Carbon Brainprint

Final report on HEFCE project LSDHE43

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Final report on HEFCE project LSDHE43

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Contents

Annexes

Summary

The need for organisations to reduce their carbon footprint is now well accepted. HEFCE has recently published its policy (2010/01) requiring universities to set targets to reduce their greenhouse gas emissions and targeting reductions of 34% and 80% across the sector by 2020 and 2050 respectively. Universities, however, also help other organisations to reduce their own carbon footprints, both through providing existing or potential employees with the necessary knowledge and skills and, more directly, though research and consultancy projects. These reductions cannot be offset against the university's footprint, but the intellectual contribution to reducing the carbon footprint of others, termed their "carbon brainprint", is immensely valuable in meeting the challenge of global warming.

This project aimed to help quantify the HE sector's Carbon Brainprint. It used a set of case studies from Cranfield, Cambridge and Reading Universities to establish a robust, repeatable method, informed by life cycle analysis methods and PAS2050 for carbon footprinting, for calculating and verifying the contribution of universities to reducing greenhouse gas emissions. This method could be applied across the sector to assess the impact of HE intellectual activities.

Guidelines were drawn up at the start of the project and revised as the case studies progressed. These included general principles, based on carbon footprinting standards, appropriate spatial, temporal and conceptual boundaries for brainprint studies, the scope and limits of applicability, appropriate levels of detail, uncertainty analysis and the possible need to attribute the brainprint among project partners. The guidelines set out the main steps in a brainprint assessment: system description, boundary definition, data gathering, assessment of emissions and changes to evaluate the retrospective and prospective brainprint, and uncertainty analysis.

The case studies covered

- Ceramic thermal barrier coatings for jet engine turbine blades, which help to improve engine efficiency and reduce aircraft fuel consumption.
- Novel offshore vertical axis wind turbines that will be able to generate 'green' electricity using less material for construction than conventional designs.
- Improved delivery vehicle logistics to reduce delivery vehicle fuel use in the food sector.
- Training for landfill gas inspectors to capture emissions of methane from landfill sites.
- Intelligent buildings to reduce fuel consumption by both behavioural change and advanced monitoring and control.
- Optimising defouling schedules for oil-refinery preheat trains, to maintain efficiency and reduce the consumption of oil within the refinery.

These included developments that were already implemented in practice, including some where data on the results were available, and others that have yet to be used. All demonstrated the positive effects of research, consultancy or teaching in reducing greenhouse gas emissions, although the scale of the effect varied considerably. The largest totals came from

the jet engine thermal barrier coatings, due to the large quantities of fuel consumed by aircraft engines, and the training of landfill gas inspectors, due to substantial changes in the emissions of a highly potent greenhouse gas. In other cases the unit reductions were smaller, but the potential total effects are large if they are widely adopted.

On the basis of these studies, it seems likely that a relatively small number of projects focussed on applications with high energy or greenhouse gas flows will represent the majority of the brainprint of most institutions. Those where good monitoring data from full-scale application are available will normally be comparatively simple to assess and provide clear results.

The project has demonstrated that it is possible to begin to quantify the impact that universities have on society's greenhouse gas emissions, and that this impact is large. The current annual brainprint of the four projects assessed at Cranfield University is over 50 times the university's own annual carbon footprint.

Introduction – the Carbon Brainprint concept and project

The need for organisations to reduce their carbon footprint is now well accepted. HEFCE has recently published its policy (2010/01) requiring universities to set targets to reduce their greenhouse gas emissions and targeting reductions of 34% and 80% across the sector by 2020 and 2050 respectively. Universities, however, also help other organisations to reduce their own carbon footprints, both through providing existing or potential employees with the necessary knowledge and skills and, more directly, though research and consultancy projects. These reductions cannot be offset against the university's footprint, but the intellectual contribution to reducing the carbon footprint of others, termed their "carbon brainprint", is immensely valuable in meeting the challenge of global warming.

This aim of the project was to provide a means of quantifying this aspect of the impact of the work of HEIs. An assessment of the sector's carbon brainprint in relation to its carbon footprint will give an indication of the value of investing in HE activities as a vital component of the global fight to restrict global warming. The term *carbon brainprint* from which the concept for this project originated was proposed by the HEFCE Deputy Chief Executive, during the HEFCE consultation on its own carbon reduction targets. This importance of the project was recognised by the Carbon Trust who sat on the Steering Committee and provided advice on best practice in carbon footprinting. Research Councils UK also recognised the potential of this project and agreed to sit on the Steering Committee.

The project used a set of case studies from Cranfield, Cambridge and Reading Universities to establish a robust, repeatable method for calculating and verifying the contribution of universities to reducing greenhouse gas emissions. This method could be applied across the sector to assess the impact of HE intellectual activities.

Key objectives were:

- Develop and make available a robust methodology that will cover both retrospective assessment of existing interventions and forecasting potential future impacts.
- Establish the extent to which this methodology will be applicable, including considering to what extent the more indirect aspects of learning and teaching are quantifiable.
- Identify approaches to agreeing relative contributions of partners in collaborative projects.
- Provide a number of worked case examples demonstrating the application of the methodology.
- Develop an innovative dissemination route through a web-based Network Innovation Library (NILCarbon).
- Hold a launch event at which the method and case studies would be presented to HEFCE and HEIs, with workshop sessions to explore case studies from the participants.

Underlying principles and methods

The methods used were based on established approaches to carbon footprinting, in particular PAS 2050:2008 (BSI, 2008) and the Carbon Trust good practice guide (Carbon Trust, 2009), which are underpinned by the guidance from the IPCC (IPCC, 2006) and the methods of life cycle analysis (LCA). A set of basic guidelines were drawn up at the start of the project, then revised in the light of experience during the case studies. These are attached as an annex to this report: *Guidance for the calculation of carbon brainprints of higher education institution activities*.

One of the key ideas of these methods is to record all emissions of greenhouse gases that arise directly or indirectly in the production, use and disposal of a good or service. In practice it is necessary to define the boundaries of this assessment, and these differ according to the purpose of the assessment. For example, when considering the fuel used by transport, the boundary may be drawn tightly, including only the emissions from combustion, known as Scope 1. Alternatively, they may be set more widely to include the extraction, refining and transport of the fuel, known as Scope 3 (DECC, 2010). There are good reasons for these differences: a complete assessment of the impact of transport on greenhouse gas emissions needs to include its Scope 3 emissions. However, when compiling a complete national or international inventory, the IPCC would include extraction and refining at the points where they occur, so the transport sector needs to report only Scope 1 emissions. If it included Scope 3, the extraction and refining emissions would be recorded twice. In the case of a carbon brainprint, which is a measure of total impact and will not be used within inventories, it is appropriate to include all the indirect emissions, whenever this is feasible.

The boundaries also include the time scale used. Again, as the brainprint is a measure of total impact, it is usually appropriate to consider a comparatively long period, such as 10–20 years, though annual values are more meaningful in some cases.

A third type of boundary is the level of precision required. The guide that was arrived at was to ignore any emissions falling below 1% of the total. A corollary is to avoid spurious precision in the presentation of the results. Normally the final results should be presented to 2 or 3 significant figures, though intermediate results may use more to prevent the accumulation of rounding errors.

The brainprint calculation should be limited to the direct effects of the innovation under consideration and not try to predict indirect consequences, either positive or negative. For example, it assumes that greater fuel economy does not lead to a compensating increase in the level of use.

The brainprint can be based on an innovation that has already been introduced and calculate its effect, referred to as a retrospective brainprint, or include future effects, called the prospective brainprint. The latter will need a realistic assessment of the future uptake and use.

The types of activity for which the method is intended to be appropriate are

- Research and development leading to a new piece of equipment with lower construction, operational or disposal emissions, or extended service life.

- Research and development leading to a modification to existing equipment resulting in lower operational or construction and disposal emissions.
- Research and development leading to improved operation of existing systems.
- Training aimed directly at individuals who control or influence operations.
- Research, development and promotion of methods to produce measurable behavioural change affecting greenhouse gas emissions.

General education and pure or strategic research are less likely to be suitable for consideration, because they cannot usually be linked directly to behavioural or operational effects.

A typical study has five main phases, corresponding to sections in the report

- System description
- Boundary definition
- Data gathering
- Assessment of emissions
- Uncertainty analysis

In principle, the emissions assessment requires a baseline assessment prior to the innovation, an assessment of the emissions after the change and calculation of the difference. In practice, as in some of the case studies, before and after measurements of related variables, such as fuel consumption, may already have been made and used to give a direct measure of the change of use or consumption, from which the greenhouse gas effects can be calculated. Using either approach, the annual change, total to date (retrospective brainprint) or projected lifetime total (prospective brainprint), as appropriate, can then be calculated. Analysis of the effects of uncertainties in the data and assumptions on the final results is an important step, especially when predicting the future effects.

Case studies and results

Six case studies were chosen to test the concept with a diversity of project types. Four were from Cranfield and one each from the Universities of Cambridge and Reading. One concerned training, whereas the others were some form of research, development or consultancy. Three had already been implemented in practice, and three were in some stage of development or testing. One was the development of a complete installation, one was a modification to a single component, and the others involved a mixture of technical and behaviour modifications to system behaviour.

This report contains a brief summary of the main features of each. The full reports, provided as annexes, contain more detailed brainprint analyses, supported in two cases by longer technical reports.

Ceramic coatings for jet engine turbine blades

Ceramic thermal barrier coatings (TBCs) are applied to jet turbine blades to protect them from the high temperature gases leaving the combustion chamber and to increase the efficiency of the engine. Professor John Nicholls of the Surface Science and Engineering Group, Cranfield University has been working with Rolls-Royce plc for about 17 years to improve the insulating performance of TBCs. As a result, the TBCs used in the current generation of aircraft turbofan jet engines achieve a temperature drop about 80 ^{o}C greater than at the start of the work, with an estimated fuel saving of about 1%.

This case study considered two engine types: Trent 700, used on about half the Airbus A330 aircraft currently in service, and Trent 500, used on all Airbus A340-500 and A360-600 aircraft. The greenhouse gas emissions considered were, in order of magnitude, carbon dioxide from combustion of the fuel, emissions during extraction and refining of the fuel, and emissions of other greenhouse gases during combustion. Emissions associated with transport of the fuel were found to be negligible compared with these, and all emissions not related to fuel consumption, for example manufacture of the coating, were also assumed to be insignificant or excluded from the assessment because they were unaffected by the change in the TBC.

The baseline fuel consumption during each flight phase (landing and take-off cycle and cruise) was estimated from publicly available data. Airline activity data for A330 and A340 models from European operators was taken to represent typical patterns of use, enabling annual emissions per aircraft to be calculated. Data on current operating aircraft and orders were then used to estimate the total current and projected future emissions. From these, the higher emissions that would have occurred in the past if the improved TBCs had not been used, and the corresponding future emissions, were estimated.

The best estimates of the current emissions (the retrospective brainprint) for individual aircraft were 1016, 1574 and 1646 t CO_2e/year for A330, A340-500 and A340-600 respectively, giving 570 kt CO_2e/year for the total fleet. Including all the aircraft on order, the prospective emissions reduction was 830 kt CO_2e/year. Assuming a service life of 20 years, the total brainprint was approximately 17 Mt CO_2e.

An uncertainty analysis was performed with assumed uncertainties for aircraft activity, fuel consumption and the efficiency change. Including all these variables, the 95% confidence interval for the current annual emissions reduction was 430–720 kt CO_2e/year. The relative changes in the other output measures were similar. Assuming that older engines do not and will not benefit from the improvement, reduced the total brainprint to 14 Mt CO_2e. The assessment did not include an adjustment for the effect of emissions at high altitude, which would increase all the outputs by a factor of 1.9.

Novel offshore vertical axis wind turbines

As part of the transition to a 'low carbon economy', renewable technologies are expected to play an increasing role in reducing dependence on fossil fuels for energy and electricity. Wind power in particular is likely to become a much larger contributor to the UK's energy mix. The current dominant design for large, grid-connected wind turbines is a three blade rotor with a horizontal rotating axis. The concept of a vertical axis wind turbine (VAWT) is relatively new, but has several advantages over horizontal axis alternatives. It is able to capture the wind from any direction, and the vertical axis is such that the rotor equipment is located at base level, making it is simpler and less costly to install and maintain.

The Energy Technologies Institute (ETI) is a UK-based company formed from global industries and the UK government. One of three projects looking at new turbine design and concepts for offshore wind is the Novel Offshore Vertical Axis (NOVA) project, a UK-based consortium launched in January 2009 to look at the feasibility of a NOVA turbine.

This case study considered the potential reduction in greenhouse gases (GHGs) that could be achieved through the installation of NOVA wind turbines, in comparison to conventional horizontal axis wind turbines (HAWTs) for offshore power generation. The increased power rating of the NOVA turbines compared to current HAWTs is expected to provide considerable reductions in lifetime greenhouse gas emissions. It compared the emissions from 1 GW installations over 20 years, based on a life cycle analysis of construction, operation and disposal. The comparison used the popular Vestas V90 3 MW model and the proposed NOVA 10 MW units.

The estimated lifetime emissions were 521 kt CO_2e for the conventional design and 419 kt CO_2e for NOVA. Using budget share to attribute the reductions to the project partners, Cranfield's brainprint was 34 kt CO_2e.

As there are no current NOVA units in operation, there were high uncertainties associated with the estimates. A Monte-Carlo simulation resulted in a mean difference in emissions between the two installations of 102 kt CO_2e, with a standard deviation of 108.

Improved delivery vehicle logistics

Road transport accounts for about 20% of the total GHG emissions of the UK, and HGVs and LGVs are responsible for about one-third of these. The total direct GHG emissions from HGVs and LGVs in 2008 were about 40 Mt CO_2e.

Dr Andrew Palmer, a Cranfield University visiting fellow and former PhD student contributed to the transport recommendations for the food distribution industry following publication of The Food Industry Sustainability Strategy. These recommendations were taken up by IGD as part of the Efficient Consumer Response (ECR–UK) initiative and implemented with 40 leading UK brands. They reported that this initiative had taken off 124 million road miles (equivalent to 60 million litres of diesel fuel) from UK roads over three years (2007–2009) and 163 million road miles up to 2010, with a target of 200 million road miles by the end of 2011

The quoted reduction in vehicle use up to 2010 is equivalent to 250 kt CO_2e, but this cannot all be attributed to Cranfield University's carbon brainprint, because Dr Palmer was only one of the authors of the report and he was not an employee of the university at the time. We estimate the attributable brainprint to be 56 kt CO_2e (an average of 14 kt CO_2e/year) with a 95% confidence range of 32–87. Assuming that this is maintained until 2020, and assuming a 1%/year increase in efficiency independent of this work, which will reduce the future brainprint, gives an estimate of 190 kt CO_2e (100–300) for the period 2007–2020.

Training for landfill gas inspectors

Anaerobic deterioration of biodegradable wastes in landfill sites is an important source of greenhouse gases. Of the estimated UK total of 2330 kt methane emitted in 2008, 966 kt (equivalent to 24 Mt of carbon dioxide) came from landfill, compared with 876 kt from livestock agriculture, the next largest source. Increasing the amount of methane that is recovered and used as fuel is an important method of reducing emissions.

In 2008 Cranfield University was asked by the Environment Agency (EA) to run a 12 day course to train 12 EA officers, based on the knowledge of a retired EA industry expert. At the end of the course, the students split into two groups, each of which undertook 12 site visits. These 24 sites were subsequently assessed by the EA, who estimated that the additional measures recommended had collected an additional 7,600 m^3/hr of landfill gas. A further 12 officers have now received the advanced training, and another 70 have attended a foundation course in which they learn how to audit and assess landfill gas controls on sites.

The additional collection of methane resulting from the first set of visits is equivalent to 453 kt CO_2e/year. Extrapolating from this by making conservative assumptions about possible diminishing returns, the savings to the end of 2010 from the two groups (the retrospective brainprint) are about 1,300 kt CO_2e with a 95% confidence range of 1,100–1,600 kt CO_2e. Using the same assumptions, if both groups continue working for a further three years, the savings over the five year period (the prospective brainprint) will be 5.4 Mt CO_2e with a 95% confidence range of 3.7–7.3 Mt CO_2e.

Intelligent buildings

It is estimated that non-domestic buildings were responsible for 18% of UK total greenhouse gas emissions (582 Mt CO_2e/year) in 2010 (Carbon Trust, 2009). Of non-domestic building emissions, 34% (36 Mt CO_2e/year) is due to lighting, office equipment and catering and 46% (49 Mt CO_2e/year) is due to heating (Carbon Trust, 2009).

A team consisting of researchers at the University of Reading, the University's Facilities Management Directorate and Newera Controls Ltd. conducted two trials to measure and demonstrate the potential for two important and complementary approaches in achieving energy efficiency and greenhouse gas emission reductions in buildings. The first focused on influencing user behaviour, in an office building on the main campus. The second considered an interventionist approach in an accommodation block at the Henley Business School using intelligent monitoring and control systems.

To date, the first trial has demonstrated a 20% saving in lighting, office equipment and catering energy use, largely through user awareness and behaviour change.

The second has indicated that savings in heating energy of the order of 24% can be achieved by enhancement of legacy Building Management Systems (BMS) using a Building Energy Management System (BEMS). There is also scope for further savings if the BEMS system is extended to other services such as lighting.

Optimising defouling schedules for oil-refinery preheat trains

In an oil refinery, crude oil is heated to 360–370 °C before entering a distillation column operating at atmospheric pressure where the gas fraction and several liquid fractions with different boiling points (*e.g*. gasoline, kerosene, diesel, gas oil, heavy gas oil) are separated off. The crude oil is heated in two stages. The preheat train – a series of heat exchangers – heats it from ambient temperature to about 270°C when it enters the furnace, known as the coil inlet temperature. The furnace then heats the oil to the temperature required for distillation.

The purpose of the preheat train is to recover heat from the liquid products extracted in the distillation column. Without this, 2–3% of the crude oil throughput would be used for heating the furnace; with the preheat train up to 70% of the required heat is recovered. It also serves to cool the refined products: further cooling normally uses air or water.

Over time, fouling reduces the performance of the heat exchangers, increasing the amount of energy that has to be supplied. It is possible to bypass units to allow them to be cleaned, with an associated cost and temporary loss of performance. The cleaning schedule thus has an impact on the overall efficiency, cost of operation and emissions.

The group at the Department of Chemical Engineering and Biotechnology at Cambridge developed a scheduling algorithm for this non-linear optimisation problem. It yields a good, though not-necessarily optimal, schedule and can handle additional constraints, such as the presence of desalters with specific temperature requirements within the preheat train. This is now being developed into a commercial software product.

Data from two refineries – one operated by Repsol YPF in Argentina and the Esso Fawley Refinery in the UK – were used to model the systems and test the algorithm.

For the Repsol YPF refinery, when compared with current practice and including a constraint on the desalter inlet temperature, the most conservative estimate of the emissions reduction was 770 t CO_2/year. This assumed a furnace efficiency of 90%. The emissions reduction increased to 930 t CO_2/year at 75% efficiency and 1700 t CO_2/year at 40%. These were based on a stoichiometric estimate of the emissions from the furnace. Using a standard emission factor increased them by 7.4%.

For Esso Fawley, the estimated emission reduction compared to no maintenance was 1400 t CO_2/year at 90% furnace efficiency. This increased to 1700 t CO_2/year at 75% and 3200 t CO_2/year at 40% efficiency.

Discussion

The project has successfully developed and demonstrated an approach to assessing the benefits of HEI research, development, consultancy and training in helping other organisations to reduce their carbon footprints. The scale of the return is illustrated by the fact that the annual brainprint of the four Cranfield University projects considered is over 1 Mt CO_2e/year, or 50 times the University's own carbon footprint.

The unit reductions across a diverse range of projects inevitably vary widely. The headline numbers for energy intensive activities, such as air travel, are dramatic, but these should not overshadow the contributions in other areas. The emissions reductions for single buildings in the intelligent buildings project may appear modest, but each represents about 20% of the relevant consumption, with implications for the whole non-domestic building sector. Indeed, influencing human behaviour is fundamental to reducing all our greenhouse gas emissions.

The challenge of such diverse applications means that there is no single, simple toolkit that can be applied. The basic principles and methods summarised above and described in the guidance notes represent the extent to which we are able to prescribe the method at this stage of development. Several points arising from the case studies that may be helpful when undertaking carbon brainprint evaluations are discussed below.

Some of the case studies used detailed models (oil refinery defouling) or moderately detailed models (jet engine TBC). In the former case, the model already existed and was the basis for the work; in the latter it was needed because of the lack of fuel consumption data for specific aircraft models. These are roughly equivalent to Tier 3 (detailed, model-based) methods in IPCC terminology (IPCC, 2006). Other studies (transport logistics) were able to use recorded fuel consumption data, which greatly simplified the assessment. These are approximately equivalent to IPCC Tier 2 (consumption based) methods.

In most cases, the choice of level of detail was constrained by the available data. For a carbon brainprint, which is a high-level estimate aggregated over space (or use) and time, the extra detail that might be obtained from a model-based approach is likely to be swamped by the high uncertainty, so less detailed, and less time-consuming methods should probably be preferred when the choice is available. For example, given annual fuel consumption data for a representative sample of the correct A330 and A340 models, a reasonable estimate of the effect of improved TBCs could have been made without having to consider engine-specific fuel consumption or aircraft usage data. Indeed, this would have removed the uncertainty about converting fuel consumption from standard engine tests into flight consumption.

The simplest and clearest assessments were those such as training for landfill gas inspectors and improved transport logistics, where implementation and uptake had begun and data had been recorded in practice. Although some data were unavailable, notably the baseline, and there is always some uncertainty in data recording, these cases removed the uncertainty associated with extrapolating from research results into practice.

Where such data were not available, some cases provided clear routes to uptake, which simplified the evaluation. For the jet engine TBCs, the past and future deliveries of the relevant engine models were well defined and publicly available. However, other potential uptake routes, including other aircraft engine models and fixed industrial turbines, such as power stations, were ignored, so the results underestimate the retrospective and prospective brainprints significantly. The refinery defouling algorithm also had a clear route to a well-defined market, through the software product currently being developed, though the rate of uptake will depend on economic and other factors.

For different reasons the NOVA wind turbines and intelligent buildings projects posed the greatest challenges. In most cases other than NOVA, the innovation was a modification to the operation of a process or system, rather than a radically new installation. As the components of the modification generally had a negligible carbon footprint, the assessment only had to consider the effects. NOVA was the only project to consider new installations, so it required a complete life-cycle analysis to estimate its impact on greenhouse gas emissions. In this case one had been carried out, but for a somewhat different purpose. Without this, it would probably have been prohibitively time-consuming to do within the scale of the Carbon Brainprint project.

The intelligent buildings project used new experimental work to demonstrate substantial emissions reductions through two different approaches. The challenge here, which we have not addressed, is how to extend this to other buildings. Every building has a unique combination of location, design, systems, usage pattern and inherent efficiency. Any attempt to extrapolate from these experiments would be highly speculative.

The experience gained from these case studies helps to indicate some useful directions for ourselves and other workers interested in evaluating HEI brainprints, especially when resources are limited.

When trying to estimate the total brainprint for an HEI, or to illustrate the likely scale, a few activities are likely to be significant. These are most likely to be those in which the emissions are dominated by a single flow of energy or a gas with a high global warming potential (such as methane or nitrous oxide) which is so large that other contributions can be neglected. These are also likely to be relatively straightforward to evaluate.

Projects or courses that have already found practical application, especially where the results that affect greenhouse gas emissions have been recorded, provide the clearest demonstration of the benefits, and are usually the simplest to evaluate. In the absence of known uptake, it is helpful to have a reliable link between use and benefits, and a planned route to the market.

Many projects already include a financial justification in the proposal or final report, which may even be based on the cost of fuel saved. In future, researchers could consider including a brainprint evaluation with this. This might be extended by building monitoring or reporting into projects after delivery to the client. This could even form part of the 'Pathways to impact' or dissemination plans for research council and public sector projects. During the study, several examples were found of projects that were expected to have emission reduction benefits, but where there was no provision for monitoring. In hindsight these are missed opportunities.

Dissemination

Web site

The first phase of the web site (www.carbonbrainprint.org.uk) was developed to provide basic information and report progress in the form of a blog. The second phase was delayed by due to conflicting activities. At the time of writing, the second phase is operational, though some features have still to be added. It provides access to the documents produced in the project, including the summaries and full reports of the case studies. A search facility is included in the design, but not yet implemented. It also contains a categorised library of links to useful resources, such as the key data sources used in the case studies. In future, users will be able to submit their own reports and data sources for inclusion.

Events

The original plan for dissemination was to hold a launch event at Cranfield including presentations and workshops. The steering committee decided that it would be difficult to attract sufficient of the target audience to such an event, so various options were considered. It concluded that the best approach was to present the project at events where the appropriate audience already existed, in particular the HEFCE conference in 2012 and possibly the UUK conference in September 2011. Verbal agreement has been obtained from the Chief Executive of HEFCE to inclusion in the HEFCE conference. We also plan to promote it through established networks for university sustainability, such as the Environmental Association for Universities and Colleges, and in the press.

The project was presented at the Leadership Foundation for Higher Education conference 'Leading Transformation Change' in January 2011, along with the other HEFCE Leadership, Governance and Management projects. It generated considerable interest and questions, particularly about how it might apply to general education and subjects other than science, engineering and technology.

It also featured strongly in Cranfield's Green Week in May 2011, with a well-attended lecture and a large display including posters from the Reading and Cambridge University teams.

The project has been entered for several environmental awards for HEIs, and has been shortlisted in the Research and Development section of the Green Gown awards.

Conclusions

The project has shown that it is possible to evaluate the carbon brainprint of some HEI research, development, consultancy and training.

Some projects, especially process modification in applications with high energy or greenhouse gas flows, have very large carbon brainprints compared with the carbon footprints of HEIs. These are also the most straightforward to evaluate.

Other work may not produce such dramatic unit reductions, but could be very significant given widespread uptake and behavioural change.

HEIs are making a significant contribution to reducing society's greenhouse gas emissions.

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