UKERC

UKERC ENERGY RESEARCH LANDSCAPE: ENERGY EFFICIENCY – RESIDENTIAL & COMMERCIAL

Prepared by Prof Bob Lowe, University College London (UCL) with assistance of Dr Jim Halliday, STFC Rutherford Appleton Laboratory
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1. Overview

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Characterisation of the Field

The design, production, management and operation of buildings involve complex socio-technical processes. Buildings represent a crucial element of energy systems at all scales from local, through national to continental. Buildings and the wider built environment are key determinants of human health and quality of life. Buildings and their supporting infrastructures shelter, protect and structure almost the whole of our individual and collective lives, and the working lives of hundreds of thousands of people are devoted to their design, production, management, operation and occupation. Interactions between people and physical systems in the built environment are complex, and take place at all of these stages. As a result, energy use in buildings is a complex field of study involving many disciplines: the STEM (science, technology, engineering, and mathematics) disciplines, the professional built environment disciplines (building services engineering, architecture, construction management, surveying), the social and human sciences including economics and psychology, and a range of disciplines associated with human health. Key phenomena, such as "takeback", give rise to multiple competing hypotheses and interpretations, which can only be resolved by interdisciplinary working.

Energy efficiency is defined by the International Energy Agency (IEA) as follows: "something is more energy efficient if it delivers more services for the same energy input, or the same services for less energy input." This apparently simple formulation conceals deep problems of definition, measurement and evaluation, commensurability, intertemporality, contingency and disciplinary perspective. Garrett Hardin's first law of human ecology – "you can never do only one thing" - applies throughout the study of the built environment.

The task of improving energy efficiency in the built environment is dominated by context- and process-bound problems that arise from the deployment, as opposed to the initial development of technology. This domination is likely to increase as the UK moves towards the large-scale deployment of energy end use technologies through mechanisms such as Green Deal. The Green Deal indirectly stimulated fundamental research on U values by revealing the weakness of U value assumptions built on work done decades ago, with different equipment, different analysis techniques and for different purposes. This illustrates how high-value scientific problems can arise from the policy-driven deployment of interventions.

The Research Councils most directly involved with energy demand in buildings are the Engineering and Physical Sciences Research Council (EPSRC) and the Economic and Social Research Council (ESRC). The Technology Readiness Level (TRL) model used by EPSRC to define its own role leaves little room for it to engage with the complex and multi-layered RDD&D process in the Built Environment. Hitherto this has meant that much research in this area has been funded, not by Research Councils, but by Technology Strategy Board (TSB) and Energy Technologies Institute (ETI) and their predecessors, and by charities and agencies, such as Historic Scotland, English Heritage, and the Society for the Protection of Ancient Buildings (SPAB) (who have funded much of the recent fundamental work on solid wall U values) with interests in the area. Until the mid-1990s, the directly-funded Building Research Establishment and energy industry research centres were also major providers of built environment research. Since privatisation, this work has declined or ceased, resulting in both a loss of capacity and much-diminished access to the results of research undertaken historically by these organisations.

One of the factors that impedes progress in this area is the mismatch between the comprehensiveness of the system established by Research Councils UK (RCUK) Research to report research outcomes, and absence of such systems for other funding bodies. The Research

Outcomes System (ROS) is a web-based system through which the holders of grants awarded by AHRC, BBSRC, EPSRC, ESRC, NERC and NC3Rs are required to report the research outcomes resulting from those grants. Information reported to ROS is used to demonstrate the impact of research funding to Government, and is being made publicly available through Gateway to Research. The reporting of research undertaken for other organisations is generally less consistent and rigorous. This mismatch can lead to a situation in which researchers funded predominantly from RCUK resources may be unaware of work taking place with other sources of funding.

Research Challenges

To do justice in a few pages to the full spectrum of research in support of Energy Efficiency in Residential & Commercial Buildings is impossible. The following is written primarily from a particular perspective – building physics - and will inevitably omit important areas of work. The author's hope is that readers will interpret this review generously, and in some cases make the connections to their own experiences of researching in this area.

This "Landscape Document" groups research challenges under 14 headings, ranging from Modelling to Translational Research. Modelling of energy demand of buildings is a major task involving physics, engineering, and built environment disciplines. At this point it is worth noting that the majority of delivered energy demand (but not exergy demand) in the built environment in the UK is due to heating. As a result, heat demand is a dominant theme in UK research. At its most basic, under the headings of Materials Science, and Building Technologies and Systems, there is significant research into insulants and insulation systems – though a great deal of this work is undertaken by industry and much is based outside the UK. Modelling has been dominated for most of the last three decades by heat.

A very significant, two-pronged effort was made in this area in the 1980s. The first was coordinated by the IEA, with significant support for UK researchers from EPSRC (then known as the SERC), and focused on the development and comparison of dynamic thermal simulation packages. The initial driver of this work was the desire to understand the performance of passive solar buildings (see (Balcombe, 1992) for a discussion of the early work on passive solar from a US perspective), but the approach and the software packages that were developed have found a much wider range of uses over the subsequent decades. The second effort was spear-headed by the Building Research Establishment, but with significant input from Chapman (Chapman, 1990) (based at the Open University) and involved the development of the SAP-BREDEM family of static models of energy use, primarily for use in dwellings. Similar developments took place in other countries and an overarching framework subsequently emerged through CEN and ISO (ISO 13790).

Subsequent developments included computational fluid dynamics, to model air flow in and around buildings (and indeed, planets) and, in the last decade, combined thermal and moisture models, such as WUFI (in English, transient heat and moisture transport model). These models are likely to be central to the understanding of side-effects of insulating existing buildings.

Historically energy demand has been seen as technically determined. But the interaction of people with technical systems has over the last decade been recognised as crucial. This has led to a demand among research funders and policy makers for socio-technical models of energy demand in buildings, primarily as an aid to the development of policies and technical intervention strategies. Among the many problems faced by builders and funders of socio-technical models are the completely different languages used to describe technical systems and human behaviour. These differences are fundamental and will not be transcended easily. A broad level of knowledge on the part of research funders and major stakeholders of the disciplinary perspectives on energy demand and of the fundamental nature of the underlying processes will be essential to ensure that calls for research are well framed, and objectives are realistic.

Related to building models are stock models of the entire residential or commercial sector energy demand of a nation or region. Stock models typically rely on bottom-up models such as the UK's SAP and USA's EnergyPlus to combine measured or certified sub-system performance data based on laboratory measurements with a simple conceptual model of energy flows in buildings, to predict overall energy use. These models then estimate overall energy demand based on physical properties of buildings and systems. The problem of characterising new technologies and combinations of technologies, and representing the interactions between building fabric, systems, climate and people for the purposes of modelling is a profound one. Historically, predictions have been adequately close to performance, where this has been measured. This is less and less likely to be the case in the future. The problem is apparent even with a technology as simple as the condensing boiler. Technologies such as heat pumps, and the increasing number of buildings with multiple heat supply systems (condensing boilers and solar thermal), are likely to be even more vulnerable to systemic influences on performance. The difficulty of predicting behaviour of complex systems from sub-system performance suggests that in the future more reliance will need to be placed on empirical feedback on whole system performance from the field.

The study of the interactions between buildings and building systems and the rest of the energy supply system is an area of increasing importance, but one in which the growth of capacity lags. The UK has developed a significant capacity for energy supply system modelling through the Supergen Consortium and for whole system techno-economic modelling through the UK MARKAL / UK TIMES team. But use of physical modelling to understand the complex, multi-layered, dynamic interactions between systems such as heat pumps and the rest of the energy system is less developed. Some of the more interesting work has been done through consultancy.

All models depend on assumptions about the basic processes at work (in the case of building physics models, these start with the laws of thermodynamics), data and understandings (which, in the context of building physics, are expressed in the form of parameterisations) of the influence of wider system contexts. Recent results, particularly of convective bypasses in domestic construction and of solid wall U values, have reminded the research community of the vulnerability of all models to the absence of good empirical data and interpretation. As the demands on models increase, so the need for high quality empirical work will also increase. The lack of emphasis over the last three decades on physical measurement of buildings has left the UK capacity for such work significantly reduced. Conversely, advances in measurement and imaging technology, coupled with the ongoing IT revolution, have made it possible to undertake work more quickly, with greater precision and at significantly lower cost than ever before. The necessity of measuring performance and detecting and diagnosing unintended consequences of unprecedentedly large-scale interventions in the building stock sufficiently quickly to assist policy makers and the supply chain, presents both a huge challenge and a huge opportunity for the UK research community.

The systematic collection and analysis of data on energy use in buildings has become referred to as **Building Energy Epidemiology**. **Energy Epidemiology** is the systematic study of the distributions and patterns of energy use and their causes or influences in populations. It uses statistical association to impose top-down, constraints on bottom-up thermodynamics. It deals with the whole energy system as well as its sub-systems, focuses on outcomes such as reduced delivered energy or carbon emissions as well as intermediate performance indicators. It is interdisciplinary, facilitating and illuminating enquiry from the perspectives of economics and social science as well as thermodynamics. It will support the developments of technologies, changes in behaviour and policies and is action-oriented. Examples of the sorts of questions that the epidemiological approach can address include: what has been the empirical impact on energy demand of successive changes in Building Regulations over the last two decades? And, what is the actual effect on energy demand of insulating existing dwellings?

There are numerous constraints on the practice of energy epidemiology. The approach requires access to large datasets on energy use and related factors. Much of this data is sensitive, and access to it has managed in a way that balances legitimate concerns over privacy and commercial confidentiality against the very large potential benefit to energy companies, policymakers and the nation as a whole. Using existing administrative datasets for purposes that they were not designed to support is likely to reveal quality control problems. Initiatives such as smart metering, have the potential to generate very much larger volumes of data than are currently available. All of these issues will need to be worked through over the coming decade.

We have already mentioned the importance of interdisciplinarity in this sector. Interdisciplinary working and training poses significant challenges for the individual researcher and research student, as well as for existing disciplines. Interdisciplinarity imposes significant additional learning requirements, requiring that researchers have at least "second-language" competence in disciplines other than their home discipline. Researchers who set out to cultivate breadth of understanding risk placing themselves at a competitive disadvantage compared with colleagues who have worked only within the confines of a single discipline. Critical disciplinary knowledge and insights risk being incompletely or incoherently transmitted to new cohorts of researchers. And yet, recent studies e.g. on deep retrofit, suggest the very high value of work that combines physical, process and social enquiry.

This is an appropriate point at which discuss the diversity of models for how buildings and energy research can support economic activity in the wider economy – the **National Importance** agenda. Models and data are not necessarily the most important end-products of such research. Among other outputs are: the movement of highly trained people into industry, and the co-creation, with industry, and embedding of knowledge in industry, about how to make new and existing buildings more efficient. Action Research represents a collaborative tradition, in the UK going back to World War II, involving academia and industry using research methods directly, to address complex problems in context. The potentially transformative capacity of Action or Intervention Research have been demonstrated by the Stamford Brook Project, which impacted directly on regulation and construction practice in the run up to the 2006 revision of the Building Regulations for England & Wales (Part L).

Despite its successes, the Stamford Brook project also revealed weaknesses, particularly around effective implementation of interdisciplinary working and capacity to undertake Action Research effectively.

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2. Capabilities Assessment

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Capability to undertake high quality research in energy efficiency in buildings exists but is dispersed across the UK, in universities (pre- and post-1995), in a number of non-academic laboratories, and in industry. As an example of some of the complexities of the sector, over the last quarter century, globally significant work on the performance of commercial buildings has been done by the Usable Buildings Trust, an organisation that has operated on the fringes of academia and industry, with funding from the Department of Environment (until 1997) and its successors, Department of the Environment, Transport and the Regions (DETR) (1997-2001) and the Department for Transport, Local Government and the Regions (DTLR); and with industrial sponsorship.

Taking the long view, in the decades following the Second World War, the UK had a number of outstanding research centres that addressed energy use in buildings, and whose research has been world-leading. As an example of this, the development in the 1980s, of the Building Research Establishment Domestic Energy Model, BREDEM, and the Standard Assessment Procedure, SAP, for the domestic sector, and the BREEAM family of environmental performance assessment tools, remain key resources for the research community, policymakers and industry. As noted earlier, since privatisation of the energy industries, much of this work has declined or ceased, resulting in both a loss of capacity and much-diminished access to the results of research undertaken historically by these organisations.

The replacement of the lost research capacity by development of centres of excellence in academia is a process that is still under way. The historic role of BRE in support of Government and the development of building regulations was replaced, between 2003 and 2008, by the FM Nectar Consortium working under Framework Contracts placed by DTLR, and its successor organisations, Office of the Deputy Prime Minster (ODPM) and the Department for Communities and Local Government (DCLG). The consortium was led by Faber Maunsell (later to become AECOM) and included at least two academic organisations, UCL and Leeds Metropolitan University.

Despite its historic strengths, the UK has been quite conservative in terms of research and development of new approaches to construction and building management, and is weaker than its peers on the Continent in this area. New, low energy building paradigms (for example, the PassivHaus standard) have not typically been developed in the UK and the UK is a clear follower and not a leader in this area. Attempts to leapfrog continental advances, e.g. through the promulgation of the Zero Carbon agenda, have tended to overlook the factors – such as a culture of training - that make analogous developments a success on the Continent, and to the extent that they have been led by colleagues in the construction industry, have tended to ignore impacts on the energy system as a whole.

Critical problems are the relatively weak integration of the different centres of capacity, and a corresponding lack of integration between funding bodies, particularly with respect to the recording and documentation of research. In the case of research procured by government departments, frequent reorganisation, coupled with reductions in departmental funding and capacity, have meant that much of this work is no longer easily accessible. A diversity of research finding organisations is almost certainly desirable, through its ability to promote a more diverse portfolio of research. The disadvantages, some set out above, can in principle be managed by encouraging all funding bodies to require research to be published in academic journals, and by insisting that all research outputs are lodged in repositories such as the UKERC Energy Data Centre.

Table 2.1 Capability Assessment

UK Capability	Area	Market potential
High	Building performance evaluation	Worldwide
High	Environmental rating systems	Worldwide
Medium	Translational research	Worldwide
Medium	Building physics	Worldwide
Medium	Building engineering	Worldwide
Medium	Building simulation	Worldwide
Medium	Building stock modelling - domestic	Worldwide
Medium	Building stock modelling - commercial	Worldwide
Medium	Whole system energy modelling	Worldwide
Medium	Human behaviour and social practices in buildings, including occupant-building interactions	Worldwide
Medium	Materials science	Worldwide
Low	Building technologies and systems	Worldwide
Low	Policy and regulatory system research	Worldwide
Low	Supply chain research	Worldwide

3. Basic and strategic research

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The task of defining what is basic and strategic research in this area turns out not to be a simple one. First and foremost, basic research is not necessarily the same as strategic research, particularly in a period when the environment that drives research objectives is characterised by deployment of rafts of technology and social, political and economic interventions, at unprecedented rates, with the aim of successfully negotiating the third great transformation in human ecology since the end of the last Ice Age (the first two were the development of agriculture, and the transition to a fossil-fuelled economy).

To a building physicist and materials scientist, basic and strategic research in the domain of energy efficiency of residential and commercial buildings would probably include:

- the establishment of basic physical data on building materials and systems (thermo-hygral properties such as conductivity and moisture diffusivity, U values and related properties for building systems)
- the development of techniques to measure and model the above, and, for example, to support field measurement as well as laboratory measurement
- the development of new materials and systems with properties that improve on existing.

Engineers and physicists would be likely to add to the above, the development of new or improved energy conversion systems such as heat pumps, fuel cells, light sources (of which the development of the LEDs is the most recent example). In principle, the development of low exergy systems for energy distribution should fall into this category. As an example, systems engineers and some physicists might want to include the 4th Generation District Heating Technologies and Systems (4DH) project, currently being led by Aalborg University in Denmark under the heading of basic and strategic research. But 4DH applies fundamental principles that have been understood for more than 140 years, and to a thermodynamicist it would probably look more like plumbing than basic research. Despite this, if successful, the project holds the promise of strategic impact on a range of energy systems (for example, heat pumps, and not just in the context of district heating). But the programme of work is highly applied, with significant involvement from industry – indeed, it is hard to see how the work could be conducted without such involvement – and if undertaken in the UK might well have been funded by the ETI or the TSB.

The purpose of this short discussion has been to illustrate (from a particular and deliberately limited perspective) some of the tensions implicit in the title of this section of the Landscape Document. RCUK are clearly aware of the problem, and have taken steps to address it e.g. through support for, and collaboration with, ETI and, in the future, with TSB.

As noted at the beginning of this document, there are many disciplines, other than physics and engineering that are involved in researching energy efficiency in buildings. From the perspectives of these disciplines, the range of what might be considered to be basic and strategic research is even wider. To give some examples from one more disciplinary perspective, to a social scientist, basic research might include the theoretical work of Theodore Schatzki on the inter-relationships between social practices and material arrangements, which has the capacity to illuminate the processes and consequences of innovation. It might also include the development of systems to collect data that describe empirically the interplay between social practices and infrastructure. And it might include the structure, practices and culture of the construction industry, and their relationship to innovation and building and system performance.

For the purposes of this document, the procedural definition of basic and strategic research is research that is funded by the research councils. One example has already been given to illustrate the problematic nature of this definition – the fact that recent and arguably fundamental work on *in situ* U values of walls has been funded by Historic Scotland, English Heritage, and the Society for the Protection of Ancient Buildings. A second example is the work of Leeds Metropolitan University on the physical and forensic measurement of the physical performance of buildings, most of which has been undertaken with funding from a mix of sources including Joseph Rowntree Foundation, TSB, the National Trust, Partners In Innovation (a precursor to TSB) and industry. As well as supporting the development and refinement of techniques such as co-heating testing, the work has demonstrated the existence of a technical design to as-built performance gap in both new and refurbished dwellings. How and to what extent this gap can be closed is likely to be one of the most important questions for the energy efficiency in buildings community in the coming decade.

Structure of Research Council Support

Research Council support for Energy Research is organised through the RCUK Energy Programme. Current priorities of the Energy Programme are:

- taking a whole systems approach to energy options, supply and usage
- ensuring a rapid exploitation through collaboration with ETI
- growing our portfolio in demand reduction and transport
- focusing our postgraduate training through energy themes
- continuing to support research in sustainable power generation and supply and alternative sources.

The largest portion of funding both to the Energy Programme and to Energy Efficiency in Buildings comes from EPSRC. Energy Efficiency in Buildings sits primarily within the EPSRC's Energy Theme under the sub-theme Energy Efficiency (End Use Energy Demand), but with significant support from the Digital Economy, Information & Communication Technology, and Manufacturing the Future themes. Energy demand is intimately linked with whole system modelling, and with several social science themes including local and community governance, community engagement, the study of social practices, public beliefs and behaviours and the role of media, and the study of sustainable life styles.

A feature of the last decade has been a growing recognition that Energy Demand research has been underfunded and insufficiently structured.

As of 1 April 2011, Energy Demand represented just 6.7% of EPSRC's investment in Energy (though because of the difficulty of defining energy demand research precisely, this may represent an underestimate). Steps to address this joint problem have included the development of the Energy Demand Theme in the EPSRC/NERC/ESRC-funded UKERC, the 2009 TEDDI (Transforming Energy Demand Through Digital Innovation) and the 2011 BuildTEDDI (Transforming Energy Demand in Buildings through Digital Innovation) programmes, the People Energy and Buildings Programme (supported by a strategic partnership between EPSRC and EDF), the London - Loughborough Centre for Doctoral Research in Energy Demand, and most recently, the establishment of five End Use Energy End Centres. In the following we attempt to set out both the structure and current content of RCUK support for Energy Efficiency in Buildings research.

Table 3.1: Research Funding

Programme	Funding Agency	Description	Committed Funds	Period	Representative Annual Spend
RCUK Energy Programme	RCUK	The RCUK programme focuses on energy-efficient processes for saving energy from domestic lighting and appliances. It also addresses the social and economic issues that influence how we use technology and how much we are prepared to pay for energy-saving products. It has number of collaborations with both public sector and industrial partners to ensure exploitation of energy efficiency research.	£39M for all activities	Ongoing	
End Use Energy Demand (EUED) Research Centres	EPSRC, ESRC, industry	Five End Use Energy Demand (EUED) research centres, that look into the complexities of energy use across society and how energy can be both saved and used more efficiently, receive over £26 million funding from two research councils, the Engineering and Physical Sciences Research Council (EPSRC) and the Economic and Social Research Council (ESRC), and a further £13 million from industrial partners. The five centres, each funded for five years, are : • RCUK Centre for Energy Epidemiology (CEE) - led by UCL. • Centre for Sustainable Energy Use in Food Chains (CSEF) - led by Brunel University partnered with the universities of Manchester and Birmingham. • UK Indemand - led by Cambridge University – partnered with University of Bath, University of Leeds, Nottingham Trent University.	£39 million	2013-2018	

		• DEMAND: Dynamics of Energy, Mobility and Demand Centre - led by Lancaster University – partnered with the universities of Aberdeen, Birmingham, Leeds, Reading, Southampton, Sheffield, Sussex, Birkbeck College ,and UCL. • Centre on Innovation and Energy Demand (CIED) - led by University of Sussex partnered with University of Oxford and University of Manchester.			
BuildTEDDI	EPSRC	The Research Councils' Energy and Digital Economy programmes are seeking to support joint research projects concerned with the application of digital technologies to transform energy demand reduction within the envelope of a single building. BuildTEDDI (Transforming Energy Demand In Buildings Through Digital Innovation) follows on from the earlier TEDDI (Transforming Energy Demand Through Digital Innovation) programme. BuildTEDDI projects were launched in March 2012.	£6 million	March 2012-	
Centres for Doctoral Training	EPSRC	EPSRC-funded centres for doctoral training provide a supportive and exciting environment for students to carry out a challenging PhD-level research project together with taught coursework. Includes the London-Loughborough Centre, focussing on the complex, multidisciplinary task of driving down energy demand and CO2 emissions from the UK building stock.	£7.3M	2009-2018	£850K
UK Energy Research Centre Phase II	NERC	The UK Energy Research Centre (UKERC) is funded through NERC's for the Towards a Sustainable Energy Economy (TSEC) programme, but with funding also coming from the EPSRC and the ESRC. UKERC carries out world-class research into	£4.3M for Energy Demand Theme	2009-2014	£850K

		sustainable future energy systems. It is the hub of UK energy research and the gateway between the UK and the international energy research communities. Energy Demand in Buildings is a sub-theme of the Energy Demand theme. In 2012, RCUK indicated that it would consider a bid for a 3rd round of funding for UKERC.			
Cross-Discipline Interface	EPSRC	The cross-discipline interface programme aims to support the next generation of talented cross disciplinary researchers throughout their academic careers, identify emerging research and training opportunities at cross-disciplinary interfaces, fund transformative research at targeted cross disciplinary interfaces, and contribute to knowledge exchange between academia and users of cross-disciplinary research. This includes cross-research council projects such as Energy and Communities Collaborative Venture (with ESRC)		ongoing	
EPSRC Fellowships	EPSRC	Academic fellowships are available for academics at three stages of their careers: postdoctoral, early and established career researchers. There are open calls via universities for proposals in pre-set areas, including energy.		ongoing	
Information & Communication Technology	EPSRC	The ICT programme aims to bring information technology to energy building systems including human-computer interaction and research related to the digital economy programme.		ongoing	
Infrastructure & International	EPSRC	In the area of energy research, these grants are for cross-disciplinary research with an international partner.		ongoing	
Materials, Mechanical and Medical Engineering	EPSRC	The Materials, Mechanical and Medical Engineering programme seeks to improve understanding of the principles and practice of mechanical engineering. This involves the application of insight derived		ongoing	

		from the physical, computational, social and life sciences to the analysis, design, manufacture and operation of engineering systems. The programme has specific foci on mechanical systems, materials processing and medical engineering.			
Process Environment and Sustainability	EPSRC	This supports research and training in process engineering (the design, operation and maintenance of processes for chemicals and materials manufacture), the built environment, structural and ground engineering, water engineering, waste, pollution, and transport operations & management. The Programme also has responsibility for responsive mode support for energy.		ongoing	
Public Engagement	EPSRC	This programme seeks pioneer new ways of stimulating research across disciplines and breaking down the barriers to multidisciplinary collaboration. Now known as Pathways to Impact.		ongoing	
User-Led Research	EPSRC	Discretionary grants given to researchers on a one-off basis.		ongoing	
People, Energy and Buildings	EDF/EPSRC	EDF and EPSRC have entered into a strategic partnership and Energy Efficiency/Demand Reduction in buildings is the first research area in which EDF and EPSRC are developing an activity. The research Councils Energy Programme (RCEP) and EDF have invested £4 million in a collaborative research programme in the general area of the social and economic sciences of energy efficiency in buildings.	£4M	2009-2013	£1M
Tyndall Centre Energy and Emissions Theme	Initially NERC, EPSRC and ESRC; now universities and grants	The Tyndall Research Centre opened in November 2000, with core funding from NERC, EPRSC and ESRC and with support from the DTI (now BIS). The Tyndall Centre has been one of the more significant developments in this area, with links to centres of expertise in the built environment	The Centre was funded by Research Council grants until 2010, now funded by the participant Universities, and specific project	2000 -	

		(UMIST), climate science (Climate Research Unit UEA and Hadley Centre for Climate Prediction and Research) and social and political science (CSERGE, UEA). The Tyndall Centre Energy Theme is framed by the need for a sustainable energy transformation, and considers a multitude of issues and perspectives: from technologies and economies to behaviours and societies; from micro-scale to systemic; from retrospective to prospective; from mitigation to adaptation. The Energy Theme brings together natural and physical scientists, social scientists, engineers and economists to conduct interdisciplinary and policy relevant research.	grants		

Table 3.2: Key Research Providers

Name	Description	Sub-topics Covered	No of staff	Field
De Montfort University: Institute of Energy and Sustainable Development (IESD)	The Institute employs a multi-disciplinary team of Professors, Lecturers and Researchers - supported by higher degree students - who are respected internationally for the quality of their work. Their disciplines range from mathematics and physics, through engineering, to economics, sociology and psychology. This enables them to lead multi-disciplinary projects that address environmental, economic and social research problems.	• People and Energy • Sustainable urbanism	10 faculty, 15 researchers, 18 PhD students	Geography and Environmental Sciences
Imperial College: Digital Economy Lab	Through connecting citizens, business and government to real-time intelligence and enabling 'smart' decision making, the Digital Economy could revolutionise almost every aspect of our everyday lives leading to better monitoring and controlling of infrastructure to reduce CO2 emissions and waste.	• People and Energy	2 faculty, 3 researchers, 3 PhD students	Business and Management Studies
Department of Sociology And Lancaster Environment Centre Lancaster University	Department of Sociology : Current research includes examining the relationship between consumption, everyday practice and ordinary technology. Leads the EUED DEMAND: Dynamics of Energy, Mobility and Demand Centre - partners include the universities of Aberdeen, Birmingham, Leeds, Reading, Southampton, Sheffield, Sussex, Birkbeck College ,and UCL. Lancaster Environment Centre : Special interests : how energy is related to notions of need, rights and justice; on the work of energy managers using energy management and control systems; on the dynamics of energy use in everyday life	• People and buildings		Sociology
Loughborough University: Civil and Building Engineering	The civil and engineering department of Loughborough University specialises in energy efficiency and low carbon technologies for the built environment. The	• Sustainable construction • Buildings energy	23 faculty, 28 researchers, 44 PhD	Civil Engineering

Name	Description	Sub-topics Covered	No of staff	Field
	department centres on the understanding of energy use in buildings as a science discipline.	modelling • Energy monitoring • HVAC systems development •	students	
Environmental Change Institute, Oxford University	The ECI work on energy concentrates on understanding the links between social and individual behaviour, technologies, policy formulation and markets. It is organised by themes : The energy in buildings theme encompasses work on low energy buildings and appliances, low-carbon housing refurbishment and energy management; the behaviour and society theme includes research on energy demand and low-carbon communities; and the policy, equity, security and fuel poverty theme investigates practices, supply chain, governance and policy related to energy systems, as well as carbon markets and futures analysis, and fuel poverty.	• Energy in buildings • Behaviour and society • Policy, equity, security and fuel poverty	13 researchers	Architecture and the Built Environment
Energy Systems Research Unit, Strathclyde University	ESRU undertook fundamental work on dynamic thermal simulation and building physics simulation throughout the 80s and 90s. Current research within ESRU is concerned with the development and testing of new methods and technologies for energy reduction and supply, and the evolution of computational tools to assist designers in their attempts to devise clean and sustainable solutions. ESRU has developed HUE a housing energy model (which can be applied at National housing stock level, community or Local Authority level or to individual dwelling level) designed to support domestic carbon and energy policy formulation, carbon foot-printing and roadmap formulation, strategic or concept low carbon design, carbon and energy performance rating, and cost	• Building environment and energy modelling		Architecture and the Built Environment

Name	Description	Sub-topics Covered	No of staff	Field
	effective improvement identification			
University of Bath: BRE Centre for Innovative Construction Materials	The Centre conducts leading research, development and consultancy in the field of innovative and sustainable construction materials. Developing the use of radical, low-carbon building materials and reinforcement technologies for the construction industry, the centre is assisting in reducing the UK's eco footprint - vital to mitigate the projected doubling of cement-based CO2 emissions by 2050.	• Sustainable construction • Materials science	15 faculty, 10 researchers, 25 PhD students	Civil Engineering
University of Cambridge: The Martin Centre for Architectural and Urban Studies	The sustainable building group addresses issues related to the modelling, design, construction, monitoring and use of buildings, both in the UK and internationally, developing innovative technologies, methodologies and tools for sustainable design. Coordinated within the Cambridge Energy Efficient Cities Initiative with Departments of Engineering, Architecture, Chemical Engineering, Computer Science, JBS and BP Institute at the University of Cambridge.	• Sustainable construction • Energy monitoring	3 faculty, 3 researchers, 10 PhD students	Architecture and the Built Environment
University of Cambridge: Materials Science & Metallurgy	Work includes solid-state lighting to reduce electricity consumption, materials for higher-temperature (and therefore more efficient) gas turbines, innovative processing for energy-efficient materials extraction, lighter weight materials for energy-efficient transport, more efficient refrigeration, lower-energy electronics, and sensors for efficient control.	• Materials science • Building controls	5 faculty, 7 researchers, 10 PhD students	Metallurgy and Materials
University College London: UCL Energy Institute and Bartlett School of Graduate Studies	The UCL Energy Institute brings together different perspectives, understandings and procedures in energy research, transcending the boundaries between academic disciplines. There is some crossover with the Complex Built Environment Systems group (CBES) in the Bartlett School of Graduate Studies. CBES is a team of academics working together to gain a deeper understanding of the physical performance of built environment choices and their implications for energy	• Building environment and energy modelling • Energy monitoring • Data frameworks and analysis • People and Energy	38 faculty, 35 researchers, 45 PhD students	Architecture and the Built Environment

Name	Description	Sub-topics Covered	No of staff	Field
	use, health, conservation, productivity and climate change.			
Science, Technology and Innovation Studies, School of Social and Political Science, University of Edinburgh	The Group are working on the theme of innovation studies, and includes studies of energy systems, and thus offers impartial, evidence-based advice to public and private stakeholders	• Policy, equity, security and fuel poverty		Politics and International Studies
Energy Policy Group, University of Exeter	The Energy Policy Group (EPG) at the University of Exeter specialises in the interdisciplinary study of energy policy, placing sustainability and change at the heart of debates about energy policy and governance. The Group works collaboratively with stakeholders and researchers on the economics and politics of energy to find new and innovative approaches for enabling the transition to a low carbon, sustainable and affordable energy system.	• Policy, equity, security and fuel poverty	6 faculty, 9 PhD students	Politics and International Studies
University of Manchester: Manchester Architectural Research Centre	Work lead by social construction of design, principally focusing on the field of sustainable architecture. Research into the nature of urban sustainability as it is played out within competing discourses of green building. Also research work on urban climatology and its relationship with urban and building design and the planning process; and studying the social scientific understanding of habitual behaviour in areas of everyday consumption with consequences for sustainability; and investigating the issue of energy consumption as a socio-technical phenomenon by unpacking the social and material dimensions of energy and carbon challenges related to 'thermal experience' in domestic settings	• Sustainable urbanism • Urban climatology • People and buildings	5 faculty, 3 researchers, 3 PhD students	Architecture and the Built Environment
University of Plymouth: Environmental	The main research concentrations of this group are in the fields of building science and technology and construction management. Projects deal with a breadth	• Sustainable construction • Materials science	5 faculty, 5 researchers, 10 PhD	Architecture and the Built Environment

Name	Description	Sub-topics Covered	No of staff	Field
Building	of sub-topics, like for instance thermography, laboratory and in-situ measurements of thermal and humidity properties of building materials, building performance simulation, off-site construction, low and zero carbon technologies, POE (Post Occupancy Evaluation), building operational conditions and control (including occupant behaviour and climate change), values and attitudes regarding sustainability, and many others.	• People and buildings	students	
University of Reading: Construction Management and Engineering	Research in energy efficiency in buildings at Reading is centred in the Technologies for Sustainable Built Environments (TSBE) Centre. The TSBE is structured around sustainable building and services systems, energy management in buildings and infrastructure systems.	• Sustainable construction	12 faculty, 18 researchers, 5-10 PhD students	Civil Engineering
University of Southampton: Electronics and Computer Science	Research of electronics and computer science related to energy efficiency of buildings. Includes research into agent-based modelling and intelligent systems for energy management and smart buildings and developing low-powered devices to feed this data to occupants in the future.	• Photonics • Agent-based modelling	5 faculty, 10 researchers, 6 PhD students	Computer Science and Informatics
The Sussex Energy Group, University of Sussex	The Group specialises in research in two areas : a) Transitions to sustainable energy systems. Research under this theme looks principally at the dynamics of both established and new energy systems at various scales: locally, nationally, and internationally. It also analyses the processes that are helping and hindering transitions to more sustainable, low carbon energy systems. Insights from these projects inform many of our engagements with and recommendations to policy-makers, businesses and civil society organisations. b) Governance of sustainable energy systems. Under	• Behaviour and society • Policy, equity, security and fuel poverty	12 faculty, 10 researchers, 11 PhD students	Sociology Politics and International Studies

Name	Description	Sub-topics Covered	No of staff	Field
	this theme, we analyse the formulation and implementation of energy policies locally, nationally and internationally. This includes studying the way industry, government and civil society identify and promote particular energy challenges and options. We focus on how governments intervene with policies and other measures to guide the development of energy systems - and the often complex process of balancing policy objectives including emissions reduction, enhanced energy security and socially just access to energy.			

4. Applied research

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UK capabilities in the application of energy efficiency research to residential and commercial buildings can be found in academia and in major private sector consultancies.

The nature of energy efficiency in the built environment is that there is a large amount of applied research funding that comes both from research councils, energy companies, and government departments. Historically government buildings research was carried out the Building Research establishment (BRE), which was privatised twenty years ago to create BRE Ltd. The company has been at the centre of applied research in energy and buildings for UK government departments from diverse perspectives of engineering, policy making, and behaviour change in relation to energy efficiency in buildings. In more recent times, other private companies have also provided applied research to the government sector.

The main programmes for applied research in energy efficiency of commercial and residential buildings come from government-sponsored housing surveys that include extensive surveys of energy consumption of buildings in the domestic sector. Out of these surveys emerges another major strand of applied research of predicting the energy performance of buildings for the purposes of satisfying Part L of the building regulations. This research is coordinated by private sector research but with significant input from academia.

In the non-domestic sector, there is no overall survey of the building stock or its energy use to draw upon for applied research in these buildings.

Another strand of research is the production of new materials that can reduce energy demand and raise the internal temperature of a building.

A final strand is the reduction of fuel poverty in domestic households, where its members cannot afford to keep adequately warm at reasonable cost, given their income.

There has been an upsurge of applied research funded by research councils, private industry, and government-sponsored organisations. This renewed focus on the applications of energy efficiency research and multidisciplinary projects that focus on socioeconomic dimensions of energy efficiency incorporating human behaviour, human-computer interaction, and economic growth.

Table 4.1: Research Funding

Programme	Funding Agency	Description	Committed Funds	Period	Representative Annual Spend
English Housing Survey	DCLG and DEFRA	Commissioning of a new database for the analysis of the energy use of residential and commercial buildings as part of the English Housing Survey and the fuel sub-sample that will	£16.5M +	2007-2014	£4M

		monitor energy use in buildings that will take place in 2012-13.			
Sustainable Buildings Research	DCLG	Research into the application of new European Building Performance Directives, revisions to Part L of the Building regulations, development of calculation methodologies such as SAP and SBEM, and guidance to the Code for Sustainable Homes. Future rounds of funding for this type of research is dependent on the pace of revisions of these building performance standards at both the national and European level.	£1.3M spent in 2007/08 for major revisions	Ongoing and responsive	£200K to £1+M
Sustainable energy analysis and research	DECC	DECC funds sustainable energy and fuel poverty policies and programmes. This involved modelling of the energy use of buildings, the impact of policies on energy use in buildings, promotion of technologies that save energy use, and connecting energy efficiency gains with a reduction in fuel poverty.		Ongoing and responsive	£17.7M for all science-related research in 2010/11
Buildings Perspective	Energy Technologies Institute	The Energy Technologies Institute is a UK based company formed from global industries and the UK government. The ETI aims to: • Develop intervention strategies for a range of housing types. • Produce a prioritised list of product and process technology gaps whose solution through further projects would have the most significant impact on CO2 reduction & customer value. • Assess the enhanced benefits that can be achieved should these intervention strategies be implemented, towards the UK's 2020/2050 targets.	£3M	2010-2013	£1M
Energy Multidisciplinary Applications	EPSRC	Applied, user-led multidisciplinary research activities in partnership with other research councils, Energy Technologies Institute, Technology Strategy Board and government.	£11.3M	ongoing	£3.3M
Digital Economy	EPSRC	Supports research to rapidly realise the transformational impact of digital technologies on aspects of community life, cultural experiences, future society, and the economy. Brings	£3.2M	ongoing	£1.1M

		together a community of researchers (from diverse disciplines including social science, engineering, computer science, the arts and medical research) and users (people, business, government) to study, understand and find solutions to real problems.			
	English Heritage	Support for research with particular impact on existing and heritage buildings.		ongoing	
	Historic Scotland	Technical Research at Historic Scotland is structured around better understanding of traditional materials and their use in historic and other structures. We are at the forefront of technical research relating to the built environment through commissioned work with sector specialists, joint initiatives with academic institutions and in-house research.		ongoing	
	Joseph Rowntree Foundation	Support for a research with potential impact on social equity		ongoing	
	SPAB (Society for the Preservation of Ancient Buildings)	Support for research with particular impact on existing and heritage buildings.		ongoing	

Table 4.2: Key Research Providers

Name	Description	Sub-topics Covered	No of Staff	Sector
AECOM (formerly Faber Maunsell)	AECOM is a global provider of professional technical and management support services to a broad range of markets, including transportation, facilities, environmental, energy, water and government. Faber Maunsell was formerly independent and has done significant research in this sector.	• Sustainable construction • Sustainable urbanism • Public policy • Data analysis		Consulting engineers
BRE Group (formerly known as the Building Research Establishment)	BRE is an independent and impartial, research-based consultancy, testing and training organisation, offering expertise in every aspect of the built environment and associated industries. BRE researches and promotes innovation in sustainable products, buildings, communities and businesses.	• Sustainable building • Energy modelling • Energy monitoring	548 research staff, most of which are related to this topic	R&D Science and Engineering
Cambridge Architectural Research	Cambridge Architectural Research is an independent consultancy providing specialist advice for the construction industry, design professions and policy-making institutions.	• Energy modelling • Sustainable urbanism	c. 20 staff	Social science research
Energy Monitoring Company	The Energy Monitoring Company (EMC) specialises in all aspects of the monitoring and modelling of energy consumption in buildings.	• Energy monitoring	2 staff	Consulting engineers
Energy Saving Trust	Besides its role as a consumer advocacy group, the EST offers consultancy advice to government and industry in energy monitoring and field trials, data analysis, policy analysis, housing stock consultancy, and project management.	• Public policy • Energy monitoring • Data analysis		Other non-departmental public body
School of the Built Environment, Heriot Watt University	The school's Centre of Excellence in Sustainable Building Design specialises in architectural engineering, construction management and planning; and the Institute for Housing, Urban and Real Estate Research carries out social and	• Sustainable construction • People and Energy	40+ faculty	Architecture and the Built Environment

Name	Description	Sub-topics Covered	No of Staff	Sector
	urban policy research.			
Imperial College: Digital Economy Lab	Through connecting citizens, business and government to real-time intelligence and enabling 'smart' decision making, the Digital Economy could revolutionise almost every aspect of our everyday lives leading to better monitoring and controlling of infrastructure to reduce CO2 emissions and waste.	• People and Energy	2 faculty, 3 researchers, 3 PhD students	University
Kiwa - GASTEC at CRE	GASTEC is a practical energy management and low carbon consultancy, training and product testing company.	• Sustainable construction	<50 staff	Consulting engineers
Building Performance and Energy Group within Leeds Sustainability Institute (LSI),Leeds Metropolitan University	The Leeds Building Performance and Energy Group, specialise in the monitoring and measurement of building performance and energy efficiency. The direct contributions that building fabric, services and occupant behaviour have on the energy used in response to the external environment are central to our work. Expert knowledge exists across the sector, with research being applied to new domestic and non-domestic buildings as well as existing buildings with retrofit interventions. Work in the field and laboratory is used to test prototypes through R&D programmes. Broader fields of energy, water, infrastructure, poverty and sustainability are covered within the LSI.	• Whole building performance • Elemental performance • Field tests • Building simulations • Hydrothermal modelling • Domestic and non domestic • Unoccupied fabric and service testing • In-use monitoring, with fabric and • People and energy behaviour • Health • Economics and payback • Water quality • Energy and renewables	<50 staff 12 dedicated researchers building performance. 10 PhD	University
Civil and Building Engineering in Loughborough University:	The civil and engineering department of Loughborough University specialises in energy efficiency and low carbon technologies for the built environment. The department centres on the understanding of energy use in buildings as a science discipline.	• Sustainable construction • Buildings energy modelling • Energy monitoring • HVAC systems development	23 faculty, 28 researchers, 44 PhD students	University
Optima Energy	Provides advanced solutions for monitoring &	• Data analysis		Management

Name	Description	Sub-topics Covered	No of Staff	Sector
	targeting, bill validation, contract analysis and financial forecasting.			consultancy
Optimat	This is a research consultancy with a strong component of the study of technology commercialisation.	• Public policy	<20 staff	Management consultancy
Low Carbon Building Group, School of Architecture, Oxford Brookes University	The Group specialises in carbon accounting, building performance monitoring, post-occupancy evaluation, low-carbon retrofitting and climate change adaptation of buildings and neighbourhoods. The Group also has expertise in the study of thermal comfort, in particular the adaptive approach based on field surveys. Other related areas of expertise include: urban energy modelling using Geographical Information Systems (GIS), low carbon communities and design of low-energy buildings in diverse climates.	• Energy monitoring • Post-occupancy evaluation	7 faculty, 4 researchers, and PhD students	Architecture and the Built Environment
Ricardo- AEA	Ricardo-AEA works as a consultant to the European Commission, the UK Government and the UK Regulators on the design and implementation of energy efficiency policies.	• Public policy	10 staff	Consulting engineers
SKM Enviros	SKM Enviros is a consultancy in climate change and renewables, compliance and permitting, contaminated land and remediation, corporate sustainability, health and safety solutions, planning and environmental impact assessment, sustainable development, waste and resources management and water environment.	• Public policy • Sustainable urbanism	500 staff in total	Consulting engineers
University College London: UCL Energy Institute and Bartlett School of Graduate Studies	The UCL Energy Institute brings together different perspectives, understandings and procedures in energy research, transcending the boundaries between academic disciplines. There is some crossover with the Complex Built Environment Systems group (CBES) in the	• Building environment and energy modelling • Energy monitoring • Data frameworks and analysis • People and Energy	38 faculty, 35 researchers, 45 PhD students	University

Name	Description	Sub-topics Covered	No of Staff	Sector
	Bartlett School of Graduate Studies. CBES is a team of academics working together to gain a deeper understanding of the physical performance of built environment choices and their implications for energy use, health, conservation, productivity and climate change.			
Energy Technologies Research Institute, University of Nottingham	The Low energy buildings group brings together architects and engineers, working to develop cutting-edge building designs and technologies. These include heat pumps, innovative insulation that helps keep buildings cool as well as warm, and environmentally friendly cooling and heating systems.	• Sustainable construction • Energy monitoring	16 faculty	Architecture and the Built Environment
Construction Management and Engineering, University of Reading	Research in energy efficiency in buildings at Reading is centred in the Technologies for Sustainable Built Environments (TSBE) Centre. The TSBE is structured around sustainable building and services systems, energy management in buildings and infrastructure systems.	• Sustainable construction	12 faculty, 18 researchers, 5-10 PhD students	University
School of the Built Environment, University of Salford	The school's Centre for Information Technology in Construction (CITC) specialises in developing Construction IT and has made contributions in communication, visualisation, integration, and intelligent systems research, process protocols, product models, knowledge-based systems and numerous integrated computing environments. Current efforts focus on developing modelling and simulation environments for the virtual prototyping of sustainable buildings and cities.	• Energy monitoring		Architecture and the Built Environment Computer Science and Informatics
School of Architecture, University of Sheffield	The Sustainable Design, People and Performance Group and Building Environments Analysis Unit (BEAU, formerly known as Building Energy Analysis Unit) within the School of	• Sustainable construction • Energy monitoring • Post-occupancy evaluation	5 faculty, 15 researchers, 20 PhD students	Architecture and the Built Environment

Name	Description	Sub-topics Covered	No of Staff	Sector
	Architecture aim to promote research, teaching and consultancy in the field of energy and environmental issues related to the built environment, and working closely with the Building Industry and Research Councils to develop low energy and low carbon buildings.			

5. Development and Demonstration Funding

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In the area of energy efficiency in buildings, demonstration projects and research facilities are mutually interchangeable entities.

Basic and applied research into energy efficiency in buildings can either take place in specialised demonstration buildings or take place in buildings in the community as one-off projects.

Demonstration buildings were first established by the UK Government as part of their buildings research programme by what eventually became the Building Research Establishment for issues that included air permeability of materials, daylighting, and solar gain. These buildings were intended as testing grounds for new building materials for walls and windows. Later, they became testing grounds for renewable energy technology. Later demonstration projects have been established by a combination of environmental charities (Centre for Alternative Technology), "energy fayres" as part of a local authority partnership (Milton Keynes Energy Park). The latter is an example of research facilities that exist in the community instead of in a demonstration project.

The Green Deal and the Energy Companies Obligation (ECO) have been included as demonstration funding programmes. The Green Deal allows bill payers to make energy efficiency improvements and repay the cost through their energy bills. This scheme will also include measures to improve the energy efficiency of the private rented sector; under the Green Deal landlords will face no upfront costs when improving their properties. The ECO aims to reduce the UK's energy consumption and support people living in fuel poverty. It is hoped that both of these schemes will contribute to increased uptake of energy efficient devices in domestic properties.

Although not strictly demonstration funding programmes, Renewable Heat Incentives (RHI) and Feed In Tariffs (FIT) have been included below, as they will encourage occupants to invest in sustainable technologies in the home, and if successful, will reduce demand on the rest of the energy supply system. These schemes pay occupants a defined tariff for their renewable heat and electricity production, incentivising investmentin both solar PV and technologies such as heat pumps. The PV Feed In Tariff, directly incentivises energy efficiency in homes rated E, F or G, through preferential tariffs for higher rated dwellings. It is possible that the RHI will indirectly incentivise energy efficiency, as a way of reducing total investment costs. The national rollout of Smart Meters, which will help occupants control their energy use, should also contribute to an improved energy efficiency of the building stock.

There are several past examples of research done in energy efficiency in the community led by social housing providers with the primary objective of reducing fuel poverty with energy efficiency as a useful by-product (Hull, Birmingham). There is a current imbalance of these research facilities towards socially rented or part-owned housing tenures with significantly fewer examples in private owner-occupied housing tenures.

There are no research facilities, either in demonstration buildings or in the community, that specifically target the non-domestic building sector at the same scale as for the residential sector. There are commercially led research projects that take place within developers (such as British Land) and major engineering companies (such as Arup) to deliver innovative buildings on a one-off basis. There is some, but understandably limited knowledge transfer between industry and academia.

Table 5.1 Demonstration Funding Programmes

Programme	Funding Agency	Description	Number of projects	Committed Funds	Period	Representative Annual Spend
Building Performance Evaluation	Technology Strategy Board (TSB)	The programme provides full funding for the evaluation of the energy and sustainability performance of new buildings and developments in both domestic and non-domestic sectors.	16	£8M	2012-2019	£1M
Decent Homes	Homes and Communities Agency (HCA)	The Decent Homes Programme aims to improve the condition of homes for social housing tenants and vulnerable households in private sector accommodation and social housing in England.	1 M + households	£22 billion from 2001 - 2009	Started in 2000, ongoing, estimated completion 2018	£2 billion
Energy Multidisciplinary Applications	EPSRC	Applied, user-led multidisciplinary research activities in partnership with other research councils, Energy Technologies Institute, Technology Strategy Board and government. This can and has included demonstration projects involving retrofit of dwellings.	c. 5	£c. 1M	Ongoing	c. 200K
Energy Companies Obligation (ECO)	ECO is funded by energy suppliers	The ECO was introduced in January 2013 to reduce the UK's energy consumption and support people living in fuel poverty. Parliament passed the the Electricity and Gas (Energy Companies Obligation) Order 2012 on 4 December 2012 and it is now in effect. The ECO will run until March 2015, supporting the installation of energy efficiency measures in low-income households and areas, and in properties that are harder to treat.		£1.3 billion every year.	Jan 2013 – March 2015	£1.3 billion every year. The ECO Affordable Warmth and Carbon Saving Community obligations will together provide support worth around £540 million per year to low-income households.

		There are 3 obligations under the ECO : 1) Carbon Saving Community Obligation – which provides insulation measures to households in specified areas of low income. It also makes sure that 15% of each supplier's obligation is used to upgrade more hard-to-reach low-income households in rural areas; 2) Affordable Warmth Obligation - This provides heating and insulation measures to consumers living in private tenure properties that receive particular means-tested benefits; 3) Carbon Saving Obligation - This covers the installation of measures like solid wall and hard-to-treat cavity wall insulation, which ordinarily can't be financed solely through the Green Deal.				The ECO Carbon Saving Obligation is worth around £760 million per year.
Feed in Tarffs (FIT)	DECC	Through the use of FITs DECC hope to encourage deployment of additional small scale (less than 5MW) low carbon electricity generation, particularly by organisations, businesses, communities and individuals who have not traditionally engaged in the electricity market. This will allow many people to invest in small-scale low carbon electricity, in return for a guaranteed payment for the electricity they generate and export. The FIT rules incentivise energy efficiency in inefficient homes through higher tariffs for homes rated D and above.			April 2010 - ongoing	
Green Deal	DECC	Under the Green Deal, bill payers will be able to get energy efficiency improvements without having to front up the cash. Instead, businesses will provide the capital, getting their money back via the energy			Feb 2013 for upto 25 years	

		bill. At the heart of the offer is a simple rule: estimated savings on bills will always equal or exceed the cost of the work.				
Housing Market Renewal Programme	Department for Communities and Local Government	The Programme aims to tackle the problems of neighbourhoods with acute low housing demand in the North of England and Midlands. Much of this involves improving the quality of the physical infrastructure of the neighbourhoods concerned. The focus is on sustainable regeneration, over 40,000 houses have been refurbished so far. There have been nine housing market renewal pathfinders set up by the Government so far, including Salford, Rochester and North Staffordshire.	9 Housing market renewal pathfinders established	£1.2 billion to March 2008, a further £1 billion committed up to 2011.	2002 – 2018	£200 M
Low Impact Buildings Inonovation Platform	Technology Strategy Board (TSB)	TSB have invested >35m in over 400 projects through the Low Impact Buildings Innovation Platform since May 2008. These include Retrofit for the Future, which funded the retrofit of 119 properties. Other examples include: £8 million for a Building Performance Evaluation competition and £5 million for a Design for Future Climate: Adapting Buildings competition.	10+	£35 M	2008 onwards	£11 M
Renewable Heat Incentives	DECC	The Renewable Heat Incentive is a new Government-backed measure introduced in 2011/2014 to make it worth your while to produce renewable heat. The RHI aims to help accelerate deployment of renewable heat by providing a financial incentive to install renewable heating in place of fossil fuels.			Non-domestic support in November 2011, domestic support April 2104	
The National Refurbishment Centre		The National Refurbishment Centre is supporting the practical delivery of green refurbishment and retrofit, based on data	Utilises 500 refurbishm		Ongoing	

		collected from a nationwide demonstration network of up to 500 refurbishment exemplars. The National Refurbishment Centre aims to foster a more joined-up approach to finding the practical measures needed to refurbish buildings in volume. Different task groups examine the following key strategy areas: Solutions (technology solutions and energy efficient products), Finance (cost effective use of refurbishment packages), Policy, Skills and Training and Behavioural Change.	ent exemplars			
Warm Front	DECC	The Warm Front scheme installed insulation and heating improvements to make homes more energy efficient. The scheme provided heating and insulation improvements to households on certain income-related benefits living in properties that are poorly insulated and/or do not have a working central heating system. Qualifying households could get improvements worth up to £3,500. (£6,000 where oil central heating and other alternative technologies are recommended). There were similar schemes available in Scotland, Wales and Northern Ireland	127,000 homes helped in 2010/2011		The Warm Front scheme closed to new applications on 19 January 2013	
Warm Homes (Scotland)	Scottish Government	The Warm Homes Fund is a new £50 million pound Scottish Government initiative which aims to provide loan funding for renewable energy projects (including district heating) to support communities in fuel poverty. Registered Social Landlords (RSLs) and local authorities can apply, as well as energy services companies (ESCOs) formed		The Scottish Government is making £50M available - £3.25 million in 2012/13, £18.75 in 2013/14 and	2012 - 2015	

		by RSLs or local authorities.		the remaining funding will be allocated in 2014/15.		

Table 5.2: Major Demonstration Projects

Name	Description	Sub-topics covered	Total Project Cost	Public Sector Funder	Public Sector Funding	Period
BRE Innovation Park	The BRE Innovation Park is a world leading and ground breaking demonstration development designed to give a glimpse of how the future delivery of sustainable buildings and communities can be achieved not only in the UK but around the world. It features eight of the world's most sustainable houses (built to the Code for sustainable homes), a health centre of the future, a refurbished Victorian Terrace and over 400 different construction innovations and emerging technologies as well as a state of the art community landscape design.	• Code for sustainable homes • Sustainable construction • Renewable technologies				Current construction was completed in 2005, although monitoring and demonstration facilities are still in use.
Centre for Sustainable Energy (CSE)	The Centre for Sustainable Energy (CSE) helps people and organisations from the public, private and voluntary sectors meet the twin challenges of rising energy costs and climate change. They give advice, manage innovative energy projects, train others to act, and undertake research and policy analysis. At any one time CSE have between 50 and 60 different and separately funded projects under way. All of these are helping people and communities to meet real needs for both	• Training • Sustainable building • Renewable technologies				

	environmentally sound and affordable energy services					
CoRE – Centre of Refurbishment Excellence	The Centre of Refurbishment Excellence (CoRE) is a partnership between private industry, Stoke City Council, Stoke College and the Building Research Establishment. CoRE is transforming a derelict Victorian pottery factory into a 6000 sq m centre of excellence and knowledge transfer link to sustainable refurbishment.	• BREEAM standard demonstration facility. • Showcasing sustainable refurbishment products. • Workforce training		Sponsors: BRE, Stoke City Council, Stoke College		Ongoing, first phase completed Autumn 2011.
Eco-towns	Originally planned by the Labour government, eco-towns aim to provide between 5,000 and 15,000 new homes. As well as being affordable, well-designed, well-built and 'green', they will be well linked to existing towns and have facilities such as schools, health centres, parks and allotments. The plans include calls for net carbon dioxide emissions across all the buildings within an eco-town, measured over a year, should be zero or less than zero. Although there is less publicity for the scheme by the new coalition government, planned schemes continue to progress towards construction starts.	• Sustainable building • Sustainable urbanism	£60M			2011-2020
Energy Technologies Building, University of Nottingham	A new, exemplar low carbon building on the University of Nottingham's Jubilee Campus, dedicated to RD&D in sustainable energy technologies. Construction started in summer 2011 and was completed in September 2012. This is a showcase building,	• Sustainable building				2012 onwards

	demonstrating a range of low carbon technologies which leads the way towards meeting the government's target for all new public buildings to be 'zero carbon' by 2018. The building incorporates energy efficient materials and is design to minimise its demands for heating, cooling, lighting and ventilation.					
FutureFit	FutureFit will deliver low carbon refurbishments to 102 Affinity Sutton homes across the country using a range of low, medium and high cost packages of measures. The project is structured around 22 different archetypes – types of housing that are common to Affinity Sutton's stock and to the social housing sector as a whole. There are two phases to the project; the works and installation phase and the monitoring and evaluation phase. Reports will be produced after each phase – one in summer 2011 and one in summer 2012. It will drill down into the practicalities of delivering low carbon retrofit to social housing stock and work out how much carbon reduction you can get for your money.	• Retrofit • Monitoring and Evaluation			£1.2 million internally funded	2009 - 2011
Greenwatt Way	Scottish and Southern Electric have constructed 10 new energy efficient homes, which are now being lived in and undergoing a two year monitoring project. The homes are different archetypes, with two one bed flats, a terrace of two bed houses, a terrace of	• Zero carbon homes • Energy use monitoring	£3.65 million	Funded by SSE		Dwellings built 2010, two year monitoring period to 2012.

	three bed houses and two three bed detached houses.					
SuperHomes	An ongoing Energy Savings Trust programme to transform the existing housing stock in the UK, with the ultimate aim of reducing domestic carbon emissions by 60 %. The scheme is building and promoting a network of exemplar, energy efficient old dwellings, which will be local and publicly accessible, within 15 minutes, to nearly everyone in the country.	• Energy-efficiency retrofit • Existing building				Ongoing
Retrofit for the future	The Technology Strategy Board invited proposals for suppliers to design and install new high performance solutions to dramatically improve the energy efficiency of houses. Companies were invited to bid for contracts to work with social housing providers, refurbishing example buildings and evaluating their environmental performance. The competition and demonstration programme, delivered more than 50 demonstration prototypes and will be managed by the Technology Strategy Board in collaboration with social landlords.	• Sustainable building • Refurbishment • Energy monitoring	£10M			2009-2011
Refit West	Refit West aims to tackle the energy efficiency of homes. The project aims to reduce carbon emissions from existing housing stock with private ownership and support delivery of energy and resource efficiency work to 1000 homes by the end of 2011. The project also aims to create a replicable	• Existing housing stock • Energy Efficiency				Ongoing

	model for delivery and financial mechanism that can support the large-scale refurbishment and increase demand for energy efficiency work by homeowners in the west of England.					

6. Research Facilities and other Assets

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Research facilities and assets in the UK for energy efficiency in buildings consist of both physical and statistical models. These models predominantly describe housing, but there are also some assets relevant to the non-domestic sector. The physical models are demonstration projects that are testbeds for new materials, technologies, and living arrangements that affect the heat demand and supply of buildings and have been in existence for the last fifty years. Statistical models are more recent with the advent of computing power that enables sophisticated models to emerge instead of using reference tables. These models are built out of major datasets on buildings, their physical makeup, and their occupants. Again, most of the data and modelling are on the residential sector and not the non-domestic sector.

Demonstration buildings have been part of energy efficiency research, with two major centres at Watford and East Kilbride currently operated by BRE, with several past examples, including the Milton Keynes Energy Park with supplied significant amounts of data for energy efficiency research in the 1980s. There are also technology demonstration sites and skills training facilities in the UK including the Centre for Alternative Technology in Wales. Again, these are facilities servicing the residential sector.

Statistical models of both the residential and non-domestic sector have been developed for both the new build for stock modelling of the residential and commercial sectors. These databases are used to assess the impact of future retrofitting and implementation of technologies that reduce energy demand.

Table 6.1: Research Facilities and Assets

Name	Description	Type of asset	Scale of operation	Annual Operating Budget
BRE Test Facilities And Innovation Park	BRE's testing services are supported by expert consultancy and research capabilities, and include: • Performance assessment and service life design and prediction of all construction elements. • Problem solving construction troubleshooting and building investigations, for example indoor air quality. • Research and development testing often as part of innovation projects. • Design testing, including: acoustics, air quality, airtightness, HVAC systems, wind tunnel testing, geotechnical.	Test facility	Number of staff unknown	Unknown
BRE Domestic Energy Model (BREDEM)	BREDEM 2012 is a model for estimating the energy consumption in dwellings for space heating, water heating, lighting and electrical appliances, and cooking.			
Cambridge Housing Model	This model was developed by Cambridge Architectural Research Limited. The Cambridge Housing Model is closely linked to SAP 09, and has been the basis for the 2011, 2012 and 2014 editions of the Housing Energy Fact File (These documents follow on from the Domestic Energy Fact File series, which was produced by BRE until 2008).	Model		
Centre for Alternative Technology, Wales	CAT is an education and visitor centre which demonstrates practical solutions for sustainability. It covers all aspects of green living: environmental building, eco-sanitation, woodland management, renewable energy, energy efficiency and organic growing.	Laboratory / Centre	20	£3M for all activities
CoRE – Centre of Refurbishment Excellence	The Centre of Refurbishment Excellence (CoRE) is a partnership between private industry, Stoke City Council, Stoke College and the Building Research Establishment. It provides, in a purpose built complex marrying the old and the new, an exhibition space and a national training facility in the techniques and materials needed to refurbish the UK housing stock to the highest modern standards. CoRE is transforming a derelict Victorian pottery factory into a 6000 sq m centre of excellence and knowledge	Laboratory/ Centre		

	transfer link to sustainable refurbishment.			
English Housing Survey (EHS)	In April 2008 the English House Condition Survey (EHCS) was integrated with the Survey of English Housing (SHE) resulting in a new survey known as the English Housing Survey (EHS). The EHS has three component surveys: a household interview, followed by a physical inspection and a market value survey of a sub sample of the properties. It also now forms part of the Office for National Statistics Integrated Household Survey (HIS). The reports are available for download via the Communities and Local Government Website.	Database		
Home Energy Efficiency Database (HEED)	The Home Energy Efficiency Database was designed and implemented to help monitor and improve the UK's housing stock. The database includes data on property characteristics, heating systems, insulation installed and micro generation technologies installed. HEED now contains at least 1 piece of date-stamped information for approximately 51 % of the UK's homes. Registration and use of HEED is free of charge, but restricted to certain non-commercial organisations.	Database	Number of staff unknown	Unknown
National non-domestic energy and emissions model (N-DEEM)	Data from the NDBS database have been used by the Building Research Establishment (BRE) to construct a national non-domestic energy and emissions model (N-DEEM). N-DEEM links national floor areas from the NDBS database, to figures for specific energy use, disaggregated by fuel and application.	Model		
Non-Domestic Building Stock Database (NDBS)	The National Non-Domestic Building Stock (NDBS) project, ran for ten years from 1991 to 2001. The database was constructed from data from the Valuation Office of the Inland Revenue and a series of street surveys of non-domestic buildings on 3,500 addresses in central Manchester, Swindon, Tamworth and Bury St Edmunds.	Database		
Scottish Enterprise Technology Park (East Kilbride)	The Scottish Enterprise Technology Park (SETP), located in Scotland's largest new town, East Kilbride, began life over 50 years ago as the National Engineering Laboratory (NEL), which undertook research and development work for both government and business including a major site for the BRE recently expanded to include the Energy Technology Centre. Innovation Park at Ravenscraig currently in the master planning stage.	Test facility	<10	£2.8M for research (annual report)
Simplified Building Energy Model (SBEM)	SBEM is a software tool developed by BRE that provides an analysis of a building's energy consumption. SBEM is used for non domestic buildings in support of the National Calculation Methodology (NCM) and the Energy	Model		

	Performance of Buildings Directive (EPBD). The tool helps to determine CO_2 emission rates for new buildings in compliance with Part L of the Building Regulations. It is also used to generate Energy Performance Certificates for non-domestic buildings in construction, sale or let. The tool is accompanied by a basic user interface called iSBEM.			

7. Networks

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Energy efficiency in buildings in the UK does not have a central research network. Instead, there are specific networks that talk to disciplines within the energy efficiency realm. There are major cross-discipline networks within UKERC and the Sustainable Development Research Network. Well-developed networks do exists that deal specifically with sustainable construction or building simulation. Researchers outside of building science are attached to various international networks such as urban meteorology or energy efficient economy, but these connections are looser and, without critical mass in the UK, require extensive international connections for information exchange.

Table 7.1 Networks

Network	Established	Description	Membership	Activities
Association of Environmentally Conscious Builders	1989	AECB, the Sustainable Building Association, is a network of individuals and companies with a common aim of promoting sustainable building. It brings together builders, architects, designers, manufacturers, housing associations and local authorities, to develop, share and promote best practice in environmentally sustainable building.	Membership is open to individual supporters, private companies, and educational institutions.	The AECB's three main roles are • To provide a forum for members and others to discuss, test and share principles and methods of sustainable building • To draw this experience together into rigorous standards To inform and lobby the construction sector and government
European Council for an Energy Efficient Economy	1993	eceee is a non-profit, membership-based European NGO.	Membership of eceee is open to both organisations and individuals	The goal of eceee is to stimulate energy efficiency through information exchange and co-operation. An analogous network exists in the USA (ACEEE) in which most academics also participate. There is an extensive database of opportunities and relevant information at the European level. There are also workshops and summer studies organised in alternate years from the ACEEE.
International Building Performance Simulation Association-England	2006	IBPSA England is an affiliate of International Building Performance Simulation Association, a non-profit international society of building performance simulation researchers, developers and practitioners, dedicated to improving the built environment.	Academics in "centres of excellence" for building performance and corporate partners involved in green building initiatives.	Regular meetings and workshops. Forum for the exchange of information between researchers, developers and practitioners operating in the area of building performance simulation and related issues. Connected to international network and conferences (IBPSA).
International Initiative for a Sustainable Built Environment	Before 2004	International not-for-profit organization focused on a global sustainable built environment.	Membership is open to both individuals and organisations	Major organiser of a series of regional feeders to its international conference and heavily associated with the journal Building Research and Information. Promotes an alternative open source methodology for

				the energy performance of buildings to LEED and BREEAM called SB-Tool.
Passive and Low Energy Architecture		PLEA serves as an open, international, interdisciplinary forum	Membership is open to professionals, academics and students from over 40 countries.	Promotes high quality research, practice and education in environmentally sustainable design. International conferences and workshops; expert group meetings and consultancies; scientific and technical publications; and architectural competitions and exhibitions.
Sustainable Development Research Network		SDRN aims to facilitate and strengthen the links between providers of research and policymakers across government, in order to improve evidence-based policymaking to deliver the UK government's objectives for sustainable development.	Open to all interested researchers and analysts	Newsletter and events to contribute to sustainable development by encouraging the better use of evidence and research in policy-making.
UKERC National Energy Research Network	2004	NERN aims to network energy researchers from all disciplines, giving members visibility of a wide and multifaceted area and providing opportunities through information and through interaction with other members.	All organisations and individuals involved in energy research who can make a contribution towards energy R&D in the UK	Free informational resource to develop the coherence and capacity of UK energy research, with regular newsletters, jobs postings, and blogs.
UK Green Building Council	2007	The UK Green Building Council (UK-GBC) is a membership organisation that is campaigning for a sustainable built environment – one that minimises negative environmental impacts while maximising benefits for people everywhere.	Membership is composed mostly of construction and engineering firms and consultancies with some involvement of major academic research centres. Not open to individuals.	The UK-GBC organises task groups to tackle pressing issues, events for information exchange primarily between practitioners but also academics, and an information centre of government policy, regulations, and relevant research.
UK Passivhaus Trust		The Passivhaus Trust is an independent, non-profit organisation that will provide leadership in the UK for the adoption of the Passivhaus	Membership is open to individual supporters, private companies, public sector organisations, and	The Passivhaus Trust aims to: • preserve the integrity of Passivhaus standards and methodology. • promote Passivhaus principles to the

		standard and methodology. Its aim is to promote the principles of Passivhaus as a highly effective way of reducing energy use and carbon emissions from buildings in the UK, as well as providing high standards of comfort and building health.	educational institutions.	industry and government. • undertake research and development on Passivhaus standards in the UK.

8. UK Participation in EU Framework Programmes

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Up to now, Framework Programmes (FPs) have been the main financial tools through which the European Union supports research and development activities covering almost all scientific disciplines. FPs are proposed by the European Commission and adopted by Council and the European Parliament. The 7th framework (FP7) has finished (for new funding) and has been replaced by Horizon 2020, the first proposals for which are now being submitted. Energy efficiency is cited specifically as a topic area.

Current calls for research are oriented around energy efficient buildings and smart cities and communities. Uptake is centred in very few research centres and agencies in the UK.

Table 8.1: EU Framework Programme Participation

Project	Objectives	Action Line	Type of Action	UK Participants	Co-ordinator and partners	Total Funding	EU Funding	Duration	Annual Spend
ACtions in low income Households to Improve energy efficiency through Visits and Energy diagnosis (ACHIEVE)	The aim of ACHIEVE is to contribute to practical (energy uses and behaviours) and structural (retrofitting buildings) solutions for reduction of fuel poverty in Europe.	FP7- ENERGY / Intelligent Energy Europe	Medium-sized research project	Severn Wye Energy Agency	Groupe Energies Renouvelables Environnement et Solidarités, France plus 6 partners	€1.3M	€1M	2011-2014	€430K
Ecoheat4Cities (ECOHEAT4CITIES)	The main aim is to promote the use of renewable sources coupled to an overall decrease of primary energy consumption and development of higher efficiency on the heating and cooling market.	FP7- ENERGY / Intelligent Energy Europe	Medium-sized research project	BRE	Euroheat and Power, Belgium plus 7 partners	€988K	€800K	2010-2012	€494K
Environmental Design in University Curricula and Architectural Training in Europe (EDUCATE)	EDUCATE seeks to foster competence in sustainable environmental design at all levels of architectural education and practice aiming to achieve comfort, well-being and energy efficiency in new and existing buildings.	FP7- ENERGY / Intelligent Energy Europe	Knowledge Transfer	University of Nottingham Architectural Association	University of Nottingham plus 8 partners	€1.6M	€1.2M	2009-2012	€530K
European Network of Information Centres	ENESCOM aims at enhancing the role of local communities in mitigating climate change by creating a common	FP7- ENERGY / Intelligent Energy Europe	Knowledge Transfer	Powys County Council	Unione di Comuni Valle del Samoggia, Italy	€1.8M	€1.3M	2010-2012	€900K

Project	Objectives	Action Line	Type of Action	UK Participants	Co-ordinator and partners	Total Funding	EU Funding	Duration	Annual Spend
promoting Energy Sustainability and CO2 reduction among local COMmunities (ENESCOM)	methodology to promote and develop capacity building in energy sustainability and for the adoption of sustainable energy policies.				plus 14 partners				
IDEAL-EPBD	The IDEAL-EPBD project aims to investigate why energy certificates seem to hardly motivate dwelling owners to take measures to improve the energy performance of their dwelling.	FP7- ENERGY / Intelligent Energy Europe	Consumer -focused project	BRE	Energy research centre of the Netherlands plus 9 partners	€1.3M	€1M	2007-2011	€300K
Sharing urban sustainable energy strategies - promoting the Covenant of Mayors (COME2COM)	come2CoM aims to promote the Covenant of Mayors within Europe by empowering cities and municipalities to prepare a baseline emissions inventory and a Sustainable Energy Action Plan.	FP7- ENERGY / Intelligent Energy Europe	Knowledge Transfer	Severn Wye Energy Agency	B.&S.U. Beratungs- und Servicegesellschaft Umwelt mbH, Germany plus 14 partners	€1.5M	€1.0M	2010-2012	€500K
Universities and Students for Energy Efficiency (USE EFFICIENCY)	Students will be the main actors of the project. They will participate in an innovative, practical training experience in tandem with building technicians in team-work activities.	FP7- ENERGY / Intelligent Energy Europe	Medium-sized project	Brunel University	University of Rome "Tor Vergata", Italy plus 12 partners	€1.8M	€1.2M	2009-2012	€530K

9. International Initiatives

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International activities, especially in buildings performance monitoring and modelling, have increased through information exchanges that have developed both inside of the International Energy Agency (via the various Implementing Agreements, which are also now known as Multilateral Technology Initiatives) and in more organic networks that have developed in the last 30 years. Even though there are significant policy and market structure barriers to international cooperation in the field of energy and buildings, the sharing of datasets, experiments and models have become more widespread. In addition, these networks have become a place for connections to be made between research from different national contexts to learn from one another and inspire collaborations.

Table 9.1: International Activities

Name	Type	Description	UK Contact Point
Demand Side Management Programme	IEA Implementing Agreement (Multilateral Technology Initiative)	The IEA Demand-Side Management Programme is an international collaboration of 20 countries working together to develop and promote opportunities for demand-side management (DSM). DSM offers solutions to problems such as load management, energy efficiency, strategic conservation and related activities.	Paul Davidson, Building Research Establishment
District Heating and Cooling	IEA Implementing Agreement (Multilateral Technology Initiative)	District Heating and Cooling (DHC) has proven to be a major contributor to Greenhouse Gas (GHG) reduction in many member countries and recognition of DHC's importance is growing. In fact, many countries where it is established are renewing their commitment to DHC as they find new ways to use the technology to reduce environmental impacts. DHC facilitates linkages between supplies that are environmentally desirable and end users that could not otherwise make use of those energy sources.	Robin Wiltshire, Building Research Establishment
Efficient Electrical End-Use Equipment	IEA Implementing Agreement (Multilateral Technology Initiative)	The co-operation will focus on efficiency of electrical end-use equipment. Energy efficiency is more than ever a top priority on the international agenda. Using energy-efficient equipment is the most cost-effective short-term path to greater energy security and lower greenhouse gas emissions to combat climate change.	Mike Walker, DEFRA
Energy in Buildings and Communities	IEA Implementing Agreement	The IEA (International Energy Agency) Energy in Buildings and Communities Programme (EBC, formerly ECBCS) carries out research and development activities toward near-zero energy and carbon emissions in the built environment. The R&D activities focus on the	Prof Paul Ruyssevelt UCL Energy Institute, University

(EBC)	(Multilateral Technology Initiative)	integration of energy-efficient and sustainable technologies into healthy buildings and communities. EBC projects and activities have produced long-lasting decision-making tools and integrated systems technologies. Outcomes from the Programme are publicised through many seminars and conferences. EBC's mission is to develop and facilitate the integration of technologies and processes for energy efficiency.	College London
Heat Pumping Technologies	IEA Implementing Agreement (Multilateral Technology Initiative)	The IEA Heat Pump Centre (HPC) is an international information service for heat pumping technologies, applications and markets. The goal is to accelerate the implementation of heat pumps and related heat pumping technologies, including air conditioning and refrigeration.	Penny Dunbabin, DECC