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Towards Sustainable Higher Education:

Environmental Impacts of conventional campus, print-based and electronic/open learning systems

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Higher Education and Sustainability

This paper reports the results of a study that forms 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 Weisäcker et. al., 1997). At least 90% ('factor 10') reductions are expected to be needed if allowance is made for the growing population of the developing South to reach decent living standards (Carley and Spapens, 1998; UNEP, 1999).

Several strategies have been proposed for reaching a 90% improvement, including the 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 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 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) as well as the Government's 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 involving twenty-five UK HE institutions (Forum for the Future, 1999) and its successor HE 'Partnership for Sustainability' scheme, started in 2000 (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. Full details of this work are in Roy, Potter and Yarrow (2002 and 2003) and are summarised in this paper. This considered the following HE delivery systems for both undergraduate and postgraduate courses:

- Campus-based full time courses;
- Campus-based part time courses;
- Mainly print-based, part-time distance learning courses;
- Partly electronically taught, part-time distance learning courses.

The latter two categories were mainly provided by the UK Open University (OU), but an electronically delivered course from a conventional university was also included.

Method of Investigation

The HE study involved a detailed environmental assessment of the key components of alternative course delivery methods. Campus-based full time courses involve face-to-face teaching, with students living at home or in term-time accommodation and attending lectures, etc. For most there is also travel between their main 'home' and term-time residences. Part-time students generally do not need term-time accommodation, but combine a limited time at campus with home-based study. The distance teaching system is very different. For the OU, specially developed course materials are sent to students for part-time study at home, with tutorial support by part-time tutors (Associate Lecturers). In the OU's electronically taught courses, teaching material is provided via a dedicated web site that partially replaces the physical production and distribution of course books and audio-visual materials. Likewise, a computer-mediated assessment and tuition system has largely replaced student/tutor travel to local study centres for optional face to face tutorials and the examination involved in the print-based courses. Similar arrangements exist for electronically delivered courses by other universities.

Crucial differences between the full-time campus, part time campus, part-time distance and part-time electronic delivery systems concern the need for course-related *travel*; the consumption of energy for *residential heating*, *campus sites* and *computing*; and use of *paper and printed matter* for course preparation and study. Data were gathered on these key areas, with a focus on energy consumption and CO_2 emissions, as these

provide a good proxy for major environmental impacts (Chambers et. al., 2000), including climate change. However, for some environmental issues (e.g. land take and biodiversity) other measures would be needed. Information to compare the systems came mainly from student/staff surveys of 20 UK courses involving the four HE delivery systems, together with national statistical information. 13 of the courses had an environmental focus or element. For reasons of confidentiality, apart from the OU courses, the names of the other universities are not specified.

It should be emphasised that the 'electronic' courses were not entirely electronically-delivered teaching. For example, the largely electronically taught OU T171 *You, your computer and the Net* was designed for pedagogical effectiveness to use Web based materials that guide study of two set books, supported by electronic tuition, conferencing and assignment submission. Equally the 'print-based' OU undergraduate course, T172 *Working with our Environment*, does offer optional electronic conferencing as well as face-to-face tutorials.

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 (including for electronic 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 (not discussed in this paper).

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. A total of 243 students were surveyed undertaking six undergraduate and four postgraduate full-time courses at campus universities. The three part-time courses at campus universities involved a smaller sample of 21 students.

For distance teaching, one undergraduate and two postgraduate mainly print-based OU courses were surveyed, with a total of 284 fully or partly useable student questionnaires being obtained. The survey for the partially electronically-delivered T171 was conducted in two stages (503 responses for Travel and 343 for Energy/Materials). A further 66 students returned information for two other part-electronic OU postgraduate courses and an electronic-delivered postgraduate distance learning course at another UK university.

55 and 65 Associate Lecturers responded respectively to the OU T172 and T171 tutor surveys, which was considered a good sample to represent the OU courses as a whole. Only one academic was surveyed for each of the campus courses (usually the lecturer who distributed the student questionnaires).

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 equivalent to 10 hours of total study, with 360 points required for an undergraduate degree and 180 points for a Masters degree.

Campus-based and distance learning courses

Perhaps the most startling result is that the distance learning courses we 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 full-time campus based university courses (see Table 1 and Figure 1 for the CO_2 data). Part-time study at campus universities cut energy and CO_2 emissions by 65% and 61% respectively per student per 10 CAT points compared to full-time campus study.

There are three main reasons for the cut in environmental impacts:

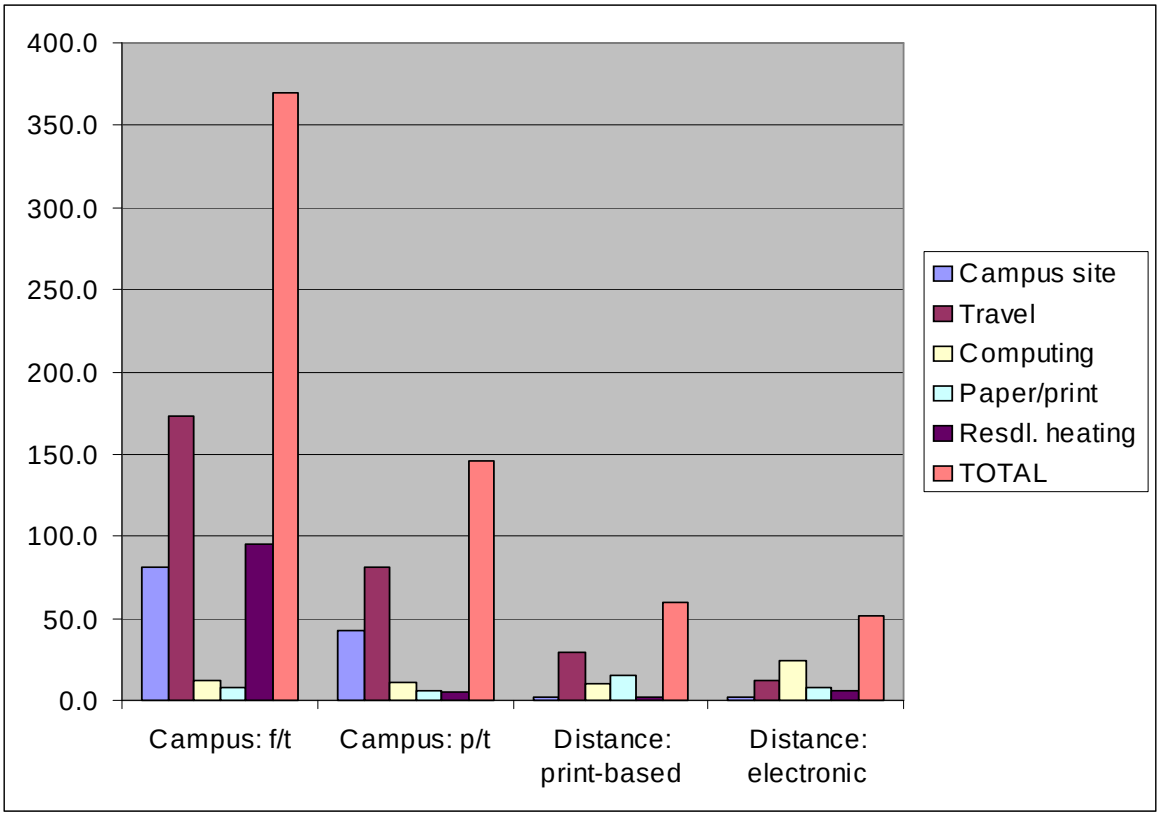
1) The elimination, inherent to distance learning, of much staff and student travel. There was also a substantial, though lesser, cut for part-time courses.
2) The reduction in campus site emissions per student due to economies of scale in distance learning systems.
3) The reduction in the residential energy for students who live in their main home while studying (which is generally true for part-time and distance students. Some campus students also live at 'home' during term, which has been allowed for in our study).

Although the purchase and use of computers and consumption of paper and printed matter differs between the various delivery systems, they account for a relatively small difference in the overall environmental impact.

Table 1: Average CO_2 emissions (kg per student per 10 CAT points)

	Campus site	*Transport*	*Computing*	*Paper/print*	*Residential heating*	*TOTAL*
UK campus full time	81.1	173.3	12.6	7.7	94.8	**369.5**
UK campus part time	43.0	81.0	10.7	5.7	5.1	**145.5**
Mainly print-based distance	1.8	29.6	10.1	15.7	2.1	**59.2**
Partially electronic distance	1.7	11.7	24.0	7.9	6.6	**51.9**

Figure 1: Average CO_2 emissions for different HE provision systems (kg per student per 10 CAT points)



Course related travel

There are striking differences in transport emissions in the different HE delivery systems. For full-time students at 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. 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 overseas students in particular, travel to and from 'home' could involve considerable distances, usually by air. This has implications for decisions whether to provide university accommodation which will tend to reduce students' term-time commuting distances or to encourage students to live at 'home' thus eliminating travel between home and term time residences.

For part-time campus students, travel-related emissions were cut to 47% that of full-time students, and that of distance taught students was even less, averaging 11% of the full-time campus students. With distance students studying from home, the total amount of travel was, of course, inherently much lower than at the conventional universities. The main reasons for OU students' travel were to enquire, register and prepare for the course, to obtain books, and for the print-based courses to attend tutorials and the examination. For the postgraduate distance courses there were also some field trips and day schools. For the electronic-delivered courses, there were further cuts in travel, but with some variation between the courses surveyed (e.g. some had home-based electronic examinations while others did not).

Campus site impacts

Official data from the UK Higher Education funding councils on student numbers, fuel costs and energy consumption were obtained for 9 of the 11 campus sites of the UK universities in the survey. Because the data on individual universities is confidential, only averages can be reported. In any case, since the focus of our study is on how the delivery of 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.

The funding council's database provided separate information on residential and non-residential energy consumption. For campus site impacts only the latter was used (with residential energy use incorporated into our residential energy data). An important consideration is that not all campus energy is used for teaching, so it was necessary to allocate a proportion of 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 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.

Using the 68% factor to adjust for teaching-related uses, the energy consumed for the full-time campus courses was about 883 Megajoules per student per 10 CAT points, which produces some 81 kg of CO_2 per student per 10 CAT points. The equivalent figures for the part-time courses were about half of these, as part-time delivery spreads campus impacts over a larger number of students

For the OU this scale effect is accentuated. Because its multi-media courses are mainly developed at its central campus and then presented (with updates) to large numbers of home-based students (from T171 with some 40 000 students over its five-year life to some 1200 students over six years for an OU post-graduate course), the site impacts per OU student per 10 CAT points are very low. These impacts 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. On average the impacts were 18 MJ and 2 kg CO_2 for both the electronically delivered and the print-based OU courses.

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 (only some 2%) than those of the full-time campus courses. This is mainly due to the economies of scale of teaching 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.

Residential energy consumption

For most full-time students an inherent part of studying at a campus university is living away from 'home' during term-time. This raises the issue of whether to include 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 full-time students living away from home involves a duplication of dwellings, *all* energy used in term-time residences is intrinsically part of that system.

For students living in university residences official data from the UK Higher Education funding councils on fuel costs and residential energy consumption of seven of the ten UK universities in the survey were obtained and was averaged at 1245 MJ and 110 kg CO_2 per student per 10 CAT points. 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* (DETR, 2000) provided statistical information on average household energy consumption and CO_2 emissions which was then scaled for the higher occupancy of student households giving 1410 MJ and 102 kg CO_2 per student per 10 CAT points.

For OU students who study from home, and full- or part-time 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 that we noted was the relatively high amount of additional heating claimed by students of the mainly electronically-taught courses. This produced an average of 4.4 kg of CO_2 per student per 10 CAT points, compared to 1.3 kg of CO_2 for the mainly print-based OU courses. We do not know for certain the reason for this difference. However, several responses to the qualitative part of the questionnaire suggest that it is probably due to students on electronically-delivered courses staying up late to connect to the Internet in order to access the course material, surf the Web, etc., and leaving their home heating on longer than normal.

Computing and paper and print consumption

To estimate computing impacts we obtained data on student and staff computer use (including on-line use), plus the embodied energy of computer purchases, associated with each course. There are differences in the environmental impacts of computing between the different methods of course provision. Not surprisingly, the electronically taught and tutored courses had the highest computing impacts, at nearly twice that of full-time campus students and three times that of OU print-based courses. Indeed, for the partially electronically delivered courses, computing was the major environmental impact at about 200 MJ and 24 kg CO_2 per student per 10 CAT points. The unusually low computing use recorded by part-time campus students is odd and is probably due to the small sample.

For paper use we obtained figures on handouts, books, etc. used in campus courses, and the printed course materials and books involved in the distance taught courses. Students and staff were also asked to estimate their own paper consumption. The total amount was used to estimate the embodied energy and emissions involved. Print based distance teaching consumed about twice as much paper as full-time campus and partially electronically provided courses. Interestingly, campus-based part-time study used the least paper. 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 undergraduate campus-based and distance learning courses

The key three factors of transport, campus site and residential energy account for most of the almost 90% difference in energy and emissions between the full-time campus based and the distance taught HE courses.

Electronic and print based distance learning courses

There was relatively little difference in the emissions between the paper-based and the partially electronically taught and tutored courses. Overall the electronically taught

distance learning courses showed a 12% reduction in CO_2 emissions*.* This modest improvement does not appear to bear out the claims made for the environmental benefits of electronically provided services, such as e-learning. Furthermore, when we originally examined only the OU undergraduate courses, we had a matched pair of otherwise comparable courses, T172 (paper-based) and T171 (part electronic). For these two, the part-electronic T171 produced 20% *higher* CO_2 emissions (Roy, Potter and Yarrow, 2002).

Once we added in the postgraduate distance courses, the results swung the other way, but the methods of delivering these courses are more mixed, with one involving only electronic tutoring – its course materials being print-based. This suggests a more complex situation, which our study has not entirely explained. However, it is clear that, at best, electronic delivery and tuition produces only a marginal environmental improvement.

Although electronic delivery cuts transport and paper use, there are counterbalancing factors. Obviously even partly electronically-delivered courses involve high usage of computers, including on-line use, and hence significant energy consumption. There is also significant embodied energy in the additional computing equipment that some students need to purchase to study such courses. We also 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.
2. Another less expected effect is the apparent wish of some OU T171 students to meet informally face to face, given the limited or no provision of formal face to face sessions, thus involving local travel. For the postgraduate courses there is no such travel evident. Possibly the students have learned to interact satisfactorily by electronic conferencing, etc.
3. Some OU T171 students appear to heat their homes more than normal for study purposes*,* probably while staying up late accessing the Internet during winter months. As noted earlier, for the postgraduate electronic courses, this effect was much lower.

In aggregate, all these factors serve to counteract much of the savings in energy and emissions from a reduced amount of printed matter and reductions in staff/student travel for the electronically-delivered distance courses compared to the mainly print-based courses.

Campus-based full time and part-time courses

Compared to campus-based full-time courses, campus-based part-time courses cut CO_2 emissions by over 50%. This is not as much as achieved by distance teaching, but is still very substantial. Like distance teaching, the main reductions in environmental impact are due to reduced travel, increased utilisation of the campus site and cuts in residential heating. We only surveyed a small number of part-time students in this study, and further work on the environmental impacts of this type of course delivery would be worthwhile.

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 delivery systems. One reason of course why this issue has been ignored is that it is eclipsed by other pressing questions such as the costs, educational effectiveness, social accessibility and socio-economic benefits of higher education.

This study shows that part-time study at a campus university produces about 35%-40% of the environmental impacts of full-time campus study. But the use of distance learning courses reduces the energy and emissions involved in providing higher education to only 10-15% of those from full-time campus-based systems. Our survey involved only one non-OU distance learning course and further verification from other distance teaching institutions would be useful.

De-materialisation through ICT?

The introduction of electronically taught and tutored courses seem to offer only minor environmental advantages over mainly print-based distance learning courses. This result runs counter to many claims that have been made about the 'de-materialisation' effects and resultant environmental benefits of information and communications technologies (ICT). This research questions the assertion that ICT necessarily produces much environmental gain. Instead, it has identified more significant factors in reducing environmental impacts. The reduction in energy and emissions in the distance learning system is due to the elimination of much of the travel and campus/residential buildings infrastructure required for campus systems. This is because distance learning systems increase the utilisation of existing infrastructure, such as students' homes, televisions, telephones, study centres, etc. that have been obtained 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 home-based students, whether mainly through print or electronic media. ICT will only produce environmental benefits if it helps to reduce transport needs and/or enables a service to share existing infrastructure, without incurring large 'rebound' effects.

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 rather than bringing them to the UK to study? The UK Open University already provides distance learning to overseas students in many countries via such partnerships.

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 20% of the total energy and emissions per full-time 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.

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, but the environmental impacts of this have not been adequately explored. Education policy must, of course, balance pedagogical, social, economic and environmental factors in deciding the future mix of campus full and part-time, distance learning, 'mixed mode' (e.g. Internet teaching plus intensive face to face weekends) and e-learning courses.

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