectively for a typical house and family, as compared to assumed base level clothing of 0.55 clo. Given that space heating gives rise to about 24% of UK emissions, clothing would reduce UK emissions by between 7% and 16%. Given the considerations i to v above, it would seem reasonably cautious to take 10% as a realistic estimate for overall national savings.

Table 6-1 give some typical clo values (from Nevins et al; 1974) for various articles of clothing. The Table also shows the approximate room temperature reduction equivalent, and the energy and carbon savings produced if everybody additionally wore that item of clothing. To a first approximation one can find the total clo value by simply adding the individual clo values for each item of clothing worn. Therefore, given the rule of thumb of 6 ^{o}C per clo, one can estimate the effect of each item. Thus a warm sweater or jacket is worth some 2 to 3 ^{o}C, warm trousers 2 ^{o}C, and (if you like that sort of thing) lined knee high leather boots 2 ^{o}C.

It is perhaps not a socially inconceivable notion that people might wear warm vests rather than no vest (3% reduction in UK carbon emission); sweaters rather than no sweaters (3.7%); warm rather than cool jackets (1.2%), and heavy rather than light trousers (0.6%); or the equivalent of these. If they did, UK carbon emission would fall by about 8.5%, which is more than a third of the way towards the Toronto target.

If a man wears a warm vest, a warm shirt, a warm sweater, a cool jacket, briefs, warm trousers, warm knee socks and high shoes then the total ASHRAE adjusted clo value is 1.6. The comfort temperature for this level of clothing is 15.8 ^{o}C if sitting, more than 5 ^{o}C less than for typical clothing levels in houses. If everyone wore such clothing, then as argued above, UK emissions would be reduced by up to 16% - maybe 10% after allowances have been made.

If a person wears a warm rather than cool jacket, and thermal underwear, then the ASHRAE clo value is 1.9 and the sitting comfort temperature drops to 12.8 ^{o}C: UK carbon emissions due to space heat would fall by 80%, and UK emission would be reduced by 19% after making allowances. As noted above, such low temperatures would probably cause discomfort for some people. If so, other measures such as extra, and possibly socially unacceptable clothing such as gloves would be required. Alternatively, spot heating could be focused where required. The author directed his angle poise lamp at his hands to provide extra warmth.

6.2.1.2 Commentary

The analysis quite clearly shows the importance of clothing levels on energy used for maintaining thermal comfort. For modest increases in the levels of clothing which are currently worn, energy savings of the same order as those which might be obtained by insulation can be achieved. For higher clothing levels, savings well in excess of those arising from insulation are possible. Of course, both measures should be deployed - insulation and better clothing. Clothing still reduces energy consumption by a substantial proportion if the building is insulated.

It seems reasonable to conclude that extra clothing could reduce UK emissions by around 10%. This potential reduction will diminish as insulation levels increase. However the current trend towards decreasing clothing levels and more prevalent overheating could substantially maintain the potential savings due to increased clothing levels.

The economics of clothing is not analysed here. However it is obvious that the cost of energy saving (£/GJ) through insulation is increased if higher levels of clothing are worn. This is not to imply that clothing should be seen as a replacement for cost-effective insulation and ventilation control. Clothing can make significant savings at most practicable insulation levels. Furthermore, there are reasons for limiting the extent to which conservation acts in existing buildings. Very high levels of insulation are difficult to integrate into existing buildings, and ventilation control has its limits for technical reasons and because indoor air pollution can become a problem at low air change rates.

Table 6-1 : Clothes, temperature, energy and carbon emissions

	Item	Insulation Value (Clo)	Temp equiv (^{o}C)	Energy Saving (PJ)	Carbon saving (MtC)	Proportion of UK carbon
Women	**Cool vest**	0.20	1.2	108	3.1	2.0%
	Warm vest	0.30	1.8	162	4.7	3.0%
	Long underwear tops	0.25	1.5	135	3.9	2.5%
	Cool long sleeve blouse	0.20	1.2	108	3.1	2.0%
	Warm long sleeve blouse	0.29	1.7	157	4.5	2.9%
	Cool sleeveless sweater	0.17	1.0	92	2.7	1.7%
	Warm sweater	0.37	2.2	200	5.8	3.7%
	Cool jacket	0.31	1.9	167	4.8	3.1%
	Warm jacket	0.43	2.6	232	6.7	4.3%
	Warm tights	0.25	1.5	135	3.9	2.5%
	Long underwear bottom	0.25	1.5	135	3.9	2.5%
	Thermal underwear bottom	0.35	2.1	189	5.5	3.5%
	Warm skirt	0.22	1.3	119	3.4	2.2%
	Cool trousers	0.26	1.6	140	4.1	2.6%
	Warm trousers	0.32	1.9	173	5.0	3.2%
	Cool knee socks	0.06	0.4	32	0.9	0.6%
	Warm knee socks	0.08	0.5	43	1.2	0.8%
	Shoes	0.03	0.2	16	0.5	0.3%
	High shoes	0.15	0.9	81	2.3	1.5%
	Knee high boots	0.25	1.5	135	3.9	2.5%
	Knee high lined boots	0.30	1.8	162	4.7	3.0%
	Cool dress	0.17	1.0	92	2.7	1.7%
	Warm dress	0.63	3.8	340	9.8	6.4%
Men	**Cool vest**	0.2	1.2	108	3.1	2.0%
	Warm vest	0.3	1.8	162	4.7	3.0%
	Long underwear tops	0.35	2.1	189	5.5	3.5%
	Cool shirt long sleeve	0.14	0.8	76	2.2	1.4%
	Warm shirt	0.37	2.2	200	5.8	3.7%
	Cool sleeveless sweater	0.17	1.0	92	2.7	1.7%

	Warm sweater	0.37	2.2	200	5.8	3.7%
	Cool jacket	0.35	2.1	189	5.5	3.5%
	Warm jacket	0.49	2.9	265	7.7	4.9%
	Long underwear bottom	0.25	1.5	135	3.9	2.5%
	Thermal underwear bottom	0.35	2.1	189	5.5	3.5%
	Cool trousers	0.26	1.6	140	4.1	2.6%
	Warm trousers	0.32	1.9	173	5.0	3.2%
	Cool knee socks	0.06	0.4	32	0.9	0.6%
	Warm knee socks	0.08	0.5	43	1.2	0.8%
	Shoes	0.04	0.2	22	0.6	0.4%
	High shoes	0.15	0.9	81	2.3	1.5%
	Knee high lined boots	0.3	1.8	162	4.7	3.0%
	Overalls	0.55	3.3	297	8.6	5.5%

Clothing 'technology'

Everyday clothing is designed with aims such as good style, practicality, and economy. Clothing for extreme environments is designed with the thermal comfort as a high priority. Such clothing uses design features for dynamic thermal regulation. Wearing high levels of clothing makes it easy to overheat when increasing activity, from sitting, for example, to working. Thus special clothing might have vents which through which warm air is lost by bellows action when a person is active - a sort of negative feedback cooling system. The advent of new materials and control technologies potentially allows for advances in the design of clothing which is thermally appropriate, and yet acceptable in terms of the other aims of clothing design set out above.

Micro design

It is possible to improve thermal comfort by design at an intermediate scale between that of clothing and room or house. People spend a large and probably increasing proportion of time sitting down at work or at home, and design effort could be put in here. Furniture, such as the old high backed padded armchairs, can effectively increase the clo value. Modern materials and designs might be used to produce furniture which is attractive, convenient and effective.

Spot heating with radiant electric fires used to be very common. These focus heat on or near people. For short periods people, or at least one side of them, are heated, rather than heating the whole room. Eventually the heat is transferred to the whole room.

Nonetheless significant savings could be accrued from modern equivalents of heating appliances which are focused in space and time.

Building design

The modelling results revealed a number of factors which should be included in designing for energy conservation in heating systems. As was illustrated, for a typical house and occupants, most rooms are used intermittently. Substantial gains could be made if the heating of buildings were better zoned, and if the thermal mass of the building were less. Heating control systems should therefore individually control the temperature and heating timing of each major zone or room of the house. Consideration should be given to thermally isolating the zones within houses such that the heat transfer from zones which need heating (such as a sitting room) to ones which do not (unoccupied bedrooms) is reduced.

6.2.2 Electric Appliances and Lighting

Domestic electric appliances and lighting are responsible for about 15% of UK carbon emissions. A number of studies (for example Johansson et al, 1989; Eyre, 1990; March, 1990) have assessed the technical and economic potential for energy savings in this class of equipment. Table 6-2 summarises estimates made by the author of electricity consumption, emission and savings for UK domestic electrical appliances and lighting. It has been assumed that 1990 emissions and electricity generation are the benchmark. The maximum savings relate to the best current prototype models which may be commercially available in less than ten years. The last column shows the non discounted cost of electricity saving based on an assumed average price of domestic electricity of 7 p/kWh.

If consumers were to select the best appliances, the electricity consumption of this class of equipment may be reduced by about 44 TWh, or 80%, from 54.8 TWh to 10.6 TWh. This would lead to a reduction of about 5.5% in UK carbon emissions. This category of reduction should perhaps not be included as a lifestyle change since there is often no appreciable outward difference between low and high energy appliances.

Eyre has analysed the potential for electricity savings due to lighting in all sectors. He estimates that the minimum potential reduction of some 20 TWh is equivalent to 2% of UK carbon emissions. For the service sector, he estimates that 12.7 TWh could be saved economically. However, this saving can not be brought about by the private behaviour of people, it requires business decisions by managers in that sector.

Table 6-2 : Domestic electric appliances and lighting

	CURRENT STOCK							CONSERVATION			
	Electr-icity use	**Life**	**Owner-ship**		**Carbon Emission**		**Electr-icity Cost**	**Maxi-mum saving**		**Extra Cost**	**Cons-ervation Cost**
	kWh/a	yrs	%	TWh	MtC	%UK	M£	%	TWh	£	p/kWh
Fridges	300	12	57%	3.9	0.8	0.5%	271	90%	0.4	45	1.4
Fridge/freezers	725	12	43%	7.1	1.5	1.0%	494	85%	1.1	70	0.9
Freezers	725	12	39%	6.4	1.3	0.9%	450	90%	0.6	80	1.0
Washing machine	200	12	86%	3.9	0.8	0.5%	271	65%	1.4	45	2.9
Cooker	1000	12	45%	10.2	2.1	1.4%	713	80%	2.0	150	1.6
Colour TV	280	8	89%	5.6	1.2	0.8%	395	90%	0.6	30	1.5
B&W TV	100	8	43%	1.0	0.2	0.1%	68	60%	0.4	10	2.1
Clothes dryer	300	10	31%	2.1	0.4	0.3%	147	75%	0.5	50	2.2
Dishwasher	500	10	7%	0.8	0.2	0.1%	59	80%	0.2	100	2.5
Miscellaneous	250	10	100%	5.7	1.2	0.8%	396	60%	2.3	40	2.7
Lighting	360	8	100%	8.1	1.7	1.1%	570	85%	1.2	30	1.2
Hot water	1000	15	68%	15.4	3.2	2.1%	1077	70%	4.6	300	2.9
TOTAL				54.8	11.5	7%	3834		10.6		

6.2.3 Hygiene (hot water)

Some 6% of carbon emission arises from the provision of hygiene services with hot water. It has been beyond the scope of this study to analyse the pattern of hot water use for personal hygiene (showering, bathing), and for the cleansing of dishes, clothes and other miscellaneous items. Even less has there been time to accurately estimate savings due to lifestyle change. However some indication of the scope may be taken from the estimates that showering uses less than 50% of the hot water used in a bath, and that washing dishes by hand uses about 30% to 70% of the hot water used by a typical dishwasher.

6.2.4 Summary

Increased clothing could probably reduce UK carbon emissions by something in the range 7% to 16% - although greater reductions might be possible if better designs of thermal clothing were to become available. A value of 10% is assumed to be feasible in the medium term.

The prudent selection of domestic electric appliances and lighting equipment could reduce emissions by up to 5.5% over the next ten to twenty years provided the more efficient models are marketed. Perhaps assuming 3% savings over fifteen years is reasonable cautious.

Potential savings for other building services including hygiene have not been assessed here.

Overall then, carbon emission might be reduced by 10% to 21.5% through lifestyle change and private consumer decisions in the building services sector. An overall figure of 13% is taken as being feasible.

6.3 Passenger transport

This section analyses the pattern of passenger transport in the UK. It systematically assesses the effects of changing transport demand, selecting technologies and using technologies efficiently such that emissions are reduced. A model (NTSMOD)developed by the author which is based the National Travel Survey (NTS) has been used to estimate the pattern of emission arising from current surface passenger transport, and to estimate the effect of the behavioural changes analysed in this section. Air transport has a number of special features and so is treated separately.

In 1990 about 27% of UK primary energy was used in providing transport, and this resulted in a carbon emission of some 40 MtC which is 26% of UK carbon emission. It is difficult to precisely allocate the use of transport fuels separately to passenger and freight transport because of a lack of statistical information. Nevertheless, it can be estimated that about 20% of primary energy is used for passenger transport, and for this latter it results in about 28 MtC of carbon emissions (18% of UK). Road and rail passenger transport account for about 80% of passenger energy use and emission (22.4 MtC), and air passenger traffic accounts for the remaining 20%.

A later section discusses the role of aircraft in global warming. Although is relatively minor in terms of carbon emission, being about 20% of passenger transport, it is probable that its significance in terms of global warming is much greater.

People travel from place to place for a variety of reasons to do with work, education and pleasure and so forth. The more trips made, and the longer, the more energy is used and the greater the emission of pollutants. People use many means of transport: foot, cycle, car, bus, train and plane being the most common. These means have very different implications in terms of energy use, carbon emission and environmental impact.

In general energy use and carbon emissions resulting from passenger transport increase as:

- the total distance travelled increases (i.e. number and length of trips);
- the speeds and accelerations involved in travel increase;
- trips shift to cars from other modes;
- the proportion of seats occupied on vehicles has falls;
- the fuel economy of vehicles decreases.

These factors will be assessed separately in the following sections, and then the model will be used to estimate quantitative changes in emission. In all the following analysis it is assumed that the <u>number</u> of trips made is unchanged. People will enjoy the same amount of access to business and leisure facilities as at present. The potential savings which might arise from more radical changes in lifestyle such as mass home working are not estimated.

6.3.1 Past, Present and Official Future

The past four decades have seen the total distance travelled by people in the UK increase by more than 200%. At the same time the predominance of the car has grown such that its share has risen from 27% to 85% of passenger kilometres; whilst simultaneously the share of cycling and bus has fallen in proportional and absolute terms. The distance (in passenger kilometres) travelled by bicycle has fallen by over 75%, and by bus over 50%.

Figure 6-5: UK Domestic Passenger Transport: 1952-1990

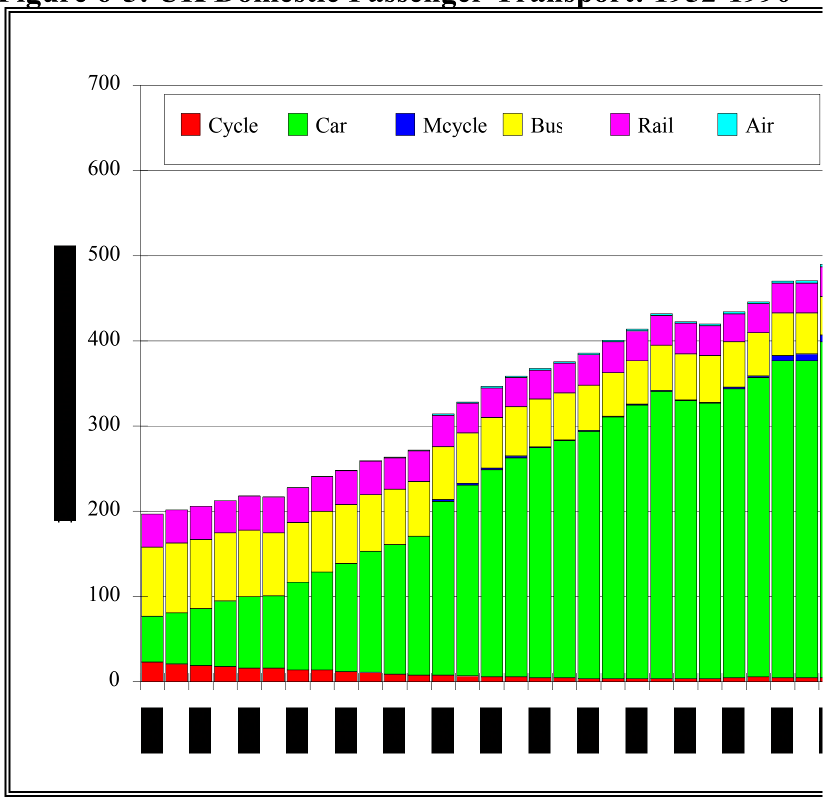


Figure 6-6 shows the cumulative carbon emission for passenger transport for stage lengths up to a certain distance as calculated with NTSMOD. This excludes international air transport. 80% of carbon emissions arise from journeys of less than 100 km (60 miles). The graph also demonstrates the overwhelming dominance of the car. This highlights the importance of addressing emission control for short journeys, and for controlling emission from cars.

Figure 6-6: Cumulative Carbon Emission by Purpose, Mode and Trip Length

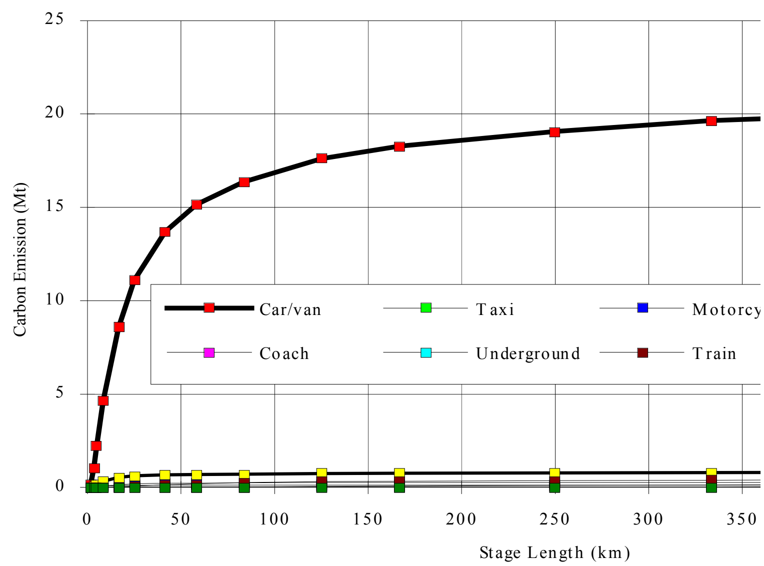
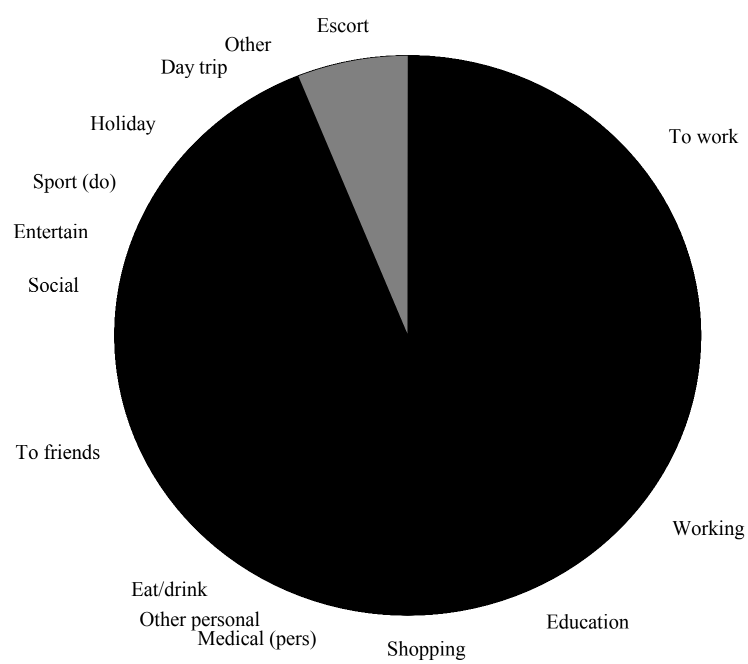


Figure 6-7 shows the allocation of carbon emission to the various purposes of travel. This has been calculated using NTSMOD in conjunction with the journey structure data given by purpose in the NTS. To a first approximation carbon emission patterns reflect the distribution of passenger kilometres across purposes. The correspondence is not exact however because factors such as modal mix, vehicle occupancy rates, and congestion are different for the various purposes.

Figure 6-7: Carbon emission by purpose of travel



Travelling to and from work gives a rise to about 28% of emission, and travelling during the course of work to 15%. Visiting friends accounts for 16%, and shopping for 9%.

These travel purposes have spatial and temporal journey patterns typically associated with them. For example, travelling to and from work predominantly occurs during fairly narrow morning and evening periods. These journeys also result in a large diurnal tidal flow in and out of employment centres. These characteristics impact heavily on congestion and the potential scope for switching economically to public transport modes. Visiting friends on the other hand, has much less regularity in terms of timing (although it mostly occurs outside of the working day) and origin and destination. Prima facie therefore, there are reasons for supposing the scope for shifting these journeys to public transport is less.

6.3.2 The Official Outlook

The Government forecast of future road transport demand is embodied in a projection made by the DTp, and this is summarised in Transport Statistics of Great Britain (1991) in Table 2.47. Car traffic is projected to increase in the period 1990 to 2025 by between 71% and 113%; goods vehicle traffic by 64% to 195%; and bus traffic to remain static. The DTp projection is based on a few assumptions and relationships, the most important being GDP, fuel prices, demand elasticity and household size. There is an assumption that the quality of service will not change significantly in that congestion will not increase so as to increase travel time. The official forecast does not analyse a number of matters in an explicit way, at least publicly. The implications of the traffic forecast in terms of number and lengths of trips by purpose are not expressed. Neither are the consequences for congestion analysed, nor the load factors of cars. No government Department, including the DTp and the DoE, has published any detailed assessment of the environmental impact of the traffic forecast, or indeed of the possible effects of emission bubble limits or other environmental regulation on growth.

The official projection can not easily be used as a benchmark with which to compare the scenarios developed here. Indeed, one must question whether the forecasts are credible given that important factors and interactions are ignored in the forecasts. Therefore it is best to view the estimates of emission savings due to various measures made below as <u>relative</u> to the "official future", rather than in absolute terms. This issue is revisited at the end of the section on passenger transport.

6.3.3 Demand choices

The demand for passenger transport may be defined in terms trips or journey stages which can be classified by purpose, frequency, length, timing, means of transport, speed and so forth. The most detailed national study of this kind for the UK is the National Transport Survey (NTS). Although extremely useful, the NTS is a description of the travel phenomenon arising from the context of its time. Other information, analysis, theorising and speculation is required in order to understand why people travel as they do, and to suggest how the pattern of travel might change fortuitously, or be changed deliberately, in the future.

Steadman and Barrett (1991) investigated the potential impact of town planning on transport demand and reviewed some of the factors which influence the demand for transport. They found that there was evidence that land use and transport planning could significantly reduce the demand for transport over a period of one to two decades. There is evidence which strongly indicates that land use change, such as out-of-town shopping, is important in increasing transport demand. The authors concluded that land use planning could reduce total transport emissions by 10-15% over a period of 25 years. Planning is however generally outside the control of most citizens.

However, it seems that people are making short and medium term private decisions which lead to demand growth. As mass car ownership increases and car travel costs decline relative to income, there has been an increased propensity to travel greater distances quite independently of land use change. Longer trips are made to and from work, and for recreation. NTS data indicate that the average length of journey increased by a third between 1975 and 1985. A significant part of this increase is due to these consumer choices, rather than change in physical land use pattern. It is difficult to quantify the extent to which the average length of journey could be reduced by choices such as deciding to leave near work, or going to local rather than distant shops, pubs, schools and so on. Figure 6-7 above showing the distribution of carbon emission by purpose of travel indicates that private decisions to live near work and friends, and use local shops are most important. The scope for telecommuting and teleshopping have increased with the development of information technologies - this is discussed briefly by Steadman and Barrett. As time passes the proportion of economic activities which can be conducted with such technologies will probably increase, thus decreasing the essential need to travel for those purposes. A recent study by Strategic Workstyles called The Economics of Teleworking concluded that 15% of the working population could work from home, and that this would save £2 billion per year in fuel. Carbon emissions would fall by about 4% if 15% of travel to work were to cease (15% of the 28% estimated above). However reductions through teleworking and tele-other-things may be counterbalanced by leisure travel.

The author suggests that a reduction in average journey length of 10% through individual decisions about location and use of local facilities might be feasible over a ten year period.

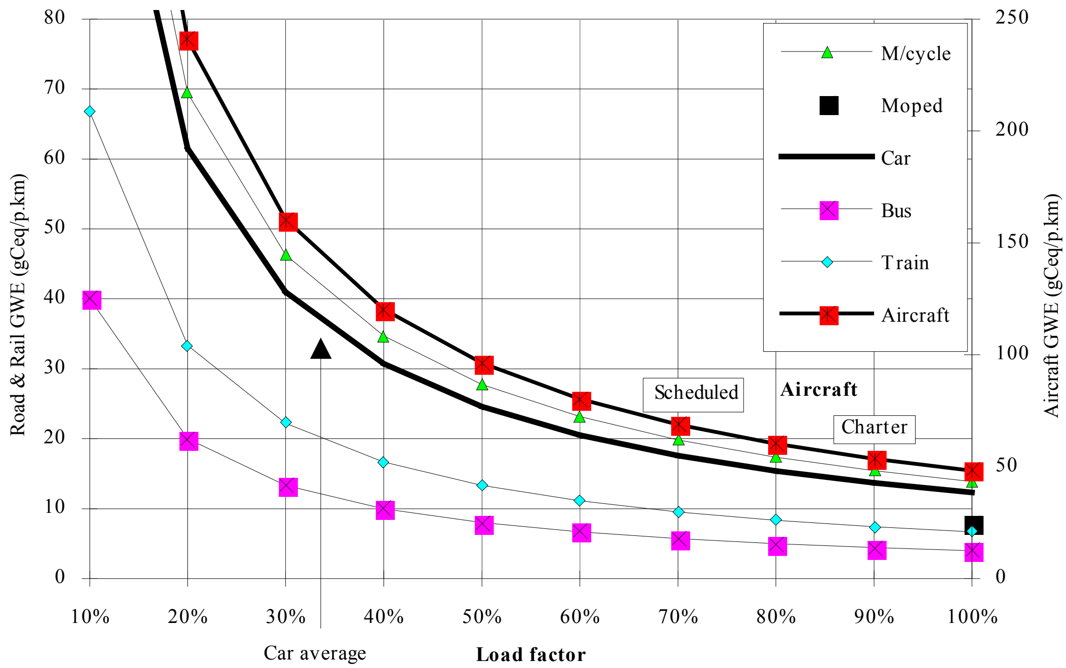
The frequency of trips (journeys made each week for various purposes) has changed more slowly than journey length historically. Transport technology and land use change has had little effect on the need to journey to work and school, or the desire to seek recreation away from home - but it has made it easy to travel further. It has been assumed in the projections made below that the number of trips does not change.

6.3.4 Transport modes

The choice of mode for travel makes a large difference to environmental impact. Walking, cycling and other human powered means of travel incur negligible extra environmental impact in terms of emissions, or indeed anything else. Mechanised forms of transport display an enormous variation in emissions. Perhaps the three most important factors are the size of vehicle, occupancy rate or load factor, and speed.

Figure 6-8 below shows the Global Warming Effect (GWE) of travelling a kilometre by different modes. This Figure is based on fuel consumptions for the different modes which may be considered typical, but for most modes of consumption range of at least 2:1 will be found because of differences in technology and operating conditions. GWEs are expressed here in terms of grammes of carbon equivalent (g Ceq), that is to say the GWE as compared to that brought about by 1 g of carbon. Aircraft emit nitrogen oxides (NO_X) which produce ozone - a global warming agent of great effect at the altitude at which aircraft commonly fly. To allow for this NO_X effect, aircraft carbon emission has been multiplied by a factor of 2.5 to convert to Ceq . This factor could be larger or possibly smaller, and its value depends on the time scale of warming being considered. Even if the factor were zero, aircraft would in most circumstances be the worst mode of transport. (Note that air travel has a separate y axis because it emits so much more than the other modes). Surface vehicles also emit gases other than carbon dioxide, including NO_X (but at ground level), which affect global warming. At present however, it is thought that the effect of these gases is much less than that of the carbon dioxide. (A probable exception to this is the GWE of refrigerant fluid loss from vehicles with air conditioning). The load factor is the proportion of carrying capacity used which for passenger transport is taken to be the percentage of seats occupied. Note that by this definition many rush hour buses and trains have load factors greater than 100% because of people standing. To a good approximation the energy use of most modes is independent of the proportion of seats occupied.

Figure 6-8: Global warming of transport modes



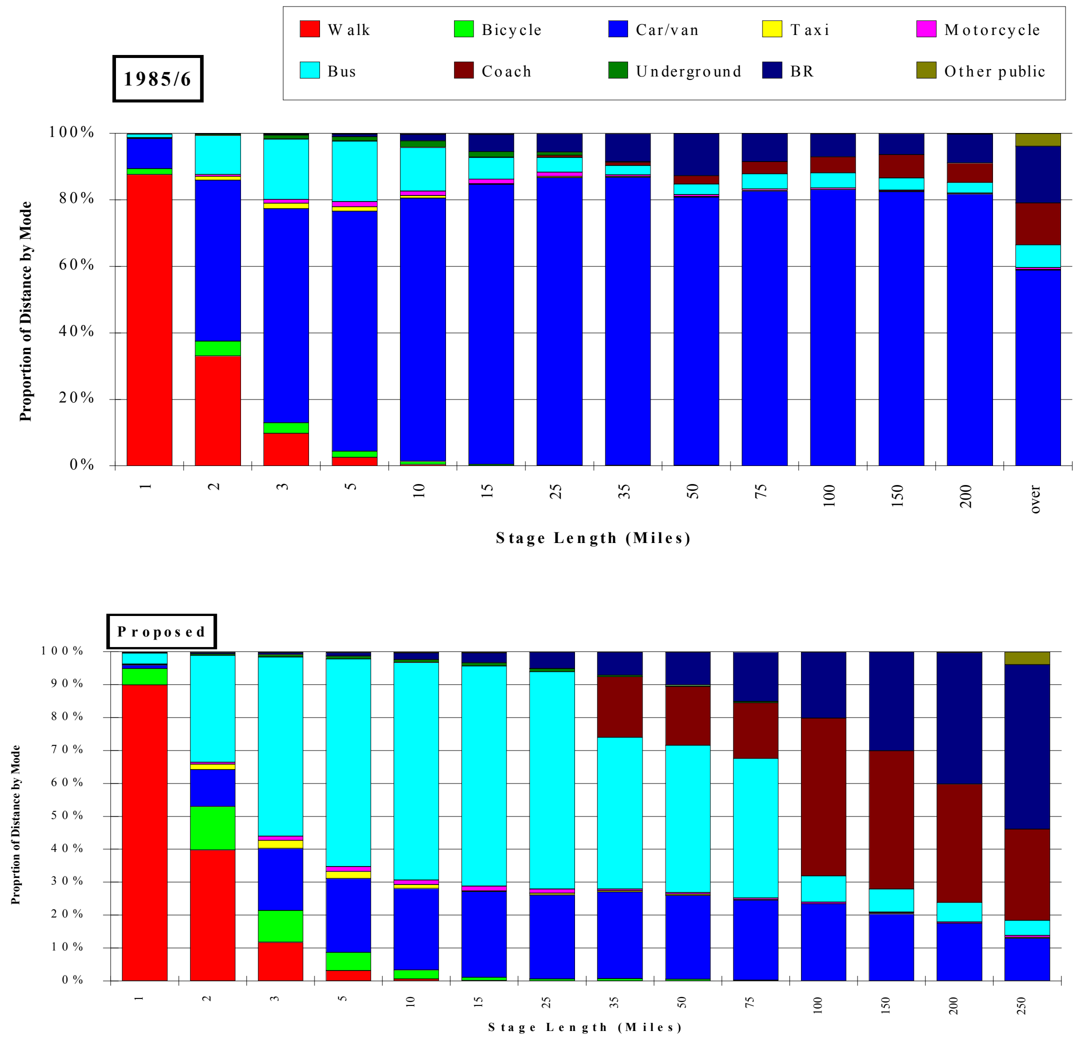
It is quite clear that provided the load factor is above a minimum, that in most conditions buses and trains are superior to cars in terms of global warming. In terms of private mechanised transport the moped is best and is superior to buses or trains except when these have high load factors. The bus is generally superior to the train although in practice the distinction is not so clear because of the large range of designs and operating conditions of these modes. As well as reducing emissions, switching to modes of surface transport other than the car lead to less congestion. This improves energy efficiency all round, enhances the prospects for pedestrians and cyclists, and reduces other impacts due to cars such as visual impact and social division in urban areas.

Plainly the GWE of different transport modes is such that a shift to any mode other than the car except for aeroplane (and perhaps motorcycle) will reduce emissions substantially. Unfortunately there have been no detailed studies of the potential for modal shift, and the consequences thereof, in social, economic and environmental terms, for the UK as a whole. The modal shift assumed to be feasible by the author follows from a series of judgements based on historical evidence, and generalisations from national studies for other countries (e.g. for the Netherlands: Novem), and certain local studies for the UK. Figure 6-9 shows the current modal split for different stage lengths, and the proposed future modal split. Currently travel by car is the dominant mode for all stage lengths except those less than one mile.

For the shortest distances a small shift to foot and bicycle has been assumed. For medium distances a substantial shift to buses is assumed possible. The reason for this is the energy efficiency of buses, and their flexibility and low infrastructure costs as compared to train or tram. A large proportion of the investment would be in the buses themselves, and the road capacity would of course be adequate because overall vehicular traffic would be reduced with the shift from car to bus. For longer stage lengths it is assumed that rail and coach can displace the car to a significant degree. The potential for a shift from car to rail may be quite constrained in the short term because of the relatively limited track routes and access points (stations) as compared to road. It has therefore been assumed that a significant amount of long distance travel is by coach. A certain degree of shift from car to bus and train could be realised, especially at off-peak times, without any significant additions to the capacities of these modes. However the modal shift assumed here would entail extra investment both in rolling stock, and in infrastructure such as railway track and bus and rail stations. There would however also be savings in the short and long term because of reduced congestion and less requirements for road building and road transport servicing.

The potential reduction offered by the moped has been omitted here. Given their low speed and lack of comfort, they would not be suitable for longer journeys. However they might be a useful means for some journeys up to 10 to 20 km.

Figure 6-9: Modal split – 1985/6 and proposed

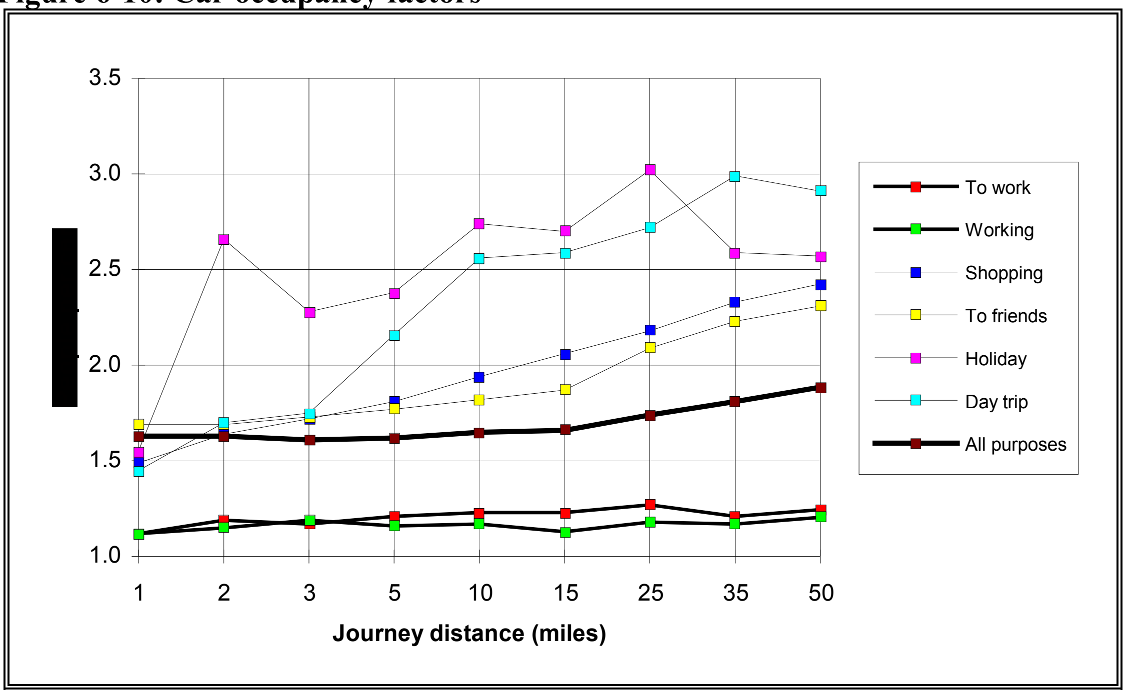


6.3.5 Using cars efficiently

People can significantly reduce the fuel use and carbon emissions of car travel by planning, coordination and careful driving.

The first consideration is planning to minimise the number and length of journeys made by car. There is no doubt that the marginal financial cost of car travel is so small for most people that they are careless in planning their use of cars. For most people small but significant reductions in emissions could be made. For example: the nearest shops or facilities could be used; or journeys could be integrated (for example combining shopping with transporting children). It is difficult to assess from travel data the savings that could be so made. Apart from reducing the total distance the car travels, integrating trips would mean that there would be fewer cold starts, and cars use two to four times as much fuel for the first 5 to 10 km if cold rather than hot (see an account of this below). It is also worth trying to use cars when the roads are less congested. Some TRRL research (Waters, Laker; 1980) suggests that congested traffic conditions increase fuel consumption by some 25%: other researchers (Easingwood Wilson et al; 1977) reported that in Glasgow an instrumented car spent 40% of its time stationary during which some 20% of fuel was used. The impact of modal shift on congestion is discussed in the concluding section.

Figure 6-10: Car occupancy factors



Driving more carefully can reduce fuel consumption and emissions significantly. Good anticipation and low acceleration and deceleration can reduce consumption; researchers at TRRL (Laker, 1981) found that drivers on an urban test circuit could reduce fuel consumption by some 20% by careful driving. Although some of this reduction was due to lower speeds, some 75% of the saving was achieved by more economical driving. Cruising more slowly saves fuel. A petrol car driven at 80 kph (50 mph) rather than the UK maximum limit of 115 kph (70 mph) uses 20% to 25% less fuel per kilometre. Analysis by Fergusson and Holman (1990) showed that the total fuel consumption of UK cars would fall by 2.4%, 4.4% and 5.8% if motorists adhered to maximum speed limits of 70 mph, 60 mph and 50 mph respectively.

To a first approximation the amount of fuel used by a car does not increase with the number of people in the car. Currently cars are typically two thirds empty, with an average of some 1.7 people in cars which can usually carry five people. Figure 6-10 shows how car occupancy varies with distance and purpose of travel. As might be expected, occupancy generally increases with distance; and is low for work related travel but high for holiday travel.

If average occupancy could be increased to 1.8 people, emissions would drop by some 5% to 10%. This would be the equivalent to the occupancy of cars used for travelling to and from work increasing by 30%. The potential increase is larger for travel to and from work than most purposes because the occupancy rate is currently low, and because there is one common terminal (the place of work) shared by many employees.

It would seem reasonable to assume that fuel savings in cars of 10% to 20% could be made by the above behavioural changes in car use: a mid range figure of 15% is taken.

6.3.6 Buying cars

Considerable reductions in fuel consumption and emissions could be obtained if people chose the most fuel efficient cars. In a certain technical sense the efficiency of cars has been increasing in the post war period because of improvements to many aspects of the engine, transmission, body and tyres. However the average speed and acceleration of cars marketed and purchased has increased to the extent that many cars today would have been thought of as sports cars three decades ago. Worsening congestion has also limited potential gains realised through technical improvements. An interesting question then is: how much would fuel consumption be reduced if people bought the most fuel efficient cars available?

A database of over one thousand commercially available cars has been assembled. These range from 300 cc diesel mini-cars available in France to large luxury cars such as the Rolls Royce. The fuel consumption of these cars is determined in three standard EC driving cycles (urban cycle, steady 56 mph, steady 75 mph). The cars are allowed to warm to laboratory temperature and then idled for 40 seconds before testing. They are neither cold, nor fully warmed up. The EC test figures may be weighted to give an indicative overall figure for fuel consumption. Respective weightings of 40:50:10 for urban, 56 and 75 mph cycles have been used here, as are sometimes used by the DTp.

Table 6-3 : Petrol and diesel fuels compared

		Petrol	Di
Density	kg/litre	0.738	0.
Energy	MJ/litre	34.7	3
Carbon	%C wt	87.6%	86.
	gC/litre	646	
	gC/MJ	18.6	1
Adjust			
Refinery overhead?		1.05	1
Cold start		1.19	1
Adjusted	C/litre	681	

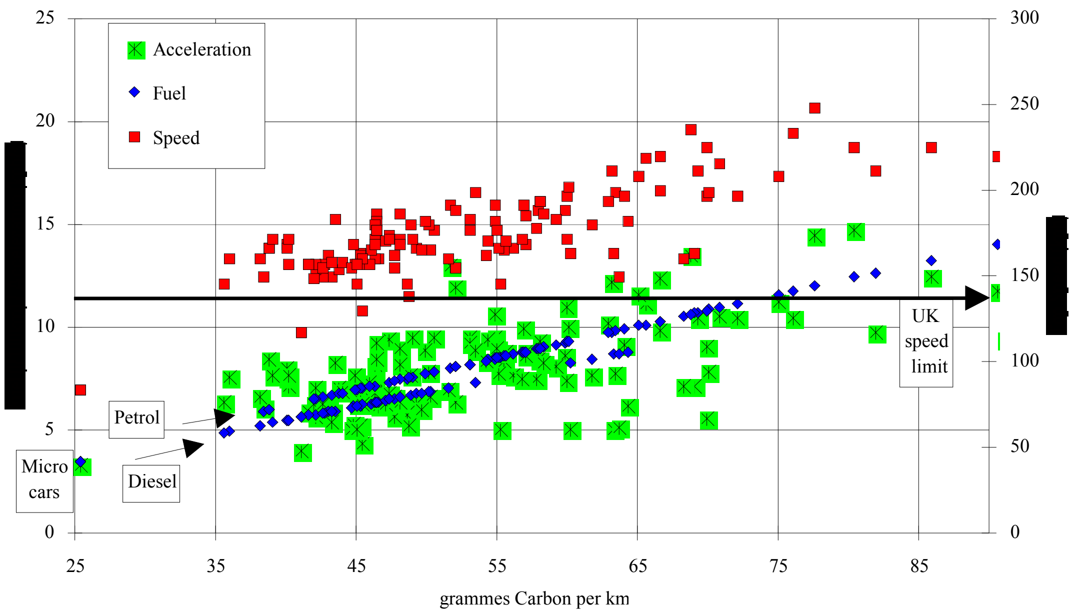
These test data have to be adjusted to account for the different physical characteristics of petrol and diesel fuel, and to make some allowance for actual conditions cars are operated within. Also, the energy overhead incurred in refining petrol and diesel should be added in. The overhead is different for petrol and diesel, and depends on many factors including the sulphur contents of the crude oil, and the maximum allowed trace element component of petrol and diesel. Most importantly, diesel is 15% denser than petrol, and contains more carbon and energy per litre. Consequently, in terms of carbon per energy (grammes of carbon per MJ), petrol and diesel are almost the same.

For a given performance in terms of acceleration, diesel cars consume less fuel in terms of l/100km as determined by EC test cycles. Pearce and Waters (1980) have conducted tests on the cold start performance of a diesel and a petrol car. These tests showed that cars perform badly when cold consuming three to five times as much fuel per kilometre as when fully warmed up. These researchers estimated that for travel patterns described by the National Travel Survey, if 50% of car journeys were from cold starts, the petrol car would use 1.19 times its warmed up consumption, and the diesel car 1.06 as much. These figures are used to adjust the test cycle fuel consumption. It may be that a higher proportion of starts are cold, but on the other hand, in the EC test cycle cars do not start the cycle without some warming up.

The weighted fuel consumption may be plotted against various factors. Figure 6-11 shows the how the weighted petrol consumption of a selection of petrol cars (l/100km) varies with capacity and performance. From this it is clear that the general, and expected, trends are that fuel consumption increases with the maximum acceleration and top speed of the car.

It is also quite clear from the database that diesel cars are generally more economical for the same performance for medium and large cars. However, the widespread use of diesel motors in cars is a recent phenomenon and the rate of technical change is more rapid than for petrol engines. As a consequence the relationship between performance and fuel consumption is much less clear for diesel cars than for petrol cars. For example, the fuel economy of the fast Citroen diesels is as good or better than many slower diesels from other manufacturers. A diesel car offering the same acceleration as an average petrol car consumes about 25% less fuel (in litres/100km), and emits about 22% less carbon per kilometre. However, particularly for new small cars, the best petrol engined cars are as good as diesels in terms of energy consumption (MJ/km, not l/100km) and carbon emission. Nonetheless, the loss of efficiency of diesels when cold is less than for petrol, such that the energy and fuel consumption of diesel cars as operated on the road is almost certainly lower than for petrol cars offering equivalent performance. Further analysis of this issue is required.

Figure 6-11: Cars — carbon emission, fuel and performance

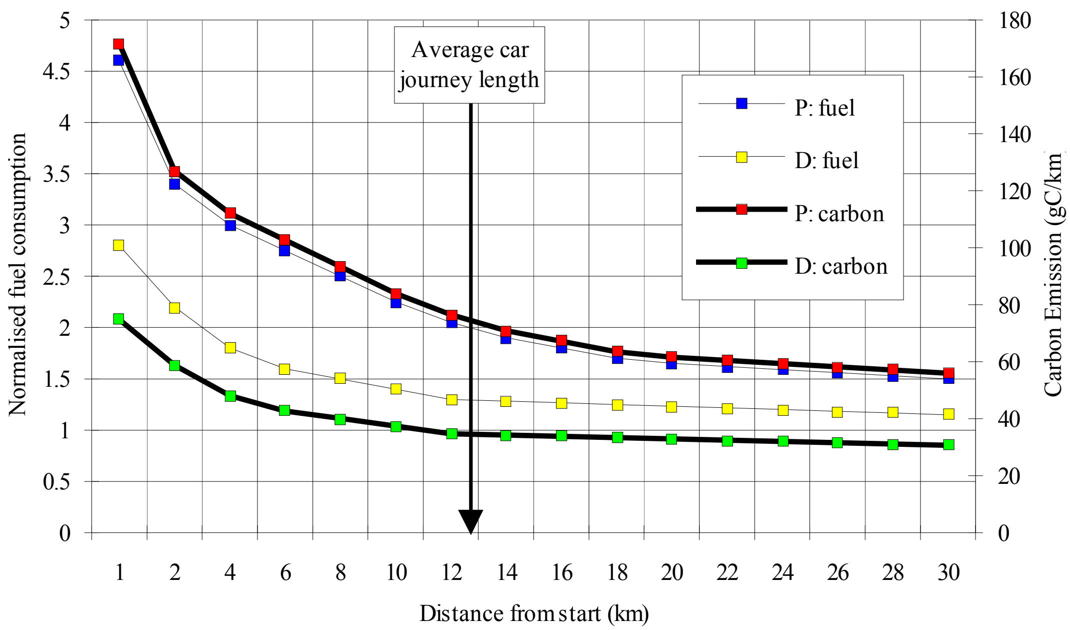


6.3.6.1 Cold starts

The EC tests are conducted with cars partly warmed prior to the test. Research at the TRRL (Pearce, Waters; 1980) has shown the fuel consumption of cars is very poor when the engine is cold. Figure 6-12 is based on their results for the cars when tested over various circuits at 64 kph (38 mph). It shows how the normalised fuel consumption varies with the length of a cold start journey for a petrol and diesel car, and the concomitant carbon emission. It is surprising how long it takes for cars to warm up: this is clearly an area deserving of urgent technical innovation by motor manufacturers. It is apparent that diesel engines do not suffer the same cold start penalty as petrol engines, and they warm up faster. Pearce and Waters also found that the idling fuel consumption, in litres per minute, of the petrol car was 15% greater than the diesel. However in terms of overall energy and carbon emission this is a relatively small difference because of the higher volumetric energy and carbon content of diesel fuel.

The severe penalty of starting from cold further increases the importance of planning short car journeys well. Better still would be to switch to foot or cycle, or to a vehicle that is already warmed up and operating efficiently - such as the bus.

Figure 6-12: Car cold start consumption



Another interesting observation to be obtained from the database sample displayed in Figure 6-11 is that the vast majority of models sold in the UK are capable of exceeding the legal speed limit found in most countries by a considerable margin.

Now, what is a car for? What services does it give us? At the individual level cars provide:

- dry transport;
- load carrying;
- comfortable transport;
- the transport of people who are not very mobile;
- a social display;
- door to door travel where parking restrictions allow;
- fast transport for some journeys.

These advantages do only apply at the individual level. Considered from a social point of view cars incur many penalties. Cars are relatively dangerous compared to most other modes of transport. They disenfranchise the poor, young and old from adequate transport facilities. Compared to other modes, they are bad in terms of emissions, visual impact and effect on local communities. Because of their inefficient use of road space, they cause congestion and consequently can reduce the speed of travel for all.

In what sense does a large petrol fuelled limousine capable of accelerating to 60 mph in 8 seconds with a top speed of 110 mph provide more service than a small diesel or economical petrol car which reaches 60 mph in 14 seconds and has a top speed of 95 mph? In most respects of physical service provision, excluding perhaps internal space and comfort, the limousine and the small car are almost indistinguishable in practice. Increasingly the comfort of small cars improves with enhanced noise control, suspension and road surfacing. The extra acceleration provided by the limousine, even if fully used, will increase the average speed of the vast majority of journeys in the UK by small amounts. Provided the driver stays within legal limits, the limousine's extra top speed makes no difference to journey times. TRRL research indicates that around 40% of car travel time in cities is spent stationary. The National Travel Survey (NTS; 1988) reports that the average speed of car journeys in 1985/6 as being 14/15 mph for journeys less than a mile; 22 mph for journeys between 5 and 10 miles; and 42/44 mph for journeys of over 50 miles. In terms of numbers of trips, and distance travelled, journeys less than 10 miles are dominant. Data provided by the DTp, some of which is unpublished, indicate that in excess of 45% of car kilometres are performed on built-up roads the vast majority of which have a speed limit of 30 and 40 mph. This highlights the importance of minimising congestion and waiting time, rather than increasing the power, speed, acceleration and fuel consumption of cars.

Therefore, in respect of useful physical services actually provided, there seems to be little difference between the two archetypal cars. One is therefore left with the view that the most important reason for having a large fast car rather than a small slow one is that of social display - 'if you've got it, flaunt it'.

At present the average capacity of the UK car stock is about 1.6 litres, and in excess of 95% of them are petrol cars. The weighted consumption of an average new 1.6 litre petrol car is estimated, regression analysis of the database, to be 7.8 l/100km. This equates to 2.7 MJ/km energy consumption, and 50 g of carbon emission per kilometre. Table 3-1 shows the fuel and emission estimates for the average UK car bought today, for the best small cars available, and for and the small French diesel cars which are not available in the UK. The lowest levels of energy consumption and carbon emission for new cars available in the UK are 1.7 MJ/km and 32 g/km respectively. Thus, other things being equal, substituting the best currently available cars for the average over the next decade would cause carbon emission to fall in the ratio 50:32 - a reduction of 36%.

Table 6-4 : Best current cars

Manufacturer	Model	Fuel Type	Weighted l/100km	Energy MJ/km	Carbon g/km
French various	*0.3 - 0.6 litre diesel minicars*	*D*	*3.0 ?*	*1.15*	*21.90*
Citroen	AX 10 E, RE & TGE	P	5.0	1.72	32.03
Citroen	AX 11 TGE, TRS & TZX	P	5.0	1.73	32.35
Daihatsu	Charade Diesel Turbo 101	D	4.5	1.73	32.86
Renault	5 TL 3 door Prima	P	5.1	1.78	33.17
Citroen	AX 14 TGD & DTR	D	4.6	1.75	33.34
Ford	1.8 D Saloon	P	5.3	1.83	34.06
Renault	5 Campus 3/5 door	P	5.3	1.85	34.54
Renault	5 TL 3 door Prima	P	5.3	1.85	34.54
Ford	1.1 Saloon	P	5.4	1.88	35.01
Peugeot	205 Style/XLD/GLD/ GRD 1.8	D	4.8	1.85	35.08
Suzuki	Swift 1.3 GLX	P	5.4	1.89	35.18
Various	Average new 1.6 l. petrol	P	7.75	2.69	50.13

In France it is possible to purchase a range of small and efficient two and four seat cars. They are fitted with modern equipment and are powered by diesel engines of capacities ranging from 0.3 to 0.7 litres. Their fuel consumption is quoted as being 2.5 to 3.0 litres/100km, although it is not possible to exactly compare this figure with standard driving cycles, not least because their top speed is much less than the 75 mph of the high speed cycle (their power and speed is limited because of licencing restrictions). Furthermore, it is not known how much of other pollutants such as NO_X or particulates these vehicles might emit. However the production of most of the pollutants (NO_X, CO_2, particulates, HC) will in general decrease as the fuel consumption and cubic capacity of a diesel or petrol car decreases; also, pollution control technologies such as catalytic converters or particulate traps can be fitted to small engines as well as large ones. The Japanese also make mini cars. These are small, but generally more powerful and faster than the French minicars. Consequently they generally do not offer the such good fuel economy.

Such cars, or indeed the bubble cars of yesteryear, demonstrate what is relatively easily achieved in terms of attaining low energy consumption. These cars do not feature novel expensive technologies. Indeed they are in some respects under designed . For example, the French minicars generally have only two gears - one forward, one reverse. They are energy efficient because they are relatively small and slow compared to typical modern cars. The advantages of small cars in congested urban conditions are particularly large. Should such minicars become available in the UK, then if 50% of car travel were in such mini cars, and the other 50% in the best cars listed in Table 6-4, then carbon emissions from cars would fall in the ratio 50:22 - a reduction of 56%.

The author argues that the selection or small cars should be made in conjunction with a major switch to bus and rail for longer journeys. The great majority of car journeys would then be in the 10 to 80 km range where high speed and acceleration have little effect on total journey times. For occasional long car journeys a larger more powerful car could be hired. At present cars are bought to meet all purposes, from ferrying the solitary commuter to work at moderate speed, to shipping the whole family to France for a holiday. Plainly it is not possible to design a single machine which accomplishes such a wide range of tasks efficiently. If appropriate cars were selected as outlined here, then the proportion of car journeys made in mini cars could rise beyond the 50% mooted above, and emissions would fall accordingly.

6.3.6.2 Safety

Economical cars are generally smaller and lighter than their thirstier brethren. Other things being equal, a big car is safer than a small car because it suffers less deceleration in accidents and provides more body for absorbing the energy of impact and accommodating deformation. It seems there are few publicly available statistics which facilitate a comparison of the safety of cars of different design and performance. However, to a significant degree, this safety problem arises because small vehicles are mixed with larger ones; this is of course even more significant for those travellers who emit no pollution - pedestrians and cyclists. This safety issue has to be addressed and resolved by the authorities at every level of government.

6.3.7 Air transport

About 0.8% of UK domestic passenger travel is by air (TSGB; 1991). Thus, although air travel is generally more energy intensive per passenger kilometre than other modes, its fuel use for domestic travel is currently a very small proportion of total fuel use. The bulk of aviation fuel supplied in the UK is consumed during international flights. Although much of the fuel is not actually burnt in the UK airspace, it seems probable that any aviation fuel loaded in the UK will be made the responsibility of the UK in any international emission control negotiations and agreements. Therefore it is appropriate to include it in the UK's global warming budget.

6.62 Mt of aviation fuel were uplifted by all types of aircraft in 1990 (TSGB; 1991). This is equivalent to 312 PJ. Data given in the Annual Abstract of Statistics (1991) shows that 53.8 PJ of aviation fuel was used by Defence: this is 17% of total UK aviation fuel use. Commercial aviation consumed about 258 PJ of fuel. This must be allocated to passenger and freight duty; but this is difficult to do. This is partly because of a lack of fuel consumption data differentiating between freight only and mixed passenger and freight flights, and because a large proportion of freight is carried along with passengers. This latter leads to a conceptual difficulty.   The author has assumed that 90% of civil aviation fuel use may be allocated to passenger transport.

Barrett (1991) has reviewed the general environmental impact of air transport, and has made estimates of its contribution to global warming. Air transport generally accounts for a small proportion of carbon emission; Barrett estimated it contributes to 2.7% of global fossil carbon emission. However, aircraft emit a mixture of other pollutants at an altitude where the atmosphere is very sensitive in terms of chemistry and global warming. The current scientific view is that extra ozone formed as a result of the emission of nitrogen oxides (NO_X) from aircraft is significant in terms of global warming. (It may also be that other pollutants such as water are also important.) There are considerable scientific uncertainties about this at present, and the relative contribution of NO_X depends on the time horizon of global warming used. The warming effect of the NO_X can be expressed as a proportion of the warming effect of the carbon emission. For a 20 year time horizon the value is probably between 2.6 and 26, and for a 100 year horizon, between 0.7 and 7. Currently the scientific view seems to be that estimates in the lower part of this range are closer to the truth, but scientific understanding is changing rapidly and this may change substantially.   Barrett outlines the consequences of assuming a range of assumptions for this equivalence.

Table 6-5 gives estimates of how much UK global warming can be attributed to aircraft. An overhead of 5% to allow for refining losses has been added to the aviation fuel consumption. It is assumed that 85% of aviation fuel consumption occurs at an altitude near the tropopause where NO_X emission leads to ozone and global warming. A range of carbon equivalents and time horizons for NO_X are assumed in order to work out the carbon equivalent of the NO_X emission of aircraft. This equivalent is then added to the carbon emission to arrive at a total carbon emission equivalent. This is compared to the emissions of carbon and carbon equivalent from the UK, from transport and from passenger transport: other non-carbon greenhouse gases are not included here. The carbon equivalent of the NO_X emission is added to carbon emission to arrive at new totals for carbon emission.

Table 6-5 : Contribution of aircraft to UK global warming

				All air-craft	%UK	%Trans-port	Com-mercial	Passenger	%UK	%Trans-port	%Passenger
Energy			PJ	328			271	244			
Carbon			MtC	6.0	4%	15%	4.9	4.4	3%	11%	16%
NOx	yrs	Eq									
	20	2.5	MtCeq	12.1	7%	23%	10.0	9.0	6%	18%	25%
		25		120.6	44%	75%	99.8	89.8	58%	69%	77%
	100	0.7		3.4	2%	8%	2.8	2.5	2%	6%	8%
		7		33.8	18%	45%	27.9	25.1	16%	38%	48%
Total	20	2.5	MtCeq	18.0	10%	31%	14.9	13.4	9%	25%	33%
Global		25		126.5	45%	76%	104.7	94.2	61%	70%	77%
Warming	100	0.7		9.3	6%	19%	7.7	7.0	4%	15%	20%
		7		39.7	20%	49%	32.9	29.6	19%	42%	52%

Using the low equivalences aircraft account for 6% of total UK global warming due to carbon dioxide over a 100 year time horizon, and 10% over 20 years: for brevity this is referred to as 6-10%. (There are conceptual and practical problems in using different time horizons which there is no room to discuss that here.) With the higher equivalences these estimates rise to 20-45%.

For commercial passenger air transport, their carbon equivalent emissions using the low NO_X equivalences are 4-9% of UK emissions, 15-25% of transport, and 20-33% of passenger transport. (For the high equivalences the figures are 19-61%, 42-72% and 52-77% respectively.) Even if the low equivalences are taken, aircraft are an important portion of the UK's total contribution to global warming, and very significant in the context of global warming from transport. Aircraft carbon emissions alone constitute 4% of the UK total, and 15% of the transport total.

Barrett (1991) surveys the general measures which might be applied to reduce pollution from aircraft; these include technical and operational measures. Consumer choices can directly affect the operations of aircraft in terms of the extent to which aircraft are used, and the way in which they are used. About 70-80% of air passenger journeys are for leisure, as opposed to business. Leisure and business passengers can reduce pollution as follows:

- Reduce long distance travel. Take local holidays, or, if for business, use telecommunications.
- Travel by train or boat instead of plane. Typically this results in more than 50% global warming reduction per passenger kilometre.

- Use charter rather than scheduled services. On average charter flights have an occupancy factor of 90%, whereas for scheduled services it is about 70%. Typically there is 25% reduction in global warming going by charter rather scheduled flight.
- Book as far in advance as possible. The more advanced the booking, the better the occupancy factor can be.

The lack of data and difficulty of analysing the patterns of air travel and the scope for improved operation coupled with the scientific uncertainty, means it is not possible to quantify the effect of consumer choice on emission with any precision or certainty. It would however seem reasonable to assume that consumer choice might reduce emissions by something of the order of 10% through making the choices bulleted above.   Work is urgently required on this issue because of the large proportion of global warming caused by aircraft - a proportion moreover which is rapidly increasing because air travel is the fastest growing sectors of transport and of the economy.

6.3.8 Overall impact of behavioural change

The preceding sections have described the carbon emission reductions due to passenger transport that might be achieved by a number of lifestyle changes.

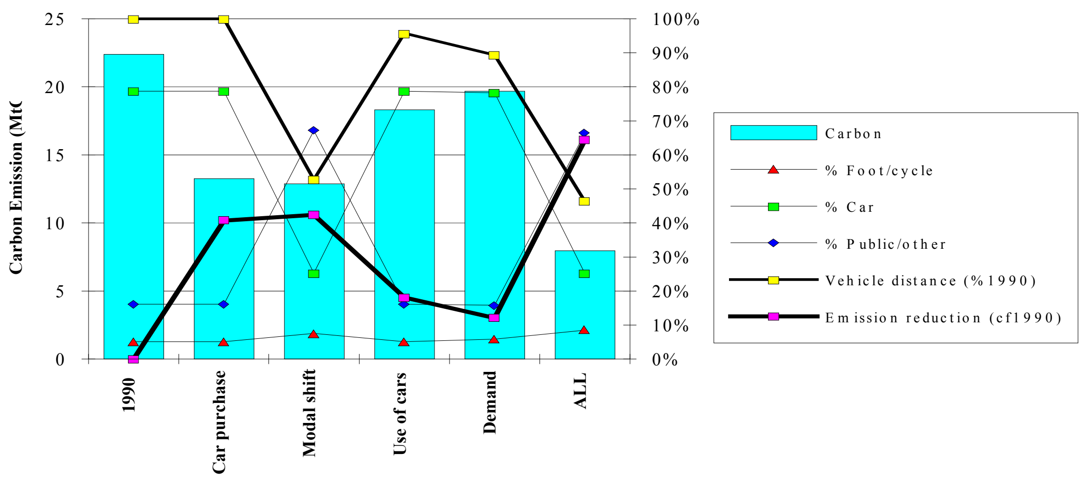
For UK domestic passenger transport, NTSMOD has been used to calculate fuel use and carbon emission. Certain key assumptions and simplifications are currently used in the model.   Particularly important is the assumption that the load factor of public transport does not change from current levels. (In fact information is poor about current occupancy rates). NTSMOD incorporates algorithms for estimating the effects of cold starts and congestion on fuel use. The author judges the savings estimated due to changes in the diesel petrol split, and to reduced congestion, are probably of the right order. However neither NTSMOD, nor any other model of which the author is aware, use accurate validated algorithms for estimating the detailed effects of these effects and interactions in road traffic at either the national or local level.

NTSMOD was run using the behavioural changes described in the text above, with each of these changes assumed separately, and in concert. The results in terms of carbon emission are shown in Figure 6-13. This also shows the percentages of passenger distance accomplished by three modal categories (foot/cycle; car/taxi; public and other); and the total vehicle distance and emission savings as compared to 1990.

Two changes: selecting the most economical cars; and shifting mode; separately reduce emissions by about 40%. Improving the use of cars (driving style, occupancy, journey timing) reduces emission by 18%; and reducing the demand (journey choice, location decisions) reduces emission by 12%.

If all the changes occur together, carbon emission is reduced by 65%. The total distance travelled by vehicles is reduced by 50%, and that by cars by 75% with modal shift being most influential in bringing about this reduction. Congestion would obviously be much reduced. The model predicts that the average fuel consumption of cars would fall by 4% because of the reduced congestion alone.

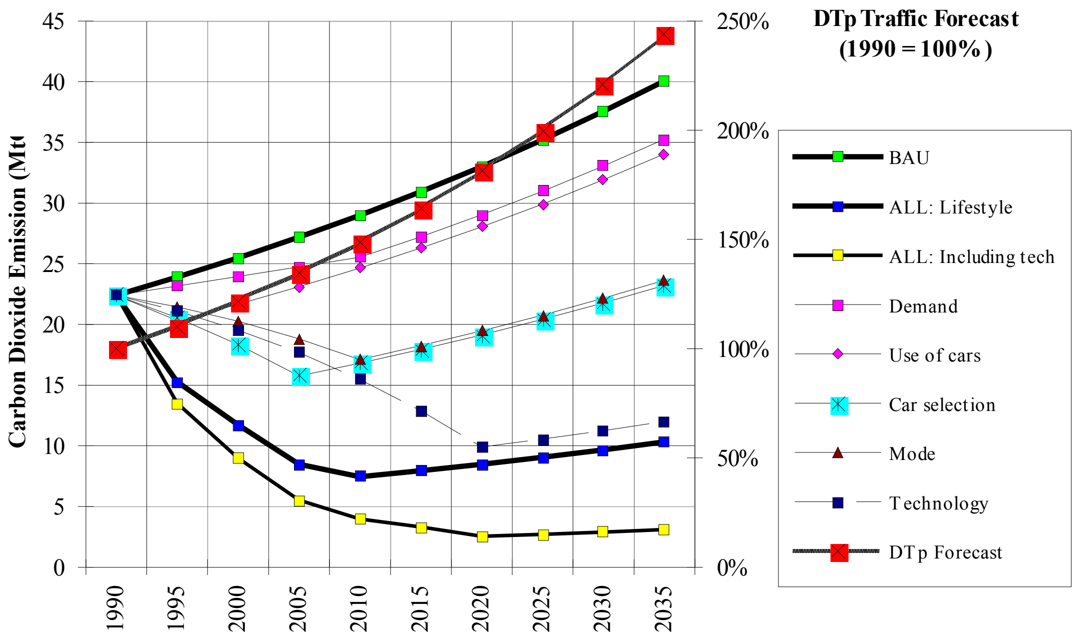
Figure 6-13: Changes and carbon emission from UK domestic passenger transport



The preceding analysis has not considered how the emissions from transport might be changed over time through consumer choice. Figure 6-14 shows illustrates the profiles of emission assuming the reductions due to lifestyle change are applied over different periods. The reference emission case is based on the DTp traffic forecast coupled with an assumed 0.7%/a decrease in the carbon emission per passenger kilometre. This rate of decrease is assumed to result from countervailing trends: less emission through technical advance; and more emission because of increased congestion and increased power. As mentioned previously, the DTp have not published a carbon emission scenario based on their traffic forecast. Their scenario is used here purely as a benchmark, and not as a view of the most likely outcome if current policies and trends are continued.

The reduction over this base case is shown for the individual lifestyle changes, and for them all applied together. A further curve shows the effect of an assumed reduction of 70% in emission per kilometre through technical innovation in vehicles (rather than lifestyle changes). The lowest curves shows the result of combining all the lifestyle changes and technical innovation. It may be seen how emission rises steeply and continuously in the reference case. The lifestyle changes bring about reductions or slowed growth in emission over a period, but then emission growth resumes as the potential of these changes is fully taken up.

Figure 6-14: UK passenger carbon emissions: 1990 to 2035



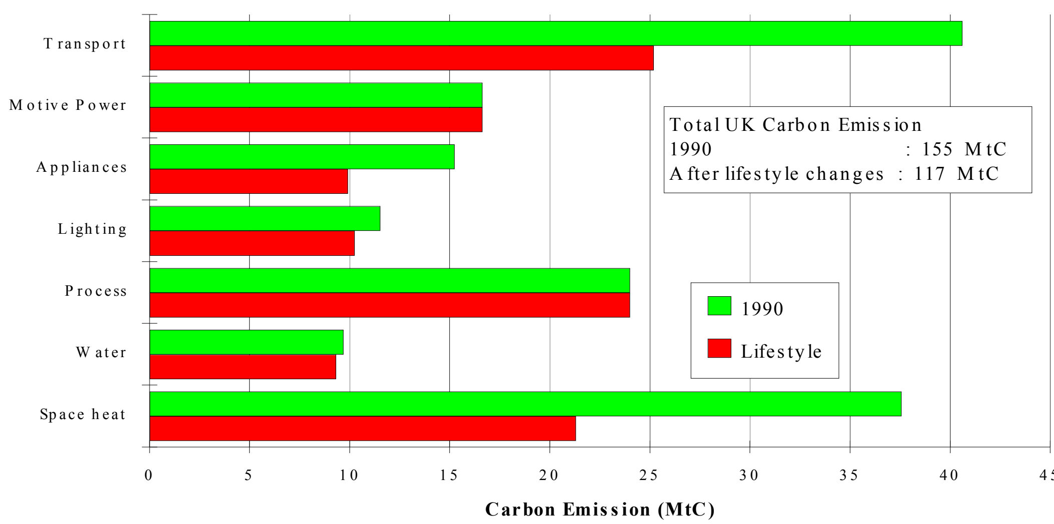
6.4 Overall change to UK emissions

The preceding detailed sections on energy use in buildings and passenger transport have described potential behavioural changes, and have made estimates of the carbon emission reductions consequent to those changes. We may now add these together, and revisit our overview of the UK as a whole. The global warming due to the carbon dioxide and NO_X emission of aircraft on international flights is omitted here, despite its importance. It is omitted because of the scientific uncertainties, and because it is more difficult to quantify the effect on carbon emission of altered consumer behaviour.

Figure 6-15 summarises the effects of the postulated lifestyle changes on carbon emission from the different sectors. Overall, the changes reduce carbon emission from 155 MtC to 117 MtC - a reduction of 25%. Some of the lifestyle changes, such as wearing more clothes, could in principle be introduced quite quickly; others, particularly the selection of energy efficient cars and appliances, will take longer to take effect because of the rates of stock turnover. People may not easily be led to change their behaviour quickly and in practice the lifestyles changes may be slower than the rate suggested by technical considerations alone. Whilst such voluntary lifestyle changes might be occurring there would be other changes in emissions due to factors such as growth in the GDP per capita, demographic change, the changing structure of the economy and changes to energy technologies. It has been beyond the scope of this study to appraise the effects of these factors. Therefore the potential reduction due to lifestyle changes is here compared to 1990 emission, rather than some possible future situation.

The case study has demonstrated the importance of people's behaviour in terms of using and selecting technologies and systems. In the main this relates to technologies already in place, or to technologies already marketed. There is no reliance here on existing or innovatory technologies which have doubts attached to them for reasons of technical feasibility, economic or social cost, or environmental impact. Also, most of the potential for emission reduction through lifestyle change could be achieved in less than fifteen years. This is in contradistinction to technical measures such as introducing highly efficient buildings or power stations with 'economic' lives of 30 or more years. As described in the section on global carbon emission and warming, the rapidity of reduction is important.

Figure 6-15: Effect of lifestyle on UK carbon emission



Lifestyle change therefore has an important role to play in the short and medium term. In the longer term, its importance depends on whether technologies are developed which allow an unrestrained lifestyle to followed without significant environmental impact. The author's judgement is that such technologies are as yet well over the horizon, and therefore the effects of lifestyle will always be important.

This UK case study has only covered technologies which provide personal services in a fairly direct manner. The opening analysis of UK carbon emission suggested that about 36% of emission arises from the manufacture and distribution of goods and services, excluding personal services. If personal services provided at work are included this rises to 57%. There has been no consideration so far of how the consumer choice and level of consumption of goods and services such as furniture, houses or banking might impact on this category of carbon emission. How much would carbon emission be reduced if people bought wooden rather than brick houses; how much if they bought English pears rather than Chilean grapes or strawberries out of season; how much if they bought old master paintings rather than flying to Bangkok?

It has not been an objective of this study to thoroughly analyse the energy requirements and carbon emission implications of the manufacture and supply of materials, goods and services. Yet people can affect energy use and carbon emission by the amounts and types of goods and services they purchase as well as by selection and use of technologies, and so this issue should be raised. The next section introduces some aspects of this issue but does not attempt to provide an estimate of possible carbon emission reduction through such choices.

6.5 Effect of commodity choice

Resources are used to build and manufacture material goods, and to provide services. In most countries a large proportion of the energy so used is fossil, and so carbon dioxide is released. The question arises as to what the energy requirements of producing different products is, and what the concomitant carbon emissions are. In addition carbon emission is an important by-product of the production of primary materials such as iron and cement: it arises because of the chemical changes involved, not because of fuel use. The following gives some examples of the energy and carbon emission of goods and services, and concludes with a discussion of how consumer choice might affect emission.

6.5.1 Carbon emission from production

The resource inputs to physical commodities and services can be divided into two categories: direct and indirect. To make a car, direct inputs of resources such as fuel and steel to the car manufacturing plant are required. In addition, the car manufacturing plant requires inputs of raw and processed materials (water, steel, plastic, rubber etc.) and services (finances, telecommunication etc.). These other inputs also required resources for their production, and these resources, from the perspective of car manufacturing, are called indirect inputs. These indirect inputs can be traced back through the whole economy, and the path can be circular (e.g. the production of lorries requires steel, and the production of steel requires lorries). The volume of indirect inputs is estimated by iterative calculations using input-output matrices. Generally the analysis accuracy is limited by the level of detail of the economic data available and so often the indirect resource inputs are not traced throughout the economy. Furthermore, the data is often very dated. Another problem is that energy is input into imports outside of the country. For example the UK imports most of its copper. It thus avoids expending energy on producing copper from ore by smelting, which is generally more than the energy used fabricating products from copper.

The gross resource requirement is the sum of the direct and indirect inputs. Often, but not always, the direct energy input of a manufactured item is greater than its indirect input. The energy inputs for the various sectors may be disaggregated into the different fuels, and the carbon emission for each estimated based on emission coefficients. Given the data, the total direct and indirect resource for any physical good or service may be estimated. For example the gross amounts of energy, water or steel needed to produce a good can be estimated. Similarly the gross carbon emission, or other environmental input such as acid emission, brought about in the production of a good can be estimated.

Figure 6-16 shows the distribution of direct primary energy use and carbon emission for the principal sectors of production in the UK in 1990. The allocation of primary energy to these sectors has been estimated from UK energy statistics (DEn, 1991), and the carbon emission from this using the appropriate emission factors. In this case the energy use and carbon emission of the provision of personal services has not been separated out as in the preceding sections of the UK case study.

About a third of carbon emission arises from sectors producing primary materials and products: agriculture, iron and steel and other metals, mineral products and chemicals. The bulk of these primary materials is used in the manufacturing sectors, mechanical engineering through to construction, which bring about another third of emissions from the production sectors. Finally there are the miscellaneous and public administration sectors, which mainly produce services, which account for the last third of emission. These sectors, along with households and transport, absorb the net output of the primary and manufacturing industries. Figure 6-16 illustrates that the ratio of energy used to carbon emitted varies little across the sectors with the notable exception of iron and steel. This is because the energy mix of these sectors is such that the weighted carbon emission coefficient varies little: it is in the range 18-20 tC/TJ for most sectors.

Figure 6-16: Energy and carbon in UK production (1990)

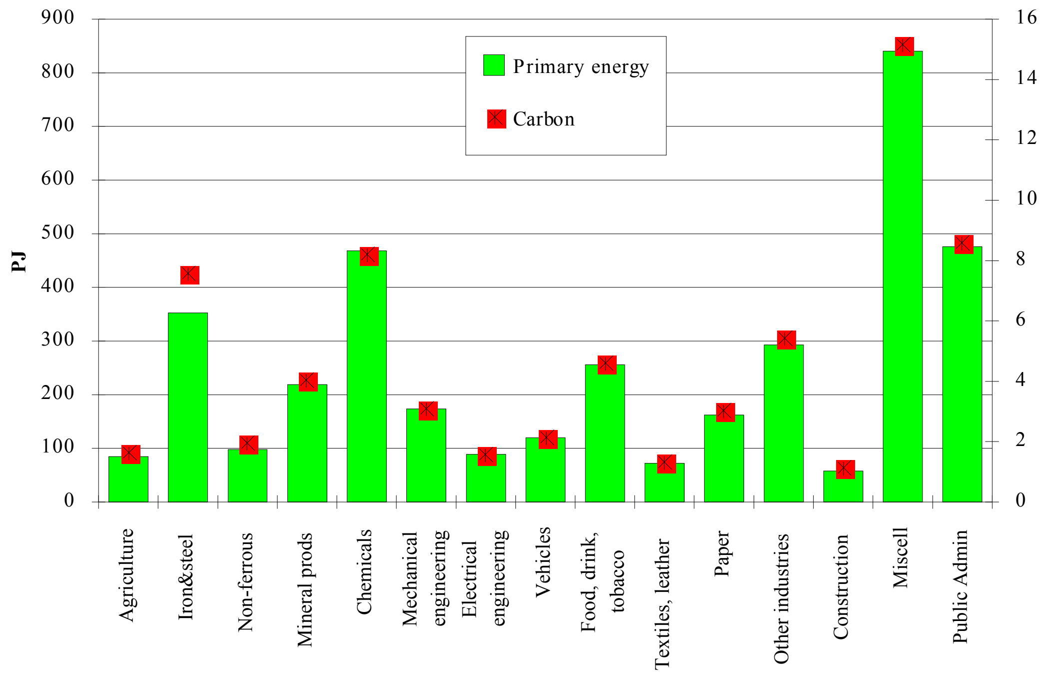


Table 6-6 gives illustrative gross energy requirements of some materials and manufactures. These are illustrative in the sense that, apart from the data limitations mentioned above, the energy requirements vary from country to country and across time. Furthermore many of the estimates of requirements do not account for all indirect inputs. Most of the information and analysis in this Table is 20-25 years old and is comes from two principal sources. The first, The Energy Accounting of Materials, Products, Processes and Services (TNO, 1976), was mainly used for information about materials. The energy requirements are given in physical units (GJ/t), but relate to many different countries. The second, Energy Analysis of the 'Report on the Census of Production, 1968' (Casper et al, 1975) is for the UK only. Its drawbacks are the age of its data, and the fact that energy requirements given per £ (1968) gross output value, rather than physical units. This latter limitation is because the data is too coarse to discriminate between the requirements for most consumer commodities (e.g. between a refrigerator and washing machine). The 1968 monetary values have been converted to 1990 values using a single factor for inflation. In reality different factors will apply to different products. It can be expected that the energy requirements of most of these commodities will have declined with improved process and energy supply efficiency. The author has estimated the energy requirements and carbon emission for a house and a car made in the UK.

A more recent analysis of the energy requirements of manufacturing in the UK has been made for 1980 (DEn, 1984). The analysis is very detailed and looks at energy requirements at the process level, rather than for the sectors as a whole. However it concerns direct energy requirements only. Casper et al show that the direct energy requirements for the commodities in Table 6-6 (taken from their study), range from 5% to 25% of the total energy requirements. Direct and indirect carbon emission would reflect this. Neither of the above references contains an analysis of the energy requirements of services such as telecommunication, banking or education. The author has given an example of the direct energy and carbon quantities for one service - air travel.

The carbon 'requirement' of commodities will depend on the energy requirement, and on the mix of energy sources used. For example we could assume that the production of aluminium requires 100 GJ of electricity per tonne: this would reflect a mix of scrap and ore inputs. If electricity came from hydropower the carbon emission would be close to zero, whereas if it came from a coal fired power stations emission would be about 7 tonnes of carbon per tonne of aluminium. The author has used a coefficient in the range 18-20 tC/TJ judged to be appropriate to the particular sector of production.

The gross energy requirements (GER) are given in GJ per tonne for materials, GJ per unit for some commodities, and MJ per 1000 £ (1990) for others. Where possible carbon emission is given per tonne, per unit and per 1000 £. These may be called the energy and carbon intensities of commodities.

It is emphasised again that this Table is for illustration only. The error in the estimates of energy and carbon requirements is unknown, but is undoubtedly large. The Table is meant to demonstrate that the materials used to make a particular product can affect its carbon emission implications: a wooden table will (probably) bring about less emission than one made of steel and other synthetic materials. It is also meant to show that some commodities bring about more carbon emission per £ value than others.

We see that the energy and carbon emission of solid materials varies by some 75:1, from aluminium to brick. Aluminium would have to be very extensively recycled if its GER were to approach that of steel. This is important if, for example, considering weight reduction by substituting aluminium for steel so as to improve the fuel economy of cars. A (dated) comparison of the energy requirement of manufacturing a car varies greatly from a European car to a US car; it is not clear how much of this difference is due to the mere weights of the cars, and how much to energy efficiencies in manufacturing and material intensities. Sample data from the study of Casper et al shows a variation of about 2.5:1 (in the sample) in energy and carbon intensity. Although it is problematic to update this information, it is at least internally consistent.

The last category of illustrative information is the energy and carbon equivalent intensities of flights of different distances. This only accounts for aviation fuel; the energy and carbon emission of aircraft manufacture, and of providing ancillary airport and other services is not included. Nonetheless, the carbon intensity of air travel is 5 to 30 greater than that estimated for those goods and manufactures included in the Table.

It is possible to remove atmospheric carbon by making long lived physical commodities such as buildings and furniture partially or wholly out of wood or wood products.   Dry wood typically contains more than 50% carbon by weight.   The energy use and carbon emissions associated with the production and processing of wood would have to accounted for. An extra per capita stock of 1 tonne of carbon in commodities would absorb several years of a per capita emission of around 0.1 - 0.2 tC/a, a level suggested as being a long term target by the analysis in chapter 3. Of course once the stock of wooden commodities were complete the carbon going into the stock would be balanced by that going out. Consequently there would be no further net removal of carbon from the atmosphere.   Nonetheless such storage could delay the rate at which societies have to adapt themselves so as to limit the atmospheric concentrations of carbon dioxide. Biomass products could be used to partially substitute for other materials which cause carbon emission, including steel and cement discussed in the next section.

Table 6-6 : Illustrative energy and carbon requirements of some commodities

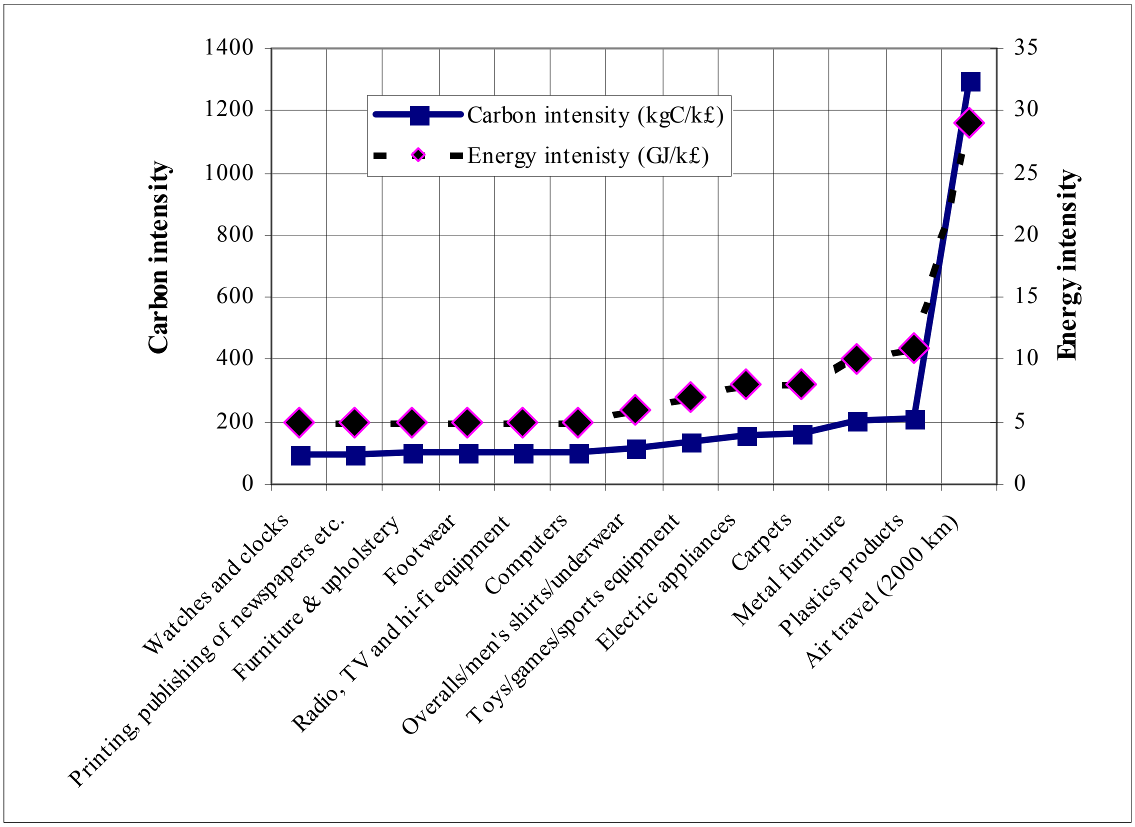
	Gross Energy Requirement	Carbon Emission			
Materials	GJ/tonne	tC/tonne			
Water	0.0075				[1]
Aluminium	5 - 371				[1]
Steel	25	0.53			[1]
Copper	54				[1]
Cement	5	0.09			[1]
Brick	5	0.09			[1]
Glass	21	0.39			[1]
Rock wool	14	0.26			[1]
Wool	24	0.46			[1]
Polyester	53	1.01			[1]
Paper & Board	40	0.74			[1]
Car plastics	50	0.87			[1]
	Gross Energy Requirement	Carbon Emission	Energy Intensity	Carbon Intensity	
Manufactures	GJ/unit	tC/unit	GJ/k£	kgC/k£	
UK house (average, 1990)	360	6.7	4.5	84	[3]
Car (900 kg, Europe, circa 1970)	65	1.2			[1]
Car (1600 kg, USA, circa 1970)	125	2.4			[1]
Car (average UK, 1990)	60	1.1	6.0	114	[3]
Truck (Europe, circa 1970)	544	10.9			[1]
Commodity groups (UK, 1968)			GJ/k£	kgC/k£	
Watches and clocks			5	93	[2]
Radio, TV and hi-fi equipment			5	104	[2]
Computers			5	105	[2]
Electric appliances			8	154	[2]
Metal furniture			10	207	[2]
Carpets			8	163	[2]

Overalls/men's shirts/underwear	6	119	[2]
Footwear	5	101	[2]
Furniture & upholstery	5	100	[2]
Printing, publishing of newspapers etc.	5	95	[2]
Plastics products	11	212	[2]
Toys/games/sports equipment	7	137	[2]
Air travel	GJ/k£	kgCeq/ k£	[3][4]
1000 km	22	986	[3]
2000 km	29	1297	[3]
5000 km	51	2330	[3]
10000 km	55	2510	[3]
20000 km	64	2909	[3]

Sources & notes:
[1] TNO (1976),
[2] Casper et al (1975),
[3] Author's estimates
[4] Accounting for fuel burnt in aircraft only. Carbon expressed in carbon equivalent to account for effect of NOx.
[5] Author's estimates of carbon emission from energy requirement

A graph of carbon intensity per commodity value follows.

Figure 6-17: Carbon intensity per commodity value



6.5.1.1 Carbon emission and chemical change

The production of some important primary materials involves CO_2 release due to chemical changes. The production of iron from ore requires the reduction of iron compounds which are usually oxides. The oxygen these compounds is mostly removed by reduction with carbon (in the form of coke) to form CO_2. The degree to which reduction is necessary mainly depends on the degree of recycled iron and steel which is already reduced. In the UK in 1990, the reduction of some 18 Mt of iron ore requires about 3.8 Mt of carbon, which is some 2.5% of anthropogenic UK carbon emissions. Cement manufacture results in the emission of CO_2 because of the chemical transformation involved; calcium carbonate ($CaCO_3$) is calcined to form calcium oxide (CaO) and CO_2 which is released. Globally some 2% of CO_2 emissions arise from cement manufacturing (ORNL, 1989). Using ORNL coefficients, one can calculate that the production of cement in the UK (currently about 17 Mt) of results in a carbon emission of 2.3 Mt, or 1.5% of UK emissions. Some CO_2 is eventually reabsorbed into the cement, but it is uncertain how much on average.

Thus, in total the chemistry involved in the production of these two materials in the UK results in up to 6.1 Mt of carbon emission, or 4% of the UK 1990 total. This is a small but significant proportion even now. If a reduction in excess of 94% in per capita carbon emission is eventually required, as is suggested by the analysis in chapter 2, it may be seen that for the UK about three quarters of the remaining allowance would be taken up with the production of steel and cement alone. Plainly efforts will be required to reduce the emission from these processes. This would include measures such as the less wasteful use of these materials, increased iron scrap recycling to the degree this is beneficial in net terms, and eventually the widespread use of 'environmentally friendly' substitutes.

6.5.2 Capital and running carbon emissions

The main emphasis in this study, and in most of others of carbon abatement, has been on the carbon emission arising from the use rather than the manufacture of technologies such as cars and buildings. This is because for many if not most technologies the emissions from running technologies are greater than those consequent to manufacturing - at the present. However as and if technologies become more energy efficient the proportion of emission due to manufacturing will generally increase.

Table 6-7 illustrates this for the UK car. Currently the average UK car is driven about 16400 km per year and at an average of about 30 mpg. The average life of a car is about 9 years. The author estimates that manufacturing a car brings about some 1.1 tonnes of carbon emission, of which about a third arises from the production of the materials (steel, glass, plastics etc.) , with the remainder being incurred by the process of manufacture itself (i.e. forming, assembling, finishing etc.). The average UK car currently emits about 1 tC for each year of operation. Given the figure of 1.1 tC for manufacturing, one arrives at the result that a little over 10% of the total life cycle emission of carbon due to the current average UK car is brought about by manufacturing. This proportion will increase if the fuel economy of the car is increased, and if the distance covered by the car decreases. This trend can to a degree be counterbalanced by the fact that improved fuel efficiency will partly be accomplished by decreasing the weight of the car. This will reduce the energy and carbon costs of materials if the average energy intensity of materials is the same. The non-material energy costs incurred in manufacturing a large car will also generally be larger than manufacturing a small one.

The author has used illustrative assumptions for manufacturing emissions of increasingly economical cars such that emission falls from 1.1 tC for the 10 l/100km car down to 0.7 tC for the 2 l/100km car. If the distance covered is 16000 km then the proportion of carbon emission due to manufacturing rises from 10% for today's average car to 25% for the most efficient model. For a car driven half this distance, the proportion rises to 40%.

The lifestyle changes investigated above explicitly assume the selection of smaller more economical cars, and a reduction in car travel by choosing to use nearer facilities and planning car journeys. In addition, a possible implication of the modal shift away from cars is that the distance covered by cars decreases more rapidly than the number of cars. If so, the average distance covered by cars would decrease. All of these effects would increase the proportion of carbon emission due to manufacturing. The selection of small fuel efficiency cars will in general lead to a reduction in manufacturing emissions.

One can take a wider perspective and consider the carbon emissions arising from manufacturing the alternative passenger transport vehicles (buses, trains etc.) and the from the building of transport infrastructure (roads, railways etc.). It is probable that a significant modal shift away from cars, as proposed above, would lead to a net reduction in carbon emission for the production of the whole rolling stock and infrastructure.

Table 6-7 : Carbon emission in manufacture and running a car

Manufacturing energy	GJ/car	60	56	51	45	37
Manufacturing carbon	tC/car	1.1	1.0	0.9	0.8	0.7
Fuel consumption	mpg	28	35	47	71	141
	l/100km	10	8	6	4	2
	MJ/km	3.5	2.8	2.1	1.4	0.7
	Annual distance (km)					
Carbon total (tC)	16000	10.8	8.8	6.8	4.7	2.6
	12000	8.4	6.9	5.3	3.7	2.1
	8000	6.0	4.9	3.9	2.8	1.6
Manufacturing/lifetime	16000	10%	11%	14%	17%	25%
carbon emission	12000	13%	15%	17%	22%	31%
	8000	18%	20%	24%	29%	40%

Building a house requires some 360 GJ of energy and results in about 6.7 tC of carbon emission. The author estimates that of the order of 80% of energy and carbon is due to the production of building materials (brick, cement, steel, glass etc.), and the remainder is due to energy used in transport and on building site machinery. Space heating with gas results in the emission of about 0.6 tC per year for a typical house. (There is a great range in both of these figures). Assuming a life of 100 years, the manufacturing emission of such a typical house constitutes 11% of total lifetime emission from space heating. If however space heating requirements are reduced by 70% through technical conservation measures and lifestyle change, then, if manufacturing emissions are assumed to be unchanged, manufacturing constitutes some 38% of life cycle emission. As for cars, the manufacturing requirements become very significant if running requirements are low. This has several implications. First, the savings in manufacturing energy and carbon that might be made by selecting houses made with more use of non-traditional materials such as timber or timber products could be significant.   Second in many cases it may be best to retrofit install conservation measures to existing buildings, rather than build new ones. The energy or carbon payback time in replacing an average UK dwelling with a new efficient house is the of the order of ten to twenty years. The degree to which this is possible obviously depends on many other factors such as the general condition of the house, the need for houses at new locations, and so on.

These two examples above, the car and the house, use illustrative estimates of energy and carbon requirements which may be quite inaccurate. The examples nonetheless indicate how more attention should be paid to manufacturing emissions as the running emissions are reduced through the selection and development of energy efficient technologies. They also indicate how the informed selection and use of cars and houses might reduce emission from manufacturing as well as use.

6.5.3 Commodity choice and expenditure pattern

Consumers can reduce the carbon emission consequent to their purchase of goods and services by:

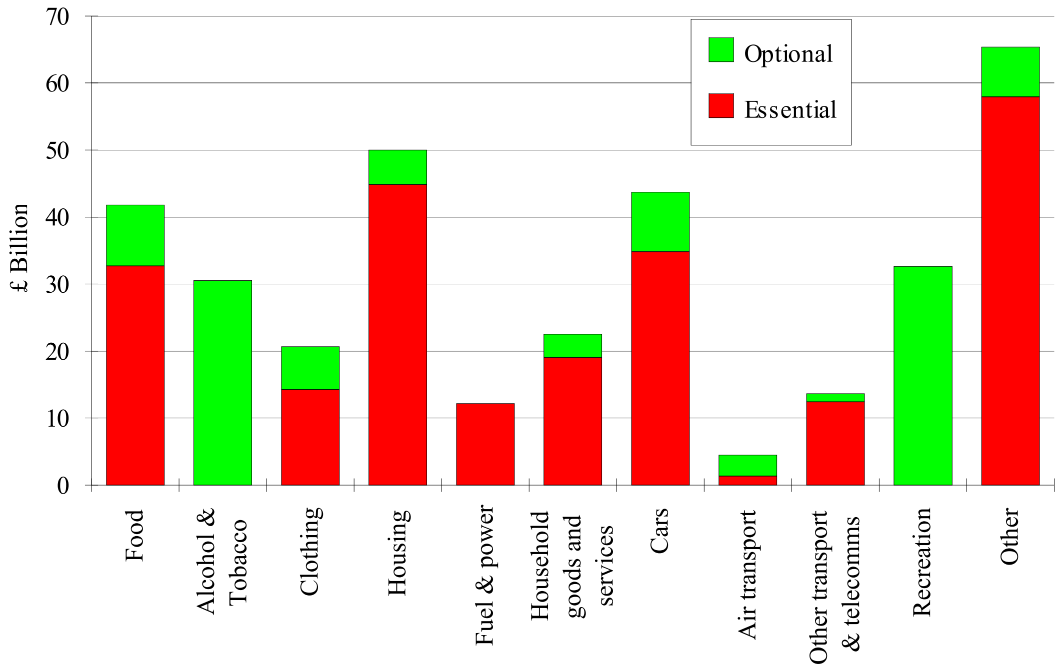
- selecting commodities which provide the same utility, but which are less carbon intensive;
- switching optional expenditure to categories of commodity which are less carbon intensive;
- purchasing less overall.

Within a certain commodity category, a particular 'model' of good can provide the same or similar utility as another and yet require less energy carbon for its manufacture. For example a wooden house or item of furniture could be seen to provide the same utility as the same commodity made out of more carbon intensive materials such as brick, steel or synthetic fibres.

A certain level of expenditure is necessary for the provision of essential commodities such as basic food and shelter. However, for most people in the UK a proportion of their disposable income can be spent on what may be regarded as inessential commodities such as alcohol, electronic entertainment or holidays: this may called optional expenditure. Figure 6-18 shows the pattern of consumer expenditure in the UK in 1990. The author has made conservative estimates of what proportion of expenditure in each category might be regarded as optional. This is varies from an obvious 100% for some categories, such as alcohol, tobacco and recreation, to lower more arbitrary proportions for others. Overall some 70% of expenditure may be regarded as essential. Carbon abatement would result if people directed this optional expenditure away from carbon intensive commodities towards those needing less energy and carbon per £ value for their production. For some categories there are practical limits to which this redirection can occur. For example redirecting £1000 of expenditure on a long distance flight to the purchase of potable alcohol might save energy and carbon, but not people's livers. For others, redirected expenditure could potentially be less limited. Spending £1000 on works of art rather than air travel would presumably reduce emission dramatically, and the potential for such expenditure is very large since it is not limited by natural resources. It is not possible here to accurately estimate the potential carbon abatement which might be achieved through such alterations to expenditure, but perhaps some notion of its potential effect can be given. If a third of optional expenditure were redirected to commodities with an average 33% lower carbon intensities, then overall emission from production would be reduced by 10%: and UK emission by 6%. A reduction of this order could be achieved by redirecting expenditure away from air travel to almost anything else. A proper assessment of the scope for abatement through altering expenditure would require robust estimates of the carbon intensities of goods and services, and a refined analysis of the potential redirection of expenditure to the various categories.

The last option of reducing overall expenditure has the most fundamental implications. To a first approximation a 10% reduction in expenditure would result in a 10% reduction in carbon emission from those sectors of the economy producing goods and services. If people were to spend less they would either have to save more or earn less. Savings are ultimately stored or deferred consumption and saving could not occur to an indefinite degree. Less expenditure ultimately means less production, and less wealth as measures by any of the conventionally defined indicators such as GNP. Reduced expenditure would impact on the whole economic and social structure. It would have to be predicated on a definite departure from orthodox social and economic objectives.

Figure 6-18: UK expenditure pattern (1990)



7. OTHER COUNTRIES

The UK case study analysed in some detail the effect of lifestyle on certain elements of energy consumption. Since such analytic procedures have not been applied in the same way to other countries it is not possible here to estimate lifestyle savings in industrialised countries (ICs) other than the UK with great precision. However it is important to so do because the potential lifestyle savings in ICs are generally large in proportional terms, as demonstrated by the UK case study, and because these countries presently account for the bulk of carbon emissions. Furthermore the non-industrialised countries (NICs) tend to follow ICs in terms of lifestyle, insofar as their wealth allows. As argued above, certain aspects of the 'modern' lifestyle can not be developed without aggravating environmental impacts of one sort or another.

To a degree it is wrong to analyse lifestyle issues purely on a country basis. In most ICs there is a significant proportion of the population who have inadequate levels of service provision. In the UK, for example, some 12% of the population live in cold or very cold houses (DoE, 1991), and the emphasis on private car transport disadvantages those who can not drive, or are not wealthy enough to own a car. Conversely, even in the poorest countries there is a significant number of people who have comfortable 'western' lifestyles. However data is usually poor at the sub-national level, and if it does exist, the analysis becomes that much more complex. Furthermore, policies and programmes are to a large degree determined nationally.

A model (SCENAGEN) developed by Barrett and Protheroe (1992) was used to assess the effects of different energy policy programmes, and has been applied to all European countries and a subset of CIS states. The policy programmes include:

- Lifestyle changes; These are of the type discussed in detail previously.
- Conservation; This includes the reduction of useful energy demand through measures which include insulation, ventilation control, heat recovery, and general energy efficient design.
- Increased efficiency; This entails the improvement of efficiency in the technical sense of conversion technologies transforming a greater proportion of fuel input into useful energy. This applies to end use devices such as boilers, light bulbs and car engines; and to supply technologies and systems such as power stations (electricity only and CHP), and district heating.
- Fuel switching; Carbon (and acid) emission can be reduced by switching to low carbon gas from coal and oil, and to zero carbon renewable or nuclear energy.

Different levels and rates of implementation of each policy can be assumed. The programmes can be assessed in isolation, or in any combination. The model allows a rapid assessment of assumed carbon emission control strategies for many countries. The assumed strategies are based on exogenous technical and economic analysis. Although the programme assumptions are based on a number of general and country specific studies, at present the model's usefulness is as a broad brush analytic tool. Currently it is assumed that renewable energy supply to end use sectors remains at current levels. This is because the potential supply from renewable energy sources varies greatly from country to country for reasons including gross availability, environmental suitability, and cost. Very detailed country specific studies are therefore required. Technologies such as cars, buildings, power stations and boilers show greater similarity across countries; and indeed the trend is one of convergence as these technologies are internationalised (in some cases inappropriately).

7.1 Industrialised countries

SCENAGEN has been used to illustrate the effects of the programmes for the richer European countries, and the USA, where lifestyle change can have most impact in terms of carbon emission reduction. The USA has been included because of its importance as a carbon emitter. These countries account for approximately a third of current global fossil carbon emission. The assumptions made about the possible levels of reduction through lifestyle are moderate as compared to those arising from the UK case study. This is because there is no foundation of detailed analysis to base the assumptions on. This is cautious in that the probability is that the savings in other ICs should be of the same order as in the UK.

The model was first used to illustrate the effects of the programmes acting separately and in combination for the year 2010. The relative and absolute effects are shown in Figure 7-1 and Figure 7-2. The first Figure shows the proportional reduction in carbon emission as compared to the base scenario.

Denmark is a slight oddity in that its carbon emissions increase after fuel switching. This is because it is producing a surplus of electricity from CHP plant following changes in the market following conservation, and changes in market share. The surplus electricity is assumed to be exported, but the carbon emissions are allocated to Denmark.

Figure 7-1: Effect of control programmes on carbon emission (2010)

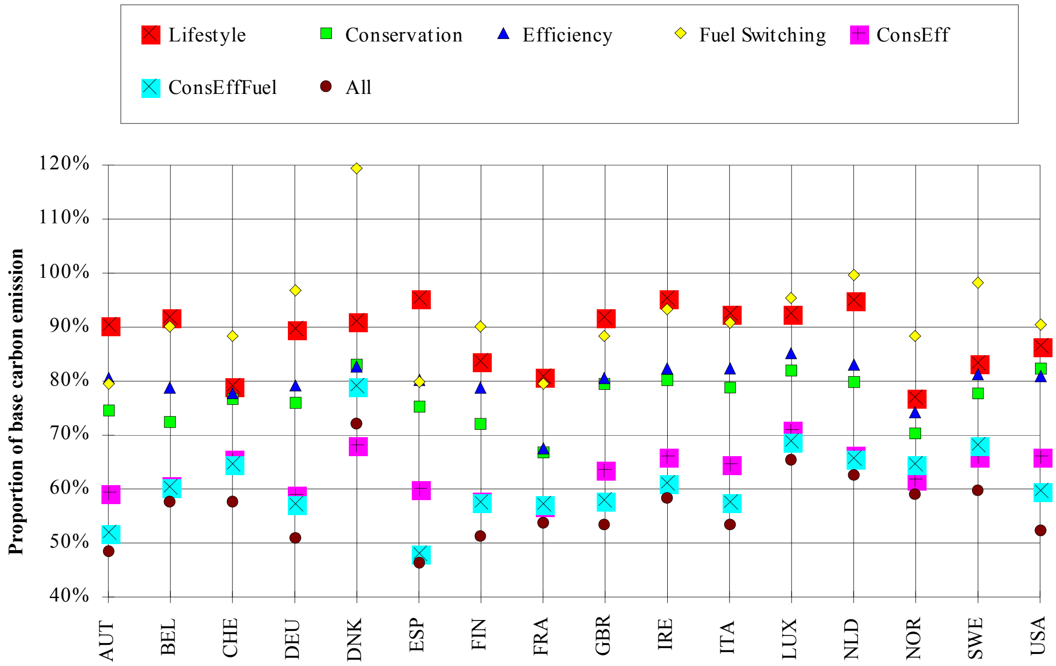
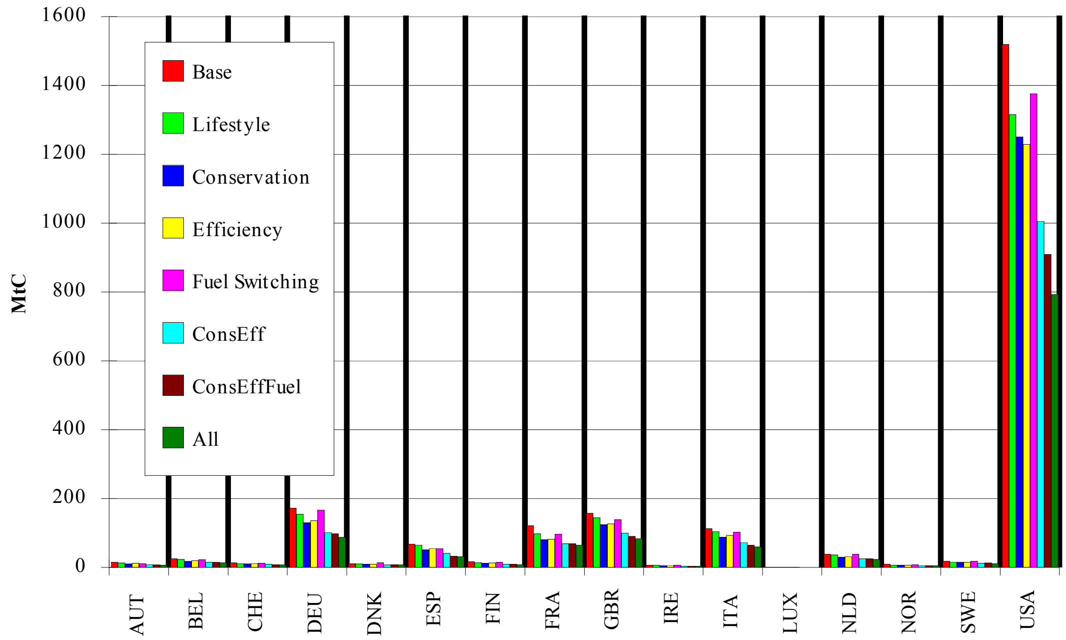


Figure 7-2 depicts the absolute carbon emissions for all cases for 2010.

Figure 7-2: Carbon emission in 2010



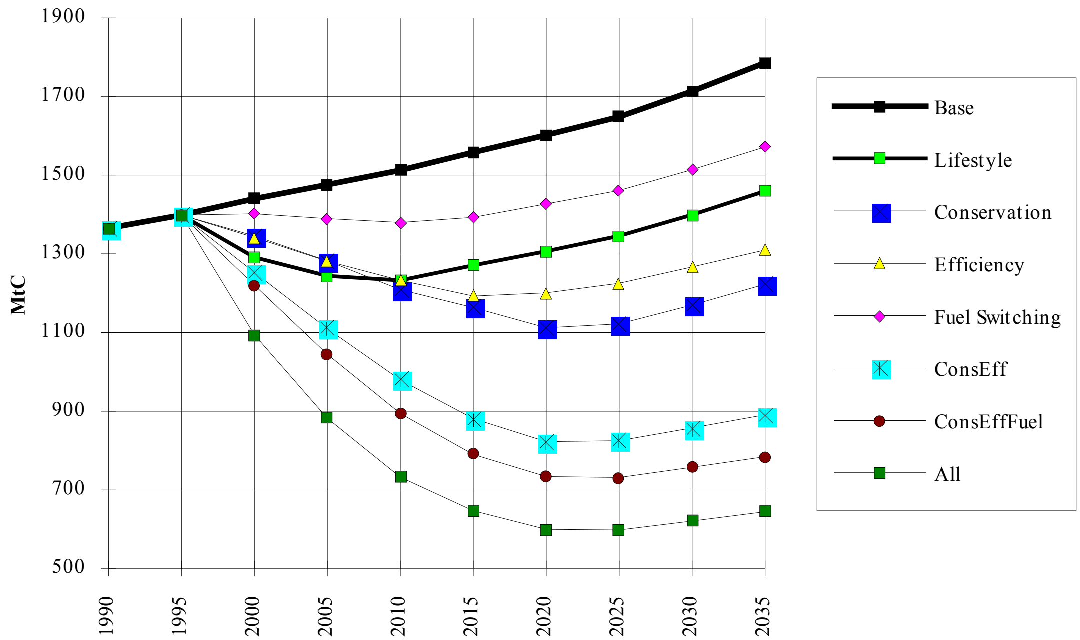
SCENAGEN has also been used to explore scenarios for the USA in order to assess the potential impact of lifestyle change on this major emitter. The base scenario is based on a constant GDP growth of 2%/a, with no lifestyle change and modest improvements to conservation and efficiency, and some switch to gas. The variants from the base assume quite firm control programmes, with the exception of increasing renewable energy. These scenarios are consistent with other studies (e.g. Chandler, 1990). Figure 7-28 depicts the impact of various combinations of carbon control programmes on emissions from the USA.

The impact of lifestyle change is significant on its own, and acting in conjunction with the other programmes. Over most of the scenario period lifestyle change is reducing annual carbon emission by about 15-20% as compared to the base case or other programmes; such that it reduces aggregate carbon emission over the whole period (1990-2025) by the same proportion. This reflects the rather cautious assumptions made about the potential effects of lifestyle change: there is a prima facie case for supposing that emission reduction could be proportionately larger in the USA than the 25% resulting from the UK case study.

The combination of programmes reduces annual emissions by 53% by 2035 as compared with 1990. This is more than half way to the target for 2090 for the USA suggested by the global carbon analysis in chapter 2.

It is notable that emissions begin to take an upturn after 20-30 years. This is because the most of the programmes have had full impact by this time. (The major exception to this is improved efficiency in power stations where it is assumed that the it takes 40 years for the full gain.) The implication is that in two or three decades time, the programmes will have to be pushed further. This would require new technologies and the greater introduction of renewable energy sources if possible. Perhaps a more fundamental review of lifestyle would also be warranted.

Figure 7-28: US Carbon emission scenarios



7.2 Non-industrialised countries

The responsibility for the historical and present emission of carbon dioxide rests overwhelmingly with the ICs. However this preponderance will diminish to the extent that ICs reduce emissions, and NICs increase them because of increasing standards of living and population growth.

People in NICs are attempting to improve their lifestyles in the sense of enhancing the level of services. For many in the poorest countries (energy) services such as effective cooking, lighting, heating and transport are non-existent, or at very low levels. For some services in some countries, energy efficiency and low impact energy supply allow an increase in service without increasing environmental impact, indeed the overall impact may be reduced. In some cases, it may be a matter of substituting one environmental impact (such as deforestation) for another (such as emissions from fossil fuels). It is to be hoped that services will be developed, with due regard to other concerns (including the environment), to the point where all can enjoy 'comfortable' lives.

NICs can attempt to bypass the energy inefficient patterns found in ICs. For example, the pattern of land use is dependent on the provision of transport, and vice versa. An emphasis on private car use influences land use in such a way that societies become reliant on an energy inefficient mode of transport. Conversely, forethought in land-use planning and the provision of effective mass transport might prevent NICs becoming locked into energy intensive transport.

As and if the wealth of the poorer countries grows an increasing proportion of the population can aspire to and achieve certain elements of the lifestyle of people in rich countries. This aspiration is, amongst other things, the result of national objectives as well as of individual hopes. There is also pressure from the suppliers in the ICs as they look for new and larger markets around the world.

8. INFLUENCING LIFESTYLE CHANGE

Plainly the kinds of lifestyle change explored here would be against the trends and aspirations manifest in most countries - rich or poor. Furthermore, there is a common, often unstated, philosophy underpinning trends in growing consumerism that consumption should not be in any way constrained (see for example the quotes from Galbraith in chapter 3). To do so would be deleterious to improvements in the quality of life, and to progress in the form of, for example, economic growth. However this philosophy is increasingly challenged by environmental concerns and limits. For example, what is the balance of the enhanced quality of life brought by private motoring for some, against the decreased quality of life for all due to the environmental degradation consequent to that activity? Obviously larger scale environmental degradation, such as that threatened by climate change, will put more pressure on the notion that increased consumption of any kind can be allowed to increase indefinitely.

To a large extent the ease with which the adoption of more environmentally benign lifestyles can be brought about depends on the perception of individuals and governments of these issues. If the short and long term benefits of lifestyle change are apparent then the prospects for change are improved. This perception can be enhanced through the provision of information and general education. There are limits to what people can and will accomplish as private individuals. Action by government and other public bodies is a necessity. This is especially so when there are collective vicious circles to be broken: an effective switch from car to bicycle and public transport requires public action such as cycle and bus lanes. Lifestyle is directly influenced by government through the use of education, financial incentives, regulation and investment.

The remainder of this chapter briefly discusses some methods of influencing people's behaviour and lifestyle. It is intended to be introductory, rather than to be a comprehensive analysis and discussion. As for implementing other carbon abatement measures, such as energy efficient technologies, a judicious mixture of the methods would have most effect.

8.1 Information and education

The provision of information and education is the 'softest' means of changing behaviour. Its effectiveness is difficult to predict, but the obvious impact of education and the level of expenditure on advertising indicates that they are effective. Certain aspects of lifestyle can possibly only be changed by these means. It is difficult to conceive of other ways of encouraging people to wear appropriate clothes and alter thermostats, or to use cars more carefully.

8.1.1 General

Consumers are bombarded with information about the supreme qualities of various goods and services though advertising. For many key technologies and services much of this advertising exalts qualities which are ultimately deleterious to the environment. For example, the speed and size of cars are generally emphasised much more than their fuel efficiency, which indeed may not be mentioned at all. Furthermore they are often shown being driven at high speed or with great acceleration.

In contradistinction, there is relatively little educational material showing people how they can select the best technologies and use technologies efficiently. Even less are people effectively educated about the impacts that their behaviour and lifestyle have on the environment. There are occasional government advertisements exhorting people to "save it", and some of these give detailed tips such as how to avoid overheating. This sort of education should be made much more comprehensive. Advertising is only one outlet. A complementary, but probably more effective channel, is the education system. The main reason for this is that the bulk of expenditure on advertising comes from private companies whose objective is the promotion of consumption. Education is also better at advancing people's understanding of issues and responses than advertising's sound or sight bites.

Rectifying the imbalance between promoting consumption rather than conservation would be aided by more extensive advertising standards: these could be largely voluntary as at present, or regulated.

8.1.2 Commodity selection

The provision of information about the fuel or energy consumption of goods and services and the associated carbon emission or global warming should be made mandatory. At present in most countries consumers can only obtain this information without difficulty, if at all. The provision of such information would educate consumers, and allow them to include environmental considerations in their selection of commodities.

Often fuel efficient technologies offer overall cost savings to consumers - this information should also be provided. Care has to be taken to ensure that the information is sufficiently precise without being incomprehensible to the layperson. This information should be given for technologies such as cars, appliances and houses in mandatory labelling and advice schemes. Such information could also be given for services such as air transport.

8.2 Financial incentives

There are plethora of financial incentives and disincentives which may be applied so as to encourage people to reduce the more ruinous forms of consumption. Essentially this means increasing the cost to consumers of harmful behaviour through some form of taxation, and/or decreasing the cost of benign behaviour through tax relief or subsidy. For certain activities the true costs are not accurately reflected. For example, the methods and criteria for appraising public investment in roads and rail are not comparable.

Taxes can be quite general, or they may be focused on particular activities or segments of the population. A general taxation on the unwanted environmental input, in this case carbon dioxide, will generally suppress levels of that input. In the case of carbon emission a tax on fuel has been the suggested practical route. Unfortunately the fuel cost element of running technologies such as a car or a house is generally a small proportion of the total cost of purchasing and running them. Furthermore initial purchase costs generally loom larger in consumer's mind than later running costs. Consequently the fuel tax imposed has to be very high to have much impact. Capros et al (1991) showed that a 40$/barrel equivalent carbon tax, which would increase fuel prices by 50% to 120%, but would only reduce UK carbon emission in 2005 by 7.7% as compared to a reference scenario. Limiting such a tax to politically feasible levels would make its impact very small. A more indirect tax on fuel might be applied to the purchase cost of technologies: the thirsty car would have larger purchase tax imposed than the thrifty car. However such a tax would also probably have to be large: the smallest and most efficient cars already cost some 40% less than the average 1.6 litre car in the UK.

The removal of some existing subsidies, and the application of additional ones can influence behaviour. The removal of tax relief on company cars is an example or removing a subsidy. Increased subsidies could be given to modes of transport other than the car. Experience has shown that subsidies can have a large effect on the extent to which public transport is used.

8.3 Public investment

Private individuals can modify their lifestyles significantly through purely private decisions about the use and selection of technologies. However there are many instances where public investment is required. For example, a certain number of journeys can be shifted from car to rail or bus without extra investment. However an extensive shift would require investment in rolling stock such as trains and buses, or infrastructure such as stations and bus lanes. Individuals can only stimulate such investment by increasing demand for those services, but they are only likely to do so if these services are adequate. This vicious circle is best broken by public rather than individual action.

8.4 Regulation

Regulation already has a big effect on energy use and emission. For example, standards are applied to the thermal efficiency of boilers and buildings, and road speeds are limited by law. Such regulation could be tightened in some areas, and extended to cover other technologies and activities. One advantage of regulation is that its effects are more predictable than the other means described in this chapter. Another is that there is less need for consumers to digest complex information and take decisions.

8.4.1 Energy efficiency standards for technologies

Energy efficiency standards as applied to boilers and buildings could also be applied to other energy using technologies such as domestic appliances and cars. Such standards are relatively easy to devise and implement. They also have a very large and predictable effect: the UK case study shows that carbon emission from cars would be reduced by 45% if standards corresponding to the most efficient small cars were applied. They do impact on lifestyle (the small slow car rather than the big fast one) but generally not very greatly.

8.4.2 Use of technologies

It is generally difficult to regulate the ways in which people use technologies. Such regulation is often politically problematic because it is a direct and visible constraint on people's everyday behaviour, and thus raises the spectre of an attack on personal freedom. This form of regulation can be difficult and expensive to enforce.

One significant area of practicable regulation of technology use the use of cars. Fergusson and Holman (1990) showed for the UK the effects of stopping the current law breaking in terms of excessive speed, and of reducing the speed limit further and enforcing it. The restriction of the use of cars in cities is an effective way of encouraging less polluting modes and reducing carbon emission.

9. CONCLUSIONS

It has been shown that reductions in per capita carbon emission of the order of 90% and more are required from industrialised countries given assumptions about global carbon emission targets, population growth and international equity. These assumptions have to be substantially amended to significantly diminish the reductions required. To reach this order of carbon abatement by technological means alone is problematic. Energy efficiency measures and benign energy sources run into rapidly increasing marginal economic and environmental costs at very high levels of deployment.

The study has demonstrated that fairly minor changes to lifestyle can reduce carbon emissions significantly and rapidly. The analysis of the UK is quite detailed and shows that a reduction of the order of 25% is possible without extreme lifestyle changes. A more broad brush appraisal of the effects of lifestyle for a selection of other rich countries indicated that large reductions are possible there too. Therefore lifestyle change should take its place alongside technological measures as one of the options available in carbon abatement strategies. Some carbon abatement may be achieved through people altering patterns of expenditure. The potential here is probably significant, but it has not been assessed in quantitative terms in this study.

With trends continued consumption will increase, and so generally will the pressure on the environment. Environmental costs and constraints will in turn affect the pattern of production and consumption. It is difficult to influence people to change their lifestyles, but the pressure to do so will probably increase. The benefits of so doing in terms of quality of life have become apparent in recent times and will become more so in future. This has already resulted in public policies which implement lifestyle changes, at least locally. Restricting the access of the private car to the centres of some European cities is an example. There are few signs of individuals freely choosing lifestyles with less impact.

The possibility, if not probability, is that in the longer term more radical departures from the current lifestyles of people in industrialised countries will become an essential ingredient of environmental protection strategies. At the same time the benefits of such change may become more apparent in economic and quality of life terms, and it therefore may become more desirable. Indeed, the likelihood is that people and politicians will not adapt themselves unless the benefits of so doing are clearly seen to outweigh the costs. It may even be that changing some elements of the conventional lifestyles will allow other elements to be sustained or increased. For example, reducing carbon emission from air transport might allow further enjoyment of domestic holidays whilst keeping total emissions within some target.

These conclusions are not inimical to consumption per se. The question is what level of consumption of different goods and services are compatible with environmental aims.

The answer to this depends in part on the technological context of the time. Technical measures which reduce environmental impact should be used as far as possible. However, their deployment is limited by the extent they are socially acceptable, cost effective and do not merely substitute one environmental impact for another equally serious.

9.1 Further work

A large proportion of this study is taken up with the attempt to quantify the effects of certain relatively minor lifestyle changes in the UK. Many areas of interest were not covered at all, and a number of topics would benefit from deeper analysis.

9.1.1 Needs and services: concepts and futures

More precise concepts of human needs and services need to be developed. These concepts require careful definition, and where possible quantification. This would facilitate better projections of future needs. If, as the author argues, there is a balance between levels of service and environmental protection, there will be increasing negotiations about what this balance should be. This will occur at the local, national and international scale.

How will changes in demographic, social and economic structures and patterns affect future needs? The UK case study took 1990 as its date for comparing minor lifestyle changes with the status quo. It would have been better to have made a projection for, say, the year 2010. But then the effects of changes such as increased average age, smaller households, greater optional expenditure, different working patterns, a larger services sector, and technological development would have to be accounted for.

9.1.2 Other environmental benefits

The lifestyle changes analysed here would bring reductions in environmental inputs other than carbon dioxide. An appraisal of other benefits, such as reduced noise, visual obtrusion and emission of other gases from road traffic, would be useful. It would enhance the perception of the general benefits of these changes and so make them more likely to occur as circumstances require.

9.1.3 Economic aspects

The study contains no analysis of the economic consequences of lifestyle change. Generally the changes suggested will result in overall financial savings to consumers in meeting their needs. Of course it is argued that because of reduced environmental impact there will be other benefits which may not directly be expressible in monetary terms. However there is an extra 'cost' in that visible changes in service are implied. Work would could usefully done in developing a conceptual framework for analysing this issue, and in quantifying costs and benefits where possible.

The lifestyle changes, as for any change in consumption pattern, would have wider economic impacts. There is the question of what alternative goods or products consumers would spend any saved money on. Plainly the large reductions in fuel use, and the shift from the private car, would impact heavily on certain sectors of the economy.

9.1.4 Building services

A more detailed analysis of thermal comfort conditions and clothing in domestic and non-domestic buildings could be carried out in order to arrive at firmer estimates of the carbon emission reduction potential. The reduction of emissions through altering cooking and hot water use was not analysed in the case study.

9.1.5 Transport

The multifarious effects of a large shift away from cars could be studied in more detail. The reduction in congestion could be very significant in terms of reducing fuel consumption and journey times. Particularly important is a proper assessment of the potential for rail and bus to carry many more passengers, and a quantification of the investment required in these modes, and investment savings in roads because of reduced road traffic.

9.1.6 The resource requirements and environmental inputs of commodities

The gross energy requirements and carbon emission of producing most goods and services are not well known, although a fragmented picture is gradually emerging from a number of research programmes. It would be profitable to compile a database showing the resource requirements and environmental inputs (of carbon in particular) associated with goods and services.

9.1.7 The effects of changing consumption patterns

It would be useful to properly estimate the effect on carbon emission of consumers changing their pattern of expenditure (e.g. by purchasing clothes rather than foreign holidays), or of buying one form of commodity rather than another (e.g. a wooden rather than a brick house). This would require a comprehensive understanding of the current pattern of expenditure, and a methodology for estimating how much change might be feasible and acceptable.

9.1.8 Implementation

A thorough analysis of the methods of influencing lifestyle change is required. Case studies of past experience of the influence of methods such as education, advertising and taxes would give an indication of how behaviour might be altered. This would form a firm base for proposing particular programmes aimed at encouraging people to take up a more environmentally benign way of life. The many ways in which government action would facilitate changes in people's behaviour need elucidating.

9.1.9 Detailed case studies of countries other than the UK

It would be interesting to do detailed studies of industrialised countries other than the UK. It seems obvious that the USA would be a leading contender for this: it is the largest emitter as a country; it has a very high per capita emission; and it serves as model to aspire to for many people. A 15% carbon emission reduction achieved through lifestyle change in the USA would be more than the entire emission of the UK.

10. GLOSSARY

10.1 UNITS

	Acronym	Expansion	Measure
Prefixes	k	kilo	1000
	M	Mega	1000 000
	G	Giga	1000 000 000
	T	Tera	1000 000 000 000
	P	Peta	1000 000 000 000 000
	E	Exa	1000 000 000 000 000 000
Energy	J	Joule	Basic unit of energy
	Wh	Watt-hour	= 3600 J = 3.6 MJ
	toe	tonne of oil equivalent	= 42 GJ
	tce	tonne of coal equivalent	= 27 GJ
Other	m	metre (metric length)	
	g	gramme (metric weight)	
	t	tonne (metric weight)	
	tC	tonne of carbon	
	tCeq	tonne of carbon equivalent in terms of global warming	
	p.km	Passenger kilometre	

10.2 GENERAL

Acronym	Expansion
C	Carbon
GWE	Global Warming Effect
NOx	Nitrogen Oxides
GDP	Gross Domestic Product

10.3 INSTITUTIONS

Acronym	Expansion	Country
CSO	Central Statistical Office	UK
DEn	Department of Energy	UK
DoE	Department of Environment	UK
DTp	Department of Transport	UK
EC	European Community	
ERR	Earth Resources Research	UK
ETSU	Energy Technology Support Unit	UK
HMSO	Her Majesty's Stationery Office	UK
IATA	International Air Transport Association	
IC	Industrialised Country	
ICAO	International Civil Aviation Organisation	
IEA	International Energy Agency	
IPCC	International Panel for Climatic Change	
NIC	Non-Industrialised Country	
ORNL	Oak Ridge National Laboratory	USA
TRRL	Transport and Research Laboratory	UK
TSGB	Transport Statistics of Great Britain	UK

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