Sustainable services, electronic education and the rebound effect

Journal Item

Paper for Environmental Impact Assessment Review

Sustainable services, electronic education and the rebound effect

Horace Herring* and Robin Roy

Department of Design and Innovation, Faculty of Technology,

The Open University, Milton Keynes, MK7 6AA, UK.

ABSTRACT
This paper challenges the belief that improving the efficiency of resource use will necessarily lead to lower consumption. Findings are presented of a study by the UK Open University of the environmental impacts of three higher education delivery systems. Initial analysis indicates that the distance-taught courses involve 90% less energy and CO2 emissions than the campus courses. Electronic delivery does not result in a reduction in energy or CO2 emissions compared to print-based distance learning, due to rebound effects e.g. in use of computers. The paper concludes that to limit consumption we need to deal with rebound effects and practice 'sustainable consumption'.

Introduction
Undoubtedly the world is rapidly changing under the growing influence of Information and Communication Technologies (ICTs), but whether for better or worse is the subject of much debate and controversy. Some argue that we will become an information society with the potential to substitute information and knowledge for material products. This process, termed 'dematerialisation', would consequently bring a big reduction in energy and material consumption without any cutbacks in economic growth. Others, such as protesters at G8 conferences, argue this change hastens the process of globalisation, and only encourages more transport of materials and people, with consequent increased energy use and environmental destruction.

The UK Labour Government is firmly of the former view, terming it the New Economy, and extolling the benefits of the internet and its economic opportunities – the e-commerce (Wilsdon, 2001). A more critical look is being undertaken by the *Factor 10 Visions* project at the UK Open University (OU). This is examining the feasibility of achieving up to factor 10 (90%) reductions in the energy consumed and emissions produced by three sectors – transport, housing and higher education (HE) (Roy, Potter and Smith, 2001). In Section 6 of this paper the initial findings of the Factor 10 HE study are presented, which examines the environmental impacts of three higher education systems – conventional campus, print- based and electronically delivered distance learning.

1. ICT use growing in the UK
It is estimated that in the UK service sector in 1994 IT equipment (computers, printers, fax, and telecommunications equipment) consumed about 6% of electricity used in that sector – over two-thirds of this was in offices (Pout et al., 1998). In the UK domestic sector in 1998 the DECADE project estimates IT equipment only used about 1% whilst other ICTs, such as TVs and videos, were much more significant, accounting for about 9% of electricity use (Fawcett et al., 1998).

Electricity use in TVs is rapidly increasing due to the impact of cable and satellite decoders, which are on standby – that is drawing power even when the TV is switched off (Siderius, 1998). DECADE estimates that decoders currently use about 1% of UK domestic electricity, a figure that will certainly increase as consumers switch from analogue to digital TV.

2. Indirect energy use with ICTs

* Corresponding author. Email h.herring@open.ac.uk. Fax 01908-858407

Only about half of consumers' energy use comes directly through their purchases of electricity and fuel in the home and fuel for their cars, the other half comes indirectly through the purchase of goods and services (Noorman and Uiterkamp, 1998). This indirect energy use is involved mostly in the manufacturing process. The energy used in manufacture of appliances, including ICTs, is considerable, when taken into account their world-wide production in tens or even hundreds of millions. The (primary) energy used in the manufacture of a PC is about 5-12 GJ, and a colour TV 2.8 GJ, which compares to 13 GJ used to manufacture a refrigerator, and 83 GJ a car (Hilty et al., 1999; Hilty and Ruddy, 2000).

The internet, fax and phone are also not energy-free communication. The energy consumption per telephone line ranges from 90-144 kWh/year, about half for space heating at the exchanges, and the rest for running the exchange equipment, and operating air conditioning and ventilation systems (Hilty et al., 1999). Given that there are tens of millions of lines in each country, the national energy use is significant. The true energy cost is much higher once indirect energy use is taken into account.

3. The energy costs of information and leisure

One important area affected by ICTs is leisure (or recreation) and information, which are postulated as central themes in visions of the post-industrial or dematerialised society. A Finnish study of consumer energy consumption (Heiskanen and Pantzar, 1997), taking into account both direct and indirect energy use, found that the 'transport, information and leisure category' had the largest energy consumption at 32% of total consumption. (For a similar analysis for the Netherlands see Noorman and Uiterkamp, 1998.) Here energy is required for the production of goods, such as cars and television sets, for their operation, and for the construction and maintenance of infrastructure, such as roads and cables. Finnish time use studies indicate that the average time spent on leisure activities is about 6 hours a day, with watching TV accounting for about a quarter of that time, and reading about 15%. The survey found that these two most time-consuming activities are also the least energy intensive recreational activities (apart from perhaps just talking to family and friends, and some sporting activities such as walking). The most energy intensive recreational activity is anything that involves travel, either by car or long distance transport such as by plane.

Heiskanen and Pantzar (1997) estimate that reading a library book (that is read a 100 times) is the least energy-intensive activity consuming only 0.5 MJ. However reading a newspaper or a purchased book consumes far more energy than just watching 3 hours of TV (2 MJ). Going out is very energy intensive because of the travel costs: they estimate a night at the theatre is 180MJ, a day at the races is 220 MJ, and even a game of golf is 216 MJ.

Thus how consumers choose to spend their leisure time is very relevant from an environmental viewpoint. Frequenting the public library could be very virtuous, but not if one drives there! Here ICTs can make a big impact due to their ability to deliver information and entertainment to the home, eliminating the need to travel. But, as Heiskanen and Pantzar (1997) ask:

will the information super-highway do away with the urge to travel?...Will consumers actually substitute one good for another, or will they want to have it all: the television on, the newspaper on the table, and electronic news pointlessly self-scanning as the consumer of all this information dozes on the couch?

They make the comparison with claims made in the early 1980s about the paperless office, which never happened and actually turned out to be the opposite.

However consumers only have a limited amount of time for consumption activities during the day – there has to be time-budgets. Mikko Jalas (2000) uses the concept of time-use rebound effects to analyse how time saved, such as through use of ICTs, is spent. Like Heiskanen et al. (1997), he analyses Finnish household energy data and time use surveys to determine the energy intensity of selected household activities, with very similar results. He argues that replacing activities with an above average energy intensity, such as driving or eating in restaurants, will (on average) result in activities with a lower energy intensity (and vice versa). Thus on-line shopping with home delivery will save energy (the time saved by driving to the shop will be spent on a less energy intensive activity). But replacing your DIY car repair by taking your car to a garage will result in increased energy use (as you indulge in more intensive activities). Thus use of the internet, a low energy intensive activity, could reduce overall energy consumption, but only if there is a shift away from other non ICT activities; not if it only replaces time spent watching TV.

4. Rebound effect and ICTs

Despite the continuing dematerialisation of digital electronic equipment – a rapid trend to less power use per appliance – there has not been a reduction in their total energy use. As Lorenz Hilty and his colleagues comment (1999):

This apparent contradiction is a typical example of the rebound effect: the rapid dematerialisation has been compensated for – even definitely overcompensated for – by growth in the demand for computing and communication power.

The concept of the 'rebound effect' is well known and much debated amongst energy economists (Herring, 1999). It has been further explored in a recent paper by Mathias Binswanger (2001) who has investigated the effect of substitutability of time for energy. As he remarks:

Time saving devices usually require more energy as is most evident from transport, where an increase in the efficiency of time use (faster modes of transport) tends to be associated with a larger input of energy....the overall effect of time-saving technological progress will be an increase in energy use.

Hilty and Ruddy (2000) remark that ICTs have three effects: substitution, optimization and induction. The first two can reduce energy use, but the induction effect arising from the globalisation of markets and distributed forms of production due to telecommunication networks offsets the other effects by far. Basically ICTs facilitates the world wide division of labour and thus causes far more transport energy use (particularly for long distance freight and tourist travel). A further problem, especially for waste disposal, is the short innovation cycles causing ICT appliances to be disposed of long before the end of their technical service lives.

5. Sustainable consumption

So what can be done to lessened the environmental impacts of ICTs? There have been calls from environmental philosophers for a change in values, to change our lifestyle, towards what may be called 'voluntary simplicity' or 'sufficiency' (Rudin 1999). The desire by environmentalists (and religious teachers throughout the ages) to curb our material appetites has led to an upsurge of interest in the idea of 'sustainable consumption'. Laurie Michaelis, a researcher into the ethics of consumption, believes that we should aim to develop ideals of the good life that can be achieved without excessive material consumption (Michaelis, 2000).

However sociologists Eva Heiskanen and Mika Pantzar, while sympathetic to such moral changes, see difficulties. They argue that if anything has been learnt from consumer research on environmental issues, it is that a change in beliefs, attitudes or values does not necessarily lead to lifestyle change. They comment: (1997):

It is easy to agree that value change is needed, but new values are not swiftly taken up. Values are embedded in culture, both material and social... The dissemination of such ideas, and the setting in place of supporting institutions takes at least a hundred years. Obviously, we cannot wait that long for sustainable consumption.

Scientists and engineers have instead of value changes emphasised the technical possibilities of a shift to less resource intensive types of consumption. One solution they advocate is the concept *of service efficiency, which may be defined as providing a maximum of useful end-services to consumers using the minimum of materials and energy u*se (Heiskanen and Pantzar, 1997). There is an extensive literature on this concept and many attempts to design new types of service-producing machines that deliver energy services using innovative combinations of market goods and services and household labour (Roy, 2000). Once such attempt is that by the Dutch Ministry of Environment in its programme *Sustainability and Quality Lifestyles for the Year 2000*, which included such services as rent-a-car programmes, restaurant services, telecommunications and bulk delivery of goods to consumers.

6. Environmental impacts of E-Learning and other Higher Education systems

For ICTs perhaps the most talked about is the Internet, with its potential to transform the way information and services (like insurance, education, recreation and entertainment) are delivered to consumers. This point about the ability of ICTs to tranform services is not new, it was made in the early 1980s by Gershuny and Miles, who also pointed out the ability of the Open University (OU) to transform teaching methods by what they called 'tele-education' (Gershuny & Miles 1983: 190). The OU continues to be at the forefront of using ICTs for teaching and is undertaking research to examine the potential of the Internet to radically reduce resource consumption. This is part of the *Factor 10 Visions* project at the OU which is examining the potential for technical and behavioural changes to achieve up to factor 10 (90%) reductions in the energy consumed and CO_2 emissions produced by three sectors, taking into account consumption growth and rebound effects (Roy, Potter, and Smith, 2001).

Two of the sectors, housing and personal transport which together account for about half the UK's delivered energy consumption and CO_2 emissions, are obvious candidates. But why examine the third, higher education (HE) an already partly dematerialised service with comparatively minor environmental impacts? Firstly, HE is growing fast, especially in the UK where the Government has set ambitious expansion targets to a 50% participation rate of under 30 year olds by 2010. Secondly, there is considerable potential for further dematerialisation of HE through the expansion of distance and e-learning systems. Thirdly, were there to be substantial cuts in environmental impacts from major sources such as transport and housing, an indirect rebound effect could be via the diversion of consumer expenditure into services such as HE. If these services cannot be delivered sustainably, then improvements in the current major polluters could be counterbalanced by rising environmental impacts from previously relatively 'insignificant' service sectors.

A further reason is that an opportunity arose to undertake an environmental audit of not only the UK Open University's established distance learning courses delivered mainly via print and audio-visual material, but also the further dematerialised system of courses delivered and tutored mainly electronically. Could such e-learning methods offer the potential for up to a factor 10 reduction in environmental impacts, especially when compared to traditional campus-based methods of course production and presentation?

The *Factor 10 Visions* Higher Education study

The *Factor 10 Visions* HE study compares the environmental impacts of three different modes of UK higher education:

- Conventional campus-based courses;
- An Open University (OU) mainly print-based, distance learning course*: T172 Working with Our Environment*;
- An Open University mainly electronically delivered and tutored, distance learning course: *T171 You, Your Computer and the Net*.

This study is continuing and this paper reports some early results for the two OU courses and two of the campus-based university courses surveyed (for further details see Roy, Potter, Smith and Yarrow, 2001 and Roy, Potter, Yarrow and Smith, 2002). The principal environmental burdens of these different HE modes were identified through simplified system models (Roy, Potter, and Smith, 2001).

A conventional university is characterised by a single or multi-site campus for face to face teaching with students living at home or in term-time accommodation and travelling to lectures, etc. For many there is also travel between 'home' and term-time residences. The OU delivers course material directly to students for part-time study at home, with optional face to face tutorials run by part-time Associate Lecturers.

All systems involve a campus that consumes resources and produces emissions, although the OU campus is mainly for course development rather than teaching. All modes also involve consumption of paper, books, etc., use of computers, travel to other study-related sites such as libraries, and heating of home and/or term-time residences. The main differences between the two OU models are in the delivery of course materials and the need for students and tutors to occasionally travel to a local study centre. In the electronically delivered course, presentation via a dedicated Internet site has largely replaced the physical production and distribution of course materials.
The main differences between the three systems are thus in the amount of course-related travel; the consumption of energy for residential heating, for powering campus sites and for computing; and use of paper and printed matter for course preparation, delivery and study.

Data to compare the systems came mainly from student/staff surveys of the two courses at the OU and at eight UK universities (plus one Irish university), whose campuses included urban and rural sites. The two conventional universities included in this paper are one town centre, multi-site and one out-of-town, single campus university. Analysis of the remaining campus-based courses will help to determine how representative these two are.
The environmental impacts of staff preparation and tuition of the courses, is not included here. However, this is likely to be relatively small, and we have data on these elements for future analysis.

Energy consumption and CO2 emissions were used as measures, as these provide a good proxy for key environmental impacts (Chambers et. al., 2000). To ensure comparability all results were normalised per student per 10 CAT points using the standard UK HE Credit Accumulation and Transfer (CAT) system whereby 1 CAT point is approximately 10 hours student study and 360 CAT points are required for an undergraduate degree. The out of town campus course lasted 10 weeks and was worth 20 CAT points, the town centre campus course was 11 weeks and 10 CAT points, while the part-time OU courses each lasted 34 weeks and counted for 30 CAT points. Three of these courses had an environmental focus, while the OU T171 course was an introduction to computing and the Internet.

Key results

Environmental impacts were expressed as 'energy consumption and CO2 emissions per student per 10 CAT points'. For example, to calculate emissions from computer use the following formula was used:
Total computing time per week/No. students x Length of course x 10 CAT points/CAT points of the course.
The result was then converted to energy and CO2 emissions using data on a typical PC's electricity consumption and CO2 per kWh for UK electricity. Where possible we used delivered energy (i.e. the energy consumed by the end-user) for the calculations, although in certain cases in which there would be only a minor effect on the results we employed available primary energy data.

<u>Course-related travel</u>

For the conventional universities, transport for the course was split between local term-time travel, when students were based near campus, and travel between their main/usual 'home' and any term-time residence. Most of the local travel was for commuting to campus, but also included travel between campus sites, to libraries etc.

The data revealed the surprising fact that the town centre campus course students commuted nearly six times the distance of the students of the out-of-town course (340 km compared to 60 km per student per 10 CAT points. This is probably because the out-of town campus is largely self-contained with student accommodation, facilities and sites within walking distance, while half of the town centre course's students lived at their main home and some had a long way to travel to campus by bus or train. On average the town centre campus students also travelled over twice as far between their main 'home' and campus as the out-of town course's students (1340 km compared to 610 km per student per 10 CAT points). This seems to be because those who lived away from home during term appeared to be from the local area, and travelled frequently to and from their main home mainly by car or bus.

The travel data was converted into energy and kilograms of CO2 using best available UK or other data on the fuel consumption of the travel modes and the carbon content of the fuels involved. [1] It was assumed that travel as a car passenger involved no additional CO2 emissions. However, this would not be so if, for example, a relative made a trip especially to transport the student between home and university. This is a likely source of underestimation compared to the OU situation where, because students study from home, such travel does not take place.

Total travel, energy consumed and CO2 emissions per student per 10 CAT points was 1680 km, 2300 MJ and 170 kg at the town centre campus and 670 km, 1040 MJ and 78 kg at the out of town campus. Travel energy and CO2 emissions for the town centre campus students were thus over twice those for the out of town students, largely due to much greater term-time commuting.

For the OU courses, with the students studying from home, the total amount of travel was inherently much lower than at the conventional universities. For the print-based T172 there was a total of 83 km of course-related travel per student per 10 CAT points, mainly by car and rail, and involving 152 MJ energy and 12 kg CO2. This compares to 52 km travel for the electronically delivered T171, usually by car, and involving 118 MJ and 9 kg CO2. Most of the difference was due to the greater distance traveled by T172 students to attend tutorials at their local study centre. An interesting rebound effect of the electronically delivered T171 is the ten times greater travel to meet other students (at 8 km/student/10 CAT points) than undertaken by T172 students. The limited, if any, face-to-face tutorial contact offered to T171 students stimulated some to meet informally on their own initiative. Overall there was a cut by about a third in the distance traveled and a quarter in the energy consumed and CO2 emissions generated by the electronically delivered compared to the print-based distance learning OU course.

However, the interesting comparison is with the campus-based courses. Compared to the two campus-based courses considered here, the OU methods of delivery represent an approximate 90–96% (factor 10–25) reduction in course-related travel, energy and CO2 emissions. [2] Even though we need to confirm how representative the two campus based courses are, there are clearly enormous reductions in student travel-related emissions. Most of this reduction is due to the reduced need for mobility inherent to a distance learning course. Staff and student travel may be further reduced by substituting electronic conferencing and tuition for face to face tutorials.

The campus site

Official data on the fuel costs and total energy consumption of seven of the eight campus sites of the UK universities in the survey were obtained. Because the data on individual universities is confidential, only averages can be provided here. These show that the average non-residential energy consumption of the seven campuses was nearly 14400 MJ per year per full-time equivalent student. This is equivalent to 1200 MJ per student per 10 CAT points. [3] The data on annual purchases of gas, oil and electricity at each campus was used to calculate the average campus site fuel mix and hence emissions of approximately 1500 kg CO2 per year per student or 125 kg CO2 per student per 10 CAT points. A scoping study indicated that, because of the large student numbers on the OU courses (about 10,000 per year on the electronic delivered T171 and 1500 per year on T172), the site impacts per OU student per 10 CAT points are minimal. These are estimated at just 1 MJ and 0.1 kg CO2 for T171 and 6 MJ and 0.5 kg CO2 for T172.

Computer purchase and use

Information was gathered on the use of the students' own computers (use of university computers was excluded as this was part of the university site). The data for hours in use was converted into energy consumption and CO2 emissions. These data apply to a stand-alone computer. For the electronically delivered OU T171 course, especially, a substantial proportion of computing time was likely to have been spent connected to the Internet to study or download course material. Time would be also be spent online connected to the OU's conferencing system for posting messages to tutors and other students and for sending and receiving emails. [4] The energy involved in computer communications is uncertain. However, an estimate of an additional 0.36 MJ/hr was calculated based on a Dutch life cycle analysis study of different methods of sending messages (Remmerswaal et al., 2001). Since this figure is regarded as a lower estimate, a figure of 0.45 MJ/hr was taken as the additional energy of a computer connected to a remote network, thus approximately doubling its total energy consumption and emissions when in stand-alone use. Taking this into account, computer use (and associated energy and emissions) per student per 10 CAT points averaged:

32 hours (16 MJ, 2 kg. CO2) for the out of town campus course;
107 hours (53 MJ, 7 kg. CO2) for the town centre campus course;
161 hours (121 MJ, 15kg. CO2) for the electronically delivered T171;
63 hours (31 MJ, 4 kg. CO2) for the print-based T172.

The low use of students' own computers at the out of town campus possibly reflects the close proximity of university machines, whereas more students worked at home at the town centre campus. Not surprisingly, the electronically delivered T171 had the highest average computer use, energy consumption and CO2 emissions of all – nearly 2.5 times the use and over three times the energy and emissions for the other courses.

The purchase of computing equipment also involves environmental impacts due to the embodied energy involved. For example, 21% of the town centre campus and 17% of T171 students bought a PC, either alone or together with other equipment, mainly to study the course. In order to allocate environmental impacts an estimated 9000 MJ embodied energy per PC was used, based on the range of 5-12 GJ per PC mentioned earlier (Hilty and Ruddy, 2000). It was further assumed that a computer mainly used for study lasts for 3 years, and was then attributed according to the CAT points of each course. [5]

This translates into the following average embodied energy and emissions per student per 10 CAT points:

54 MJ, 5 kg CO2 for the out of town campus course;
81 MJ, 8 kg CO2 for the town centre campus course;
45 MJ, 4 kg CO2 for the electronically delivered T171;
27 MJ, 3 kg CO2 for the print-based T172.

However, given the differences in the various estimates in the energy and emissions associated with computer production, these figures should be regarded as approximate.

Print and paper consumption

Over 6 kg of printed material is mailed to each student of the 30 point OU T172 course. Although much of the teaching material for T171 course is delivered electronically, this is used for guided study of two set books. Together with the other printed material required by its students, the T171 printed matter weighs 1.2 kg. [6] All students were asked to estimate the number of sheets of paper consumed in studying their courses. This included paper for photocopying, printing emails and material from the Internet (of particular relevance to T171), and for assignments. They were also asked about the number of course-related books and periodicals purchased. Generic information was used to produce an estimate of the lifecycle amounts of energy and CO2 involved. [7]

The use of paper for printing from the T171 Internet site (about 100 sheets or 0.5 kg per student per 10 CAT points) is of note. This appears to be a rebound effect, with the dematerialised delivery re-materialising via the students' printers! Nevertheless, total energy and CO2 emissions from all T171 paper and print consumption (38 MJ and 4.3 kg CO2) is about half that of the T172 course (79 MJ and 8.4 kg CO2).

An interesting trend is the continuing pattern of the town centre campus course having greater impacts (a total of 131 MJ and 15 kg CO2 for paper and print per student per 10 CAT points) than both OU courses and the out of town campus one (27 MJ and 3 kg CO2). The high consumption of paper and print by the town centre campus students might again be associated with the dispersed site making library use inconvenient and increasing the need for books, periodicals, photocopying and printing.

Residential Heating

The students were all asked if they heated their term-time residence and/or main home beyond normal use for the purposes of study. The main additional heating sources were gas central heating and electric room heaters. The approximate energy and CO2 emissions per student per 10 CAT Points were calculated from these responses. [8] The largest amount of additional heating was required by the town centre campus students, at over 13 hours per student per 10 CAT points. This was probably because during term-time most lived at their main home or in rented accommodation. This contrasts with the out of town campus students, most of who lived in university residences and thus only noted an average of 2.3 hours additional heating.

An interesting rebound effect is the relatively high amount of additional heating claimed by students of the electronically delivered OU T171 course. At 5.5 hours/student/10 CAT points this compares to 1.4 hours/student/10 CAT points for the print-based T172 course. The difference is probably mainly due to T171 students staying up late at night to connect to the Internet in order to access the course material, thus leaving their home heating on longer than normal.

However, the amount of residential energy to attribute to a course requires careful consideration. For the OU students most of whom who live and study at their usual home, it is reasonable to include only ‘additional’ heating. For the campus students we also only counted additional heating of non-university accommodation. It could be argued, though, that *all* term-time residential heating should be included for the campus students. This would involve the heating of university residences as well as houses, flats etc. occupied by students during term-time. We have some data on this, but it requires further analysis. Until then residential energy and emissions of the campus students might be regarded as an underestimate.

Environmental impacts of campus-based and distance HE systems

The overall pattern (Figures 1 and 2) provides some very interesting preliminary conclusions, bearing in mind that these are based on data involving several – we believe realistic – assumptions and approximations. First, the OU courses involve nearly 90% (factor 10) less total energy consumption and CO2 emissions (per student per 10 CAT points) than two conventional campus-based courses. Much of this is due to the elimination, inherent to distance education, of home to campus travel and commuting. Another major saving in distance learning is campus site energy consumption. This is due to the economies of scale in teaching many thousands of students from one central campus. The other differences between campus-based and distance education – computing and paper/print use – are of much smaller magnitude. There may be a considerable saving in residential heating in distance education systems, but the scale of this is still to be resolved.

Figures 1 and 2 (see separate file EIARPaperFig1_2Final.xls)

Second, e-learning, at least as practiced by the UK Open University, does not appear to result in a reduction in total energy and CO2 emissions compared to print-based distance learning. Indeed the electronically delivered and tutored OU T171 course appears to involve over 25% more energy and emissions per student per 10 CAT points than the print-based T172 course. The main reason for this appears to be that, in the T171 course, greater energy and emissions from student purchase and use of computers (including additional time spent on-line), together with rebound effects such as printing from the Internet site and more additional home heating, counter-balance the reduced need for printed matter and travel to tutorials. This finding will need to be investigated further through inclusion of the emissions arising from the activities of the course tutors.

Such further analysis together with analysis of the remaining campus courses data, and consideration of aspects such as the energy consumption of the term-time accommodation of campus students, will be included in the full report of this project (Roy, Potter, Yarrow and Smith, 2002) and continuing research in this area being conducted at the Open University.

Behavioural change

It is worth noting that the annual energy and CO2 emissions involved in HE study represent only a proportion (from some 3% for a part-time OU student to about a third for a campus-based full-time student) of the total annual emissions per capita of the UK population. [9] This means that changes in behaviour towards the environment as a result of taking a HE course may be as important as the impacts arising from its production and delivery. We have evidence of significant changes in behaviour of students who have taken the OU courses. For example, many students of the environmentally focused T172 course claimed they had reduced car use, improved home energy efficiency, started recycling or to shop for locally produced food, as a result of studying the course. For many students of the computing oriented T171 course it acted as a catalyst, giving them basic Internet literacy. As such, some felt that the course had reduced the amount they traveled – they could now shop or obtain information via the Internet, work from home, or communicate with friends using e-mail. For others the same Internet literacy had stimulated increased travel, for example by giving access to low cost flights or new contacts. Details of these changes in behaviour have been reported elsewhere (Smith et. al., 2001) and will be included in analysis of the qualitative data from this project. It is important however to stress that such behavioural effects are dependent on the curriculum and so should be considered entirely separately from the impacts of different systems of course delivery, discussed earlier.

Finally, it is important to point out that this study is concerned with the *environmental* impacts of different modes of HE. Other issues such as the educational effectiveness or social aspects of campus versus distance education are not considered, and may have to be balanced against environmental gains.

It is interesting to compare the pattern of energy use and emissions in HE, with that in other service activities, such as conferences and Internet book retailing. In all these activities transport use dominates. For example, an energy analysis of a conference held in Zurich in October 2001 found that air travel alone to the conference accounted for 87% of its CO2 emissions – train and car travel accounted for another 10% (Hilty and Gilgen, 2001). An analyis of Internet book retailing in the United States, found that about two thirds of energy use and emissions was caused by book delivery to customers by truck and air freight (Mathews and Hendrickson, 2001). Selling books over the Internet but delivering them by air does not lead to energy savings, compared to buying books at traditional bookshops.

7. Conclusion

Service system efficiency in itself is not a panacea for sustainable consumption as the gains are easily offset by rebound effects together with an increase in the number and variety of products consumed. Also, as researchers into the cultural aspects of consumption have shown, it is necessary to understand how and why we consume. Products often transform the needs and services of consumers. This is why innovations that are meant to be efficient, and to reduce the need for resources, often have the opposite effect.

As F-J Radermacher remarked (quoted in Hilty and Ruddy, 2000):
The trap that we have fallen into again and again over the course of technical progress consists of our always using progress on top of whatever went before (the rebound effect). This effect predicts that market forces and humanity's apparently unlimited capacity for consumption will use new technology to convert more and more resources into more and more activities, functions, services and products.

What can be done about the rebound effect? There are a variety of methods – financial, regulatory and voluntary – none of which are easy to implement in a ‘free trade’ world or are popular with consumers. European Union regulation may help to make appliances more efficient or to lower standby losses, but it cannot curb consumption. The simplest, and perhaps most urgent environmental goal, is to reduce CO_2 emissions. Here the strategy should be to shift away from fossil fuels, particularly coal, towards less carbon intensive fuels, such as gas, and ultimately towards non-fossil fuels, such as renewables and nuclear. In order to encourage this shift we need ecological tax reform and in particular a carbon tax.

However ultimately what is needed, to limit energy consumption and emissions, is a policy of energy sufficiency or energy conservation (Herring, 2001). We need somehow to de-link economic growth from resource consumption, and to adopt a policy of 'sufficiency' which is *living well on less*. For this low energy future ICTs will be important and necessary, but we must be aware that they may induce more material and energy throughput. For it seems ICTs are unlikely to reduce our energy use unless they reduce our desire (or our ability) to travel. For this to happen we need a change in lifestyles, a change in our culture, and a vision of new services to reshape that lifestyle.

ACKNOWLEDGEMENTS
The authors would like to thank Stephen Potter, Karen Yarrow and Mark Smith for their contributions to the research, analysis and previous publications on which the *Factor 10 Visions* HE study is based.

References

Binswanger, M. Technological Progress and Sustainable Development: What about the Rebound Effect? Ecological Economics 2001 36:119-132.
Chambers, N, Simmons C, Wackernagel M.. Sharing Nature's Interest. Ecological Footprints as an Indicator of Sustainability. London, UK: Earthscan. 2000.
Fawcett, T, Lane K, Boardman B. Lower Carbon Futures, DECADE Project, Environmental Change Institute, Oxford University. 2000.
Gershuny J., Miles I. The New Service Economy. London, UK: Frances Pinter, 1983.
Heiskanen, E, Pantzar M. Towards Sustainable Consumption: Two New Perspectives. Journal of Consumer Policy 1997 20: 409-442.
Herring, H. Does energy efficiency save energy? The debate and its consequences. Applied Energy 1999 63: 209-226.
Herring, H. Why we need Energy Conservation not Energy Efficiency. Paper for energyresources2001 Conference. http://www.rmr-energyresource2001.com/
Hilty, L, Gilgen P. Preface. In: L Hilty, P Gilgen. (editors). 'Sustainability in the Information Society'. 15th International Symposium: Informatics for Environmental Protection, 10-12 October 2001. Zurich. Metropolis Verlag, Marburg, Germany, 2001: 7-12.
Hilty, L, Ruddy T. Towards a Sustainable Information Society. Informatik No 4, August 2000 :2-9.
Hilty, L, Ruddy T, Schulthess D. The Resource Intensity and Dematerialisation Potential of Information Society Technologies. : Solothurn University: Switzerland. 1999.
Jalas, M. A time use approach on the materials intensity of consumption, Helsinki School of Economics and Business Administration, Finland. 2000.
Mathews, S, Hendrickson C. Economic and environmental implications of online retailing in the United States In: L Hilty, P Gilgen. (editors). 'Sustainability in the Information Society'. 15th International Symposium: Informatics for Environmental Protection, 10-12 October 2001. Zurich. Metropolis Verlag, Marburg, Germany, 2001: 65-72.
Michaelis, L. Ethics of Consumption, Oxford: Centre for Environment, Ethics and Society. 2000.
Noorman, KJ, Uiterkamp TS. (Editors). Green Household? Domestic Consumers, Environment and Sustainablity, London: Earthscan. 1998.
Pout, CH, Moss SA, Davidson PJ. The Non-Domestic Building Energy Fact File. London: Construction Research Publications. 1998.
Remmerswaal, H., et al., Comparison of different methods of sending messages on the basis of Life Cycle Analysis, in Proceedings Towards Sustainable Product Design Conference 6, Amsterdam, The Netherlands, October, Centre for Sustainable Design, Surrey Institute of Art and Design, Surrey, UK, 2001, pp. 178-182.
Roy, R, Potter S, Smith M, Yarrow K. Towards sustainable higher education systems. In: 'Sustainable Services and Systems'. Towards Sustainable Product Design 6 international conference, Oct. 2001, Amsterdam, Netherlands. Centre for Sustainable Design, Surrey Institute of Art and Design, UK, 2001: 98-106.
Roy, R, Potter S, Yarrow K., Smith M. Towards sustainable higher education: Environmental impacts of conventional campus, print-based and electronic distance learning systems. Report DIG-07, Design Innovation Group, The Open University, Milton Keynes, UK, May 2002.

Roy, R, Potter S, Smith M. Exploring ways to reach sustainability in transport, housing and higher education. In: 'Sustainability at the Millennium: Globalisation, Competitiveness and the Public Trust', Greening of Industry Network Ninth International Conference, January 2001, Bangkok, Thailand, (CD-ROM, 2001).
Roy, R. Sustainable product-service systems, Futures, 2000 32: 289-299.
Rudin, A. How improved efficiency harms the environment, http://home.earthlink.net/~andrewrudin. 1999.
Siderius, H-P. Standing up to the standby, Appliance Efficiency, 1998 1: 58.
Smith, M, Roy R, Potter S. Exploring ways to reach Factor 10 – De-materialisation in higher education. In: Proceedings, 2001 International Sustainable Development Research Conference, April 2001, Manchester, UK, ERP Environment, Shipley, UK, 2001: 250-257.
Wilsdon, J. (Editor). Digital Futures: living in a dot-com world. London, UK: Earthscan. 2001.

FIGURE CAPTIONS

Figure 1 Energy consumption in the delivery of two campus based and two distance learning courses (MJ per student per 10 CAT points). 360 CAT points are needed for a UK undergraduate degree.

Figure 2 Carbon dioxide emissions arising from the delivery of two campus based and two distance learning courses (kg per student per 10 CAT points). 360 CAT points are needed for a UK undergraduate degree.

Notes

1. Average primary energy fuel consumption for cars is 3.5 MJ per vehicle km = 5.64 MJ per vehicle mile (Potter, 2001, p.44). For cars, an assumed 80:20 petrol:diesel split was based on National Travel Survey data, with petrol 2.42 kg CO2 per litre, diesel 2.71 kg CO2 per litre, giving an overall average of 0.393 kg CO2 per vehicle mile.
Bus uses diesel at 2.09 MJ and 0.147 kg CO2 per passenger mile. For rail, a 50:50 diesel: electric split was assumed, giving an overall average of1.69 MJ and 0.165 kg CO2 per passenger mile. For Metro/underground a 30:70 split was assumed, giving an overall average of 2.09 MJ and 0.28 kg CO2 per passenger mile. Motorcycle/moped uses petrol at 0.16 kg CO2 per passenger mile. Air (long-haul) is 3.81 MJ per passenger mile and 0.26 kg CO2 per passenger mile.
2. E.g. Energy reduction: town campus v T171 = (2300 – 118)/2300 = 0.95 (i.e. 95% or factor 20)
3. 14400 MJ x 10 CAT points/120 CAT points per year. This assumes that all campus energy consumption is related to course production, administration and teaching, so is probably an overestimate. Based on the relative funding of teaching and research, it is estimated that about two-thirds of UK campus energy consumption is for teaching related purposes.
4. Based on a typical desktop PC power consumption of 125 watts (Hilty and Ruddy, 2000) and 0.44 kg CO2 per kWh for UK electricity. About 90% of all students used desktop PCs. It was assumed that T171 students spent two-thirds of their computing time on-line and the other courses 10% on-line.
5.. Assuming an average of 9000 MJ per PC of which 50% is electricity (0.44 kg CO2 per kWh) and 50% oil (0.25 CO2 per kWh), gives an average of 0.345 kg CO2 per kWh. Producing a PC involves 9000 x 0.345/3.6 = 863 kg CO2. 3 years = 360 CAT points, so a 20 CAT point course would be allocated 20/360 x 10/20 of a computer per 10 CAT points then averaged per student.
6. i.e. 2 kg/ student/10 CAT points for T172 and 0.4 kg/student/10 CAT points for T171. Emissions per kg due to mailing are relatively small, estimated at about 9 MJ/kg (Remmerswaal et al., 2001) and 0.3 kg CO2 per kg (Sykes, K. Personal communication, Post Office, 23 Feb. 2001).
7. 100 sheets office paper weighs about 0.5 kg, an average book 0.8 kg, a typical periodical 0.3 kg. Paper production involves approx. 18.5 MJ delivered energy and 2.54 kg CO2 per kg and (news) print 30.7 MJ delivered energy and 3.29 kg CO2 per kg (www.environmentaldefense.org/pubs/Reports, Dec. 2000). Other sources give higher emissions per kg paper and print, so this data is to be confirmed.
8. For gas: using the National Home Energy Rating *Surveyor 3* program, a typical UK gas centrally heated house under standard occupancy produces 5.2 tonne CO2 per year. Assuming a 32 week

heating season, increasing heating produces additional 0.9 kg CO_2 per hour. For electricity: Assume a 2 kW electric room heater and electricity at 0.44 kg CO_2 per kWh.
9. Total carbon emissions UK 2000 = 152 m tonnes = 2.8 tonnes carbon per capita = 10.2 tonnes CO_2 per capita. Assumes full-time student does 120 CAT points per year at an average 300 kg CO_2 per 10 CAT points and OU student does 60 CAT points per year at 30 kg CO_2 per 10 CAT points.

7500 words.

Herring&Roy_PaperFinal.doc