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Factoring sustainability into the Higher Education service system

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Abstract

This paper summarises the findings of the first phase of a major study of the environmental impacts of an important service system – higher education (HE). The study assessed three methods of providing HE: conventional campus-based courses and distance/open learning courses using print-based and electronic delivery, with the following key findings.

1) On average, the distance taught Open University (OU) courses involved 90% less energy and CO_2 emissions (per unit of study) than the campus based courses, mainly due to reductions in student travel and housing energy consumption, plus scale economies in campus site utilisation.

2) The OU e-learning course had over 20% *higher* environmental impacts than the print-based OU course, due to higher use of computing, paper consumption for printing Web-based material, and extra home heating during Internet access.

Programmes to reduce the environmental impacts of HE should be broadened beyond 'greening' the campus and the curriculum to include the impacts of student travel and housing. The study challenges claims that 'de-materialisation' and using ICT to provide services such as HE necessarily reduces environmental impacts. Service system environmental impacts depend mainly on ~~its~~ requirements for transport and a dedicated infrastructure of buildings and equipment. ICT will only benefit the environment if they reduce the service's requirements for these elements.

Keywords: Service system; higher education; environmental impacts

Biography of Authors

Robin Roy is Professor of Design and Environment at the Open University. His research interests include eco-design, sustainable technologies and the management of design and innovation. He has published eight books and over sixty research papers on these and other topics.

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Ms Karen Yarrow is a Research Consultant with a background in psychology and education. She has a particular interest in the development of sustainable education systems.

Factoring sustainability into the Higher Education service system

Higher Education and Sustainability

This paper reports the initial results of a study that is part of a wider project called *Factor 10 Visions* undertaken by members of the Open University's Design Innovation Group (Roy, Potter and Smith, 2001). This project builds upon the DIG's previous research on eco-design (Smith, Roy and Potter, 1996) and work conducted for an Open University course, T172 *Working with Our Environment* (Potter, 2000; Roy, 2000a). The project explores the potential for radical changes in selected product-service systems to address climate change and other global environmental issues. For the industrialised countries, such as the UK, to tackle such issues it is estimated that anything between 60% ('factor 2.5') and 95% ('factor 20') reductions in fossil fuel and other resource consumption plus associated carbon emissions will be needed during this century (RCEP, 2000; von Weizsäcker et. al., 1997). At least 90% ('factor 10') reductions are expected to be needed if allowance is made for the growing population of the developing South to reach decent living standards (Carley and Spapens, 1998; UNEP, 1999).

Several strategies have been proposed for reaching a 90% improvement, including the ecodesign of products (e.g. Brezet et. al., 1997) and 'dematerialization' by replacing products with services (Charter and Tischner, 2001; Cooper and Evans, 2000; Roy, 2000b). However, a major difficulty in designing 'sustainable' products or services is that environmental impacts depend not only on the material intensity of the service itself, but also on the wider system in which the product or service is used. Reductions in environmental impacts may be outweighed by consumption growth, compounded by direct and indirect 'rebound' effects such as a lowering of resource costs leading to a growth in demand (Herring, 1999; Stevels, 2001). The *Factor 10 Visions* project seeks to allow for consumption and rebound effects and explore what changes to existing product-service systems might be capable of delivering up to 90% emission reductions in three sectors – personal transport, housing and higher education.

A study of the environmental impacts of higher education (HE) was included because this is a fast growing service sector, with the UK Government setting an expansion target of 50% participation of

18–30 year olds by 2010. Existing environmental studies on HE have focused mainly on improving environmental management at university and college campuses (e.g. Davey, 1998; Delakowitz. and Hoffmann, 2000) and on 'greening the curriculum'. In the UK, both issues were the subject of the Toyne Report (Department of the Environment, 1993) and its subsequent Review (Department of the Environment, 1996). These issues were also the main focus of Forum for the Future's 'HE21' Initiative that involved twenty-five UK HE institutions from 1997-99 (Forum for the Future, 1999) and its successor HE 'Partnership for Sustainability' scheme, started in 2000 and involving eighteen UK universities and colleges (Parkin, 2001). The global *Talloires Declaration* of University Leaders for Sustainability and the European COPERNICUS Charter have similar aims. However, no previous research exists on the environmental 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. The *Factor 10 Visions* HE study seeks to fill this gap by assessing the total environmental impacts of different systems for providing UK higher education. The first phase of this work, reported in Roy, Potter and Yarrow (2002) and summarised in this paper, considered three HE delivery systems:

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

Method of Investigation

The HE study involved a detailed environmental assessment of the three course delivery methods.

Models of higher education systems

In order to identify the key differences between the systems, models of the above three modes of providing HE courses were developed (Figures 1-3).

Figures 1-3

Conventional HE institutions are characterised by a single or multi-site campus for face to face teaching, with students living in term-time accommodation and commuting to lectures, etc. For most

UK and overseas students there is also travel between their main ‘home’ and term-time residences (although some UK students continue to live at ‘home’ all the time). The OU distance/open learning system is very different. It delivers specially developed course materials (books, CD-ROMs, etc.) directly to the student for part-time study at home, with face to face and/or electronic tutorial support from part-time tutors (called ‘Associate Lecturers’). This applies to both the OU’s UK-based students and overseas students taking OU courses at a distance in Continental Europe, Russia and elsewhere. In the OU’s new electronically taught courses, teaching material is provided via a dedicated web site that has partially replaced the physical production and mailing of course books and audio-visual materials of the established mainly print-based courses. Likewise, a computer-mediated assessment and tuition system has largely replaced the need for students and tutors to travel to a local study centre for optional face to face tutorials.

The models showed that the main differences between the three systems are in: the amounts of course-related *travel* and the consumption of energy for *heating* students’ residences; the energy for powering *campus sites* and for *computing*; and use of *paper and printed matter* for course preparation and study.

Having identified the differences in the course delivery systems, data were gathered to enable their environmental impacts to be compared. The study focused on energy consumption and CO_2 emissions, as these provide a good proxy for key environmental impacts, including climate change (Chambers et. al., 2000). However, for some environmental issues (e.g. land take, biodiversity and noise) other measures would be needed that would require further investigation.

Data to compare the systems came mainly from student/staff surveys of nine campus courses and two OU courses, together with national statistical information. The campus courses (from seven English, one Scottish and one Irish university) were chosen to reflect a mixture of locations, from city centre to suburban and ‘out of town’. All, except two taught Masters courses, were at undergraduate level and all except for three of the undergraduate courses had an environmental focus or element. The Open University (OU) courses, which are taught to both UK and overseas-located students, were the mainly print-based T172 *Working with our Environment* and the largely electronically taught T171 *You, your computer and the Net*. It should be emphasised that T171 is not entirely electronic. It has been designed for pedagogical effectiveness to use Web based materials that guide study of two set books, supported by electronic tuition and conferencing. Neither is the T172 course entirely print-based. It offers optional electronic conferencing as well as face to face tutorials. Overall the sample involved comparable groupings of students being taught via the three delivery systems.

Staff and student questionnaires

Structured questionnaires were developed for students, academic staff and, for the OU, the part-time tutors of the courses concerned. The student survey obtained the following information for each course:

- Purpose, distance, frequency and mode of travel connected with study of the course e.g. to attend lectures or tutorials, visit libraries, purchase books, etc.
- Energy and paper consumption associated with computing for the course. Especially for the electronically delivered OU T171 course, downloading and printing material from the web site.
- Printed matter consumed for books and other publications purchased for the course, and/or to provide OU printed course materials, plus paper used for photocopying, assignments, etc.
- Use of home heating in connection with study of the course (including heating method and fuel used).
- 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 teaching of the courses plus, when required, administrative information such as the length and credit rating of the course. The results reported in this paper involve a total of 234 students surveyed in the nine campus universities. The student sample for the OU courses, by their nature, was larger than for the campus courses. A total of 205 fully or partly useable student questionnaires were returned for OU T172; and 503 and 343 for T171 (which was conducted in two stages: Travel and Energy/Materials). Likewise 55 and 65 Associate Lecturers responded respectively to the OU T172 and T171 tutor surveys, while only one academic was surveyed for each of the campus courses (usually the lecturer who distributed the student questionnaires).

The effects of the courses on staff and student attitudes and behaviour towards the environment were also investigated, but any such effects are obviously dependent on the *content* of the courses concerned. Behavioural effects therefore should be viewed separately from the relative environmental impacts of course delivery systems and are not discussed in this paper.

Key results

Because the courses surveyed were of different lengths and workloads (with some full time and others distance-taught part-time), it was necessary to devise a standard unit of measurement to make a valid comparison between the various course delivery systems. This was based upon the UK Credit Accumulation and Transfer (CAT) system, whereby 1 CAT point is equivalent to 10 hours of total study. Most UK courses are measured in CAT points, with 360 points required for an undergraduate degree and 180 points for a Masters degree. Environmental impacts for all the courses were therefore normalised in terms of *average energy consumption, and CO_2 emissions, per student per 10 CAT points.* 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 delivered energy and CO_2 emissions using data on a typical PC's electricity consumption and CO_2 per kWh for UK electricity (for details see Roy, Potter and Yarrow, 2002).

Conventional and distance/open learning courses

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

There are three main reasons for this result:

1) The elimination, inherent to distance learning, of much staff and student travel.

2) The reduction in campus site emissions per student due to economies of scale in distance/open learning systems.

3) The reduction in the residential energy associated with studying for OU students who study from home, as well as for campus students who live at 'home' during term.

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.

Course related travel

For the conventional universities, transport for the course was split between (a) term-time travel (predominantly commuting from their student accommodation to campus, but also travel to off-campus libraries or on field trips), and (b) travel between their main/usual 'home' and any term-time residence. For overseas students, travel to and from 'home' could involve considerable distances. 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 point).

For the OU courses, with the students studying from home, the total amount of travel was inherently much lower than at the conventional universities. The main reasons that some OU students travelled were to visit a Regional Centre to enquire about the course, and to obtain books and other course materials. For the OU print-based course there was also travel to a study centre for optional face to face tutorials and to take the compulsory end of course examination – the electronic course conducted these activities on-line.

Compared to full-time campus HE, distance education inherently involves substantial reductions in travel-related environmental impacts – averaging about 92%. However, the reductions in travel in moving from print-based to electronic distance/supported open learning are less, at least as practised by the Open University. The cut, compared to the print-based course, was of 30-50% from an already low base.

Campus site impacts

Official data were obtained from the UK Higher Education funding councils on student numbers, fuel costs and total energy consumption of seven of the eight UK university campus sites in the survey. Because the data on individual universities is confidential, only averages can be reported. In any case, since the focus of this study is on how the delivery of HE courses affects environmental impacts, it is not really concerned with factors, such as the age of buildings, that will vary between individual campuses. So it seemed appropriate to correct for such site-specific variations by using the average energy and emissions of all the surveyed campus sites.

As not all campus energy is used for teaching functions it was necessary to allocate a proportion of the consumption to research and other non-teaching activities. The best and most readily obtainable data was of the annual teaching and research funding provided by the Higher Education Funding Council for England (HEFCE) to the seven English universities in our survey. On average teaching accounted for about two-thirds (68%) of the total for HEFCE-funded teaching and research at these institutions.

The data show that total non-residential energy consumption for the seven campuses averaged nearly 14400 MJ per year per full-time equivalent student. Using the 68% factor to adjust for teaching-related uses, this is equivalent to about 9650 MJ per student per year or 805 MJ per student per 10 CAT points (given that a student typically accumulates 120 CAT points per year).

For the OU, because its multi-media courses are mainly developed at its central campus and then presented (with updates and new assessments) to large numbers of students over several years, the site impacts per OU student per 10 CAT points are very low. These were estimated from the number of days spent by the course team working at the OU campus on a course's development and initial presentation. This produced approximate figures of 1.4 MJ and 0.1 kg CO_2 for the electronically delivered OU T171 (with some 40,000 students over its probable five-year life) and 6 MJ and 0.5 kg CO_2 for the print-based OU T172 (with an estimated 9000 students over six years).

Even given that the figures are approximate, it is clear that campus site energy and emissions per student per 10 CAT points for the distance/open learning OU courses are enormously lower (perhaps only some 1%) of those the conventional campus courses. This is mainly due to the economies of scale of teaching many thousands of students from one central campus. A sensitivity analysis indicated that major scale economies still applied even if an OU course had only 50 students per year (see Roy, Potter and Yarrow, 2002).

Residential energy consumption

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 we decided against such models, allocation of residential energy to full-time campus courses remains a debatable issue.

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. For students living in shared houses, lodgings, etc. it was not possible to gather direct information on energy consumption. Instead the 1996 *English House Condition Survey* provided statistical information on average household energy consumption and CO_2 emissions which was then scaled for the higher occupancy of student households (DETR, 2000). 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.

For OU 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 consumed when taking a course (e.g. for heating and lighting a study room at home). Likewise, for the campus lecturers and OU tutors, we asked for *additional* home heating associated with teaching the course. The survey 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.

One interesting ‘rebound’ effect noted was the relatively high amount of additional heating claimed by students of the mainly electronically taught OU T171 course. At 5.5 hours/student/10 CAT points this compares to 1.4 hours/student/10 CAT points for the print-based OU T172 course. We do not know for certain the reason for this difference. Studying on-line, or downloading material for printing, required students to be at their computer. Also, several responses to the qualitative part of the questionnaire suggest that T171 students stayed 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.

Computing and paper and print consumption

There are differences in the environmental impacts of computing between the different methods of course provision. Not surprisingly, the mainly electronically taught and tutored Open University T171 course had the highest computer use of all. It involved over 2.5 times the hours of computing (including on-line use) of the print-based OU T172 course and over twice that of the average UK campus course. In contrast, the campus courses and the print-based OU T172 course involve similar amounts of paper and printed matter, while the partially electronically taught OU T171 course appears to roughly halve the amount of paper and print required. However, these differences are relatively minor when compared to the differences in travel, campus site and residential energy impacts for the campus and distance learning systems.

Impacts of campus-based and distance/open learning courses

Overall the differences in energy and CO_2 emissions between the campus and Open University courses are summarised in Figures 4 and 5.

Figures 4 and 5

As can be seen from Figures 4 and 5, the key three factors of campus site, transport and residential heating account for most of the 90% difference in energy and emissions between the face to face campus based university courses and the distance taught OU courses. As noted above the issue of residential energy remains controversial, but even if a lower proportion of residential heating was allocated to studying a full-time campus course, very substantial differences between the systems would remain.

The impacts of the other two factors– computer purchase and use, and consumption of paper and printed matter – although important in the differences between the *print-based* and *electronic* OU courses (discussed below), are relatively minor components of the difference between the OU and the campus courses.

Electronic and print based distance/open learning courses

Perhaps the most unexpected finding is that the mainly electronically taught and tutored OU course, *T171 You, your computer and the Net,* appears to involve 23% more energy and 21% more emissions per student per 10 CAT points than the mainly print based OU course, *T172 Working with our*

*Environment***.** Although the OU T171 course is not fully electronic, this result does not appear to bear out the claims of de-materialisation often made for electronically provided services, such as e-learning. This surprising result is partly due to the obvious fact that even a partly electronically taught course such as T171 involves high usage of computers, including on-line use, and hence significant energy consumption. The other reason is that we found three examples of 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. It is possible that, as T171 is an introductory -level course, students printing off most Web-provided materials may be a temporary effect until they get accustomed to studying on-line. There is some evidence that T171 students print off less material from later parts of the course. This will be explored by surveying other electronically taught courses in Phase 2 of this study.
2. Another less expected effect is the apparent wish of some OU T171 students to meet informally face to face, given the limited or no provision of face to face tutorials. This involves local travel.
3. As noted above, some OU T171 students appear to heat space(s) in their homes more than normal for study purposes, probably while staying up late accessing the Internet during winter months.

All these factors serve to more than outweigh the savings in energy and emissions from a reduced amount of printed matter and reductions in staff/student travel for OU T171 when compared to the mainly print-based OU T172 course.

Differences between campus courses

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

1) Low term-time travel distances appear to be associated with courses at self-contained, often out of town, campus sites with a high proportion of students living in university residences. High term

time travel distances appear to be required for courses at multi-site, often urban, campuses with a high proportion of students living at and commuting from their main 'home'.

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

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

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

Conclusions

This study has focused on a largely ignored issue of higher education, namely the environmental impacts of taking a course via campus-based and distance learning systems, including a partially electronically taught course. A reason why this issue has been ignored is that it is eclipsed by questions such as the costs, educational effectiveness, social accessibility and socio-economic benefits of such higher education systems.

This study shows that through the use of distance/supported open learning courses it is possible to very significantly reduce the energy and emissions involved in providing higher education compared to conventional campus-based systems. Even though some of our data is based on estimates and there can be discussions about issues such as how much residential energy to allocate to studying, this result is very clear. Surprisingly, the introduction of electronically taught and tutored courses does not seem to offer any environmental advantages over established mainly print-based distance/open learning courses. In fact, due to 'rebound' effects, partially electronic taught courses seemingly involve higher energy and emissions. This result runs counter to many claims that have been made about the 'de-materialisation' effects and resultant environmental benefits of information and communications technologies (ICT). It will be the subject of further investigation in Phase 2 of this project.

De-materialisation through ICT?

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

The reduction in energy and emissions in the distance/supported open learning system is due to the elimination of much of the travel and campus/residential buildings infrastructure required for campus based systems. This is because the OU distance/open learning system is one that increases resource efficiency. It utilises 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.

Some policy issues

This study has also raised some significant policy issues for the HE sector. 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 on environmental grounds to educate more overseas students via development partnerships with educational institutions in a student's home country (as the OU does for its overseas students) rather than bringing them to the UK to study?

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

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

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Figure captions

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

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

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

Figure 4 Energy consumption of campus and Open University courses (averages per student per 10 CAT points)

Figure 5 Carbon dioxide emissions of campus and Open University courses (averages per student per 10 CAT points)

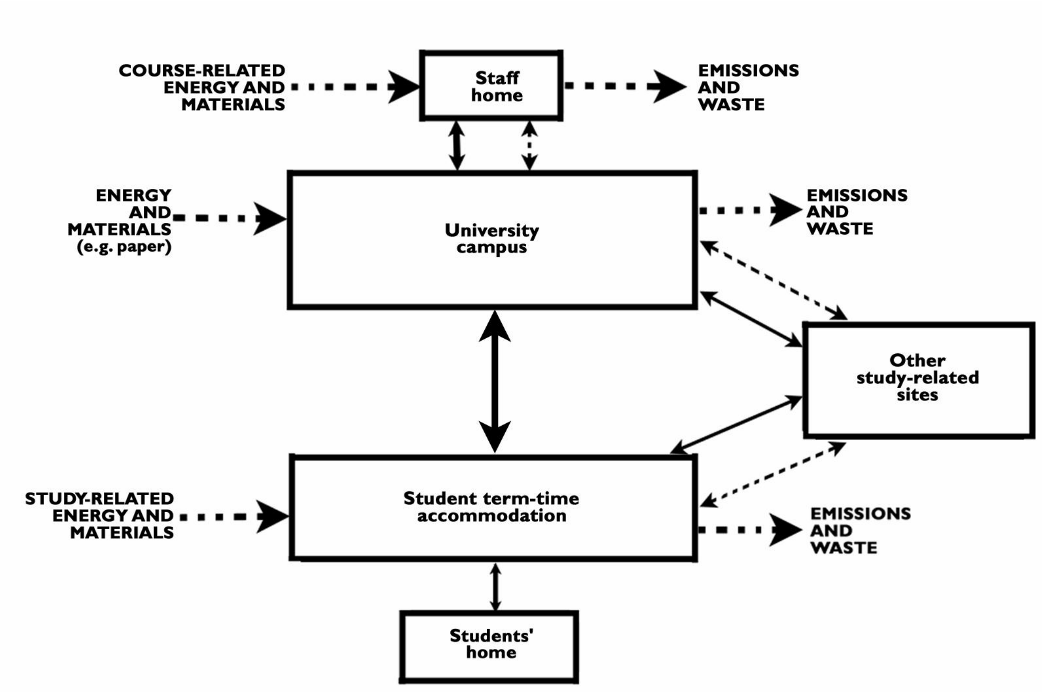

Figure 1

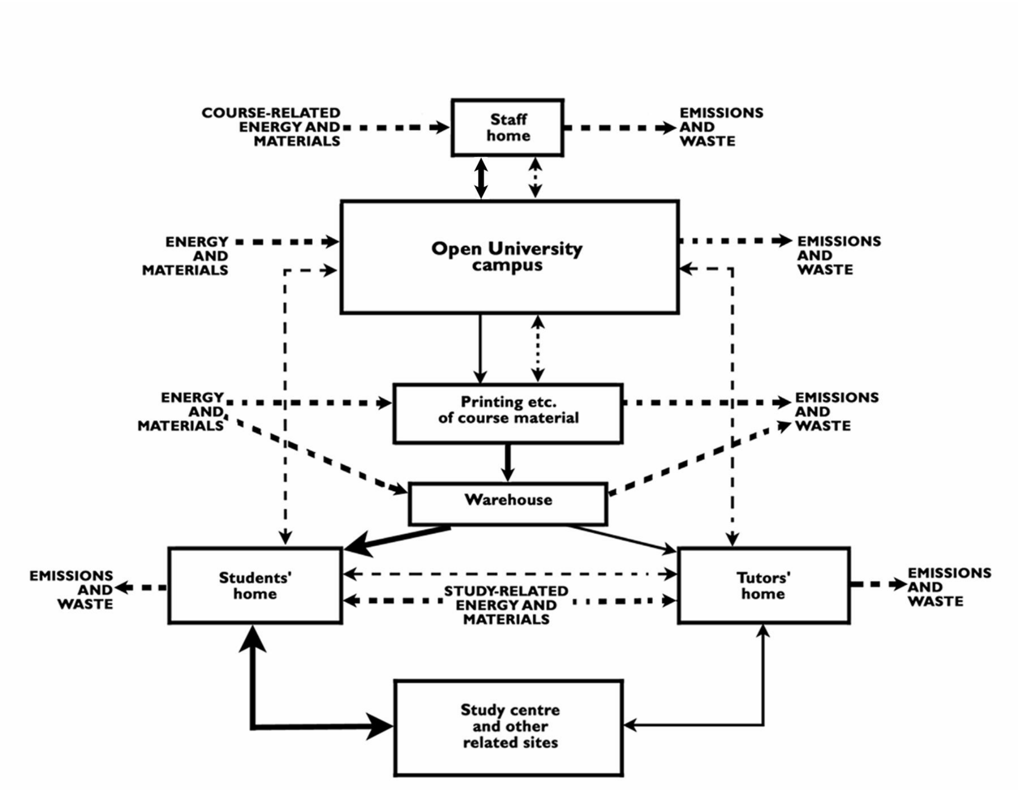

Figure 2

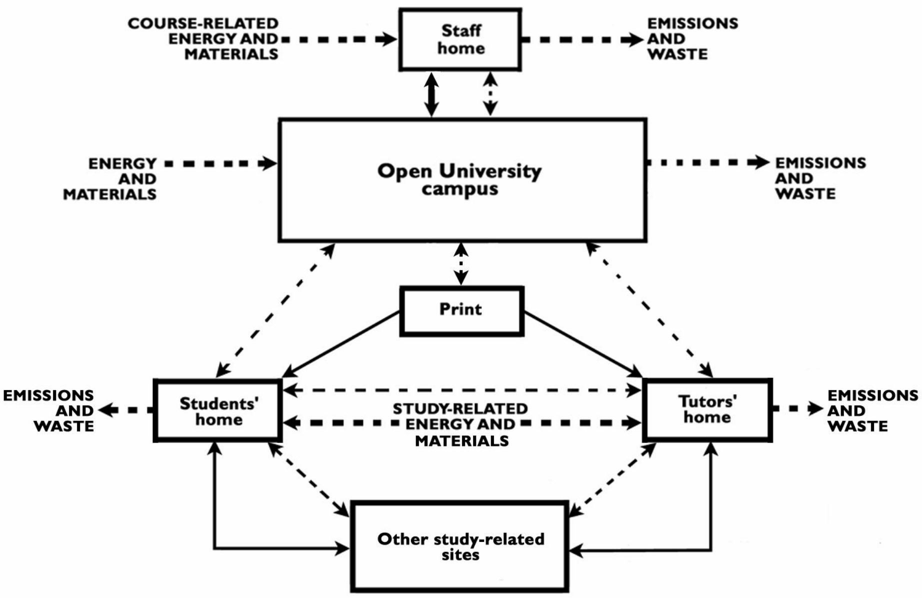

Figure 3

Key:

[FIGS 1-3 + KEY TIFF FILES ARE AVAILABLE IF REQUIRED]

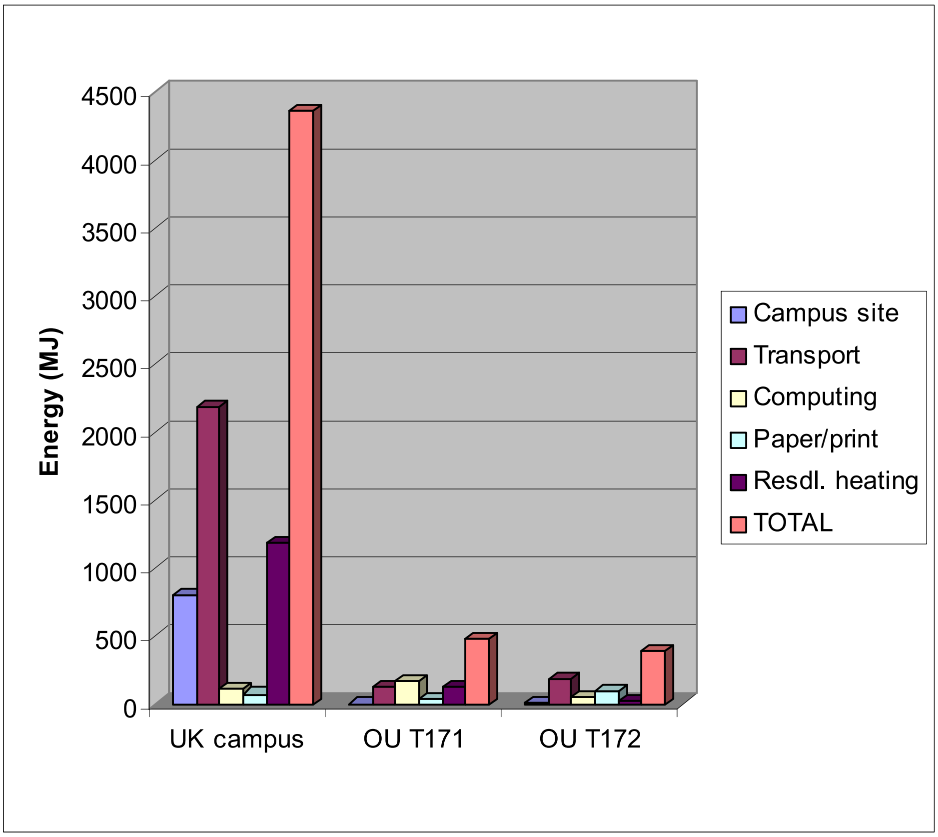
4500
4000
3500
3000
2500
2000
1500
1000
500
0
Energy (MJ)
UK campus
OU T171
OU T172
Campus site
Transport
Computing
Paper/print
Resdl. heating
TOTAL

Figure 4

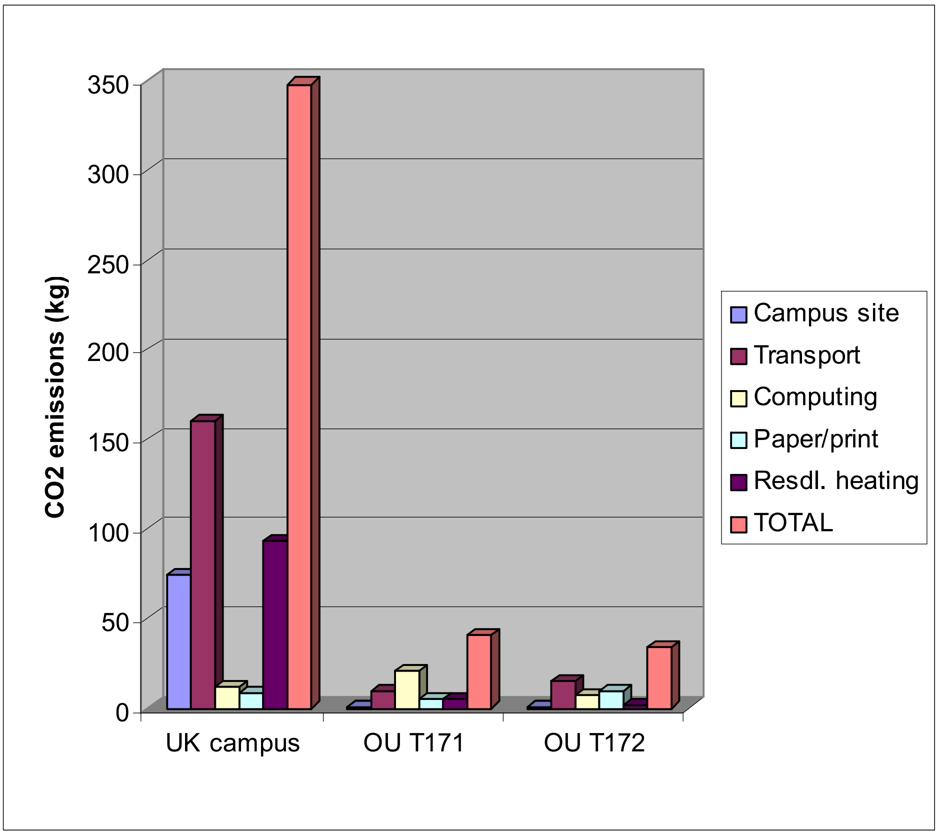

Figure 5

[FIGS 4-5 EXCEL FILES PROVIDED]