UNIVERSITY OF EXETER


# Annual Report 2015

## Centre for Energy and the Environment

# About SWEEG

*The South West Energy and Environment Group (SWEEG) is a collaborative research partnership between public sector organisations in the South West which aims to share information and research on energy and environmental issues in the built environment.*

As a coordinating member, the Centre for Energy and the Environment (CEE) carries out technical research for the group. All research completed by the Centre is disseminated among SWEEG partners and work of wider interest is published in technical and academic journals. A list of this year's publications can be found at the end of this report. Further details about the Centre and SWEEG are available at www.exeter.ac.uk/cee.

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## Current SWEEG Members

Devon and Cornwall Police Authority
Devon County Council
East Devon District Council
Exeter City Council
Mid Devon District Council
Royal Devon & Exeter NHS Foundation Trust
Teignbridge District Council
Torbay Council
University of Exeter

*Organisations wishing to enquire about SWEEG or commission work from CEE should contact:*

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### Front cover

*CEE now has thermal imaging capability. This image was taken on the Streatham Campus at the University of Exeter.*


# Introduction

## About the Centre

*The Centre for Energy and the Environment has been working with government, local authorities, public sector organisations and businesses for over 35 years, carrying out research which directly impacts environmental outcomes and policies.*

As a research group within the University of Exeter, the Centre is uniquely placed to provide bespoke research which can help reduce carbon emissions and energy consumption.

Our expertise covers all aspects of the built environment including sustainable building design, efficiency in existing buildings, carbon reduction strategies, adaptation to climate change, renewable and community scale energy, thermal and daylight modelling, acoustic design, transport, waste and all related policy areas.

Research at the Centre ranges from 3 to 5 year Research Council programmes to short applied projects in both the public and private sector. Staff from the Centre teach within the University and can deliver bespoke CPD training programmes or provide academic supervision for Knowledge Transfer Partnerships with industry.


## About the Staff

**Tony Norton** *Head of the Centre*

A Chemical Engineer with a background in the international energy industry, Tony's experience of economic and commercial issues around energy provision is extensive and includes policy advice to government. Tony's work at the Centre focusses on energy aspects of local planning and the development of CHP and heat networks.

**Dan Lash** *Senior Research Fellow*

Dan studied architecture and specialises in low energy building design including natural ventilation, lighting, thermal performance and comfort.

**Andrew Mitchell** *Research Fellow*

Andrew qualified as an Environmental Engineer and now specialises in building performance monitoring, acoustics, air quality and transportation.

**Andrew Rowson** *Research Fellow*

Andrew is an Engineering Mathematician with a background in construction and engineering. He studies renewable energy technology and policy.

**Matt Eames** *EPSRC Research Fellow*

Matt is a Physicist who is researching novel thermal modelling techniques to help prevent overheating in buildings under the impact of climate change.

**Mike Wood** *PhD student*

Mike has worked in acoustics and as a Research Fellow at the Centre. He is in the third year of his PhD developing early stage building models.

**Edward Shorthouse** *PhD student*

Edward is a third year PhD student looking at overheating in buildings and the health impacts of extreme weather.

# Policy and Planning

## The Future for Zero Carbon Buildings in Devon

*Having taken a lead in planning for zero carbon new homes in 2006, the UK government has recently abandoned the policy. Work at the Centre anticipates the role of the European Energy Performance of Buildings Directive.*

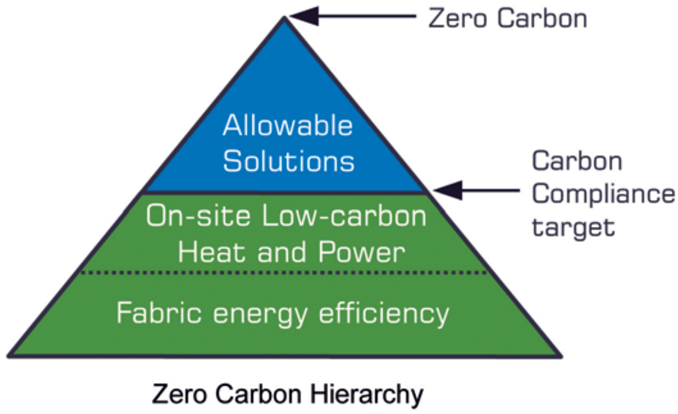
The publication of *Building a Greener Future* in 2006 put forward a ten year timetable to achieve 'true' zero carbon for new homes. This would have meant no net carbon dioxide emissions from regulated uses (governed by building regulations) or unregulated uses (from cooking and appliances). The target was considered ambitious but achievable, particularly in larger developments where site-wide district heating and combined heat and power become viable.

Local authorities in Devon have been at the forefront of low carbon development, using evidence-based local policies to support and deliver real schemes such as Cranbrook, the new low carbon community to the east of Exeter.

Nationally emissions were due to be reduced in two steps and while the first step was taken in 2010 (a 25% reduction), the rules were subsequently relaxed. In 2013 the 44% target was reduced to 29% and an exemption for small sites (under ten homes) announced in 2014 effectively excluded one in five of all new homes from the targets altogether.

In July 2015, despite calls from the Committee on Climate Change to implement the zero carbon homes standard without further weakening, the carbon offsetting scheme known as 'Allowable Solutions' (designed to assist where on-site solutions were seen as impractical) was scrapped along with the proposed increase in energy efficiency standards that had been scheduled for 2016.

Concerns have been raised by Chartered Institution of Building Services Engineers (CIBSE) and others that Allowable Solutions would not fulfil the requirements of the European Energy Performance of Buildings Directive (EPBD) but the Government's decision not to proceed with zero carbon means that homes built between 2016 and 2020 will have reduced emissions targets unless relevant local policies are in place. Under the EPBD the UK has to deliver nearly Zero Energy Buildings (nZEBs) from 2021 (2019 in the public sector) and developments where build programmes extend beyond 2020 could be faced with more stringent requirements than those proposed through




*A zero carbon hierarchy as envisioned by the Zero Carbon Hub. Carbon targets are initially met with a combination of fabric improvements and on-site generation. Where targets are not achievable developers fund a range of off-site measures known as 'Allowable Solutions'.*

Allowable Solutions and the prospect of having to deliver them over a shorter time scale. While efficiency standards will be kept 'under review' considerable uncertainty remains in an industry which has spent much of the past 10 years investing in the delivery of energy efficient homes.

This short term policy vacuum is unhelpful, particularly for new developments like those under way in Monkerton and South West Exeter. Fortunately Local Authorities in Exeter and Teignbridge have strong local policies for the delivery of low carbon heat which the Centre continues to support. A separate district heating scheme to connect the Royal Devon and Exeter Hospital with the University's St. Luke's campus, the City Council offices and a new pool complex also continues to progress with support from the Centre. Meanwhile in East Devon the Centre has taken a fresh look at the evidence for low carbon heat in the area between Cranbrook and Monkerton. The work suggests that there is an opportunity to enhance energy performance as house numbers grow from the 3,500 homes foreseen in 2008, to 12,500 as is currently envisaged.

# District Heating Opportunities in Newton Abbot

*Two sites near Newton Abbot were investigated to examine the potential for district heating and combined heat and power. On larger sites energy and carbon regulations can potentially be met at a lower cost than individual heating solutions.*

*Early stage analysis of the sites was based on information contained in the Teignbridge Local Plan which anticipates the availability of building land and provides potential development maps (left). Using site specific constraints theoretical build out profiles were established (right) which provided sufficient detail to build economic models for the developments under different scenarios.*

The sites at Houghton Barton to the north west and Wolborough to the south east of Newton Abbot are the two largest proposals within the Teignbridge Local Plan and are considered strategically important to the development of the town. They are expected to provide at least 3,300 new homes (with at least 20% affordable homes) and 28 hectares of land for employment, providing a range of opportunities for established and start up businesses. Two new primary schools and a secondary school are required as well as community infrastructure, including a network of green infrastructure. New link roads are envisaged at both sites to support a sustainable transport network and improve movement across the town. The Local Plan is also specific about maximising opportunities for renewable and community scale energy.

District heating needs to be competitively priced for site developers as well as for the building occupants, so a detailed understanding of the long term expenditure and income for the scheme is required. The nature of the costs and opportunities for district heating are often poorly understood at the earliest stages of a development and opportunities are quickly lost once work on site has commenced. Early indications of feasibility through modelling can therefore provide an insight into the economic potential of a project and may attract investors from energy service companies (ESCOs) to install and operate the district heating system.

Early stage modelling requires many assumptions to be made including the eventual heat demand across the site from the diverse range of heat users. The rate at which homes are built out and the resultant energy profile over time can be crucial to the economic viability of a project. Other estimates that have to be made include the cost of the pipework and connection to the energy centre. Sensitivity to fluctuations in wholesale energy prices must also be considered.

The analysis suggests an annual heat load (including losses) of 14 GWh per annum at Houghton Barton and a similar figure for Wolborough which has a higher load but fewer losses. Capital costs for the two schemes are estimated between £16.4m and £18.2m and internal rates of return of up to 10% are considered feasible.

# Sustainable Buildings

## Modelling Energy Performance and Building Design

*The Centre works with clients to set sustainability standards in new buildings and improve in-use performance through 'Soft Landings' processes. We also investigate the energy implications of design options and ensure compliance with regulations.*

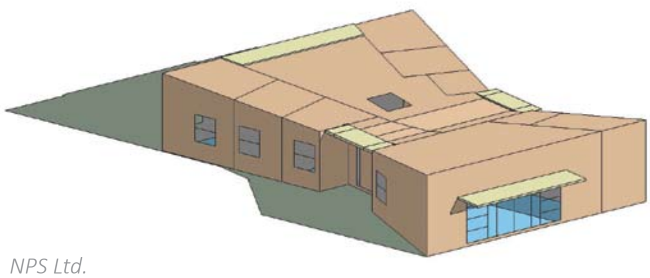

*The Long House at Holsworthy, designed by NPS for North Devon Hospice, will provide an uplifting and tranquil environment in which to provide specialist care for patients and their families.*

The most recent iteration of the building regulations was introduced in April 2014 and included a one year 'transitional arrangement' allowing projects registered before April 2014, and commencing site works by April 2015, to comply with the previous version of Part L (2010). This cut-off date has now passed and the Government has recently announced that it will not introduce the previously expected improvements to the standards in 2016. All new non-domestic buildings will therefore be required to meet Part L 2014 for the foreseeable future.

The Centre has undertaken Part L and Energy Performance Certificate (EPC) modelling on a range of projects this year including at Bradley Barton Primary School, Mill Water School and Sports Hall, Sidmouth College and the Long House, a specialist hospice care and support unit at Holsworthy. Our experience on these projects has shown that new building designs will need to provide both an efficient building fabric and improved performance in services to achieve compliance with Part L.

The design and analysis of new and existing spaces through the application of building physics models remains a core competence at the Centre. The use of dynamic thermal modelling enables us to advise on occupant comfort, the risks of overheating and the potential impact of climate change. We also provide appraisals of heating, ventilation and lighting strategies.

Display Energy Certificates (DECs) have been mandatory for public buildings since 2008; the certificates themselves require updating annually while the accompanying Advisory Reports (ARs) remain valid for seven years. The majority of buildings at the Streatham and St.Luke's campuses at the University have now been revisited and each building inspected to highlight opportunities for improving energy performance. The site visits have revealed a significant improvement over this period and numerous instances where old and inefficient heating has been replaced with modern systems. Over the same period there have been significant technological advances leading to improved energy performance in buildings; for example LED lighting, more robust cavity wall insulation, and higher efficiency cooling plant, all of which have been deployed at some point and could be implemented further across the estate. However the age of some of the building stock, coupled with the high cost and disruptive nature of the highest impact interventions, means that some buildings will remain hard to treat.



*NPS Ltd.*

*This simplified model of the Longhouse typical of that used in used in building modelling software such as the IES Virtual Environment. Here it is being used to perform analysis of shading and solar insolation.*


# Targeting Fuel Poverty in Off-Gas Grid Areas

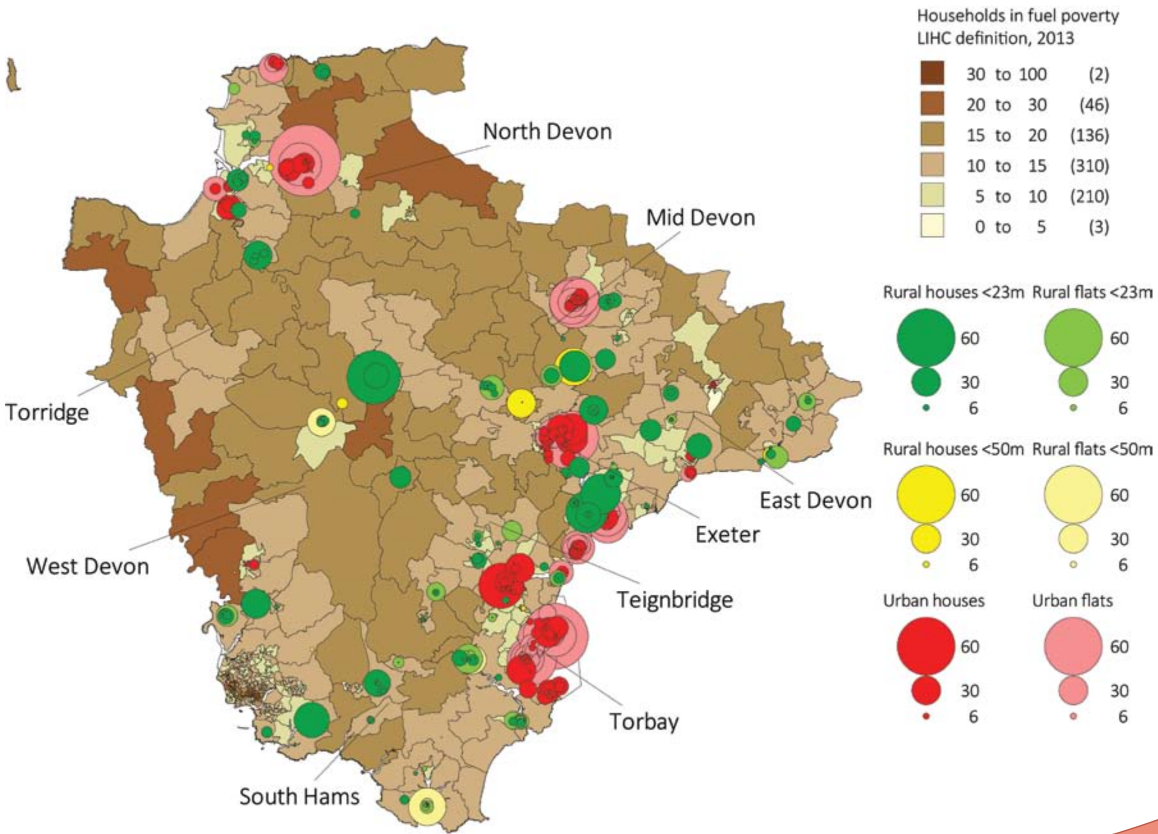
*As the 'CosyDevon' partnership, Devon Authorities have won £1.13 million from the DECC Central Heating Fund in a bid to tackle fuel poverty. The Centre is using multiple data sources and GIS analysis to help the partnership prioritise spending.*

Fuel poverty has long been associated with homes in rural areas, particularly those without access to mains gas and where electricity or solid fuels are the predominant forms of heating. People living in fuel poverty routinely under-heat their homes which increases the risk of damp and deterioration and has a detrimental effect on the health and well-being of occupants.

The fund will be used to target homes in severe fuel poverty (under the Low Income, High Cost (LIHC) definition) by applying a 'worst first' approach. Properties where proximity to the gas grid means that a gas connection is technically feasible, but costs are likely to be beyond the means of households, are therefore prioritised. At least half of the properties will be in rural areas so the Centre has had to use a range of data sources to create a model which targets properties that meet all of these criteria.

Data from the Department of Energy and Climate Change (DECC) identifies approximately 22,500 unconnected properties in Devon which are within 50m of the gas grid. The DECC data are somewhat coarse and so more detailed analysis was carried out using the Energy Saving Trust (EST) Home Analytics Data. This statistically generated dataset contains a level of uncertainty but includes details of the property construction, tenure, age as well as ECO eligibility and Index of Multiple Deprivation (IMD) data.

Cross referencing these data sets further, using fuel poverty statistics and some more detailed manual analysis of gas grid maps, helped to identify candidate properties that are closer still to the gas grid (within 23 m). Having reduced the number of potential homes to the few hundred that will benefit most, the partnership can target its resources in the areas identified.




*One of several thematic maps produced for the project.*

*This shows the number and location of properties identified as candidates for a gas connection (based on proximity) and mapped by postcode.*

*This is overlaid on a set of government fuel poverty statistics from 2013 based on the LHIC definition.*

# Energy Efficiency

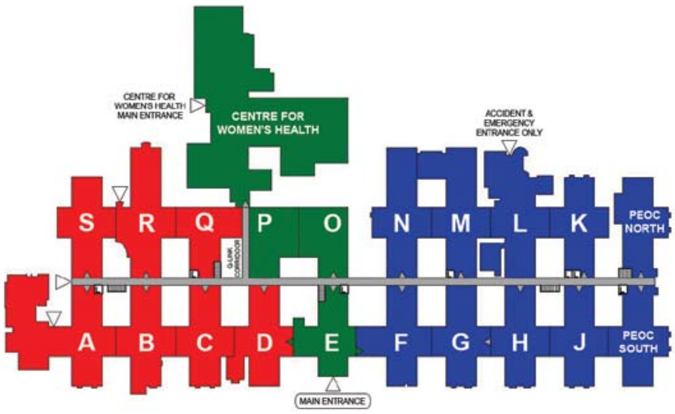
## Metering at the Royal Devon and Exeter Hospital

*A review of the metering of gas and electricity supplies at the main RD&E Wonford site has highlighted opportunities for implementing a site-wide Automatic Meter Reading (AMR) system and outlined some of the technical constraints.*

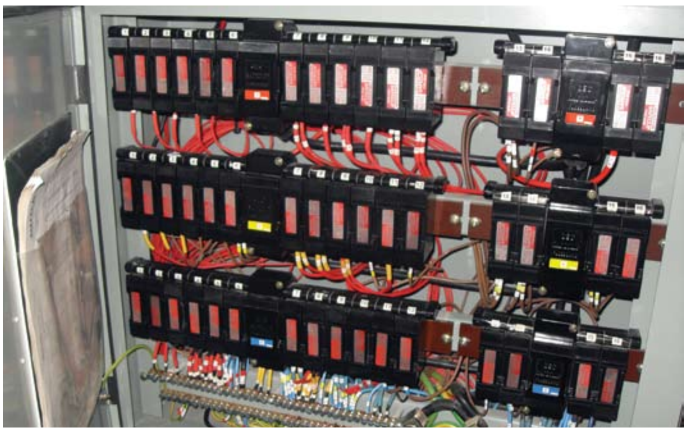
Manual meter reading imposes a practical limit on the resolution of consumption data and inevitably compromises the extent to which data can be used for energy management.

Automatic Meter Reading (AMR) uses a range of technologies that make use of mobile, wired and wireless communication networks to relay energy data from multiple sources to a central server. Readings taken in real time, on a half-hourly basis or less, can reveal more detailed variations in consumption patterns. When data is adjusted to account for seasonal variations in the weather, or patient admissions for example, it can give early indications of abnormal energy use which might indicate failure of plant or control systems. Over the longer term profiles for individual buildings can be developed to help prioritise spending on energy refurbishment and capital projects.

AMR will not deliver energy savings on its own and sufficient resource has to be invested into collating and analysing the data. On a large site such as a hospital the volume of data can quickly become overwhelming so commercial management software is often required. At the RD&E Wonford site the main electricity and gas supplies are already metered on a half-hourly basis and individual buildings are often submetered although not all are compatible with AMR. There is also scope to improve metering at internal substations which would allow for submetered data at the building level to be reconciled. Error checking becomes increasingly important on larger sites with many sensors.



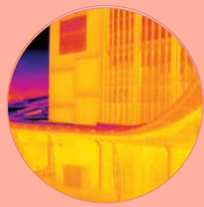

*The hospital is laid out as a grid consisting of blocks referred to as 'templates'. Lessons learned from the detailed monitoring of Template 'M' could be applied in other areas.*

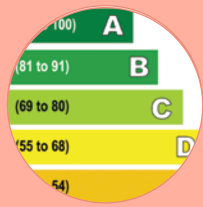


*Extensive re-wiring of circuits may not be practical so a combination of selective monitoring and apportioning may be used instead.*

The main hospital building is subdivided into blocks or 'templates' (see above) although the electrical distribution system does not correspond exactly to the template boundaries so metering at the top level would only provide an approximate energy split. For the investigation 'M Template' was selected as it provided a representative mix of activities and a range of high power equipment, such as x-ray machines. A series of progressively more detailed submetering strategies were devised with up to 43 electricity meters and two heat meters. This would be enough to meet the best practice guidelines, where it is recommended that at least 90% of the annual energy consumption (for each fuel) should be able to be assigned by its end use.

Achieving this level of detail inevitably comes at a cost which could amount to £1.9 million if rolled out across the whole site. CIBSE guidelines indicate that the energy saved from an active monitoring and management regime could amount to £170,000 per annum for a site of this size giving a simple payback period of around 11 years.







# Thermal Imaging of Substations at the University of Exeter

*The Centre conducted thermal imaging surveys of high voltage substations on the Streatham campus. Thermographic images can identify a range of faults and provide baseline images from which to assess deterioration in performance over time.*

Thermal radiation is emitted by all matter above absolute zero and is a function of the temperature of the object. Detected radiation can therefore be used to create temperature maps which can reveal localised heating, thermal bridging or susceptibility to moisture. The relationship between the energy of the radiation, and temperature is governed by the Stefan-Boltzmann Law:

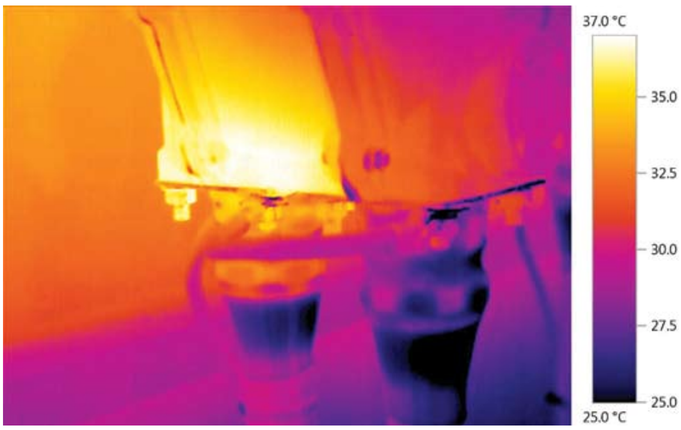
$$E = \varepsilon \sigma T^4$$

where $E$ is the power in W/m$^2$, $\varepsilon$ is the emissivity, $T$ is the temperature in Kelvin and $\sigma$ is the Stefan-Boltzmann constant.

Radiation in solids and liquids originates from the molecules that are within 1µm (one thousandth of a millimetre) of the exposed surface and is therefore regarded as a surface phenomenon. For a perfect emitter (known as a black body) the value of $\varepsilon$ is 1, while for real objects the value is lower and must be accounted for if temperature readings are to be reliable. For brick or metals with a matt finish values of 0.90 to 0.95 are more typical. Shiny surfaces however often reflect the radiation from surrounding objects while ambient conditions and the geometry of the object being surveyed can also affect temperature readings so thermal images need to be analysed with care.

Most people are familiar with infrared images of buildings which clearly demonstrate the benefits or problems with insulation, but thermography is also widely used in preventative maintenance and diagnostics. In electrical applications infrared cameras can detect high electrical resistance, short circuits or earth faults all of which may be manifested in higher temperatures. Blockages in the fins of cooling radiators can also be seen clearly. In mechanical systems heat related anomalies can be found due to friction in motor bearings and fans, deterioration in insulation materials and leaks or blockages in pipes.

Inspections were carried out in nearly all of the 25 high voltage substations on the Streatham Campus, focussing on transformer cooling fins which can become blocked, feeder pillars and battery charging stations where overheating may occur. The survey identified one connection on a transformer which appears to





*Elevated temperatures on a connection to a transformer at Harrison Building. Note the white highlight on the zinc plated bolt to the left which is due to reflected radiation from the high temperature region.*

be warmer than expected (see above) and was highlighted for further investigation. Elsewhere the images will be retained to form a thermographic record of the installations which is expected to be repeated on an annual basis. Comparisons with earlier images will help to identify early signs of deterioration and allow for timely maintenance and repair.

# Renewable Energy

## Review of Solar PV Potential in Torbay

*Torbay Council has considered installing photovoltaic panels at a number of public buildings as a way of generating additional income and reducing carbon. Analysis at the Centre has helped to highlight the business case for doing so.*


*Options to exploit solar potential of two roof top car parks in Torbay were assessed and while there is scope for up to 100 kW of PV capacity, relatively high costs coupled with low levels of electricity consumption are likely to limit the business case.*

A scoping study commissioned in 2011 provided the council with a number of sites where photovoltaic (PV) panels might be feasible including schools, theatres, the cinema and landmark buildings such as Torquay Town Hall and the Brixham Fish Market. Since then the solar industry has undergone significant changes; panel prices have fallen dramatically and at the same time the structure and eligibility for the incentive payments known as Feed-In Tariffs (FITs) has undergone a number of changes.

The Centre was asked to review the initial study and to consider the financial viability of PV at each site. The feasibility of installing PV on the top decks of two multi storey car parks, not considered in the original assessment, was also evaluated.

Unit costs were derived from work commissioned by DECC to track the falling costs of solar installations over time. Estimates for car park sites were more complicated as most installations are bespoke and require engineering calculations to be carried out to assess structural integrity and wind loading. Estimates based on conversations with installers indicated that unit costs were likely to be somewhat higher than traditional roof mounted arrays.

Potential income components from FITs include a generation tariff (linked to EPC ratings), an export tariff for unused electricity and the avoided costs of imported electricity. Given that avoided costs can be up to three times that of the export tariff, the business case is improved where on-site utilisation is increased. A utilisation factor of 50% for generated electricity is assumed for buildings in general, although for car parks modelling suggested utilisation factors of between 13% and 37%.

Financial analysis of the building based systems gave capital costs in the region of £195,000 with an Internal Rate of Return (IRR) over 25 years of 11%. It was noted that there was very little difference in the rate of return between larger and smaller sites. This highlights a flaw in the original study where attempts were made to optimise returns based on 'sweet spots' in the tariff structure. The result in most cases was that only a small portion of the available roof space was used for PV. Tariffs however are structured to give a fixed return, largely independent of scale, so the financial gains from this approach are at best marginal.

The relatively high unit costs for the car park installations coupled with low utilisation factors gave a negative IRR for both sites. If the generated electricity could be used in buildings, or if vehicle charging ports were incorporated into the car parks, utilisation and financial outcomes could be improved substantially.

Since this work was completed, announcements in August 2015 have proposed large tariff reductions which are likely to render most of these projects unviable.

# Integrating Renewable Heat Technologies

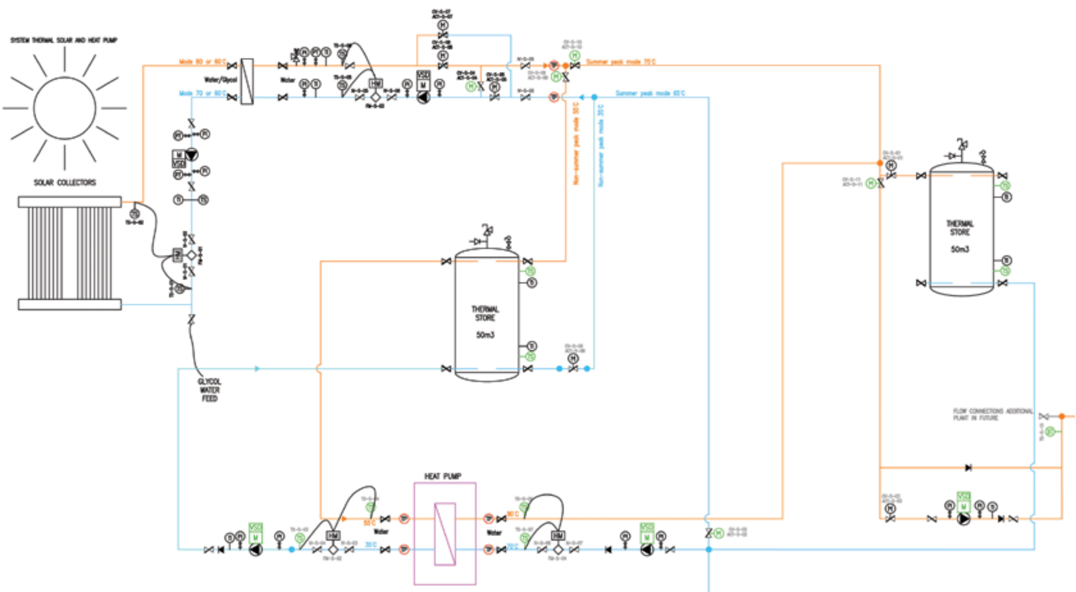
*The Centre has helped to secure funding for a £1.5 million demonstration project to trial an integrated low carbon heating solution at Cranbrook that will be based on combining solar thermal and heat pump technology.*

Heat networks are fundamental to the UK heat strategy and while modelling has suggested that up to 14% of all heat could be supplied by heat networks by 2030, current deployment is in the region of 2%. The Heat Networks Demonstration Small Business Research Initiative (SBRI) Competition is designed to stimulate innovation and promote the heat network deployment.

Having demonstrated feasibility in Phase 1 of the competition, the project team, led by E.on and supported by commercial heat pump specialists Star Renewables and large scale solar thermal experts SK Solar, now have the challenge of implementing an integrated heating system including solar thermal panels, heat pump technology and thermal storage. The Centre has devised a metering strategy to complement the monitoring of the main system which will allow the performance of individual components to be assessed as well as the behaviour of the control system and the overall system efficiency. Output from the existing solar array on the roof of the Energy Centre is monitored separately and will be used to determine the extent to which the heat pump could be powered by PV.

The system will have several modes of operation; in the summer the heat network can be run at a lower distribution temperature and the 2,000 $m^2$ solar thermal array will be able to provide hot water directly to the heat network via a high temperature thermal store. In the winter months the solar thermal system will feed an 850 kW heat pump via a low temperature thermal store. This store accumulates water at around 55°C and allows the heat pump to operate without excessive cycling. The heat pump discharges water at around at 85°C into the high temperature store from where it can be called upon by the network.

The challenge will be to provide a control system that makes the most of the solar resource while minimising emissions associated with gas and electricity. Early modelling suggests that carbon savings are greatest when the solar thermal system is able to operate alone, however the result is sensitive to the carbon intensity of grid electricity (currently 0.462 $kgCO_2e/kWh$). If a combination of PV and grid electric can reduce the carbon intensity of electricity to 0.3 $kgCO_2e/kWh$ or less, the case for running the heat pump to boost solar thermal output improves.




*Process and Instrumentation Diagram showing the integration of the solar thermal array with the heat pump and two thermal stores. In the Summer the solar thermal output can be fed directly to the high temperature thermal store.*

*In the winter the network is run at a higher temperature which the solar thermal is unable to meet on its own so a heat pump boosts the water temperature to around 85°C. A comprehensive data logging system will be used to monitor the control system and measure the overall system efficiency.*

# Research and Knowledge Transfer

## Energy Modelling with Gaussian Process Emulation

*As part of the EPSRC funded 'eTherm' research project, the Centre has been researching Gaussian Process emulation as a method for decreasing the time it takes to simulate energy use in buildings.*

One of the biggest challenges facing building designers is the time it takes to perform different types of analysis. Modelling the performance of a building relies on a number of complex variables such as weather, occupant behaviour and the performance of building materials. As the number of parameters increases, evaluating all of the potential permutations becomes increasingly difficult and is impractical in most circumstances.

Our current research is therefore focussed on ways to model and analyse buildings more efficiently. We have been attempting to do this using Gaussian Process (GP) emulation.

Simulation involves modelling the underlying state of building using the laws of physics. This can be computationally expensive and time consuming. Emulation by contrast is a process which synthesises the output of a simulation allowing calculations to be performed much more quickly (see below).

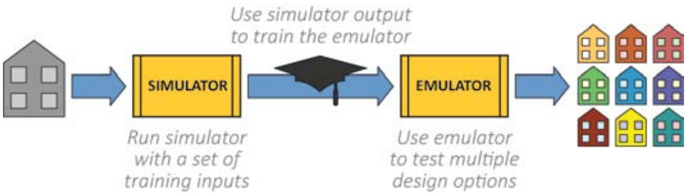


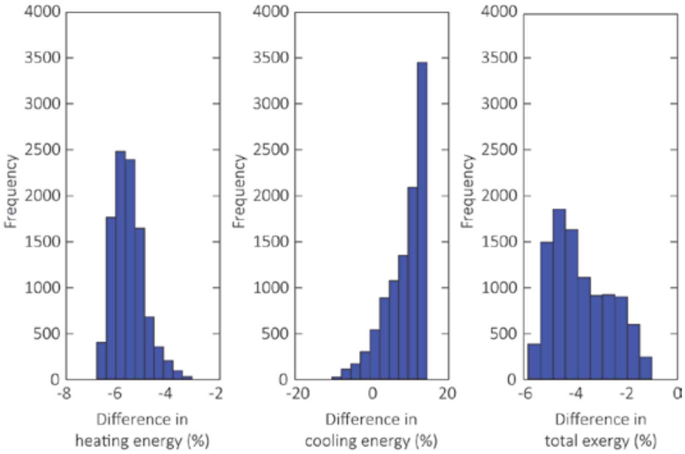

*Diagram illustrating the emulation process. The results of multiple detailed building simulations are used to 'train' the emulator which is then able to generate outputs for a wide range of input parameters much more rapidly.*

In some ways GP emulation is similar to linear regression; in two dimensions this is the equivalent of finding a line of best fit through a graph. This also can be done mathematically in higher dimensional spaces, although the results are somewhat harder to visualise. Where GP emulation differs is that it can find an approximation for almost any type of output and importantly, can provide an estimate of its own accuracy. This is something that traditional forms of emulation cannot achieve.

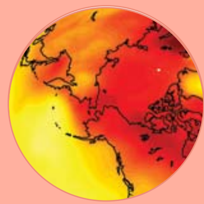
Once the emulator has been 'taught' with outputs from the simulator it is many orders of magnitude faster than the simulator. The practical range of problems that the emulator can solve are therefore much greater than the simulator alone. The main focus of the research has been finding applications for this approach that are likely to be useful in the field of building design.

Current work is focused on how GP emulation can be used to help designers make buildings more 'robust' as the climate changes. Building performance factors such as energy use and incidences of overheating can be optimised even under the influence of external factors such as occupancy, behaviour and weather conditions that are hard to predict. It is hoped that this work will be the first of its kind to facilitate robust design strategies that will be useful in a commercial context.

As part of the project, we have recently published a paper on how the process can be used to optimise a building model, based on the annual energy use, and we have also shown how building design is likely to be influenced by forthcoming changes to the UK test reference years (TRYs). The figure below shows some of the outputs of this research which highlight how the new TRYs are likely to reduce requirements for heating, but significantly increase them for cooling.




*Distribution of the percentage change of the difference between the new and original test reference years for heating energy, cooling energy and total exergy for Edinburgh.*



# Creating Future Weather Files

*The Centre has been awarded a £1m EPSRC grant to generate predicted hourly weather from now until the end of the century. The weather data will be used to get a better understanding how buildings will perform under future weather scenarios.*


The research project COLBE (the creation of localized current and future weather for the built environment) is a collaboration with the University of Bath, Newcastle University and the Met Office and will transform the way that building scientists and engineers consider the effects of different weather conditions on the built environment.

Internal building environments can be very sensitive to periods of extreme weather and the design of many current buildings does not provide sufficient resilience to be able to maintain internal conditions within the range necessary to provide sufficient protection for occupants. It is hoped that this research will improve the resilience of future buildings to such events by improving our understanding of the relationship between building performance and the weather.

While awareness of the dangers of overheating in buildings is increasing, there are growing concerns about building performance during sudden periods of extreme cold. Interior environments are increasingly managed and the effects of a disruption to the energy and water supplies or infrastructure to a building as the result a cold snap could be equally problematic. The effect on occupants of a rapidly cooling building and speed with which critical temperatures might be met are not well understood. Answers to these and other questions are likely to be key elements in considerations of wider energy security issues. The UK has been a net energy importer since 2004 and while uncertainties in the geopolitical landscape proliferate, we currently import 46% of our energy.

A significant element of the project will be the creation of an hourly time series of predicted weather for the next 85 years up until 2100. Among 'typical' weather days, extreme conditions such as heat waves and cold snaps will feature. The different weather characteristics will be tested on over 1200 different building designs in order to investigate the internal building response and the additional loads on building systems such as central heating and air conditioning.

It is widely accepted that climate change will have a significant impact on UK building design and energy use, both in the near and distant future. Predicted temperature changes are also large enough to have a detrimental effect on occupant comfort and in more severe cases could cause some buildings to fail to meet minimum standards altogether. The need for a better understanding of future weather trends is therefore vitally important if modern building designs are to be sustainable in the future.

# Acoustics

## Acoustic Design Advice for Custody Centres

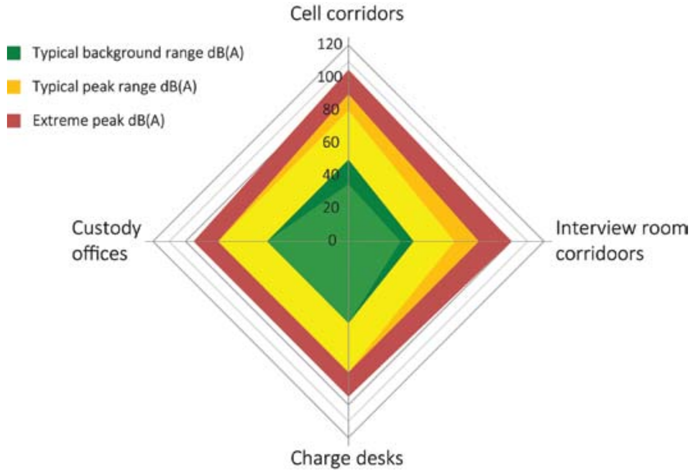
*The Centre was commissioned by Devon and Cornwall Police to review the standards of acoustic performance in a range of existing custody centres and provide design guidance for the proposed new custody centre at Middlemoor in Exeter.*

Sound can have physiological and psychological effects on building occupants and high acoustic performance standards are an integral part of any well designed working environment. Unwanted sound (noise) can be detrimental to efficiency and comfort, and can have an adverse effect on occupants, particularly in sensitive areas such as custody centres. By contrast good acoustic design, which includes careful planning of the building layout, will go a long way to facilitate reliable communications and reduce stress levels for staff and detainees.

Conditions in three local custody centres were monitored through observations and unattended measurements of noise levels in different areas including the charge desk, custody office, cell corridor and interview corridor spaces. The buildings in Exeter, Torquay and Plymouth are very different in their construction, the Exeter Heavitree Road site dates from the mid 1960s and will be replaced with the new building at Middlemoor, while the Torquay Police Station was originally built in the 1940s and redeveloped in 2000. The custody suite at Charles Cross in Plymouth underwent major refurbishment in 2013.

Measurements revealed considerable variability in sound levels at different times and across the three sites. Noise events associated with individual detainees are responsible for much of this variability, and while there is some correlation between high levels and busier periods such as weekend evenings, noise levels in general were not closely correlated with admissions.

Concerns that noise levels might breach exposure action values as specified in the Noise at Work Regulations (2005) were shown to be unfounded. Noise levels rarely come close to the current lower exposure action value of 80 dB(A) so the possibility of hearing damage for staff is remote (see radar plot). Noise can still induce stress so efforts to reduce exposure remain an important aspect of the design process. Indeed, elements of good practice acoustic design were evident in the use of sound absorptive materials, and routes through the buildings which avoided corridors serving interview rooms.




*Radar plot showing the average and maximum recorded noise doses for each monitoring period in different areas of the custody centres. Typical noise levels show no sign of exceeding health and safety guidelines.*

A set of recommendations was collated based on accepted acoustic standards and the typical noise levels encountered during the measurement periods. The potential for inmates to create a noise disturbance can be reduced by specifying quiet cell hatches, resilient flooring and concealed heating systems. The building layout should be planned to separate noisy and noise-sensitive areas, partition walls and floors should be specified to reduce the transfer of airborne and impact-borne sound and sound absorption provided where practicable. Open plan designs are proposed in some areas although these would require careful design to control the propagation of noise. Detailed ray tracing modelling is therefore recommended and the use of sound absorbent screens, cellular rooms and the ability to remodel spaces should also be considered. Finally, limits have been proposed for indoor noise levels arising from off-site noise sources and noise from building services and equipment that will be permanently installed.


# Publications

*Details of documents produced by the Centre this year are shown below.*

*SWEEG members can download documents from www.exeter.ac.uk/cee/sweeg*

### Briefing Papers

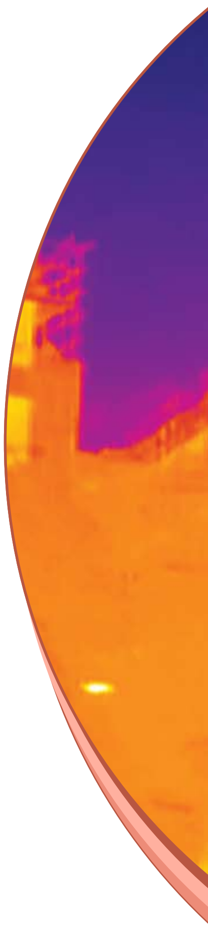
| Number | Title | Author(s) |
|---|---|---|
| 107 | *The Future for Zero Carbon Buildings in the UK* | A.D.S. Norton |

### Internal Documents

| Number | Title | Author(s) |
|---|---|---|
| 889 | *Potential Energy Savings from Replacing Windows at Cockington Primary School, Torquay.* | D. Lash |
| 890 | *A Review of the Carbon Assessment and Cost Analysis of Mixed Plastic Recycling in Cornwall.* | T.A. Mitchell and A.D.S. Norton |
| 891 | *As Built Part L Modelling of a Classroom Extension to Sidmouth College.* | D. Lash |
| 892 | *Specification for SBEM Modelling at As Built Stage Mill Water School.* | D. Lash |
| 893 | *As Built Stage Part L Modelling of Bradley Barton Primary School.* | D. Lash |
| 894 | *Assessment of Solar PV Feasibility for a Number of Sites in Torbay.* | D. Lash |
| 895 | *A Review of Metering at the Royal Devon and Exeter Hospital Site, Wonford, Exeter.* | T.A. Mitchell |
| 896 | *A Short Review of the Ernesettle Waste Wood Thermal EfW proposal.* | A.D.S. Norton |
| 897 | *Mill Water Sports Hall: As Built Part L and EPC Modelling.* | D. Lash |
| 899 | *Houghton Barton Urban Extension, Newton Abbot. An Initial Feasibility Assessment of Site Wide District Heating and Combined Heat and Power.* | A. Rowson and A.D.S. Norton |
| 900 | *Wolborough Urban Extension, Newton Abbot. An Initial Feasibility Assessment of Site Wide District Heating and Combined Heat and Power.* | A. Rowson and A.D.S. Norton |
| 901 | *North Devon Hospice As Built Report for Part L and EPC.* | D. Lash |
| 903 | *Identification of Homes in the Vicinity of the Gas Grid Without Gas Connections.* | T.A. Mitchell |
| 904 | *Thermal Imaging Survey of the University of Exeter's High Voltage Substations.* | T.A. Mitchell |

### Journal Publications

| Title | Journal | Author |
|---|---|---|
| *Generating Near-extreme Summer Reference Years (SRY) for Building Performance Simulation.* | Building Services Engineering Research and Technology. doi: 10.1177/0143624415587476 | Jentsch M.J., Eames M.E., Levermore G.J. |
| *An Update of the UK's Test Reference Year: The Implications of a Revised Climate on Building Design.* | Building Services Engineering Research and Technology. doi: 10.1177/0143624415605626 | Eames M.E., Ramallo-Gonzalez A.P., Wood M.J. |
| *An Update of the UK's Design Summer Years: Probabilistic Design Summer Years for Enhanced Overheating Risk Analysis in Building Design.* | Building Services Engineering Research and Technology. Accepted | Eames M.E. |



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