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Designing low carbon higher education systems:

Environmental impacts of campus and distance learning systems

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Abstract

Purpose

This paper summarises the methods and main findings of a study of the environmental impacts of providing higher education (HE) courses by campus-based and distance/open learning methods.

Methodology

An environmental audit, with data from surveys of 20 UK courses – 13 campus-based, 7 print-based and online distance learning courses – covering travel, paper and print consumption, computing, accommodation, and campus site impacts. Results were converted into energy and CO_2 emissions per student per 100 hours of degree study.

Findings

Distance learning HE courses involve 87% less energy and 85% lower CO_2 emissions than the full-time campus-based courses. Part-time campus HE courses reduce energy and CO_2 emissions by 65% and 61% respectively compared to full-time campus courses. The lower impacts of part-time and distance compared to full-time campus courses is mainly due to a reduction in student travel and elimination of much energy consumption of students' housing, plus economies in campus site utilisation. E-learning appears to offer only relatively small energy and emissions reductions (20% and 12% respectively) compared to mainly print-based distance learning courses, mainly because online learning requires more energy for computing and paper for printing.

Research limitations

Assumptions were made in order to calculate the energy and emissions arising from the different HE systems. E.g. it was decided to include all the energy consumed in term-time accommodation for full-time campus students while part-time campus and distance learning students live at home only requiring additional heating and lighting for study. Future studies could include more distance and blended learning courses offered by institutions other than the UK Open University and impacts other than CO_2 emissions.

Practical implications

Existing HE sustainability programmes should be broadened beyond considering campus site impacts and 'greening the curriculum'. Indeed, were HE expansion to take environmental impacts seriously, then part-time and distance education should be prioritised over increasing full-time provision. This appears compatible with the Leitch Review of Skills (2006) on continuing education and training for the UK workforce.

Originality/value

The only existing quantitative study of this issue.

Keywords

Energy, CO_2 emissions, higher education, distance learning, e-learning

Biographical Notes

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Robin Roy is Professor of Design and Environment at the Open University with a background in mechanical engineering, design and planning. Since joining the OU he has contributed to many courses, including Working with our environment: technology for a sustainable future; Design and designing; and Innovation: Designing for a sustainable future.

He is head of the Open University Design Innovation Group, which he founded in 1979. His research interests include the design of sustainable products and systems, including low and zero carbon household energy systems, the management of design and innovation, and creative thinking for invention and design. He has written or edited eight books and published over seventy research papers on these and other topics.

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Stephen Potter is Professor of Transport Strategy at the Open University. He graduated in Geography and Economics at University College London before taking a transport and urban design PhD at the Open University.

His research includes the design of sustainable products and systems, the diffusion of cleaner transport technologies and the development of sustainable transport policies. This also includes work on specific topics such as travel plans and the design of transport environmental taxation. He has written or edited eight books and over a hundred research articles and papers.

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Karen Yarrow is an independent research consultant with a background in psychology and ergonomics and further education teaching. She has worked with Professors Roy and Potter on the higher education and environment project described in this paper and on a recent project on consumer adoption and use of energy efficiency measures and renewable energy technologies.

Introduction: Higher education and the environment

This paper reports the results of a study that forms part of a wider project *(Factor 10 Visions)* exploring the potential for radical changes in product-service systems to address climate change and other global environmental issues (Roy, Potter and Smith, 2001). It is estimated that for the industrialised countries to tackle such issues, anything between 60% and 95% reductions in fossil fuel and other resource consumption will be needed during this century (RCEP, 2000; von Weisäcker et. al., 1997). The UK government has set itself a target of reducing the nation's carbon emissions by 60% from 1990 levels by 2050 (DTI, 2006), which is to become legally binding with interim targets. At least 90% ('factor 10') reductions are needed by 2100 if allowance is made for the growing population of the developing South to reach decent living standards (UNEP, 1999).

The *Factor 10 Visions* project seeks to explore what changes to existing product-service systems might deliver up to 90% emission reductions in three sectors – personal transport (see e.g. Potter and Warren, 2006), housing (see Roy, 2006) and higher education (HE).

A study of the environmental impacts of HE was included because this is a fast growing service sector, with for example the UK Government setting an expansion target of 50% participation of 18-30 year olds by 2010. HE is a growing, consumer of energy and resources and generator of emissions and waste. Estimated total energy use of the UK HE building stock in 2002/03 was 7.4TWh, which equates to 1.6% of the UK's industrial, commercial and public sector energy, or around 0.54 million tonnes of carbon emissions per year, some 2% of light industrial and commercial, public sector and farming emissions (Fawcett, 2005). Moreover, UK HE building energy is estimated to have risen by about 5% from 2000/01 to 2002/03. In addition, UK further and higher education establishments are estimated to produce some half a million tonnes of waste per year, about 3% of all UK commercial waste – some 100 kg per student, over half of which is paper and card (Waste Watch, 2005).

Environmental programmes for the HE sector have focused mainly on two issues: reducing energy consumption and waste on university and college campuses (e.g. Davey, 1998; Delakowitz. and Hoffmann, 2000; Sorrell, 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). Focusing on energy, the Carbon Trust Higher Education Carbon Management programme is providing support and guidance to enable thirty-three UK universities and colleges to reduce energy costs and carbon emissions from the buildings and vehicles they manage (Carbon Trust, 2006).

However, with the exception of Higher Education Performance Improvement project (HEEPI, 2005) most of these existing programmes do not consider the impacts of the whole HE system. For example, the significant impacts of staff and student travel are often neglected. The University of Bradford conducted a carbon survey of its operations which found that emissions from commuting traffic to the university were very similar to total emissions from its building stock (Hopkinson and James, 2005).

Emissions from international student air travel to and from UK universities have been estimated at around 652,000 tonnes carbon equivalent in 2003/04; an increase of 44% from 2000/01. Commenting on these estimates Fawcett (2005) observes that ‘there is little evidence that the sector has begun to acknowledge the environmental implications involved in recruitment of international students’.

One of the ways that the environmental impacts of HE could be reduced is through home-based open and distance learning, including e-learning courses provided online via the internet. This is because distance learning reduces or eliminates conventional higher education infrastructure and activities such as staff and student travel, buildings for teaching and term-time student accommodation. An increasing number of conventional UK HE institutions are providing distance learning courses, modules and degrees as part of their offering, either as an alternative or addition to face to face teaching. For example, Birmingham University offers numerous courses via an e-learning system called WebCT VLE, also used by many other UK universities including Coventry and Sheffield (Hobsons Distance Learning, 2007). World-wide there are many distance learning universities offering undergraduate and postgraduate degrees via print and electronic media, such as Indira Ghandi National Open University, India and Allama Iqbal Open University, Pakistan and a fast growing range of e-learning modules and courses, some of which are free access such as MIT’s OpenCourseWare open educational resource. However, no previous research exists on the environmental impacts of different HE course production and delivery systems, including the potential of e-learning methods to radically reduce energy consumption and emissions. Even the recent UK Higher Education Funding Council for England’s report on Sustainable Development in Higher Education (HEFC, 2005) fails to mention the potential of open and distance learning to reduce environmental impacts, despite the UK having one of the world’s first and largest distance learning universities, the Open University (OU).

The *Factor 10 Visions* higher education project fills this gap by assessing the total environmental impacts of different HE systems. Full details of this work summarised in this paper may be found in Roy, Potter and Yarrow (2002, 2004 and 2005). The project examined the following systems of providing both undergraduate and postgraduate courses:

- Campus-based full time courses;
- Campus-based part time courses;
- Distance learning part time courses provided mainly via printed materials;
- Distance learning part time courses delivered mainly or partly online via the internet.

The latter two categories were mainly provided by the (UK) OU, but a part-time e-learning course from a conventional university was also included in the study.

Methodology

The HE study involved a detailed environmental assessment of the key components of these alternative course delivery methods. Conventional campus-based full time courses involve face-to-face teaching, with students living at home or in term-time accommodation and travelling to attend lectures, to use libraries and laboratories, for field trips, 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 UK OU in its ‘classic’ mode, specially-developed printed course books and supplementary printed and audio-visual materials are mailed to students for part-time study at home, with tutorial support by part-time tutors (called Associate Lecturers) – a system often described as supported open learning. In the OU’s online courses, teaching material is provided via a 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 travel to local study centres for optional face to face tutorials and to take any examinations. Most OU courses now blend print-based and online materials and also face to face and online tuition. Similar arrangements exist for fully or partly internet delivered e-learning courses by other universities. Whether a course counts as mainly print-based or mainly online depends on the proportions of print, face to face and internet-delivered materials and tuition in the blend.

The four methods of HE course delivery were structured into systems diagrams, which identified the key differences between full-time campus, part time campus, part-time print-based distance and part-time online courses . The major differences identified concern the requirements for course-related travel; the consumption of energy for powering campus sites, for computing and for residential heating, and the consumption of paper and printed matter for teaching and learning. One approach to estimating the environmental impacts of these different course delivery might have been to use a ‘top down’ resource flow accounting methodology using available national statistical data as used in study of the direct and indirect carbon footprint of UK schools. This showed that energy consumption and transport were responsible for nearly 70% of schools’ carbon emissions with paper and furniture a further 10% (SDC, 2006).

Although there is UK national data on the energy use of campus buildings, which this project was able to use, there is no consistent information on the other key differences between the HE course delivery systems and new data needed to be gathered. Hence the approach used was a ‘bottom up’ method employing student and staff surveys of twenty UK courses covering the four HE delivery systems in order to provide a detailed inventory of activities for a given course. This provided information such as the amount of travel undertaken, the consumption of books and paper, the hours of computer use, etc. involved in studying the course. A wide range of studies and statistical sources were then drawn upon in order to estimate the energy and CO_2 emissions of these activity and consumption patterns. For example data were obtained on the life-cycle energy used to produce paper and books, to manufacture computers and use them in both standalone and online modes, and for commuting by various forms of transport. Data were also obtained on energy use for home heating and for mailing print materials (see Roy, Potter and Yarrow, 2002 for full details).

Energy consumption and CO2 emissions were used as the main indicators of climate change and also provide a proxy for some other key environmental impacts such as power station and vehicle emissions (Chambers et. al., 2000).

In detail, the 20 courses surveyed were:

- 10 full-time face to face campus courses. 6 were undergraduate and 4 were at masters level);

- 3 part-time face to face campus courses. 2 were undergraduate and 1 was a masters. 2 were part-time versions of the full-time campus courses;
- 3 part-tine distance taught, mainly print based OU courses. 2 were postgraduate, but the majority surveyed were taking the 1 undergraduate course, T172;
- 4 part-time distance taught courses, 3 OU and 1 non-OU, delivered partly or wholly online. 3 were postgraduate, but again the majority surveyed were taking an undergraduate OU course, T171.

The sample produced an appropriate balance of campus based and distance taught 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 courses had an environmental focus or element. For reasons of confidentiality, apart from the OU courses, the names of the other universities are not provided.

It should be emphasised that while the non-OU e-learning course was delivered almost wholly online, to make best use of different media the OU e-learning courses were not entirely provided online via the internet. For example, the largely online OU introductory computing course T171 *You, your computer and the net* was designed for pedagogical effectiveness as a blend of specially prepared web based materials, two printed set books, supported by online tuition, conferencing and assignment submission. Equally the mainly print-based OU undergraduate introductory environment course, T172 *Working with our environment*, does offer optional online messaging and discussion via student and tutor computer conferences as well as face-to-face tutorials at local study centres.

Student and staff questionnaires

To obtain the new information required to compare the four HE delivery systems questionnaires were developed for students and academic staff, and in addition for the OU the Associate Lecturers, for the courses concerned. These covered the course production, delivery and study activities by these groups linked to key environmental impacts. 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, visit libraries, purchase books, etc.
- The paper consumption associated with computing for the course, including for online courses, downloading and printing material from the course web sites.
- Paper used for photocopying, assignments, etc.; in books and other publications purchased for the course; and/or to provide OU printed course materials.
- Use of residential heating in connection with study of the course.

Information was also gathered on students' behavioural changes arising from completing the course that have environmental implications. (This aspect is not discussed in any detail in this paper but is the subject of a separate publication: Yarrow, Roy and Potter, 2002).

The campus lecturer and OU Associate Lecturer surveys asked similar questions to the above 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 full-time courses at conventional campus universities. The part-time courses at campus universities involved a smaller sample of 21 students.

For distance teaching, three mainly print-based OU courses were surveyed, with a total of 284 fully or partly useable student questionnaires being returned. The survey for the OU's partly online introductory computing course was conducted in two stages; producing 503 responses for data on course related travel and 343 responses concerning energy and paper consumption. A further 66 students returned information for two other part online OU postgraduate courses and an online postgraduate course at another UK university catering for part-time students.

55 Associate Lecturers completed questionnaires about the travel, computing, etc. involving in tutoring the OU introductory environment course and 65 ALs responded for the introductory computing course, which was considered a good sample to represent the OU courses as a whole. In addition an estimate was obtained, based on records kept by a representative course team member, of the travel, computing, paper, etc. required by the full-time OU staff in preparing and presenting the courses.

The campus lecturer questionnaires sought parallel information on travel, computing, paper and additional household energy consumption involved in administering, preparing, teaching, and assessing the courses concerned. Only one campus lecturer per course was surveyed, who was also asked what proportion of the course their input represented. All the information was then factored up to make an estimate of the energy and carbon dioxide emissions for all the staff involved in the course's delivery.

Key results

As noted above, the information on activities associated with staff preparing and delivering the courses, and the students in taking them, was used to calculate the energy and CO_2 emissions associated with each one. 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. Under 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. This allowed the results between different course delivery systems to be compared in a systematic manner.

Campus-based versus distance learning courses

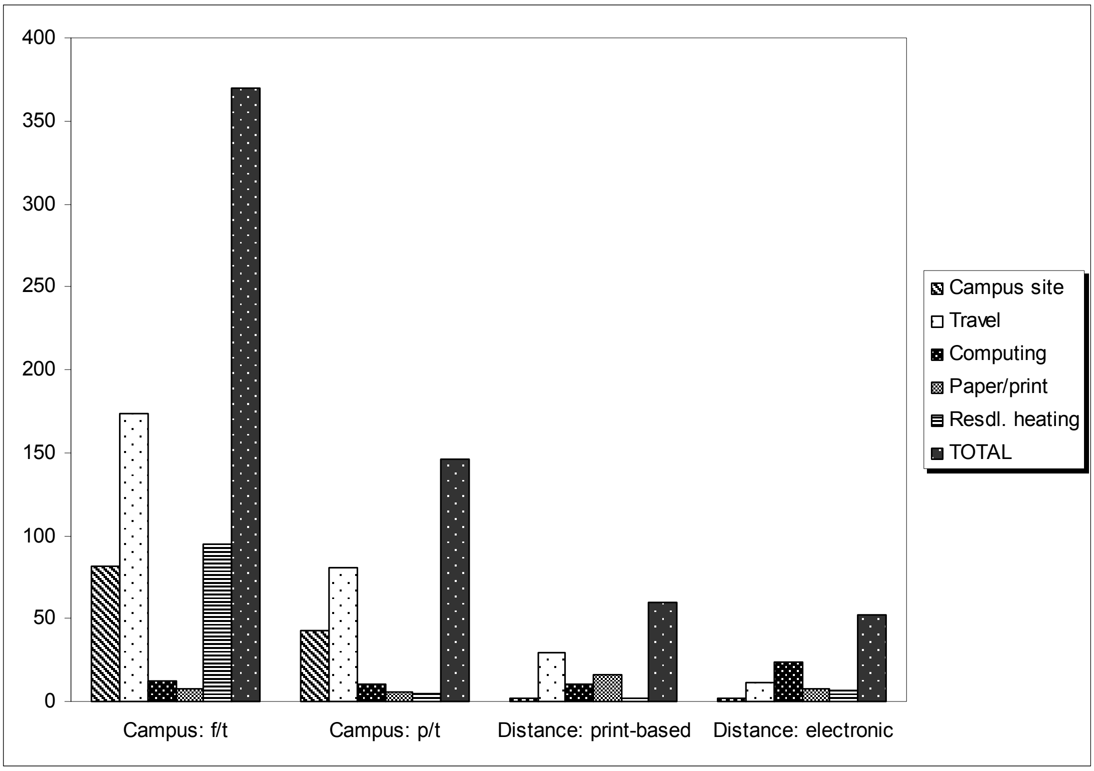
The overall results for the energy consumption and CO_2 emissions from analysing the survey and auditing data are summarised in Table 1 and Figure 1. The patterns for energy and associated CO_2 emissions are very similar.

Table I: Energy consumption of campus and distance learning courses (average MJ per student per 10 CAT points)

ENERGY (MJ)	Campus site	Travel	Comp-uting	Paper/print	Resdl. heating	TOTAL
Campus: full time	883.0	2304.4	119.7	66.3	1193.5	4567.0
Campus: part time	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

Notes: 1 kWh = 3.6 MJ
1 CAT point is equivalent to 10 hours total study. 360 CAT points are required for an UK undergraduate degree and 180 CAT points for a Masters degree.

Figure 1: Carbon dioxide emissions for campus and distance learning courses (average kg CO_2 per student per 10 CAT points)



The main findings were:

Compared to full-time campus-based courses, students undertaking part-time, face to face study at campus universities reduce energy use and CO_2 *emissions by 65% and 61% respectively per student per 10 CAT points*. This was due to three key factors:

1. The reduction in the residential energy for students who live at their main home while studying. (A proportion of full time campus students also live at 'home' during term, which has been allowed for in the analysis.)

2. A significant reduction in travel. (Even though part-time students may travel further to study, a reduction in the frequency of trips means overall travel is cut by more than half.)

3. A more intensive utilisation of campus facilities.

Only a relatively small number of part-time students were surveyed in this study, and further work on the environmental impacts of this type of course delivery would be worthwhile to confirm this result.

The above factors are also present for students taking the part-time print-based and online distance learning courses, but with the environmental improvements being even greater, particularly the reduction in campus site emissions per student due to large economies of scale in distance learning systems. There is also a further reduction in transport emissions with the elimination, inherent to distance learning, of much staff and student travel. The net result is that *the distance learning courses on average involved 87% less energy consumption and produced 85% fewer* CO_2 *emissions per student per 10 CAT points than the full-time, face to face campus based university courses*.

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

The following sections report these results in more detail.

Course related travel

There are striking differences in transport emissions between the different course delivery systems. For full-time students at conventional universities, transport required to study 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.

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. Since students of distance learning courses usually study at home (or at places they normally travel to anyway), the total amount of course required travel was inherently much lower than at the campus 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 at local centres, which for some students could involve round trips of 50 km or more. For the postgraduate distance courses there were also some field trips and day schools. With online courses, there were further cuts in travel, (e.g. some had home-based examinations or final assignments conducted electronically).

These results include the emissions from travel for course preparation and teaching purposes obtained for the campus lecturers, the OU central staff and Associate Lecturers.

Campus site impacts

Official data from the Higher Education Funding Councils for England and Scotland on student numbers, fuel costs and energy consumption were obtained for 9 of the 11 campus sites of the UK universities in the study. Because the data on individual universities is confidential, only averages can be reported. In any case, as the focus of our study is on how course delivery affects environmental impacts, it is not really concerned with site-specific variations.

The Funding Councils' databases 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). Not all campus energy is used for teaching, so it was necessary to allocate a proportion to research and other non-teaching activities. Data on the English universities in our survey from the Higher Education Funding Council for England (HEFCE) indicated that on average teaching accounted for about two-thirds (68%) of the total for HEFCE funding at these institutions.

Using the 68% factor to adjust only 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 generally spreads campus impacts over a larger number of students. (Our campus energy consumption was verified in another study which gave the average gas and electricity consumption for teaching and research in 22 establishments as 2241 kWh per full-time student equivalent – Waste Watch, (2005)). Adjusting for teaching energy and given that a full-time student generally studies 60 CAT points per year; this translates into 914 MJ per student per 10 CAT points.)

For the UK OU this scale effect is greatly accentuated. Because its courses are mainly developed at its central campus and then presented, with updates, to large numbers of home-based students (ranging 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 presentation. On average the impacts were 18 MJ and 2 kg CO_2 for both the partly online and the mainly print-based OU courses.

It is clear that campus site energy and emissions per student per 10 CAT points for the distance 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.

This assumption may over-estimate the residential energy requirements of campus-based systems, but even if it were halved, energy consumed in term-time student accommodation for a full-time campus course would still exceed that for other modes of course delivery by some five to ten-fold.

For students living in university residences 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 adjusted 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 Associate Lecturers, we asked for additional home heating associated with teaching the course. The survey asked for the fuel 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 online 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 are unsure of the reason for this difference. However, several responses to the qualitative part of the questionnaire suggest that it is probably due to students of online 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 online use), plus the embodied energy of computer purchases, associated with each course. Not surprisingly, the online courses had the highest computing impacts, at nearly twice that of full-time campus students and three times that of OU mainly print-based courses. Indeed, for the mainly internet-delivered and tutored courses, computing was the largest 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, figures were obtained on handouts, books, etc. used in campus-based courses and the printed course materials and set books involved in the distance taught courses. Students and staff were also asked to estimate their own paper consumption, which was particularly important for courses delivered online. The total amount was used to estimate the embodied energy and emissions involved, plus the energy involved in mailing printed distance learning materials. The different patterns of paper use resulted in print based distance teaching consuming about twice as much energy as campus and online courses. 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.

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.

Print based versus online distance learning courses

There have been many claims that 'de-materialisation' from the use of information and communications technologies (ICT) will provide substantial environmental benefits (e.g. Hilty et al., 2000). As such it would be expected that print-based distance learning courses would have higher environmental impacts than online courses due to the physical production and distribution of learning materials rather than delivering them electronically. In practice, the difference is relatively small. Overall the mainly or partly online courses showed a 20% reduction in energy and a 12% reduction in CO_2 emissions compared to the mainly print-based courses. 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 this study originally examined only the OU undergraduate courses, it involved a matched pair of otherwise comparable courses, T172 (mainly print-based) and T171 (mainly online). For these two, the mainly online T171 produced 20% *higher* CO_2 emissions (Roy, Potter and Yarrow, 2002).

Once the postgraduate distance courses were added to the sample, the results swung the other way, but these courses had different blends of print and online provision, with one involving only online tutoring – its course materials being print-based. This suggests a more complex situation, which our study has not fully explored. However, it seems that, at best, online delivery and tuition produces only a marginal improvement in energy and CO_2 emissions over print-based distance learning.

Although online delivery cuts transport and paper use, there are counterbalancing factors. Clearly even partly online courses involve considerable computing, including internet use, and hence high energy consumption. There is also significant embodied energy in the additional computing equipment that some students need to purchase to study such courses. Our study also found three examples of so-called 'rebound' effects of online learning:

1. The preference of many students to download and print off a high proportion of online 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 materials on the course website.

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 tutorials, thus involving local travel. For the postgraduate courses there is no such travel evident. Possibly by the time they reach postgraduate study, the students have learned to interact satisfactorily by online conferencing, etc.

3. As noted earlier, 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. For the postgraduate online 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 mainly online courses compared to the mainly print-based courses.

Conclusions

This project has concentrated on a largely ignored issue, namely the relative environmental impacts of different methods of delivering HE courses, whether by full or part-time face to face teaching, by print-based or online distance learning, or by blends of these methods. One reason why this issue has been ignored is that it is eclipsed by other questions such as the costs, educational effectiveness, social accessibility and socio-economic benefits of HE, whether by conventional or distance methods of delivery. The other main reason is that almost all policy and practice regarding HE and the environment has focused on conventional campus institutions and has thus concerned reducing the impacts of the campus estate and/or 'greening' the curriculum. This is probably the first study to examine the relative environmental impacts of alternative systems of course delivery.

One of the main results of this project is that *studying a part-time face to face course at a conventional campus university involves about 35%-40% of the energy and* CO_2 *emissions of taking an equivalent full-time course*. However, the most striking finding is that *distance learning reduces the energy and emissions involved in studying a higher education course dramatically to only 13%-15% of those arising from an equivalent full-time, face to face campus-based course*.

De-materialisation through ICT?

Another key finding is that online courses seem to offer relatively minor environmental advantages over mainly print-based distance learning courses. This result runs counter to many claims that have been made about 'de-materialisation' from the use of ICT. This study questions whether ICT necessarily produces much environmental gain for HE. Instead, it has identified why distance learning systems, regardless of the media used, have low environmental impacts; namely elimination of much of the travel and built infrastructure required for campus-based systems. This is because distance learning systems produce eco-efficiency gains by the greater utilisation of existing infrastructure, such as students' own homes and ICT equipment, and educational buildings used as study centres. Another key factor is the economies of scale in the utilisation of campus infrastructure when developing distance learning courses that are offered to large numbers of home-based students, whether mainly through print or electronic media.

Changes in student attitudes and behaviour

The energy and emissions directly associated with taking a course only account for a proportion of a student's impacts on the environment. The course could result in changes in students' attitudes and behaviour that reduces, or increases, their environmental impacts. Such behavioural effects are clearly dependent on curriculum content and so should be considered entirely separately from the impacts of different course delivery systems, which is the focus of this paper.

Nevertheless, two-thirds of the courses we surveyed had an environmental content and, in particular, we identified 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 (Yarrow, Roy and Potter, 2002; Crompton, Roy and Caird, 2002). Such examples of changes in behaviour provide support for the emphasis placed on ‘greening the curriculum’ in most programmes on HE and sustainability.

HE and environmental Policy

This study has raised other significant policy issues for the HE sector. Like Fawcett (2005) we have identified that air travel associated with overseas students studying in the UK is an important environmental impact. Recruiting overseas students to study in the UK is strongly promoted 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 UK OU does for some of its courses) rather than bringing them to the UK to study?

This study also notes a very wide range in campus impacts, with the most efficient campus consuming 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 accounts for about 20% of the total energy and emissions per full-time student per 10 CAT points. The emphasis placed on the campus site in existing schemes for ‘greening’ HE needs to be balanced by considering other elements of the system, notably student travel and housing, the impacts of which are widely ignored in policy documents on sustainability in HE.

Regarding the provision of HE courses online, the pedagogical issues involved are being debated and researched, but the environmental implications have not been adequately explored.

Overall, HE policy must, of course, balance pedagogical, social, economic and environmental factors in deciding the mix of campus full and part-time, ‘blended’ (e.g. online plus face to face learning), distance and e-learning courses. It is notable that the recent major UK report on Sustainable Development in Higher Education (HEFCE, 2005) contains no mention of the very significant environmental benefits of distance learning or e-learning. Were the expansion of HE to take environmental impacts seriously, then part-time and distance education should be prioritised over increasing conventional full-time campus-based provision. This appears compatible with the recommendations of the Leitch Review of Skills (2006) which emphasised the need for continuing education and training up to degree level of the UK workforce.

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