University of Salford MANCHESTER

APPLIED BUILDINGS AND ENERGY RESEARCH GROUP

AN OVERVIEW

Welcome to the Applied Buildings and Energy Research Group Review – we have produced this report to provide a map to some of the work we have done over the last 5 years. Not only does it help us promote the work we have done, but also allows us to see how we have developed by looking at the wide range of activities we have engaged with since early 2012, when we were formed.

ABERG was established with a vision to address energy efficiency in the built environment. We would do this by collecting data to provide real evidence as to what does and does not work. We aimed to be clear, simple and pragmatic. This view has allowed us to build a body of work, which we are sharing with you here, but it has also changed the way we see our mission, which is as much about how we do things as our organisational goals.

***Making a difference** with our work still sits at the centre of what we do. We still focus on energy efficiency, but we think more widely about what that means in terms of health, comfort and **wider building performance** as it affects occupants. We have also considered ways of more easily and more meaningfully researching these questions by developing new methods. We try to do this within a spirit of enquiry, asking "what if?" questions and **challenging ourselves to think differently**. All of these ideas are backed up with the thing that is at the very centre of what we do – **working with others**.*

The work presented here shows not just our team's successes, but the successes of all the people and organisations who have worked with us. Major companies, universities, local authorities, social housing and community groups have all worked with us. This capability goes to the centre of what we do; it is how we learn, create impact and engage with the world around us and is central to our success. We would like to thank all of the people who have worked with us, taught us new things and helped us achieve our goals. We remain practical problem solvers, but recognise the great opportunity we have to influence, ask questions and take risks.

Professor Will Swan

ABOUT THE APPLIED BUILDINGS AND ENERGY RESEARCH GROUP

The core goal of the Applied Buildings and Energy Research Group is to be an inter-disciplinary, evidence-led research team to support the delivery of a reduction in the end use energy demand of buildings and related topic areas, such as internal environments.

Fundamentally, we are concerned with improving the performance of buildings and outcomes for occupants in both domestic and commercial buildings. We focus on working in partnership with industry, governmental bodies and research bodies to provide evidence and solutions to address these issues.

We have the following key aims:

- Support the development of effective data collection and monitoring approaches to assess the energy performance of buildings.
- Collect evidence with regard to the performance of buildings in terms of their fabric and systems performance.
- Collect evidence with regard to the influence of human behaviours and the impact on adoption of building improvements and the influence on end use energy demand.
- Collect evidence with regard to the implementation of sustainable building refurbishment.
- Work with relevant stakeholders to develop practical solutions to improve the performance of buildings as driven by the evidence.

WHAT WE DO

The Applied Buildings and Energy Research Group (ABERG) is based within the School of the Built Environment at the University of Salford and is a very active research group established to address concerns surrounding energy use in buildings.

The focus is practical and covers research and consultancy services in the following areas:

Whole House Testing	Field Monitoring	Modelling	Sensors and Methods	Policy, People and Communities
Testing products and systems at the whole house level in the Salford Energy House	Environmental and energy consumption monitoring, U values, thermography	Energy models, 3D models, drone scans and BIM	Development of new sensors and building test approaches	Looking at the impact of building performance on people

The ABERG team is multidisciplinary because real world problems cannot be solved from one perspective alone. ABERG members are drawn from across the University, bringing together academics with specialisms in psychology, engineering, computing and construction management.

ABERG is committed to supporting the development of effective solutions and works closely with industry and communities. This results in a wide variety of partnerships, including product manufacturers, installers, social housing providers, local authorities, academics and policy makers. These partnerships are an essential aspect of understanding the problems, shaping research and embedding solutions in practice.

THE SALFORD ENERGY HOUSE TESTING FACILITY

Construction

The house is a traditionally constructed, terraced building (with a neighbouring property). It has solid brick walls, suspended timber floors, lath and plaster ceilings and single glazed windows. In its current state it is uninsulated. The heating is provided by a wet central heating system, fired by a gas condensing combination boiler. All of this can be changed to suit the testing requirements required by clients.

Chamber environment

The external environment surrounding a dwelling can potentially make a significant difference to how much energy is required to heat the building. It is for this reason that we have developed the chamber to recreate a series of external weather conditions:

- Rain (up to 200mm each hour)
- Temperature ranges from -12°C to +30°C (with an accuracy of +/- 0.5°C)
- Wind (localised and chamber wide) upto 10 m/s
- Snow.

Past tests

Since opening, the following funded testing has taken place

- Performance of building controls (TRV and thermostats)
- Performance of insulation solutions (of all kinds)
- Testing of various building performance tests (Coheating, in situ U-value monitoring etc.)
- Door and window heat loss testing
- Monitoring the performance of electrical heating systems.

The Energy House, a traditional style terrace house, with two rooms on the ground floor (living room and kitchen diner), the upstairs consists of two bedrooms and a bathroom.

MONITORING AND DATA ANALYSIS

The test facility uses a range of monitoring equipment which logs data and displays it through a custom time series program. This provides live data feeds and real time analysis of the data points listed below. Currently the Energy House has a large number of sensors which are able to read down to one second resolution.

This can generate over 2.8 Gigabytes in a week-long test. The Energy House is an exceptionally flexible test facility, which is reflected in its monitoring system that accepts a variety of sensor configurations. In this way, every test setup is unique. However, a typical setup for an experiment is given below:

Measurement	Locations	Number of sensors
Air temperatures	Every corner of each room at three different heights; centrally in each room, floor void and roof void	89
Relative humidity	Centrally in each room, floor void and roof void	7
Chamber air temperatures and relative humidities	Side, front and rear	3
Heat meters (measuring energy output)	On each radiator and complete flow and return circuit	7
External thermal imaging	Side, front and rear	3
Electricity consumption and power	Mains incoming, individual circuits and individual appliances	25
Gas consumption	Taken from main using MID meter and counter	1
Heat flux	Each external element (walls, floor and roof)	Approximately 25
Boiler performance	Flue temperature, flow and return temperature and rates and pipe temperatures	8

All of this information is fed through a wired network to a server. From here the data is collected and analysed using a custom piece of software. This can then be accessed by researchers whether working on campus or over the internet via a web page. Real time analysis and calculation can also be carried out, which aids the prediction of thermal constants and helps predict when steady state conditions will occur as part of an experiment.

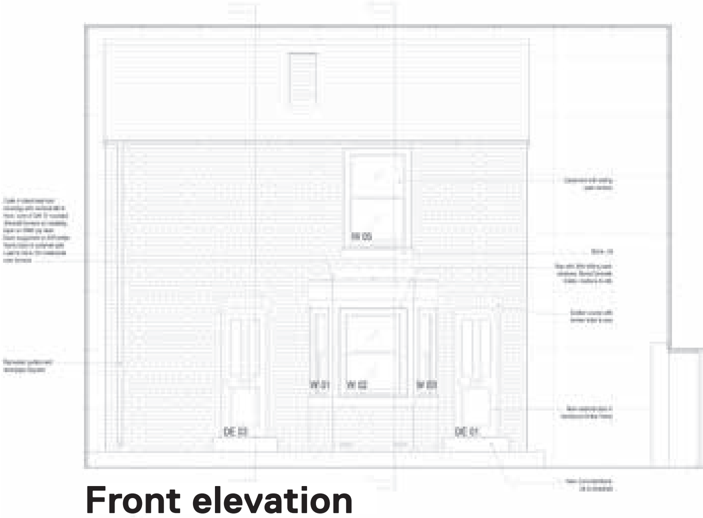
ENERGY HOUSE

A unique testing asset, the Energy House is the only full-scale building in an environmental chamber in Europe, and the only full-scale brick-built test facility in a controlled environment in the world. The Energy House has been designed and developed to allow leading academics and researchers to conduct scientific research, to improve the energy efficiency of hard to treat properties, in collaboration with industry.

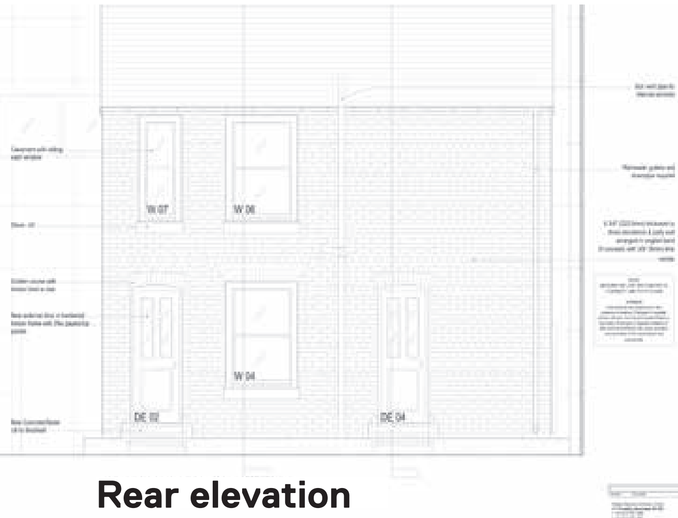
This includes the development and testing of new materials, systems and products as well as looking at behaviour change associated with the adoption of energy efficiency measures in the home.

The Energy House is also breaking new ground in terms of building physics, carrying out many verification tests for methodologies that are currently used (and being developed) to test the energy performance of buildings and address the gap between design and as-built performance.

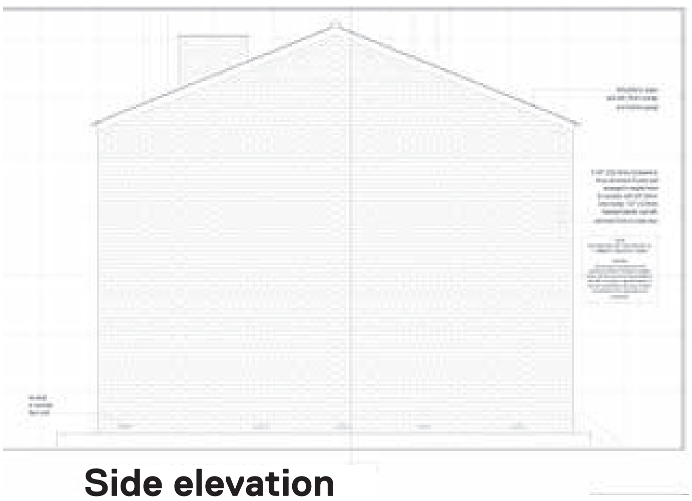
APPENDIX A: DRAWINGS



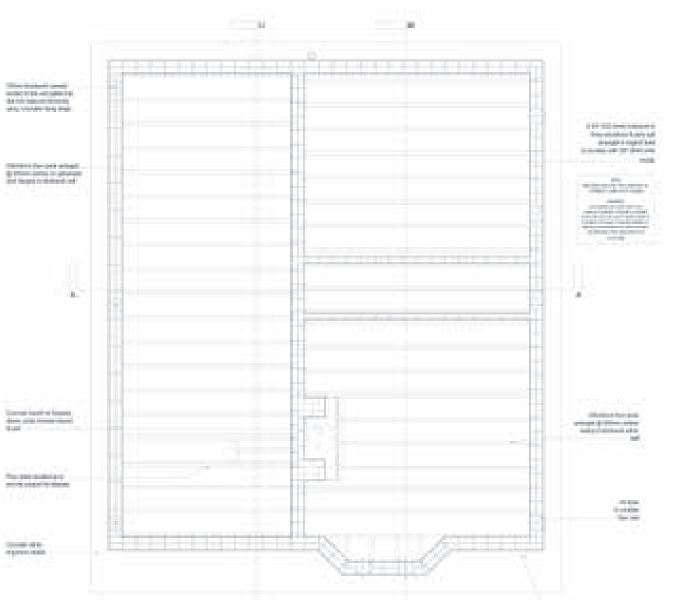
Front elevation



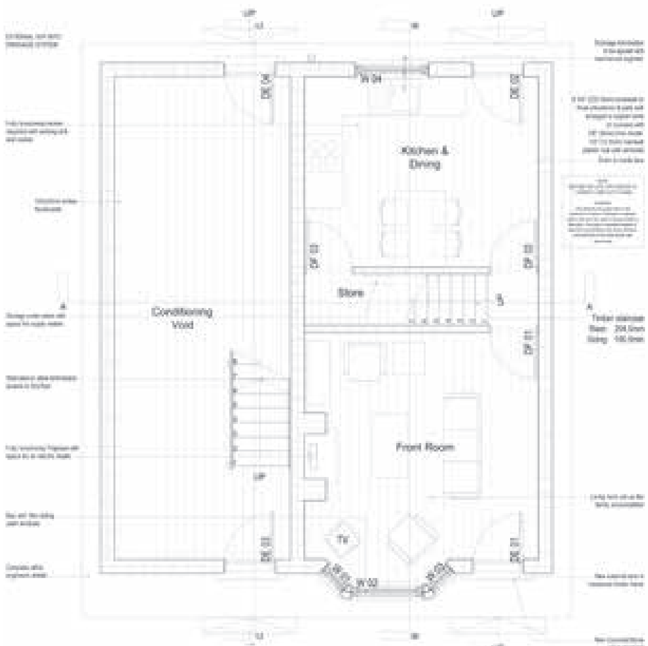
Rear elevation



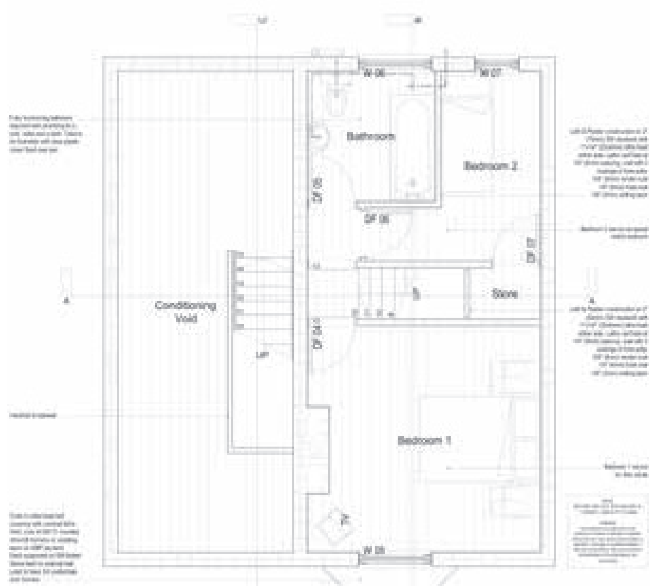
Side elevation



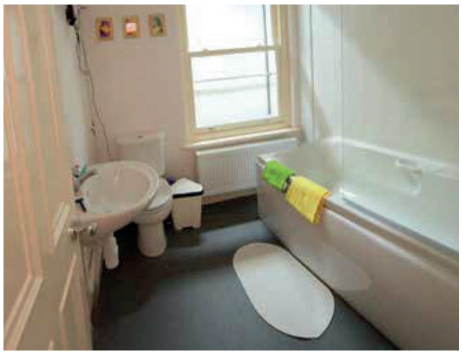
Ground floor



Ground floor



First floor



ENERGY HOUSE CASE STUDIES - OVERVIEW

Since opening its doors in January 2011, the Energy House team have carried out research on many retrofit solutions ranging from heating controls to whole house insulation systems. This research has been carried out for clients ranging from small companies (SME) through to large multinational companies. We have also worked extensively with research institutions from the UK and across the EU.

Initial work undertaken was focused on our capacity to quickly establish the performance of products in a domestic setting. However, as we progressed the work widened to explore issues such as methods for measurement and unique characterisations of elements of properties that were not possible to undertake in the field.

MAJOR PROJECTS

BEAMA CONTROLS PROJECTS

BEAMA (British Electrotechnical and Allied Manufacturers' Association) have carried out four phases of research with the Energy House team. The research has focused on the impact of different heating control sets on the consumption of energy in heating a home. The work aimed to bridge the gap between laboratory-based work and fieldwork, neither of which fully recreate a real-life, yet controlled, environment.

The study looked to assess the impact of three different types of control arrangements and how they affected energy consumption, internal room temperatures and system performance. These types of controls arrangements are common in many UK homes – although some 7 million homes do not have a full set of basic heating controls.

- Boiler thermostat only (no local controls)
- Boiler thermostat and living room thermostat
- Boiler thermostat, living room thermostat and thermostatic radiator valves (TRVs)

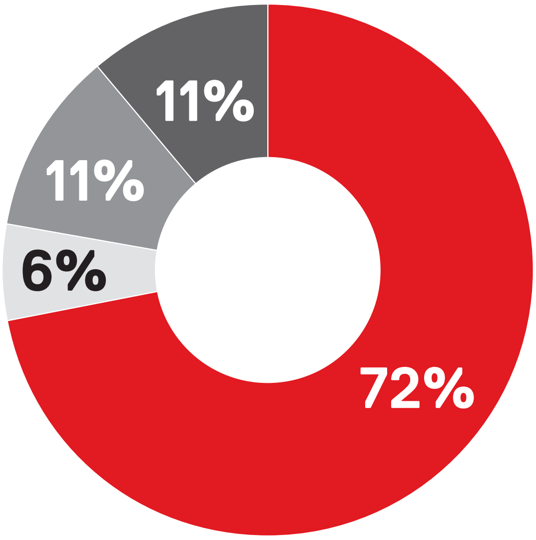
The test conditions were designed to understand the impact of the controls as a single factor – all other conditions remained the same throughout all of the tests. These conditions were.

- Recreated average winter temperatures by holding the environmental chamber at 5°C
- Designed and installed a heating system to CIBSE Domestic Heating Design Guide standard
- Collected data on gas and electricity consumption, internal temperatures, flow and return rates and temperatures and mean radiant temperatures

TIME PROPORTIONAL AND INTEGRAL THERMOSTAT RESEARCH

Scenario	Reduction in Heating Energy Consumption
No Temperature Control	0%
Living Room TPI Thermostat Only	33%
Living Room TPI Thermostat and TRVS	53%

Electro-mechanical Thermostat Control Research	Reduction in Heating Energy Consumption
No Temperature Control	0%
Living Room Thermostat Only	12%
Living Room Thermostat and TRVS	41%



Contribution to reduction

- Solid wall insulation
- Loft insulation (top up)
- Floor upgrade (suspended timber)
- Replacement glazing

Contribution of each thermal upgrade measure to the reduction in whole house heat loss of the fully retrofitted test house.

SAINT GOBAIN – WHOLE HOUSE RETROFITS PHASE 1 AND 2

Saint Gobain is a large multinational company whose brands include British Gypsum, Isover, Celotex and many more. With the specific focus on retrofitting existing dwellings, Saint Gobain has carried out four phases of testing at the Energy House. Working in partnership with Leeds Beckett University, research was carried out to examine savings offered by retrofitting fabric measures to the Energy House as a complete system, and carrying out a series of controlled tests on the dwelling. The measures were then removed one by one, and the building was subject to the same series of tests. This allowed the team to establish the specific energy savings figure attributed to each measure. This level of testing has never been carried out before in controlled conditions, so the results were a unique contribution to the pool of knowledge in retrofit.

RESEARCH PARTNERSHIPS

St Gobain Recherche: Rapid Building Performance Evaluation Tool

The project involved an investigation and verification of a patented test methodology known as the QUB method. This is designed to rapidly determine the energy performance of a dwelling. This test can be carried out in approximately 48 hours, when compared to approximately 2-3 weeks for the current method. The project involved conducting a series of tests over a 6 week testing window using dynamic and steady state temperatures in the chamber. This work was published through the International Energy Agency in 2013 asa joint piece of research between the Energy House team and Saint Gobain.

University College London: Development of U Value measurement for Suspended Timber Floors

The measurement of heat loss through any floor is difficult to model and measure. This is further complicated with a suspended floor as a varying amount of air passes through the void at any one time. In addition many junctions and both regular and irregular thermal bridges can occur (such as floor boards, joists and fixings).

A project was devised to carry out a high resolution study of heat transfer through the ground floor of the Energy House, under controlled and steady state conditions. This involved the use of over 25 heat flux transducers to measure and monitor heat loss through the ground floor.

This led to what we believe to be the clearest data available worldwide for heat loss through a suspended floor under steady state, but real world, conditions.

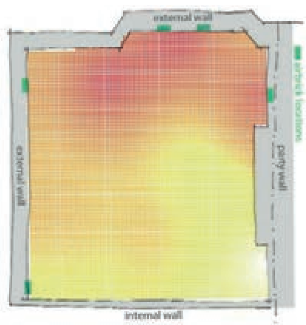
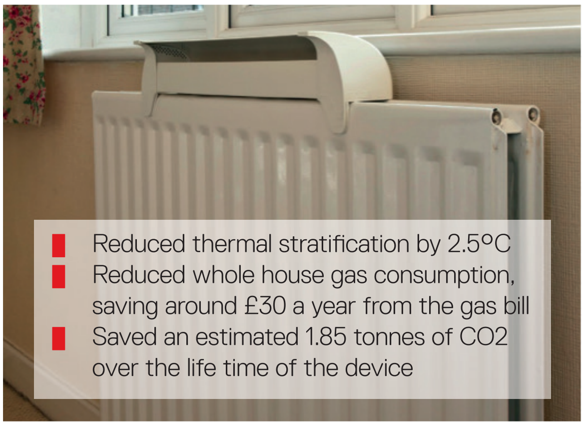


Figure 1

Figure 1is a diagrammatic heat map to visualise the variation of measured floor heat-loss, based on 14 locations in the Salford Energy House living room.

Radfan

Radfan are a SME who developed a low cost technology to improve the heat flow from radiators using a fan mounted on the surface. We recreated the temperature of an average winter by keeping the chamber at 5°C and collected data using a range of sensors that included the radiator surface temperature, air temperature at various points in the room, heat flux measurements, gas consumption and the electric consumption of the Radfan devices.



Micro Weather Stations

The Energy House, in partnership with Dyer Environmental Controls, is currently developing a micro weather station. This unit will record and transmit wirelessly weather observations. This unit is cost effective and easy to deploy, needing no power supply or infrastructure. The self-sufficient device will transmit data such as rainfall levels, solar radiation, wind speed and temperature, as well as other measurements. This data can be used to measure micro climates around buildings and carry out localised weather observations in remote locations.

Energy House Wireless U-Value Sensors

The Energy House team measures U-values in the Energy House and out in the field on a regular basis. We have found that equipment available to do this is not user-friendly or cost effective for researchers. To address this we developed a new sensor to enable U-values to be measured accurately and cost effectively with the recorded data being made available wirelessly and viewable on the cloud. This unit is in the process of being brought to the commercial market.

Arcada/Salford Research Partnership on Rapid U-value Measurement

Arcada University of Applied Sciences in Finland have developed a sensor to rapidly estimate U-values of elements. Working with the University of Salford this sensor is being developed to progress to a mass market. The partnership recently won a competition sponsored by the Building Research Establishment (BRE) entitled "Rapid measurement of heat losses from walls". As the winner of the competition, funding was provided to carry out controlled laboratory "hot box" testing and also for a field trial to be completed.

MEASURING ENERGY EFFICIENCY IN THE FIELD

We have been undertaking field based monitoring since 2012 – we have been involved in the wide range of projects where we have undertaken detailed monitoring of more than 120 homes. To do this we use a range of techniques to understand what energy is being used and what the outcomes are for the occupants.

- Measurement of gas and electricity consumption
- Measuring internal environments such as temperatures, humidity and CO^2 levels
- Measuring the performance of the building fabric through the use of thermography, air permeability and ins situ U-values
- Understanding the occupant through interviews and questionnaires

This means we can understand energy efficiency from a number of different perspectives such as efficiency of the building fabric, systems efficiency, comfort and the impact of occupants.

While this understanding of energy efficiency is at the core of what we do, we are always looking for new ways to better understand building performance and how the occupant experiences buildings.

Enhancing Visual Perception Using Digital Modelling

Dr Sura Al-Maiyah is currently collaborating with the University of Portsmouth (Dr Karen Fielder and Mr Martin Schaefer), and the National Trust on Using Digital Modelling for Enhancing Visual Perception in heritage buildings. The project focuses on one of the treasures of the National Trust's historic house at Mottisfont, Hampshire, known as the 'Whistler Room', so-called because of the trompe l'œil interior painted by the artist Rex modelling and surveying techniques to document historic interiors in three dimensions and to understand seasonal variations in daylight conditions. The use of emerging digital technologies for heritage preservation and interpretation is a growing area of interest within the heritage sector and a focus for the new ICOMOS-UK Digital Technologies Committee.

MODELLING

Modelling is an important part of understanding energy consumption in buildings. These models can by mathematical, such as the Standard Assessment Procedure or Energy Plus, or visual such as Revit or photogrammetry – or we can combine them to make visual simulations for energy consumptions and building performance. We have capabilities with both IES and Energy Plus, as well as developing capabilities with photogrammetry and drone scanning.

Energy Plus and In Situ Data

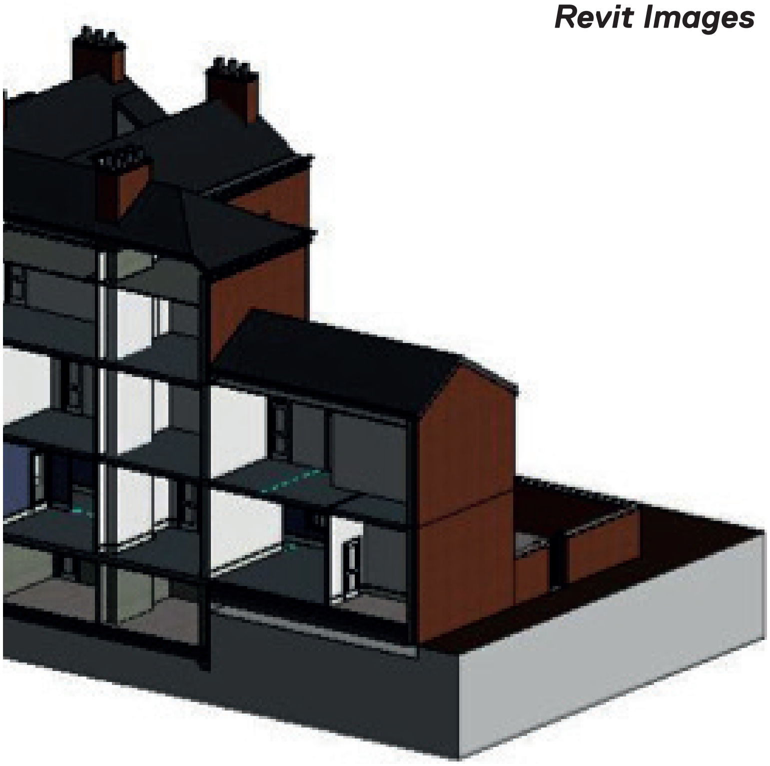
When ABERG was initially developed we focused on in situ data, or data we gather from experiments. We have used these skills to develop a modelling approach, which takes this data and refines these models to make them more reflective of the real world.

We have taken the Energy House and modelled this to a high degree of accuracy. When a client runs a short test in the house, we can take their data and tell them what might happen in the future over a long period – to help them understand how their product might respond to a changed climate for example.

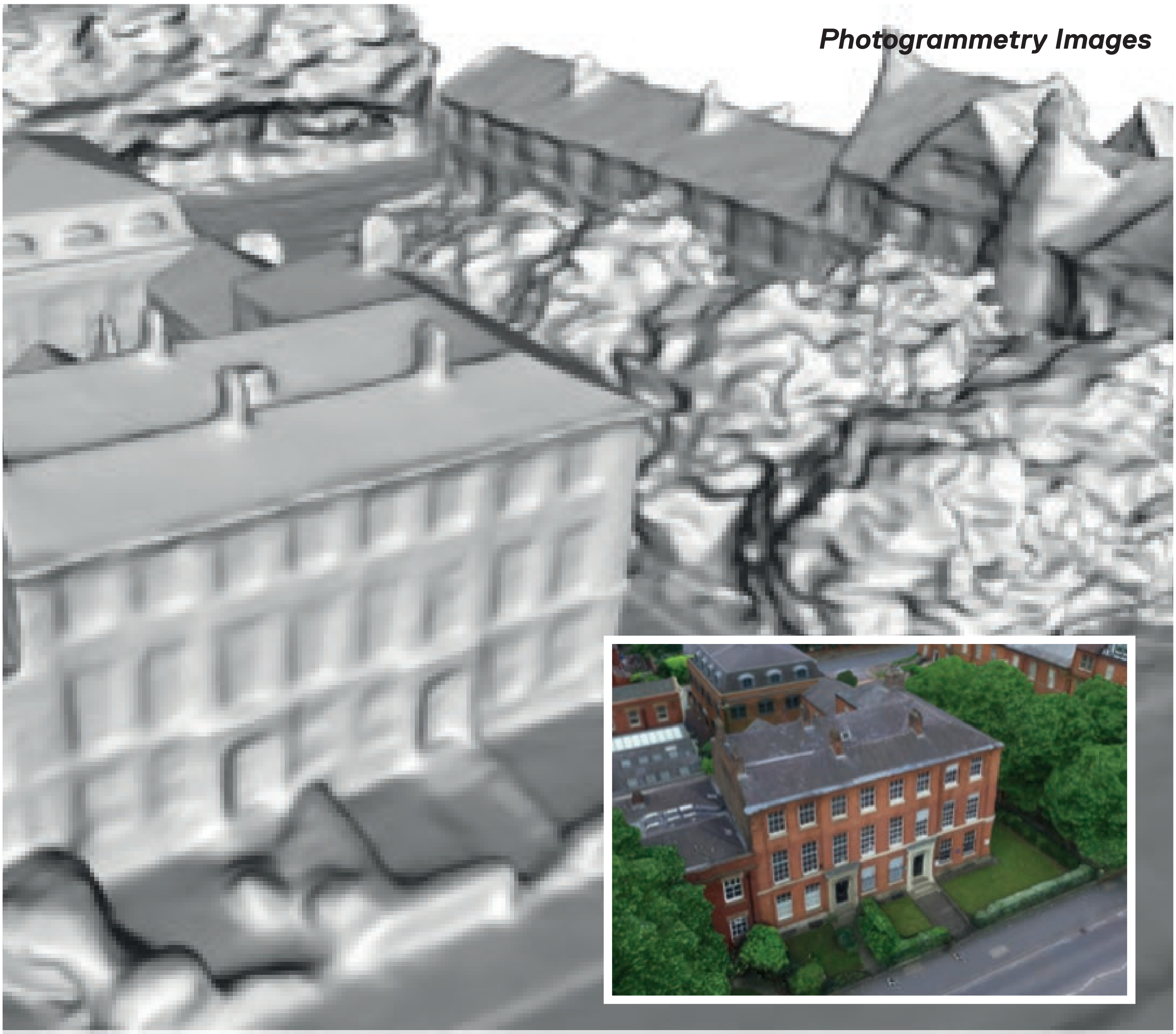
Photogrammetry and BIM

As part of a British Council-funded research project on the subject of Heritage Building Information Modelling (HBIM), a 3D virtual model was created of the landmark building Joule House, the home of the Universities Research and Innovation unit. This Building was the home and laboratory of James Joule, the noted physicist who established the principal of the mechanical equivalent of heat. His name has been given to the unit of energy, the Joule. For this work, two models were created, one using photogrammetric techniques, which provides a full photorealistic and spatially accurate model of the outside of the building, and also a Revit BIM model of the internal and external building using data form a measured survey. This allows the two models to be compared for detail and accuracy. The outputs of this exercise will be used to inform spatially accurate building energy models and simulations.

Revit Images



Photogrammetry Images

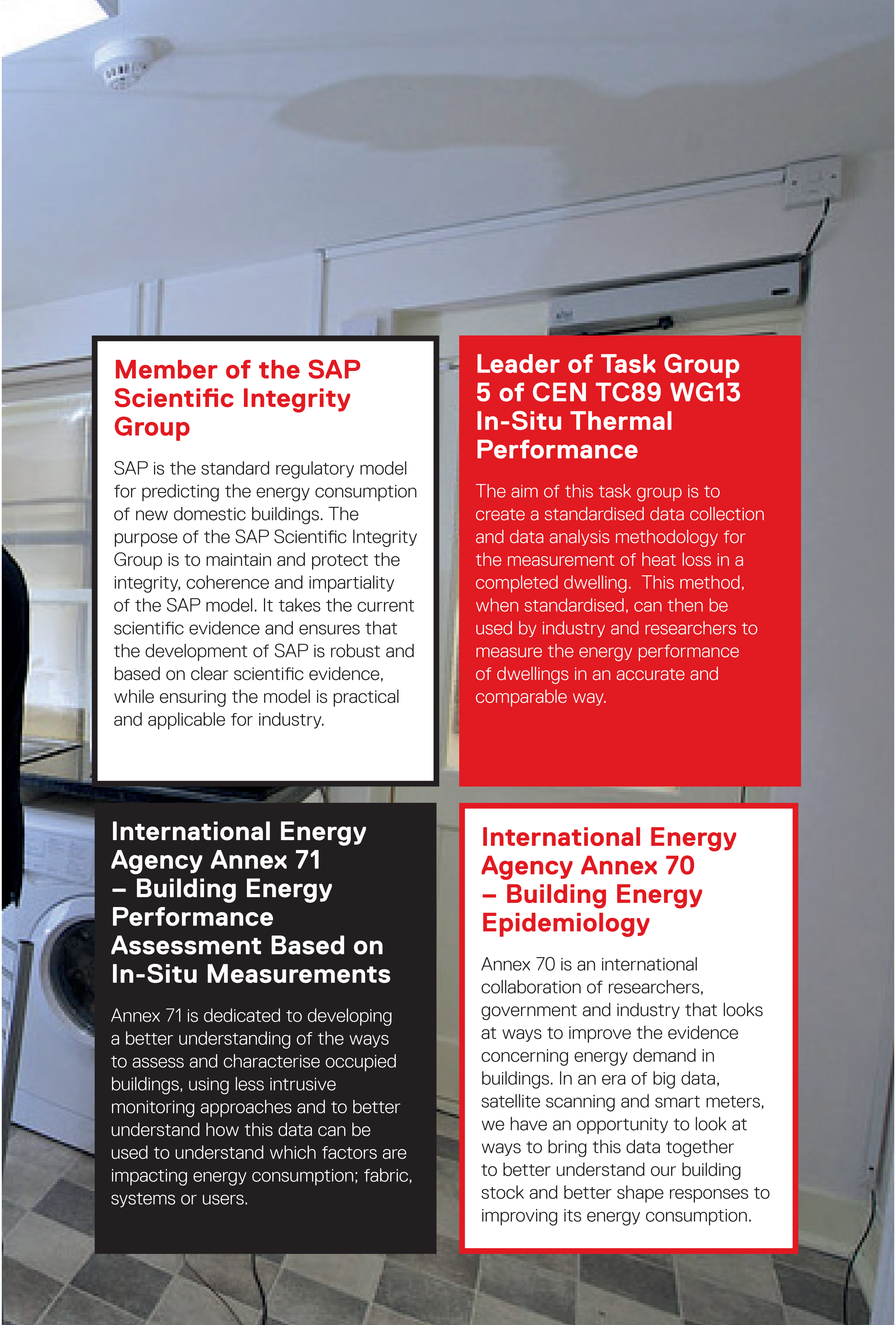


NETWORKS AND ENGAGEMENT

Being connected to the networks in the sector helps us to keep up to date with the latest thinking, as well as supporting groups who are trying to deliver an energy efficient built environment. These relationships help us shape the agenda and learn from some of the leading research groups in the world. In addition, we regularly contribute to reports and consultations, such as the Zero Carbon Hub Performance Gap Report and Each Home Counts.

Greater Manchester Low Carbon Buildings Group

As part of Greater Manchester, we contribute our expertise to a number of different groups and projects within area. The main group we are currently involved with is the GM Low Carbon Buildings Group, which looks at the domestic and non-domestic stock, including private and public buildings. This group shapes the strategy for the city-region and we provide technical insight into this group.



Member of the SAP Scientific Integrity Group

SAP is the standard regulatory model for predicting the energy consumption of new domestic buildings. The purpose of the SAP Scientific Integrity Group is to maintain and protect the integrity, coherence and impartiality of the SAP model. It takes the current scientific evidence and ensures that the development of SAP is robust and based on clear scientific evidence, while ensuring the model is practical and applicable for industry.

Leader of Task Group 5 of CEN TC89 WG13 In-Situ Thermal Performance

The aim of this task group is to create a standardised data collection and data analysis methodology for the measurement of heat loss in a completed dwelling. This method, when standardised, can then be used by industry and researchers to measure the energy performance of dwellings in an accurate and comparable way.

International Energy Agency Annex 71 – Building Energy Performance Assessment Based on In-Situ Measurements

Annex 71 is dedicated to developing a better understanding of the ways to assess and characterise occupied buildings, using less intrusive monitoring approaches and to better understand how this data can be used to understand which factors are impacting energy consumption; fabric, systems or users.

International Energy Agency Annex 70 – Building Energy Epidemiology

Annex 70 is an international collaboration of researchers, government and industry that looks at ways to improve the evidence concerning energy demand in buildings. In an era of big data, satellite scanning and smart meters, we have an opportunity to look at ways to bring this data together to better understand our building stock and better shape responses to improving its energy consumption.

LOOKING TO THE FUTURE - ENERGY HOUSE 2.0

Our current major project is the development of a new facility Energy House 2.0. We are looking to develop a major new facility which will support innovation in not only energy efficiency, but we will also be looking at smart and connected homes, new materials and new building techniques.

This ambitious new proposal aims to develop a major international centre for major companies, SMEs, research partners and local and national government to come together and extend our understanding of building performance.

WHAT OUR PARTNERS SAY

"The Energy House offers a unique facility for testing of specific performance parameters in a built environment under controlled conditions. This paired with the knowledge, experience and enthusiasm of the Energy House Team make using the facility both enjoyable and productive".

Tom Cox
UK Research and Development Manager
Saint Gobain

"It was highly interesting working with the team and the facility at Salford University Energy House. The team were quick to grasp concepts and helped us tailor our objectives into a feasible research study; the test environment is exceedingly flexible and well monitored, ensuring that we had a significantly robust data set at the end of the test period."

Darren McMaho
Marketing Director
Viessmann UK

"The combination of an authentic house, comprehensive telemetry supported by knowledgeable and very helpful staff provided an extremely productive research environment."

Tim Wells
Engineering Manager
Stelrad

"When it came to proving the effectiveness of the Radfan, we were really keen to test the product in an environment that closely reflected a real life home. We wanted to avoid testing in classic scientific lab conditions as any results may be difficult to reproduce in real homes by our customers. The Energy House was therefore the natural choice for us to make sure that the Radfan would work in the majority of UK homes."

Roland Glancy
Inventor of Radfan

SoBE

School of the Built Environment

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