Factor 10 Visions project:
Higher Education Sector

Towards Sustainable Higher Education:
Environmental impacts of conventional campus, print-based and electronic distance/open learning systems

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Phase 1: Final Report

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Executive Summary

This report gives the findings of the first phase of a major study of the environmental impacts of three different methods of providing higher education (HE) courses:

- Conventional campus-based courses – from seven English, one Scottish and one Irish university.
- A mainly print-based, distance/supported open learning course offered by the (UK) Open University.
- A mainly electronically taught and tutored, distance/supported open learning course offered by the Open University.

It should be emphasised that this is an *environmental* assessment of these different HE systems and does not attempt to assess their educational effectiveness or socio-economic costs and benefits.

KEY FINDINGS

- On average, the production and provision of the distance/supported open learning courses consumed 90% less energy and produced 90% fewer CO_2 emissions (per student per 10 CAT points) than the conventional campus based university courses. (*1 CAT point is equivalent to 10 hours total study and 360 CAT points are required for an UK undergraduate degree.*)

- The much lower impacts of distance/supported open learning compared to campus based courses is mainly due to a major reduction in the amount of student travel, economies of scale in utilisation of the campus site, and the elimination of much of the energy consumption of students' housing. (*The purchase and use of computers and consumption of paper and printed matter accounts for a relatively small difference between the distance and campus systems.*)

- E-learning courses may not offer any environmental advantages over mainly print-based distance/supported open learning courses. In fact, largely due to high student use of computing, consumption of paper for printing off Web-based material, and additional home heating (probably for night time Internet access), the partial e-learning course surveyed involved over 20% greater energy and emissions than the print-based course.

- Different campus courses involve a wide range of environmental impacts. Courses with low energy and emissions (per student per 10 CAT points) tend to have a high proportion of students who live at home while studying. The courses may also be taught at a compact, self-contained campus, perhaps containing energy efficient buildings.

- Existing programmes aimed at reducing the environmental impacts of higher education should be broadened beyond considering campus site environmental management and 'greening the curriculum' to include the impacts of student travel (especially travel between 'home' and university) and student housing.

- Nevertheless, there is evidence that HE courses with student-relevant environmental content can have a highly positive effect on student attitudes and behaviour towards the environment. (*This is the subject of a separate report on this project.*)

- Generally, this study challenges claims about the 'de-materialisation' effects and environmental benefits of using ICT to provide services such as HE. The environmental impacts of a service depend mainly on its requirements for travel and a dedicated infrastructure of buildings and equipment. The use of ICT or other methods will only benefit the environment if they reduce the service's requirements for energy-intensive transport, dedicated equipment and heating and lighting of buildings.

Background

The study forms part of a wider project called *Factor 10 Visions*. This is examining the potential for up to 90% (‘factor 10’) reductions in energy consumption and carbon dioxide (CO_2) emissions in three UK sectors – personal transport, housing and higher education – in order to help to tackle climate change while allowing the developing world to reach decent living standards.

A study of the environmental impacts of HE was included because it is growing fast, with the UK Government setting an expansion target of 50% participation by 2010. Also, existing work (e.g. the UK Toyne Report, and the global *Talloires Declaration*) has focused on campus site environmental management and on ‘greening the curriculum’. No previous research exists on the impacts of the HE course production and delivery system, including the potential of the Internet and other e-learning methods to radically reduce energy consumption and emissions.

Method

Systems models of the above three modes of providing HE courses showed that their main differences are in the amounts of course-related *travel*; the consumption of energy for *residential heating*, powering *campus sites* and for *computing*; and use of *paper and printed matter* for course preparation and study. Data to compare the systems came mainly from student/staff surveys of the courses, together with national statistical information. All, except two taught Masters courses, were at undergraduate level and all except for three of the undergraduate courses had an environmental focus or element.

The Open University (OU) courses were the mainly print-based T172 *Working with our Environment* and the largely electronic T171 *You, your computer and the Net*. It should be emphasised that T171 is not entirely electronic. It has been designed for pedagogical effectiveness to use Web based materials that guide study of two set books, supported by electronic tuition and conferencing. Neither is the T172 course entirely print-based. It offers optional electronic conferencing as well as face to face tutorials.

The effects of the courses on staff and student attitudes and behaviour towards the environment were also investigated. But any such environmental effects are obviously dependent on the *content* of the courses concerned, and therefore should be viewed as an entirely separate issue from the effects of delivery systems. *Changes in attitudes and behaviour towards the environment arising from study of the courses is thus dealt with in a separate report and only touched upon in this one*.

Key results

To enable the environmental impacts of the different courses to be directly compared, these impacts were normalised in terms of *average energy consumption, and CO_2 emissions, per student per 10 CAT points.* In the UK Credit Accumulation and Transfer (CAT) system, 1 CAT point is approximately equivalent to 10 hours of total study, with 360 points required for an undergraduate degree and 180 points for a Masters degree.

It should be borne in mind that this is the first phase of the project whose results are based on several assumptions and approximations that are discussed in detail in the report. Future work will re-examine these assumptions and survey additional courses and types of HE delivery system, including conventional part-time and e-learning courses, to test the findings given here.

Conventional campus compared to distance/open learning courses

Perhaps the most startling result is that the two OU distance/supported open learning courses we examined on average involved 90% less energy consumption and produced 90% fewer CO_2 emissions *per student per 10 CAT points* than the conventional campus based university courses. Interestingly, this is a ‘factor 10’ reduction in environmental impacts.

There are three main reasons for this result:

1) The elimination, inherent to distance learning, of much staff and student travel. The main journeys eliminated are students travelling between their permanent ‘home’ and the university and between any term time residence and the campus. The distances involved greatly exceed those normally involved in an OU course, e.g. travel to tutorials at a local study centre.

2) The reduction in campus site emissions per student due to economies of scale in distance/open learning systems. A course developed by a team based mainly at a single campus can be presented – with updates – to many hundreds or thousands of students over a period of years.

3) For OU students who study from home, and campus students who live at ‘home’ during term, it is reasonable to consider only any *additional* residential heating involved in taking a course. For full-time campus based students, many of whom live away from ‘home’ during term, it seems appropriate to count *all* the energy consumed per student in those term-time dwellings, since being at university is their main occupation and their lifestyle requires use of this energy.

Summary Table: Total energy and emissions of campus and Open University courses (averages per student per 10 CAT points)

ENERGY (MJ)	Campus site	Transport	Computing	Paper/print	Resdl. heating	TOTAL
UK campus	805	2183	112	75	1188	**4363**
OU T171	1.4	132	177	42	125	**477**
OU T172	7.1	189	60	103	30	**389**
CO_2 EMSSNS (kg)	**Campus site**	**Transport**	**Computing**	**Paper/print**	**Resdl. heating**	**TOTAL**
UK campus	74	160	12	8.7	93	**348**
OU T171	0.1	9.9	21	4.6	5.5	**41**
OU T172	0.6	15	6.9	9.5	1.6	**34**

As can be seen from the summary Table, the above three factors account for most of the 90% reduction in energy/emissions. The impacts of the other two factors– computer purchase and use, and consumption of paper and printed matter – although important in the differences between the print-based and electronic OU courses are relatively minor components of the difference between the OU and the campus courses.

Electronic compared to print based distance/open learning courses

Perhaps the most unexpected finding is that the mainly electronically taught OU T171 course appears to involve over a fifth *more* energy and emissions per student per 10 CAT points than the mainly print based OU T172 course. One reason is that even a partial e-learning course such as OU T171 involves high use of computers, including on-line use, and hence significant energy consumption. The other reason is the following so-called ‘rebound’ effects:

1) The preference of many students to download and print a high proportion of Web based learning materials, mainly for reasons of portability and ease of study with hard copy.

2) The apparent wish of some T171 students to meet informally face to face, given the limited or no formal face to face sessions.

3) Some T171 students appear to heat their homes longer than normal for study purposes, probably mainly while accessing the Internet late in the evening or at night.

These factors serve to outweigh the savings from the reduced need for printed matter and staff/student travel for OU T171 compared to the mainly print-based OU T172 course.

Differences between campus courses

The above comparisons conceal the wide range of energy consumption and emissions figures for the campus courses. It is not the main concern of this project to study these differences, but they do raise some interesting issues.

1) Low term-time travel distances appear to be associated with courses at self-contained, often out of town, campus sites with a high proportion of students living in university residences. High term time travel distances appear to be required for courses at multi-site, often urban, campuses with a high proportion of students living at and commuting from their main ‘home’.

2) The home-university distances travelled by students vary widely. This seems to depend largely on whether the course serves mainly students from the local area, or has a high proportion of overseas students who regularly fly considerable distances between home and the university.

3) Residential energy consumption depends mainly on whether students lived at, or away from, ‘home’ during term. In environmental (although of course not necessarily in social) terms it may be desirable to encourage students on campus based courses to live at home and attend a local university, even if this means some additional commuting.

4) The most efficient campus consumed less than a third of the non-residential energy per student of the least efficient. But although the campus site is an area worthy of attention, on average it only accounted for about a fifth of the total energy and emissions per student per 10 CAT point course. The emphasis placed on the campus site in existing schemes for ‘greening’ HE could therefore be balanced by focusing also on other environmental issues, notably student travel and housing.

The environmental impacts of higher education

How significant a proportion of an individual’s total environmental impact is involved in taking a HE course? This study estimates that a student’s annual CO_2 emissions from taking a full-time campus course are high, at nearly 40% of total annual CO_2 emissions for an average member of the UK population. In contrast, a part-time OU student’s CO_2 emissions due to study are only about 2% of average total emissions (or 4% of the total if they were studying at the same rate as a full-time student).

Changes in attitudes and behaviour

The energy and emissions directly associated with studying a HE course only account for a proportion of a student’s impacts on the environment. This means that changes in *behaviour* towards the environment as a result of taking that course may be as important as the impacts arising from its production and delivery.

We have evidence of significant changes, both positive and negative, in the environmental behaviour of students who took the courses, especially the OU ones. It is important to stress that such behavioural effects are dependent on curriculum *content* and so should be considered quite separately from the impacts of different systems of course delivery. They will thus be discussed in a separate report. The effect of courses on student behaviour does, however, indicate that 'greening the curriculum' is a key element of attempts to reduce HE's environmental impacts.

The role of ICT in sustainable services

This study shows that e-learning courses may involve greater environmental impacts than established print-based distance/supported open learning courses. This result runs counter to many claims that have been made about the 'de-materialisation' effects and resultant environmental benefits of information and communications technologies (ICT).

Instead, our research has identified more significant factors in reducing environmental impacts that could apply across the whole service sector. This is the extent to which providing the service depends on energy-intensive travel and a dedicated infrastructure of buildings, facilities and equipment.

Service systems will only become sustainable if they offer similar or better functions than traditional products or services with reduced dependence on energy intensive transport, dedicated buildings and other infrastructure. This may be most effectively achieved by a service using or 'piggy backing' on existing infrastructure. Only if ICT helps to reduce transport needs and/or enables a service to share existing infrastructure, without incurring large 'rebound' effects, will it contribute towards sustainability.

Policy issues

This study does not seek to argue that, because of lower environmental impacts, one mode of HE provision should be preferred over another. Rather it aims to provide environmental information to decision-makers, which can then be included along with educational, social and economic considerations.

It has raised some interesting policy issues. For example, we have identified that air travel associated with overseas students studying in the UK is an important environmental impact. This is a widespread practice, promoted by government and HE institutions for a variety of economic and development reasons. Yet, would it be preferable on educational and social as well as environmental grounds to educate more overseas students via partnerships with educational institutions in a student's home country rather than bringing them to the UK to study?

Another issue is the implications of attempts to provide HE courses presented entirely on-line via electronic media. The pedagogical issues of on-line learning are being debated and researched, the environmental issues have so far been ignored.

Finally, it is important to emphasise again that this study has only been concerned with the *environmental* impacts of different modes of providing HE courses. The social, economic and pedagogical aspects were not considered. UK policy must, of course, balance these against environmental gains in deciding the mix of conventional, distance/supported open learning, 'mixed mode' (e.g. Internet teaching plus intensive face to face weekends) and e-learning courses to expand HE to offer the planned 50% participation rate of 18-30 year olds by 2010.

1. The Factor 10 Visions project

This report gives the findings from the higher education (HE) sector study of the *Factor 10 Visions* project undertaken by the Design Innovation Group (DIG) at the Open University. This project builds upon the DIG's previous research on ecodesign (e.g. Smith, Roy and Potter, 1996) and work conducted for an Open University course, T172 *Working with Our Environment* (Potter, 2000; Roy, 2000a).

The project explores the potential for radical changes in selected product-service systems to address climate change and other global environmental issues. For the industrialised countries, such as the UK, to tackle such issues it is estimated that anything between 60% ('factor 2.5') and 95% ('factor 20') reductions in fossil fuel and other resource consumption plus associated carbon emissions will be needed during this century (RCEP, 2000; von Weisäcker et. al., 1997). At least 90% ('factor 10') reductions are expected to be needed if allowance is made for the growing population of the developing South to reach decent living standards (Carley and Spapens, 1998; UNEP, 1999).

Several strategies have been proposed for reaching a 90% improvement, including the ecodesign of products (e.g. Brezet et. al., 1997) and 'dematerialization' by replacing products with services (Charter and Tischner, 2001; Cooper and Evans, 2000; Roy, 2000b). However, a major difficulty in designing 'sustainable' products or services is that environmental impacts depend not only on the material intensity of the service itself, but also on the wider system in which the product or service is used. Reductions in environmental impacts may be outweighed by consumption growth, compounded by direct and indirect 'rebound' effects such as a lowering of resource costs leading to a growth in demand (Herring, 1999; Stevels, 2001).

The *Factor 10* project seeks to allow for consumption and rebound effects and explore what changes to existing product-service systems might be capable of delivering up to 90% emission reductions in three sectors – personal transport, housing and higher education. In the HE sector we are considering the period up to 2010, in the other two sectors the time period extends to 2020 and 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.

This report does not cover our housing and transport studies, which are continuing, and whose initial results have been reported elsewhere (e.g. Roy, Potter, and Smith, 2001).

2. Towards Sustainable Higher Education

Why examine higher education (HE), an already partly dematerialised service system, which a detailed input-output study (Simon and Dixon, 2001) indicates has relatively minor environmental impacts compared to housing and personal transport? (The latter sectors together account for about half the delivered energy consumption and CO_2 emissions in the UK.) Firstly, HE is growing fast, especially in the UK where the Government has set ambitious expansion targets of a 50% participation rate of under thirty year olds by 2010. Part-time, life-long and continuing HE, including students taught through distance and open learning systems such as the (UK) Open University, are attracting large and increasing numbers. Secondly, HE is becoming concerned with how it might be 'greened'. For example, university leaders from over forty countries have signed the *Talloires Declaration*. This sets out a plan of action for universities to address environmental problems through teaching, research, training and policy formation, as well implementing practical programmes of resource conservation, recycling, and waste reduction.

Thirdly, if the continued growth in services such as HE cannot be delivered sustainably, then rising environmental impacts from these previously relatively ‘insignificant’ sectors could counterbalance improvements in the current major polluters.

A further reason is that the opportunity arose to undertake an environmental audit of not only the (UK) Open University’s established distance/supported open learning courses taught mainly via print and audio-visual material, but also the further dematerialised system of courses taught mainly electronically via the Internet. 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?

This point about the ability of information and communication technologies (ICTs) to transform services is not new. It was made in the early 1980s by Gershuny and Miles (1983), who also pointed out the ability of the Open University (OU) to transform teaching methods by what they then called ‘tele-education’. Recent studies have investigated the effects of ICT on the impacts of services such as conferences and book retailing. In these services the impacts of transport dominate. For example, an energy analysis of a conference held in Zurich found that travel to the conference alone accounted for 97% of its CO_2 emissions (Hilty and Gilgen, 2001). An analysis of Internet book retailing in the US, found that about two thirds of energy use and emissions was caused by book delivery to customers (Mathews and Hendrickson, 2001). Selling books over the Internet but delivering them by air did not lead to energy savings, compared to buying books at traditional bookshops.

2.1 The Factor 10 Higher Education study

Existing work on HE and the environment has focused mainly on improving environmental management at university and college campuses (e.g. Davey, 1998; Delakowitz. and Hoffmann, 2000) and on ‘greening the curriculum’. In the UK, both issues were the subject of the Toyne Report (Department of the Environment, 1993) and its subsequent Review (Department of the Environment, 1996). These issues were also the main focus of Forum for the Future’s ‘HE21’ Initiative that involved twenty-five UK HE institutions from 1997-99 (Forum for the Future, 1999) and its successor HE ‘Partnership for Sustainability’ scheme, started in 2000 and involving eighteen UK universities and colleges (Parkin, 2001). The global *Talloires Declaration* of University Leaders for Sustainability, mentioned above, and the European COPERNICUS Charter have similar aims. However, no previous research exists on the environmental impacts of the HE *delivery* system, including the environmental effect of new ICTs being used as part of innovative course delivery methods.

The *Factor 10 Visions* HE study is attempting to fill this gap by assessing the total environmental impacts of different systems for providing UK higher education. The first phase of this work, discussed in this report, considered three HE delivery systems:

- ***Conventional campus-based courses;***
- ***An Open University (OU) mainly print-based, distance/supported open learning course;***
- ***An OU partly electronically taught and electronically tutored, distance/supported open learning course***

The effects of the courses on staff and student attitudes and behaviour towards the environment were also investigated. But any such environmental effects are obviously dependent on the *content* of the courses concerned, and therefore should be viewed as an entirely separate issue from the effects of delivery systems. Changes in attitudes and behaviour towards the environment arising from study of the courses is thus dealt with in a separate report and only touched upon in this one.

The principal environmental burdens of the above three different HE modes were identified through simplified system models (Figures 1 to 3) and the audit focused upon the key differences between the three systems.

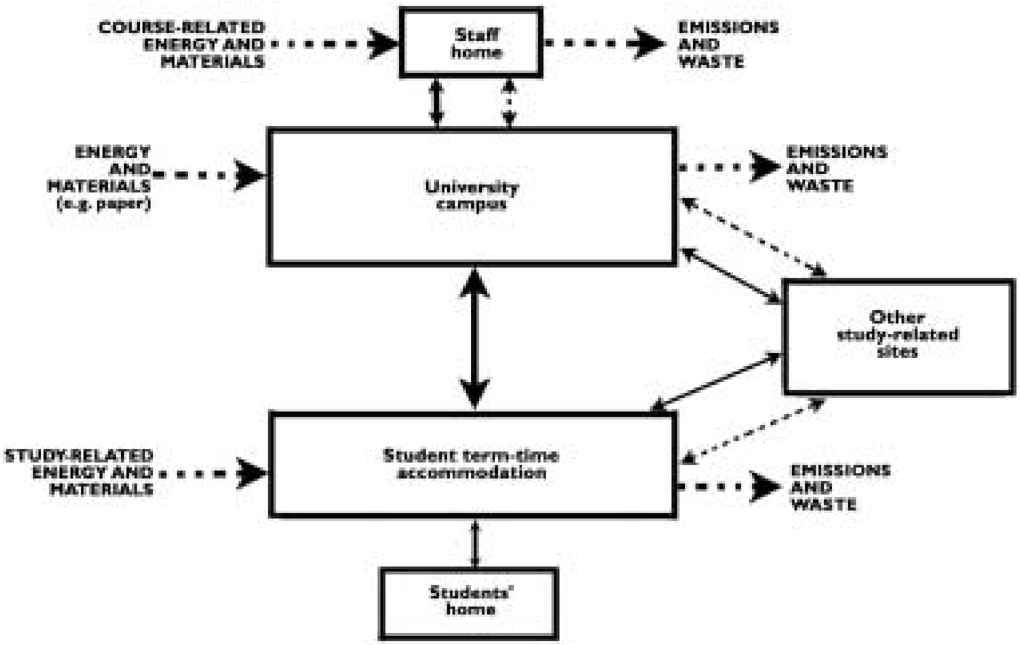

Figure 1 Conventional system – full-time campus-based course

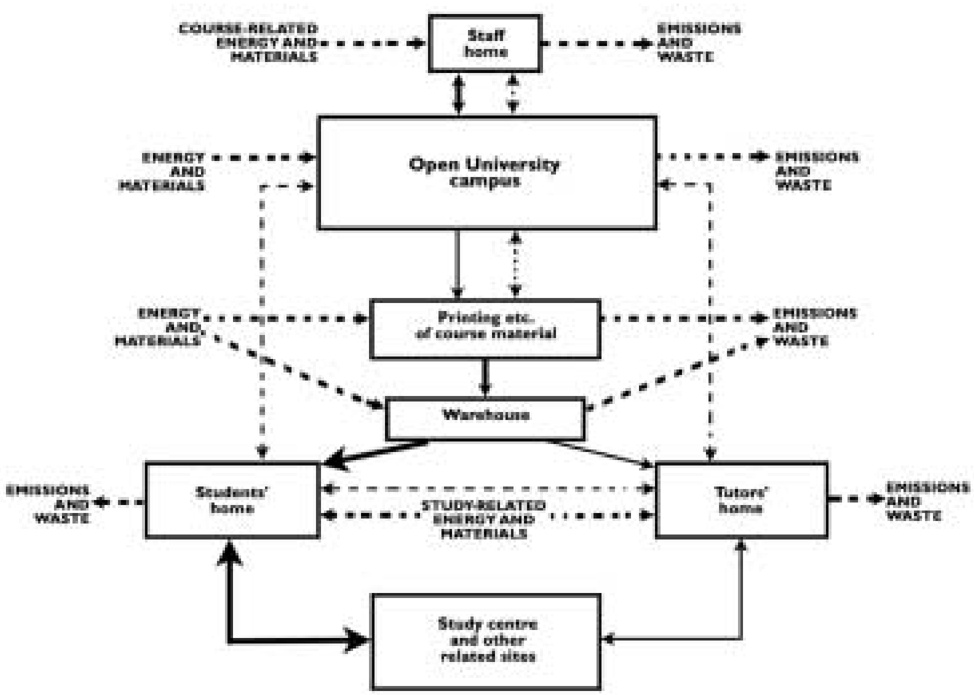

Figure 2 Open University system – mainly print-based distance/supported open learning course

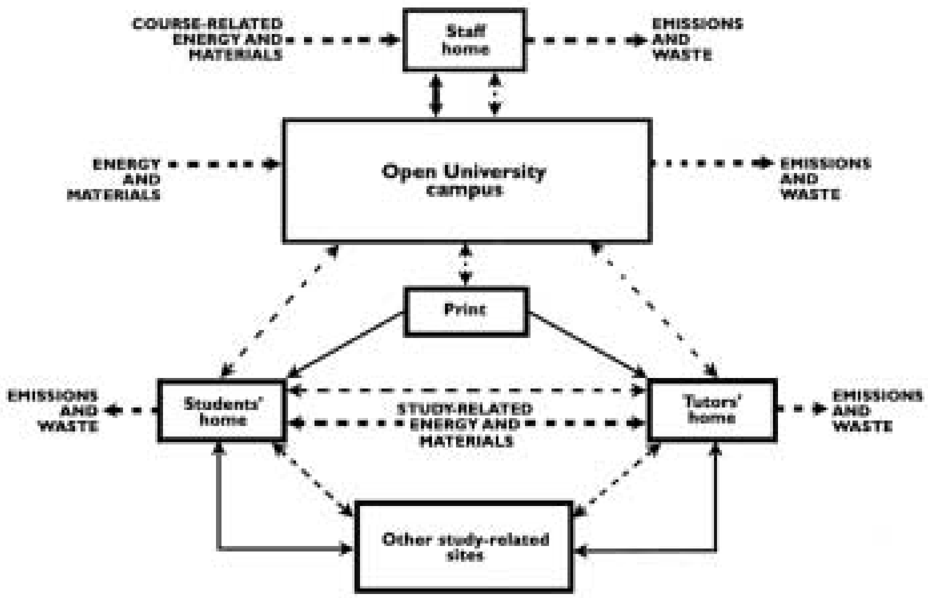

Figure 3 Open University system – mainly electronically taught distance/supported open learning course

Conventional HE institutions are 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 and from the campus to attend lectures, use libraries, laboratories, etc. For many there is also travel between their main or usual 'home' and term-time residences. The OU system is very different. It delivers specially developed course material directly to students for part-time study at home, with optional face to face tutorials at local study centres offered by part-time tutors (Associate Lecturers), who also provide support to their student group via mail, telephone and/or email and computer conferencing. The OU is a distance education system, but one that places considerable emphasis on student support. *Hence it is more accurate to describe the OU as offering supported open learning and why the term 'distance/supported open learning' is used in this report to describe its courses.*

All systems involve a campus that consumes energy and resources and produces emissions, although the OU campus is mainly for administration and 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 and lighting of home and/or term-time residences.

The main differences between the two OU models are in the delivery of course materials, the assessment system and the need for students and tutors to occasionally travel to a local study centre. In the electronically taught OU course (T171 *You, your computer and the Net*) teaching material provided via a dedicated web site has partially replaced the physical production and distribution of specially written course books and audio-visual materials required for the mainly print-based course (T172 *Working with our Environment: Technology for a sustainable future*). Likewise, in T171 a computermediated assessment and tuition system has largely replaced mailing of written assignments, attendance at an examination centre, and the optional face to face tutorials in T172. However, the electronic course is based around study of two conventionally printed set books bought by students and at least one face-to face meeting has been offered to supplement the electronic tuition system. The T171 course is therefore not fully electronic, but based on a mix of methods of supported open learning at a distance designed for production efficiency and pedagogical effectiveness. Neither is T172 entirely print-based. For the majority of students who have access to a computer, it offers optional computer based exercises and electronic conferencing.

There are important differences too in the way courses are prepared and presented in the conventional campus and OU systems. In the campus-based system, teaching staff plan the course and present lectures, etc. face to face, travelling from home to the campus and other sites as required. In the OU systems, a team of academics, regional staff, designers, editors and audio/video producers plan and develop the course materials for delivery to students via print and/or electronic media. Development of this material involves travel to the OU's Milton Keynes campus, its Regional Offices, and other sites, for example to attend course team meetings, use office and library facilities, and to record audio and video programmes.

The main differences between the three modes are thus the amount and type of course-related travel, the consumption of energy for powering campus sites, for computing and for heating and lighting of homes, and the consumption of paper and printed matter for course preparation, delivery and study.

Having identified the key differences in the course delivery systems, data were gathered to enable their environmental impacts to be compared. We focused on energy consumption and CO_2 emissions as these provide a good proxy for most environmental impacts (Chambers et. al., 2000). They are, of course, also key measures for assessing effects on climate change.

Table 1 Details of the sample of courses surveyed

University	**Locat-ion**	**Course/module**			**Number valid qustnaires. returned**	
Campus		**Title**	**Duratn. (weeks)**	**CAT[1] points**	**Students**	**Lecturers /tutors**
A	Urban	Environment & services (module)	12	15 [3]	28	1
B	Urban	M.Sc. Environmental change & mgmt.	24	180	12	1
C	Urban	Business Studies (modules)	30	120 [3]	13	0
D	Urban	Industrial design & technology	11	10	33	1
E	Urban	Resource use & sustainable development.	13	10	46	1
F	Urban	Corporate environmental management.	11	10	54	1
G	Rural	Water resource policy & management.	10	20 [3]	33	1
H	Urban	M.Sc. Transport engineering	30	180	9	1
I	Rural	Environmental Science (module)	30	15 [3]	6	1
Open	N/a	T172 *Working with our Environment*	36 [2]	30	205	65 [5] + 1 [6]
Open	N/a	T171 *You, your computer and the Net.*	36 [2]	30	503 + 343 [4]	55 [5]

1. The UK Credit Accumulation and Transfer (CAT) system in which 360 points are required for an undergraduate degree.
2. Part-time, including 2 weeks preparation period.
3. Estimates based on proportion of 360 CAT point degree.
4. 503 valid responses to Transport, 343 valid responses to Energy/Materials questionnaires.
5. Part-time tutors (OU Associate Lecturers).
6. OU central academic (course team author).

Most of this data came from student and staff surveys of two courses at the OU and courses at nine campus universities – seven English, one Scottish and one in the Irish Republic. The campus courses were chosen to reflect a mixture of university locations, from city centre to suburban and 'out of town'. All, except two taught Masters courses, were at undergraduate level and all except for three of the undergraduate courses had an environmental focus or element (see Table 1).

2.2 Survey method

Structured questionnaires were developed for students, academic staff and, for the OU, the part-time tutors of the courses concerned. These questionnaires were administered in different ways as appropriate to the course. To the campus students by their lecturer; to the OU T171 students and tutors via the course web site or electronic conferencing system; and to the campus lecturers, and the students and tutors of the OU print-based T172 course by post.

The student survey obtained the following information for each course:

- Purpose, distance, frequency and mode of travel connected with study of the course e.g. to attend lectures or tutorials, visit libraries, purchase books, etc.
- Energy and paper consumption associated with computing for the course. Especially for the electronically delivered OU T171 course, downloading and printing material from the web site.
- Paper used for photocopying, assignments, etc.; for books and other publications purchased for the course; and/or to provide OU printed course materials.
- Use of home heating in connection with study of the course.
- Behavioural changes arising from completing the course that have environmental implications.

The campus staff and OU tutor surveys asked similar questions relating to their preparation and/or tuition of the courses plus, when required, administrative information such as the length and credit rating of the course.

As shown in Table 1 the student sample for the OU courses, by their nature, was larger than for the campus courses. A total of 205 fully or partly useable student questionnaires were returned for OU T172; and 503 and 343 for T171 (which was conducted in two stages: Travel and Energy/Materials), while the campus student returns ranged from 6 to 54. Likewise 55 and 65 Associate Lecturers responded respectively to the OU T172 and T171 tutor surveys, while only one academic was surveyed for each of the campus courses (usually the lecturer who distributed the student questionnaires) even if the course was presented by more than one person.

For full details of the methodology see Appendix 1 'Methodology of the Factor 10 Visions HE study'. The assumptions and simplifications on which the study is based are discussed below in section 4.4 as well as in Appendix 1.

3. Key Results

To enable the environmental impacts of the different courses to be directly compared, these impacts were normalised as ***average energy consumption, and CO_2 emissions, per student per 10 CAT points*** (usually abbreviated in the remainder of this report to *MJ/student/10 CAT* or *kg CO_2 /student/10 CAT*).

The details are outlined in the box below and discussed in Appendix 1 section 3.

Normalising results per student per 10 CAT points

In the UK Credit Accumulation and Transfer (CAT) system, 1 CAT point is approximately equivalent to 10 hours of study (including private study); with 360 points required for an undergraduate degree and 180 points for a Masters degree.

For example, to calculate and normalise emissions from computer use the following formula was used:

Total computing time per week/number students x length of course x 10 CAT points/CAT points of the course.

This gives the average hours of computing per student per 10 CAT points.
The result was then converted to energy and CO_2 emissions using data on a typical PC's electricity consumption and CO_2 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 (e.g. transport fuels) we employed primary energy data.
For some calculations a factor was required to scale an activity or amount of consumption to a particular time period (e.g. travel per term or annual campus energy consumption). In such cases, for a standard three-year, 360 point undergraduate course, one term is counted as 40 CAT points and one year as 120 CAT points. (See Appendix 1 for details.)

3.1 Campus site impacts

3.1.1 Conventional university campuses

Official data from the UK Higher Education funding councils on student numbers, 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. In any case, since the focus of our study is on how the delivery of HE courses affects environmental impacts, it is not really concerned with factors, such as the age of buildings and climatic conditions, that will vary between individual campuses. So it seemed appropriate to correct for such site-specific variations by using the average energy and emissions of all the surveyed campus sites.

Also, not all campus energy is used for teaching functions, so it was necessary to allocate a proportion of the consumption to research and other non-teaching activities. There is no easy way to achieve this. The best and most readily obtainable data was of the annual teaching and research funding provided by the Higher Education Funding Council for England (HEFCE) to the seven English universities in our survey. On average teaching accounted for about two-thirds (68%) of the total for HEFCE-funded teaching and research at these institutions. It is assumed that administrative functions are distributed between teaching and research in roughly in the same proportion. This figure compares to a proportion of approximately 75% funding for teaching and 25% for research (including research funds provided by research councils and other sources) at all UK HE institutions (AUT, 2001).

The data show that total non-residential energy consumption for the seven campuses averaged nearly 14400 MJ per year per full-time equivalent student. Using the 68% factor to adjust for teaching-related uses, this is equivalent to about 9650 MJ per student per year or 805 MJ per student per 10 CAT points.[1] As is explained in Appendix 1 section 4, 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 mean CO_2 emissions. This was then used to calculate the average teaching related site emissions: at approximately 885 kg CO_2 per year per student or 74 kg CO_2 per student per 10 CAT points. [2]

3.1.2 Open University campus

For the OU, campus energy consumption was obtained from the Estates Department and a scoping study with one academic staff member using a similar method to that outlined below for the travel analysis was employed.[3] In this case an estimate was made of the number of days spent by the course team over 2.5 years working at the OU campus on the course's development and initial presentation. This indicated that, because of the large student numbers on the OU courses, the site impacts per OU student per 10 CAT points are minimal. These are estimated at just 1.4 MJ and 0.1 kg CO_2 for the electronically delivered T171 and 6 MJ and 0.5 kg CO_2 for the print-based T172. In addition, an estimate of the heating and lighting of local study centres for the tutorials provided for the T172 students was made. This worked out at just 1.2 MJ/student/10 CAT and 0.1 kg CO_2/student/10CAT.[4] These are simply not areas of major environmental impacts in the OU system.

3.1.3 Conventional and Open University campus site impacts

It is clear that, whatever the approximations involved in the above calculations, campus site energy and emissions per student per 10 CAT points for the distance/open learning OU courses are enormously lower (only some 1%) of those the conventional campus courses (Figure 4). This is mainly due to the economies of scale of teaching many thousands of students from one central campus.

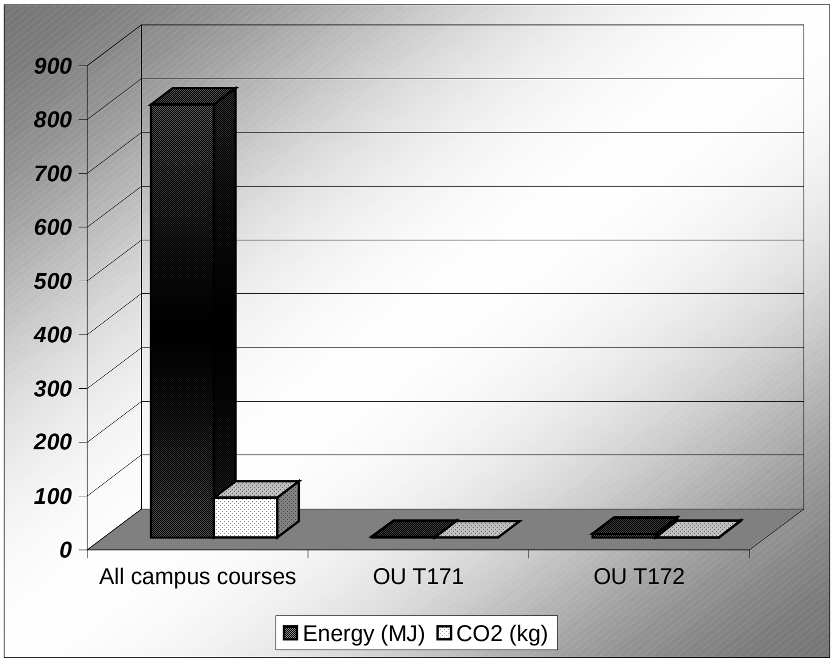

Figure 4 Comparison of conventional and distance teaching campus site energy and CO_2 emissions (average per student per 10 CAT points)

3.2 Course-related travel

All students were asked to detail the travel involved to pursue the course they were taking. Likewise, campus lecturers and OU tutors were asked to provide information on the travel involved in preparing and/or presenting the courses concerned. Travel was categorised into a number of trip purposes and the students and staff detailed the number of trips made, typical round-trip distance and the method (mode) of transport used, including walking, cycling and motorised modes. For each course, the total distances travelled by the various modes were converted into energy and kilograms of CO_2 using best available

UK or other data on the fuel consumption of the travel modes and the carbon content of the fuels involved.[5] These figures were then averaged per student per 10 CAT points. Details of the data collection and analysis method are detailed in Appendix 1 section 6.

3.2.1 Campus student travel

For the conventional universities, transport for the course was split between term-time travel, when students were based near campus, and travel between their main/usual 'home' and any term-time residence. For students living at their main/usual home during term the latter trips would obviously not apply. Term-time travel at all campus universities is predominantly commuting between term-time residence and campus, but also included travel between campus sites, to off-campus libraries etc. For students living at their main/usual home during term the latter trips would not apply. For overseas students, travel to and from 'home' could involve considerable distances.

Table 2 shows the distances, energy and CO_2 emissions for each of the campus courses surveyed for these two broad categories of travel and Table 3 provides the totals. Both tables separate the data for the 8 UK courses from the one Irish course, partly to allow national comparisons and partly because the Irish course appeared to involve relatively high levels of term-time travel impacts. This was mostly due to the distances its students commuted to campus, mainly by car.

Table 2 Campus students' term time and home–campus course related travel (average per student per 10 CAT points)

		All course-related term-time travel/student/10 CAT			All travel between home & term-time residences/stud./10 CAT		
Campus course	Location	Distance (km)	Energy (MJ)	CO_2 emissns (kg)	Distance (km)	Energy (MJ)	CO_2 emissns (kg)
A	Urban	220	254	32	2278	5303	369
B	Urban	274	399	28	1996	4610	315
C	Urban	521	1121	78	821	980	91
D	Urban	301	152	11	210	181	17
E	Urban	281	357	30	179	191	17
F	Urban	340	419	35	1343	1879	134
G	Rural	58	78	5.4	610	967	73
H	Urban	80	85	6.0	65	167	12
Av. UK		***259***	***358***	***28.3***	***938***	***1785***	***129***
I	Rural	454	1161	81	507	470	33

There was considerable variation between student travel patterns for the different campus university courses. One reason is the fact that some of the courses (e.g. course C) involve travelling between campus sites or trips to other study sites (e.g. courses D, B and E for fieldwork). Another reason is the differences in the type of campus and the student population. An example is the contrast between the high term time travel of students of course F, at an town centre, multi-site campus, and the relatively low term time travel of course G, at an out-of-town, single site campus. The data revealed the surprising fact that the town centre campus course students commuted nearly six times the distance/student/10 CAT of the students of the out-of-town course. The former travelled almost all by rail or bus, while the latter travelled about equally by walking, bus and car. 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. The town centre campus students also had high levels of travel between their main home and the university. 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 home mainly by car or bus.

However, this course's students travelled much less between their main home and university than those of courses A and O. This is due to the high proportion of overseas students of the latter courses many of whom travelled long distances to and from their home countries by air.

Indeed ***students' occasional travel between their main 'home' and the university was in all cases greater than the amount of regular term time travel*** (on average over three times the distance/student/10 CAT). This has implications for decisions concerning the provision of university accommodation which will tend to reduce students' term-time commuting and encouraging students to live at 'home' thus eliminating travel between home and term time residences.

Table 3 Total campus students' course related travel (average per student per 10 CAT points)

	All course-related student travel/stud./10 CAT		
Campus course	Distance (km)	Energy (MJ)	CO_2 emissns (kg)
A	2498	5556	401
B	2270	5009	343
C	1342	2102	169
D	510	333	28
E	460	547	48
F	1683	2298	169
G	668	1045	78
H	146	252	18
Average (UK courses)	***1197***	***2143***	***157***
I	961	1631	114
Average (all courses)	**1171**	**2086**	**152**

3.2.2 Open University student travel

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 electronically taught T171 there was an average of 33 miles (52 km) for all course-related travel/student/10 CAT points. Over half of these trips were by car, as driver or passenger, the remainder by various modes including motor cycle, bus and rail. The main reasons for T171 students' travel were to enquire, register and prepare for the course (25% of the total distance); to obtain books and other course material (21%); and to attend optional face to face sessions (at 8 miles (13 km) or 24% total). At least one face to face meeting was offered to T171 students, mainly as a result of pressure from the OU local Regions, although the central course team did not originally intend such contact.

The above figures compare to an average total of 52 miles (83 km) travel/student/10 CAT for the print-based T172. Again, about half of these trips were as car driver or passenger, the remainder by various modes including motor cycle, bus and rail. Most of the difference from T171 was due to the greater distance travelled by T172 students to attend optional tutorials and day schools (at 31 miles (50 km) or 61% total distance) and to take the end of course examination at a local centre (13% total distance). The T171 course did not require the latter journey as it included an end of course assessment, submitted electronically, rather than an examination.

An interesting 'rebound' effect of the electronically delivered T171 is the ten times greater distance travelled to meet other students (at 5 miles (8 km)/student/10 CAT or 15% of the total) than undertaken by T172 students. The limited, if any, face-to-face contact offered to T171 students stimulated some to meet informally on their own initiative. Only 0.1% of T172 travel was to meet fellow students informally, presumably because the tutorials provided adequate face to face contact.

Overall there was a cut by about a third in the distance travelled and a quarter in the energy consumed and CO_2 emissions generated by the electronically taught compared to the print-based distance learning OU course (Table 4). If however the face to face sessions for T171 are removed, making the course entirely electronically tutored as was originally intended, the reduction in travel compared to T172 is over 50%. Such a measure might of course result in the T171 students seeking greater informal face to face contact. Clearly the issue of how best to provide the supported distance/open learning that the OU provides is more than a matter of reducing the need for students to travel. It requires addressing the learning and other needs that generate travel.

Table 4 Total Open University students' course related travel (average per student per 10 CAT points)

	All course-related student travel/stud./10 CAT		
OU course	Distance (km)	Energy (MJ)	CO_2 emissns (kg)
T171 (mainly electronically taught)	53	118	8.7
T172 (mainly print based)	83	152	12
OU Average	**68**	**135**	**10**

3.2.3 Campus staff travel

The lecturers who distributed the student questionnaires were also asked to report their course-related travel – to prepare, administer, teach and tutor the courses. As for the students, the lecturers were asked for the number of trips for various course-related purposes, round trip length and mode of travel used. The questionnaire involved procedures to allocate a proportion of travel made for other academic purposes to the specified course and to scale up the travel they undertook for teaching the course to the total number of course staff involved (See Appendix 1 section 5 for details). This means that the results are approximate, as they assume that the one lecturer surveyed per course is representative of the whole teaching team for that course. This approximation may be justified on the basis that the distance travelled/student/10 CAT points by lecturers is relatively small compared to student travel (Table 5), which is why this project concentrated upon the latter. On average, lecturer trips represent only about 2% of the total amount of travel associated with the courses.

Most lecturer travel is commuting using a variety of modes between home and campus (37% of total distance/student/10 CAT). Other important trip purposes by lecturers are for travel between campus sites (24%) and other course-related travel (25%).

Table 5 Total campus lecturers' course related travel (average for all course teaching staff per student per 10 CAT points)

		All course-related staff travel/stud./10 CAT		
Campus course	Location	Distance (km)	Energy (MJ)	CO_2 emissns (kg)
A	Urban	5.8	7.4	1.0
B	Urban	2.9	3.7	0.3
C	Urban	no data	No data	No data
D	Urban	72	253	18
E	Urban	2.3	7.9	0.6
F	Urban	4.5	4.7	0.5
G	Rural	1.6	5.7	0.4
H	Urban	3.1	1.9	0.6
Av. UK		***13***	***41***	***3.0***
I	Rural	165	324	23
Av. All		**32**	**76**	**5.5**

3.2.4 Open University staff travel

Staff travel for the OU courses is divided between the central and regional members of the course teams who plan, develop and maintain the courses, and the local tutors (Associate Lecturers) who provide optional face to face tutorials to students, as well as marking assignments, etc.

To obtain data on course team travel for the courses, a scoping study was carried out with one of the main authors of the T172 course.[6] His travel to attend course team meetings, to prepare written and audio-visual material, etc. over 2.5 years totalled about 2500 miles (4000 km). His travel was then scaled up to the whole course team assuming each of its 14 full equivalent members travelled a similar distance and by similar modes. It was felt that this approximate method of calculation was justified, given that the travel, energy and emissions/student/10 CAT points were very small when divided between the 9000 students expected to take the T172 course over 6 years before it is substantially revised (Table 6). The same assumptions were made for the T171 course, but with course team travel spread over the 40,000 students expected to take the course over 5 years before it is withdrawn or revised. For the T171 course staff travel/student/10 CAT is negligible, although we have included the estimates in Table 6 (see Appendix 1, section 5.3).

For Associate Lecturer travel a representative sample of tutors were surveyed and a tutor:student ratio of 1:20, typical for these courses, was used in the calculations. Again, the distance/student/10 CAT travelled by tutors is only a relatively small proportion of the total amount of travel associated with the OU courses (Table 7, although at about 12% for T171 and 15% for T172 it is greater than the average percentage for the campus courses). Most OU tutor travel is to and from tutorials and day schools, (29% total distance/student/10 CAT for T171 and 62% for T172). In T171 such face to face tutorials were limited to one formal session. The other main travel purpose was to Regional centres for meetings, training, etc. (62% distance/student/10 CAT for T171 and 27% for T172).

Table 6 Open University course related staff travel (average per student per 10 CAT points)

	All course-related tutor travel/stud./10 CAT [1]			All course team travel/stud./10 CAT [2]		
OU course	Distance (km)	Energy (MJ)	CO_2 emissns (kg)	Distance (km)	Energy (MJ)	CO_2 emissns (kg)
T171 (electronic)	6.8	13	1.1	0.5	0.6	0.1
T172 (print)	13	34	2.5	2.1	2.6	0.3

1. A tutor:student ratio of 1:20 was used. 2. Based on scoping study of one T172 central academic.

Table 7 Total Open University staff course-related travel (average per student per 10 CAT points)

	All tutor and course team travel/ stud./10 CAT		
OU course	Distance (km)	Energy (MJ)	CO_2 emissns (kg)
T171 (electronic)	7.2	14	1.2
T172 (print)	15	37	2.8
OU Average	**11**	**25**	**2.0**

3.2.5 Campus and Open University travel

Table 8 compares the total travel distance, energy and CO_2 emissions for the campus based with the distance/supported open learning OU courses.

Compared to the campus-based courses, the OU methods of delivery represent a very great reduction in total course-related travel, energy and CO_2 emissions (Figure 5). Compared to the campus courses, this reduction ranges from 91% (factor 12) for the print-based T172 OU course to a 94% (factor 16) for the electronically delivered T171 OU course. There are clearly enormous reductions in travel-related environmental impacts inherent to distance education – averaging about 92% (factor 13). However, the reductions in travel in moving from print-based to electronic distance/supported open learning, at least as practised by the Open University, are smaller at 30-50%. The reduction depends on whether face to face tutorials are offered to students of electronically delivered courses and on the degree of 'rebound' due to students travelling for informal face to face meetings when there is little or no formal provision.

Table 8 Summary staff and student travel for campus and Open University courses (averages per student per 10 CAT points)

Summary	All course-related travel/student/10 CAT pts		
	Distance (km)	Energy (MJ)	CO2 emissns (kg)
UK campus students	*1197*	*2143*	*157*
UK campus lecturers	*13*	*41*	*3.0*
UK campus total	***1210***	***2183***	***160***
All campus students	*1171*	2086	152
All campus lecturers	*32*	76	5.5
All campus total [1]	**1203**	**2162**	**158**
OU T171 students	*53*	118	8.7
OU T171 staff	*7.2*	14	1.2
OU T171 total	***60***	**132**	**9.9**
OU T172 students	*83*	152	12
OU T172 staff	*15*	37	2.8
OU T172 total	***98***	**189**	**15**
OU Average	***79***	***160***	***12***

1. Including one Irish campus course

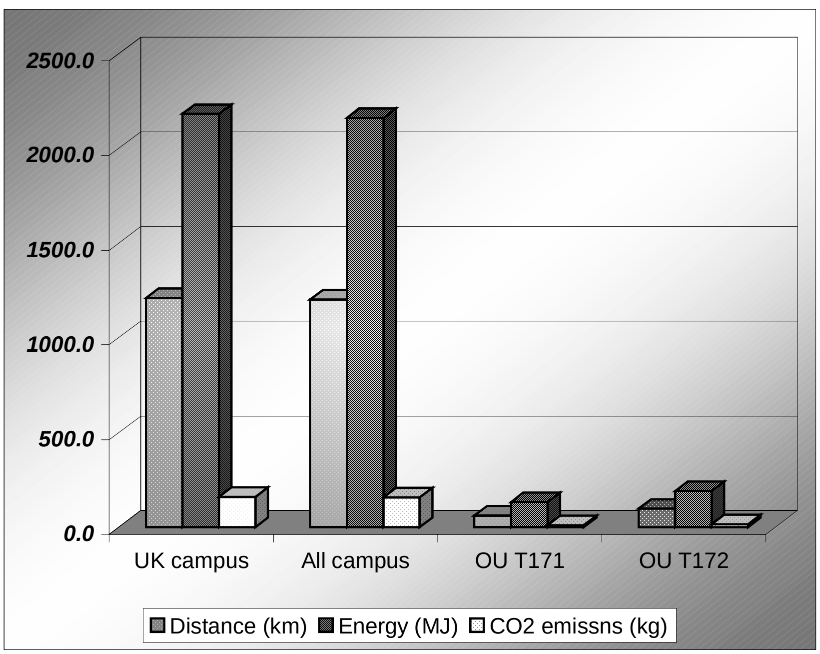

Figure 5 Staff and student travel for campus and Open University courses (averages per student per 10 CAT points)

3.3 Computer purchase and use

Students, campus lecturers and OU tutors provided information on the number of hours in a typical week they used their *own* computers for tasks connected with the course. Use of university computers was excluded, as this was considered as part of the campus site impacts. The computer usage data was converted into energy use and CO_2 emissions by using generic figures on the average energy consumption of a desktop PC (about 90% of all computers used were desktop machines) and the carbon content of fuels to generate electricity (see Appendix 1 section 7.1).

These data apply to a stand-alone computer. For the mainly electronically taught 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 on-line connected to the OU's 'First Class' conferencing system for posting messages to tutors and other students and for sending and receiving emails. 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 (LCA) study of different methods of sending messages (Remmerswaal et al., 2001, see Appendix 1 section 7.2). The main author of the LCA regards this figure as a lower estimate[7], so a figure of 0.45 MJ/hr was estimated as the additional energy of a computer connected to a remote network. A stand-alone PC consumes 0.45 MJ/hr, so our estimate is that on-line use doubles its total energy consumption and emissions. Also the amount of time students and staff spent on-line was not asked in the surveys, so an estimate had also to be made concerning this. By considering the nature and type of computing required for the different courses, we made a educated guess that the OU T171 staff and students spent two-thirds, and participants in all the other courses 10%, of their total computing time on-line.

Information on purchase by staff and students of new or upgraded computing equipment mainly for the course was also gathered, as additional computing equipment involves environmental impacts due to, among other factors, the embodied energy involved in its production. In order to allocate environmental impacts, based on replacement cycles at the OU [8] it was estimated that a computer mainly used for teaching or study lasts for 3 years. The impacts were then further attributed according to the CAT points of each course (for details see Appendix 1 section 7.3.)

3.3.1 Campus students computing

Table 9 details the campus students' purchase and use of their own computers mainly for their course. There is considerable variation in the patterns of purchase and use, which appear to be related to the nature of the campus, as well as the course. For example, the relatively low use of students' own computers on the course at university G, many of whose students live in university residences on a self-contained, out of town campus, possibly reflects the easy access to university machines. In contrast course H, presented at a town centre campus many of whose students live at home, involved more students in purchasing personal computers and using them off-campus.

It is notable that the average embodied energy arising from computer purchases is about twice that arising from computer use. However, given the differences in the various estimates of the energy and emissions associated with computer production,[9] and the assumptions involved in allocating computer purchases to course CAT points, this result should be regarded as provisional.

Table 9 Campus students' purchase and use of computers (per student per 10 CAT points)

Campus Students	Course-related own computer use/ student/10 CAT			Course related computer purchases/ student/10 CAT		
Course	Usage (hours) [1]	Energy (MJ)	CO_2 emissns (kg)	Number PCs	Energy (MJ)	CO_2 emissns (kg)
A	102	50	6.6	0.015	135	13
B	87	43	5.7	0.005	45	4.3
C	36	18	2.4	0.007	63	6.0
D	122	60	7.9	0.009	81	7.8
E	71	35	4.6	0.009	81	7.8
F	107	53	7.0	0.009	81	7.8
G	32	16	2.0	0.006	54	5.2
H	19	9.6	1.3	0.006	54	5.2
Average UK	***72***	***36***	***4.7***	***0.008***	***74***	***7.1***
I	160	79	10	0.008	72	6.9
Average All	**82**	**41**	**5.3**	**0.008**	**74**	**7.1**

1. Including 10% time on-line

3.3.2 Campus lecturers computing

Table 10 provides the same information for each campus lecturer who responded to this part of the survey, scaled up to the whole teaching staff for his or her course. Here there is insufficient data to discern any pattern except to note that – assuming the surveyed lecturers were representative – the impact of their computing (per student per 10 CAT points) is relatively small given that it is spread over the number of students taking each course.

Table 10 Campus lecturers' purchase and use of computers (per student per 10 CAT points)

Campus Lecturers [1]	Course-related own computer use/ student/10 CAT			Course related computer purchases/ student/10 CAT		
Course	Usage (hours) [2]	Energy (MJ)	CO_2 emissns (kg)	Number PCs	Energy (MJ)	CO_2 emissns (kg)
B	n/a	n/a	n/a	0	0	0
D	0.9	0.5	0.06	0.001	9	0.86
E	0.3	0.2	0.02	0	0	0.00
G	n/a	n/a	n/a	0	0	0
H	n/a	n/a	n/a	0	0	0
Average UK	***0.6***	***0.3***	***0.04***	***0.0002***	***1.8***	***0.17***
I	13	6.6	0.86	0.006	54	5.18
Average All	**4.8**	**2.4**	**0.31**	**0.001**	**11**	**1.01**

1 All course lecturers. 2. Including 10% time on-line

3.3.3 OU students computing

Similar data were obtained for the Open University students with the results shown in Table 11. Not surprisingly the mainly electronically taught and tutored OU T171 course involved some 2.5 times the computing time of the print-based OU T172 course. But the energy and emissions arising from T171 students' computing were nearly four times greater because it was assumed that they spent much more of their computing time connected to an energy-consuming network than the T172 students. Again not surprisingly, the T171 students bought more computers mainly in order to study the course than the T172 students with resultant greater impacts from embodied energy and emissions.

Table 11 OU students' purchase and use of computers (per student per 10 CAT points)

OU Students	Course-related own computer use/student/10 CAT			Course related computer purchases /student/10 CAT		
Course	Usage (hours)	Energy (MJ)	CO_2 emissns (kg)	Number PCs	Energy (MJ)	CO_2 emissns (kg)
T171 - electronic [1]	161	121	15	0.005	45	4.3
T172 - print [2]	63	31	4.1	0.003	27	2.6
OU Average	**112**	**76**	**9.6**	**0.004**	**36**	**3.5**

1. Including 67% time on- line.
2. Including 10% time on-line.

3.3.4 OU tutors computing

The computer purchase and use data for the Open University tutors (Associate Lecturers) is shown in Table 12. Again the electronically taught and tutored T171 course involved over 2.7 times the amount of tutors' computing time of T172 and nearly five times the energy and emissions arising from both purchase and use of computers for tutoring the course. For the OU course team, the scoping study of one central academic's computer use during course development scaled up to the whole team indicated negligible impacts when averaged per student per 10 CAT points.[10]

Table 12 OU tutors' purchase and use of computers (per student per 10 CAT points)

OU Tutors [1]	Course-related own computer use /student/10 CAT			Course related computer purchases /student/10 CAT		
Course	Usage (hours)	Energy (MJ)	CO_2 emissns (kg)	Number PCs	Energy (MJ)	CO_2 emissns (kg)
T171 - electronic [2]	7.7	5.8	0.7	0.0006	5.4	0.5
T172 - print [3]	2.8	1.4	0.2	0.0001	0.9	0.1
OU Average	**5.3**	**3.6**	**0.5**	**0.0004**	**3.2**	**0.3**

1. A tutor:student ratio of 1:20 was used.
(The impacts of OU course team computing/student/10 CAT were negligible and were ignored.)
2. Including 67% time on-line.
3. Including 10% time on-line.

3.3.5 Campus and Open University computing

Table 13 Summary staff and student computing for campus and Open University courses (averages per student per 10 CAT points)

Summary	All course-related computing/ student/10 CAT			
	Usage (hours)	Purchases (no.)	Energy (MJ)	CO_2 emissns (kg)
UK campus	73	0.008	112	12
All campus [1]	87	0.009	127	14
OU T171	169	0.006	177	21
OU T172	66	0.003	60	6.9

1. Including one Irish campus course.

Not surprisingly, the mainly electronically taught and tutored Open University T171 course had the highest computer use of all. It involved over 2.5 times the hours of computing of the print-based OU T172 course and over twice that of the average UK campus course. The associated energy and CO_2 emissions for T171 (taking into account the greater proportion of time T171 students were likely to have spent on-line and hence consuming more energy) were three times those of the T172 course but only some 60-70% greater than for the average UK campus course (Table 13). The difference is mainly due to the embodied energy of the larger number of computers purchased for their courses by the campus students. This may be because campus students tend to be younger than OU students and hence may be less likely to already own a home computer.

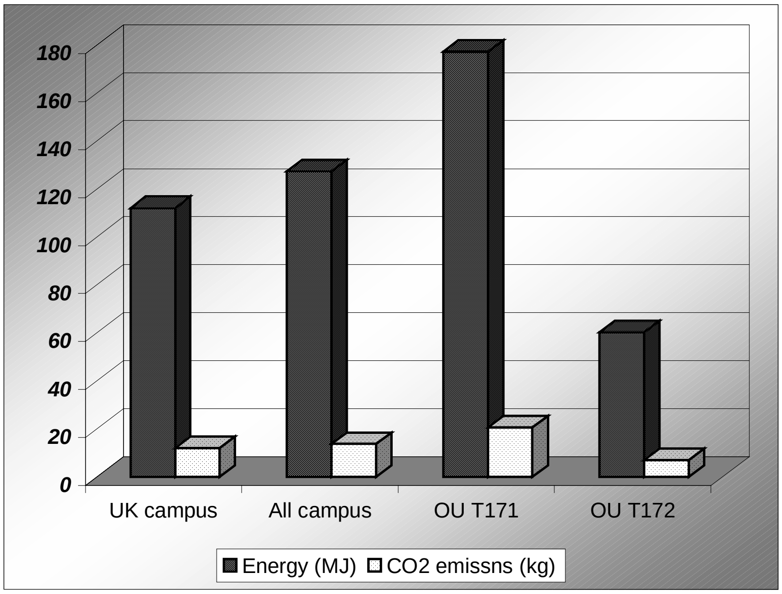

Figure 6 Staff and student computing impacts for campus and Open University courses (averages per student per 10 CAT points)

Overall, as Figure 6 indicates, ***there are considerable differences in the environmental impacts of computing between the different methods of course provision. However, these differences are relatively minor when compared to the differences in travel and campus site impacts for the face to face and distance/supported open learning systems.*** Nevertheless, purchase and use of computers, including on-line use, for the mainly electronically taught OU T171 course accounted for more energy and emissions than either travel or campus site impacts. Indeed, as will be seen, computing is the largest source of impacts for this course. This shows that previously areas of minor environmental impact may become dominant in a 'de-materialised' version of a service.

3.4 Consumption of paper and printed matter

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, and for assignments. They were also asked about the number of course-related books and periodicals purchased. (Books, etc. from libraries were ignored as they are shared among many users.) The period for estimating consumption of paper and printed matter varied as appropriate to the mode of course delivery and survey method (see Appendix 1, section 8).

The Open University, of course, provides its students with specially written course books and other printed and audio-visual materials. Over 6 kg of printed material is mailed to each student of the 30 point OU T172 course (i.e. 2 kg/student/10 CAT points, ignoring the course video and audio-tapes). Although most of the OU T171 teaching content is provided electronically, the two set books purchased by students [11] plus some printed material mailed by the OU weigh a total of 1.2 kg. (0.4 kg/student/10 CAT points).

The research team weighed samples of office paper, academic books and periodicals. This data together with generic information was used to produce an estimate of the amounts of life cycle *delivered* energy and CO_2 involved in the students' consumption of paper and printed matter. Postal distribution involves a further small amount of energy and emissions (Remmerswaal, 2001;

Sykes, 2001), which was added to the OU totals. Any transport involved in buying books, etc. is covered by the travel questions. (For details of all these calculations see Appendix 1, section 8.)

3.4.1 Student and staff consumption of paper and print

Table 14 shows that student consumption of paper and printed matter for an average campus course is similar to that for the print-based OU T172 course. In the distance/open learning course the printed course materials provided by the OU weigh almost the same as the books and periodicals purchased by the campus students. The rest is probably paper consumed by campus students in the form of photocopies and handouts.

Perhaps as expected, the mainly electronically taught OU T171 course (despite its two set books) involves less paper and printed matter than both the print-based OU T172 course and the average campus course. In fact OU T171 students consume roughly half the weight of paper and print, involving nearly half the energy and emissions, when compared to all the other courses. This takes into account the considerable amount of paper is used by T171 students for printing off study materials from the course Web site and for printing emails, conference messages, etc. This appears to be a rebound effect, with the ‘dematerialised’ electronic teaching at least partly re-materialising via the students’ printers.

The question of whether people are willing and able to study on-screen material is, of course, of considerable interest in educational research, but is beyond the scope of this project. Feedback from OU T171 students who took the course in 2000 indicates that two-thirds printed half or more of the 483 pages of Web site course materials while a quarter printed out none or ‘only the odd page’.[12] The main reasons for wanting paper copy were its portability (30% total responses), preference for working from paper rather than screen (20%); ease of finding their way through the material and making notes on a paper copy (both 16%); having a record of learning (14%).

Table 14 Students consumption of paper and printed matter (per student per 10 CAT points)

Students	Sheets of paper (no.)	kg	Printed course material (kg)	Books & periodicals purchased (no.)	kg	**Total weight paper & print (kg)**	**Total energy in paper & print (MJ)**	**Total CO_2 from paper & print (kg)**
UK campus	*(195)*	*1.0*	*n/a*	*(3.3)*	*1.7*	***2.7***	***71***	***8.1***
All campus [1]	(217)	1.1	n/a	(3.4)	1.8	**2.9**	**76**	**8.5**
OU T171 Website	(96)	0.5	0.4 [2]	(0.9)	0.4	**1.5**	**38**	**4.3**
Other	(42)	0.2					**+ 1.8** [3]	**+ 0.1** [3]
OU T172	(22)	0.1	2.0	(1.2)	0.5	**2.6**	**79**	**8.4**
							+ 18.0 [3]	**+ 0.6** [3]

1. Including one Irish campus course. 2. Including T171 set books. 3. Postal distribution

An interesting trend, not shown in Table 14, is the pattern of the some campus courses having considerably greater impacts (/student/10 CAT) than others. For example, the relatively high consumption of paper and printed matter by students of the course at one town centre campus university might be associated with the dispersed site making library use inconvenient and increasing the need for purchasing books and periodicals, making photocopies and printing.

The pattern for staff consumption of paper and print is similar to that of the students, but the amounts are much smaller because of the ratio of lecturers and OU tutors to students that is taken into account when calculating per student per 10 CAT points (Table 15). As before, the scoping study of the impacts of the paper and print consumption by the OU course teams indicated that these were negligible when spread over the very large numbers of students involved. [13] This is despite the vast amounts of paper, photocopies and publications consumed during OU course development (estimated at some 700 kg for the T172 course team).

Table 15 Staff consumption of paper and printed matter (per student per 10 CAT points)

Lecturers and tutors	Sheets of paper (no.)	Sheets of paper kg	Printed course material kg	Books/ other publications purchased (no.)	Books/ other publications purchased kg	**Total weight paper & print (kg)**	**Total energy in paper & print (MJ)**	**Total CO_2 from paper & print (kg)**
UK campus	*(33)*	*0.16*	*0*	*(0.1)*	*0.02*	***0.2***	***3.6***	***0.6***
All campus [1]	(43)	0.21	0	n/a		**n/a**	**n/a**	**n/a**
OU T171 [2]	(5.4)	0.03	0.02	(0.1)	0.03	**0.1**	**2.1 + 0.2** [3]	**0.2**
OU T172 [2]	(4.9)	0.02	0.1	(0.1)	0.02	**0.1**	**4.1+ 0.9** [3]	**0.5**

1. Including one Irish campus course. 2. A tutor:student ratio of 1:20 was used. 3. Postal distribution

3.4.2 Campus and Open University consumption of paper and print

Overall, the ***campus courses and the print-based OU T172 course involve similar amounts of paper and printed matter with associated energy and emissions, while the partially electronically provided OU T171 course appears to roughly halve the amount of paper and print required*** *(Figure 7). This takes into account the 'rebound effect' of many students printing off some or most course materials from the Web site in order to study them, as well as printing other material such as emails, conference messages and draft assignments*. There is thus some evidence of de-materialisation through e-learning, even for the guided study of two set books using web based teaching material with mainly electronic tuition that is the basis of the OU T171 learning system.

The associated energy and emissions are highest for the print based OU T172 course because of the large amounts of printed material provided – over twice those for the electronic OU T171 course and nearly twice those for the campus courses.

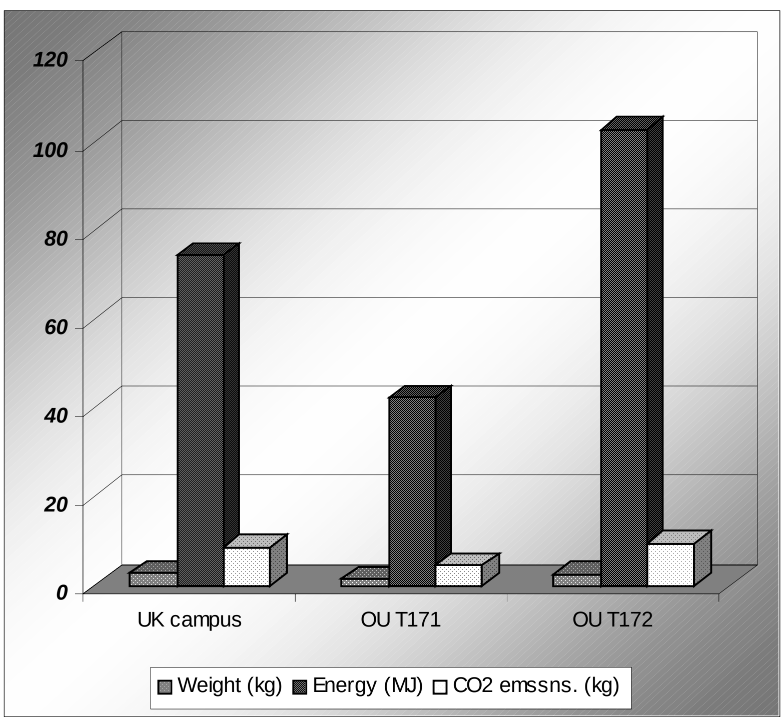

Figure 7 Total impacts of paper and printed matter consumption (per student per 10 CAT points)

However, ***considering the energy and emissions from paper/print consumption plus computing, it appears that the environmental impacts of the partially electronic OU T171 course are over one third greater than the print based OU T172 course and nearly a fifth greater than the average campus course.*** This appears to challenge claims about the 'de-materialisation' effects of using ICT to provide services such as HE. But, even the combined impacts from computing and paper/print consumption are relatively small compared to those from travel and the campus site. It is these latter factors that seem to account for the major difference between the distance and conventional course delivery systems.

3.5 Residential energy

Being a student entails having a place to live while studying, which will of course require energy for heating, lighting, etc. However, the amount of residential energy to attribute to a course requires careful consideration. In the UK space heating accounts for most of the residential energy consumed during the October to May heating season. For the part-time OU students most of whom live and study at home, as well as for the campus students who live at their main home during term, it seems reasonable to consider only *'additional'* heating related to studying the course. (Additional lighting energy was ignored, as it was calculated to be small compared to heating).[14]

Students were therefore asked where they lived during term and, if they lived at home, whether they heated its space(s) above normal use for the purposes of study (e.g. by leaving the central heating on longer than normal or using an electric room heater). The additional energy involved was then calculated from the hours of additional heating during the months the home was normally heated plus the source employed (see Appendix 1, section 4.3).

For the full-time campus students who live in university residences or in shared flats, houses, lodgings, etc., it could be argued that *all* term-time residential energy consumption should be included. We debated this issue at length before deciding that being at university and taking the course is a student's main occupation that influences his or her whole lifestyle and thereby necessitates use of this energy. This residential energy is the student's share of the total heating, hot water and lighting energy consumed in their term-time residence, weighted according to the CAT points of the course.

Because of a limit on the number of questions we could reasonably expect respondents to answer, students who lived in flats, etc. were not asked for the extensive information needed to directly calculate their share of residential energy consumption. Instead indirect measures had to be used. For those living in university residences official data from the UK Higher Education funding councils on fuel costs and total residential energy consumption of five of the eight UK universities in the survey were obtained. The numbers of residential places was not provided in the official statistics and so this had to be obtained from the universities' accommodation officers. Because the energy data on individual universities is confidential, only averages can be provided here. As noted in Section 3.1 in relation to the campus site, since our focus is on how course delivery affects environmental impacts, it is not really concerned with factors, such as the type of buildings and heating system, that will vary at the student residences provided by different universities. So it seemed appropriate to correct for such site-specific variations by using an average for the survey universities' residential energy and emissions.

For students living in shared houses, lodgings, etc. *The English House Condition Survey* provided statistical information on average household energy consumption and CO_2 emissions. (DETR, 2000; see Appendix 1, section 4.3.2 for details).

For the campus lecturers and OU tutors, we asked for *additional* home heating associated with teaching the course. The scoping study of one OU T172 course team member was used to estimate additional home heating involved in course development. [15]

3.5.1 Students' residential energy consumption

About a quarter of the campus students lived in a university or college hall of residence. Nearly half lived in a flat or house, lodgings, or a room in a flat or house, and the remaining quarter at their main, usual or permanent home (Table 16).

For the students living in university residences, the mean energy consumption was about 25,400 MJ per year per residential place. This equates to 1220 MJ per student per 10 CAT points, since a year's study over a 30-week period during the heating season is worth 120 CAT points. Using the same method as for the campus sites (see Appendix 1, section 4.1), the data on annual purchases of gas, oil and electricity were used to estimate the average fuel mix of the university residences. This was then used to calculate the emissions: of approximately 105 kg CO_2/student/10 CAT.

For students living in flats, houses, etc. we did not gather information on the number of people sharing the accommodation, therefore only approximate estimates can be provided of residential energy use per student.

Using the *Energy Report* of the English House Condition Survey (DETR, 2000), the average energy consumption of the English housing stock in 1996 (the most recent survey year) was about 88,000 MJ per dwelling per year. The mean household size in 1996-7 was 2.4 persons. We could not find any data on the occupancy of student households, but given that a 3 bedroom dwelling is typical of the UK stock, we made an estimate of 3 students per household for those living in shared houses, flats etc. On this basis, over 30-weeks of term-time occupation during the heating season the residential energy consumed is 1410 MJ per student per 10 CAT points (a figure comparable to that for the university residences). Likewise the *English House Condition Survey* gives mean CO_2 emissions of the housing stock in 1996 as 6373 kg per dwelling per year. Using the above method of estimation, this equates to 102 kg CO_2 per student per 10 CAT points for students living in shared houses, flats, lodgings, etc.

Table 16 UK campus students' residential energy and emissions (average per student per 10 CAT points)

Campus students term-time accommodation	Percent.	Average energy (MJ)	Average CO_2 (kg)
University residences	29	1220	105
Flats, houses, lodgings	44	1410	102
Main or usual home [1]	27	174	7.4
Other	0.4	d/k	d/k
Weighted average	**100**	**1023**	**77**

1. *Additional* heating only.

As noted above, for the campus students living at home during term and the home based OU students we obtained data on the amount of *additional* heating for the purposes of studying their course.

The main additional heating sources were gas central heating and electric room heaters. The approximate energy and CO_2 emissions per student per 10 CAT Points were calculated from the responses (Tables 16 and 17. See Appendix 1, section 4.3.3).

Table 17 OU students' additional course related residential heating (average per student per 10 CAT points)

Open University students	Gas CH (hours)	Electric heater (hours)	Average energy (MJ)	Average CO_2 (kg)
OU T171 - electronic[1]	4.4	1.1	**117**	**5.2**
OU T172 - print [2]	0.9	0.5	**24**	**1.2**

1. N= 343 2. N= 205.

An interesting rebound effect is the relatively high amount of additional heating claimed by students of the mainly electronically taught 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 OU T172 course. We do not know for certain the reason for this difference. However, several responses to the qualitative part of the questionnaire suggest that it is probably due to T171 students staying up late to connect to the Internet in order to access the course material, surf the Web, etc., thus leaving their home heating on longer than normal. This will be discussed further in the separate report on the qualitative responses to the surveys.

3.5.2 Staff residential energy consumption

The campus lecturers and OU tutors were asked to estimate the hours of additional heating when working at home on tasks connected with the course. The energy and emissions were calculated in the same way as for the home based students (Table 18).

Table 18 Staff course related additional residential heating (average per student per 10 CAT points)

Staff	Gas CH (hours)	Electric heater (hours)	Average energy (MJ)	Average CO_2 emssns. (kg)
Campus lecturers	2.3	16	165	16
OU T171 course team + tutors [1]	0.3	0.1	7.6	0.3
OU T172 course team + tutors [1]	0.1	0.2	5.7	0.4

1. Hours additional heating for OU staff is only for *tutors*, MJ and CO_2 emissions is total for *course team + tutors*.

As before the scoping study of a central academic member of one of the OU course teams was used to estimate the order of magnitude of additional home heating involved in course development. Spread over the large numbers of students taking the OU courses the amounts concerned per student per 10 CAT were small at 0.6 MJ and <0.1 kg CO_2 for T171 and 2.7 MJ and 0.2 kg CO_2 for T172. [16]

3.5.3 Campus and Open University residential energy

Compared to the campus-based courses surveyed, the OU system of home-based learning represents a very great reduction in residential energy consumption and associated emissions *(Figure 8)****.*** *Most of this reduction is due to the fact that for the OU courses only additional heating for study needs to be counted.* For the campus-based courses, except for those students who live at home during term, it seems reasonable to include each student's share of the total energy consumption of their term-time residence, whether this is university accommodation or a rented house or flat or lodgings. *Campus students who live at home during term are similar to OU students in their relatively small requirement of residential energy*, since it may be assumed that the dwelling would be heated anyway (Figure 8).

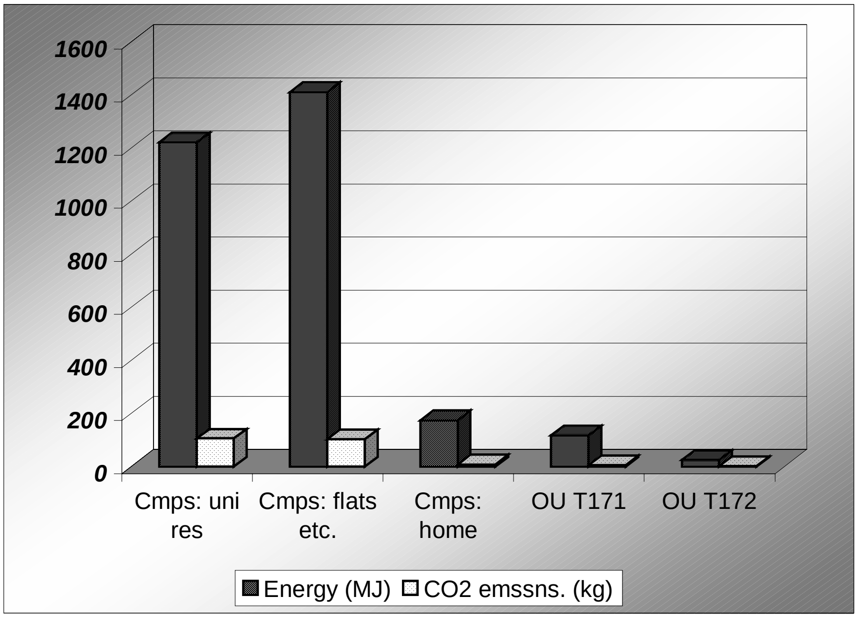

Figure 8 UK campus and OU students' residential energy and emissions (average per student per 10 CAT points)

To the data shown in Figure 8 any additional heating of staff homes associated with course preparation, tuition, marking etc. needs to be added. This provides the comparison between the total staff and student residential energy and emissions arising from the campus courses with those for the OU courses shown in Table 19.

Table 19 All course-related residential energy and emissions (per student per 10 CAT points)

Staff & student residential energy consumption	Basis	**Energy (MJ)**	**CO_2 emssns. (kg)**
UK campus weighted average	All term-time energy	1188	93
OU T171 - electronic	Additional heating	125	5.5
OU T172 - print	Additional heating	30	1.6

Compared to the campus courses, the reduction in residential energy and emissions per student per 10 CAT points ranges from an average of about 92% for the electronic T171 OU course to about 98% for the print-based T172 OU course. However, ***there is an interesting 'rebound effect' on residential energy consumption in moving from print-based to electronic teaching and tutoring of OU courses. This is probably due to students staying up at night to connect to the Internet in order to access the course material and the electronic conferences, thus leaving their home heating on longer than normal.*** *But this effect is very small when compared to the residential energy involved in campus based systems.*

4. Comparisons and discussion

This environmental audit reveals, and for the first time quantifies, major differences in the impacts of alternative higher education systems. It should be borne in mind that these differences are based on data and calculations involving several, we believe realistic, assumptions and approximations – these will be outlined below in section 4.4 and are fully detailed in Appendix 1.

4.1 Conventional campus compared to distance/open learning courses

Perhaps the most startling result is that ***the two Open University distance/supported open learning courses we examined on average involve 90% less energy consumption and produce 90% fewer CO_2 emissions per student per 10 CAT points than eight conventional campus based courses at UK universities***. This 'factor 10' reduction is a interesting result for a project entitled *Factor 10 Visions*. There are three main reasons for the very large reduction in the energy and emissions for distance/supported open learning courses compared to conventional face to face higher education. They are revealed clearly in Figures 9 and 10, which show that the energy and emissions results follow very similar patterns.

1) *The elimination, inherent to distance/open learning, of much staff and student travel*. The main journeys eliminated are students travelling between their usual or permanent 'home' and the university and between any term time residence and the campus, e.g. to attend classes. The distances involved can be quite large, especially home/university trips for overseas students, and greatly exceed those involved in staff and student travel for an OU distance/ supported open learning course, e.g. to attend tutorials at a local study centre.

2) *The very large reduction in campus site emissions per student from distance/open learning systems* in which a multi-media course developed by a team based mainly at a single campus can be presented – with new assessments and updating – to many thousands of students over a period of years. Over a five year life it is likely that the OU T171 course will be studied by 30,000 to 40,000 students, while the OU T172 course is likely to be studied by about 9000 students over six years. Not all OU courses serve as many students as these popular introductory courses. But even with the minimum likely student numbers for an OU course (about 50 per year) the economies of scale in terms of OU campus site emissions/student/10 CAT remain very great when compared to conventional campus based teaching (see Appendix 1, section 5.4).

3) *For part-time OU students who study from home it is reasonable to consider only any additional residential energy involved in taking a course*, in particular additional space heating required for study in winter months. Whereas, for full-time campus based students, many of whom live away from 'home' during term in university residences or houses, flats and lodgings, as was discussed earlier it seems appropriate to count *all* the energy consumed per student in those term-time dwellings. This is because students who live at home would normally be heating and lighting this dwelling anyway, while those campus based students who live away from their main 'home' during term do so mainly because they are taking a course.

The above three factors account for most of the factor 10 reduction. The energy and emissions arising from the other two elements – computer purchase/use, and consumption of paper/printed matter – although important for the OU courses, are relatively minor for the campus courses. But the differences in the impacts of computing and paper/print consumption between the conventional and distance/open learning systems are much less than for the other factors. This can be seen clearly in Figures 9 and 10 and Table 20.

Table 20 Total energy and emissions of campus and Open University courses (averages per student per 10 CAT points)

ENERGY (MJ)	Campus site	Transport	Computing	Paper/print	Resdl. heating	TOTAL
UK campus	805	2183	112	75	1188	**4363**
OU T171	1.4	132	177	42	125	**477**
OU T172	7.1	189	60	103	30	**389**
CO_2 EMSSNS (kg)	**Campus site**	**Transport**	**Computing**	**Paper/print**	**Resdl. heating**	**TOTAL**
UK campus	74	160	12	8.7	93	**348**
OU T171	0.1	9.9	21	4.6	5.5	**41**
OU T172	0.6	15	6.9	9.5	1.6	**34**

4.2 Electronic compared to print-based distance/open learning courses

Perhaps the most unexpected finding is that ***the mainly electronically taught and tutored OU course,*** *T171 You, your computer and the Net****, appears to involve 23% more energy and 21% more emissions per student per 10 CAT points than the mainly print based OU course,*** *T172 Working with our Environment****.*** Although the OU T171 course is not fully electronic, this result does not appear to bear out the claims of de-materialisation often made for electronically provided services, such as e-learning. This surprising result is partly due to the obvious fact that even a partly electronically delivered course such as T171 involves high usage of computers, including on-line use, and hence significant energy consumption. The other reason is the following so-called ‘rebound’ effects:

1) *The preference of many students to download and print off a high proportion of electronically provided learning materials* for reasons of portability, ease of reading, note making and reference. Feedback from OU T171 students indicates that two-thirds print half or more of the approximately 500 pages of Web site course materials. Printing clearly consumes paper and the associated energy and emissions involved in paper production.

2) Another less expected effect is the *apparent wish of some OU T171 students to meet informally face to face, given the limited or no provision of formal face to face sessions*, thus involving local travel.

3) Also s*ome OU T171 students appear to heat space(s) in their homes more than normal for study purposes*, probably while staying up late accessing the Internet during winter months.

All these factors serve to outweigh the savings in energy and emissions from a reduced amount of printed matter and staff/student travel for OU T171 when compared to the mainly print-based OU T172 course. It should be emphasised, again, that T171 is not an entirely electronically provided course. As noted earlier it has specifically been designed to use Web based learning materials which wrap-around two set books plus some other printed materials supported by electronic tuition and conferencing plus at least one optional face to face meeting. Neither is the T172 course entirely print-based. It offers optional computer-based exercises and electronic conferencing as well as a programme of face to face tutorials. However, the emphasis in T171 is on electronic provision while that of T172 is on print.

The education and environmental implications of teaching via fully electronic systems warrant further investigation.

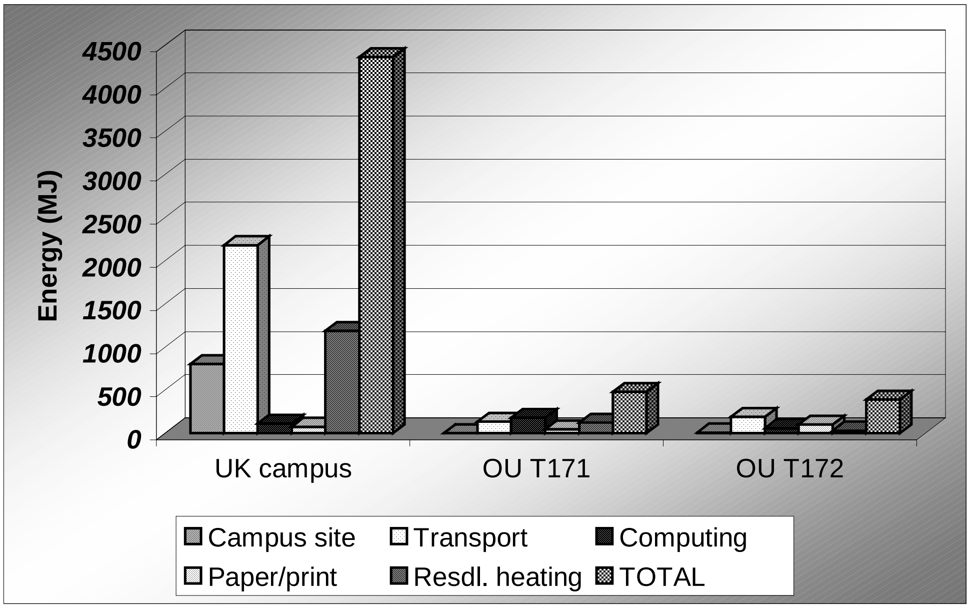

Figure 9 Energy consumption of campus and Open University courses (averages per student per 10 CAT points)

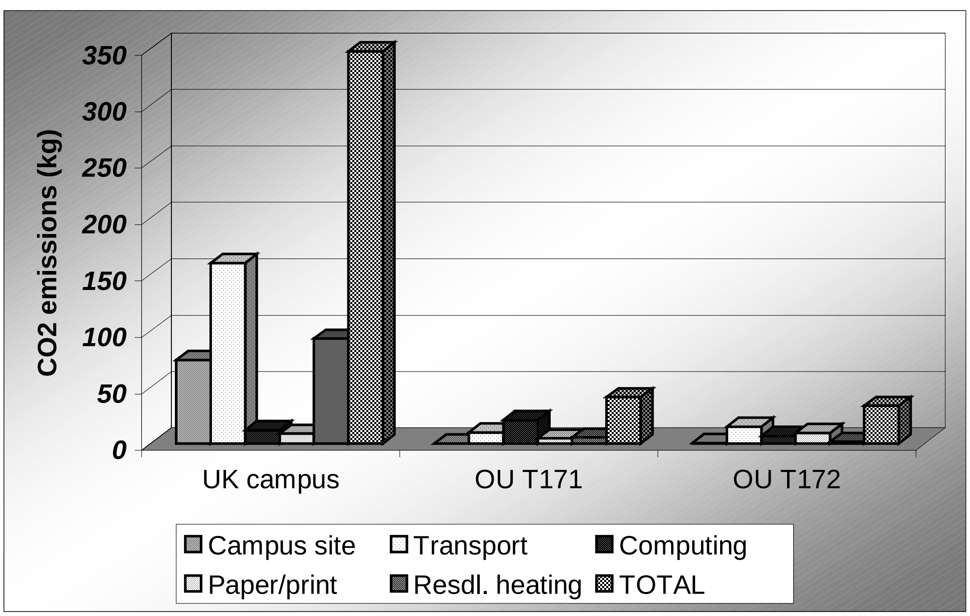

Figure 10 Emissions of campus and Open University courses (averages per student per 10 CAT points)

4.3 Differences between campus courses

The comparison in section 4.1 above is between the *average* figures for energy and emissions per student per 10 CAT points for the sample of eight UK campus based courses and those for the two OU courses. These averages conceal the fact that the campus courses involve a very wide range of energy consumption and emissions figures. It is not the main concern of this project to study these differences in detail, but they do raise some interesting issues such as the following.

4.3.1 Term time student travel

The key factor of term time student travel, and associated energy/emissions, ranged from about 60 km (78 MJ, 5 kg CO_2) at one campus to over 520 km (1120 MJ, 78 kg CO_2) per student per 10 CAT points at another. The higher figure is well over eight times that of the lower. The course that involves little term time travel is located at an out-of town, largely self-contained campus, 55% of whose students live in university residences. A third of this course's trips are by foot or bicycle, while the remaining journeys are relatively short trips by bus or car. The course that involves the greatest amount of term-time travel is at a multi-site campus within a metropolitan region, 60% of whose students live at home. Most trips involve relatively long distances to and from the various campus and other study sites, almost entirely by car. The location and layout of university campuses, and access to public transport and university residences, has implications for the amount of term time travel required by students and consequent environmental impacts.

Student commuting is an important environmental impact of higher education that has attracted little attention. *Some universities have developed 'travel plans' to manage student and staff travel. But rather than suggesting a modification of established travel patterns, our study indicates that the main impacts are determined by the key components of a campus system.*

4.3.2 Home/university travel

The home-university distances travelled by students at the eight UK campuses range by even greater amounts, from 65 km (167MJ, 12 kg CO_2) to 2280 km (5300MJ, 370 kg CO_2) per student per 10 CAT points. The course with the least home/university travel serves mainly students from the local (Scottish) area, while the one with the most travel has a high proportion of overseas students many of whom regularly fly very considerable distances between home and the university. ***Home/university travel can involve even greater environmental impacts than student commuting****, especially for courses serving UK students from the whole country and (in particular) a high proportion of overseas students*.

4.3.3 Residential energy

Energy consumption of university residences at the five institutions for which we had data varied, perhaps surprisingly, by only some 20% above and below the mean of 1220 MJ per student per 10 CAT points. For students living in flats, houses and lodgings we had to use an average of 1410 MJ per student per 10 CAT points derived from official housing statistics rather than empirical survey data. Even if these two figures are only approximate, the key issue was whether students lived at, or away from, 'home' during term. This determined whether all term time residential energy consumption or just additional heating of the students' usual home for course related purposes might be considered to be relevant. Again there was a wide range, from 3% to 60% of students living at home during term, dependent on the availability of university student residences. There are indications of a possible trade-off between reduced residential energy consumption if students live at home during term and increased commuting distances. However, in most cases the greatly reduced residential energy consumption from living at home is more important than the possible impacts of increased commuting. ***In terms of the environment (although, of course, not necessarily in social or educational terms) it may be desirable for students on campus based courses to live at home and attend a local university***.

4.3.4 Campus site energy

Although the data are confidential, the non-residential energy consumption of the campus sites varied considerably. The most efficient campus consumed less then a third of the energy per full-time equivalent student of the least efficient. There is clearly much that could be done to improve the energy efficiency of UK campus buildings, lighting, equipment, etc. One of the campuses in our survey plans to source all its electricity from renewable supplies from autumn 2002. As on average electricity accounts for over half of the fuel purchased by our sample campuses, shifting to 'green electricity' is one relatively easy way to significantly reduce CO_2 emissions. Other measures that might be taken include increased use of low energy lighting, purchase of energy efficient computing and other equipment, and improved insulation and glazing of buildings.

But although the campus site is an area worthy of attention, it only accounted for 18% of the total energy and 21% of the total emissions per student per 10 CAT points for an average campus course. ***The great emphasis placed on reducing campus site impacts in existing schemes for' greening' higher education could therefore be balanced by focusing also on other environmental issues identified in this study, notably student travel and housing.***

4.3.5 Computing and paper

There were also considerable differences in the hours of home computing, the consumption of paper and the purchase of books and periodicals by the students of the different campus courses. The differences appear to be related to the type of campus (e.g. whether self-contained or multi-site), the proportion of students who live in university residences, and the requirements of the course. However, as these sources together account for an average 5% of the total campus course impacts, attempting to reduce them (e.g. by better library provision) may not be worthy of much attention, at least from an environmental standpoint.

4.4 Assumptions and simplifications

This environmental audit is largely based on new empirical information. But, as is inevitable when attempting to audit a system as complex as HE, it was necessary to make a number of assumptions, estimates and simplifications. These are detailed in Appendix 1, but the main ones are as follows:

1) All the normalised calculations (per student per 10 CAT points) are, of course, sensitive to the CAT points of the courses sampled. In most cases the CAT points were known, but in four cases they had to be estimated from the number of teaching hours or the contribution of the course or module to a particular degree qualification.

2) In the absence of any available information, an assumption about the proportion of campus site energy required for teaching functions was based on the average division of UK higher education funding council finance between teaching and research in 2001 (at about 68% for teaching). Other means for estimation, based on teaching/research/administrative staffing or building space, might

have been used, but the data was not readily available or necessarily more accurate.
For the OU courses all campus site energy was allocated to teaching functions, but no allowance was made for the energy consumption of the regional offices. Given that the consumption per student per 10 CAT points of the central campus for the OU courses was very small, this simplification would not make much difference.

3) We obtained information on the energy consumption of student residences for five of the campus universities in our survey, and the course-related additional household heating for students (including OU students) who lived at their main ‘home’ when studying. However, because of the complexity of the information required, no data were gathered on the residential energy consumption of campus students who lived in houses, flats, lodgings, etc. during term. Instead an estimate was made based on the energy consumption and emissions of an average dwelling from the latest *English House Condition Survey*, plus an assumption about the average numbers likely to be occupying the dwelling. It may be that this produces an underestimate since students may be living in older, less efficient housing than average, but this effect might be balanced if the occupancy is actually higher than our assumed 3 persons per dwelling.

4) The decision to attribute all, rather than just additional, term-time residential energy of students who lived away from home during term was a difficult one that has a significant effect on the results. The effect of the decision could be tested by recalculating the residential energy impacts using information we gathered from all students concerning any additional course-related residential energy they used.

5) To calculate the course-related environmental impacts of the campus lecturers and the OU course teams only one individual was surveyed in each case. It was assumed that this person was representative of all those involved in preparing and presenting each course and scaled up according to their particular contribution. It was felt that this assumption was justified given that staff impacts, especially for the OU courses with their very low staff:student ratios, are relatively minor compared to student impacts. (However, many of the OU tutors were surveyed in order to calculate the environmental impacts involved in supporting the two distance/open learning courses.)

6) The additional energy involved in operating a computer ‘on-line’ compared to stand-alone mode is only an approximation based on another study of the energy involved in sending a message within a local region via email and other methods. It may be that the energy involved when a computer is connected via a complex network to a remote Internet site may be greater than our estimate. We also estimated that students of the electronically delivered OU course would spend two-thirds of their computer time on-line, while for the other courses only 10% of computing time would be on-line. The above estimates will be checked in the course of further studies in this field, although they are only really significant in comparisons of electronically taught and print-based distance learning.

4.5 Changes in attitudes and behaviour

The energy and emissions directly associated with studying a HE course only account for a proportion of a student’s impacts on the environment. The whole point of an education system is, after all, to *educate*. This education could result in changes in a person’s attitudes and behaviour that reduces, or increases, their environmental impacts. ***Such changes in behaviour towards the environment as a result of taking a course may be as, or more, important than the impacts arising from its production and delivery***. *It is important 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 provision, that is the focus of this report*.

Quite a large proportion of our survey involved courses with an environmental content and, in particular, we noted some significant changes in behaviour of students who took the OU courses. For example, many students of the environmentally focused T172 *Working with our Environment* course claimed they had reduced car use, improved home energy efficiency, begun recycling or to shop for locally produced food, mainly as a result of studying the course. For many students of the T171 *You, Your computer and the Net* course it acted as a catalyst, giving them basic Internet literacy. As such, some felt that the course had reduced the amount they travelled – 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.

A few examples of changes in behaviour claimed by the students are given in the box. They do provide support for the emphasis placed on 'greening the curriculum' in existing programmes on higher education and the environment.

Effects of HE courses on behaviour towards the environment

Below are some typical questionnaire responses regarding changes in personal or household consumption and travel behaviour claimed by Open University and campus students as a result of taking the courses:

T171 You, Your computer and the Net

- *'The course, as shown me how to get information without leaving my computer - less travelling!'*
- *'I now work from home more avoiding a 160 mile round trip to office.'*
- *'Staying up late to study and practise Web design.'*
- *'I travelled more to meet up with members of another tutor group I met online.'*

T172 Working with our Environment

- '*We now compost all organic waste and recycle paper, glass and cans.'*
- *'We changed from two cars to one, and lower engine size. I now cycle to work giving a reduction of overall fuel used of 70%*.'
- '*We shop for food now with an awareness of 'food miles' and what's in season*.'
- '*We moved house to reduce travel to and from work*.'

Campus courses

- *'I* d*ress up warm to reduce heating. Recycle everything, including clothes. I repair equipment where possible and buy vegetables from local shops.' (Course E.)*
- *'I volunteered for the Conservation Trust.' (Course B.)*
- *'Recycling is always considered when designing.' (Course D.)*
- *'I use the computer more and waste more paper.' (Course A.)*
- *'Increased energy used at night for work.' (Course E.)*

Changes in attitudes and behaviour as a result of studying the courses will be discussed in detail in a separate report that will present analysis of the qualitative data from this project.

5. Conclusions

This study has focused on a largely ignored issue of higher education, namely the environmental impacts of taking a course via different delivery systems. One reason of course why this issue has been ignored is that it is eclipsed by other pressing questions such as the costs, educational effectiveness, social accessibility and socio-economic benefits of higher education.

This study does not seek to argue that, because of lower environmental impacts, one mode of HE provision should be preferred over another. Rather we intend to provide environmental information to HE decision-makers, which can then be included along with the usual educational, social and economic considerations.

5.1 The environmental impacts of higher education

Another reason why environment has so far not been considered very important is that the environmental impacts of studying might be relatively minor when compared to the total annual impacts of an individual's living and consuming.

What then are the impacts of HE relative to other activities? In 2000 total UK carbon emissions from all sources were 9300 kg CO_2 per capita.[17] Based on our findings a typical full-time campus-based student would take courses worth 120 CAT points per year at an average 300 kg CO_2 per 10 CAT points while an OU student might take 60 CAT points per year at 30 kg CO_2 per 10 CAT points. *The full-time campus students' annual course-related emissions work out at nearly 40% of the total annual CO_2 emissions of an average member of the UK population. The part-time OU students' emissions due to study are only about 2% of average annual CO_2 emissions (or about 4% for the equivalent CAT points/year as a full-time student)*.[18] This is, of course, simply another reflection of the 'factor 10' difference in the environmental impacts of conventional versus distance study.

As was noted in section 2 of this report, the education sector education sector produces a relatively small proportion of the total environmental impacts of the UK economy. Nevertheless, ***when someone becomes a full-time conventional campus student, their higher education involves a substantial proportion of their total environmental impacts***. Although students tend to have less income than average and thus are able to consume less, the above estimate does not include impacts of the leisure, sporting and other activities that students engage in while at university.

In contrast, becoming a OU student involves very little additional impacts compared to those arising from their general living and consuming. The basic reason is that much part-time distance learning utilises existent activities and facilities rather than depending on a separate educational infrastructure.

5.2 The role of ICT in sustainable services

This study shows that through the use of distance/supported open learning courses it is possible to reduce the energy/emissions involved in providing higher education very significantly compared to conventional campus-based systems. However, the introduction of electronically taught and tutored courses does not seem to offer any environmental advantages over established mainly print-based distance/open learning courses. In fact, due to 'rebound' effects, partially electronic taught courses seemingly involve higher energy and emissions. This result runs counter to many claims that have been made about the 'de-materialisation' effects and resultant environmental benefits of information and communications technologies (ICT).

This research therefore questions the assertion that ICT necessarily produces environmental gains. Instead, our research has identified more significant factors in reducing environmental impacts that could apply across the whole service sector. This is the extent to which providing the service depends on energy-intensive travel and a dedicated infrastructure of buildings, facilities and equipment.

The reduction in energy and emissions in the distance/supported open learning system is not mainly due to the use of ICT as such, but to the elimination of much of the travel and campus/residential buildings infrastructure required for campus based systems. This is because the OU distance/open learning system is utilising infrastructure, such as students' homes, video-recorders, televisions, telephones, study centres, etc. obtained and used mainly for other purposes. Another key factor is the economies of scale in the utilisation of campus buildings and other infrastructure when developing courses to be offered to large numbers of students, whether mainly through print or electronic media.

More generally, this study challenges the concept of 'de-materialisation' and the way in which the environmental benefits of ICT have been analysed and presented. Service systems will only become sustainable if they offer similar or better functions than traditional products or services with reduced dependence on energy intensive transport, dedicated buildings and other infrastructure. This may be most effectively achieved by a service using or 'piggy backing' on existing infrastructure. Only if ICT helps to reduce transport needs and/or enables a service to share existing infrastructure, without incurring large 'rebound' effects, will it contribute towards sustainability.

5.3 Towards sustainable HE – Future work and policy issues

This Phase 1 *Factor 10 Visions* higher education project has raised a number of policy issues as well as questions for further investigation, including the following:

- Will the findings of this study be confirmed by examining a larger sample of courses, in particular by including part-time and 'mixed mode' (e.g. Internet teaching plus intensive face to face weekends) campus courses and additional OU courses, both print-based and partially/mainly electronic?
- What are the environmental as well as the educational implications of attempts to provide HE courses presented entirely on-line via electronic media? The pedagogical issues are being debated and researched, stimulated by initiatives such as the discussion document *On-line distance education: principles for good practice* (AUT, 2002). The environmental issues are related to the pedagogical ones through questions such as whether students can learn effectively via on-screen rather than printed material and whether on-line conferences and tuition can replace face to face meetings. The environmental issues have so far been ignored, including by government bodies addressing the long-term future of education such as the DfES/DTI Foresight Programme's 'Information, Communication and Media Panel'.[19]
- What might be the environmental impacts of the UK governments plan to expand the further and higher education system to allow a 50% participation rate of 18-30-year-olds by 2010?
  To explore this question an attempt could be made to model the environmental effects of expanding the education system via different mixes of conventional face to face, print-based distance/supported open learning, 'mixed mode' and e-learning courses.
- HE policy, both in the UK and internationally, has so far failed to consider environmental issues beyond campus site environmental management and 'greening the curriculum'. Is this because the environmental impacts of student travel and housing simply not recognised? Or are they too

controversial to address? For example, we have identified the air travel associated with overseas students studying in the UK is an important environmental impact. Yet this is a widespread practice promoted by UK government and HE institutions for a variety of economic and development reasons. Yet, would it be preferable on pedagogical and social as well as on environmental grounds to educate more overseas students via partnerships with educational institutions in the student's home country rather than bringing them to the UK to study? (The Open University has for some years been involved in such partnerships.)

More generally, what are the social and financial, as well as environmental implications of encouraging more UK students to live at 'home' while studying?

Finally, it is important to emphasise again that this study has only been concerned with the *environmental* impacts of different modes of higher education. UK HE policy must, of course, balance the social, economic and pedagogical issues against environmental gains. This study has identified key environmental impacts that can now be included by policy makers when making their decisions.

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Notes

[1] 9650 MJ/yr. x 10 CAT pts./120 CAT pts/yr.

[2] 885 kg/yr. x 10 CAT pts./120 CAT pts/yr.

[3] Potter, S. and Roy, R. (2001) Scoping study of T172 production environmental impacts, *Unpublished working paper*, Design Innovation Group, The Open University, September.

[4] If heating and lighting a study centre for a tutorial for a 20 student group requires an additional 5 kWh x 4 tutorials = 5 x 4/20 = 1 kWh per student. 1 kWh x 10 CAT /30 CAT = 0.3 kWh x 3.6 = 1.2 MJ/student/10 CAT. If this consumption is electricity = 0.3 x 0.44 kg CO_2 = 0.1 kg CO_2/student/10 CAT.

[5] Details in Potter, S. (2001) Transport CO_2 calculations *Unpublished working paper*, Design Innovation Group, The Open University, July; Roy, R. (2001) Energy and emissions conversion factors, *Unpublished working paper*, Design Innovation Group, The Open University, December and Appendix 1 section 6.

[6] Potter, S. and Roy, R. (2001) op cit. Note 3.

[7] Remmerswaal, H. *Personal communication*, March 2002.

[8] Leszczynski, J. *Personal communication*, Open University, 2001.

[9] Roy, R. (2001) Energy and emissions conversion factors *Unpublished working paper*, Design Innovation Group, The Open University, December and Appendix 1, section 7.3.

[10] Potter, S. and Roy, R. (2001) op cit. Note 3 and Appendix 1 section 5.3.

[11] The OU mailing to T171 tutors includes the set books.

[12] Summary of T171 Student Module Evaluations for 2000 presentations, The Open University, 2001.

[13] Potter, S. and Roy, R. (2001) op cit and Appendix 1 section 5.3.

[14] Average number hours additional heating = approx. 5 hours/student/10 CAT for all courses. Assume 10 hours 40W additional lighting = 0.4 kWh = 1.4 MJ and 0.2 kg CO_2.

[15] Potter, S. and Roy, R. (2001) op cit. Note 3 and Appendix 1 section 5.3.

[16] Potter, S. and Roy, R. (2001) op cit. Note 3 and Appendix 1 section 5.3.

[17] In 2000 total UK final energy consumption was 6720 million GJ and carbon emissions from all sources were 152 million tonnes (DTI, 2001). 152 m tonnes carbon/59.76 m population x 44/12 x 1000 = 9326 kg CO_2.

[18] Full-time campus student = (300 kg x 120/10 CAT)/9326 kg = 38.6%. OU student (studying at half rate of full-timer) = (30 kg x 60/10 CAT)/9326 = 1.9%

[19] Universities in the Future, April 2002, (http://www.foresight.gov.uk, accessed, April 2002.)