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EXPLORING WAYS TO REACH SUSTAINABILITY IN TRANSPORT, HOUSING AND HIGHER EDUCATION

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ABSTRACT

In the industrialised North anything between 60% and 95% reductions in resource consumption and CO_2 emissions may be needed to avoid global environmental problems, while allowing the population of developing countries to reach decent living standards.

This paper reports preliminary results of a study of the potential for up to Factor 10 (90%) reductions in three sectors – housing, transport and higher education. Housing and transport are responsible for about half the energy demands and emissions from UK households, while education is a growing service sector with the potential for significant dematerialization through distance learning and electronic delivery.

A pilot study has been conducted of the strategies needed to reduce CO_2 emissions from personal transport to a level recommended by the Inter-Governmental Panel on Climate Change. A model of the factors that generate the overall amount of emissions was used to explore alternative scenarios. The result is a scenario that achieves the required 60% reduction in emissions by 2020 through a combination of technical and behavioural changes. Similar methodological approaches will be used to explore the environmental improvements that might be achieved in the three chosen sectors over the period from 2010 to 2050 and beyond.

Keywords: transport, housing, higher education, Factor 10, sustainability.

1. INTRODUCTION

This paper reports preliminary findings from a research project being undertaken by the Design Innovation Group (DIG) at the Open University. This project is based on the Group's previous work on ecodesign (Smith, Roy and Potter, 1996) and material produced for new Open University course, T172 *Working with Our Environment* (Potter, 2000; Roy, 2000a).

It is increasingly recognised that, to mitigate the effects of climate change and to address other global environmental issues requires major reductions in consumption of energy (particularly fossil fuels with their CO_2 emissions) and resources. For the industrialised North, anything between Factor 4 (75%) and Factor 20 (95%) reductions in energy and resource consumption may be needed, if allowance is made for the population of developing countries to reach decent living standards (Carley and Spapens, 1998; UNEP, 1999, Weaver et. al. 2000).

But is a Factor 10 (i.e. 90%) reduction in energy/resource use and emissions from the industrialised world even *theoretically* possible in the required time-scales, say, by 2050 when global population is expected have increased by over 50% to nearly 9 billion people?

Several strategies have been proposed for reaching Factor 10 improvements. One involves the (eco) design of products for reduced environmental impacts throughout their lifecycle (e.g. Behrendt et. al., 1997, Brezet et. al., 1997). However, a major difficulty in developing 'sustainable' product designs is that total environmental impacts depend on the wider system in which the product is used. For example, it is possible to design a 'greener' car, but (as will be shown later) if ownership continues to rise and journey distances lengthen, then overall environmental impacts will increase even if each vehicle is 'greener'.

2. FROM PRODUCTS TO SYSTEMS

Our project started with the concept that a shift from products to services and new product-service systems – sometimes called 'dematerialization' – could play a major role in reaching Factor 10. Such new systems of products and services could include car sharing, and new patterns of ownership, such as appliance leasing. These might deliver the functions of existing products, but at a lower energy and resource demand (Meijkamp, 1997; Roy, 2000b: Cooper and Evans, 2000). But we became increasingly aware that you can not meaningfully measure changes in environmental impact at the level of the individual product. The reduction in environmental impacts may be outweighed by a growth in consumption, usually compounded by direct and indirect 'rebound' effects. A *direct* rebound effect arises if more demand for a 'green' product is stimulated when its purchase or running cost is reduced through efficiency gains. For example, if a car has a better fuel consumption, the cost of motoring is reduced and people may drive more. Indirect rebound effects involve the question as to if there is reduced consumption of energy and/or materials, on what will any money saved be spent? One, albeit anecdotal, example of an *indirect* rebound effect was linked to membership of a commuting car pool club. One couple participating in a USA scheme used the money saved by car pooling to fly off on a long-distance holiday – thus creating more CO_2 emissions than had they continued to commute to work in their own cars!

Overall, Herring (1999) argues that it is not sufficient to improve the energy and resource efficiency of products and services at the micro level because rebound effects can lead to increased consumption at the macro level. The aim should be to reduce environmental impacts by a variety of policies, including ecological taxation and changes to the *supply* system and not just attempting to reduce energy and resource *demand* through eco-efficiency.

This analysis draws the crucial conclusion that it is impossible to move towards sustainability if the system under consideration is limited to products alone. Thus, in approaching the question of achieving a Factor 10 improvement in environmental impacts, we concluded that a wider systems boundary was needed, allowing for overall levels of consumption and rebound effects. Our approach has developed into one that looks at how ecodesign and new product services might be combined with more radical shifts in patterns of production and consumption in order to reach the desired reductions in environmental impacts.

2.1 A Household Focus

Our starting point is households. Household heating, lighting and appliances are directly responsible for nearly a third of energy delivered in the UK and a quarter of CO_2 emissions. If personal transport is included, this rises to about half of delivered energy and nearly half of CO_2 emissions. Also about 60% of goods and services (including personal transport) purchased in industrialised countries are for domestic consumption (OECD, 1998), giving rise to indirect demands for energy, water and materials. This figure was supported by Dutch studies, which calculated that indirect household energy and resource consumption due to purchases of food, clothing, furniture, recreation, etc. represented some 60% of the total consumption (Noorman and Uiterkamp, 1998; Vringer and Block, 2000).

Various methods have been used to estimate the household activities that give rise to the greatest environmental impacts, including Ecological Footprints (Wackernagel and Rees, 1996; Simmons and Chambers, 1998). Typically 70% of a household's 'footprint' arises from direct energy consumption and personal transport, so those are key areas to tackle. The importance of reducing household emissions from energy and transport is confirmed by a major US study using input-output analysis (Brower and Leon, 1999). That study indicates that another key household environmental impact is the land used for personal transport and house-building.

Higher education represents a contrast to the obvious impacts of housing and transport. It is part of the fast-growing service sector and has the potential for significant 'dematerialization' through distance learning and electronic delivery via the Internet. Education might also act as an absorber of the indirect rebound effects of reduced consumer expenditure on energy and transport.

Our study therefore explores the potential for up to Factor 10 reductions of environmental impacts in three sectors – personal transport, housing and higher education – over the period from 2010 to 2050 and beyond. We take the UK as the model for industrialised countries, but recognise that it has both similarities and differences from other OECD countries.

3. TRANSPORT PILOT STUDY

The personal transport study emerged from work undertaken for the Swedish Energy Agency (Potter, 1998) that was further developed into teaching material for the Open University's *Working with our Environment* course (Potter, 2000) and has now became a pilot for this research project.

Personal transport provides a good example of the problems discussed above concerning achieving an actual reduction in environmental impacts from a consumption activity. In discussions on reducing environmental impacts from the operations of cars and passenger transport, often only one part of the system generating total emissions is considered. For example, emphasis may be placed on reducing emissions by vehicle design or alternative fuels, but such improvements may fail to make much difference in practice as increases in the amount of travel and behavioural change compensate for the vehicle improvements. A classic example is the 'CAFE' fuel economy regulations in the USA. These have improved car fuel economy by over a third since the mid 1970s, but growing vehicle use has more than compensated for this, part of which is due to lower running costs arising from better fuel economy.Thus, although vehicle energy efficiency has improved, the total amount of fuel consumed has risen.

The opposite extreme is the view that the main response should be behavioural change, with a dramatic shifts to cycling and public transport and cuts in car and air travel. But if we are to achieve a radical reduction in environmental impacts, individuals and politicians balk at the prospect of 'turning the clock back' to a level of mobility much lower that enjoyed by people today.

3.1 Exploring the Issue

A useful way to explore this issue is to express environmental impacts as the result of a simple formula. One such formula was originally proposed by Paul and Anne Ehrlich (1990) and developed by Ekins et al (1992). They proposed the equation that environmental impacts (I) are a product of Population (P) x Consumption (C) x Technology (T).

So, if current environmental impacts are taken as an index of 1.0, you get a baseline position of:
$P \times C \times T = 1$

For transport, this approach can be adapted to disaggregate total travel into key emission-generating factors. A number of studies have established that the fuel consumed in driving vehicles represents some 90% of total life cycle energy consumption (e.g. Teufel et al, 1993, Hughes, 1993), so this is the issue upon which to concentrate. The formula model can be adapted as follows to calculate the environmental impacts from motorised travel. For this, the baseline situation would be:

Population	Car journeys per person	Journey length	Vehicle occupation	Emissions per vehicle km.	Total emissions
1 x	1 x	1 x	1 x	1	= 1

This simple formula can now be used to explore possible futures and alternative scenarios. In the first instance a 20-year time-scale was taken. For simplicity, the pilot study concentrated on the key global issue of CO_2 emissions from personal transport.

3.2 Business as Usual scenario

Concentrating now upon current trends in the UK, what might the CO_2 index be by the year 2020? With UK population roughly stable, this can be left out for the moment, but other key factors are shown in Table 1.

Table 1. Key factors in UK car use 2000 to 2020

Factor	Index in 2020	Basis for calculation
Car journeys	1.5 (approx.)	Average about 600 per person per year (currently rising by 14 per year)
Journey length	1.2	Averages 13.6 km (rising by 0.14 km per year)
Car occupancy	1.1	Averages 1.6 (declining by 0.3% per year)
Fuel consumption	0.88	Averages 9.1 litres per 100 km across the car fleet (presently improving by only 0.2% per year – but assume it is accelerated so 8 l/100 km is achieved)

Sources: Noble and Potter (1998) and DETR, *Transport Statistics Great Britain.*

For a 20-year time-scale, a continued use of fossil fuels for personal transport, or as feedstock to 'alternative' fuels like electricity or hydrogen, seems likely. Such a future would result in the formula becoming:

Population	Car journeys per person	Journey length	Vehicle occupation	Emissions per vehicle km.	Total emissions
1 x	1.5 x	1.2 x	1.1 x	0.88	= 1.7

So, if we go on as we are, the model suggests that CO_2 emissions will increase to 1.7 times their current level (a growth of 70%).

This, of course, is only at the level of the UK. Such an isolationist approach to a global issue is not acceptable. Car ownership and traffic levels per capita in the developing world are growing much faster. There are around 550 million vehicles in the world, of which 400 million are cars (Mackenzie and Walsh, 1990). These are heavily concentrated in the industrialised nations. On average there are fewer than 100 cars for every 1000 people in the world, with four times this level in the UK (370) and over six times (650) in the USA. Car ownership is forecast to rise sharply in non-OECD countries, particularly in Eastern Europe and Asian economies. If historic rates of growth are maintained, the global vehicle population could exceed one billion in as little as 20 years time, with the number of car journeys expected to rise even faster.

As shown below, a global Business As Usual (BAU) run of this simple model suggests a quadrupling of CO_2 from personal transport within 20 years. Population growth could well be less, but these calculations assume UK figures for journey lengthening, a relatively small decline in vehicle occupancy, and assume fuel economy improves at the UK rate. All of these factors would probably be less favourable in developing nations, so this underestimates the likely rise in CO_2 emissions.

Population	Car journeys per person	Journey length	Vehicle occupation	Emissions per vehicle km.	Total emissions
1.5 x	2.3 x	1.2 x	1.1 x	0.88	= 4.0

If we were to rely on efficiency measures alone, the index for CO_2 emissions per vehicle kilometre would have to be drastically cut. For the UK, to stop CO_2 emissions from personal transport worsening would require the emissions index to be cut to 0.50. It is enlightening to express this figure in terms of average car fuel economy. To achieve this index figure would represent a doubling of average car fuel economy from 9.1 litres per 100 km to 4.55 l/100 km (60 mpg). At the global level, the emissions index would need to be 0.22 to hold transport's CO_2 emissions at current levels, requiring a 4.5 factor improvement in fuel economy. This would require, within 20 years, the world's car fleet averaging about 2 l/100 km (150 mpg).

The thought of achieving a global average car fuel economy of 150 mpg within 20 years suggests that the sums are starting to look beyond the realms of feasibility. Moreover, this is without even attempting to *reduce* CO_2 emissions from personal transport in order to tackle climate change.

3.3 Reducing Transport's Environmental Impacts

The IPCC (Houghton et al., 1990) suggest that, to stabilise atmospheric concentrations of carbon dioxide, emissions need to be cut to 40% of their 1990 level. Returning to the UK situation, it is reasonable to assume that the transport sector would need to contribute a proportionate cut. Since transport's CO_2 emissions have already risen by 15% since 1990, the total for the index needs to be not 0.4 but 0.34. Again, if we were to rely on efficiency measures alone, the index for emissions per vehicle kilometre would need to be drastically reduced, from 0.88 to 0.17:

Population	Car journeys per person	Journey length	Vehicle occupation	Emissions per vehicle km.	Total emissions
1 x	1.5 x	1.2 x	1.1 x	**0.17**	= 0.34

If fossil fuels were used, fuel economy would need to improve to an average of about 1.6 l/100 km (approx. 170 mpg). Allowing for a proportion of less fuel-efficient vehicles, much of the car fleet would need to achieve in excess of 200 mpg. This, of course, is referring to Britain alone. The necessary improvement in fuel economy becomes even greater once a global perspective is taken, as shown below:

Population	Car journeys per person	Journey length	Vehicle occupation	Emissions per vehicle km.	Total emissions
1.5 x	2.3 x	1.2 x	1.1 x	**0.075**	= 0.34

Using conventional fossil fuels, the global average fuel consumption needs to be 0.6l/100 km (514 mpg) in 20 years. Taking a longer perspective with further population and car use growth, this would need to be around 0.4 l/100 km (706 mpg) by 2030. We are thus into the realms of Factor 17 – 25 efficiency improvements and probably a Factor 50 improvement needed by 2050.

Even if, over a 20 year time-span, such figures look utterly unrealistic, might renewable energy and alternative fuels allow such a target to be reached? Even if the use of renewable fuels is assumed, the level of efficiency improvement remains a major one. If 85% of the global car fleet used renewable fuels with no net CO_2 emissions, the rest would still have to manage 2.8l/100 km (100 mpg) in order to hit the IPCC sustainability target.

If the scenario date were pushed back, such technical improvements might appear possible, but equally, the growth in car use and population would require even more efficiency improvements. It is clear that even if, by 2050, all internal combustion engine vehicles were replaced by hydrogen fuel cell vehicles, the production of this hydrogen would have to use 50 times less fossil fuel than is currently consumed by the world's car fleet. The inevitable conclusion is that, improvements to vehicle technology cannot represent a viable approach to reducing transport's CO_2 emissions to a sustainable level, for either a 20-year or longer time-scale.

3.4 Modal Shift Scenario

A much-advocated alternative approach to cutting transport's environmental impacts is to promote modal shift from the car to less energy-intensive, forms of transport. To evaluate this option requires a return to a UK focus, as it is difficult to obtain and use global figures for key factors such as modal share and journey length.

To explore the effect of modal shift requires the formula model to be split into the three main components of motorised travel – car, bus and train. This is not to say that non-motorised travel (walk and cycle) is unimportant, but they do not generate CO_2 emissions. Trip shifting to walk and cycle can be accommodated in the model by altering the 'journeys per person' figure for the motorised modes.

The Baseline Index is now as follows. This allows for energy use per passenger kilometre by train and bus being, on average, about half that of cars (Potter, 2000).

Journeys per person	Journey length	Vehicle occupation	Emissions per vehicle kilometre	Modal share	Total emissions
Car: 1.0 x	1.0 x	1.0 x	1.1 x	0.88	= 0.97
Bus: 1.0 x	1.0 x	1.0 x	0.5 x	0.10	= 0.05
Rail: 1.0 x	1.0 x	1.0 x	0.6 x	0.02	= 0.01

TOTAL = 1.03 (i.e. approx. 1)

A modal shift scenario could be based around the targets suggested by the UK's Royal Commission on Environmental Pollution (RCEP, 1994). In 20 years, this would cut car's share from 88% of motorised trips to 65%, with bus increasing to

25% and rail to 10%. Improvements to fuel economy could be at the BAU historic rate, as are the changes in car occupancy, although the shift to public transport is likely to raise average occupancy levels of buses and trains. The calculation is shown below:

Journeys per person	Journey length	Vehicle occupation	Emissions per vehicle kilometre	Modal share	Total emissions
Car: 1.5 x	1.2 x	1.1 x	1.1 x 0.88	0.65 x	= 1.25
Bus: 1.5 x	1.2 x	0.8 x	0.5 x 0.88	0.25 x	= 0.16
Rail: 1.5 x	1.2 x	0.8 x	0.6 x 0.88	0.10 x	= 0.08

TOTAL = 1.49

The net result is a near 50% increase in CO_2 emissions! The energy efficiency improvements arising from modal shift are insufficient to counterbalance the rise in other factors in the formula. An important component of this is the increase in the amount of travel, which involves not only motorised trips becoming longer and more frequent, but also the substitution of short trips by foot with longer trips by car. Simply to get the total to equal 1.0 would require car modal share to be cut to 30%, with bus rising to 40% and train 30% – a degree of behavioural change unlikely to be acceptable.

3.5 A Multiple Approach

This simple model demonstrates clearly that the only technically and politically practical way that transport's CO_2 emissions can be cut is to *combine* changes in both vehicle technology and behavioural factors. The latter cannot just be modal shift, for even combining modal shift and Factor 4 improvements in vehicle energy efficiency would not hit the 60% reduction target in CO_2 emissions.

One combination of changes that would hit the 60% CO_2 reduction target is the following run of the formula model:

Journeys per person	Journey Length	Vehicle Occupation	Emissions per Vehicle Kilometre	Modal Share	Total Emissions
Car: 1.3 x	1.0 x	1.0 x	1.1 x 0.25	0.65 x	= 0.23
Bus: 1.3 x	1.0 x	0.8 x	0.5 x 0.4	0.25 x	= 0.05
Train: 1.3 x	1.2 x	0.8 x	0.6 x 0.4	0.10 x	= 0.03

TOTAL = 0.31

This particular combination involves:

- a 30% increase in all motorised journeys (rather than 50% in the BAU scenario);
- holding all but rail journey lengths at current levels;

- a Factor 4 (75%) improvement in car fuel economy and a 60% improvement for buses and trains;
- a modal shift to bus and train to the level suggested by the Royal Commission on Environmental Pollution (1994).

The first two factors would involve walk and cycle trips being retained or increased. Overall for the UK, a Factor 4 improvement in vehicle fuel economy needs to be combined with significant modal shift and a halt in trip lengthening to the hit the CO_2 reduction target recommended by the IPCC. The amount and length of journeys are crucial factors, and yet are rarely considered in the transport/environment debate. If all the factors that generate emissions from travel are not addressed, an unrealistic improvement in individual factors is required.

Overall, this pilot study suggests that similar methodological approaches could be used to explore the environmental improvements that might be achieved by technical, behavioural and socio-economic changes in all three of the project's sectors.

4. HOUSING

For housing, what might be an appropriate target to adopt? For the UK cutting transport CO_2 emissions by the IPCC target of 60% is probably the maximum achievable by 2020 and may not be reached until much later. Clearly this is not the 90% reduction that may be required by 2050 and beyond. Could this Factor 10 target be reached by the UK housing sector, thus compensating for some of the shortfall in transport?

Most UK homes are not energy efficient. The average rating of homes in England on the UK government's SAP (Standard Assessment Procedure) measure of energy efficiency is about 45 out of 100. And only about 15% of English homes have reasonable standards of energy efficiency i.e. a SAP of 60 or more (Shorrock and Walters, 1998; DETR, 2000). It is relatively easy, with simple insulation and heating system improvements, to upgrade existing homes to a SAP rating of 70. This would cut CO_2 emissions by about 30%. New UK housing is being built with SAP ratings of 80 or more, producing emissions about 50% of the current average home. A few UK developers are beginning to build homes to higher levels of energy efficiency. For example, a 1999 commercial development of 20 houses in Nottinghamshire has a SAP rating of over 100 through high levels of insulation, solar water heating, and passive solar gain. The houses, which only cost about 10% more to build, also collect rainwater for toilet flushing. Such homes could probably achieve a 60% reduction in total CO_2 emissions.

But even if all 23m existing UK homes were upgraded or replaced to these current best practice standards by 2050 (or more realistically by 2100) that would produce less than a 60% reduction in emissions. This is partly because of direct rebound effects. The heating standards of some 40% of English homes are currently inadequate, including about a quarter of all households in so-called 'fuel poverty'. Thus much of any improvement in UK housing energy efficiency is expected for many years to result in higher indoor temperatures rather than fuel saving (DETR, 2000). Secondly, the number of houses is expected to grow, largely to cater for the growing number of single person households. For example, four million new homes are expected to be built in the next 20 years. This increase in the number of homes, it is calculated, will result in an increase in CO_2 emissions from UK housing between 2010 and 2020 even if a major programme of energy efficient measures is implemented (Hay, et al, 1999). As with transport, increasing consumption is eliminating improvements from eco-efficiency, at least in the short to medium term.

Technically, of course, individual dwellings can be built to much higher levels of energy efficiency, as has been shown by numerous ultra-low-energy homes that have been built across Northern Europe over the past 25 years (e.g. Olivier and Willoughby, 1996).

An example is the Autonomous Urban House built in 1993 near Nottingham, England. As well as being almost entirely solar heated, it is independent of mains water and sewage, and has a photo-voltaic (PV) array to generate about half of the electricity required for water heating, lights and appliances. Fossil fuel energy consumption is about 10% of a typical house i.e. a Factor 10 reduction. But the cost was relatively high, because of the extra space required for the conservatory, water collection and the £15,000 PV array.

For other individual zero-energy houses a 60%-80% reduction in life time CO_2 emissions has been calculated, taking into account the extra embodied energy involved in incorporating their energy saving and other features (Viljoen and Thompson, 1996). However, living in such houses requires commitment from the occupants, for example to open and close windows to admit and vent heat as well as to operate other environmental features such as composting toilets.

Lower costs and even higher levels of energy efficiency can be achieved by grouping homes in small communities, who then share some of the extra work involved in sustainable living. An example is the terrace of five earth-sheltered houses, the Hockerton Housing Project near Nottingham, which stay warm all year round with no heating system at all. All the heat required comes from the sun, collected in the conservatories, and stored in the thermal mass of the heavily-insulated building. Monitoring by the Building Research Establishment shows that these houses use 75% less energy than a conventional UK house built to 1995 standards (BRECSU, 2000). When a wind turbine for electricity generation is built, energy consumption of these houses is likely to be less than 5% of current UK averages, i.e. a Factor 20+ reduction. But again the occupants can only achieve this level of sustainability through a commitment of 16 hours per household per week to the project, not just to energy saving but to other communal activities such as local water collection and sewage treatment, transport sharing and growing vegetables.

The idea of attempting to achieve sustainability at community level has been taken further in number of new eco-villages built in Sweden and elsewhere. An UK example is the Beddington Zero Energy Development project in south London. The aim is net zero CO_2 production, for community of about 200 people. This is being achieved by building 90 solar heated homes, together with offices and a combined heat and power plant. This plant is fuelled by locally growth wood irrigated with wastewater from sewage processing. Car sharing, home working and other methods are planned to reduce transport demand.

Although there are only a few such ecological housing projects at present, the numbers are growing. Chappells and Shove (2000) studied 11 ecological housing projects in the UK, the Netherlands and Sweden. These varied from local authority schemes for low-income families to housing co-operatives and self-build schemes, including the Hockerton project. The projects involved different mixes of energy and water conservation, waste recycling and local sewage treatment. The key problems were not so much technical ones, but the social and behavioural issues involved in attempting to live more sustainably. The success of the projects depended on the extent to which the homes attempted to be independent of mains services and the extent to which living in these homes was the active choice of the people concerned.

Other ways of reducing the environmental impacts of shelter have been explored by the European Union funded Sushouse Project (Anderson et. al., 2000). These include ideas ranging from ‘comfort management’ companies providing household warmth and light services, to radical concepts for active ‘intelligent’ homes and heated clothing.

Our project intends to explore the key components that make up CO_2 emissions from UK housing, based for example on the energy consumption formula suggested by Shorrock and Walters (1998). This will be employed to explore the effects of scenarios comprising different mixes of existing, upgraded, new conventional and ecological housing – together with socio-technical changes such as those suggested by the Sushouse project – that might be achieved by 2020, 2050 and beyond. If these do not produce the 60%-90% CO_2 emission reductions from housing (or as in the transport pilot study, require unrealistic changes), making up the shortfall would require changes to the energy *supply* system, in particular the potential for shifting mains electricity supply for homes to renewable energy sources.

5. HIGHER EDUCATION

5.1 Introduction

Personal transport and housing have the potential for delivering much higher levels of eco-efficiency, notably in their use of energy. But, as we discussed earlier, unless accompanied by other policies to control increasing levels of consumption or to change the energy supply system, rebound effects could reduce or eliminate the environmental benefits of any efficiency gains. Higher education, especially part-time continuing education, may have the potential for absorbing some of these rebound effects by providing a service activity on which consumers could spend their time and money. However, the potential benefits of such a shift from consuming products to services, depends on the extent to which education is actually ‘dematerialised’.

Traditional modes of delivering higher education through campus-based courses are being challenged by the increasing access to distance learning through both print-based and electronic forms of communication. In response to growing demands for part-time studies, conventional universities have tended to add the distance delivery of courses, rather than using this method of teaching for full-time students. There are variations in the design of such distance-teaching systems, with different degrees of face-to-face contact (Burt (1997). However, the main provider of part-time distance teaching in the UK is the Open University (OU), established in 1969. The OU pioneered degree-level, distance education using specially produced books, radio and television and is now increasingly involved in distance learning via electronic media, including CD-ROM, computer conferencing and the Internet.

This part of our Factor 10 project will involve a comparison of the environmental impacts of four different modes of higher education:

- traditional, face-to-face teaching at campus based universities – full-time courses;
- traditional, face-to-face teaching at campus based universities – part-time courses;
- an OU distance learning course undertaken mainly with printed material;
- an OU distance learning course presented via the Internet.

The study will investigate the effects on travel demand, energy and paper consumption and equipment requirements of the production, presentation and delivery of the selected courses via these different modes.

5.2 Models of Conventional and Distance Learning Universities

The traditional university is characterised by a single or multi-site campus where staff and students congregate. The OU has a relatively small campus because it does not have to support a resident undergraduate population. Course material is delivered directly to students for part-time study at home, and additional educational support is mainly delivered through tutorials held in local sites, such as colleges. There is a heavy reliance on students being able to weave their studies into their individual domestic arrangements.

An underlying assumption of this study is that the principle environmental burdens of a higher education establishment can be identified through a simplified system model. This also has the effect of identifying appropriate boundaries. The different higher education models for this study are illustrated in Figures 1 to 4.

The boxes show the physical elements of each system. Solid arrows indicate movement of people and materials between these physical elements, while dotted arrows show inputs of energy and materials to, and outputs of emissions and wastes from, the elements. Lighter dotted arrows indicate electronic communication links.

All models share a campus that consumes resources and energy and emits waste. All models also include ‘other study-related sites’, such as libraries use of which may involve physical travel, and Internet sites that students may access electronically. Other common elements are the main ‘home’ residence of students and staff and, in the OU models, the homes of part-time tutors. The network of tutors (called Associate Lecturers) is an important feature of OU education. On a print-based course they provide occasional face-to-face tutorials, plus telephone and postal support to the study of the course material. However, increasingly, even these OU courses are supported via computer communications. On an electronically presented OU course, the tutors support largely via email and electronic conferencing.

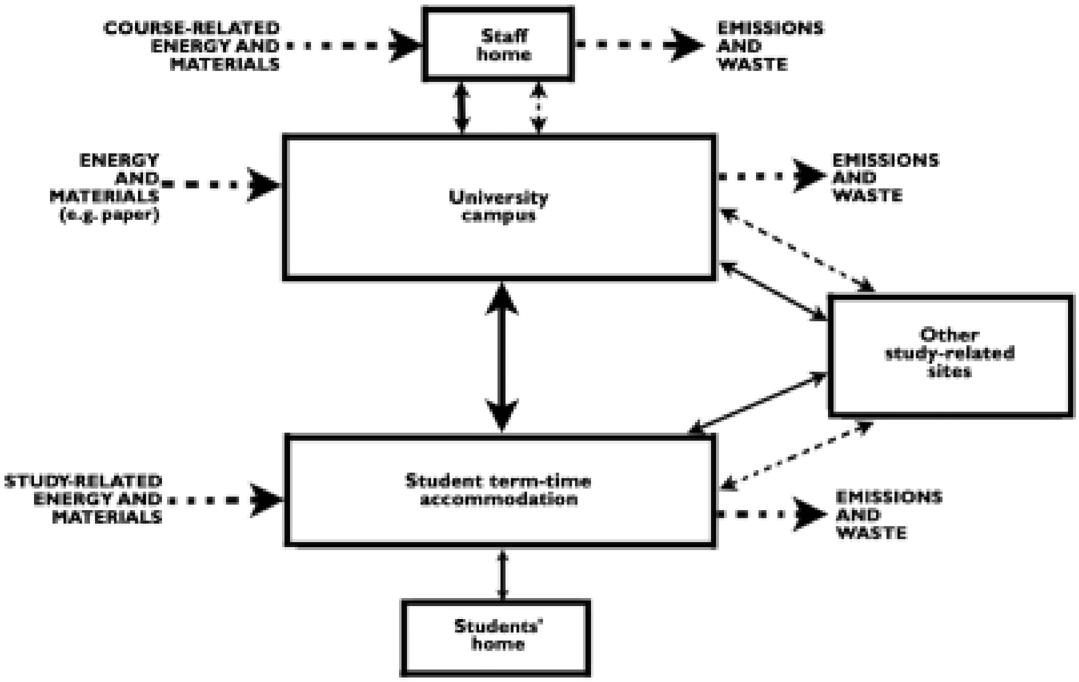

Figure 1. Conventional campus-based system – full-time course

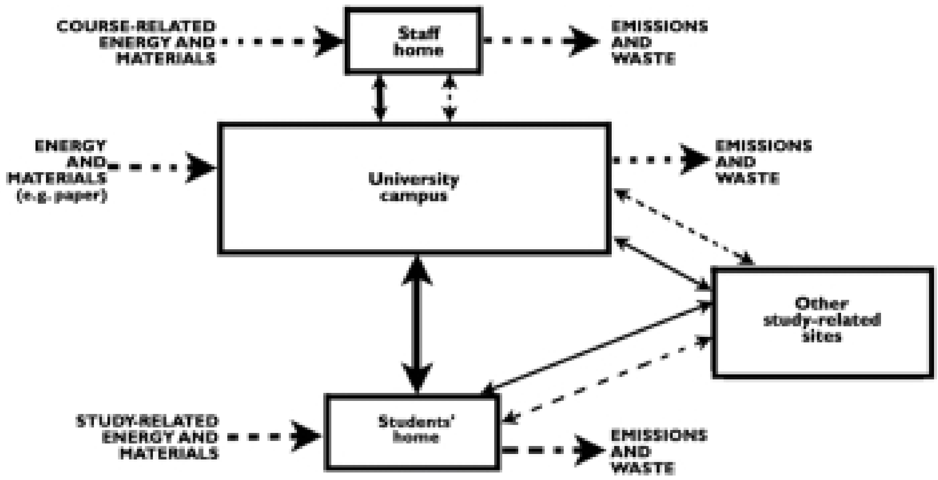

Figure 2. Conventional campus-based system – part-time course

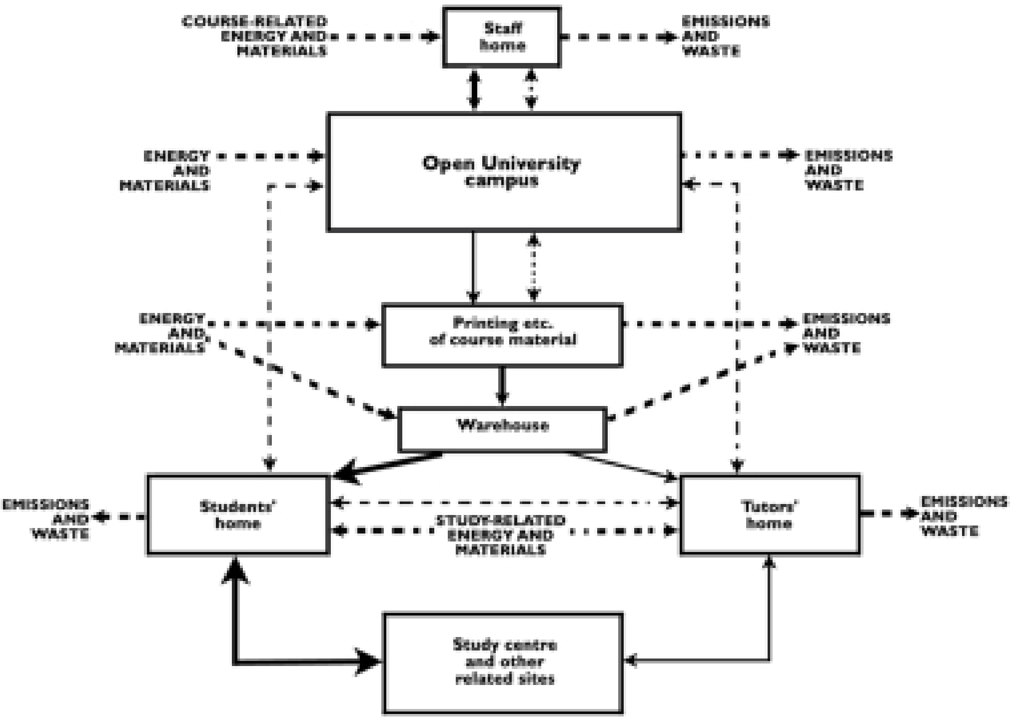

Figure 3. Open University distance education system– print-based course

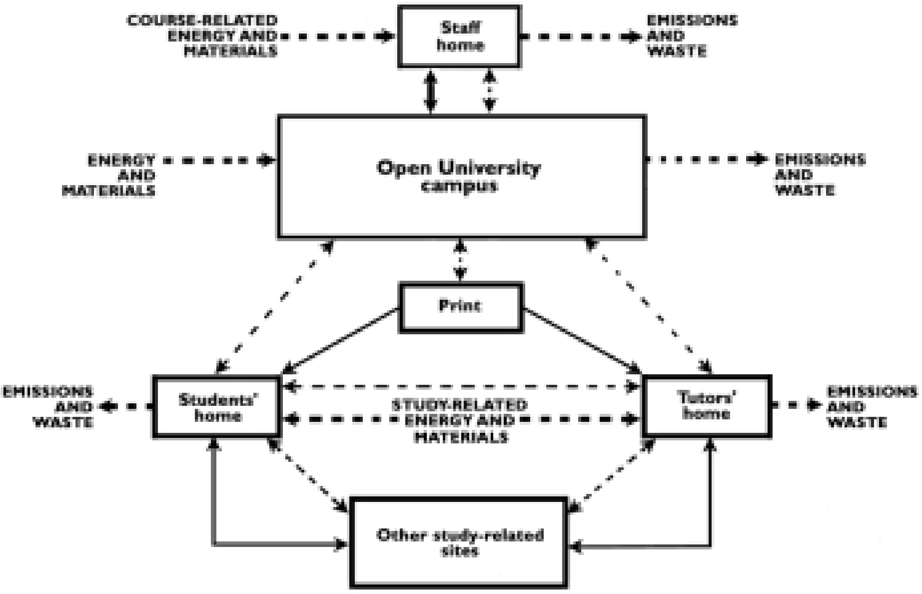

Figure 4. Open University distance education system – Internet-based course

The main differences between the two OU models lie in the production and distribution of course materials and the need for students and tutors to regularly travel to a study centre. In the electronic delivery model course production and distribution using computers and telecommunications have largely replaced the physical production, warehousing and distribution of printed course materials. However, even in the electronic system some printed material is involved and some face-to face tutorials may be required. The main difference between the full and part-time campus based models are whether students are assumed to live in term-time accommodation or in their main home residence.

5.3 Data Requirements

To compare the environmental impacts of different courses, considerable data will be required. The impact, notably related to energy and paper use and staff travel, of a university campus needs to be established, since this is a common feature of all models. Some of this data for conventional UK universities has been collected from contributors to the 'HE 21' exercise initiated by Forum for the Future (1999). Some data for overseas universities also exists (e.g. Delakowitz and Hoffmann, 2000).

The second factor is the nature of student travel patterns and domestic energy use. The latter is important for analysing the environmental effects of studying at home. For example, it is currently unknown how much additional or marginal energy consumption for computing and home heating can be attributed to distance learning. Some data are available, but more detailed student surveys of travel and study behaviour will be needed. It is proposed to collect this from the current cohort of undergraduate students studying a print-based and an electronically delivered OU course.

The print-based course is entitled *Working with our Environment: Technology for a Sustainable Future* (T172), an introduction to technology and environment launched in 2000 and studied by over 1500 students. T172 is delivered in the conventional manner of OU courses, where students receive printed material through the post, and receive academic support through written comment on assignments supplemented by non-compulsory face-to-face tutorials, telephone and/or email.

The electronically delivered course is called *You, Your Computer and the Net* (T171), which in 2000 was taken by nearly 15,000 students! T171 is an introduction to computers and the Internet delivered largely via a dedicated Web site, together with two printed books, and tutored via an electronic conferencing system.

Two sets of questionnaires have been produced to determine some of the major environmental impacts of home based, part-time studying, and will be distributed to students of both courses after their examinations. The survey seeks information on the following:

- Distance, frequency and mode of travel connected with study of the course e.g. to purchase books or equipment, attend tutorials, visit libraries, etc.

- Energy and paper consumption associated with computer use during the course. And especially for T171, patterns of downloading and printing course material from the Internet. This is one potential rebound effect of electronic delivery. Students may print off copies of course material rather than study it on screen, thus not reducing paper consumption relative to a print-based course.

- Additional household energy consumption associated with studying. The survey aims to identify any above normal use of heating and lighting as a result of studying the course.

- Behavioural changes arising from completing the course that have environmental implications e.g. any changes in travel patterns, energy or materials consumption.

Although T171 is a basic computing course and not specifically geared to raising awareness of environmental issues, one possible effect of studying the course might be that behavioural patterns are changed, for example by enabling its students to use the Internet for shopping. T172 on the other hand is specifically geared to making students more aware of the environmental consequences of their actions and so greater changes in both attitudes and behaviour concerning the environment might be expected. Strictly speaking, therefore, because behavioural effects are dependent on the course content they should not be part of the environmental comparison of the different methods of delivery.

In addition to the environmental impacts associated with students' study of these OU courses, an assessment will be made of the energy and materials consumed in preparing, distributing and tutoring them.

Similar methods will be used to assess the environmental impacts of the campus-based HE system for both full and part-time courses. Although partial environmental audits have been conducted on a number of university sites, none have involved staff or student travel surveys, the impacts of computer systems on energy consumption, or paper used in the production and presentation of courses. Contacts have been established with other UK universities willing to compile this information.

5.4 Implications of the Research

In this study of higher education, it is assumed that, unlike in transport or housing, technological and behavioural changes such as the growth of home computing can be effected and diffused relatively rapidly. It is possible to envisage 2010 as a target date for reducing the environmental impact of this sector by 60%, with strategies for much greater reductions by 2020. As in the other sectors, the potential rebound effects of the use of technology should be carefully assessed, as these could potentially outweigh any environmental advantages.

6. FUTURE WORK

One issue raised by the work so far in these three sectors is that the time-scales for change are very different. Education has the shortest potential time-scale in which environmental impacts may be reduced. For transport, the life of a car averages around 8-10 years and transport projects (e.g. the planning and construction of new public transport systems) typically take at least the same amount of time to implement. For housing, the replacement cycle is much longer, with a 50-year or longer time-scale needed.

We therefore intend to develop a series of scenario dates across our three study areas so as to explore whether and how the overall effective 60% to 90%+ reduction in environmental impacts needed to achieve global sustainability might be achieved. This involves the transport pilot study being developed to consider a 2050 scenario in addition to the current one for 2020 and the education case study adopting scenarios for 2010 and 2020. As noted above, the housing study will disaggregate key components in order to explore the relative roles of housing design, behavioural change and energy supply improvements over 20 and 50-year periods and beyond.

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