Factor 10 Visions project:
Higher Education Sector

Towards Sustainable Higher Education:
Environmental impacts of campus-based and distance higher education systems

Robin Roy, Stephen Potter, Karen Yarrow and Mark Smith

Final Report

DIG-08

March 2005

Acknowledgements

We wish to especially thank Horace Herring, of the Open University Energy and Environment Research Unit, who participated in many of the discussions on this project and made invaluable comments on draft materials.

We should also like to thank all the individuals and organisations that helped us undertake this large and complex project, including the following:

Campus universities

All the lecturers and students from the eleven universities who participated.

The Open University

The many individuals and departments at the OU who helped with information, advice and practical assistance:

- Gill Kirkup, Katrina Tomkins, Nick Haycox and Jenny Curtis of the Institute of Educational Technology.
- Sam Sandhu, Jane Moore and Pamela Wardell of Learning and Teaching Solutions.
- Simon Levine and John Hodgson of the Estates Department.
- Martin Weller, Karen Dolan, Michelle Gander and Ernie Taylor of the T171 course team and all the T171 students and Associate Lecturers who participated.
- Sally Crompton and Judith Anderson of the T172 course team and all the T172 students and Associate Lecturers who participated.
- Julia White, Glenna White and Karen Ross of the M879, B730/BZX730 and T833 course teams and all the students of those courses who participated.
- Sally Boyle, Department of Design and Innovation.
- Margaret Barnes, secretary, Design Innovation Group.

Funding

The project was financed in part under the OU Research Committee’s Strategic Research Initiative; in part by Professor Geoff Peters, Pro-Vice Chancellor (Strategy, Planning and Partnerships); and in part by the Faculty of Technology and the Design Innovation Group.

The Research Team

- Robin Roy, Professor of Design and Environment, Department of Design and Innovation, The Open University. Email: r.roy@open.ac.uk
- Stephen Potter, Senior Research Fellow, Department of Design and Innovation, The Open University (Professor of Transport Strategy from January 2005). Email: s.potter@open.ac.uk
- Karen Yarrow, Research Consultant, Stratford-upon-Avon. Email: kmyarrow@aol.com
- Mark T. Smith, Research Fellow, Department of Design and Innovation, The Open University, (until May 2001).

Design Innovation Group,
Department of Design and Innovation,
Faculty of Technology,
The Open University,
Milton Keynes MK7 6AA
(United Kingdom)
Tel: +44 (0)1908 653970 (direct line)
Fax: +44 (0)1908 654052

Contents

Executive Summary

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

- ***Conventional campus-based full-time courses;***
- ***Conventional campus-based part-time courses;***
- ***Print-based distance taught courses;***
- ***Part electronically-delivered distance taught courses.***

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 learning courses consumed nearly 90% less energy and produced 85% 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.*)

- Part-time campus-based courses also cut energy and CO_2 emissions, though by a lesser extent (energy by 63% and CO_2 emissions by 62%).

- The much lower impacts of distance 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. These are also key factors for the reduction in the environmental impacts of part-time course delivery.
(*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 appear to offer only a small reduction in energy consumption and CO_2 emissions (20% and 12% respectively) when compared to mainly print-based distance learning courses. This is 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).

- 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.

- 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, virtually all existing work (e.g. the UK Toyne Report, the global *Talloires Declaration* and recent UK Department of Education and HE Funding Council sustainability strategies for education) has focused mainly 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 four 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 for five of the undergraduate courses had an environmental focus or element.

The survey was of 20 HE courses, which involved:

- 10 full-time campus courses (of which 6 were undergraduate and 4 were masters);
- 3 campus part-time courses (of which 2 were undergraduate and 1 was a masters);
- 3 distance taught, mainly print based courses (all of which were OU courses, and 2 were, postgraduate but the majority surveyed were on the undergraduate course);
- 4 distance taught courses with some degree of electronic delivery (3 OU and 1 non-OU, of which 3 were postgraduate, but again the majority surveyed were on the undergraduate 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. Such effects are therefore discussed in a separate report (Yarrow, Potter and Roy, 2002) and summarised in Appendix 3.

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.

Conventional campus compared to part-time and distance learning courses

Part-time campus courses cut energy and CO_2 emissions by nearly two-thirds compared to full-time campus-based study. However, perhaps the most startling result is that the distance learning courses examined on average involved nearly 90% (87%) less energy consumption and produced 85% fewer CO_2 emissions *per student per 10 CAT points* than the conventional campus based university courses. 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 a distance-taught 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 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 distance and part-time 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. But for full-time campus based students who live away from ‘home’ during term, it seems appropriate to count *all* the energy consumed per student in those term-time dwellings, since for those students an inherent part of studying at a campus university is occupying an separate residence during term-time. The proportion of residential energy to allocate to different modes of study is not a straightforward issue, but whatever approach is used does not alter the basic findings.

As can be seen from the summary charts below, the above three factors account for most of the almost 90% reduction in energy and 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 distance 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 how little difference there exists between the mainly electronically taught and tutored courses and the print-based distance courses. On average there was a 20% reduction in energy and 12% cut in CO_2 emissions. One reason is the high use of computers, including on-line use, and hence significant energy consumption. The other reason is the following so-called ‘rebound’ effects:

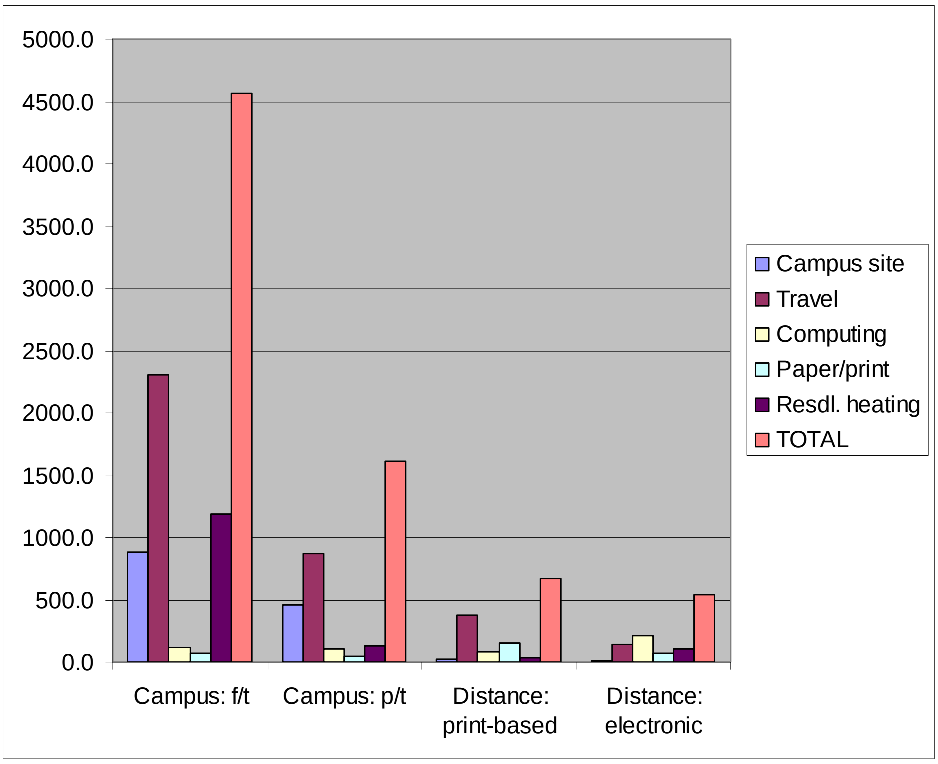
1) The preference of many students (at least initially) to download and print a high proportion of Web based learning materials, mainly for reasons of portability and ease of study with hard copy.

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

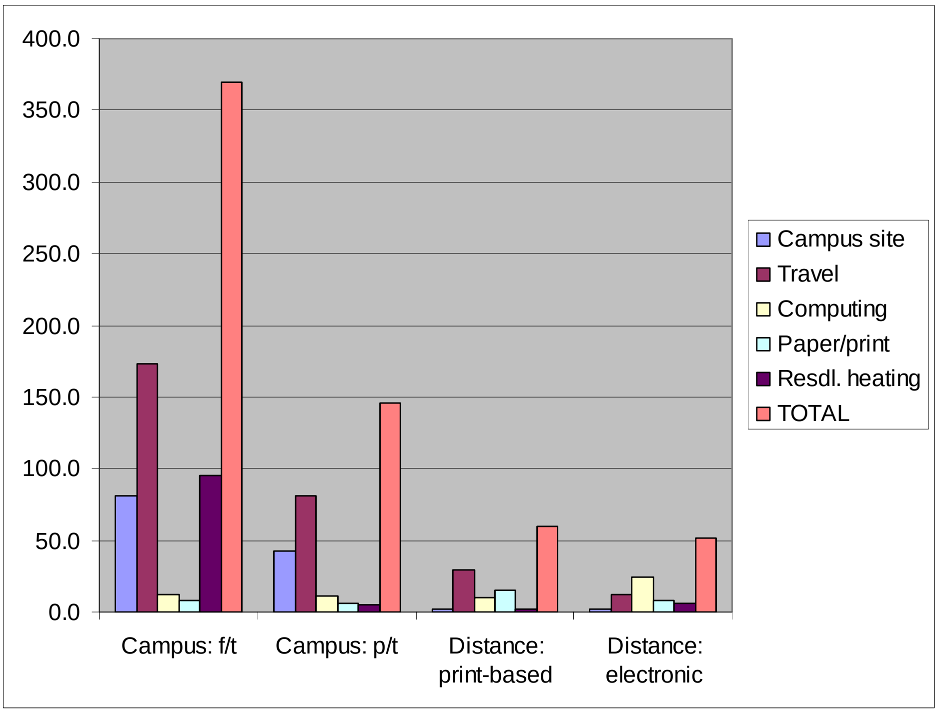
3) Some students appear to heat their homes longer than normal for study purposes, probably mainly while accessing the Internet late in the evening or at night.

These factors partly counterbalance the savings from the reduced need for printed matter and staff/student travel compared to print-based distance taught courses.

Summary chart 1: Energy consumption of campus and distance courses (average MJ per student per 10 CAT points)



Summary chart 2: CO_2 emissions of campus and distance courses (average kg per student per 10 CAT points)



Are Open University courses unique?

It may be thought that the reductions in environmental impacts from distance taught courses we found might be confined to the Open University open learning system. In order to provide at least a preliminary answer to this question, we included in our study one non OU HE institution that provides some part-time courses both face to face at its campus and via Internet based electronic delivery.

Analysis of the data showed that the electronically delivered course from this institution reduced energy by 91% and CO_2 emissions by 89% (per student per 10 CAT points) compared to a face to face course from the same department. When we compared the electronically delivered course from this institution with the mainly electronically taught OU courses, we found that the non-OU course involved just 17% more energy and 24% more CO_2 emissions (per student per 10 CAT points) than the OU courses and with much smaller student numbers.

In other words, the reductions in energy and emissions from distance learning systems do not seem to be confined to the Open University system. Of course, since this result is based on comparing just one non-OU institution which provides distance learning with the OU, it would need confirmation.

Differences between campus-based 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.

Changes in attitudes and behaviour towards the environment

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. 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 summarised in Appendix 3. 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 offer relatively little reduction in environmental impacts compared to established print-based distance learning courses. This result runs counter to many claims that have been made about the major ‘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 widely 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.

Similar issues apply to the planned expansion of HE provision in other countries, notably China, although the actual environmental impacts and contribution to sustainable development of different modes will depend on local conditions and would need to be the subject of further research.

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% and 95% 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). The UK has set itself a target of 60% reduction in CO_2 emissions by 2050 and an interim target of 20% reduction by 2010 to tackle climate change. However, at least 90% ('factor 10') reductions are expected eventually 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 60% to 90% improvement, including the eco-design 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 60% 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?[1] Firstly, HE is growing fast, especially in the UK where the Government has set an expansion target 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 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

[1] The housing and personal transport sectors together account for about half the delivered energy consumption and CO_2 emissions in the UK.

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 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) as well as the recent DfES green action plan for education (Department for Education and Skills, 2003). 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), its successor HE ‘Partnership for Sustainability’ scheme, started in 2000 and involving eighteen UK universities and colleges (Parkin, 2001) and the Higher Education Funding Council for England’s draft sustainability strategy and plan for HE (HEFCE, 2005). 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. This study considered four HE delivery systems:

- ***Conventional campus-based full-time courses;***
- ***Conventional campus-based part-time courses;***
- ***Mainly print-based distance taught courses;***
- ***Part electronically-delivered distance taught courses.***

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 discussed in a separate report (Yarrow, Potter and Roy, 2002) and summarised in Appendix 3.

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.

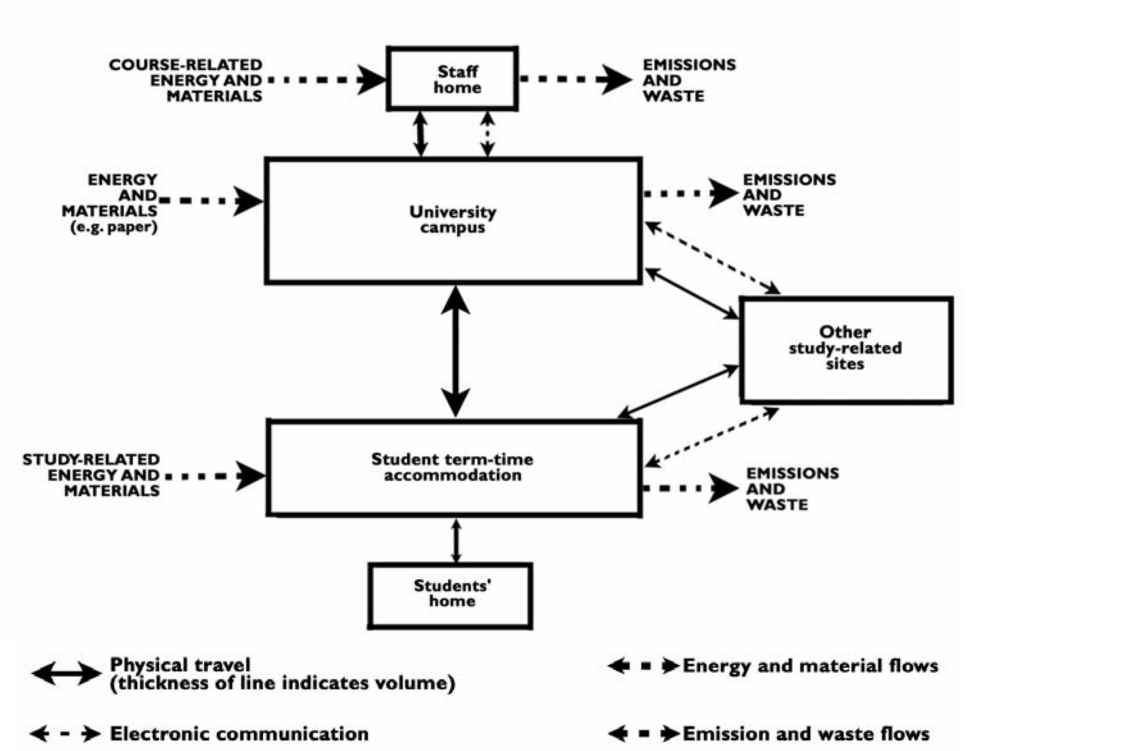


Figure 1 Conventional system – full-time campus-based course

Student Residential Block

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 commuting 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.

Part-time campus courses involve a similar system to full-time, but with less demand for travel and student accommodation. Most part-time students will attend lectures and tutorials on campus, but will usually remain living at their main ‘home’.

Distance teaching is very different. Specially developed course material is delivered directly to students for part-time study at home. Tutorial support systems vary with institutions. For the Open University, there are optional face to face tutorials at local study centres offered by part-time tutors (called Associate Lecturers), who also provide support to their student group via mail, telephone and/or email and computer conferencing. Most of the distance taught courses in this study were provided by the Open University. *Because of the emphasis placed by the OU on student support 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.*

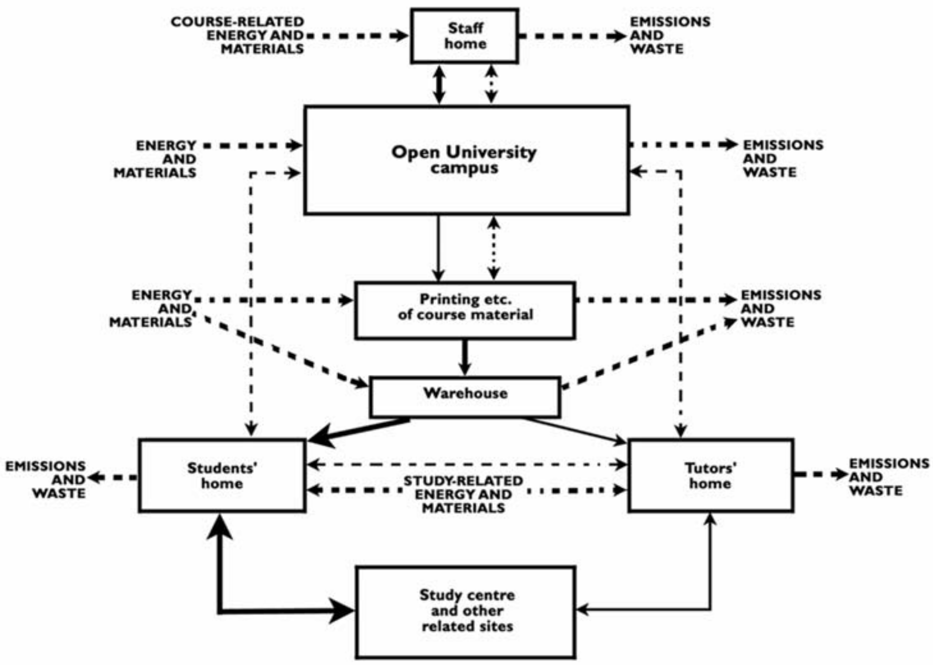


Figure 2 Distance taught print-based distance/supported open learning course
(based upon the Open University system)

Electronically delivered distance teaching is where, rather than print-based materials being sent to students and face-to-face tutorials held, study material is electronically delivered (e.g. via the Internet or on CD ROM) and tutorials may also be undertaken electronically. Practices vary greatly as to the degree of electronic delivery and teaching that is undertaken. For example, 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. Likewise, in T171 a computer-mediated assessment and tuition system has largely replaced mailing of written assignments, attendance at an examination centre, and the optional face to face tutorials in print-based OU courses. However, the electronic course is based around study of two conventionally printed set books mailed to 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 the main print-based OU course surveyed, T172 *Working with our environment,* entirely print-based. For the majority of students who have access to a computer, it offers optional computer based exercises and electronic conferencing. One of the OU courses included in our survey, BZX730 *Managing performance and change*, has mainly print-based teaching material but provides electronic tuition and assignment submission.

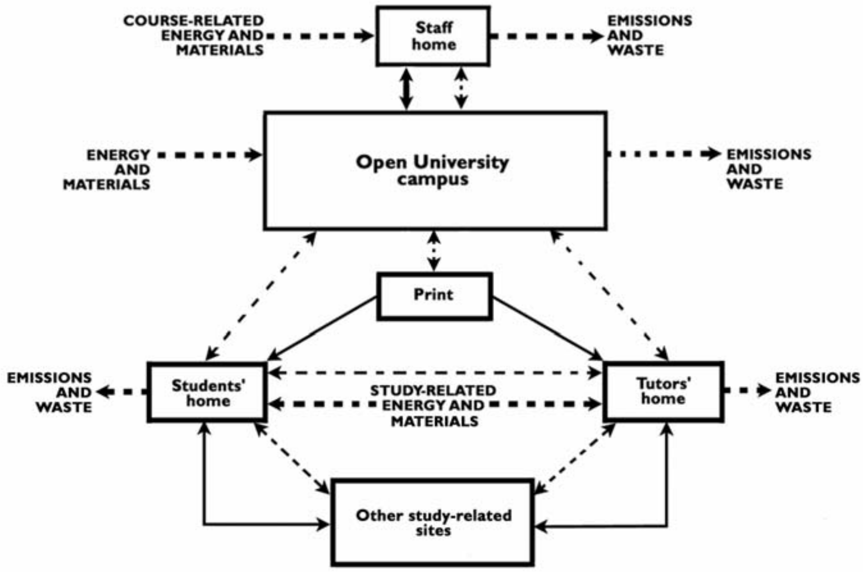


Figure 3 Part electronically taught distance/supported open learning course
(based upon the Open University System)

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.

There are important differences too in the way courses are prepared and presented in the conventional campus and distance teaching systems. In the campus-based system (both full and part-time), 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 distance teaching systems (as practised by the OU), 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. However, for some environmental issues (e.g. land take, biodiversity and noise) other measures would be needed that would require further investigation.

2.2 Survey method

The survey was of twenty HE courses (carried out in two phases in 2000/1 and 2002/3), which involved:

- 10 full-time campus courses (of which 6 were undergraduate and 4 were at masters level);
- 3 campus part-time courses (of which 2 were undergraduate and 1 was a masters. 2 were part-time versions of the full-time campus courses);
- 3 distance taught, mainly print based courses (all of which were OU courses, and 2 were postgraduate, but the majority surveyed were on the undergraduate course, T172);
- 4 distance taught courses with some degree of electronic delivery (3 OU and 1 non-OU, of which 3 were postgraduate, but again the majority surveyed were on the undergraduate course, T171);

The sample produced an appropriate balance of undergraduate and postgraduate courses. The campus courses were chosen to reflect a mixture of university locations, from city centre to suburban and ‘out of town’. Thirteen of the twenty courses had an environmental focus or element.

Table 1 provides basic information about the size of full and part-time campus courses and the number of students and tutors that responded. Table 2 contains the same information for the sample of print based and mainly/part-electronic distance taught courses. For confidentiality the non-OU courses and institutions have been anonymised and allocated an identification letter from A to N.

Table 1: Details of the sample of conventional campus courses surveyed

University	Location	Course/module			No. valid Qs. Returned	
Campus: Full-time		**Title**	**Duration (weeks)**	**CAT points (1)**	**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	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	Urban	M.Sc. Sustainability, Planning and Environmental Policy	30	180	12	0
J	Rural	M.Sc. Design and Sustainability	30	180	3	0
Campus: Part-time						
K	Urban	B.Arch. Environment and Services	12	15	9	0
L	Urban	M.Sc. Transport Engineering	30	180	3	0
M	Urban	BSc. Global Environmental Issues	10	36	9	0

Footnotes: see Table 2.

Table 2: Details of the sample of the distance/open learning courses surveyed

University	Location	Course/module			No. valid Qs. Returned	
Distance: mainly print-based		**Title**	**Duration (weeks)**	**CAT points (1)**	**Students**	**Lecturers/Tutors**
Open (2)	N/A	T172 Working with Our Environment	36	30	205	65 (5) +1 (6)
Open (2)	N/A	T833 Implementation of New Technologies	24	30	20	0
Open (2)	N/A	B730 Managing Performance and Change	36	45	59	0
Distance: mainly/partially electronic delivered						
Open (2)	N/A	T171 You, Your Computer and the Net	36	30	503+343 (4)	55 (5)
Open (2)	N/A	M879 Distributed Applications and E-Commerce	24	15	46	0
Open (2)	N/A	BXZ730 Managing Performance and Change (electronic tuition)	36	45	9	0
N	Urban	M.Sc. Geographical Information Science	30	180	11	0

Notes:
1. The UK Credit Accumulation and Transfer (CAT) system in which 360 points are required for an undergraduate degree and 180 points for most Masters.
2. Part-time, some courses 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 used in our environmental audit of the courses came from student and staff surveys conducted in two phases during 2001 and 2002. Structured questionnaires were developed for students, academic staff and, for the OU, the part-time tutors of the two of courses concerned. These questionnaires were administered in different ways as appropriate to the course. To the full and part-time campus students, the questionnaires were administered 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 of the other OU courses by post. Questionnaires to the tutors of the OU print-based T172 course and the students of the non-OU electronically taught course were mostly distributed and returned by email.

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 courses, 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 and 2, the student sample for the undergraduate 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. The OU postgraduate courses involved smaller samples, comparable to the campus-based courses. 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 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 Course-related travel

All students were asked to detail the travel involved in pursuing 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.[2] 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.

3.1.1 Full-time 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

[2] 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.

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 3 shows the distances, energy and CO_2 emissions for each of the campus full-time courses surveyed for these two broad categories of travel. Table 4 provides the combined totals.

Table 3: Full-time campus students' term time and home–campus course related travel (average per student per 10 CAT points)

		All course-related term-time travel			All travel between home & term-time residences		
Course	**Location**	**Distance (km)**	**Energy (MJ)**	**CO_2 emissns (kg)**	**Distance (km)**	**Energy (MJ)**	**CO_2 emissns (kg)**
A	Urban	219.8	253.7	32.4	2278.2	5302.6	368.5
B	Urban	273.7	398.9	28	1996.4	4609.6	314.9
C	Urban	521.0	1121.3	78.2	821.1	980.4	91
D	Urban	300.6	152.1	10.7	209.8	180.8	17.2
E	Urban	280.9	356.7	30.3	179.2	190.5	17.4
F	Urban	340.2	418.7	35.2	1343.2	1879.4	134
G	Rural	57.6	77.8	5.4	610.4	966.8	72.5
H	Urban	80.2	84.7	6.0	65.4	167.4	12.4
I	Urban	354.2	686.3	54.4	758.5	1361	99.8
J	Rural	1527.9	2638.6	215.4	772.8	811.2	79.2
Average		***395.6***	***618.9***	***49.6***	***903.5***	***1645.0***	***120.7***

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 (F) travelled almost all by rail or bus, while the latter (G) 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, course F's students travelled much less between their main home and university than those of courses A and B. 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. It may be lucrative and educationally beneficial for universities to bring overseas students to the UK, but they are a group with inherently high environmental impacts.

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).

Table 4: Total campus full-time students' course related travel (average per student per 10 CAT points)

	Total course-related travel		
Course	Distance (km)	Energy (MJ)	CO_2 emissns (kg)
A	2497.9	5556.3	400.9
B	2270.1	5008.5	342.9
C	1342.1	2101.7	169.2
D	510.4	332.9	27.9
E	460.1	547.2	47.7
F	1683.4	2298.1	169.2
G	668.0	1044.6	77.9
H	145.5	252.1	18.4
I	1112.7	2047.3	154.2
J	2300.7	3449.8	294.6
Average	***1299.1***	***2263.9***	***170.3***

3.1.2 Part-time campus student travel

The sample of part-time students was relatively small, but the results were consistent with what might be expected from our analysis of the course delivery systems involved. No home –term-time residence travel was recorded, although for some part-time courses this could be involved. Course related travel averaged 560 kilometres per student per 10 CAT points (Table 5), compared to 396 kilometres for the full-time students. This higher amount of travel in studying part-time courses might be expected, with possibly longer trips to the campus than for full-time students living in their term-time residences.

However, there is the elimination of all travel between home and the term-time residence. This means that overall, part-time students travel an average of 560 kilometres per student per 10 CAT points compared to the average of 1,299 kilometres by full-time students. The impact of overseas' students travel plays a major part in the reduction in travel between full and part time course systems.

Table 5: Total campus p/t: students' course related travel (average per student per 10 CAT points)

Campus p/t: Students	Total course-related travel (1)		
Course	Distance (km)	Energy (MJ)	CO_2 emissns (kg)
K	267.3	368.9	44.8
L	144.9	507.6	35.4
M	1272.4	1627	153.8
Average	***561.5***	***834.5***	***78.0***

(1) P/T campus students are assumed to live at their main home

3.1.3 Distance-taught student travel

For the distance-taught courses, with the students studying from home, the total amount of travel was inherently much lower than at the conventional universities. The reasons for the reduction were also different (distance-taught courses can be taken with equal ease by overseas and domestic-based students). The results for the three OU print-based courses are shown in Table 6.

Table 6: Total distance print-based students' course related travel (average per student per 10 CAT points)

Distance print-based : Students	Total course-related travel		
Course	Distance (km)	Energy (MJ)	CO_2 emissns (kg)
T172	82.9	152.3	11.8
T833	27.9	78.6	5.7
B730	202.7	574.2	41.2
Average	***104.5***	***268.4***	***19.6***

The average distance travelled is just over 100 kilometres per student per 10 CAT points, which is about a tenth of the amount of travel involved for full-time campus students and less than a fifth of the travel of part-time students. However the amount of travel varies considerably for the three courses surveyed. The relatively high travel for course B730 may be due to it having a residential school. There may also be variations simply due to the proportion of students attending tutorials.

For the electronically-delivered courses the results for individual courses are more closely clustered around the average of 50 kilometres per student per 10 CAT points (Table 7). Thus electronic delivery of distance taught courses halves travel and associated environmental impacts compared to print-based distance teaching. The non-OU electronic distance taught course (N) actually recorded less travel, energy use and emissions than the OU courses, but not exceptionally so. This suggests that the environmental improvement achievable by distance teaching (and electronic delivery in particular) is achievable in smaller HE institutions than the Open University. It is not just the OU's scale of operations that produces the cut in environmental impacts.

Table 7: Total distance electronic taught students' course related travel (average per student per 10 CAT points)

Distance electronic: Students	Total course-related travel		
Course	Distance (km)	Energy (MJ)	CO_2emissns (kg)
T171	52.5	117.6	8.7
M879	71.8	159.8	12.6
BZX730	38.3	84.4	6.5
N	38.8	57.6	5.5
Average	***50.4***	***104.9***	***8.3***

Further analysis indicates some important detail. The two OU courses T171 and T172 represent a useful 'matched pair' in that they are both introductory Level 1 Technology courses. For the electronically taught T171, there was an average of 52 kilometres travelled per student per 10 CAT points compared to 83 km travel/student/10 CAT for the print-based T172. For T171, over half of 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.

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. Clearly the issue of how best to provide supported distance/open learning is more than a matter of reducing the need for students to travel. It requires addressing the learning and other needs that generate travel.

Overall there was a cut by over half in the distance travelled and 60% in the energy consumed and CO_2 emissions generated by the electronically taught compared to the print-based distance learning courses.

3.1.4 Campus courses 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 8), which is why this project concentrated upon the latter. On average, lecturer trips represent under 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%). It was assumed that campus staff travel for part-time courses is same as for full time courses.

Table 8: Total campus lecturers’ course related travel (average for all course teaching staff per student per 10 CAT points)

Campus: Lecturers		**Total course-related travel**		
Course	**Location**	**Distance (km)**	**Energy (MJ)**	**CO_2 emissns (kg)**
A	Urban	5.8	7.4	1
B	Urban	2.9	3.7	0.3
C	Urban	n/a	n/a	n/a
D	Urban	72.1	252.8	17.6
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
I	Urban	n/a	n/a	n/a
J	Rural	n/a	n/a	n/a
Average		***13.2***	***40.6***	***3.0***

1. Assumes staff member surveyed is representative of all teaching staff for the course.

3.1.5 Distance taught courses' staff travel

For the OU courses (which constitute the majority of the distance taught course sample), staff travel is divided between the central and regional 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.[3] 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 that were expected to take the T172 course over 6 years before it was substantially revised[4]. Were the impact to be larger, further work would have been justified, but as this scoping study indicated course team staff travel was so small, the research concentrated on other areas.

For the OU's 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 (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). The smaller courses (T833 and B730) did have higher staff travel, which may be a scale effect.

The overall results for the print-based distance courses are shown in Table 9.

Table 9: Total distance print-based course-related staff travel (average per student per 10 CAT points)

Distance print-based: course team & tutors	Total course-related travel		
Course	**Distance (km)**	**Energy (MJ)**	**CO_2 emissns (kg)**
T172	15.3	36.7	2.8
T833	28.3	191.2	18.8
B730	15.6	92.5	8.6
Average	***19.7***	***106.8***	***10.1***

1. Based on scoping study of one T172 central academic+ data on T172 tutors, adjusted for course team size and student populations.
2. Student:tutor ratio of 1:20 for all courses.

Staff travel for the OU print-based distance courses, at an average of just under 20 kilometres per student per 10 CAT points, is some 50% higher than for staff teaching at conventional campus universities. This may well be expected, particularly as there can be significant amounts of travel to tutorials.

For electronically-delivered OU courses, the course team's role would be similar to that of a non-electronic course. Thus, in order to calculate course team travel, the same assumptions were made as for T172, above. However, particularly for T171 which has large student numbers (some 40,000

[3] Potter, S. and Roy, R. (2001) op cit. Note 3.
[4] Student numbers were actually about 7000, but this only makes a marginal difference to the result.

students were expected to take the course over 5 years before it was withdrawn or revised) course team travel is spread over a much larger student body[5].

The main difference with electronically delivered courses is that travel to tutorials is cut (although some electronically-delivered courses do continue to have conventional tutorials). The overall effect is that staff travel for the electronically delivered courses is reduced compared to the print-based distance courses. The figure is virtually the same as for staff at conventional campus universities (Table 10).

However, the scale effect seems important here. For smaller electronically-delivered courses, the amount of travel is comparable to print-based courses. This is probably because they retain a conventional examination with travel to the exam centre. Interestingly, as before, the one non-OU distance taught course registers the lowest amount of travel, energy use and emissions, indicating that the environmental improvement is not just a product of the OU's scale, but of the mode of course delivery.

Table 10 Total distance electronic course-related staff travel (average per student per 10 CAT points)

Distance electronic: course team & tutors	Total course-related travel		
Course	**Distance (km)**	**Energy (MJ)**	**CO_2 emissns (kg)**
T171	7.2	14.0	1.2
M879	25.5	45.1	4.4
BZX730	15.6	71.5	7.2
N	5.5	6.2	0.7
Average	***13.4***	***34.2***	***3.4***

1. Based on scoping study of one T172 central academic+ data on T172 tutors, adjusted for course team size and student populations.
2. Student:tutor ratio of 1:20 for all OU courses.

Overall there is a cut by nearly a third in staff travel between print-based and electronically-delivered distance courses, although course size can explain much of this difference.

3.1.6 Travel comparisons

Table 11 and Figure 4 compares the total travel distance, energy and CO_2 emissions for the campus based courses with distance learning courses.

The first point is that ***student travel is a very major environmental impact.*** Staff travel, perhaps not surprisingly, is quite minor – amounting to only one percent of the total travel impacts. In any assessment, attention therefore needs to be focused on student travel.

Compared to full-time campus-based courses, part-time delivery results in a substantial reduction in travel impacts. The distance travelled is cut by some 56%. A lot of this is because part-time study is difficult for overseas students, and so a number of long air trips are consequently eliminated. However the elimination of daily commuting to campus is also of importance.

[5] T171 student numbers were actually about 21,000 over 3 years until the course was first revised, and a further 18,500 over the next 4 years until withdrawn (total 39,500) but this only makes a very slight difference to the impacts.

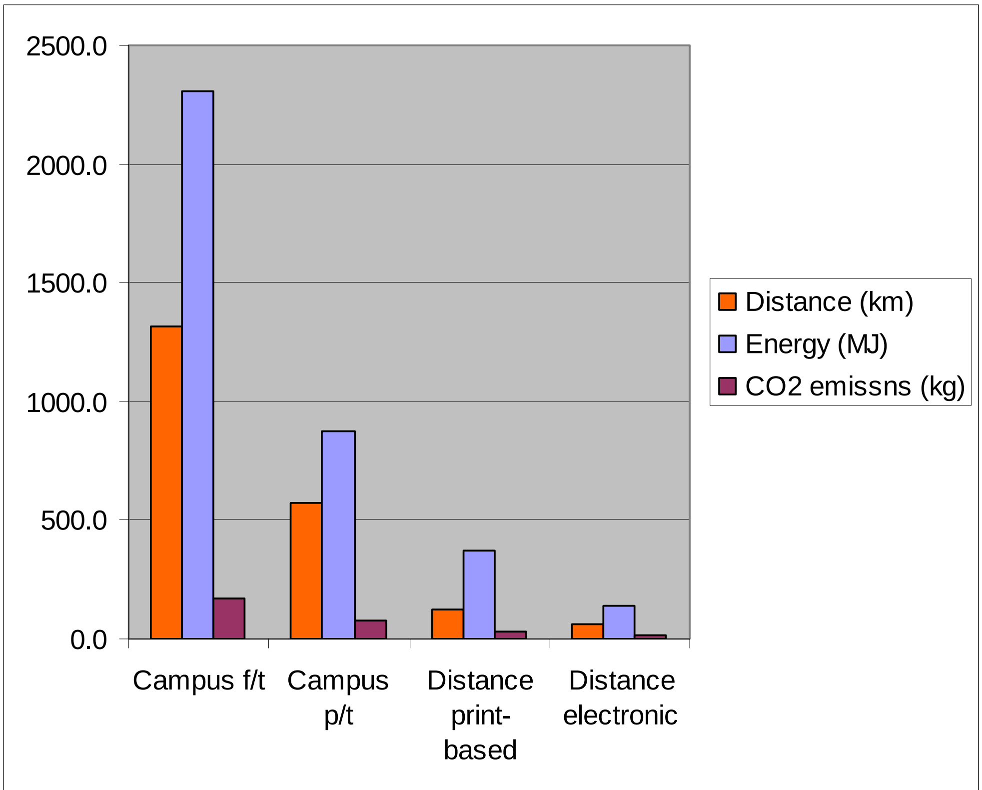
Table 11: Summary student & staff travel for campus and distance learning courses (average per student per 10 CAT points)

Course delivery system	Distance (km)	Energy (MJ)	CO_2 emissns (kg)
Campus f/t: students	1299.1	2263.9	170.3
Campus f/t: lecturers	13.2	40.6	3.0
Campus f/t: total	***1312.3***	***2304.4***	***173.3***
Campus p/t: students	561.5	834.5	78.0
Campus p/t: lecturers	13.2	40.6	3.0
Campus p/t: total	***574.7***	***875.1***	***81.0***
Distance print-based: students	104.5	268.4	19.6
Distance print-based: staff	19.7	106.8	10.1
Distance print-based: total	***124.2***	***375.2***	***29.6***
Distance electronic: students	50.4	104.9	8.3
Distance electronic: staff	13.4	34.2	3.4
Distance electronic: total	***63.8***	***139.1***	***11.7***

Distance teaching is available to both domestic and many foreign students, but eliminates even more travel. Student and staff travel for the print-based distance courses was under 10% of that of the full-time campus-based courses. Electronic delivery of distance courses cut this further to a mere 5%.

It should be noted that the biggest cut in travel impacts comes not from electronic delivery but from shifting to part-time and, in particular, distance modes of teaching. The further reduction achieved by electronically delivered courses also depends on whether face to face tutorials are offered to students and on the degree of 'rebound' due to students travelling for informal face to face meetings when there is little or no formal provision.

Figure 4: Staff and student travel for campus and Open University courses (averages per student per 10 CAT points)



3.2 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 (covered later in this report). 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 courses, a substantial proportion of computing time was likely to have been spent connected to the Internet to study or download course material. For the OU electronically-delivered courses, 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[6], 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 an educated guess that the for the electronically-delivered distance courses 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 [7] 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.)

3.2.1 Campus students computing

Tables 12 and 13 detail the full and part-time 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 may to be related to the nature of the campus, as well as the course.

***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,[8] and the assumptions involved in allocating computer purchases to course CAT points, this result should be regarded as approximate.

---

[6] Remmerswaal, H. *Personal communication*, March 2002.
[7] Leszczynski, J. *Personal communication*, Open University, 2001.
[8] Roy, R. (2001) Energy and emissions conversion factors *Unpublished working paper*, Design Innovation Group, The Open University, December and Appendix 1, section 7.3.

Table 12: Campus f/t students' purchase and use of computers (per student per 10 CAT points)

Campus f/t: Students	Course-related own computer use			Course related computer purchases		
Course	**Usage (hours)**	**Energy (MJ)**	**CO_2 emissns (kg)**	**Number PCs**	**Energy (MJ)**	**CO_2 emissns (kg)**
A (1)	102	50.4	6.6	0.015	135.0	12.9
B (1)	87	43.2	5.7	0.005	45.0	4.3
C (1)	36	18.0	2.4	0.007	63.0	6.0
D (1)	122	60.3	7.9	0.009	81.0	7.8
E (1)	71	34.9	4.6	0.009	81.0	7.8
F (1)	107	53.1	7.0	0.009	81.0	7.8
G (1)	32	15.6	2.0	0.006	54.0	5.2
H (1)	19	9.6	1.3	0.006	54.0	5.2
I (2)	21	9.6	1.3	0.02	180.0	17.3
J (2)	28	17.6	2.2	0.01	90.0	8.6
Average	***63***	***31.2***	***4.1***	***0.010***	***86.4***	***8.3***

1. Including estimated 10% time on-line.
2. Including % time on-line obtained in survey.

For part-time students, computer use was surprisingly low (Table 13). These figures should be used with caution as the results may have been affected by the small sample involved.

Table 13: Campus p/t students' purchase and use of computers (per student per 10 CAT points)

Campus p/t: Students	Course-related own computer use			Course-related computer purchases		
Course	**Usage (hrs.) (1)**	**Energy (MJ)**	**CO_2 emissns (kg)**	**No. PCs**	**Energy (MJ)**	**CO_2 emissns (kg)**
K	56	20	3.4	0.01	90	8.6
L	11	5	0.7	0.01	90	8.6
M	27	12	1.6	0.01	90	8.6
Average	***31***	***12.3***	***1.9***	***0.010***	***90.0***	***8.6***

1. Including % time on-line obtained in survey

3.2.2 Distance-taught students computing

Similar data were obtained for the distance taught students. These, of course, would not have computers available on site, as is the case for campus-based students and so the use of their own computers would be expected to be higher. This was indeed the case. For the print-based distance courses, (Table 14) computer usage was some 40% higher than for full-time students on campus-based courses. However, the wide variation in own computer use by the full time students should be taken into consideration, with many courses registering computer use of over 100 hours per student per 10 CAT points. The nature of the course as well as delivery mechanism must be an important factor determining computer use.

Table 14: Distance print-based students' purchase and use of computers (per student per 10 CAT points)

Distance print-based: Students	Course-related own computer use			Course-related computer purchases		
Course	**Usage (hours)**	**Energy (MJ)**	**CO_2 emissns (kg)**	**Number PCs**	**Energy (MJ)**	**CO_2 emissns (kg)**
T172 (1)	63	31.0	4.1	0.003	27.0	2.6
T833 (2)	84	54.0	7.2	0.000	0.0	0.0
B730 (2)	121	74.0	9.9	0.006	54.0	5.2
Average	***89***	***53.0***	***7.1***	***0.003***	***27.0***	***2.6***

1. Including estimated 10% time on-line.
2. Including % time on-line obtained in survey.

Not surprisingly the mainly electronically taught and tutored courses had an even higher use of students' own computers. The comparison between the matched T171 and T172 is particularly salient. The electronically-delivered 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 on-line 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. The highest level of computer use was for the postgraduate computing course, M879 *Distributed applications and e-commerce* – given the subject area this is not surprising.

Table 15: Distance electronic students' purchase and use of computers (per student per 10 CAT points)

Distance electronic: Students	Course-related own computer use			Course related computer purchases		
Course	**Usage (hours)**	**Energy (MJ)**	**CO_2 emissns (kg)**	**Number PCs**	**Energy (MJ)**	**CO_2 emissns (kg)**
T171 (1)	161.2	121.1	15.1	0.005	45.0	4.3
M879 (2)	350.0	205.3	27.4	0.003	27.0	2.6
BZX730 (2)	104.0	67.0	8.9	0.009	81.0	7.8
N (2)	97.0	62.0	8.3	0.020	180.0	17.3
Average	***178.1***	***113.9***	***14.9***	***0.009***	***83.3***	***8.0***

1. Including estimated 67% time on-line.
2. Including % time on-line obtained in survey.

3.3.3 Campus lecturers computing

Table 16 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 very small given that it is spread over the number of students taking each course.

Table 16: Campus f/t lecturers' purchase and use of computers (per student per 10 CAT points)

Campus f/t: Lecturers	Course-related own computer use			Course related computer purchases		
Course	**Usage (hours)**	**Energy (MJ)**	**CO_2 emissns (kg)**	**Number PCs**	**Energy (MJ)**	**CO_2 emissns (kg)**
A(1)	n/a	n/a	n/a	n/a	n/a	n/a
B (1)	n/a	n/a	n/a	0	0	0
C (1)	n/a	n/a	n/a	n/a	n/a	n/a
D (1)	0.9	0.45	0.06	0.001	9	0.86
E (1)	0.3	0.15	0.02	0	0	0.00
F (1)	n/a	n/a	n/a	n/a	n/a	n/a
G (1)	n/a	n/a	n/a	0	0	0
H (1)	n/a	n/a	n/a	0	0	0
I (2)	n/a	n/a	n/a	n/a	n/a	n/a
J (2)	n/a	n/a	n/a	n/a	n/a	n/a
Average	***0.6***	***0.30***	***0.04***	***0.0002***	***1.8***	***0.17***

It was assumed that lecturers' purchase and use of computers would be similar for part time courses.

3.2.4 Distance courses tutors computing

The computer purchase and use data for the Open University tutors (Associate Lecturers) on the print-based distance taught courses is shown in Table 17. 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.[9]

Compared to student use of computers, that of staff is very low at 3 hours compared to 89 hours (per student per 10 CAT points).

Table 17: Distance print-based staff purchase and use of computers (per student per 10 CAT points)

Distance print-based: course team + tutors	Course-related own computer use (1)			Course related computer purchases (2)		
Course	**Usage (hours)**	**Energy (MJ)**	**CO_2 emissns (kg)**	**Number PCs**	**Energy (MJ)**	**CO_2 emissns (kg)**
T172	2.8	1.4	0.2	0.0001	0.9	0.1
T833	2.8	3.6	0.5	0.0001	0.9	0.1
B730	2.8	1.8	0.3	0.0001	0.9	0.1
Average	*2.8*	*2.3*	*0.3*	*0.0001*	*0.9*	*0.1*

1. Computer use = course team + tutors, including estimated 10% on-line.
2. Computer purchase = tutors only, based on T172 data.

As might be expected, for the electronically taught and tutored courses, computer use by tutoring staff was higher (Table 18).

Table 18: Distance electronic staff purchase and use of computers (per student per 10 CAT points)

Distance electronic: course team + tutors	Course-related own computer use			Course related computer purchases (3)		
Course	**Usage (hours)**	**Energy (MJ)**	**CO_2 emissns (kg)**	**Number PCs**	**Energy (MJ)**	**CO_2 emissns (kg)**
T171 (1)	7.7	5.8	0.7	0.0006	5.4	0.5
M879 (1)	7.7	7.6	0.9	0.0006	5.4	0.5
BZX730 (1)	7.7	6.2	0.8	0.0006	5.4	0.5
N (2)	n/a	0.8	0.1	n/a	7.2	0.5
Average	***7.7***	***5.1***	***0.6***	***0.0006***	***5.9***	***0.5***

1. Computer use = course team + tutors, including estimated 67% on-line.
2. Course lecturers' computer purchase and use (estimates).
3. Computer purchase = OU tutors only, based on T171 data.

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

3.2.5 Computing comparisons

The overall use of computers by students and staff for the different course delivery systems is summarised in Table 19 and Figure 5.

Table 19: Summary of student and staff computing for campus and distance learning courses (per student per 10 CAT points)

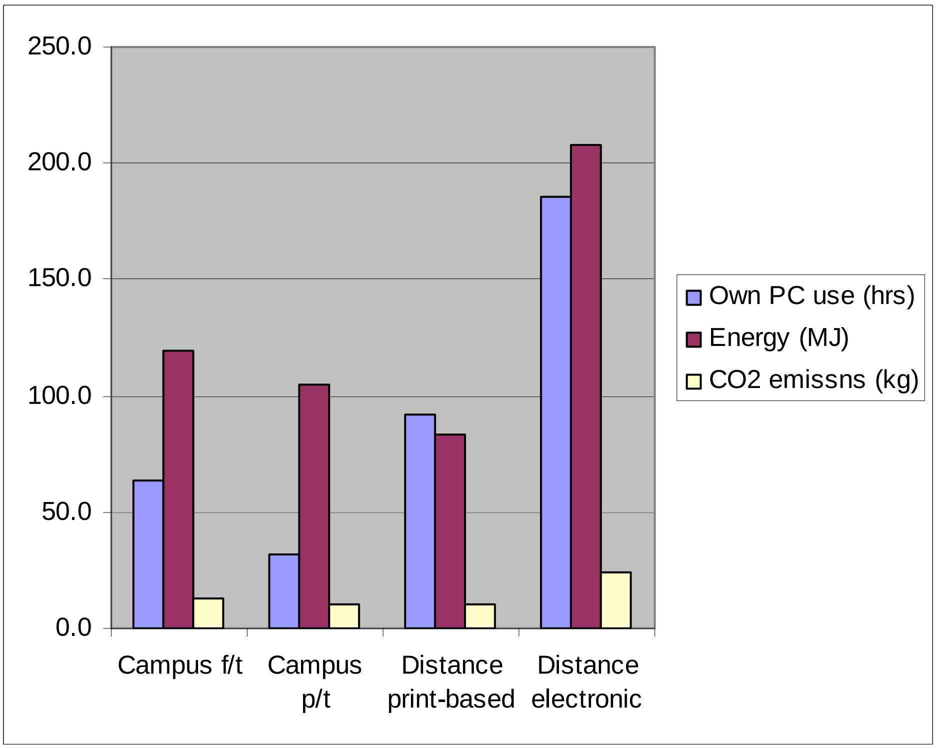
Course delivery system	Usage (hours)	Number PCs	Energy (MJ)	CO_2 emissns (kg)
Campus f/t: students	62.6	0.010	117.6	12.4
Campus f/t: lecturers	0.6	0.0002	2.1	0.2
Campus f/t: total	***63.2***	***0.010***	***119.7***	***12.6***
Campus p/t: students	31.3	0.010	102.3	10.5
Campus p/t: lecturers	0.6	0.0002	2.1	0.2
Campus p/t: total	***31.9***	***0.010***	***104.4***	***10.7***
Distance print-based: students	89.1	0.003	80.0	9.7
Distance print-based: staff	2.8	0.0001	3.2	0.4
Distance print-based: total	***91.9***	***0.003***	***83.2***	***10.1***
Distance electronic: students	178.1	0.009	197.1	22.9
Distance electronic: staff	7.7	0.001	10.9	1.1
Distance electronic: total	***185.8***	***0.010***	***208.1***	***24.0***

This is one category of environmental impacts that is very dependent on course content. Some courses require more computer use than others. However, there do appear to be some overall trends associated with mode of delivery. Not surprisingly, the electronically delivered distance courses had the highest computer use of all (and tended to be courses whose subject involved computing). They had over twice the hours of computing of the print-based distance courses, and nearly three times that of full-time campus based courses (although it should be noted that computer use on institutional machines would raise this figure. This analysis excludes them as their use is counted in the audit within site impacts).

Print-based distance teaching also exhibits high computer use (nearly 50% higher than full-time campus courses). Given that these two sets of courses did not particularly involve computing subjects, this represents a more valid comparison.

Regarding energy use, a key factor is the embodied energy involved when additional computers and equipment is purchased in order to study a course. The distance electronic courses register the highest results with energy and CO_2 emissions averaging 75% more than the full time campus courses and more than twice that of the part-time and print-based distance courses. Again the nature of the courses themselves must be an important factor as well as the method of course delivery. There is only a relatively small reduction (30%) between the more comparable full-time campus and distance print-based courses. 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 5: Staff and student computing impacts for campus and Open University courses (averages per student per 10 CAT points)



Overall, although there are some differences in the ownership and use of computers between the four course delivery systems, these are but one of several key factors and the net influence of the course delivery system is difficult to ascertain. Furthermore, as Figure 5 indicates, the differences in the environmental impacts of computing between the different methods of course provision are relatively minor when compared to the differences in travel and campus site impacts for the face to face and distance learning systems. Nevertheless once electronically-delivered courses are considered in their own right, computing is the largest source of impacts within this system. ***This shows that previously minor areas of environmental impact may become dominant in a 'de-materialised' version of a service.***

3.3 Consumption of paper and printed matter

All students in the survey 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 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.
Any transport involved in buying books, etc. is covered by the travel questions. (For details of all these calculations see Appendix 1, section 8.)

For its distance-taught courses, the Open University provides its students with specially written course books and other printed and audio-visual materials. For the OU's paper-based distance courses, an audit of printed materials for T172 was undertaken. Over 6 kg of printed material is mailed to each student of this 30 point course (i.e. 2 kg/student/10 CAT points, ignoring the course video and audio-tapes). Even electronically-delivered courses involve some paper and printed materials. The OU's T171 was taken as an example, for, although most of the OU T171 teaching content is provided electronically, the two set books purchased by students [10] plus some printed material mailed by the OU weigh a total of 1.2 kg. (0.4 kg/student/10 CAT points). Postal distribution involves a further small amount of energy and emissions (Remmerswaal, 2001; Sykes, 2001), which was added to the totals for the distance-taught courses.

3.3.1 Student and staff consumption of paper and print

Table 20 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.

Table 20: Students' consumption of paper and printed matter (per student per 10 CAT points)

Students	sheets of paper		printed course material	books and periodicals		Total weight	Avg. energy (MJ)	Avg. CO_2 emssns. (kg)
	no.	kg	kg	no.	kg	kg		
Campus: f/t	166	0.9	0	2.7	1.5	2.4	62.8	7.2
Campus: p/t	99	0.5	0	1.9	1.2	1.7	46.1	5.2
***Distance: print-based** (1)*	132	0.7	2	1.3	1.9	4.6	150.8	15.2
***Distance: electronic** (1)*	169	0.9	0.4	1.2	1.2	2.5	67.6	7.7

1. Includes postal energy and emissions.

The overall pattern of energy and CO_2 emissions shows the lowest impact is by part-time students. The margin is not great between them and there is a roughly similar impact for conventional campus full-time study and distance electronic. It may only be marginal, but significant to note that the distance electronic courses use more paper than any other method of HE course delivery! This takes into account the considerable amount of paper used by students on the electronic courses 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'.[11] 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%).

---

[10] The OU mailing to T171 tutors includes the set books.
[11] Summary of T171 Student Module Evaluations for 2000 presentations, The Open University, 2001.

Distance print-based courses consume far more paper and print materials than the other methods of course delivery – using some 2.4 times the energy compared to full-time campus study and electronic distance delivery and 3.3 times that of conventional part-time study.

An interesting trend, not shown in Table 20, is the pattern of the some campus courses having considerably greater impacts (per 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 21). 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 large numbers of students involved. [12] 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 21: Staff consumption of paper and printed matter (per student per 10 CAT points)

Staff	sheets of paper		printed course material	books and periodicals		Total weight	Avg. energy (MJ)	Avg. CO_2 emssns. (kg)
	no.	kg		no.	kg	kg		
Campus: f/t	33	0.16	0	0.1	0.02	0.2	3.6	0.5
Campus: p/t	33	0.16	0	0.1	0.02	0.2	3.6	0.5
Distance: print-based *(1,2)*	4.9	0.02	0.1	0.1	0.02	0.1	5.0	0.4
Distance: electronic *(1,2)*	5.4	0.03	0.02	0.1	0.03	0.1	2.3	0.2

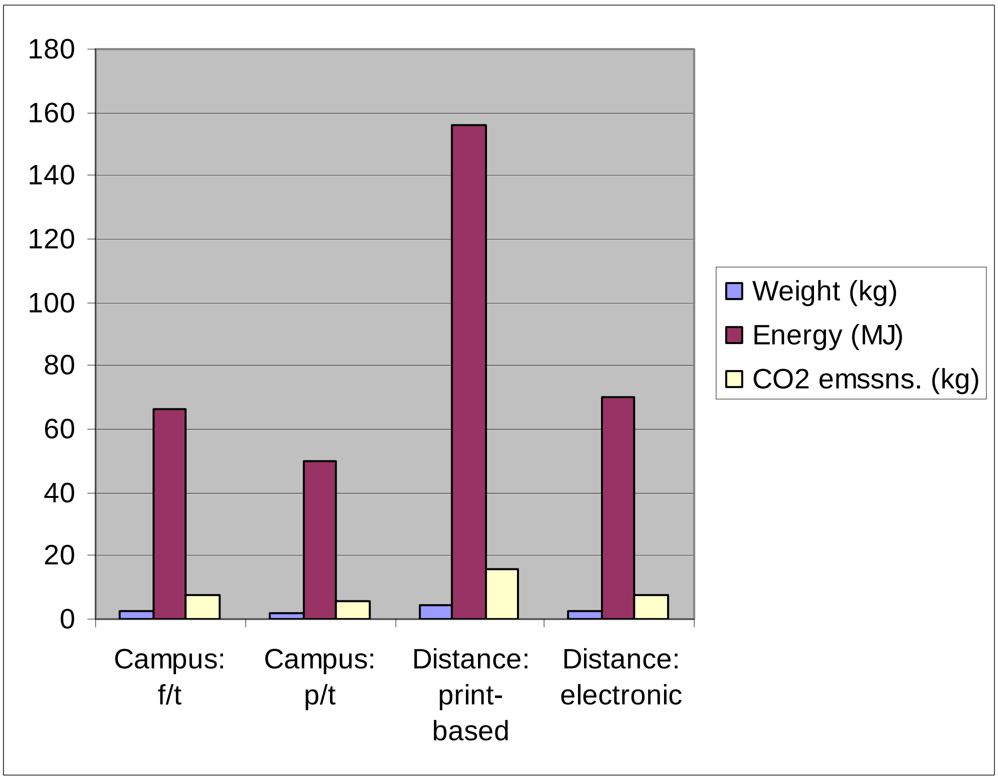
1. Includes postal impacts for distance courses.
2. Course team + tutors' consumption for distance courses.

3.3.2 Paper and print comparisons

Overall, ***the print-based distance-taught courses involve the highest consumption of paper and printed materials. Electronic delivery of distance courses more than halves paper and print consumption. Thus, there is some evidence of de-materialisation through e-learning. However this only brings the amount used down to the level already achieved by conventional campus full-time courses. The least paper and print consumption was for campus part-time courses. Reduction in paper and printed material use in conventional universities seems associated with good library access.***

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

Figure 6: Total impacts of paper and printed matter consumption (per student per 10 CAT points)



However, there is an issue of the inter-relationship between paper and print and computing use. The increased computing use in the electronically delivered courses is, in part, associated with their lower paper use. It is therefore appropriate to compare both paper and computer use and associated environmental impacts (Table 22). This would particularly be so in considering claims about the 'de-materialisation' effects of using ICT to provide services such as HE.

Table 22: Total energy and CO_2 for paper/printed matter plus computing (per student per 10 CAT points)

	Paper and print		Computing		TOTAL	
	Avg. energy (MJ)	Avg. CO_2 emssns. (kg)	Avg. energy (MJ)	Avg. CO_2 emssns. (kg)	Avg. energy (MJ)	Avg. CO_2 emssns. (kg)
Campus: f/t	63	7	120	13	183	20
Campus: p/t	46	5	104	11	150	16
Distance: print-based	151	16	83	10	234	25
Distance: electronic	68	8	208	24	276	32

Considering the total energy and emissions from paper/print consumption plus computing, the mainly electronically-delivered distance courses have overall higher energy use and CO_2 emissions than both the print-based distance courses and the conventional campus-based courses. This challenges claims about the 'de-materialisation' effects of using ICT to provide services such as HE.

However, this finding should be set in the context that 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 account for the major difference in the environmental impacts between the distance and conventional course delivery systems.

3.4 Residential energy

For most students, an inherent part of studying at a conventional campus university is living away from 'home' during term-time. This raises the issue of whether to include in the estimates of campus-based system impacts all the energy consumed per student in their term-time residences, or whether only a proportion should be counted. After detailed consideration it was concluded that, since for students living away from home, taking a full-time campus course involves a duplication of dwellings, *all* energy used in term-time residences is intrinsically part of that system. Nevertheless, ways to allocate a proportion of residential energy to studying were explored e.g. estimating the amount of time spent at the term time residence actually studying a course of a given CAT point value. But this raised several conceptual and practical problems (e.g. how much time might be counted as 'study' as opposed to 'social', etc., what proportion of study time is spent at the residence rather than on campus, and how much time sleeping could be attributed to supporting study activities?). So, even though the research team decided against such models, it is accepted that the allocation of residential energy to full-time campus courses remains a debatable issue.

Students were therefore asked where they lived during term. For students 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 and was averaged. Because of a limit on the number of questions we could expect respondents to answer, students who lived in shared houses, 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. This involved the use of the 1996 *English House Condition Survey,* which provides statistical information on average household energy consumption and CO_2 emissions. This was scaled for the higher occupancy of student households (DETR, 2000; see Appendix 1, section 4.3.2 for details).

Interestingly there was only a small difference between the residential energy used in university accommodation (1220MJ per student per 10 CAT points) compared to shared housing (1410MJ). The estimate of residential energy use was, of course, only for 30 teaching weeks a year. No account was taken of reduced energy use at the main home while students were away. This would be marginal compared to the additional energy consumed at the term-time residence.

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. In any case, since the focus of our study is on how the delivery of HE courses affects environmental impacts, this study is not really concerned with factors, such as the age of buildings and climatic conditions, which 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.

For part-time and distance-taught students who study from home, and campus students who live at 'home' during term, no additional dwellings are involved. But *additional* household energy is often involved when taking a course. Our survey therefore concentrated on additional heating. Additional lighting energy was ignored, as it was calculated to be small compared to heating.[13] The students were asked whether, for the purposes of study, they heated space(s) in their home above normal use (e.g. by leaving the central heating on longer than normal or using an electric room heater). The additional

[13] 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.

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).

Likewise, for the campus lecturers and OU tutors, the survey asked for *additional* home heating associated with teaching the course. 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.[14] The survey also asked for the source as well as extra hours of heating, to provide the most accurate estimate possible of energy use and CO_2 emissions.

3.4.1 Student residential energy consumption

Over a quarter (29%) of the campus students lived in a university or college hall of residence. 44% lived in a flat or house, lodgings, or a room in a flat or house, and just over a quarter (27%) at their main, usual or permanent home (Table 23).

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 shared houses, flats, 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, as noted above, that is 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 23: Campus f/t students' residential energy and emissions (average per student per 10 CAT points)

Campus f/t: Students		Residential energy	
Term-time residence	**Percentage** (2)	**Energy (MJ)**	**CO_2 emssns. (kg)**
University residences	29	1245	110
Flats, houses, lodgings	44	1410	102
Main or usual home (1)	27	174.1	7.4
Weighted average	***100***	***1028.5***	***78.8***

1. *Additional* home heating only.
2. Phase 1 survey data.

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

As noted above, for the campus students living at home during term and the home based part-time and distance-taught students, we obtained data on the amount of *additional* heating for the purposes of studying their course. The results for part-time students are shown in Table 24. This was a relatively small sample and the only additional heating source was gas central heating. The approximate energy and CO_2 emissions per student per 10 CAT Points were calculated from the responses (See Appendix 1, section 4.3.3).

Table 24: Campus p/t students' residential energy and emissions (average per student per 10 CAT points)

Campus p/t: Students	Residential heating (2)		
	Gas CH (hrs)	**Energy (MJ)**	**CO_2 emssns. (kg)**
K	7.2	166.6	6.5
L	n/a	n/a	n/a
M	3.1	70.8	2.8
Average	***5.1***	***118.7***	***4.6***

1. P/t campus students are assumed to live at their main home.
2. *Additional* home heating only.

Tables 25 and 26 show the corresponding data for the print-based and electronically-taught distance students. The main additional heating sources were gas central heating and electric room heaters. Again, the approximate energy and CO_2 emissions per student per 10 CAT Points were calculated from the responses

Table 25: Distance print-based students' course related residential heating (average per student per 10 CAT points)

Distance print-based: Students	Residential heating (1)			
Course	***Gas CH (hours)***	***Electric heater (hours)***	**Energy (MJ)**	**CO_2 emssns. (kg)**
T172	0.9	0.5	24.0	1.2
T833	0.7	0.0	16.7	0.7
B730	1.5	1.0	40.8	2.2
Average	***1.0***	***0.5***	***27.2***	***1.3***

1. *Additional* home heating only.

Table 26: Distance electronic students' course related residential heating (average per student per 10 CAT points)

Distance electronic: Students	Residential heating (1)			
Course	**Gas CH (hours)**	**Electric heater (hours)**	**Energy (MJ)**	**CO_2 emssns. (kg)**
T171	4.4	1.1	117.0	5.2
M879	1.9	0.6	48.0	2.2
BZX730	3.2	3.2	97.1	5.7
N	n/a	n/a	n/a	n/a
Average	***3.2***	***1.6***	***87.4***	***4.4***

1. *Additional* home heating only.

An interesting rebound effect is the relatively high amount of additional heating reported by students of the electronically taught courses, particularly the OU T171 and BZX730 courses. At 4.4 and 3.2 hours/student/10 CAT points this compares to an average of 1.0 hours/student/10 CAT points for the print-based distance courses. We do not know for certain the reason for this difference. However, several responses to the qualitative part of the questionnaire for T171 suggest that it is probably due to 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. Possibly changes to internet service packages (which increasingly offer unlimited access for a fixed fee) might reduce this effect. However there will be continuing need for long connection time to the internet by such courses, so additional home heating seems likely to be a structural feature of electronically-delivered courses.

3.4.2 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 27).

Table 27: Staff course related additional residential heating (average per student per 10 CAT points)

All Staff	**Residential heating (1)**			
	Gas CH (hours)	***Electric heater (hours)***	**Energy (MJ)**	**CO_2 emssns. (kg)**
Campus f/t: Lecturers	2.3	16	165	16
Campus p/t: Lecturers (2)	n/a	n/a	7.2	0.5
Distance print-based: staff (3,4)	0.1	0.2	12.1	0.8
Distance electronic: staff (3,4)	0.3	0.1	13.8	2.2

1. Based on Phase 1 data. *Additional* home heating only.
2. Estimate based on one P/T lecturer.
3. Course team + tutors for OU courses.
4. Tutor:Student: ratio = 1:20.

Compared to student heating impacts, those of staff are relatively small. It is highest for lecturers of full-time campus courses, with a significant cut recorded for part-time and distance courses. 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 distance courses the amounts concerned per student per 10 CAT were small at 0.6 MJ and <0.1 kg CO_2 for the part electronically-delivered T171 and 2.7 MJ and 0.2 kg CO_2 for print-based T172. [15]

Overall the additional residential heating for tutors of distance taught courses was slightly higher than for part-time courses (although with the small sample for the latter this comparison should be treated with caution). Unlike for their students, the tutors of electronically-delivered distance courses only used marginally more heating than their print-based counterparts.

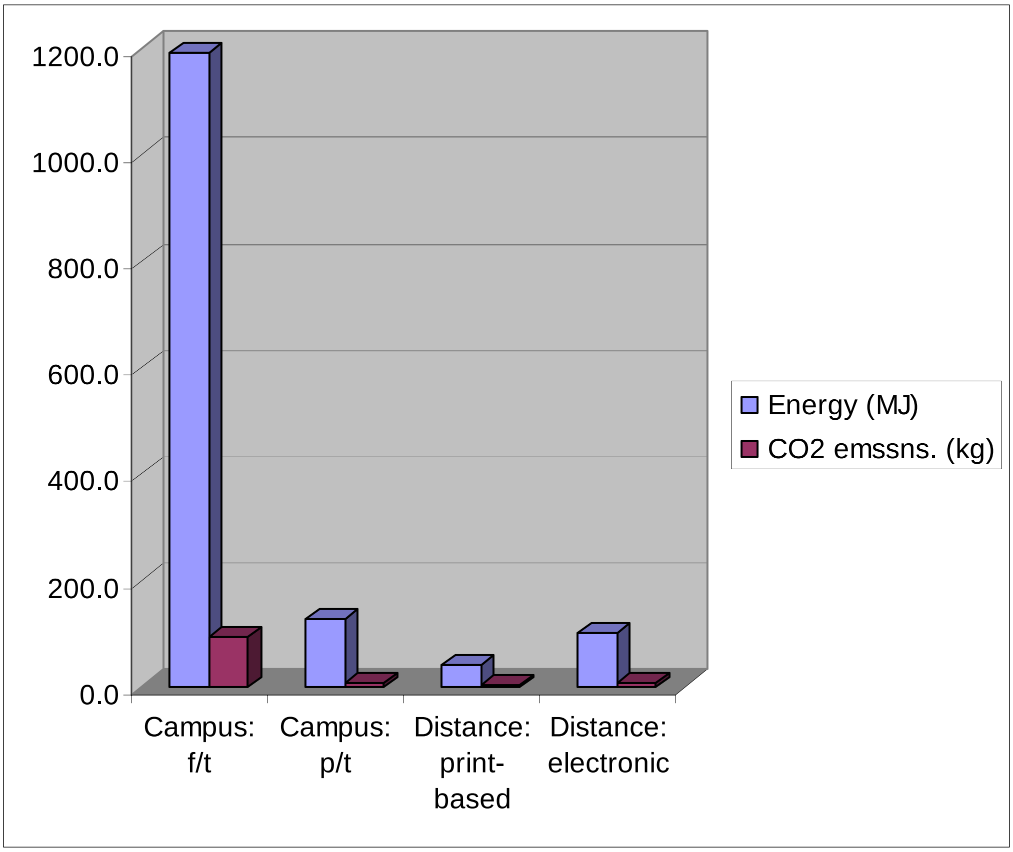
3.4.3 Residential energy comparisons

Part-time and distance courses surveyed register a very great reduction in residential energy consumption and associated emissions compared to full-time campus-based courses *(Figure 7)****.*** *Most of this reduction is due to the fact that for part-time and distance courses only additional heating for study needs to be counted.* For full-time 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 part-time or distance taught*

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

students in their relatively small requirement of residential energy, since it may be assumed that the dwelling would be heated anyway.

Figure 7: 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 four modes of course delivery (Table 28).

Table 28: Summary course-related residential energy and emissions (per student per 10 CAT points)

Course delivery system	Energy (MJ)	CO_2 emissions (kg)	Basis
Campus: f/t	***1193.5***	***94.8***	All term-time energy
Campus: p/t	***125.9***	***5.1***	Additional home heating
Distance: print-based	***39.3***	***2.1***	Additional home heating
Distance: electronic	***101.2***	***6.6***	Additional home heating

Compared to the campus courses, part-time and distance teaching is associated with a major reduction in residential energy use and associated emissions. This is a reduction of 90% per student per 10 CAT points.

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 full-time campus based systems. However, as was observed before regarding paper consumption, this is further evidence that ***challenges claims about the 'de-materialisation' effects of using ICT to provide services such as HE. The reductions in environmental impacts are counterbalanced by associated rises elsewhere in the system - in paper consumption and in home heating.***

3.5 Campus site impacts

The environmental impacts of university campus operations clearly need to be taken into account in this study. A variety of sources of information were used to calculate our standard measure of impact per student per 10 CAT points. Campus energy use was split between residential accommodation (which has already been considered in Section 3.4 above) and all other non-residential campus uses. This section considers the latter.

In considering non-residential energy use, there is a question of what proportion should be attributed to student study. A university campus is not only used for teaching students, but for research and other purposes. Information was obtained in order to identify what proportion could be allocated to teaching purposes. The best and most readily obtainable data was of the annual teaching and research funding provided by the HEFCE. This was obtained for seven of the English universities in our survey. For these, on average, teaching accounted for about two-thirds (68%) of the total funds for HEFCE teaching and research. This assumes 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).

Having used the HEFCE information to estimate a figure for non-residential campus energy use that could be allocated to teaching, this was then divided by the number of FTE (full time equivalent) students to produce the non-residential energy consumption per student per annum. This was further multiplied by 10/120 to produce our standard measure of 'per student per 10 CATS points' (full time study is equivalent to taking 120 CAT points per annum).

3.5.1 Site impact results

As noted above in section 3.5, data that we obtained on student numbers, fuel costs and total energy consumption is confidential, so only averages can be provided here. Table 29 shows the results for the campus full-time courses considered in this study. This is split between the initial 'Phase 1' survey results and those for 'Phase 2' of this study. This produced an average energy use per student per 10 CAT points of 883 MJ and just over 81 kg of CO2.

Table 29: Campus f/t course-related campus site energy consumption (average per student per 10 CAT points)

Campus f/t courses	Non-residential campus site energy (1)	
	Energy (MJ)	CO_2 emssns. (kg)
7 Phase 1 campuses	805.0	74.0
2 Phase 2 campuses	1156.0	106.0
Weighted average	***883.0***	***81.1***

1. Based on HEFCE data.
68% total energy consumption assumed for teaching.

Part-time course delivery roughly halves campus site non-residential energy use and CO_2 emissions (Table 30). This is basically due to part-time delivery spreading campus impacts over a larger number of students.

Table 30: Campus p/t course-related campus site energy consumption (average per student per 10 CAT points)

Campus p/t courses	Non-residential campus site energy (1)	
	Energy (MJ)	**CO_2 emssns. (kg)**
M	216.0	21.2
L	707.0	64.8
Average	***461.5***	***43.0***

1. Based on HEFCE data.
68% total energy consumption assumed for teaching.

The scale effect is even more apparent for the distance taught students, where the role of the campus shifts to that of course production rather than being also used for course delivery.

For the OU, campus energy consumption was obtained from the OU's Estates Department and a scoping study with one academic staff member using a similar method to that outlined previously for the travel analysis was employed.[16] 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 6 MJ and 0.5 kg CO_2 for the print-based T172 and 1.4 MJ and 0.1 kg CO_2 for the electronically delivered T171. 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.[17] The campus and other sites employed in the OU distance learning system are simply not a source of major environmental impacts for each student taught.

These figures were taken as generic for OU print and electronic delivery respectively and applied to the other courses, with the resultant figures varying by course team size and student numbers. These results for distance print-based and distance electronic courses are shown in Tables 31 and 32.

Table 31: Distance print-based course-related campus site energy consumption (average per student per 10 CAT points)

Distance print-based courses	Non-residential campus site energy	
	Energy (MJ)	**CO_2 emssns. (kg)**
T172	7.2	0.6
T833 (1)	39.6	4.0
B730 (1)	6.6	0.7
Average	***17.8***	***1.8***

1. Based on Phase 1 data factored for course team size and student population.

[16] Potter, S. and Roy, R. (2001) Scoping study of T172 production environmental impacts, *Unpublished working paper*, Design Innovation Group, The Open University, September.
[17] 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.

Table 32: Distance electronic course-related campus site energy consumption (average per student per 10 CAT points)

Distance electronic courses	Non-residential campus site energy	
	Energy (MJ)	**CO_2 emssns. (kg)**
T171	1.4	0.1
M879 (1)	32.3	3.2
BZX730 (1)	6.6	0.7
N	30.0	2.7
Average	***17.6***	***1.7***

1. Based on Phase 1 data factored for course team size and student population.

3.5.2 Comparison of campus site impacts

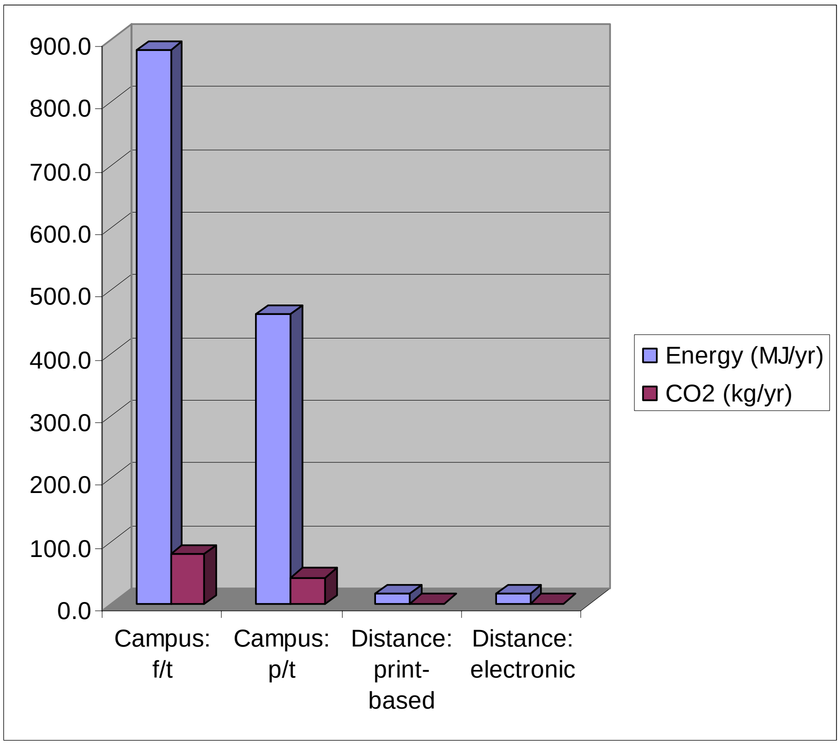
Table 33 and Figure 8 summarises the campus site impacts for the four course delivery systems.

Table 33: Summary campus site energy and emissions for campus and distance courses (average per student per 10 CAT points)

Course delivery system	Energy (MJ/yr)	CO_2 (kg/yr)
Campus: f/t	***883.0***	***81.1***
Campus: p/t	***461.5***	***43.0***
Distance: print-based	***17.8***	***1.8***
Distance: electronic	***17.6***	***1.7***

Compared to campus full-time courses, the site energy and emissions for students on part-time courses are nearly halved. However, the impacts per student per 10 CAT points of the distance learning courses are enormously lower (only some 2%) of those the full-time campus courses. This is mainly due to the economies of scale of teaching many thousands of students from one central campus. There is little difference between print-based and electronic distance course delivery.

Figure 8: Comparison of conventional and distance teaching campus site energy and CO_2 emissions (average per student per 10 CAT points)



4 Comparisons and discussion

This environmental audit reveals, and for the first time quantifies, major differences in the impacts of different higher education delivery 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.

Table 34 summarises the results of the data presented in the preceding sections.

Table 34: Total energy and CO_2 emissions of campus and distance learning courses (averages per student per 10 CAT points)

ENERGY (MJ)	Campus site	Travel	Computing	Paper/print	Resdl. heating	TOTAL
Campus: f/t	883.0	2304.4	119.7	66.3	1193.5	**4567.0**
Campus: p/t	461.5	875.1	104.4	49.7	125.9	**1616.6**
Distance: print-based	17.8	375.2	83.2	155.8	39.3	**671.2**
Distance: electronic	17.6	139.1	208.1	69.9	101.2	**535.8**
CO_2 EMISSIONS (kg)	**Campus site**	**Travel**	**Computing**	**Paper/print**	**Resdl. heating**	**TOTAL**
Campus: f/t	81.1	173.3	12.6	7.7	94.8	**369.5**
Campus: p/t	43.0	81.0	10.7	5.7	5.1	**145.5**
Distance: print-based	1.8	29.6	10.1	15.7	2.1	**59.2**
Distance: electronic	1.7	11.7	24.0	7.9	6.6	**51.9**

4.1 Differences between full-time campus courses

The first point to make is that the figures in Table 34 above are the *average* figures for energy and emissions per student per 10 CAT points for the sample of UK campus based full-time courses. These averages conceal the fact that the campus courses involve a 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.

4.1.1 Term time student travel

Full-time student term time 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.

Key Finding

Student commuting is an important environmental impact of higher education that has attracted relatively little attention. *Some universities have developed 'travel plans' in an attempt to reduce the impacts of student and staff travel (see e.g. HEPS, 2003). But even if existing travel patterns are modified through travel plans, our study indicates that significant environmental impacts from student and staff travel are inherent to a campus-based 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.

Key Finding
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.

4.1.3 Residential energy

Energy consumption of university residences at the 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.

Key Finding
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.

4.1.4 Campus site energy

This is a category that applies to all types of HE course delivery. 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 planned 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 for estate managers 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.

Key Finding
The great emphasis placed on reducing campus site impacts in existing schemes for' greening' higher education could be balanced by focusing also on other environmental issues identified in this study, notably student travel and housing.

4.1.5 Computing and paper consumption

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.

4.2 Part time courses

The differences in the energy use and CO_2 emissions between full and part-time delivery are significant. As Table 32 showed, energy and emissions are cut by nearly two-third compared to full-time campus-based study. The main reason for this substantial reduction was that there was no duplication of residences, a halving of campus site impacts due to higher resource efficiency and a cut by nearly two-thirds in travel. The latter is particularly linked to the virtual elimination of long-distance travel as part-time campus study is not appropriate for foreign students.

Key Finding
Part time course delivery reduces environmental impacts to 40% of those of full-time courses.

4.3 Conventional campus and distance/open learning courses

Distance teaching shares with part-time course delivery many factors that cut environmental impacts. To this are added some further factors. This produces perhaps the most startling result from this research:

Key Finding
The distance learning courses we examined on average involve 90% less energy consumption and produce 85% fewer CO_2 emissions per student per 10 CAT points than the conventional campus based full-time courses at UK universities.

This 90% ('factor 10') reduction in energy consumption is a significant 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 learning courses compared to conventional full-time, 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 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 distance learning course, e.g. to attend tutorials at a local study centre. Unlike with part-time courses, distance teaching is suitable for foreign students. The

travel reduction is not a result of a group of students being excluded by the mode of course delivery.

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. For example, 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 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. This is an important factor shared with part-time course delivery. 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 a student who lives at home would normally be heating and lighting that dwelling anyway, while a campus based student who lives away from their main 'home' during term does so mainly as a consequence of taking a course. For most of the latter students there is a duplication of dwellings.

The above three factors account for most of the 85%-90% reduction. The energy and emissions arising from the other two elements – computer purchase/use, and consumption of paper/printed matter – although important for the distance taught courses are relatively minor for the campus courses. But the differences in the impacts of computing and paper/print consumption between the full-time, part-time and distance learning systems are much less than for the other factors. This can be seen clearly in Figures 9 and 10.

4.3 Electronic and print-based distance/open learning courses

Key Finding
There is little difference in environmental impacts between the mainly electronically taught and tutored courses and the print-based distance courses.

Perhaps the most unexpected finding is the relatively little difference between the mainly or partially electronically taught and tutored courses and the print-based distance courses. On average the electronically delivered courses produced a 20% reduction in energy and a 12% cut in CO_2 emissions per student per 10 CAT points. Indeed for the 'matched pair' of OU foundation courses, T171 *You, your computer and the Net*, involved 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***.**

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 partially electronically delivered course 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 students on electronically tutored courses 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 students of electronically-delivered courses 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 counterbalance the savings in energy and emissions from a reduced amount of printed matter and staff/student travel compared to the print-based distance taught courses. Overall, the balance of environmental benefit and loss is closely balanced, and the environmental (as well as educational) implications of teaching via electronic systems warrant further investigation.

Figure 9: Energy consumption of campus and distance courses (average MJ per student per 10 CAT points)

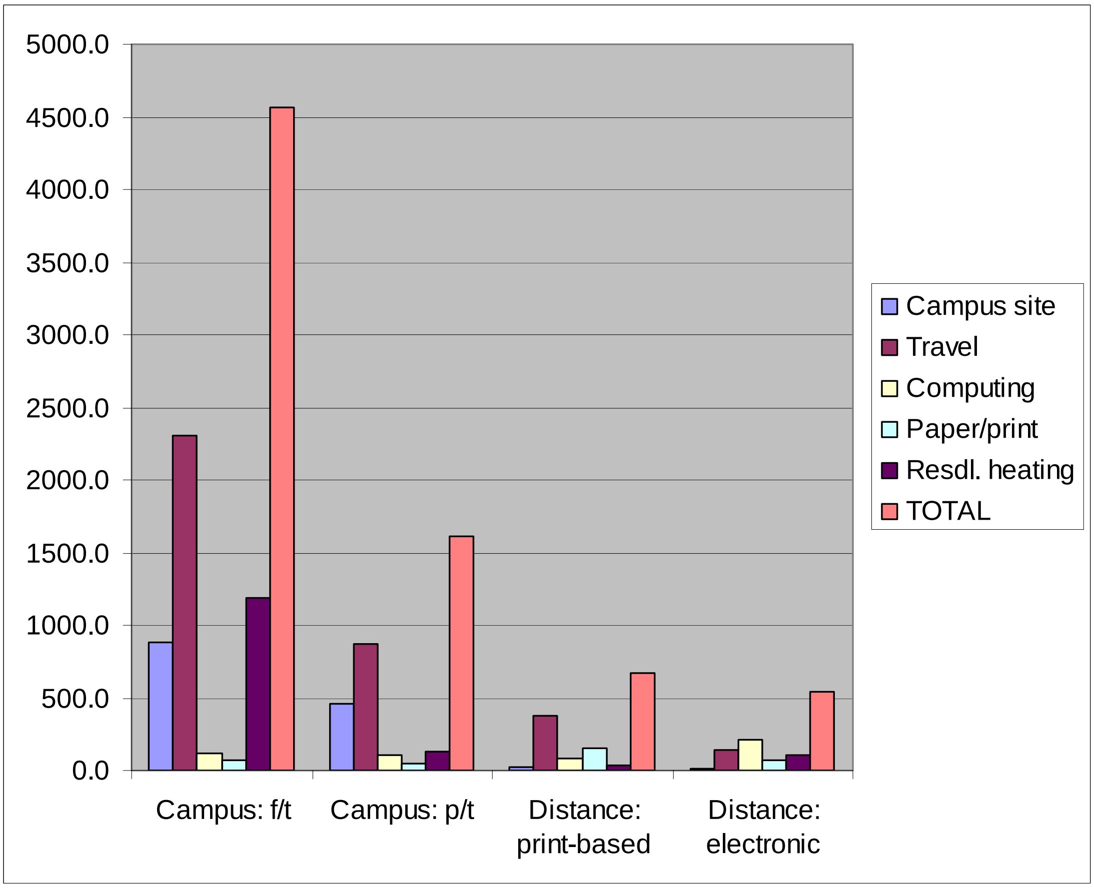
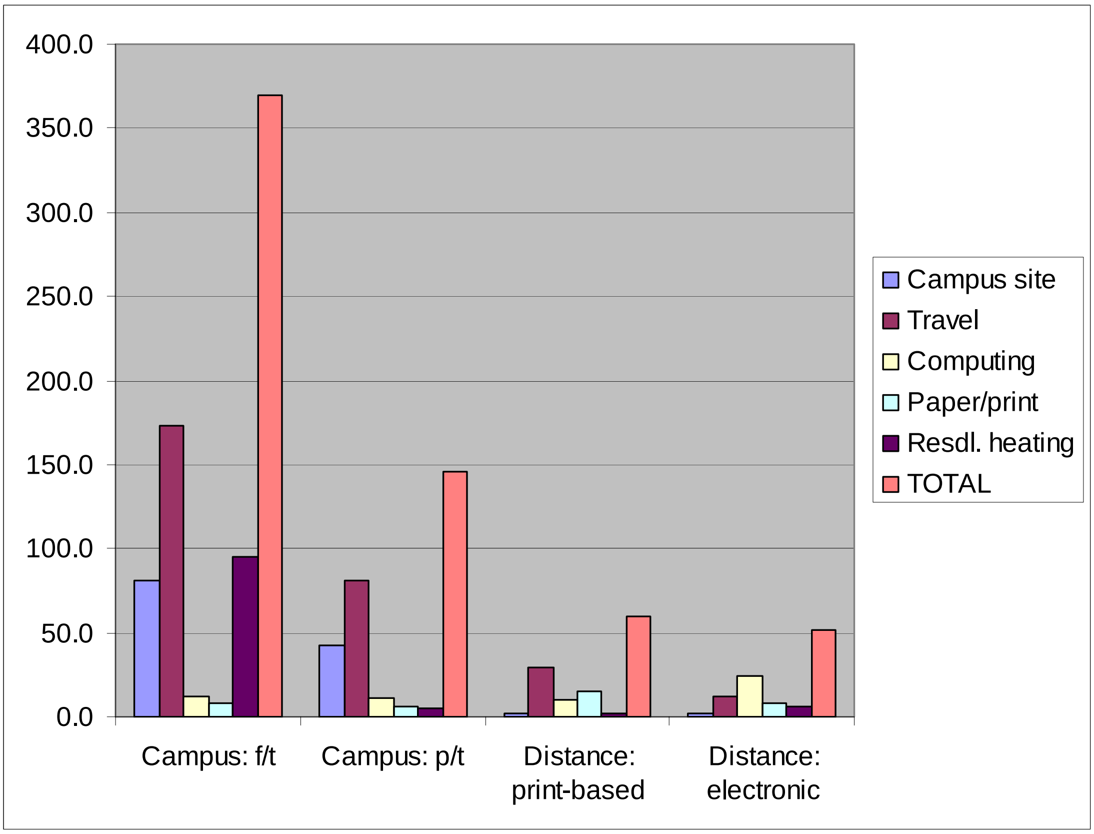


Figure 10: CO_2 emissions of campus and distance courses (average kg per student per 10 CAT points)



4.4 Are Open University distance/open learning courses unique?

It may be thought that the reductions in environmental impacts from distance taught courses we found might be confined to the Open University open learning system. In order to provide at least a preliminary answer to this question, we included in our study one non OU HE institution that provides some part-time courses both face to face at its campus and via Internet based electronic delivery.

Analysis of the data showed that the electronically delivered course from this institution reduced energy by 91% and CO_2 emissions by 89% (per student per 10 CAT points) compared to a face to face course from the same department. When we compared the electronically delivered course from this institution with the mainly electronically taught OU courses, we found that the non-OU course involved just 17% more energy and 24% more CO_2 emissions (per student per 10 CAT points) than the OU courses and with much smaller student numbers.

In other words, the reductions in energy and emissions from distance learning systems do not seem to be confined to the Open University system. Of course, since this result is based on comparing just one non-OU institution which provides distance learning with the OU, it would need confirmation.

4.5 Assumptions and simplifications

This environmental audit is largely based on new empirical information which has taken quite some time to gather and analyse. 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 five 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 seven 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 distance 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 OU distance/open learning courses.)

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 would need to 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.

4.6 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, which 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 dress 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 are summarised in more detail in Appendix 3 to this report and also discussed in a separate report (Yarrow, Roy and Potter, 2002) that 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. Nevertheless, the issue of higher education and sustainability, including addressing its environmental impacts, is receiving increasing attention; the most recent being the Higher Education Funding Council for England's consultation on its strategy and action plan *Sustainable development in higher education* (HEFCE, 2005). Yet, at the time of writing, the environmental benefits of distance learning are hardly recognised, except as a passing reference to e-learning as a way of reducing student travel in one of the Higher Education Partnership for Sustainability guidance booklets *Travel Planning for Sustainability* (HEPS, 2003).

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.[18] Based on our findings a typical full-time campus-based student would take courses worth 120 CAT points per year at an average 370 kg CO_2 per 10 CAT points while a distance-taught student might take 60 CAT points per year at 50 or 60 kg CO_2 per 10 CAT points.
The full-time campus students' annual course-related emissions work out at around 48% 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 under 4% of average annual CO_2 emissions (or about 7% for the equivalent CAT points/year as a full-time student).[19]

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

---

[18] 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.
[19] Full-time campus student = (370 kg x 120/10 CAT)/9326 kg = 47.6%. OU student (studying at half rate of full-timer) = (55kg x 60/10 CAT)/9326 = 3.5%

separate educational infrastructure. The environmental improvements are brought about largely by improved resource efficiency.

Key Finding

Distance learning is an inherently eco-efficient system of providing higher education.

5.2 The role of ICT in sustainable services

This study shows that through the use of distance 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 seems to offer little by way of environmental advantages over established mainly print-based distance learning courses due to substantial 'rebound' effects. 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).

Key Finding

This research questions the assertion that ICT necessarily produces substantial and sustainable 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 reduces the need for energy-intensive travel and a dedicated infrastructure of buildings, facilities and equipment.

The reduction in energy and emissions in the distance 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 distance learning system is utilising infrastructure, such as students' homes, computers, 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 increasing the utilisation of 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 – policy issues

This research has raised a number of policy issues as well as questions for further investigation, including the following:

- 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 widely 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'.[20]

- 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 largely failed to consider environmental issues beyond campus site environmental management and 'greening the curriculum'. The environmental impacts of student travel and housing in the conventional HE system are just beginning to be recognised. But 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? 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.

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

References

AUT (2001) *Personal communication*, Research Department, Association of University Teachers, February.

AUT (2002) *On-line distance education: principles for good practice*, Association of University Teachers (http://www.aut.org.uk/circulars/html/la7134.html)

Brezet, H. and van Hemel, C. (eds.) (1997) *Ecodesign: A Promising Approach to Sustainable Production and Consumption*, Paris: United Nations Environment Programme.

Carley, M. and Spapens, P. (1998) *Sharing the World. Sustainable Living and Global Equity in the 21st Century*, London: Earthscan.

Chambers, N., Simmons, C. and Wackernagel, M. (2000) *Sharing Nature's Interest. Ecological Footprints as an Indicator of Sustainability*, London: Earthscan.

Charter, M., and Tischner, U. (eds.) (2001) *Sustainable Solutions. Developing products and services for the future*, Sheffield: Greenleaf.

Cooper, T. and Evans, S. (2000) *Products to Services*, London: Friends of the Earth Trust, June.

Davey, A.P. (1998) Development of an environmental audit for the University of Surrey, *Eng. D. Thesis*, University of Surrey. 48-5518.

Delakowitz, B. and Hoffmann, A. (2000) The Hochschule Zittau/Görlitz. Germany's first registered environmental management at an insititution of higher education, *International Journal of Sustainability in Higher Education*, Vol. 1 No. 1, pp. 35-47.

Department for Education and Skills (2003) *Sustainable action plan for Education and Skills*, London: DfES, September. (http://www.dfes.gov.uk/sd/ accessed 24.9.03)

Department of the Environment, (1993) *Environmental Responsibility: an Agenda for Further and Higher Education*. (The Toyne Report), London: HMSO, February.

Department of the Environment, Welsh Office and Department for Education and Employment, (1996) *Environmental Responsibility. A Review of the 1993 Toyne Report*, London: HMSO, July.

DETR (2000) *English House Condition Survey. 1996 Energy Report*, London: Department of Environment, Transport and the Regions, December.

DTI (2001) *Digest of UK Energy Statistics*, London: Department of Trade and Industry. (http://www.dti.gov.uk/dti/dukes.htm accessed 12.4.02.)

Forum for the Future (1999) *The Higher Education 21 Project*, London: Forum for the Future.

Gershuny J. and Miles I. (1983) *The New Service Economy*, London: Frances Pinter.

Herring, H. (1999) Does energy efficiency save energy? The debate and its consequences', *Applied Energy*, Vol. 63, pp. 209-226.

HEFCE (2005) *Sustainable development in higher education. Consultation on a support strategy and action plan*, Higher Education Funding Council for England, January.

HEPS (2003) *Travel planning for sustainability*, London: Higher Education Partnership for Sustainability/Forum for the Future, May.

Hilty, L. and Gilgen P. (2001) Preface. In: L Hilty and P Gilgen. (eds.) *Sustainability in the Information Society*, 15th International Symposium: 'Informatics for Environmental Protection', 10-12 October 2001. Zurich, Marburg, Germany: Metropolis Verlag, pp. 7-12.

Hilty, L.M. and Ruddy, T.F. (2000) Towards sustainable information society, *Informatik*, No. 4 (August), pp. 2-9.

Mathews, S. and Hendrickson C. (2001) Economic and environmental implications of online retailing in the United States In: L Hilty and P Gilgen. (eds.) *Sustainability in the Information Society*, 15th International Symposium: 'Informatics for Environmental Protection', 10-12 October 2001. Zurich, Marburg, Germany: Metropolis Verlag, pp. 65-72.

Parkin, S. (2001) University challenged, *Green Futures*, No. 28 (May/June), pp. 50-51. (http://www.heps.org.uk, accessed January 2002.)

Potter, S. (2000) Travelling Light, Theme 2 of *Working with Our Environment: Technology for a Sustainable Future*, Milton Keynes: The Open University.

RCEP (2000) *Energy – The Changing Climate*, Royal Commission on Environmental Pollution, 22nd. Report, London: The Stationery Office.

Remmerswaal, H., et al., (2001) Comparison of different methods of sending messages on the basis of Life Cycle Analysis, In *Proceedings Towards Sustainable Product Design Conference 6*, Amsterdam, The Netherlands, October, Centre for Sustainable Design, Surrey Institute of Art and Design, Surrey, UK, pp. 178-182.

Roy, R. (2000a) You and the Environment, Theme 1 of *Working with Our Environment: Technology for a Sustainable Future*, Milton Keynes: The Open University.

Roy, R. (2000b) Sustainable product-service systems, *Futures*, Vol. 32, pp. 289-299.

Roy, R., Potter, S. and Smith, M.T. (2001) Exploring ways to reach sustainability in transport, housing and higher education, In Proceedings Greening of Industry Network Ninth International Conference, 'Sustainability at the Millennium: Globalisation, Competitiveness and the Public Trust', Bangkok, Thailand, (CD-ROM) January.

Simon, M. and Dixon, A. (2001) A comparison of eco-design potential in UK manufacturing industry sectors, Paper for the International Conference on Engineering Design, ICED01, Glasgow, Aug. 21-23. (For details of the input-output study see http://www.shu.ac.uk/design-research, accessed February 2002.)

Smith, M, Roy R, and Potter S. (2001) Exploring ways to reach Factor 10 – De-materialisation in higher education. In: *Proceedings, 2001 International Sustainable Development Research Conference*, April, Manchester, UK, ERP Environment, Shipley, UK, pp. 250-257.

Smith, M.T., Roy, R. and Potter, S. (1996) *The Commercial Impacts of Green Product Development*, Report DIG-05, Design Innovation Group, Milton Keynes: The Open University.

Stevels, A. (2001) Sustainable services and systems: the challenge for management and academia, In *Proceedings Towards Sustainable Product Design Conference 6*, Amsterdam, The Netherlands, October, Centre for Sustainable Design, Surrey Institute of Art and Design, Surrey, UK, pp. 60-66.

Sykes, K. (2001) Personal communication, Post Office, 23 February.

UNEP (1999) *Global Environmental Outlook 2000*, London: Earthscan.

von Weizsäcker, E., Lovins, A. and Lovins, L. H. (1997) *Factor Four. Doubling Wealth Halving Resource Use*, London: Earthscan.

Other published outputs of the project

Herring, H and Roy, R. (2002) Sustainable services, electronic education and the rebound effect, *Environmental Impact Assessment Review* (Special issue on Sustainability in the Information Society), Vol 22 No 5, October, pp. 525-542.

Roy, R., Potter, S., Smith, M. and Yarrow, K. (2001) Towards Sustainable Higher Education systems, In *Proceedings Towards Sustainable Product Design 6 conference* 'Sustainable Services and Systems', Amsterdam, The Netherlands, 29-30 Oct., pp. 98-106.

Roy, R., Potter, S., Smith, M. and Yarrow, K. (2002) *Towards sustainable higher education: environmental impacts of conventional campus, print-based and electronic distance/open learning systems*, (Phase1) Report DIG-07, Design Innovation Group, The Open University, Milton Keynes, May, pp. 72.

Roy, R. Potter, S. and Yarrow, K. (2002) Factoring sustainability into the higher education product-service system, *Journal of Sustainable Product Design*, No. 2, pp. 105-117. (Published 2004)

Roy, R. Potter, S. and Yarrow, K. (2004) Towards sustainable higher education: environmental impacts of conventional campus, print-based and electronic/open learning systems, 21st ICDE World Conference on Open Learning and Distance Education, 'Lifelong learning in the Networked World', Hong Kong, 18-22 February (CD-ROM, Open University of Hong Kong).

Roy, R. Potter, S. and Yarrow, K. (2004) Towards sustainable higher education: environmental impacts of conventional campus, print-based and electronic/open learning systems, in Murphy, D.; Carr, R., Taylor, J and Wong, T..M. (eds.) (2004) *Distance Education & Technology: Issues and Practice*, OUHK Press, pp. 129-145. ISBN 962-7707-47-3

Yarrow, K.M., with Roy, R and Potter, S. (2002) *Effects of HE courses on student and staff behaviour towards the environment*, Milton Keynes, UK: Open University Design Innovation Group, November.