

***Appendix 1***

**Methodology of the  
*Factor 10 Visions* Higher Education Study**

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## 1. Introduction

This Appendix explains the methods used and methodological issues raised in undertaking the higher education study. More detailed information is contained in a series of *Technical Working Papers* for the project, which have been archived by the research team. As explained in Section 2.1 to the main report, this study has used an environmental assessment method that has:

- Developed a systems model for the delivery of HE courses, covering both the components and transport/telecommunications linkages between them.
- Identified the differences between the systems, upon which the project has concentrated.
- Undertaken an environmental audit.

The research process was iterative and adjustments were made until a satisfactory result was achieved. In addition areas of major impact sometimes varied between the HE systems under examination. For example the environmental impacts of the campus site were more important for conventional universities than in the Open University system. In one case there was a preliminary scoping study to see if the magnitude of environmental impacts generated warranted more in-depth investigation.

To undertake the audit required the use of several research methods. These included accessing existing databases, compiling existing data into consistent forms, and primary data gathering via questionnaire surveys of students and staff.

As explained in the main report, the three modes of delivering HE courses were:

- Conventional system – face-to-face teaching of full-time courses at campus based universities;
- Open University system – mainly print-based distance/supported open learning;
- Open University system – mainly electronically taught distance/supported open learning;

It is intended to cover part-time conventional systems in an extension to the current study.

The broad methodological approach was explained in Section 2 of the main report and the purpose of this Appendix is to provide details regarding how this methodology was applied in practice.

## 2. Models of conventional and distance learning

Simplified systems models and descriptions of the three higher education delivery modes were presented in the main report (Figures 1-3). An underlying assumption of this study is that the principal environmental impacts of the three HE course delivery modes can be identified through such a simplified system model. This also has the effect of identifying appropriate boundaries.

## 3. Inventory units of measurement

An important issue in undertaking any comparative assessment concerns the units of measurement to be adopted. For this project, two main decisions were involved. The first was to use two major indicators of environmental impact: fossil fuel energy consumption and associated CO<sub>2</sub> emissions. A more detailed inventory of environmental impacts (e.g. covering other emissions and issues like toxic waste) would have been possible, but this would have been far more complicated and beyond the resources available for this study. In similar situations, energy and CO<sub>2</sub> emissions have been used as representing, respectively, resource use and major environmental impacts (Chambers et. al., 2000).

However the project methodology was designed to allow the later addition of other environmental impacts if desired. We purposefully separated our assessment process into first estimating the source of the environmental impact, and then converted it into energy and CO<sub>2</sub> emissions. For example, travel generation was estimated in terms of the distance travelled by car, bus, train etc. We then applied figures for fuel consumption and emissions for each travel mode to arrive at figures for energy and CO<sub>2</sub> emissions (e.g. as shown in Table 2 of the report). It would be perfectly possible to return to the distance data to estimate other environmental indicators, such as NO<sub>x</sub>, particulates, carbon monoxide, land take etc.

For energy use, the main measure used was *delivered energy*, as this was the measure provided by most of our data sources. For transport and embodied energy in computer equipment, our sources provided figures for *primary energy*. This allows for losses in the production and delivery system and is particularly important where electricity is concerned (with UK generation efficiency from primary fuels in 2000 being 41%). The use of primary energy for transport makes only a small difference compared with delivered energy (the latter being about 10% less for petroleum based transport fuels). Ideally it would have been better to be consistent, but this mix of primary and delivered energy was what our sources of information provided, and the differences were not large enough to make a significant difference to the results of our study.

A second major decision concerned how the environmental impacts should be represented to permit a comparison between the different types of HE courses in this study. Some were courses involving more study time, activities and resources, and hence environmental impacts, than others. To represent the information on a comparable basis we used the standard UK Higher Education *Credit Accumulation and Transfer* (CAT) point system. One CAT point is equivalent to 10 hours of student study (including private study, essay writing, revision for examinations, etc.). A full degree course is valued at 360 CAT points, and the majority of Masters degrees at 180 CATS points.

Our core indicator therefore became *average energy and CO<sub>2</sub> per student per 10 CAT points*. This required asking our academic respondents for the CAT points ratings of the courses surveyed. In the four cases where this was unavailable we made an estimate of the CAT points of the course from the information supplied (e.g. a course was stated as representing a particular proportion of an undergraduate degree).

Some environmental impacts in our inventory, like heating and lighting of non-residential buildings on campus sites, were obtained at the University level and, likewise, these had to be expressed per student per 10 CAT points. To do this, information on the annual number of full-time equivalent students was obtained from official statistics, with one year taken to equal 120 CAT points.

The definition of 'students' also required careful consideration, particularly in the context of the Open University part-time study where there can be significant dropout as a course progresses. For the OU, the number of students was defined as those who took the courses' first assignment, rather than those initially registered to take the course.

It should also be noted that, for the purposes of presentation, figures in the report have been rounded. This appendix also provides some indications of the levels of accuracy obtained. In general we sought to obtain and verify figures to a level of accuracy appropriate for the study. However, the rounded figures should not, in some cases, be taken as representing too high a level of accuracy. An example might be the reported figure of (say) the average weekly consumption of 191 sheets of paper per student per 10 CAT points. The estimation method used (as explained later in this Appendix) relied on the student respondent's estimates and our framing the question in the best way to help them to do that.

For calculating the weight of paper, energy and CO<sub>2</sub> emissions, accuracy to the nearest 10 or so sheets would be adequate, but we have reported the actual rounded figures.

## 4. Data sources of campus and residential energy/emissions

### 4.1 Campus energy use

As noted in the main report's Section 3.1 on *Campus site impacts*, the HEFCE and SHEFC database was consulted to provide information on the number of FTE (full time equivalent) students, and the amount that each university spent on oil, gas, and electricity for their campuses. We had direct information for the Open University from our own Estates Department.

This provided information on the expenditure on fuels. We therefore had to use pricing data to convert this into amounts of fuel, from which delivered energy values and CO<sub>2</sub> figures could be calculated. The calculations are detailed in the Box.

#### **Campus energy use and CO<sub>2</sub> calculations**

##### **Fuel Oil**

1 litre medium domestic fuel oil = 10.82 kWh<sup>1</sup>

Fuel Oil price: 17.73p per litre.<sup>2</sup>

So oil is 17.73p for 10.82 kWh, which is about 1.7 p/kWh

##### **Gas**

Gas price is 1.555p/kWh<sup>3</sup>

##### **Electricity**

Day units = 4.721 p/kWh Night units = 2.453 p/kWh<sup>4</sup>

Assume day units = 70%, night units = 30% (for the OU it is 69% day 21% night).

Average cost  $0.7 \times 4.721 = 0.3 \times 2.453 = 4.041$  p/kWh

##### **CO<sub>2</sub>**

The average over 8 campuses for which we had adequate data was:

Oil = 10% kWh/yr at 0.25 kg CO<sub>2</sub> /kWh

Gas = 33% kWh/yr at 0.19 kg CO<sub>2</sub> /kWh

Electricity = 56% kWh/yr at 0.44 kg CO<sub>2</sub> /kWh

*Mean emissions =  $0.10 \times 0.25 + 0.33 \times 0.19 + 0.56 \times 0.44 = 0.33$  kg CO<sub>2</sub> /kWh*

These conversion factors were then used to convert both the residential and non-residential campus energy fuel costs provided in the HEFCE data.

<sup>1</sup> Oberg, E and Jones, F.D (1964) *Machinery's Handbook*, 17<sup>th</sup> edition, The Industrial Press, p 1794.

<sup>2</sup> OU data for OU Belfast Office, J.Hodgson, Personal communication, Aug. 2001

<sup>3</sup> OU data for all OU sites, J. Hodgson, Personal communication, Aug. 2001

<sup>4</sup> OU data for OU Walton Hall, J. Hodgson, Personal communication, Aug. 2001.

The information on fuel expenditure was not complete for all campuses involved, so an average was taken for the campus universities surveyed for which complete data were available. This average was then applied to each individual university. Furthermore, the information for each campus is confidential and the use of individual campus data would have therefore been inappropriate.

We could have applied the average only to those sites for which there was incomplete data and used actual site-specific figures where this was available. However, the problems of incomplete data and confidentiality raised an important methodological issue. The focus of our study is on how the *mode of delivery* of HE courses affects environmental impacts. There are a number of other factors affecting energy consumption that will vary considerably between individual campuses. In particular, some will have older buildings than others, and those located in colder parts of the country will consume more for heating than those in milder areas. These factors are not a consideration of our study and so it seemed appropriate to correct for such regional and site-specific variations by using an average for all campus energy and emissions.

This principle led us in some other cases to also use averaged information. As will be noted later, this applied to car engine sizes, where there was some variation probably due to income factors.

## **4.2 Non-residential campus energy use**

Campus energy use was split between residential accommodation (considered below) and all other non-residential campus uses. In considering non-residential energy use, there was a question of what proportion should be attributed to student study. This is a significant methodological issue as we discovered that campus site energy represented a large proportion of the total environmental impacts of campus university courses. A university campus is not only used for teaching students, but for research and other purposes. As noted in the main report, the best and most readily obtainable data was of the annual teaching and research funding provided by the HEFCE to the seven English universities in our survey. On average teaching accounted for about two-thirds (68%) of the total funds for HEFCE teaching and research. (This compares to a figure of 75% funding for teaching and 25% for research, including non-HEFCE research funds, at all UK HE institutions (AUT, 2001).) It is assumed that administrative functions are distributed between teaching and research in roughly in the same proportion.

Having arrived at our 68% figure for non-residential campus energy use that could be allocated to teaching, this was then divided by the number of FTE (full time equivalent) students to produce the non-residential energy consumption per student per annum. This was further multiplied by 10/120 to produce our standard measure of 'per student per 10 CATS points' (full time study is equivalent to taking 120 CAT points per annum).

## **4.3 Residential energy use**

It was important to separately identify the energy use of residential student accommodation as this represents an important difference between full and part-time modes of course delivery. The research team debated whether student residential accommodation should be included or not in the audit. Energy used in student accommodation is in addition to that in their permanent home-place, so this is an intrinsic part of the full-time course system. The decision was therefore taken to include all term-time residential energy consumption of campus university full time students, but to make it a clearly identifiable factor. It would therefore be possible to conduct a sensitivity analysis comparing results with and without residential energy should this be necessary.

To obtain an overall average, we identified the numbers of students who lived during term in the following types of residences:

- university accommodation;
- flats, houses and lodgings;
- their main, usual or permanent home.

Given the proportion of students in each group, we estimated the average energy consumption involved for each of these groups and then, as shown in the main report (Table 16), calculated a *weighted* average per student per 10 CAT points.

For the OU and other part-time students, who normally live in their usual home when studying, and for full-time students who lived in their usual home during term, total residential energy use was not considered to be relevant for our audit. It was assumed that home energy consumption would occur whether or not the person was taking a course. In such cases we included in the audit only any *additional* home energy that arose from study purposes (see below).

#### 4.3.1 Energy use in university residences

For students living in university residences, total residential energy was obtained from the HEFCE database and divided by the number of residential places available. The latter figure was not in the database and had to be obtained separately from the accommodation officers of the universities concerned. As noted in the main report, for students living in university residences, the mean energy consumption for the five universities for which the necessary data could be obtained was about 7,050 kWh (25,380 MJ) per year per residential place. This equates to 1,220 MJ per student per 10 CAT points, since a year's study over a 30-week period during the heating season is worth 120 CAT points. Using the same method as for the campus sites (as detailed above), the data on annual purchases of gas, oil and electricity was used to estimate the average fuel mix of the university residences and hence calculate emissions of approximately 105 kg CO<sub>2</sub> per student per 10 CAT points.

#### 4.3.2 Energy use in non-university accommodation

We needed to include energy and CO<sub>2</sub> emissions from heating and lighting in non-university student accommodation (shared houses, flats, lodgings, etc.). The campus student questionnaire did not gather this information, which would have been complex and difficult to obtain and so we made an estimate using generic figures. As mentioned in section 3.5 of the main report, we used the *Energy Report* of the *English House Condition Survey* (DETR, 2000). This indicated that the average energy consumption of the English housing stock in 1996 (the most recent survey year) was 24,440 kWh per dwelling per year. The mean household size in 1996-7 was 2.4 persons. For students living in shared accommodation, we assumed a higher occupancy of 3 persons per household. We then used the average energy consumption per dwelling over a 30-week term-time occupation during the heating season. It was assumed that the residential heating for the students would occur for term times only, involving 12 weeks in October to December, 11 weeks January to March and 7 weeks April to May, making the total of 30 weeks in all. This produced the figure of 1410 MJ per student per 10 CAT points. Likewise the *English House Condition Survey* gives mean CO<sub>2</sub> emissions of the housing stock in 1996 as 6373 kg per dwelling per year. Using the above method of estimation, this equates 102 kg CO<sub>2</sub> per student per 10 CAT points for students living in shared accommodation.

We considered the above to be the best method to calculate energy use in non-university student accommodation, but we did undertake cross checks using other sources of information. This involved

the National Home Energy Rating (NHER) *Surveyor* software to generate information for a range of typical UK dwellings. Using this method, a 1960s 4-bed detached house with gas central heating uses 47,778 kWh a year. Dividing this by 30/52 provides an estimate of 27,564 kWh for the 30 weeks of term times (and 6,808 kg CO<sub>2</sub>). As term times are concentrated on the heating season, it should be noted that this is probably an underestimate of energy and CO<sub>2</sub> emissions.

Were such a 4-bedroom house to be shared by four students, then the figures need to be divided by four, producing 6891 kWh/yr/student. To produce our standard measure per 10 CAT points, with the students taking 120 CAT points per year, this total is then multiplied by 10/120 to produce 574 kWh (2066 MJ) per student per 10 CAT Points. The same calculation for emissions produces 142 kg CO<sub>2</sub> per student per 10 CAT points.

Similar calculations were undertaken for two other types of building. For a 3-bed 1930s 'semi' with a 1950s extension, shared by 3 students the result was 725 kWh (2610 MJ) and 178 kg CO<sub>2</sub> per student per 10 CAT points. For a 3-bed 1900s mid terrace house with gas central heating (also shared by 3 students) it was 538 kWh (1937 MJ) and 120 kg CO<sub>2</sub> per student per 10 CAT points.

This method produced estimates in the range of 1,900 – 2,600 MJ per student per 10 CAT points and 120 – 180 kg CO<sub>2</sub> per student per 10 CAT points. Allowing for the fact that averaging of energy use over the whole year somewhat underestimates term-time heating, figures towards the upper end of the ranges would appear appropriate – i.e. around 2,600 MJ per student per 10 CAT points and 180 kg CO<sub>2</sub> per student per 10 CAT points. This is somewhat higher than the method using the *English House Condition Survey* –and suggests that the figures we have used could well be an underestimate. However, the number of students sharing could be higher than one per bedroom, which would bring the two sets of estimates closer.

### 4.3.3 Energy use of students living at home

For students living at home (which, of course applied to OU students as well), it was assumed that normal home heating would occur anyway and so should not be attributed to the study system. However, we sought to identify the number of hours per week of *additional* heating and lighting associated with studying the student's course. The student questionnaire (see below) asked for this information, plus the type of heating system and the fuel used. The main sources of additional heating were leaving gas central heating on longer than normal and using an extra electric room heater. Again generic national information was used to turn this time information into an estimate of energy and CO<sub>2</sub> emissions. For gas central heating, data from the NHER *Surveyor* program were used. A typical UK gas centrally heated house under standard occupancy produces 5.2 tonnes of CO<sub>2</sub> per year. Additional heating consumes 23.14 MJ per hour and produces 0.9 kg of CO<sub>2</sub> per hour.<sup>5</sup> For electricity it was assumed that a 2 kW electric room heater was involved. This is 7.2 MJ of delivered energy per hour. Electricity produces 0.44 kg of CO<sub>2</sub> per kWh, so a 2 kW heater would produce 0.88 kg of CO<sub>2</sub> per hour.<sup>6</sup>

<sup>5</sup> Assuming a 15 kW boiler of 70% efficiency on 30% time each additional hour =  $15/0.7 \times 0.3 = 6.43$  kWh per hour = 23.14 MJ per hour. Using NHER *Surveyor*: a typical UK gas centrally heated house under standard occupancy produces 5.2 tonne CO<sub>2</sub> per year for primary heating. Increasing heating by 18 hours per week produces an additional 500 kg of CO<sub>2</sub> per year. Assuming 32 weeks of heating,  $500/32 = 15.6$  kg a week. Each additional hour therefore produces  $15.6/18 = 0.9$  kg of CO<sub>2</sub>

<sup>6</sup> DETR, *Environmental Reporting Guidelines for Company Reporting on Greenhouse Gas Emissions*, June 1999, [www.energy-efficiency.gov.uk/document/factfigs](http://www.energy-efficiency.gov.uk/document/factfigs)

## 5. Student and staff questionnaires

### 5.1 Questionnaire structure

The major source of information for the study involved a set of questionnaires completed by students and their lecturers or OU tutors. Three sets of questionnaires were produced for students in order to gather data on a consistent basis, while allowing for some variations due to the mode of delivery of the courses. One version was for the face-to-face teaching of full-time courses at nine campus based universities. A second version was for the Open University print-based distance/open learning course T172 (*Working with our Environment: Technology for a Sustainable Future*) and the third for the Open University electronically-taught distance/open learning course T171 (*You, your computer and the Net*).

The campus students' questionnaires were distributed and returned via one of the course's lecturers who had agreed to participate. The T172 survey was a paper questionnaire mailed to students upon course completion and the T171 survey was, of course, administered electronically via the course Web site after the completion of the third and final module of the course.

The questionnaires sought information on the following:

- Distance, frequency and mode of travel connected with study of the course e.g. to attend lectures, tutorials, visit libraries, etc. For the campus universities this also included commuting from term time residences and travel to/from their main home residence.
- Time spent per week using off-campus computers for tasks connected with the course and purchase of computer equipment mainly to study the course.
- Paper and print consumption, including books, reports, newspapers and journals purchased mainly for the course, for photocopying and assignments, and for computer printing during the course. Also, especially for T171, patterns of downloading and printing course material from the Internet.
- Additional household energy consumption associated with part-time studying. As noted in section 4.3 above, the survey sought to identify any above normal use of heating and lighting as a result of studying the course.
- Behavioural and attitudinal changes arising from completing the course that have environmental implications e.g. any changes in travel patterns, or in energy or materials consumption.

A copy of one version of the student questionnaires is in Appendix 2.

Changes in attitudes and behaviour as a result of taking a course does not relate to the mode of delivery of the course. However, the opportunity was taken to obtain limited qualitative information on the effects on staff and student attitudes and behaviour towards the environment stemming from the *content* of the courses themselves. For example, although T171 is an introductory computing course and not specifically geared to raising awareness of environmental issues, one possible effect of studying the course might be that behavioural patterns are changed, for example by enabling its students to use the Internet for shopping and/or working from home. T172 on the other hand is specifically geared to making students more aware of the environmental consequences of their actions and so greater changes in both attitudes and behaviour concerning the environment might be expected.

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## 5.2 Campus lecturer and OU tutor questionnaires

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 and they were asked what proportion of the course their input represented. This was then factored up to make an estimate of the energy and CO<sub>2</sub> emissions for all the staff involved in the course's delivery. This total figure was then divided by the number of students taking the course and weighted by the CAT points in order to produce our standard measure of 'per student per 10 CAT points'.

Similar information for tuition and assessment of the OU T171 and T172 courses was obtained from a sample of about 50 part-time OU tutors (Associate Lecturers), with questionnaires administered by email and/or by post.

## 5.3 Open University course production scoping study

The Open University system differs from campus universities in that courses are prepared centrally by a course team at the University's Walton Hall campus, but are then delivered to students with the support of locally based tutors (Associate Lecturers). The inventory of the OU courses therefore had to separately document course production and course presentation impacts. For the campus universities, production and presentation are not separated in this manner and so a single Lecturers' questionnaire covered both aspects.

A scoping study of the staff impacts of producing the print-based OU T172 course was undertaken to establish whether a full-scale survey needed to be undertaken.<sup>7</sup> This suggested that the impacts per 'main author equivalent' (based on a count of course team members weighted according to their contribution relative to a main author) was as shown in Table A1.

**Table A1: Energy and CO<sub>2</sub> emissions per 'main author equivalent' for T172**

	Energy (MJ)	Emissions (kg CO <sub>2</sub> )
Transport	5,057	525
Home energy (including computing)	5,806	407
Paper	2,060	131
Campus energy	11,466	1,150
<b>TOTAL</b>	<b>24,412</b>	<b>2,213</b>

The total course team consisted of about 14 main author equivalents, resulting in an energy consumption of 341,768 MJ and emissions of 30,982 kg of CO<sub>2</sub>. This figure is then divided by the 9,000 students taking the course over the 6-year lifetime covered by the initial production effort,<sup>8</sup> resulting in a figure of 38.0 MJ and 3.4 kg of CO<sub>2</sub> per student. For this 30 CAT point course it is therefore 12.7 MJ and 1.2 kg of CO<sub>2</sub> per student per 10 CAT points. This figure is very small compared to other environmental impacts.

<sup>7</sup> Potter, S. and Roy R. Scoping study of T172 production Environmental Impacts. *Unpublished Working Paper*, Design Innovation Group, The Open University, September 2001.

<sup>8</sup> The course may actually be presented, with updates, for 8 years or more, so the 6 years used in the estimate makes allowance for some 2 years production effort involved in updating the course.

For T171 it would be even smaller. With larger student numbers (estimated at 40,000 over 5 years of the course) and a course team and production activities about the same size as T172, energy use would only about 2.9 MJ and 0.3 kg of CO<sub>2</sub> per student per 10 CAT points.

As a result of this scoping study, it was decided not to gather more detailed information on the production impacts by staff of the OU courses and concentrate on aspects of the system where the larger environmental impacts occurred.

## **5.4 Scale effects of OU student numbers**

T171 and T172 are introductory, 'Level One' courses with high student numbers. At Levels 2 to 4 student numbers may not be so great. How sensitive are the production environmental impacts of OU courses to their student numbers?

We made an estimate based on the minimum number of students likely to take an undergraduate OU course, about 50 per year (see box).

### ***Effect of reduced student numbers on OU production impacts***

Total energy and emissions per main author equivalent for T172 = approx. 24400 MJ and 2200 kg CO<sub>2</sub> (Table A1). Assume a smaller course team than T172, say 8 main author equivalents. Total energy = 8 x 24400 = 195200 MJ and to emissions 8 x 2200 = 17600 kg CO<sub>2</sub>.

For a 30 pt course with 50 students per year over 6 years = 300 students.

$195200/300 \times 10/30 = 217$  MJ per student/10 CAT points

$17600/300 \times 10/30 = 20$  kg CO<sub>2</sub> per student/10 CAT points.

Average total energy for OU T171 and T172 courses = 430 MJ per student/10 CAT

Average total emissions for OU T171 and T172 courses = 37.5 kg CO<sub>2</sub> per student/10 CAT.

*So reducing student numbers to the minimum likely for an OU undergraduate course (50 students/year) would increase the total energy and emissions compared to a large population OU course by about 50% per student per 10 CAT points to about 650 MJ and 57.5 kg CO<sub>2</sub> per student/10 CAT points.*

This total is still represents an 85% reduction in energy and 83% reduction in emissions compared to the campus courses.

## **6. Travel energy and CO<sub>2</sub> emissions**

### **6.1 Travel data overview**

All students were asked to detail the travel involved in pursuing their studies of the course they were taking. Equally campus lecturers were asked to report travel to prepare, administer, teach and assess the course and OU associate lecturers were asked for the travel involved in tutoring T171 and T172. For both students and staff, travel was categorised into a number of trip purposes, the number of trips made, typical round-trip distance and the method (mode) of transport used (see Appendix 2). If they used a car, there was also a question on its engine size and fuel used. The data collected and definitions were designed to be the same as, or compatible with, the National Travel Survey to permit comparisons to national information to be made. For example, the definition of the mode of transport to be chosen was that 'usually or most often used' and if more than one form of transport was used, the one involved for the 'longest part of the journey' was asked to be reported.

Turning the reported travel into distances per student per 10 CAT points for a specific course required some careful calculations.

## **6.2 Regular term-time travel**

For frequently made journeys, the students were asked to report the number, distance and mode of travel of the trips made in a 'typical week' in term-time to pursue the course under consideration. This was a time period convenient for answering the question and conducive to accurate reporting.

There was also an issue of trips that combined travel associated with studies on the specified course and travel for another purpose (such as commuting to campus for lectures on different courses or modules in one day, or trips that combined travel for the course with, say, shopping). How to apportion such mixed purpose trips and assign the appropriate amount to the course upon which we were gathering data was a difficult issue. We could have:

- Asked students for *all* study related travel and then apportion the travel on the course in proportion to the ratio of the CAT points between the specific course to all courses taken that week. This might have involved some error due to timetable patterns, particularly if course teaching was gathered into blocks. It would have been unrealistic to have asked for full course timetable details to make a more accurate split.
- Ask the students to apportion the trips themselves.

We chose the latter for these regular term-time travel questions (but see discussion below).

In order to express the amount of travel in our standard unit of 'per student per 10 CAT points', the reported figure for travel associated with all the various trips for the course was first averaged per student. This was calculated by dividing the total distance travelled by the number of students who had answered the transport questions (n).<sup>9</sup> So, for example, if there were 25 students who in aggregate travelled 843 miles, then the average distance travelled per student per week was 33.7 miles.

The average distance per student per week was then multiplied by the number of weeks in the course. This gave the total travel per student taking that course. So, taking the above figure of 33.7 miles a week per student, if this were for a 13-week course, it would be multiplied by 13 to total 438 miles for the whole course.

In order to produce our standard 'per student per 10 CAT points' measure, the figure would then be further weighted by the ratio of the course's CAT points to 10 to produce a figure for miles travelled per 10 CAT points. Thus if the course were 20 CAT points, the total of 438 miles would be multiplied by 10/20 to produce a figure of 219 miles per 10 CAT points. Finally we converted the figures into kilometres (to have consistent metric units).

In summary, the calculation was:

**(Total distance per week travelled/No. of students) x (Length of course in weeks) x (10 CAT Points/CAT points of the course).**

<sup>9</sup> It should be observed that the population size 'N' and sample size 'n' varies with each mode, and is dependent on the number of valid data points. That is, the number of students that completed each section of the questionnaire for number of journeys, trip distance and mode. For this study, 'N' is regarded as the total number of questionnaires returned from each institution or OU course (T171/T172). In contrast, 'n' refers to the number of completed answers for each individual question. For example, not every student provided information about his or her travel patterns. We used 'n' to calculate averages. Where data were missing, such as mode of transport, it is impossible to determine how far they actually travelled for a given journey.

A similar procedure was adopted for the lecturer and OU tutor travel.

As a method this should produce comparable figures across all courses. However, this depended on the respondents providing the correct information. In retrospect it appears that for one important trip purpose, commuting to campus, most students appear to have reported *all* commuting trips rather than attributing a proportion of travel to the specific course. This came to light when we examined the amount of commuting travel involved for some low CAT point campus-based courses. For example, in the case of a 10 CAT point course taken in one term, travel for its study would have been out of a total of 40 CAT points for courses in that period (120 CAT points per year or per three terms). So their commuting travel attributable to that course should have resulted in reporting about a quarter (1 – 2) return commuting trips a week. However an examination of our data indicated that most (80%+) students on such 10–20 CAT point courses were reporting 5 or more round commuting trips per week. This suggested that they were not attributing a proportion of commuting trips to the course, but were simply reporting all commuting trips that week.

Although commuting was by far the largest trip category, it seemed this error may also apply to some other regular trip purposes (such as travel between campus sites). Given this situation we felt we had to assume that *all* commuting, inter-site and library trips had been reported. This required us to adjust the reported figures for the 10-20 CAT points courses. This was done by multiplying the reported distances by the ratio of the course's CAT points to the total CAT points they would have been taking in that period. So, for example, if a 10 CAT point course were taken over a one term period (with one term equalling 40 CATs points worth of study), only a quarter of the travel should be attributed to the 10 CAT point course, and the total was therefore divided by 4.

Given that some students may have reported their commuting travel correctly, this procedure seems likely to result in an underestimate of the travel impacts for campus-based students and any future application of the survey questionnaire will be modified to take this problem into account.

For the OU students, this was not a problem (no commuting being involved), and it also was not a problem for the larger, 120 and 180 CAT point (i.e. whole year) courses, for which all travel for study would be reported anyway.

It was also noted that, because occasional student travel for the course, such as field trips, were among those reported in a 'typical week', they were likely to be under reported. In retrospect such trips should have been asked for separately 'per term' and this modification has been made for future use of the questionnaire. However, for the results reported in this study there is probably an under reporting of such trips. This is more likely to affect campus courses than the OU courses.

Overall it seems likely that, due to these various questionnaire design issues, regular term-time travel by campus-based students may be underestimated.

### **6.3 Travelling between home and the university**

For journeys to and from a student's permanent place of residence, the question related to travel patterns *per term*. This returns us to the issue that the travel reported was associated with studying *all* the courses they took that term. For this set of data we (fortunately) decided to use the second adjustment method of weighting the total amount of travel by the ratio of the course's CAT points to that of the total taken in that term. For example if the course amounted to half the CAT points taken that term, only half the travel to and from their permanent home was attributed to the specific course. Our assumption was that full time undergraduate students would be taking 120 CATS points per year,

or 40 per term. So, for a 10-point course we would allocate a quarter of the home-university travel per term to that course (including trips from and to home at the beginning and end of terms).

The resultant figure was then again weighted to provide our standard ‘per student per 10 CAT points’ indicator.

In summary, the calculation was:

**(Total distance/No. of students) x (CATS points per course/CATS points per term) x (10 CAT Points/CAT points per course).**

## **6.4 Transport energy use and CO<sub>2</sub> emissions**

Having obtained information on the amount of travel and the mode of transport involved, the figures needed to be converted into measures of energy and CO<sub>2</sub> emissions per student per 10 CAT points.

A number of life cycle studies have indicated that most travel impacts (80% +) arise from the fuel consumed by vehicles in use. This study used information on life cycle fuel use (i.e. primary energy consumption, not just delivered energy). For this national data on primary fuel consumption were used in order to translate the figures from distance travelled to megajoules (MJ) per vehicle kilometre. No allowance was made for variations between sites in fuel consumption. This was in order that any differences would be due to differences in the course delivery systems and not to external factors, such as a particular university site being served by buses rather than a metro or rail station.

This approach was also taken in that a national average figure was also applied to car fuel consumption. However, again, although we did have data for each of our course samples, it was felt that for the purposes of this study it would be better to use a standardised figure.<sup>10</sup>

A problematic issue was how to allow for car passengers as opposed to car drivers. The method we adopted was to allocate *all* car fuel consumption to car driver trips and assume none to car passengers. The alternative would have been to allocate fuel use per person carried and estimate car occupancy, which would have been a difficult task (requiring additional information in an already extensive questionnaire). However it is accepted that our allocation of all fuel use to driver trips will have resulted in an underestimate of car fuel use. Such an underestimate would occur where, for instance, a non-student made a special trip in order to pick up or drop off a student. This is most likely for travel between a student’s normal home and term-time address (e.g. a parent taking a student to their university), or if they were given a lift into campus, or an OU student had a lift to a tutorial by a non-student.

The primary energy data were then converted into CO<sub>2</sub> emissions using information on the carbon content of diesel and petrol and assuming an 80:20 petrol/diesel split.<sup>11</sup>

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<sup>10</sup> We calculated an overall average based upon the car engine size data provided in the surveys by using National Travel Survey information to translate this into a fuel consumption estimate. This showed a very narrow variation around an average of 2.96MJ of delivered energy per vehicle kilometre, equivalent to around 3.5MJ of primary energy per vehicle kilometre. This average energy use for our student sample’s stock of cars is the same as the national average for all cars.

<sup>11</sup> See Potter, S. Transport CO<sub>2</sub> calculations, *Unpublished Working Paper*, Design Innovation Group, The Open University, July 2001.

## 6.5 Fuel consumption of other modes of transport

Figures on the fuel consumption of transport modes have been collated from the research report *Vital Travel Statistics*<sup>12</sup> and the parallel *Factor 10 Visions* transport study. Walking and cycling, although involving human energy, were assumed to use no additional fossil fuel energy and therefore no CO<sub>2</sub> emissions. For public transport national average occupancy rates were employed in order to calculate megajoules (MJ) per passenger kilometre from the figures for MJ per vehicle kilometre. These were as follows:

**Table A2 Transport energy use and emissions**

Transport Mode	Assumed Occupancy	MJ per passenger km	MJ per passenger mile	kg. CO <sub>2</sub> Per passenger mile
Car	1 person	3.5	5.6	0.39
Motorbike	1 person	1.6	2.6	0.18 kg
Stage Bus	20%	1.3	2.1	0.15 kg
Express Coach	50%	0.5	0.8	0.06 kg
Rail	30%	1.1	1.7	0.17 kg
Metro/Underground	25%	1.3	2.1	0.28 kg
Short haul Air	66%	3.6	5.8	0.40 kg
Long haul Air <sup>1</sup>	66%	2.4	3.8	0.26 kg

1. Long haul Air estimated by scaling energy and CO<sub>2</sub> data for short haul with CO<sub>2</sub> data for long haul.

As for cars, information on the carbon content of fuels permitted these energy data to be converted into CO<sub>2</sub> emissions. The above figures were compared to those for kg of CO<sub>2</sub> used in the *Climate Care* and *Best Foot Forward* databases.<sup>13</sup>

For motorcycles and mopeds, we assumed a 50:50 motorcycle/moped split producing an average primary fuel consumption of 1.6 MJ per *vehicle* km (2.58 MJ per vehicle mile) and 0.18 kg CO<sub>2</sub> per vehicle mile. Our method was to allocate all energy use to the driver.

We estimated the energy used by both local and inter-city trains for both diesel and electric traction. Our figure for local diesel was 0.136 kg. CO<sub>2</sub> per passenger km. This was very close to the *BestFootForward* figure of 0.145 kg. The local electric train figure was 0.177 kg, which is some 80% higher than the *BestFootForward* figure of 0.097 kg.<sup>14</sup> Assuming a 50:50 diesel/electric split, average primary fuel consumption is 1.69 MJ per *passenger* mile and average emissions 0.161 kg CO<sub>2</sub> per *passenger* mile.

For long distance (inter-city) trains, diesel trains were taken at 0.9 MJ per passenger km. (1.45 MJ per *passenger* mile) with average emissions at 0.102 kg CO<sub>2</sub> per *passenger* mile. For inter-city electric trains, average primary fuel consumption 1.2 MJ per passenger km (1.93 MJ per passenger mile) and average emissions 0.235 kg CO<sub>2</sub> per *passenger* mile. Again assuming a 50:50 split between diesel and electric trains, average primary fuel consumption is 1.69 MJ per *passenger* mile and average emissions 0.165 kg CO<sub>2</sub> per *passenger* mile.

*Thus, the local and inter-city train energy and emissions averages are essentially the same.*

<sup>12</sup> Potters, S. et al. (1997) *Vital Travel Statistics*, London: Landor Publications.

<sup>13</sup> <http://www.co2.org> <http://www.bestfootforward.com>

<sup>14</sup> Our higher figure seems to be due to three factors. The first is the type of rail service – fast trains use more energy per kilometre than slower, local trains (*Eurostar*, for example, uses 1.6 MJ per passenger km, an UK Intercity electric uses 1.2 MJ and a suburban electric train 0.7-1.0 MJ per passenger km). Second, is the assumed primary fuel mixed used to generate electricity for rail. Third, are occupancy assumptions and possibly that the size of local electric trains varies more than for local diesel trains. Nevertheless, the difference between our and the BFF figures should be noted.

For metro/underground we assumed a 30:70 split between light rail and London Underground. Our figure of 0.28 kg of CO<sub>2</sub> per passenger mile compares to a figure of 0.32 kg CO<sub>2</sub> per passenger mile for London Underground alone in an article<sup>15</sup> reporting data from *BestFootForward*.

For short haul air, the average primary fuel consumption was estimated at 3.6 MJ per passenger km (5.80 MJ per passenger mile) and average emissions at 0.246 kg CO<sub>2</sub> per passenger km (0.396 kg CO<sub>2</sub> per passenger mile).

Long-haul air was estimated at 3.81 MJ per passenger mile and emissions at 0.161 kg CO<sub>2</sub> per passenger km (0.26 kg CO<sub>2</sub> per passenger mile)<sup>16 17</sup>.

One issue to emerge was whether we should weight our emissions figures to reflect the global warming effect of high level emissions of NO<sub>x</sub> and water vapour<sup>18</sup>. An adjustment to increase the CO<sub>2</sub> impact by 50% was suggested, which would take the figure for air to 0.594 kg CO<sub>2</sub> equiv. per passenger mile. However, this was not done as we had not included NO<sub>x</sub> and water vapour emissions elsewhere in this study.

Our figure of 5.8 MJ per passenger mile for short haul air is less than half that of Maibach's<sup>19</sup> estimate of 12.72 MJ per passenger mile (7.90 MJ per passenger km). This produces 0.760 kg CO<sub>2</sub> per passenger mile compared to only 0.246 kg from our sources. For long-haul air, their figure was 4.99 MJ per passenger mile (0.32 kg CO<sub>2</sub> per passenger mile) which compares to our estimate of 3.81 MJ per passenger mile, based on scaling the short-haul data.

By way of contrast, Lufthansa estimates an 'average flight' at 3.14 MJ per passenger mile (0.24 kg CO<sub>2</sub> per passenger mile)<sup>20</sup> which is between our short and long haul estimate, but considerably lower than Maibach's figures.

The ranges involved in the various estimates are substantial. This may reflect different aircraft types and definitions of short haul, long haul and 'typical'. There appears to be less of a consensus in the data for air than for other modes. It could be argued that our figures used for air may be on the low side.

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<sup>15</sup> *The Independent*, 15 December 2000.

<sup>16</sup> Simmons, C. *Personal Communication*, Best Foot Forward, Oxford, September 2001.

<sup>17</sup> Maibach M., Peter D., Seiler B., *Ökoinventar Transporte*, INFRAS, Zürich 1995, (in German.) Provided and translated by Roland Hischier *Personal Communication*, Swiss Federal Labs for Materials Testing & Research, St Gallen, Switzerland, Nov. 2001.

<sup>18</sup> Huw Somerville, *Personal Communication*, Sustainable Business Unit, British Airways, October 2001.

<sup>19</sup> Maibach M. et al. op cit. note 17.

<sup>20</sup> Lufthansa, *Umwelbericht* (Environmental Report) 1995/1996, Frankfurt 1996 (in German.) Provided and translated by Roland Hischier *Personal Communication*, Swiss Federal Labs for Materials Testing & Research, St Gallen, Switzerland, Nov. 2001.

## 7. Computing

### 7.1 Computer use

As noted in the main report, students were asked to provide information on the number of hours in a typical week that they used their own computers for tasks connected with the course. Use of university computers was excluded, as this would be covered in the figures obtained for university site impacts. Lecturers were also asked to report their use of home computers for preparing, administering and teaching the specified course.

The computer usage data was converted into energy use and CO<sub>2</sub> emissions by using generic figures on the average energy consumption of a desktop PC and the carbon content of fuels to generate electricity. (About 90% of all computers used were desktop PCs.) The typical power consumption of desktop PC is between 120 watts (Hilty and Ruddy, 2000, p.7) and 130 watts (EU PC ecolabelling report, 2001). We therefore took a figure of 125 watts or 0.45 MJ per hour delivered energy.

CO<sub>2</sub> emissions are 0.44 kg CO<sub>2</sub> per kWh delivered UK electricity, which indicates that a typical PC produces 0.06 kg CO<sub>2</sub> per hour.<sup>21</sup>

### 7.2 Computer communications

The above figures are for a stand-alone computer. For a computer connected to the Internet, for example when OU T171 students are studying material on-line, additional energy and emissions will be involved. No reliable data appears to be available for the amount of energy concerned, so an estimate was made based on a life cycle analysis of different methods of sending messages, including by email over the Internet. Sending an email involves the messages passing through the telephone network and a number of computer routers. The amounts of energy involved will depend on the distance the message has to travel and the nature of the telephone/computer networks involved. Remmerswaal et al. calculated the amount of energy to send a one-page email within a fairly local area which they estimated would take 10 seconds and involve three routers.<sup>22</sup> The telephone network was estimated to require 8.5 J/second and each 500W router 30J/second, making a total of about 100J/second or 0.36 MJ/hour. This is likely to be a lower limit, as a message travelling a greater distance would involve more network connections and routers. We assumed therefore that a computer connected to a network consumed approximately 0.9 MJ/hour, double the energy of a stand-alone machine and, assuming the energy is all electricity, produces double the emissions at approximately 0.11 kg CO<sub>2</sub> per hour.

Although all courses are likely to involve some students' on-line use of their own computers, we had no information on the extent. However, it seems reasonable to assume that the electronically-taught and tutored OU T171 course would involve a high proportion of on-line computing time either connected to the Internet or to the OU's *First Class* electronic conferencing system (including the time students required to download and print their materials). We estimated that two-thirds of the computing time reported for T171 and 10% of the computing time for other courses might be on-line.

<sup>21</sup> A validation comparison used the BestFootForward Lifestyle Calculator (<http://www.bestfootforward.com>). This showed UK grid electricity to produce 0.43 kg CO<sub>2</sub> per kWh and PC emissions as 0.05 kg CO<sub>2</sub> per hour.

<sup>22</sup> Remmerswaal, H et al., (2001): Comparisons of different methods of sending messages on the basis of Life Cycle Analysis, in Proceedings Towards Sustainable Product Design Conference 6, Amsterdam, the Netherlands, October. Centre for Sustainable Design, Surrey Institute of Art and Design, Surrey, UK, pp 178 – 182.

### 7.3 Embodied energy in computer equipment

As well as energy involved in the use of computers, information was obtained in the questionnaires on purchase by students and lecturers of new or upgraded computing equipment mainly for study or teaching purposes. In order to allocate environmental impacts, it was assumed, on the basis of computer replacement cycles at the OU, that a computer mainly used for study or teaching would last for 3 years, and this figure was then weighted according to the CAT points of each course.

The method to do this first involved estimating the embodied energy involved. We found a wide range of estimates among the literature on this subject.<sup>23</sup> We chose to use a recent publication by Hilty and Ruddy (2000), who estimated that desktop PC production involves 5,000-12,000 MJ of primary energy. We therefore assumed an average of 9000 MJ per PC.<sup>24</sup> (Note that this is *primary* energy rather than the delivered energy used mainly in this report. Delivered energy, especially of any electricity used for PC manufacture, would be less, so our figure may be an overestimate.) The CO<sub>2</sub> content would depend on the primary fuels used and we took a simplifying assumption that 50% is electricity (0.44 kg CO<sub>2</sub> per delivered kWh) and 50% oil (0.25 CO<sub>2</sub> per kWh). This produced an average of 0.345 kg CO<sub>2</sub> per kWh. So producing a PC involves  $9000 \times 0.345/3.6 = 863$  kg CO<sub>2</sub>.

Assuming a computer life of 3 years, this would support study equivalent to 360 CAT points, so (for example) for a 20 CAT point course the total embodied energy would be allocated 20/360. This would then be multiplied by 10/20 in order to produce our standard measure 'per student per 10 CAT points'.

## 8. Consumption of paper and printed matter

### 8.1 Paper consumption

The questionnaires asked students and staff to report the number of sheets of paper used in a typical week for tasks associated with the course. The period for estimates of paper consumption varied as appropriate to the course and delivery method. For the campus staff and students it was pages in a *typical week*. For the OU T171 course, estimates were for one of the *course modules* and for OU T172 it was for the *whole course*. For students, examples such as photocopying, assignments, printing from a computer, printing off Internet pages, etc. were cited. For staff they were asked to include paper used for preparing lectures, student handouts, photocopying articles as well as printing from a computer, printing Internet pages etc. In order to convert the figures for the number of pages into energy and CO<sub>2</sub> per student per 10 CAT points information on the energy content of paper and printed materials was required.

For office paper, US data indicated that life cycle *delivered* energy amounted to 18.3 MJ per kg. This calculation was based upon a combination of virgin production and waste management, with 77% of

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<sup>23</sup> Estimates of embodied energy/emissions per PC ranged from a low of 3500 MJ and 200 kg CO<sub>2</sub> (Roland Hischier *Personal Communication*, Swiss Federal Labs for materials Testing & Research, St Gallen, Switzerland, Nov. 2001 The low CO<sub>2</sub> is probably due to low CO<sub>2</sub> from Swiss electricity generation.) to 10,000-12,000 MJ (Enquete Kommission, German Bundestag, (1998) quoted in Hilty et al. (1999) The resource intensity and dematerialization potential of information society technologies, Solothurn University of Applied Science Northwestern Switzerland p.6) and 2900 kg CO<sub>2</sub> (Miyamoto, S and Tekawa, M. 1998 Development of life cycle assessment software and application to personal computer assessment, *NEC Research & Development*, Vol. 39 No. 2, April, pp. 77- 81).

<sup>24</sup> Hilty, L.M. and Ruddy, T.F. (2000) Towards sustainable information society, *Informatik*, No. 4 (August), p. 6.

paper going to landfill and 23% to incineration. Net greenhouse gas emissions (CO<sub>2</sub> equivalent, including CH<sub>4</sub> from landfills) were 2.54 kg CO<sub>2</sub> equivalent per kg.<sup>25</sup>

We weighed a ream (500 sheets) of typical office paper to obtain a figure of 0.5 kg per 100 sheets.

## 8.2 Purchase of books and periodicals

Both students and staff were also asked for the number of books, reports, newspapers and magazines they had purchased mainly in order to study or to teach the course. The time period was the *previous term* for campus staff and students and the *whole course* for the OU respondents.

The above USA source was also used to obtain life cycle *delivered* energy for newsprint, with an estimate of 30.7 MJ per kg and net greenhouse gas emissions of 3.3 kg of CO<sub>2</sub> equivalent per kg. In the absence of other consistent data,<sup>26</sup> the newsprint figures were used for calculating the impacts of all printed matter.

For these calculations, the weight of typical printed items is required. Again, given the variation in existing published information,<sup>27</sup> we weighed different printed items ourselves. This exercise resulted in the weight of an average 'academic' paperback being 0.85 kg, an average hardback book being 0.82 kg, so an average of 0.8 kg was taken for all books. An average broad-sheet newspaper weighed in at 0.25 kg and an average 'glossy' magazine at 0.35 kg, so we took an average of 0.3 kg for newspapers and magazines.

The figures for the weight of paper, books etc. used were multiplied up by the appropriate time period for the course to produce a figure for energy used and CO<sub>2</sub> emitted per student per course. The figure was then further weighted by 10/course CAT points to produce our standard measure of average energy and CO<sub>2</sub> per student per 10 CAT points.

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<sup>25</sup> Environmental Defense Fund et al. (1995) *Paper Task Force Recommendations for Purchasing and Using Environmentally Preferable Paper*, New York: Environmental Defense Fund.

Updated at <http://www.environmentaldefense.org/pubs/Reports/ptf/acrobat/index.html>, December 2000

<sup>26</sup> Other estimates of the energy consumed in production and supply to end-user of printed matter are:

*Paperback book = 4.5 kWh = 16.2 MJ (40.5 MJ per kg for 0.4 kg book; Glossy magazine = 2.6 kWh = 9.36 MJ (31.2 MJ per kg for 0.3 kg magazine); Newspaper = 0.6 kWh = 2.16 MJ (21.6 MJ per kg for 0.1 kg newspaper).* (Chapman, P. (1975) *Fuels Paradise: Energy Options for Britain*, Harmondsworth: Penguin Books, Table 10, p. 57 Fuel cost of commodities. Based on 1968 UK Census of Production data).

Other sources included the Boston Consulting Group, *Paper and Electronic Media*, Sept 1999 quoted in Romm et al. (1999) *The Internet Economy and Global Warming*, Center for Energy and Climate Solutions, Version 1, December. (electronic), which reported newspapers as producing 3.25 kg CO<sub>2</sub> per kg. A Swiss study (Habersatter K., Fecker I. et al., *Life Cycle Inventories for Packagings*, Swiss Agency for the Environment, Forest and Landscape (BUWAL), Environmental Series No. 250 (Volume I and II), Bern 1996) put paper at 40 MJ per kg and 0.67 kg CO<sub>2</sub> per kg, and the printing of book at 49.0 MJ per kg and 0.56 kg CO<sub>2</sub> per kg. The low CO<sub>2</sub> is probably due to low CO<sub>2</sub> from Swiss electricity generation.

<sup>27</sup> Other figures include the average newspaper/magazine weighs 0.15 kg (Craig Simmons, Personal Communication, BestFootForward, Oxford, October 2001), which makes an average of 0.49 kg CO<sub>2</sub> equivalent per newspaper.

### **8.3 Open University course material**

For the OU courses, as well as the paper that the students themselves used, and the books that they may have bought, it was necessary to estimate the amount of printed course material produced and from that calculate the energy and emissions from its production and mailing. This is reported in Table 14 in the main report.

For T172 the total weight of OU printed course materials for each student (excluding folders and audio-visual tapes) was 5.35 kg, plus a 0.73 kg set book, making an overall total of 6.08 kg. The paper-based OU delivery system also involves postage. Although partly electronically delivered, the OU T171 course involved 0.6 kg of printed materials plus two set books, in total weighing 1.17 kg. According to the Post Office<sup>28</sup> the emissions from buildings, transport, equipment, etc. associated with mailing was 31.35 kg CO<sub>2</sub>/1000 items in 1999. This measure does not readily allow for a calculation per kg to be made, so we assumed that 1 item averaged 0.1 kg. This resulted in emissions being  $31.35/1000 \times 1/0.1 = 0.314$  kg CO<sub>2</sub> per kg mail. Thus the 6.08 kg. of OU T172 materials would result in 1.9 kg of CO<sub>2</sub> emissions (0.63 kg of CO<sub>2</sub> per student per 10 CAT points).

The equivalent figure for T171 is 0.12 kg. CO<sub>2</sub> per student per 10 CAT points.

No information on the energy used was provided by the UK Post Office, but a Dutch estimate of the transport energy involved in collecting and delivering mail is about 9MJ per kg.<sup>29</sup>

This total was, as usual, adjusted for the CAT rating of the course to produce our standard 'average per student per 10 CAT points' measure.

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<sup>28</sup> Sykes, K. Personal communication, Post Office, February 2001.

<sup>29</sup> Remmerswaal, H. et al., op. cit., note 22.

## ***Appendix 2***

### **The Full-time Campus Student Questionnaire**

One of the six variants of the questionnaire produced for the staff and student surveys of the campus-based and Open University courses.