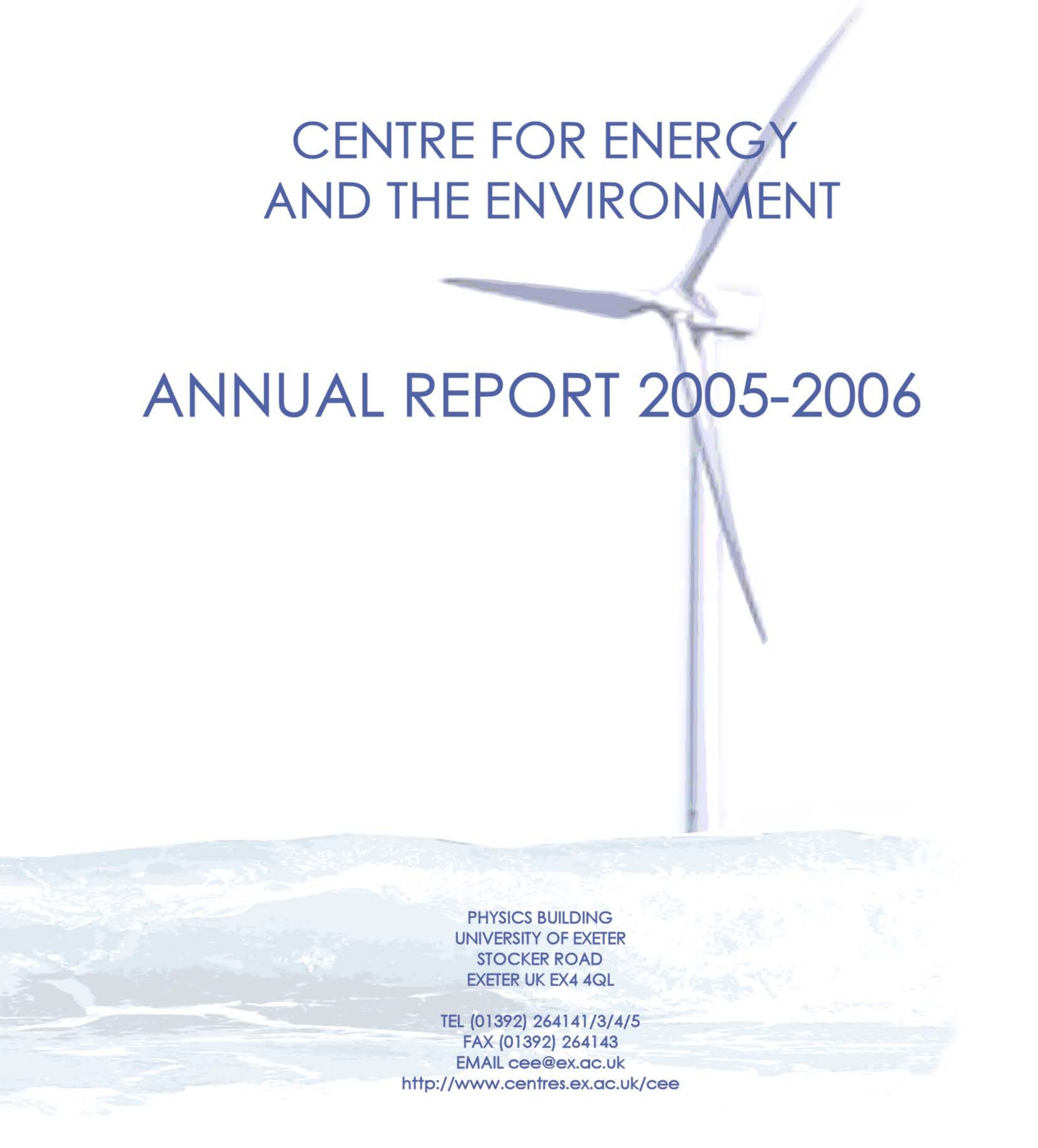
UNIVERSITY OF EXETER

CENTRE FOR ENERGY AND THE ENVIRONMENT



ANNUAL REPORT 2005-2006

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CENTRE FOR ENERGY AND THE ENVIRONMENT

ANNUAL REPORT

2005-2006

A MEMBER OF THE SOUTH WEST ENERGY AND ENVIRONMENT GROUP

SWEEG Membership

Full Members
Devon County Council
Cornwall County Council
Torbay Council
University of Exeter

Associate Members
Exeter City Council
Somerset County Council
Plymouth City Council
Devon and Cornwall Police Authority

Organisations wishing to join SWEEG should contact the scientists at the Centre for Energy and the Environment in the first instance, who will be pleased to discuss the benefits and likely costs of membership.

SWEEG and the CEE

The South West Energy and Environment Group (SWEEG) exists to provide technical advice to its member authorities in the fields of energy efficiency, natural ventilation, sustainable building, thermal comfort, waste management, building acoustics, noise pollution and other environmental issues. Much of the work is strategic in nature and is hence of interest to several of the funding authorities. The groups work is disseminated at SWEEG meetings and reports, internal documents and briefing papers. Sometimes work of wider interest is published in technical journals. Documents produced within the past year are listed at the rear of this report. A full list of publications is available on request, or is available in searchable form on the internet at http://www.ex.ac.uk/cee/publications/.

SWEEG partly funds a team of scientists located in the Centre for Energy and the Environment (CEE), which is a part of the School of Physics at the University of Exeter. The team has a broad range of analytical skills as well as technical expertise in computer-based mathematical modelling, electronic data logging and acoustic measurement.

About the Centre for Energy and the Environment

The Centre undertakes a diverse range of strategic, knowledge transfer and consultancy projects for SWEEG members. Highlights from the past year include:

- The impact of forthcoming changes to Part L of the Building Regulations through familiarisation, computer modelling, and dissemination to SWEEG members;
- An investigation into the acoustic performance of doorsets;
- Examining the potential for a waste to energy scheme in Torbay;
- Work with partners to establish the Renewable Energy for Devon project, which aims to save over 5000 tonnes of CO_2 and create 41 local jobs;
- Air quality reviews for Exeter, Plymouth and Kerrier;
- A study into the viability of wood fuel heating for schools;
- The running of *Building Bulletin 93: Acoustic Design of Schools* CPD courses;
- Numerous consultancy services, for example BB93 and BREEAM assessments.

In addition to the scientific services made available to local authorities under the SWEEG arrangement, the Centre undertakes commercial consultancy work for individuals, private companies and under academic grants. The details of this work are usually commercially confidential, and therefore the details do not feature in the annual report. Examples of funding sources from the past year include:

- Carillion, one of the UK's premier construction service companies, for acoustic design advice of the large scale school build programme in Exeter
- The Department for Education and Skills for contribution to its new building bulletin on sustainable schools
- BREEAM Schools consultancy for companies and local authorities both locally and nationally
- Contracts from building contractors to carry out pre and post-works acoustic assessments to ensure compliance with Part E of the Building Regulations
- Design advice to private clients and architectural practices, regarding acoustic design aspects of schools
- Investigations into the acoustic performance of metal deck roofing systems
- The establishment of a Knowledge Transfer Partnership (KTP) with Riverford Organic Vegetables to investigate its carbon footprint.

Areas of Expertise

Energy in Buildings
- Advice on sustainable design
- Monitoring of building services performance
- Energy auditing
- Ventilation measurement and CFD prediction

Transport and Air Quality
- Localised emission modelling
- Regional air quality assessments
- Prediction and measurement of road traffic noise

Acoustics and Noise Control
- Acoustic design advice for buildings
- Measurement of the acoustic quality of buildings
- Environmental noise measurement and assessment

Environmental Impacts
- Audits of regional energy use
- Audits of greenhouse gas emissions
- Renewable energy feasibility assessment

BREEAM
- Offices and Schools assessments
- Pre-Assessment consultation services

Computer Services
- Development of scientific software tools
- Optimisation using artificial intelligence methods

Preface

The success of SWEEG over the past 30 years has been built on the commitment of its partners and the way in which officers work together with CEE scientists to add value through the application of technical knowledge to research and solve new and relevant problems.

The mitigation of climate change requires a revolution in the way our society addresses energy and the environment. SWEEG's knowledge and experience has important contributions to make across many areas including renewable energy, sustainable buildings, carbon foot-printing and sustainable communities.

So, while the scientists' technical expertise will always lie at the core of what the CEE does, the Centre is increasingly being asked to play a more strategic role. For example, member authorities are developing sustainable energy strategies to meet the government's target of reducing CO_2 emissions by 60% from 1990 levels by 2050. These strategies inevitably focus on reducing demand, improving energy efficiency and developing decentralised and renewable energy in the region and have both a technical and structural content.

Strategic projects require the Centre to engage more broadly. The CEE has therefore been establishing links with a network of environmentally conscious organisations across the region. This network has helped the Centre to play a fuller part in facilitating progress and making a difference and SWEEG is now well placed to make a telling contribution in future.

In the coming year the Centre will be involved in many noteworthy projects, including:

- The monitoring of ground source heat pumps in Cornwall to move towards eliminating fuel poverty in off-gas grid homes in the county
- Guidance on sustainability, thermal design, acoustics and daylighting in the £30 million exemplar secondary school that is being built in Bideford
- Establishing a sustainable solution to Torbay's waste strategy, which will require both technical research and advice, practical on-the-ground collaboration and an understanding of the economics

With so many possibilities, we have taken a conscious decision to limit our acoustic work particularly in the private sector. We have learned much from our involvement with the PFI schools in Exeter and the work has highlighted a number of potential areas that need further research. The Centre's expertise in school buildings has been recognised by the DfES placing the CEE on its shortlist of preferred contractors.

Tony Norton has joined us as a SWEEG scientist after two years as a HEFCE fellow and Anthony Frost, an acoustic specialist, has left for a post which will broaden his experience. We now plan to recruit a sixth scientist and the flow of funded work will allow us to do this.

This annual report summarises much of what we have done in the past year but, more than ever, new challenges lie ahead. Climate change demands action - the Government has acknowledged the importance of the "third sector" – the coming year is also perhaps the time to map out the part SWEEG and the CEE can play in the revolution.

Trevor Preist
Director
September 2006

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Climate Change & Energy

Over the last year, the CEE has taken an important role in the development and implementation of major elements of regional climate change strategy in addition to detailed studies of building design and energy performance of buildings. The Government Office for the South West (GOSW) commissioned the Centre, together with the renewable energy group at the University of Exeter in Cornwall, to research and deliver a presentation on climate change and energy in the South West. This presentation was also delivered to an audience in Cornwall, the South West TUC, and the Board of the South West Regional Development Agency (SWRDA). Additional presentations to whole of the South West Regional Assembly and at a Gloucester County Council event are planned in the coming months.

Over the last year, the CEE has taken an important role in the development and implementation of major elements of regional climate change strategy, in addition to detailed studies of building design and energy performance of buildings

The Centre is working with GOSW on methodologies for the assessment of the carbon impacts of the new round of EU programmes in the region. In addition, the Centre ran a workshop on the economics of renewable energy at the Devon Sustainable Energy Network (DSEN) conference in March.

Renewable Energy

The Centre is a delivery partner in the Renewable Energy for Devon (RE4D) Project. RE4D promotes the demand for and supply of renewable energy in areas of Devon eligible for EU Objective 2 funding. The Centre has been active in setting up the project, and providing scientific input, database development and project management skills. RE4D has research outputs for which the Centre is the delivery partner. In parallel with RE4D, the Centre has researched the rôle of Energy Service Companies and held an event at the University in July as part of an assessment of the applicability of these types of organization.

This work is strongly linked to the Centre's participation in the Cornwall Sustainable Energy Partnership (CSEP) and the Devon Sustainable Energy Network where the Centre's scientists are active in the Buildings and RE subgroups respectively.

The Centre is currently involved in a long term project for Cornwall County Council to monitor the in-situ performance of micro-renewable technologies in the county. The aim of the project is to build confidence in this developing field, and to provide independent data. In the first instance, the study will look at ground source heat pumps (GSHP) that have been installed by Carrick and Penwith Housing Authorities. The Centre is leading the project, and is in partnership with CSEP and Cornwall College. Energy consumptions of the systems together with air temperatures will be recorded over a heating season, and this information will be augmented by questionnaire data. It is expected that similar methodologies will be applied to other micro-renewable technologies. One example is a potential project with Cornwall Sustainable Building Trust to install a range of technologies, including micro-wind turbines and photovoltaic systems, in fifty houses in Cornwall.

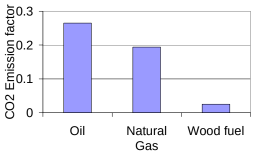
RENEWABLE ENERGY 4 DEVON
expert advice for your generation

Energy Strategy for the Isles of Scilly

The Centre was asked by Cornwall County Council to review the Isles of Scilly draft Sustainable Energy Strategy. This strategy tries to set the future for energy provision on the islands and it was very encouraging to see the islands producing such a document and thereby showing a lead to other districts in the South West. One reason for reviewing the document was because we expect the other local authorities within the SWEEG region to produce similar strategies in coming years.

However, the draft strategy lacked a number of elements which we would like to have seen, including quantitative analyses of: the current position, the direction energy use is heading and why, targets and priorities, and value for money. We also feel that such documents should give a clear reason why sustainable energy is important to those it might affect.

Sustainability has become an important element of local government policy, and although this is encouraging, such policies must be based on sound data collected via a rigorous methodology, as well as on good intent. This suggests that SWEEG needs to show leadership in the area, possibly by producing such a methodology for district councils in the region. There is an opportunity for SWEEG scientists to work with local authorities to ensure that the strategy development process have these characteristics.



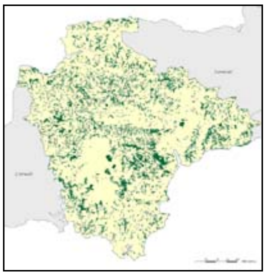
Emission factors (kg/kWh) for oil, natural gas and wood fuel

Wood Fuel Boilers

Devon County Council (DCC) is considering using automatic wood fuel heating in its school buildings in order to reduce the carbon footprint of this major element of its operations. DCC asked the Centre to investigate the viability of this strategy, particularly addressing question marks over its genuine sustainability, the reliability and quality of wood fuel supply available, and the reliability of wood fuel boilers and fuel delivery systems.

Wood is regarded as a low carbon fuel because there is no net emission from wood's growth and combustion, which can take place over similar timescales. It is estimated that, once the emissions from forestry operations and from transport of the wood are taken into account, using wood fuel rather than natural gas saves 87% of the carbon dioxide generated by heating (top image).

Automatic wood fuel heating typically uses woodchips or wood pellets. Woodchips are normally 5-50 mm long rectangular pieces of wood formed by chipping side products of forestry and the timber industry. Wood pellets are dense particles normally made of highly compressed sawdust. Devon is estimated to have more than twice the UK average resource of wood fuel per head (middle image), which is approximately equivalent to three and a half times the present demand for heating from Devon's schools. If the school buildings' thermal insulation was improved to best practice standards, the wood fuel resource would be closer to eight times the demand. Therefore, the resource significantly exceeds the increase in demand likely to be created by DCC's use of wood fuel heating, and using wood fuel can lead to greater investment of money within the county than using fossil fuels.



The distribution of woodland greater than two hectares in Devon

State-of-the-art woodchip and wood pellet boilers are designed to minimise requirements for manual intervention. Typically woodchip is agitated in its store by a sweeping arm or moving floor, then fed to the boiler by an auger screw (bottom image). Higher quality chip and pellets are fed upwards into underfed burners and larger or more moist woodchip is fed onto a moving grate burner. In the burner the wood is turned to gas and combusts, transferring its heat to the heating system's water circuit. The reliability of these automatic systems is very dependent on the correct quality of fuel being used. The most rigorous standards for woodchip and wood pellet fuel are those developed in Austria. These cover the size distribution of the fuel, its moisture content, and, in the case of pellets, its mechanical durability.

The broad conclusion of this study was that wood fuel could be viably used to heat Devon's schools if care was taken in the choice of system and fuel supply, using state-of-the-art technology with a proven track record, and agreeing well-defined fuel quality requirements with the heating system supplier and fuel supplier.

Woodchip transported by an auger screw

Waste to Energy

As part of Torbay's wider work on its waste strategy the Centre has reviewed the applicability of advanced thermal treatment of waste in Torbay. The study identified a potential process and several potentially suitable sites. Additional work is underway to provide further guidance on a number of aspects of the technology including its environmental and health impacts.

Relevant Documents

- *Briefing Paper 81*: An Assessment of the Viability of Wood Fuel Heating for Devon's Schools
- *Internal Document 426*: Advanced Thermal Treatment (ATT) to Produce Energy form Waste in Torbay

Sustainable Building & Development

The operation of buildings is a key element of mankind's contribution to climate change and should therefore be at the core of efforts to reduce greenhouse gas emissions. Increasing appreciation of the importance of low carbon buildings has been reflected in the prominence of sustainable building in the CEE's work over the last year.

The main driving forces behind this work have been:

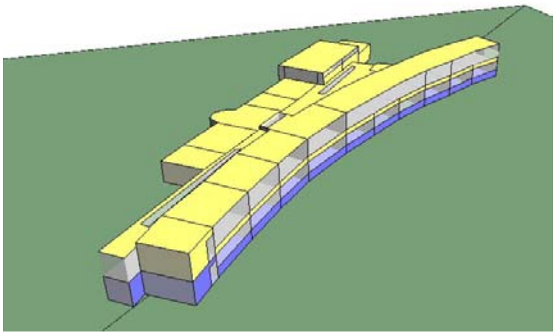
- The commitment of members of SWEEG to the reduction of the climate change impact of their activities (*e.g*. Devon's Climate Change Strategy and Cornwall's Sustainable Energy Partnership)
- Major changes to the energy in buildings regulations designed to reduce carbon dioxide emissions from the built environment
- Acknowledgement by the Department for Education and Skills (DfES) of the importance of these issues, which is reflected in their requirements for new school buildings and in the development of a new building bulletin on sustainable school design
- The demonstration of Local Authorities' commitment through support of sustainable building in Camborne Pool Redruth, Sherford and Cranbrook developments
- The regional commitment to sustainable building as set out in the draft Regional Spatial Strategy

It is expected that the Energy Performance of Buildings Directive will save 45 million tonnes of carbon dioxide by 2010… the Centre has taken an active lead role in helping the SWEEG members to meet the more demanding requirements of the new regulations

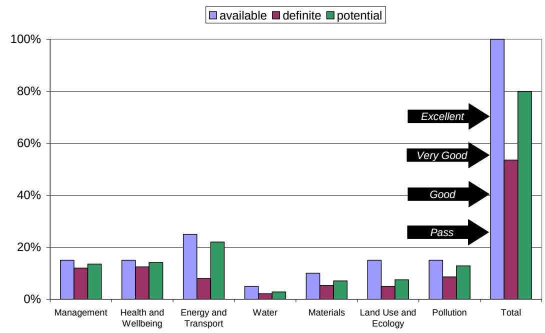
Changes to UK Legislation

The European *Energy Performance of Buildings Directive* (EPBD) became active in member states on the 1st January 2006. It is expected that the EPBD will save 45 million tonnes of carbon dioxide by 2010 (the EU is committed to saving 330 million tonnes under the Kyoto Protocol). Amongst the requirements of this directive are the development of a national methodology to calculate carbon emissions from new buildings, formal consideration of renewable energy in new buildings, the upgrading of existing buildings where work is to be carried out, regular energy inspection of building services, and energy certification of buildings. Whilst parts of the directive have yet to be implemented in the UK, amendments to the England and Wales' building regulations, specifically Part L, implement many of its requirements. The Centre has taken an active lead role in helping the SWEEG members to meet the more demanding requirements of the new regulations.

In the first instance, this has involved a thorough familiarisation with the key documents through their consultation periods. The Centre has two staff members on the *CIBSE Low Carbon Consultants Register*, which required the demonstration of a detailed understanding of the workings of UK energy legislation, and of an ability to save carbon within buildings. This familiarisation has fed into consultation sessions with SWEEG members, which brought together architects, building service engineers and other relevant staff to present findings of research by the CEE, and to discuss how the requirements are to be met. Amongst the topics that the Centre has investigated are the different strategies required to pass and exceed the regulations–



The design as modelled of Exwick Heights School, Exeter. Building Control submissions of non-domestic buildings will now typically involve dynamic thermal modelling



Spreadsheet to determine possible strategies for achieving the desired BREEAM Schools rating (normally 'Very Good' as expected by DfES)

e.g. through building design, services specification and insulation levels. This was demonstrated using live projects that are currently being built within the SWEEG region, for example Foxhole School in Cornwall and Exwick Heights (top image) and Moretonhampstead Schools in Devon. Another critical avenue for investigation was the use of various compliance tools. The Centre has made extensive comparisons between *iSBEM* – the official simple building energy model developed by the BRE, and the *IES* dynamic thermal modelling suite. The results of these studies, have been presented at four specific meetings over the last year, and have provided a very useful platform for transferring knowledge to SWEEG members, and as a forum for discussion. The Centre is continuing to assist SWEEG members in the design of low energy buildings, and computer simulation of their designs.

Lessons from BREEAM Schools

BREEAM (Building Research Environmental Assessment Methodology) is a well established mechanism in the building industry for quantifying the environmental performance of buildings. Last year, BREEAM Schools was launched, which is a modified version of BREEAM specifically for school buildings, developed in collaboration between the Building Research Establishment and the Department for Education and Skills (DfES). The DfES now expect at least a 'Very Good' rating for all new capital school projects with budgets of over £2,000,000 for secondary schools, and £500,000 for primary schools. Since the methodology is still very new, to date there has been only one school nationally that has been through the whole process to achieve a BREEAM Schools rating. The Centre has been heavily involved in BREEAM Schools assessments this year, and is currently engaged in several assessments, both for SWEEG members *e.g.* Foxhole School, Cornwall, and in a commercial capacity.

Whilst it is not yet possible to publish any specific findings from these projects, some general trends have clearly emerged. Perhaps the most positive outcome is that it is clear that the BREEAM process is having an impact on building design. Clients, architects and engineers are giving serious consideration to implementing sustainability measures that previously would have been left out. It is the establishment of quantifiable criteria backed with top-down leadership that has enabled them to strive for this. Whilst it is perhaps too early to assess whether this manifests itself in more sustainable buildings, it seems like a step in the right direction. It is also apparent that different design teams work in very different ways, and whilst there are some credits that are seen as universally easy (*e.g.* high frequency ballasts to artificial lighting), or challenging (*e.g.* limiting indoor air pollution in buildings that are in close proximity to roads or delivery routes), there is a larger grey area in between. Therefore, whilst the Centre's experiences with BREEAM are building a more refined image of how to achieve a 'Very Good' rating, it cannot be stated that there is a best solution that will suit all projects. What is very obvious though, is that the projects where we have had input from the earliest possible opportunity are likely to achieve a 'Very Good' rating far more easily. The bottom image shows an example of a spreadsheet tool that could be used to establish a strategy early in the design process to achieve a target score. Appointing a BREEAM assessor too late in the design process makes achieving some of the credits impossible, for example, the requirements of some credits to be undertaken by RIBA Stage C. In particular, many of the credits in the Management section regarding consultation with the public and various other professionals cannot be achieved retrospectively, meaning that some of the more challenging credits would need to be obtained to achieve the required rating.

BREEAM Schools was revised this year in response to feedback from the first year of its use and to take account of the changes in the energy in building regulations described above. The modifications have made the energy section more rigorous and more demanding but also provide greater rewards for improvement on the requirements of building regulations. Amongst other changes the proofs required to demonstrate compliance with some of the management and process-related credits have been made more rigorous. It is expected that this process of regular modification will allow BREEAM to evolve into a robust tool for improving the quality and environmental impact of school buildings.

Low Energy School Design

This year the CEE was fortunate to win research funding from the Department for Education and Skills for a study that looked into different ways to design a low energy school. The project concentrated on issues such as insulation levels, ventilation rates and thermal mass, rather than layout and form. The work was based on Devon Property's design for the new Exwick Heights School in Exeter.

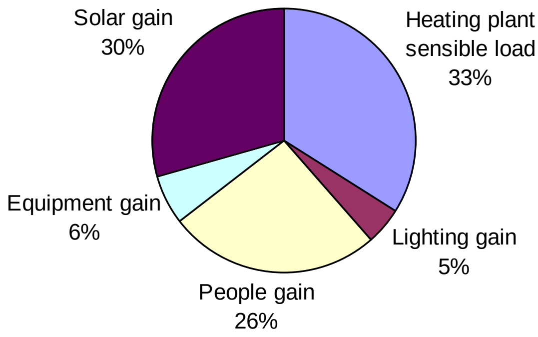
First the design was modelled as drawn, then a series of design changes were made: initially singularly and then in groups, and the reduction in annual energy uses and propensity to overheat was recorded in each case.

Several interesting results were observed, some of which were already well known within the building science community and others less so. Even for those that were well known – for example that increasing the level of insulation reduces energy consumption – the project was important in that it put a number against the likely level of improvement.

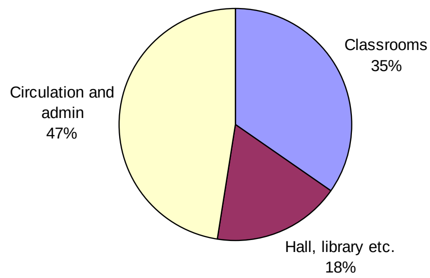
The top image shows where the initial design, which is typical of any new school, gets the heat it needs in winter. The middle image shows carbon dioxide emissions associated with the various spaces within the school, and the bottom image how it is lost from the building as heat. We immediately see that the heating system does not provide the bulk of the heat needed by the school, that classrooms use only one-third of the energy and that heat losses via conduction through the building's fabric exceed those due to ventilation and air leakage.

The various adaptations to the design finally led to the situation shown in the top two images of the facing page. We now see that the heating plant only supplies 3% of the heat required by the school and that ventilation/infiltration losses exceed fabric losses. It would be interesting to see whether this level of theoretical performance could be matched within a real school, where control of systems and behaviour of occupants may from an energy point of view be less than ideal.

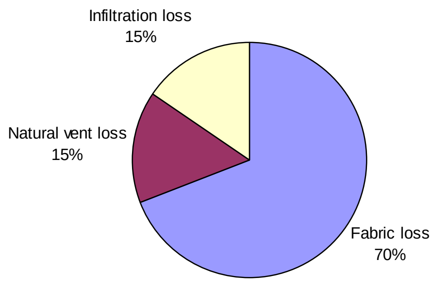
The project showed that it is possible to design a school that uses relatively little fossil fuel derived heat and gets the bulk of the heat it needs from the pupils and other free sources. However, in order to achieve this, building designers need to know what design



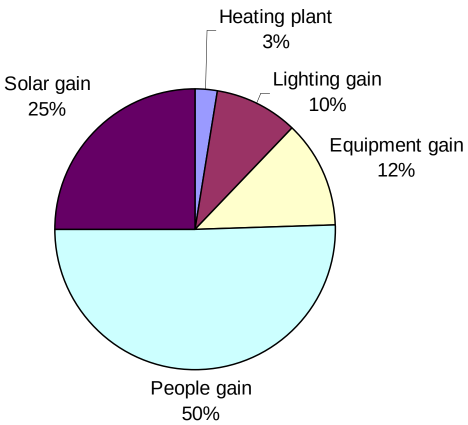
Wintertime breakdown of heat supplied by source for the initial design (baseline case)



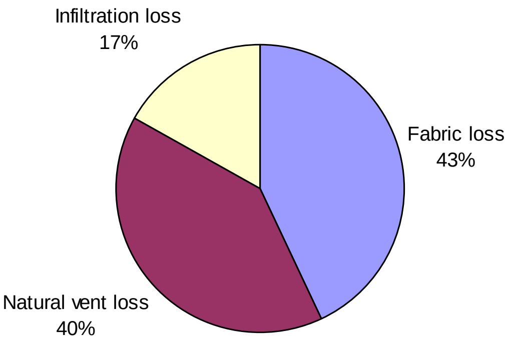
Carbon dioxide emissions within the baseline school from different space types—note how the high occupancy spaces use relatively little fossil fuel energy



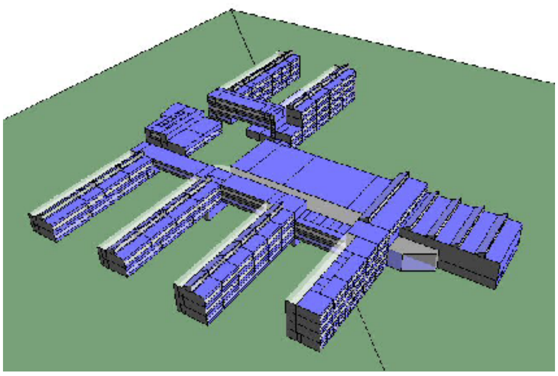
How heat is lost from the school (baseline case)



Wintertime breakdown of heat supplied by source for the final design



How heat is lost in the final design during the winter. Note how fabric losses have been reduced in importance compared with the initial design



View of an initial design of Bideford College. Classroom blocks on an East-West axis join into a main spine containing large volume spaces, and an atrium space

changes will be effective. Unless the school is super-insulated, conduction through the fabric will be the dominant heat loss path. Much of these fabric losses will be via windows, which typically lose more useful energy than they generate through solar gains or save from the reduced use of artificial lighting. Looking at other significant loss paths, as much heat is lost via unwanted air leakage as through deliberate ventilation with opening windows so efforts to make school buildings more airtight will deliver significant improvements. Orientation of classrooms makes less difference to energy consumption than many people suggest and it is possible to produce a low energy school design using both heavyweight and lightweight constructions. However, both orientation and the level of thermal mass in the construction will affect the likelihood of overheating. The project also demonstrated that design measures to minimise heating energy use in schools would be completely undermined by setting the heating system's thermostat to a higher temperature than necessary (*i.e.* > 18 ^{o}C).

About as much carbon dioxide is emitted from schools' electricity consumption as from their consumption of fossil fuels for heating, and lighting represents a significant element of this electricity load. This project showed that is possible to achieve the required levels of light in classrooms using half the installed power capacity typically specified by some authorities in new schools.

Specific Projects

The past year has seen a large increase in demand for expert sustainability input to building projects. With 30 years of experience in the field, the Centre has been well placed to assist SWEEG members in realising their ambitions. The largest building project that the Centre is advising on at present is the new £30 million Bideford Pathfinder College. Involvement commenced at the very beginnings of the project, which as our experience has shown, provides the greatest opportunity to beneficially inform the design. Input began during the writing of the brief for the project, and progressed to initial advice on sketched proposals. As the design has evolved and been refined, computer models have been built to simulate the building's performance. These have included thermal simulations to assess the heating energy demand and the probability of overheating in the school's classrooms and glazed atria, and a model examining the daylight penetrating classrooms directly through windows and via the atria of the school's novel narrow plan blocks (bottom image). Devon County Council have commissioned the CEE to provide a complete consultancy service throughout the life of the project.

The Centre has recently gained the capability to accurately model the daylight performance of spaces. Two classrooms designed by architects ARCO2 – one in Somerset, the other in Cornwall – that utilised construction techniques and materials with low embodied energy, such as straw bales and cob walls, had their daylight performance analysed. Simulations of both classrooms were both performed using the *Radiance* software – a highly accurate lighting simulation package. With this software, it is possible to simulate instantaneous lighting (both natural and artificial) conditions under a range of sky models, for example the 'overcast' sky, which enables daylight factor to be calculated. In each classroom, illuminance levels at working plane height were established (top image), glare was analysed (centre image), sunlight penetration at various times of the day and year was assessed, and views out were checked. These simulations enabled statements to be made about both the magnitude and quality of daylight the designs achieve, and allowed comparisons to be made between the two designs. Likewise, the findings also made it possible to suggest possible improvements to the design to obtain the best possible naturally lit interiors. In this instance, the simulations were run on existing buildings, and represent a different way of analysing the performance of the building than traditional monitoring, which would have involved a long measurement period to obtain a representative range of sky luminance distributions. These simulations are also well suited to be run during the early design phases, when it is still possible to make changes based on the simulation results.

In addition to consultancy connected to specific buildings, the Centre has advised on larger strategic developments. In September 2005 the Centre (with assistance form the University's Higher Education Innovation Fund) hosted a major regional conference titled "Energy Technologies in New Developments". The conference was well received and particularly timely as proposals are brought forward for the building of two new towns in Devon: Sherford to the east of Plymouth and Cranbrook to the east of Exeter.

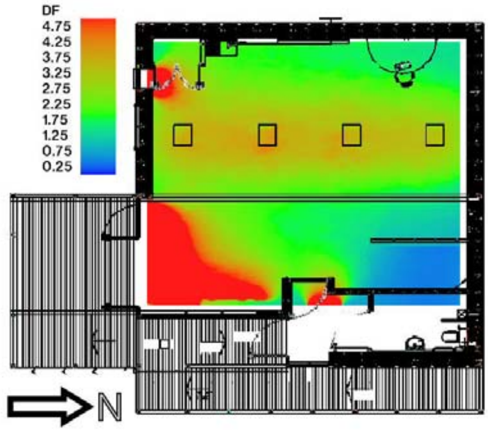
The Centre subsequently provided advice on energy demand in both new communities and gave support to the district councils, consisting of information and advice to officers and members on climate change and energy in buildings.

A potential redevelopment of the cattle market at Wheddon Cross on Exmoor gave the opportunity to analyse a smaller development with a particular focus on the renewable energy options. The work developed a hierarchical approach to the deployment of renewable energy on the site as illustrated in the bottom image.

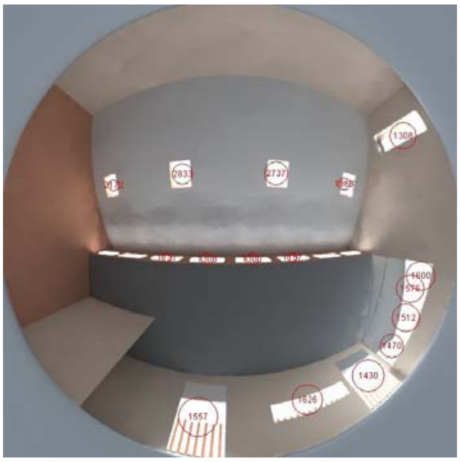
The low carbon technologies lie at the top of the chart and are to be deployed in preference to those lower in the hierarchy. The arrows represent decreasing carbon emissions and the shading of the arrows the magnitude of the energy use of the different duties (electricity the highest, water heating the lowest). The most effective carbon abatement technologies are shown in the top left corner of the chart. The work provided the development with 10%, 33%, and 100% renewable energy options.

Relevant Documents

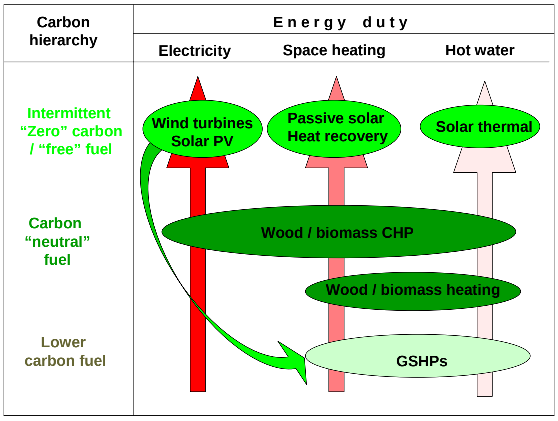
- *Contract Document 195*: Minimising Energy Use in Schools
- *Internal Document 416*: An Initial Assessment of Cranbrook Energy Demand
- *Internal Document 419*: An Initial Appraisal of Sustainable Energy Options for the Redevelopment of Cutcombe Cattle Market in Wheddon Cross
- *Internal Document 440*: A Daylight Analysis of Two Schools Utilising Straw Bales in their Constructions



Daylight Factor at working plane height falsecolour image of the modelled classroom at High Ham School

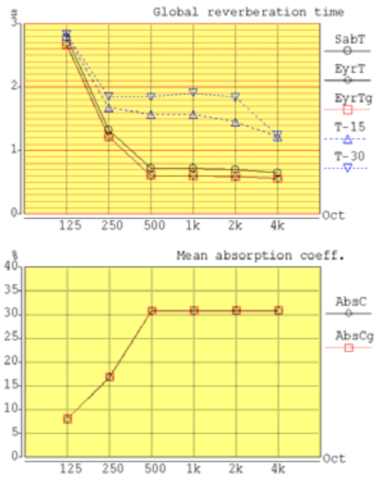


Glare analysis of the classroom at High Ham looking from the centre of the room towards the ceiling, with a fisheye projection



Low and zero carbon options for delivering energy as used in the analysis of the redevelopment of the cattle market at Wheddon Cross

Examples of relocatable classrooms which were tested for BB93 compliance. Reverberation times were short due to low ceilings, and decent levels of acoustic separation were achieved between classrooms where there was an intervening space (e.g. lobby)



	125	250	500	1k	2k	4k	
EyrT	2.68	1.21	0.61	0.60	0.59	0.56	s
EyrTg	2.68	1.21	0.61	0.60	0.59	0.55	s
SabT	2.79	1.32	0.72	0.72	0.70	0.65	s
T-15	2.81	1.67	1.57	1.57	1.45	1.22	s
T-30	2.83	1.85	1.85	1.91	1.84	1.24	s
AbsC	8.03	16.82	30.77	30.75	30.83	30.82	%
AbsCg	8.03	16.85	30.77	30.82	30.84	30.84	%
MFP	5.61	5.61	5.61	5.61	5.61	5.61	m
Diffs	24.64	24.70	24.70	24.64	24.67	24.67	%

Trunc 5000.0 ms
Rays 14038 (used/oct)
0 (lost/oct)
0 (absorbed/oct)
Angle 1.71 degrees

Output from the CATT Acoustic software, showing the longer reverberation times predicted by ray-tracing (T-15 and T-30) than by the Sabine or Eyring empirical formulae for Doubletrees School Hall, Cornwall

Building Acoustics

The Centre's involvement in the field of acoustics has continued to develop. The successful Acoustic Design of Schools course, first run in April 2005, was repeated in December 2005, May 2006 and June 2006. The course has been refined over this period in the light of attendee feedback, changes to the regulations, and knowledge gained by the CEE in its work for SWEEG and other clients. The June 2006 course was run exclusively for Lancashire County Council, and delivered in Preston. It is encouraging to see that many authorities are taking school acoustics so seriously.

Some of the Centre's more strategic work was presented at Institute of Acoustics meetings during the year. In January, a talk was given to the Building Acoustics Group demonstrating the Centre's tools to show aurally the effect of different qualities of sound insulation and reverberation control. At the Spring Conference in Southampton, the findings of a study into the acoustic qualities of relocatable classrooms were presented. These come under the jurisdiction of the Building Bulletin 93 standards if the building is to remain on site for longer than one month. The work showed that reverberation times in such classrooms are generally low and compliant owing to their low ceilings. The internal walls and doors generally provide a relatively poor level of sound insulation, but the acoustic separation between classrooms remains good where the rooms are separated by intervening lobbies, toilets and store rooms, which is a common arrangement. Measurements in a two-storey building, made specifically for the talk (top image) showed that a high degree of vertical sound isolation is achieved, probably because each storey is essentially a complete building with its own roof and floor.

Room Acoustics

The Centre's earliest involvement in building acoustics concerned excessively reverberant school halls – a problem that still arises from time to time. One recent example was a new hall at Doubletrees school in Cornwall. Plasterboard underlining had been used to cover up poor workmanship in the perforated roof liner (which was to provide acoustic absorption). This resulted in a reverberation time that was 2.5 times the statutory maximum. The problem was addressed by fitting sound-absorbent panelling to the ceiling surface. One difficulty with such halls and similar spaces is that large expanses of parallel, acoustically reflective wall surfaces may remain when absorptive products are added to the ceiling and upper parts of the walls, and low levels of furnishing mean that sound reflecting back and forth between the lower parts of the walls is not scattered. Simple reverberation formulae, such as the Sabine formula significantly underestimate reverberation times in such spaces because they assume the acoustic absorption is spread evenly around the space. One approach to the accurate prediction of the reverberation time of these spaces is the use of ray-tracing computer models. The Centre has recently purchased a new commercial model—*CATT Acoustic*—and initial trials show that it can quite easily predict accurate results for these difficult-to-predict environments. The bottom image shows the output from the software when modelling the post-remediation scenario, and compares the predicted reverberation times with Sabine and Eyring formula predictions.

The measured reverberation time for this condition was 1.7 s at 1 kHz.

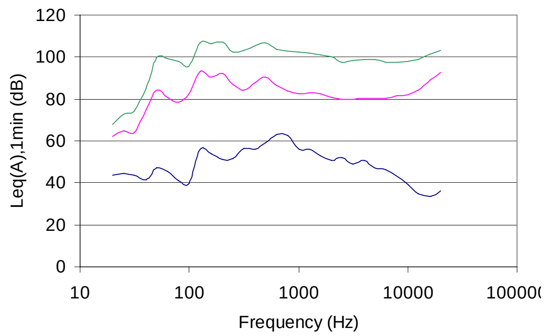
CATT Acoustic can also predict the Speech Transmission Index (STI) of a space. STI measures speech intelligibility on a score of 0 to 1 and is used by Building Bulletin 93 as a criterion for open-plan teaching spaces. Measurements of STI have been used by the Centre to evaluate the effectiveness of soundfield low level amplification systems in classrooms. *CATT Acoustic* was successfully used to reproduce the results from STI measurements of a classroom soundfield system. It should therefore be possible to use the software to model STIs reliably in open-plan spaces at the design stage, and to consider the effect of introducing soundfield systems in open plan areas and to classrooms with a poor level of sound insulation (*e.g.* due to connecting doors between teaching spaces). A potential problem when modelling the in-use performance of spaces is the need to include the absorptive and scattering effects of the furniture and occupants; this will require investigation and refinement.

Recently, in response to concerns about the intelligibility of speech in and webcasts from Devon County Hall's council chamber and committee room, STI measurements were made in these spaces. An STI measurement involves playing a test signal and measuring it at another location in the space. Changes to the test signal due to reverberation, background noise, frequency colouration and other factors are then assessed by the measurement software. In this case, a microphone for the sound system installation was placed in front of the loudspeaker outputting the test signal, to enable the effectiveness of the sound system to be gauged. By connecting an output of the sound system to the input of the measurement system, the STI of the webcast signal could also be judged. The measurements were repeated with various levels of background noise simulated in the space. The tests revealed that speech intelligibility within the rooms was greatly enhanced by the sound system and that of the audio feed to the webcast could be of very high quality, but both were heavily dependent on the microphone being correctly positioned close to the mouth (top image). This is because the microphones are designed to be highly directional to avoid background noise in the rooms being amplified as well as the speaker's voice.

Sound Transmission through Doors

Work has continued on the evaluation of the effectiveness of acoustic seals for doors; a test rig was constructed and used to measure the performance of a number of types of perimeter and threshold seal. In the light of these tests and on-site experience in recently constructed schools, further discussions will take place with the suppliers of acoustic doorsets and door seals, and recommendations will be made to SWEEG architects on suitable door specifications for schools. On a connected topic, a long-running experience with the installation of a moveable partition at Budehaven Community School illustrates just how critical seals can be to achieving the required standard of acoustic separation.

Speech intelligibility measurements at Devon County Hall's council chamber



Example noise spectra from a practice room at Holsworthy Community College. The lower line shows the spectra of the teacher talking, the middle line just drumming and the upper line band practice

Activity	Mean L_{Aeq} (dB)	Max L_{Aeq} (dB)	$L_{EP,d}$ (60 dB(A) base)
Lesson 1	90	98 (5 second)	76
Lesson 2	96	100 (60 second)	82
Band practice	110	113 (60 second)	99

Measured noise levels during various activities at Holsworthy Community College

The main atrium at St James School, Exeter

Noise Exposure of Children

As a result of tests at Holsworthy Community College in which different noise levels were simulated and teachers interviewed about how they compared with typical day-to-day noise, it was suggested that children using the school's music practice rooms might be exposed to noise levels above workplace health and safety regulations. With this in mind, Devon County Council asked the Centre to measure the exposure of those using the facility and to compare the results with the current health and safety legislation.

The sound pressure level within one of the school's practice rooms was measured. Two drum lessons and a four-piece pupil rock band were monitored. The results are shown in the graph showing example spectra, and table.

The Control of Noise at Work Regulations 2005 sets maximum levels of noise exposure in the workplace. In short, this legislation sets two action values and an exposure limit. The lower exposure action value is a daily or weekly personal noise exposure ($L_{EP,d}$) of 80 dB (A–weighted). The upper exposure action value is a daily or weekly personal noise exposure of 85 dB(A). The exposure limit value is a daily or weekly personal noise exposure of 87 dB(A). If the first action limit is breached, the employer must offer ear defenders; if the second is breached the employer must ensure ear defenders are worn. There is also a requirement that an employer should take reasonable steps to reduce exposure to noise, rather than simply relying on ear defenders. If any employee is likely to be exposed to noise at or above the upper exposure action value, the employer must reduce exposure to as low a level as is reasonably practicable by establishing and implementing measures other than the provision of personal hearing protectors.

From the table we can see that of the two drum lessons sampled, one is in breach of the first action level, and that the band practice is in breach of the upper exposure action level. This suggests that the hearing of pupils may well be being damaged. It was therefore suggested that a plan be drawn up to reduce the exposure of these involved in such activities and that the situation in other SWEEG schools be studied.

Commercial Projects

In addition to consultancy work undertaken this year for SWEEG members, the Centre has been involved in commercial acoustic work. This has significantly increased the knowledge base of the group. Over the last year all of Exeter's five secondary schools (bottom image) and Wynstream Primary School have been completely re-built under a private finance initiative (PFI) by Carillion (formerly Mowlem) plc. In addition to the BB93 assessment of the buildings' designs required by building regulations, the client, Devon County Council, specified in the PFI contract that tests be performed on the actual buildings to check their acoustic performance. Having advised Carillion on the acoustic implications of design modifications, the CEE has been intensively testing the acoustics of the new buildings over the last year and a half, especially the sound insulation between rooms, to ensure they meet the client's requirements.

The Centre has been fortunate in receiving research funding from a major roofing manufacturer. This has facilitated the construction of a facility dedicated to studying room-to-room sound transmission via roofs. This is an area of growing concern as schools frequently include lightweight roofs containing a solid or perforated liner. The test facility consists of a pair of adjacent, acoustically isolated test rooms upon which a series of different connecting roofs can be placed easily (top image).

The test chambers without a roof

Initial results indicate that:

- It is possible to acoustically isolate classrooms satisfactorily using such lightweight roofs
- As high levels of isolation are possible when the roof is perforated as when it is unperforated for the depth of partition tested
- It is critical to seal the partition to the liner in some way
- Mineral wool is as effective as proprietary foam inserts in doing this and better than scribed plasterboard (bottom image).

Relevant Documents

- *Internal Document 411:* Holsworthy CC: Noise Exposure in Music Practice Rooms
- *Internal Document 412*: Auralisation in School Design: A Talk Prepared for the January 2006 Meeting of the Institute of Acoustics Building Acoustics Group
- *Internal Document 417*: Acoustic Standards in Relocatable Classrooms – A Talk Given to the Institute of Acoustics Spring Conference 2006
- *Internal Document 415*: Appraisal of Acoustic Treatment in Doubletrees School Hall
- *Internal Document 444*: An Evaluation of Speech Intelligibility in the Council Chamber and the Daw Room at County Hall, Exeter
- *Internal Document 434*: Sound Insulation Performance of the Moveable Partition at Budehaven Community School, Following Further Remedial Action on 27th April 2006

Typical partition head detail found in schools, undergoing tests in the chamber

Air Quality

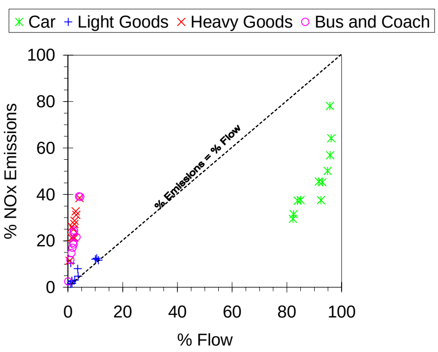
Traffic in Plymouth, one of several areas within the SWEEG region where the Centre has assisted in the air quality review cycle

Local air quality in towns and cities continues to be a cause for concern. In Devon and Cornwall, the principal source of the pollution is road traffic (as against industrial sources), and at present there appears to be little political will to provide alternatives to the private car which are competitive in terms of convenience or cost.

Local authorities have an obligation to conduct periodic reviews of air quality in their areas, comparing measured and modelled pollution concentrations with national objectives. The CEE has continued to assist Exeter City Council, Plymouth City Council and Kerrier District Council in the preparation of the screening assessments, detailed assessments, source apportionment studies and air quality action plans which form the review cycle.

The Centre's greatest involvement is with Exeter City Council, for whom monitoring data are regularly collated to determine the extent of exceedances of the air quality objectives. Nitrogen dioxide (NO_2) is responsible for all bar one of these exceedences. Having declared Air Quality Management Areas on several of Exeter's arterial routes in early 2005, the effect of specific measures that could be taken to alleviate the problem have been investigated by calculating their effects on pollution arisings and modelling the implicit pollution concentrations. Recent monitoring data have shown that further Air Quality Management Areas may be required, and the possible extent of these has been determined by further modelling work.

Kerrier and Plymouth have also declared Air Quality Management Areas, and the Centre has been commissioned to conduct source apportionment studies in these areas,. Source apportionment involves the more specific identification of the source of the pollution problem, by determining the proportion of the whole attributable to specific types of vehicle and specific vehicle routes. In general, heavy vehicles (*i.e.* buses and heavy goods vehicles) emit NO_2 at a far faster rate than light vehicles, and can be responsible for a far greater proportion of emissions than their contribution to the traffic flow would suggest (as shown in the graph). Therefore, a possible approach to alleviating air quality problems could be to restrict the movements of goods vehicles.



Comparison of emissions and throughput attributable to different vehicle types on eleven urban roads in Exeter, Plymouth and Kerrier

Relevant Documents:

- *Internal Document 424*: Exeter Local Air Quality Review 2006
- *Internal Document 457*: Exeter Air Quality Detailed Assessment for Eight New Locations in Exeter
- *Internal Document 445*: Statistics for Exeter's Air Quality Action Plan 2006
- *Internal Document 406*: Pollution Modelling of Proposed Changes to the Alphington Corridor
- *Internal Document 421*: Air Quality Statistics for the Exeter Air Quality Management Areas, for Inclusion in Devon's 2006 Local Transport Plan
- *Internal Document 423*: Evidence for changing pollution levels in the Exeter Air Quality Management Areas
- *Internal Document 456*: Source Apportionment for Plymouth's Air Quality Management Areas
- *Internal Document 441*: Source Apportionment for the Air Quality Management Areas in Kerrier, Cornwall

Internal Comfort

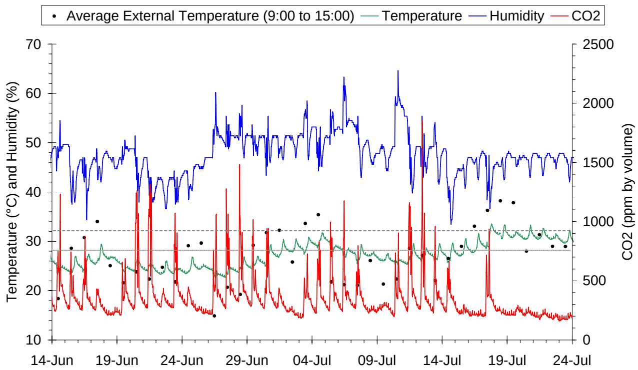
Thermal comfort is by its nature a very tangible measure of building performance. Occupants are quick to complain about excessively warm or cool conditions. Careful design is required to effect sufficient thermal control without resorting to expensive and environmentally damaging air conditioning systems.

During the past summer, the Centre has monitored the thermal performance of Heathfield Community School, Taunton (top image), in response to complaints of excessive temperatures. It was discovered that whilst high temperatures were evident, CO_2 concentrations (and therefore implicitly ventilation rates) were satisfactory (middle graph). An exacerbating factor was identified: the mechanical ventilation systems are equipped with heat recovery units which cannot be bypassed. Hence, although the mechanical ventilation provision is able to maintain air quality, it cannot effectively alleviate overheating. As a rule, the high levels of metabolic heat gain in classrooms makes the provision of heat recovery inappropriate, since heating is generally only required prior to occupied periods, when there is not a need for a high rate of ventilation.

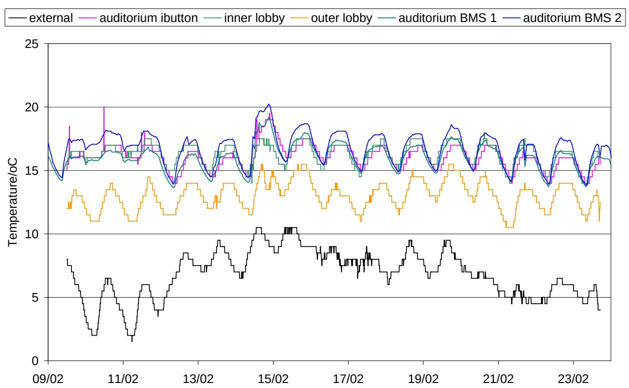
Thermal modelling of the building showed that summertime overheating would be expected even without the heat recovery units, and that this could be ameliorated by providing night-time ventilation through the mechanical system. This régime is to be adopted in an attempt to solve the overheating problem.

At the other end of the spectrum, the St James Centre in Jersey is a former church building that has been converted into a public performance space, where occupants had consistently complained of feeling cold during the heating season. Temperatures in and around the building were recorded over a two week period (bottom graph). Using these data, it was possible to estimate the air exchange rate through the building, based on assumptions of the fabric construction of the building, and gains due to the underfloor heating system, the sun, and lighting and small power. These assumptions and derivations were entered into a dynamic thermal model, and run over the same period. The simple calculations and computer models were in good agreement, giving confidence to extend the run-time of the simulation to cover a whole heating season, and to then make parametric changes to the model to establish the principle causes for the low temperatures, and the most effective solutions (top graph, facing page).

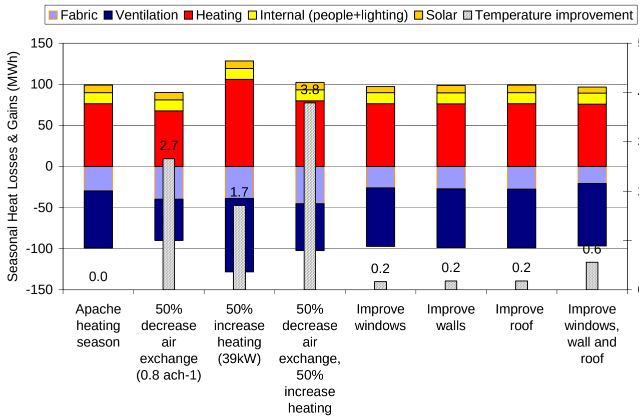
Heathfield Community School, where the Centre monitored temperatures to establish causes for overheating



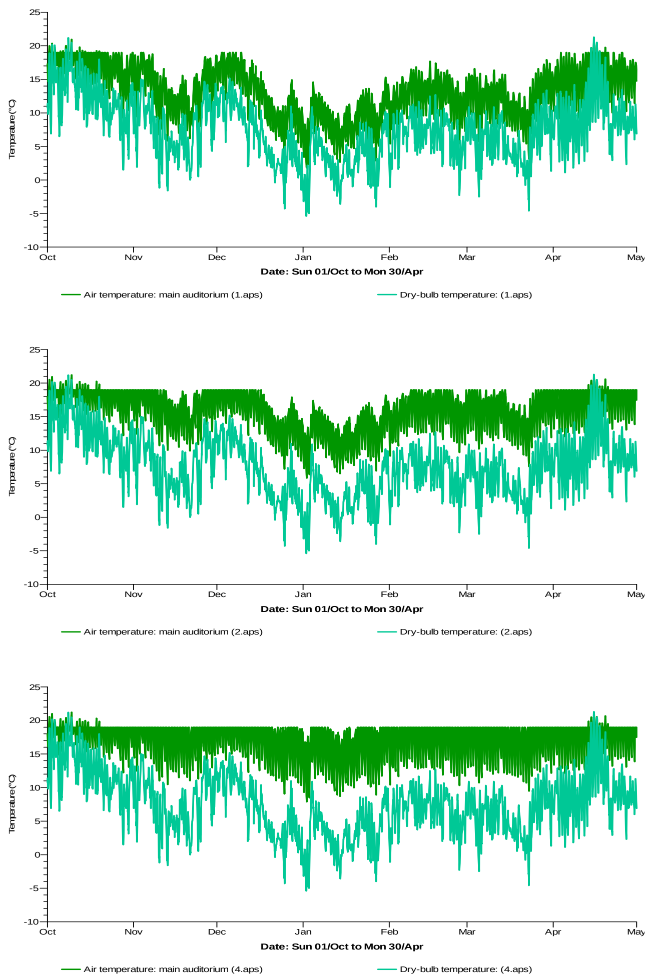
Monitored environmental parameters from Heathfield Community School



Monitored temperatures inside and outside of St. James Centre, Jersey in February 2006



How heat is lost and gained at St.James Centre with different improvements to the building, together with the average increase in internal temperature



Internal (top lines) and external (bottom lines) temperatures over the heating season at St.James centre as obtained from dynamic thermal modelling. The upper graph is for the current building, them middle graph has reduced air exchange rates, and the bottom graph has an increased heating system in addition to reduced air exchange rates

Three potential solutions were assessed: upgrading the building fabric, reducing air exchange, or increasing the output of the heating system. The modelling revealed that improving the building fabric (which would be costly and difficult to implement) would only result in marginal improvements in internal comfort, and so was eliminated as a solution for the first instance. The most pressing issue was to reduce the air exchange rate of the building, which was very high – far greater than necessary to achieve adequate levels of internal air quality – and only once this had been addressed, should consideration be given to increasing the output of the heating system. The bottom three graphs show output from dynamic thermal modelling. The uppermost of these is for the current building. For most of the year, the internal temperature is only marginally above the external temperature, and well below the 19^{o}C heating set-point. The middle graph shows the effect of reducing the air exchange rate. The internal temperature is acceptable for most of the year. Increasing the output of the heating system in addition to this (bottom graph) results in acceptable conditions nearly all of the time. It was proposed to fit controllable louvres to the air inlets to the hall, which are located below ground level.

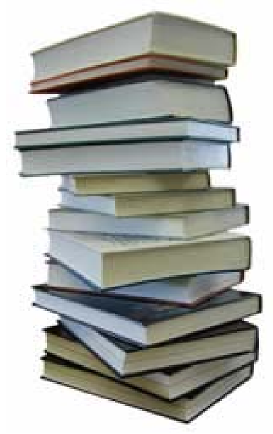
Simple building monitoring, the use of first principle calculations, and later, parametric computer modelling, enabled the main cause of the problem to be isolated, allowing resources to be focussed in the area where the biggest impact can be made.

Relevant Documents

- *Internal Document 450*: Investigation of overheating and noise levels in the humanities and modern languages building at Monkton Heathfield Community School.
- *Contract Document 202*: Measurements and analysis of the thermal environment at St. James Centre, Jersey

Publications

SWEEG publishes Reports, Briefing Papers, Software Documents and Internal Documents.



- Reports are based on in-depth studies that are often of general interest.
- Briefing Papers are usually responses to topical issues, or digests of technical or otherwise inaccessible information of interest to the membership.
- Software documents are instruction manuals for software written by the scientists.
- Internal Documents usually result from investigations into a particular problem identified by a member, but they will often be of interest to others as case studies. Occasionally there may be some restriction on the issue of Internal Documents.

In addition, the Centre for Energy and the Environment publishes material in technical journals and communicates the result of contract research to funding bodies.

A searchable document list may be found on the Centre for Energy and the Environment's web site at http://www.ex.ac.uk/cee/publications/. SWEEG members are able to download documents from the website or may request a CD containing the documents. Publications issued during the past year are listed below, and a full list of publications is available on request. Other bodies may contact the Centre to obtain printed copies of the documents in most cases.

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Publications List 2005-2006

No.	Title	Author(s)	Pages
	Scientist's Reports		
109	Analysis of Soundfield Systems in Devon Schools (Second Report)	T.A. Mitchell	27
	Briefing Papers		
81	An Assessment Of The Viability of Wood Fuel Heating for Devon's Schools	S.F.S. Hunt	39
80	A Synopsis of the Institute of Acoustics Spring Conference, 2006	T.A. Mitchell	4
79	Acoustic Performance of Elliott Buildings	T.A. Mitchell	2
	Internal Documents		
459	Achieving the predicted carbon emissions rate in Foxhole School's new hall	S.F.S. Hunt	2
458	The ADL2A Compliance of Elliot Classrooms being Transferred from St Stephen Churchtown Community School to Gorran School	S.F.S. Hunt	3
457	Exeter Air Quality Detailed Assessment for Eight New Locations in Exeter	T.A. Mitchell	8
456	Source Apportionment for Plymouth's Air Quality Management Areas	T.A. Mitchell	17
455	Acoustic Standards in Torrington Infant School	T.A .Mitchell	3
454	Actions required to achieve BREEAM Very Good at Foxhole Primary School	S.F.S. Hunt	76
453	Sound Insulation in the Music Suite at Park School, Barnstaple	T.A. Mitchell	2
452	The Acoustic Performance of the Straw Bale Extension at Padstow School	S.F.S. Hunt	3
451	Suggested remedies for reverberant classrooms at Bideford College	D. Lash	3
450	Investigation of overheating and noise levels in the humanities and modern languages building at Monkton Heathfield Community School	T.A. Mitchell & S.F.S. Hunt	8
449	Acoustic standards in the Art, Design and Media Accommodation at Cornwall College St. Austell	T.A. Mitchell	3
448	Proposed Microwave Installation, Land Adjoining Exeter Telephone Exchange	D.A. Coley	1
447	Proposed Vodafone Installation, Prince Charles Rd. Allotments	D.A. Coley	1
446	Response to the Isles of Scilly Draft Sustainable Energy Strategy	D.A. Coley	30
445	Statistics for Exeter's Air Quality Action Plan 2006	T.A. Mitchell	15
444	An evaluation of speech intelligibility in the Council Chamber and the Daw Room at County Hall, Exeter	T.A. Mitchell	17
443	The Acoustic Performance of a New Classroom at High Ham School	S.F.S. Hunt	6
442	BB93 Assessment for Moretonhampstead School	D. Lash	17
441	Source Apportionment for the Air Quality Management Areas in Kerrier, Cornwall	T.A. Mitchell	6
440	A Daylight Analysis of Two Schools Utilising Straw Bales in their Constructions	D. Lash	16
439	Noise Surveys for two potential sites for Bideford College	D. Lash	5
438	Recording background or ambient noise levels simultaneously through four individual microphones using n-Studio recording software	A.E. Frost	2
437	Acoustic Compliance Assessment of an extension to Sidmouth College	T.A. Mitchell	5
436	BB93 Analysis of the Proposed Music and Drama Block Classroom Extension to Brixham Community College	A.E. Frost	12
435	Bb93 Analysis of the Proposed English and Castle Block Classroom Extension to Brixham Community College	A.E. Frost	16
434	Sound Insulation Performance of the Moveable Partition at Budehaven Community School, Following Further Remedial Action on 27th April 2006	T.A. Mitchell	11
433	Acoustic Assessment of Trenance and Pennoweth Children's Centres, Cornwall	D. Lash	4
432	Suggested Remedies for a Reverberant Hall at Curnow School, Redruth	D. Lash	4
431	The Possibility of Disturbance from the New Hall at Ashley PS	D.A. Coley	10
430	Noise Survey of the Site for Dartington Primary School	T.A. Mitchell	7
429	BB93 Compliance Assessment of an Extension to Shaldon Primary School	T.A. Mitchell	9
428	Sound Insulation Performance of the Moveable Partition at Budehaven Community School, Following Remedial Action	T.A. Mitchell	11

427	BB93 Analysis of the Proposed Extensions to Paignton Community & Sports College	A.E. Frost	19
426	Advanced Thermal Treatment (ATT) to Produce Energy from Waste in Torbay	A.D.S. Norton	18
425	Glazing specification to achieve daylight and ventilation targets in Foxhole Primary School Hall	S.F.S. Hunt	3
424	Exeter Local Air Quality Review 2006: Updating and Screening Assessment	T.A. Mitchell, J. Leech & A. Bulleid	68
423	Evidence for changing pollution levels in the Exeter Air Quality Management Areas	T.A. Mitchell	3
422	Initial Testing of a Moveable Partition between a Gymnasium and a Dance Studio	T.A. Mitchell	8
421	Air Quality Statistics for the Exeter Air Quality Management Areas, for Inclusion in Devon's 2006 Local Transport Plan	T.A. Mitchell	4
420	Sound Insulation Calculations for the Three Classroom Extension at Hamp Junior School	T.A. Mitchell	3
419	An Initial Appraisal of Sustainable Energy Options for the Redevelopment of Cutcombe Cattle Market in Wheddon Cross	A.D.S. Norton & J.A. Crabb	30
418	Notes on Advice Provided to Reduce Flanking Transmission via the Roof Void in the 12-Classroom Extension at Ivybridge Community College	T.A. Mitchell	2
417	Acoustic Standards in Relocatable Classrooms. A Talk Given to the Institute Of Acoustics Spring Conference 2006	T.A. Mitchell	10
416	An Initial Assessment of Cranbrook Energy Demand	A.D.S. Norton	6
415	Appraisal of Acoustic Treatment in Doubletrees School Hall	T.A. Mitchell	3
414	BB93 Assessment for Withycombe Raleigh School, Exmouth	D. Lash	7
413	Analysis of Sound Transfer through Windows at Budehaven Community School (between proposed Area Resource Base and Music Suite)	T.A. Mitchell	3
412	Auralisation in School Design: A Talk Prepared for the January 2006 meeting of the Institute of Acoustics Building Acoustics Group	T.A. Mitchell	11
411	Holsworthy CC: Noise Exposure in Music Practice Rooms	D.A. Coley	9
410	Acoustic Evaluation of the Hall at Tywardreath Primary School	T.A. Mitchell	3
409	BB93 Compliance of the proposed Children's Centre at Watcombe Primary School. Investigation into the Acoustical Performance of the proposed design	A.E. Frost	4
408	BB93 Compliance of the proposed Children's Centre at Chestnut Primary School. Investigation into the Acoustical Performance of the proposed design	A.E. Frost	4
407	Dynamic Thermal Modelling of Exwick Heights Primary School to assess overheating	D. Lash	2
406	Pollution Modelling of Proposed Changes to the Alphington Corridor (Restricted Circulation)	T.A. Mitchell	8
405	Sound insulation between teaching spaces at Halwill Junction Primary School	D. Lash	2
404	Methane emissions from Tolcis landfill site	D.A. Coley	1
403	On the U-value of boiler house doors	D.A. Coley	2
402	Building Bulletin 93 Compliance Assessment of a New Separating Moveable Partition at Budehaven School	T.A. Mitchell	6

A MEMBER OF THE SOUTH WEST ENERGY AND ENVIRONMENT GROUP