Research Councils UK Energy Programme Strategy Fellowship

Summary of Workshop on

Energy in the Home and Workplace

Working Document

August 2013

This is a report of a workshop held to support the development of the Research Councils UK Energy Research and Training Prospectus at Scarman House, University of Warwick on 5-6 February 2013

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Research Councils Energy Programme

The Research Councils UK (RCUK) Energy Programme aims to position the UK to meet its energy and environmental targets and policy goals through world-class research and training. The Energy Programme is investing more than £625 million in research and skills to pioneer a low carbon future. This builds on an investment of £839 million over the period 2004-11.

Led by the Engineering and Physical Sciences Research Council (EPSRC), the Energy Programme brings together the work of EPSRC and that of the Biotechnology and Biological Sciences Research Council (BBSRC), the Economic and Social Research Council (ESRC), the Natural Environment Research Council (NERC), and the Science and Technology Facilities Council (STFC).

In 2010, the EPSRC organised a Review of Energy on behalf of Research Councils UK in conjunction with the learned societies. The aim of the review, which was carried out by a panel of international experts, was to provide an independent assessment of the quality and impact of the UK programme. The Review Panel concluded that interesting, leading edge and world class research was being conducted in almost all areas while suggesting mechanisms for strengthening impact in terms of economic benefit, industry development and quality of life.

Energy Strategy Fellowship

The RCUK Energy Strategy Fellowship was established by EPSRC on behalf of Research Councils UK in April 2012 in response to the international Review Panel's recommendation that a fully integrated "roadmap" for UK research targets should be completed and maintained. The position is held by Jim Skea, Professor of Sustainable Energy in the Centre for Environmental Policy at Imperial College London. The main initial task is to synthesise an Energy Research Prospectus to explore research, skills and training needs across the energy landscape. Professor Skea leads a small team at Imperial College London tasked with developing the Prospectus.

The Prospectus will contribute to the evidence base upon which the RCUK Energy Programme can plan its forward activities alongside Government, RD&D funding bodies, the private sector and other stakeholders. The tool will highlight links along the innovation chain from basic science through to commercialisation. The tool will be flexible and adaptable and will take explicit account of uncertainties so that it can remain robust against emerging evidence about research achievements and policy priorities.

One of the main inputs to the Prospectus is a series of four high-level strategic workshops and six in-depth expert workshops taking place October 2012 - July 2013. Following peer-review, the first version of the Prospectus will be published in November 2013 and will then be reviewed and updated on an annual cycle during the lifetime of the Fellowship, which ends in 2017.

This document reports views expressed at an expert workshop held in February 2013. These views do not necessarily represent a consensus of workshop participants nor will they necessarily be endorsed in the final version of the Energy Research and Training Prospectus.

Contents

List of Acronyms

AC	Alternating Current
CCS	Carbon Capture and Storage
DC	Direct Current
DCLG	Department for Communities and Local Government
DECC	Department of Energy and Climate Change
DEFRA	Department for Environment, Food and Rural Affairs
EEDO	Energy Efficiency Deployment Office
EPC	Energy Performance Certificate
EPSRC	Engineering and Physical Sciences Research Council
ESCO	Energy Service Company
ESRC	Economic and Social Research Council
ETI	Energy Technologies Institute
FM	Facilities Management
ICT	Information and Communications Technology
IEA	International Energy Agency
LCA	Life Cycle Analysis
LWEC	Living With Environmental Change
MARKAL	Market Allocation (Model)
NERC	Natural Environment Research Council
NHS	National Health Service
PAYS	Pay-as-you-save
R&D	Research and Development
RCUK	Research Councils UK
SAP	Standard Assessment Procedure
SME	Small to Medium Sized Enterprise
TRL	Technology Readiness Level
TSB	Technology Strategy Board

1 Overview

This document summarises the outcomes of a workshop held on 5-6 February 2013 in order to identify research and training needs relating to energy use in the home and workplace. In terms of scope, the workshop covered the follow areas, defined under the EU/International Energy Agency (IEA) energy R&D nomenclature:

- Space heating and cooling, ventilation and lighting control systems other than solar technologies
- Low energy housing design and performance other than solar technologies
- New insulation and building materials
- Thermal performance of buildings
- Domestic appliances
- District Heating
- Waste heat utilisation
- Heat pump development
- Systems analysis related to energy R&D not covered elsewhere
- Energy technology information dissemination
- Sociological, economic and environmental impact of energy, which are not specifically related to one technology area (e.g. environmental dimensions, policy and regulation, consumer attitudes and behaviour, technology acceptance)

The workshop also covered decision-making in light industry.

The workshop was organised with input from the Energy Efficiency Deployment Office (EEDO) at the Department of Energy and Climate Change (DECC) and Bob Lowe of the UCL Energy Institute.

There were 31 participants (excluding the Fellowship and facilitation teams), most of whom were academics and researchers falling within the communities supported by the Engineering and Physical Sciences Research Council (EPSRC) and Economic and Social Research Council (ESRC). In addition, a number of participants were from private sector and government organisations.

The meeting was professionally facilitated by the Centre for Facilitation Services Ltd in association with the RCUK Energy Strategy Fellowship team. This record of the meeting constitutes a working document, intended to capture the outcomes of the workshop. It represents an intermediate step in the production of a full Energy Strategy Fellowship report, which will set out the prospectus for energy research and training needs relating to energy in the home and workplace. It has two purposes; a) to provide a resource which can be 'mined' in order to produce the prospectus document; and b) to provide an account of the workshop for comment by the participants and for archival purposes.

2 Introductory Presentations

To familiarise the workshop participants with the scope of the workshop, three introductory presentations were made. The first of these was from Prof. Jim Skea (Energy Strategy Fellow) who outlined the rationale behind the RCUK Energy Strategy Fellowship and key activities, noting the role of the Prospectus in informing the future design of the RCUK's Energy Programme. The Energy in the Home and Workplace workshop forms part of a wider programme of work being undertaken through the Fellowship, including five other expert workshops, three strategic workshops and three light touch reviews.

Dr. Matthew Hannon (Energy Strategy Research Associate) then explained that the primary role of the workshop was to listen to participants' ideas relating to the area of energy in the home and workplace, in order to highlight priorities for future research and what resources will be required to undertake this research. He identified the areas of research covered by this workshop as well as those which were out of scope such as heavy industry and transport. Finally, the participants were encouraged to think about the following four dimensions when considering energy consumption in the home and workplace:

- **Setting** – The differences and similarities between energy consumption in the contrasting settings of both the home and workplace.
- **Spatial Scale** – How the different research challenges relate to a variety of spatial scales, spanning from micro (e.g. individual or household), to meso (e.g. community) and to macro (e.g. nation). International levels are out of scope for the purposes of developing the Research Council prospectus.
- **Timescales** – The different time scales across which these various research foci exist. For example, energy efficiency measures such as the nationwide roll-out of loft insulation or smart meters may take a few years, whilst overhauling a nation's building stock or radically changing the cultural beliefs that underpin existing energy consumption practices may take decades.
- **Communities** – The different communities of practice (e.g. social scientists, engineers, architects etc.) that are responsible for addressing these research challenges (e.g. building retrofits, energy efficiency appliances etc.).

After the two presentations from the Fellowship team, Liz Owen from EEDO provided a government perspective on the importance of energy consumption in the home and workplace. She described how energy efficiency was high up the political agenda with the emergence of policies such as the Green Deal and Electricity Market Reform (which incorporates aspects that support demand reduction). The Prime Minister had recently committed to promoting energy efficiency, wanting the UK to become the most energy efficient country in Europe. In part this drive was economically motivated, as reducing the UK's unnecessary costs on energy was increasingly being considered by government to be commensurate with economic growth.

3 Review of Strategic Workshops

3.1 Strategic Workshop 1: Energy Strategies and Energy Research Needs

Jim Skea briefly presented some conclusions from the first two "strategy" workshops convened by the Fellowship team. A key message from the first workshop on "Energy strategies and energy research needs" was that people's expectations about progress towards a low carbon economy lagged behind what they thought was desirable. Focusing on heat supply technologies, people had expected the deployment of district heating, solar thermal, heat pumps and fuel cells to fall well below desirable levels by 2050 while the use of conventional gas boilers would be correspondingly greater.

The participants of this workshop had concluded that research on energy use in residential and commercial buildings was very relevant to UK energy futures, that scientific capabilities were high and that the UK was modestly well placed in terms of industrial capability. However, scientific and industrial capabilities in relation to heat pumps and district heating were seen to be low. Under the International Energy Agency (IEA) classification scheme, social and economic research was lumped under the heading "energy systems analysis". This was also seen to be highly relevant for UK energy futures, with strengths in terms of both scientific and commercial capabilities.

3.2 Strategic Workshop 2: The Role of Environmental Science, Social Science and Economics

It was difficult to present high-level conclusions from the second strategy workshop on the role of environmental science, social science and economics, but some "nuggets" were presented:

- Promoting energy demand research - like Sisyphus pushing his stone up the hill
- A disproportionate effort has been put into kit as opposed to behaviour
- There is an over-reliance on economics in the design of energy policy
- Instrumental social science that helps answer policy questions is popular with funders but it rests on a foundation of fundamental, critical work.
- Language matters, but natural scientists often form the view that a social scientist's first question when approaching a subject is to question terminology and meaning
- Research Councils can and have forced better interdisciplinary working

3.3 Participants Reactions to Strategic Workshop Results

Participants then recorded their reaction to the outcomes of the strategy workshops under three headings: what surprised, delighted and disappointed them. These were discussed in table groups. The outputs are recorded in

.

Table 1 Participants' reactions to results from Strategic Workshops 1 and 2

Surprised	Delighted	Disappointed
General		
• Nothing surprised. We know the problems • Reliance on the strategy workshop and the method used • View that International Panel didn't understand the role of the Research Councils • Demand side research neglected historically	• "Communities of practice" used to frame the workshop • That the importance of energy efficiency was recognised • Reference to consumption as well as efficiency	• That there wasn't much surprise • That all the problems I thought we had with academic research in this area are true • Lack of acknowledgment of independent institutions • Not enough private R&D centres engaged
Ambition		
• That decarbonisation is not seen as essential • That conventional boilers might meet 60-70% of heating needs by 2050		• Lack of ambition or foresight in the chart to 2050 • Progress to date in this sector • No explanation of difference between "preferred" and "expected" outcomes
Interdisciplinarity		
• Why do academics find interdisciplinary work challenging?	• Recognition of need for interdisciplinarity	• It was a prosaic conclusion that interdisciplinary research takes time and effort • Interdisciplinary work stymied by structural issues, e.g. the REF • No ideas about how to take interdisciplinarity forwards • Perceived difficulty of interdisciplinarity. e.g. Collaboration between social scientists and engineers

		•
Role of the social sciences and the "technology-behaviour" balance		
• That behavioural issues are now taken so seriously • The recognition of the over-focus on technology/kit but a simultaneous perpetuation of the technology focus	• That the social science/ behaviour element has been recognized • We're moving beyond a pure engineering view • We're beginning to address the kit-behaviour balance • Recognition of multiple roles for social science – critical and instrumental • Recognition of the need for critical underpinning social science research • Recognition of need to consider behaviour/ technology interactions	• Annoyance at the implied criticism of social science. Critical questions may need to be asked from the start • Social science/behaviour separated • The kit-behaviour dichotomy – consider together
The role of economics		
• Recognition that economics is too dominant	• Recognition of over-dominance of economics	• The dominance of economics in policy-making • That economics was considered a "bad thing" in shaping policy • Dominant role of economics in modelling e.g. MARKAL type models
The role of specific technologies		
• Why worry about heating – we can retrofit for zero carbon • Lack of attention to heat pumps which we expect to play a major role • Low expectations about heat pumps/district heating		• Absence of any focus on cooling, which will probably be a big issue to arrive in the UK • Low perceived relevance of district heating • Low "expected" role of heat pumps in 2050 • Optimism about heat pumps
Capabilities		
• UK capability for technical solutions for energy efficiency was strong • That residential/ commercial competence is seen to be so high. We're good at residential, less so on commercial • That the UK is seen to be expert in energy systems analysis • That heat pump industrial capability is seen to at the same level as solar heating and way below fuel cells	• Recognition of UK lead in both energy efficiency and behavioural aspects	
Research landscape		
• That the "energy systems analysis" was just one bubble as it covers a huge range of	• Links between industry and the research base	• Bundling residential and commercial

different research • Putting residential-commercial together into one block • We're good at residential, not commercial • Bringing together tech side with behaviour side and a perceived threat whether these communities could work together		
Gaps		
• No mention of local energy governance or governance issues more generally	• Focus on affordability as well as climate change/security/economic opportunity	• Even though we're addressing the kit-behaviour balance, there is little focus on equity and people-technology interactions • Little on the usability of new technologies and their coherence with current practices • Lack of recognition that climate change will alter energy use patterns • Need more on decision-making in firms • Focus on efficiency rather than CO_2 reduction or systems issues • Organisation and control as well as kit-behaviour • Lack of attention to behaviour in industrial energy demand • Focus on individuals – what about networks, mediators? • Need more demand side focus, including engineers

A number of other discussion points fell outside the surprised/delighted/disappointed framework:

- The importance of a "reservoir" of social science that goes beyond instrumental social science. However, in what direction should this research go?
- Conceptions of demand need to move beyond individuals and organisational behaviour, to understanding it more as a system/process.
- The importance of representing models and their accuracy to decision-makers, as decisions are often based on imperfect understanding.
- Project-based construction firms and their energy-use patterns differ from firms in other sectors
- Understanding people's behaviour at home and at work, does their energy use behaviour change in the different environments, and do we need to understand that?

4 Helicopter View of the Research Terrain "As Is"

4.1 Process

The meeting divided into four randomly assigned groups. People were invited to imagine they were preparing a briefing for David Mackay (DECC Chief Scientific Adviser) on the research terrain as it is now. People first made notes individually of the questions they were currently grappling with and subsequently presented them to colleagues round the table. The groups then discussed and distilled the

key themes, transposing important themes to post-it ovals. The post-it ovals were colour-coded to reflect whether they referred to the "home", the "workplace" or "both". Each group then presented back to the plenary, sticking each post-it on a large chart, with a scale ranging from "micro" level, through "meso" on to "macro". There had been considerable push-back against the original proposal for a scale that ran through individual/household/community/city/region/nation and so the micro-meso-macro scale was adopted instead.

Table 2 reproduces the results on the chart, while Table 3 records the specific questions identified by individuals, grouped by broad theme and table group. The top-level conclusions are as follows:

- Most key issues appear to cut across the home and workplace, indicating that many issues pervaded energy consumption within both these contexts. However, in many instances the participants saw value in this distinction as some research challenges were more relevant to one of these areas than the other
- The relatively sparse number of responses relating specifically to the workplace reflects the lack of attention in the research domain which emerges from the following section of the report
- Macro-level issues appear to be entirely cross-cutting
- There is ambiguity as to what is the appropriate point on the scale for certain topics. For example, if the concern is the impact of policies on individual behaviour is that "micro" because it refers to individuals or "macro" because it refers to national policy?

A number of important crosscutting points emerged from within table discussions:

- One group noted that it important not to focus just on individuals and lose sight of "structure" itself: organisational behaviour, the physical structure of buildings etc.
- A second group noted that the household is part of a much broader socio-technical network including (e.g. with suppliers, local authorities)
- Another group noted that the concept of scale is conceptually difficult. There are ways of cutting it, e.g. policies, scales of practice, economies of scale in engineering. You can't separate different users (e.g. business, people) in a district level system

Table 2 Helicopter view of UK's current research terrain

	Home	Workplace	Both
MICRO	Vulnerable population: energy equity, behaviour, health and well-being		User technology interactions
			What is energy for? Social practices, services
			Why is there a performance gap (modelling versus actual energy use)
	Zero-carbon retrofit – whole home system		
	Motivating/influencing household energy behaviour	How do we provide better data about the non-domestic sector	
	Effect of smarter controls on domestic energy consumption	What is the role of working relative to workplaces	Quality assurance for physical structures: manufacturing processes; communication of r???; expected v actual performance
			Where do needs come from
			Engagement with consumers (domestic and commercial) to understand what makes them move to action
	Consumer research: how and why people use energy		
			Implementation: tools and policy mechanisms in practice
			What are the factors that shape impacts of living and working, particularly skills and expertise
			New business models for energy services in homes/commerce/mobility
MESO	Links between the need to reduce energy use and adapt to the future climate	Understanding business drivers and barriers for energy efficiency	Non-market, non-state actors: community; university campuses
		PAYS for commercial energy	Community and local governance
			How do you combine the economic and no-economic benefits into scheme/BIZ model evaluations?
			What can community-led energy achieve?
			Retrofitting cities and urban transition
		Reduction of energy use and CO2 emissions from industry: enabling technologies; complexity; drivers; and barriers	
	How new energy transitions affect social justice		
			To what extent can demand flexibility support system integration
			From here to 2050: low carbon pathways, their governance, actor behaviour and performance
MACRO			Foresight and alternative energy futures
			Whole system thinking: individual to national level
			Transforming social practices is not easy to map on to this scale – interconnections matter
			How the new technique of "gamification" can enable education and behaviour change
			Energy-food-water nexus: system; in the home /workplace
			Broadening the idea of heat in the energy system and build in to transitions
			Transition (big change): what are the system barriers and enablers? District heating; service companies
			Connection between supply/operations and demand
			Modelling integrating behaviour; incorporating qualitative complex critical science
			Understanding cost, benefits and trade-offs of energy efficiency: measures and non-measured
			How design, architecture and engineering influence behavioural outcomes

Table 3: Specific Questions Identified in the Table Groups

	Group1	Group 2	Group 3	Group 4
Energy behaviour	• If energy efficiency is so good, why isn't it happening? → Costs and benefits, who benefits, who pays, what is market based, what not? • Mainstream modes of operations rather than just behaviours • Social practices and the role energy plays in this: 'what is energy for?' How do these things become normal, change over time? • Concerted effort into integrating social science into bioenergy	• New ways and techniques to educate and get people engaged in demand reduction • Focus on the more positive, aspirational approach on changing consumption behaviours – game techniques for non-game situations 'gamification' • How do you influence households towards more sustainable consumption practices • Can you use personal transition moments to help do this e.g. retirement • Influencing consumption habits e.g. heating demand • Influencing behavioural outcomes through design and architectural engineering • Modelling rebound effects in the home Demand as an outcome of what people do – shifting paradigm of thinking about energy demand • What makes people act • Points of engagement with consumers • Understanding investment decision making	• How do people use energy underlying needs	• Gaining trust and building evidence of efficiency to inform decisions. • The focus should be on activities rather than places • How much can we expect the populous to engage with energy?
Energy Equity		• Reaching fuel poor and vulnerable people		• How can the system improve social justice?
User-technology interface	• Understand the interaction between people and technology in driving energy efficiency • User-technology	• Understanding urban retrofit as a socio-technical process across different scales and domains • Everything's connected to everything else	• Economic payback – non-belief in technology that works	• Smart homes: use patterns and understand how they might respond to different new technologies. What can policy do to avoid adverse outcomes?

	Group1	Group 2	Group 3	Group 4
	interactions: how do technologies get taken up or not? "What's their biography?" • Understand the behaviour change in a way that we can compare it to the role of technology • How to better understand people's thermal comfort in their homes? • Easy refurbishment that is consumer appealing: "Out with the boiler -- in with the heat pump" • Related to that: how do people relate with and live with the heating systems in their home?	• Pervasive smart interactive technologies and how people will interact with them • Smart controls through web services – pervasive sensing and overlap into other services	• Close building relationships techies/social scientists	
Energy technology and infrastructure	• How are new energy systems introduced and rolled out? E.g. a lot of interest in district heating, but how does it come into practice?	• Understanding shifts to more efficient heating systems • Focus on district heating – Role that heat plays in influencing patterns of energy demand. The role of heat in sustainability transitions. • Technology in buildings, interactions with people why does kit not work to suppliers specifications/claims • Full range of infrastructure recreates expectations • Cooling	• Teaching designers whole system, how to go to zero carbon • Improve performance to meet people's needs • System integration – heat pumps, insulation etc. Design infrastructure	• Energy management - home energy management is not something we are dealing with • What technology should be push by energy suppliers? How do you put a merit order on technologies? How do you take social aspects into account when you develop a business model?
Energy demand data and modelling	• Demand profiles • How do we narrow the gap between the	• Current consumption patterns buildings and future trends – especially non-domestic	• Prediction models not accurate	• Understand the performance gaps on efficiency • The gap between what wall insulation

	Group1	Group 2	Group 3	Group 4
	predicted performance of buildings and their actual performance (both behavioural and quality of refurbishment)? • Relation between energy use and utility use • Models: can in-depth qualitative and in-depth social science research speak to models, and is there any way we can have this conversation?	• Changing patterns of time how that works through	especially at urban scale	should deliver and what it does in practice. Why is there a performance gap? • Do performance gaps derive from skill gaps or other flaws? This is important for the uptake of the Green Deal
Commercial energy demand	• Can campuses search as exemplars for energy efficiency? "Living laboratories" • Better research to understand energy use in different sectors and buildings	• Large amount of corporate work on energy efficiency and behaviour change. How do we track his and integrate it into academic and policy research? E.g. Focus on NHS, because there is a lot of opportunity for them to drive such change.		• Underemphasis on the non-domestic sector and non-domestic places.
Energy policy	• Role of government in the transition and where it may create barriers	• Elephant in room = what happens if the narrow policy remit fails, lack of strategic thinking around what might happens. What is plan B, C, D etc. • 'Narrow set of policy instruments'. Variety of policy areas reproduce status quo • Moving consumers from grants to Green Deal/investment • SAP, EPC, Green Deal • How do we get from here to 2050 , pathways energy performance of pathways • Policy to close technology loop		
Local and community	• How can community based partnerships be	• Linked are the multiple richer visions of the types of future cities, from		• Local energy action: Key questions: What is right role for local government? What

	Group1	Group 2	Group 3	Group 4
energy governance	used to reduce energy consumption? Go beyond individual households but not to national scale • Non-state actors and their role in the transition (communities)	different perspectives (e.g. communities). Think between narrow carbon targets and towards what that actually means in terms of people's lives and surroundings • City-scale retrofit demonstrators How local authorities and housing associations develop heat systems and the challenges they face • How you resolve local objectives with national and international • More work on community governance of energy transitions and demand. Do community level projects deliver better results for sustainable energy use changes? • Community issues around energy efficiency • Altering street scene planning • Whole systems thinking – dense v distributed settlements etc.		measures are enabling? What about fuel poverty? How can the system improve social justice and wellbeing? What does smart energy actually mean?
Energy business models	• What kind of retail structure should be developed for the future energy system? • What services energy provides and how does it deliver them?	• The different types of energy business models that pertain to different sectors. • Aggregating synergies through joint provision of services.	• Adapt markets to internalise costs of carbon/peak energy • What are the business models predicts that can be sold	• What are the enabling conditions for scaling up? For each sector, what are the business models, what are the investment community's requirements. • The impact of business models on people's responses. Present models are entrenched. • What are business models and how do you research them? What about the role of communities? What about the impacts that we can't place monetary values on?
Energy supply chain and skills		• Sector skills • How we reduce associated with industry – complexity, barriers, enablers • Role of supply chain		• What sort of skills do you need to manage your home?

	Group1	Group 2	Group 3	Group 4
Cross-sectoral	• Critical social science questions in energy-food-water arena	• Link between the need to reduce energy demand and the need to adapt to future climate change		• Joined up thinking. There are two sided questions: mitigation/adaptation; demand/supply; sustainability/energy efficiency.

5 Research Capabilities: Where Are We Now?

Working individually, people were asked to identify where they thought we are now in terms of research capabilities for tackling current research challenges relating to energy in the home and workplace. They were invited to score these on a scale of 0-10 (0 = no chance, 10 = well setup) and explain their score on a post-it note. The following graph shows the distribution of the 33 post-its. The average score was 4.9 +/- 2.1. However, there was a sharp divide between the UK's competency to address 'home' and 'workplace' research challenges. The scores for post-its referring specifically to the home averaged 5.7 +/- 1.2. For the workplace, the scores averaged only 2.6 +/- 2.6. Another striking outcome is the polarisation of views about the UK's interdisciplinary research capabilities, with individual scores ranging from 3 to 7. Figure 1 summarises the results, while Table 4 divides the results into three classes: low capability (0-3); medium capability (4-6); and high capability (7-10), set out into detailed results.

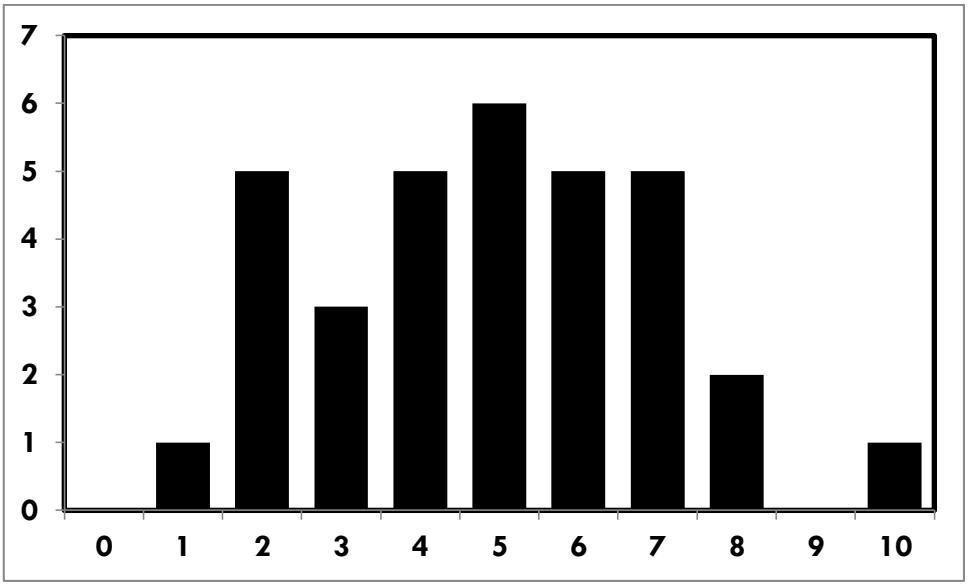

Figure 1 Distribution of perceived UK capability levels to address existing energy research challenges

Table 4 UK's perceived capability levels to address future energy research challenges

High capability levels			
7	**8**	**9**	**10**
Strong multidisciplinary research base	Ambition/zeal	N/A	Amazingly capable! Organisation, finance, interdisciplinary collaboration etc. as barriers?
We can develop solutions, but not good at research/end-user collaboration, work across disciplines can improve	Skills nationally		
Lots of data, history, effort, programmes			
Strong network of academic centres; Potential to integrate data and experience from corporate energy strategies, local government, NHS etc. Interest in demand side from Government, but… Need more effort to fund social science and promote interdisciplinary work			
Home: visible topic, lots of research calls and support			

Medium capability levels		
4	**5**	**6**
Home: performance gaps, need of more multidisciplinarity	If we asked decent questions – not just about "energy", "home", "work" we might find we're surprisingly capable but just need to be re-organised round decent questions	Home: Lots of historic data and attention, all homes similar
Very little existing research on how and why people use energy	Research is increasingly sophisticated; questions asked of it are not	Home: lots of research and evidence but maybe not joined up effectively.
Very little understanding of energy-related buying decisions in home/industry/commerce	Areas of expertise exist, what is lacking is interaction and transverse work between different areas	Long-standing research capabilities on energy, households, systems, modelling and technology
Reflects the fact that we are well placed on homes but less so on workplaces	Home: good understanding of social/behavioural aspects but still lacking overall perspective due to different disciplines/actors/policy organisations involved. Might go either way but a good starting point	We're improving but need more work on interdisciplinarity and training
Some good technical lab facilities; we are weak on socio-technical interface	Work: limited research activity in UK universities	Facilities
	Resources	

Low capability levels			
0	**1**	**2**	**3**
N/A	Work: Little data, understanding, effort, inadequate characterisation	Need more work on management and operation of commercial buildings	We're not dealing with the interconnections
		Need more research with/on supply chains	Need more capacity for close interdisciplinary working
		Work (office): much less developed in terms of evidence and data	Work: Almost no research activity
		Work: lack of research on energy efficiency uptake	
		Work: much more diverse; little data collected; but now increasing interest	

6 Research 'Hotspots' and Broader Themes for Future Energy Research

6.1 Introduction to the Exercise

This exercise was designed to identify a range of subjects that the workshop participants believed should be subject to additional UK-led research in the future, and which should therefore constitute an important part of the RCUK Energy Strategy Fellowship's *Research Prospectus*.

6.2 Methodology

6.2.1 6.2.1 Overview

In order to identify future energy research opportunities for the UK, the participants were first invited to identify 'research hotspots' that could provide valuable insights, should (further) research be conducted into them. A 'research hotspot' was defined as follows:

> 'A ***Research Hotspot*** is a potentially valuable area of future research, which has been identified by the Expert Workshop participants. It is an area in which the experts believe research challenges will emerge in the future. It may be a broad and overarching question or problem'

To help guide the participants, a couple of good-practice examples of hot spots were presented from the previous Fossil Fuel and CCS workshop,.

6.2.2 How were research hotspots generated?

The first part of the process involved the participants working individually to generate some ideas about potential hotspots. The second part required the participants to form pairs to discuss and record these hotspots with a partner. These were recorded on to coloured hexagonal post-it-notes, where green referred to Home, yellow to Workplace and blue to Home and Workplace. Colour-coding was employed to ensure that the participants continued to give consideration to the differences and similarities between research topics relating to energy use in both the home and the workplace.

Once the pairs had discussed and recorded the hotspots they were then asked to place these on a wall chart, using the micro, meso and macro scale axis as a guide. The participants then browsed the wall chart in order to examine the hotspots so that they developed a feel for what other research hotspots the other participants had identified. The participants were asked to reflect on what had already been generated and consider whether there might be other research hotspots to add to the wall chart. This process was facilitated using some random image cards as external stimuli in order to generate additional ideas. During this process the participants were also encouraged to make comments on existing hotspots if something had occurred to them during the image card exercise. There was a noticeable increase in new hotspots and comments added by the close of this activity.

6.2.3 Clustering Hot Spots at Different Scales

The clustering exercise required the participants to group similar hot spots together in order to create research clusters or themes. In order to achieve this, participants were divided into three groups charged with clustering the research hotspots assigned across the three different scales (i.e. micro, meso and macro). Each group was allocated a facilitator to help ensure that the groups had clustered all their hotspots within the hour they had available

The clustering process involved the participants examining each of the hotspots and considering how these related to other hotspots that had been assigned to the group's assigned scale (e.g. micro, meso or macro). Once they had grouped the hotspots together, they then had to assign a name to the cluster that clearly and concisely described the cluster in a way that would be meaningful to non-experts.

Figure 2 Research 'hot spot' clustering exercise

6.2.4 Grouping Clusters Together

Once the clusters were formed, the three different groups then assembled in the same room to discuss how these research clusters might be further aggregated into 'super-clusters', i.e. even broader research clusters. The process involved each group sharing one of their clusters with the other groups, at which point the other groups were encouraged to identify any clusters of theirs that might be related. Once a potential partner(s) had been identified for a cluster, the partnering was 'put to the room' for consensus. To help facilitate this process, each participant was provided with a set of three cards: red, yellow and green, which reflected the level of the individual's agreement with the proposed partnership. Green was a sign that the participant was happy with the clustering and yellow indicated some dissent but a willingness to move on. If all cards were a mixture of green and yellow, then the groups could continue with the 'super-clustering' process. However, any participants were unhappy with a cluster they were invited to show a red card and identify their reasons, after which a group discussion took place. Often this resulted in a resolution, however in other cases the clustering was rejected and the groups had to identify an alternative cluster arrangement.

6.3 Results

6.3.1 Overview

In their three groups, the participants grouped the large number of research hotspots into 25 different clusters. Subsequently, these clusters were aggregated into 16 'super-clusters', which broadly represented the areas that the participants believed should constitute the focus of additional research in the future. These 16 super-clusters are outlined in the tables below, along with the associated clusters and hot spots, as these illustrate the various research foci that make-up these broader research areas.

Some hotspots were not assigned to a cluster and are outlined in a separate table. Furthermore, a handful of hotspots were omitted from the tables below because they were either illegible or did not make sense as written. Some of the hotspots and clusters were re-worded so that they could be more easily understood. Where multiple hotspots are assigned to a cluster, these have been grouped under sub-headings for clarity.

6.3.2 Cluster 1 - Technology-Behaviour Interface

Cluster Name(s)	Scale	Hotspots
1a – *The reciprocal relationship between behaviour and technology*	**Meso**	**Home** - Could reconnection to nature mean disconnection from intensive energy use? E.g. reconnection to local food production - Quantification of 'perception gap' – Difference between people's stated energy consumption vs. actual recorded consumption (e.g. calorie and alcohol unit intake)
		Work - The impact of work/time constraints on energy demand
		Home and Workplace *Factors Influencing Energy Consumption Practices* - Detailed understanding of factors influencing on energy use (e.g. cost, comfort etc.) - Factors responsible for motivating and sustaining changes in consumption practices (e.g. catalysts, barriers, support systems etc.) *How Technology Influences Energy Consumption Practices* - Research into the role/implications of automation (e.g. smart houses, intelligent computing) for the evolution of social practices - How does technology, systems and the built environment (etc.) shape and influence people's behaviour to determine energy consumption? *Energy Efficiency Policy* - Examination of both the positive and negative, as well as the intended and unintended effects of such policies over different time and geographical scales and across different domains - How to encourage adoption of new technologies or behaviours concomitant with high energy efficiency levels *Other* - Metrics to measure the effectiveness of energy efficiency interventions
1b – *How to trigger changes in behaviour and infrastructure from the status quo*	**Macro**	**Home** - Examine opportunities to use council tax and EPCs to drive household behaviour change - Examine how energy and climate change initiatives could be led by single- and inter-faith communities e.g. Interfaith Power and Light in the US.
		Home and Workplace *Socio-technical system change* - Examination of 'sideswipe scenarios', path dependencies and lock-in (i.e. why do things remain the same?) - Focus on lock-in to technologies, practices, cultures and norms. Questions around how we might break existing lock-in and avoid new lock-in? *Understanding Energy Consumption Behaviours* - What does it mean to waste energy? - How do peoples' energy consumption behaviours develop over time? - Identify the extremes of energy autonomy that people can and are willing to achieve *Managing Energy Consumption Behaviours* - How could people's lives be more closely aligned to diurnal and seasonal cycles?

Cluster Name(s)	Scale	Hotspots
		- A user-friendly approach to personal carbon 'footprinting', involving ICT, data privacy, personal tracking etc. *Other* - The design of flexible and adaptable energy systems - Where does nature/ecology fit into this research agenda?
1c – *Changes to consumption behaviour generated by technology*	**Micro**	**Home** *Impact of Smart energy technologies* - How do households control their heating systems and how might ICT/mobile platforms affect this? - How might building-design 'script' energy efficiency behaviour? - Public acceptability of energy efficient, smart technologies. Issues surrounding affordability, equity and privacy - How will smart energy technologies impact on practices in the home? Will they increase or decrease energy use? - How will households react to smart energy technologies in the context of a greater incidence of socially embedded smart electronic devices in the home? *Other* - Disaggregated (i.e. individual to the particular household), 'time of use' tariffs: ○ How would these impact upon energy consumption behaviour? Also, what impact would it have in terms of equity, food, poverty, health etc.?
		Home and Workplace - Development of pervasive energy monitoring tools, which can be linked to improved modelling and behavioural feedback - Building/occupant diagnostics – 'rapid' identification of problem buildings and behaviours, leading to remediation and refurbishment guidance

6.3.3 Cluster 2 - Energy Budgets and Allowances

Cluster Name(s)	Scale	Hotspots
2 *- Energy budgets and allowances*	Micro	**Home and Workplace** - Do we need household and personal energy allowances? If so how should we design them, e.g. could they be traded? - Do we need household and personal carbon budgets? If so how should we design them?

6.3.4 Cluster 3 - Impact of Demographic and Social Trends on Energy Demand

Cluster Name(s)	Scale	Hotspots
3 *- The impact of changing demographic and social trends on energy demand*	Macro	**Home and Workplace** - What impact will wider social trends have on energy consumption? How might we influence these? (e.g. changes in modes of transport and/or UK economy) - What impact will demographic trends have on energy consumption and energy efficiency levels? (e.g. an ageing population, smaller households)

6.3.5 Cluster 4 - Factors Responsible for Shaping Policy Decisions

Cluster Name(s)	Scale	Hotspots
***4 -** Factors responsible for shaping of policy decisions*	Macro	**Home** - Effects of energy efficiency measures on individual's equity, health and wellbeing? How should these be incorporated into energy system and policy design?
		Home and Workplace - Where are the best/most effective opportunities for regulation both now and in the future? - Opportunities and methods for evidence based policy appraisal and evaluation (e.g. multi-criteria (economic, environmental and social) evaluation of energy efficiency projects) - Need for research to broaden range of policy design tools, including both innovative and previously 'abandoned' approaches (e.g. regulation, taxes etc.)

6.3.6 Cluster 5 - Reconfiguration and Redesign of Technology and Infrastructure

Cluster Name(s)	Scale	Hotspots
5a – *Climate change adaptation*	Micro	**Home and Workplace** - Impact of climate change on energy requirements (e.g. more cooling/less heating) - Adaptation in the context of future climate uncertainty
5b – *Cradle 2 cradle – Energy efficiency optimisation for the future*	Meso	**Home and Workplace** *Building Design and Construction* - How to eliminate the need for energy intensive cooling in present day and future climate via appropriate building design - Examine how construction industry make choices about building materials - How design interventions that reduce energy demand without affecting capacity to operate in climate extremes *Life-cycle analysis/Cradle-to-cradle* - Looking at 'grey embodied energy'- LCA applied to a building - Research into end-of-life issues associated with products and infrastructure, including decommissioning and recycling - End of life questions *Other* - Understanding trends and drivers for cooling
5c – *How to design buildings to promote occupant comfort, health and well-being*	Marco	**Home and Workplace** - How could we reduce the total volume of heated/cooled/conditioned space? - How will we satisfy our comfort needs in the future? (e.g. cooling and heating) - Identifying interventions to address fuel poverty, both technical and social - Synergies between art and energy engineering; energy saving that looks exciting and attractive, with prizes and awards for the best
5d – *Reconfiguring current technologies and processes (i.e.*	Meso	**Home** - Examination of different whole-house/system retrofit packages - Opportunities to retrofit for heritage buildings ○ Aesthetics and acceptability of retrofit of built environment (e.g. conservation areas, impact on place identity)

retrofitting)		**Home and Workplace** - Development of optimisation tools that select the best technologies for retrofitting - Development of new insulation materials (e.g. cheap thin insulants for retrofit such as 'aero-gel') - Research in the types of financial and institutional innovations required to underpin large scale urban retrofit of buildings and infrastructures

6.3.7 Cluster 6 - Governance: Community, Sectoral and Constitutional

Cluster Name(s)	Scale	Hotspots
6a – *Governance: Community, sectoral and constitutional governance*	Meso	**Home** - Community governance of energy infrastructure and demand management i.e. design, operation and reduction, not just a 'token turbine'
		Home and Workplace *Sectoral and organisational governance* - Variations in sector and sub-sector engagement with low carbon policy mechanisms - Overview of different organisations' approaches and opportunities for mutual learning - Lack of sectoral data on energy consumption (industry, services etc.) - The role of the public sector as a 'transition manager' *Large scale energy interventions* - Research into area-based geographic, holistic: energy systems, behavioural efficiency measures, renewable generation/sources etc. Can these make any significant reductions in CO_2 and impacts on equity? ○ Does large-scale geographic improvement actually make any difference? - How do you achieve massive reductions by utilising large-scale geographic improvements? *Other* - Impacts of governance and constitutional change (e.g. Scottish independence, Localism, City deals etc.) on capacity and flexibility for local energy strategies - Multi-level governance: Integrating action at different scales, i.e. community, social enterprise, local authority, business, national etc. - To investigate the lock-in effects of current and future energy policy
6b – *Community energy approach*	Meso	**Home** *Community Energy Systems* - Examine opportunities to develop community biomass systems, for instance do we any spare biomass capacity? - Learning from Sweden – integrated renewables/waste heat/ CHP and citizen education (e.g. Gothenburg/Vaxjo/Hammarby etc.) - A more holistic (systems) approach to domestic and district heat management: scheduling, scavenging, storage and control
		Home and Workplace - Cross-pollination of techniques and methodologies between communities and other sectors (e.g. motor industry, aerospace, pharmaceuticals) - Comparative study of local socio-technical energy demand networks

6.3.8 Cluster 7 - Changes and Differences in Energy Practices and End-Uses

Cluster Name(s)	Scale	Hotspots
7 - *Changes and differences in*	Micro	**Home** - Understanding of how different socio-economic groups use energy at home compared to

practices/end uses		one another

		Home and Workplace
		
		Relationship between demography and energy practices
		- Understand the impact of life stages in an ageing population: different ways of living at different life stages
		- Policies are targeted towards average and forget about demographic outliers
		- Need to go beyond the averages:
		  ○ Ranges
		  ○ Social variation
		
		Relationship between energy and satisfaction of needs/desires
		- Link between cultural notions of fun, convenience etc. and energy consumption
		- Catering for people's individual needs (e.g. comfort, food, entertainment etc.) – how do these relate to energy demand, supply and systems for delivery?
		- Comfort and clothing – Research into better clothing, clothing habits and energy use
		
		Relationship between energy practices and energy efficient buildings
		- New challenges arise in very energy-efficient buildings (ventilation, weight of hot water and electric appliances increases)
		- Research into comfort/health:
		  ○ User variability (e.g. elderly, disabled, infants etc.)
		  ○ Air tightness, comfort and health
		
		Other
		- Quantification of energy consumption relating to different energy end-uses
		- Impact of seasonal and diurnal variation on energy practices

6.3.9 Cluster 8 - Energy Related Decision Making

Cluster Name(s)	Scale	Hotspots
8a – *Energy decision making and implications at different levels*	Micro	**Home** - How do households make energy related decisions? - Deeper understanding and empirically informed modelling of household rebound effects ○ Do these matter and if so what can be done about them?
		Workplace - How and why do organisations (both SMEs and large companies) make decisions about energy use? - Deeper understanding of other modelling of workplace rebound effects. Do they matter and if so how do we compensate for them? - Research into rebound effects associated with industrial energy demand reduction measures
		Home and Workplace - Do rebound effects differ in different places (e.g. home vs. workplace)? If so they require different responses to address them?
8b – *How to understand decision making about energy efficiency decisions*	Macro	**Workplace** *Lessons Sharing* - Research into other international experiences on promoting industrial energy efficiency e.g. benchmarking, international firms and sectors - How do we build capacity in integrative design techniques for buildings and industry amongst clients and service providers?

		Factors Influencing Decision Making - Understanding the enabling conditions for energy efficiency investment decisions within each sector and sub-sectors (e.g. organisational, constitutional, regulatory etc.) - More data gathering and benchmarking required to provide the evidence base to enable organisations to make informed strategic energy decisions
		Home and Workplace - Understanding of finance/business models/solutions for energy and energy efficiency investment across industry, businesses and householders

6.3.10 Cluster 9 - Engagement with Energy Users

Cluster Name(s)	Scale	Hotspots
9a – *Novel mechanisms for engagement*	Meso	**Home** - Mobile technologies and smart cities as catalysts for demand management innovations - 'Smart communities' that respond to and engage with energy use behaviour
		Home and Workplace - Developing facilitator capacity to 'midwife' sustainable transition - Engage big energy users, with multiple connections to households and communities and businesses (e.g. NHS), to advocate and be exemplars for energy efficient behaviour - Congressional social catalyst/transmission organisations as targets for innovative projects on energy, (e.g. Churches, Football clubs, Womens' Institute, Schools) - An 'energy marketplace' for consumers – a role for supermarkets and others? Make energy fun not boring…
9b – *Understanding how to communicate/engage with the public about energy use*	Macro	**Work** - Why do people view energy provision differently to other goods and services? (e.g. unwillingness to change energy suppliers (right vs. privilege))
		Home and Workplace - How to educate people about energy from birth - Improving energy literacy of the public – get their support and buy-in from government and/or utilities to promote energy efficiency - How to engage the public in a positive way without doom and gloom - Testing out new, untried methods of engagement and education techniques - How to build sustainability into value systems - How to build faith and trust into politics of energy

6.3.11 Cluster 10 - Discrepancies between Expected and Actual Outcomes

Cluster Name(s)	Scale	Hotspots

10a – *Theory vs. performance gaps: 'Mind the gap'*	Micro	**Home**
		- Research into the gap between expected energy and actual energy use (e.g. use at the building design stage and actual occupant energy use)
		  ○ What are the causes and related solutions?
		  ○ How do we know which behavioural insights to apply in order to help us understand what works in practice?
		  ○ How narrow can this gap realistically be made?

10b – *Gaps between models outputs and reality*	Macro	**Workplace** - Causes and solutions for the gap between predicted and actual performance - Understanding the relationship between design interventions and behavioural outcomes ○ What role might processes such as building change (e.g. retrofit etc.) and building management (e.g. energy performance contracting) have on occupants' energy practices?

		Home and Workplace - Exploring gaps between models and reality

6.3.12 Cluster 11 - Development and Availability of Skills and Capabilities

Cluster Name(s)	Scale	Hotspots
11 - *Development and Availability of Skills and Capabilities*	Meso	**Workplace** - Research into the role of building professions and expertise in constructing (un)sustainable environments

		Home and Workplace
		- Ability to deploy skills at scale and across workforce
		- 'Upskilling' of workforce, in terms of both technical and social skills
		- Opportunities and processes for developing networks of trust
		- Relationship between availability of energy related skills, education and regulation
		- Research into the effectiveness of licensing and regulation of:
		  ○ Suppliers/consultants
		  ○ Models/tools
		  ○ Materials/components
		  ○ Whole buildings

6.3.13 Cluster 12 - Investigating Alternative Futures

Cluster Name(s)	Scale	Hotspots
12 - *Investigating Alternative Futures*	Macro	**Home** - Research into means of changing trajectory of system change (e.g. major demolition of out-of-date housing stock and replacement with super-efficient apartments)
		Home and Workplace *Development of Specific Scenarios* - Developing scenarios and pilot studies of the all-electric city (i.e. no gas – all renewables) - Energy systems design and policy for a world that doesn't meet CO_2 targets for 2050 - Examine the relationship between peak demand, smart grid pricing, base load and generation intermittency - Urban modelling: optimising buildings, transport and industrial energy/CO_2 *Other* - 'Practice pathways' – can we develop visions about future practices based on an understanding of current and historical diversity and on-going trends (e.g. link to 'expectations histogram' developed for technologies in workshop 1, could we do something similar for practices? If so, how?) - Research into alternative energy futures robust against uncertainties - Demand management and decentralisation – does one enable the other? Is it more sustainable/resilient? - What impact does lowering demand have on infrastructure requirements?

6.3.14 Cluster 13 - Role of innovative, high-level technologies

Cluster Name(s)	Scale	Hotspots
***13** - The role of innovative, high level technologies*	Macro	**Workplace** - What could the impact of advanced manufacturing techniques and materials be on industrial energy use? - Research on energy use by 'sunrise' industries (i.e. a new or relatively new industry that is growing fast and expected to be important in the future) and how innovative, potentially high tech developments will shape this - Research into the 'whole systems' implications of enabling technologies for industrial energy demand and CO_2 reduction
		Home and Workplace - Horizon scanning required for potential causes of disruptive change and innovation, (e.g. ICT, new materials, resource constraints) - Need for additional conceptualisation of disruption and rule-breaking (e.g. when things go wrong regarding energy)

6.3.15 Cluster 14 - Investment and finance for energy efficiency

Cluster Name(s)	Scale	Hotspots
***14** - Investment and finance for energy efficiency measures*	Meso	**Home** - Business models and incentives for micro-generation, specifically sale of surplus energy onto grid
		Home and Workplace *Green Deal/'Pay as you Save' Contracts* - Does the Green Deal work for residential and commercial customers? If not what would work? - De-risking 'pay as you save' contracts for financial services sector, (e.g. qualifications for work, materials standards and 'through-life' energy performance assurances) *Research to Support Energy Efficiency Investment* - Research to underpin financial and institutional innovations to underpin large scale urban retrofit of buildings and infrastructure - How to decrease risks or perception of risk surrounding energy efficiency? *Other* - The potential for creative refuse and repurposing of technologies. Do we always need to focus on new technologies? - How to create market/business opportunities for energy service provision

6.3.16 Cluster 15 - Equity: Ensuring fair access to comfort and well-being

Cluster Name(s)	Scale	Hotspots

***15** - Equity: Ensuring fair access to comfort and well-being*	Meso	**Home**
		- Equity and 'energy justice' questions relating to both energy demand and supply side policy
		  ○ How might we fairly apportion both pros and cons to different societal groups?
		  ○ Examination of widening inequalities in context of stagnant or falling real incomes
		- In the context of rising living costs for younger generations (e.g. inability to buy houses), what will be the impact on energy demand in the future?

		- Questions relating to equity around energy use/carbon budgets - Research to promote generational equity of energy
		Home and Workplace - How might we empower individuals and communities to 'have a voice' to shape access to energy and promote energy equity?

6.3.17 Cluster 16 - Bringing Together Data into a Coherent Evidence Base

Cluster Name(s)	Scale	Hotspots
***16** - Bringing together data into a coherent evidence base*	Macro	**Workplace** - Develop better models of changes to peoples' energy needs, (e.g. integration with climate change models) - How to collect accurate, disaggregated end-use energy data?
		Home and Workplace - Development of methods new to build evidence base, (e.g. randomised control trial using existing or new building stock) - Initiating common knowledge sharing across various public/private research projects - Research into translating common knowledge into common practices via intermediary actors (e.g. plumbers, engineers, Local Authorities etc.)

Hotspots not assigned to Clusters

Home

- Exploratory research on incentives to switch off office lights in cities, e.g. Brian Cox's 'Light out for Darker Skies' initiative

Home and Workplace

- How can energy waste be reduced via methods and technologies such as waste heat recovery, enhanced energy controls etc.
- To what extent does the supply and demand dichotomy eclipsing system integration and intermediate scales? How might we integrate the two?
- Governance of interconnections between infrastructure systems
- How to design 'in-job' satisfaction into new energy systems
- Consider missing link between top down and bottom-up change: i.e. middle out
- Realising the world is not simple – don't be afraid of complexity
- How might we deliver reductions in baseload consumption, for example from street lighting, security systems, escalators etc.?
- Can we and should we integrate the dynamics of social complexity into mathematical models of energy demand?
- 'Slow energy' – alternative lifestyles to achieve a good quality of life in different ways
- Explore benign/attractive/socially acceptable approaches to social engineering
- To what extent do user understand how energy infrastructure fits together and how does this affect their control of it?

7 Reflections on Day 1

At the beginning of Day 2 of the workshop the participants reflected in small groups about the work of the previous day, after which they were then asked to share any significant insights. The following key points were raised:

- **Reconciling Different Spatial Scales –** Are there opportunities to reconcile micro-meso-macro spatial dimensions? If so how?
- **Importance of Time-Scale** – I t is important to be aware that developments in different aspects of the energy system operate at different timescales. What are the implications of this dynamic?
- **Managing People's Expectations** - If we sat in this room in the 1950s we would have had vastly different expectations of our lifestyle than we have today. So, how do we manage the public's expectations in light of the constraints we have?

- **Embodied Energy –** There was surprise about the relatively little discussion about embodied energy. The balance between energy in use and embodied energy may start to shift in interesting ways.
- **A Demand Typology** - Appreciated moving towards a more differentiated understanding of how demand may differ across different individuals or communities
- **Need to Capture the Smaller Points of Interest** – The exercises in Day 1 brought out some smaller but very interesting ideas. Concern was expressed that these 'little gems' were not overlooked and captured forward.
- **Recognise Gaps in Technical Research** – It is important not to overlook the importance of technical gaps in relation to *Energy in the Home and Workplace* that still need to be addressed. There is a need to move towards more integrative approaches, where consideration is not only given to the types of behaviours required to promote sustainable energy consumption but also the types of technologies that will enable or underpin that desired behaviour
- **Structure of Research Framework** – Concern was raised that most of the ideas on the wall related to specific, potential research projects and that what was really needed were ideas about how to design a research framework that enabled such ideas about potential research projects to emerge over the coming years.
- **Research Methodologies and Practices –** Highlighted that there wasn't much discussion about research methodologies and how those may change over time. For example, what impact will technological innovation have on changing research practices (e.g. computers capable of handling much higher volumes of data?)
- **Terminology** - A lot of time spent discussing what different terms mean as the workshop participants span a huge range of disciplines. How can we overcome that barrier? Importantly, this multi-disciplinary interaction highlighted that there are some themes and areas that would benefit from cross-disciplinary collaboration.

8 Research Cluster 'Deep-Dive': Communities

8.1 Introduction to the Exercise

In this exercise, the participants considered how well positioned the UK was in terms of both capability and capacity to undertake research projects relating to the research clusters and super-clusters previously identified. They also identified key research questions as well as any potential challenges and highlighted what needed to be done to address these.

8.2 Methodology

Participants were first asked to nominate the research community they felt they belonged to and identify other participants that had assigned themselves to a similar community. To ensure that no single group was significantly larger than the rest, the organising team limited membership of each community to six participants. In total seven different communities of practice were identified and each group were allowed to select whichever research clusters they wanted to analyse (Table 5):

Table 5 Community groups and their selected clusters for Deep-Dive 1

Group	Community of Practice	Selected Clusters/Super-Clusters	
		No.	Description
A	Home and Community Systems	6	'Governance: Community, Sectoral and Constitutional'.
B	Smart Technology	1	'User-Technology Interface'
C	What's Energy For?	7	'Changes and Differences in Energy Practices and End-Uses'
		8	'Energy Related Decision Making'
		14	'Investment and finance for energy efficiency'
		15	'Equity: Ensuring fair access to comfort and well-being'
D	Social Technical Systems	5b	'Cradle 2 cradle – Energy efficiency optimisation for the future'
		12	'Alternative Energy Futures'
E	Retrofit Implementation	5d	'Reconfiguring current technologies and processes (i.e. retrofitting)'
		8b	'How to understand decision making about energy efficiency decisions'
F	Outcome Controlled Building Design	1	'Technology-Behaviour Interface'
		5c	'How to design buildings to promote occupant comfort, health and well-being'
		10	'Discrepancies between Expected and Actual Outcomes'
		13	'Role of innovative, high-level technologies'
G	Understanding Non-domestic Drivers of Demand	8	'Energy Related Decision Making'

To assist the deep-dive process, an activity sheet was provided to each team with the questions and some suggestions about how each question could be approached to help provide more structure and consistency to the output this time. These were as follows:

1. What are the key research questions relating to this field?
2. What capabilities / capacities do we need in place for the UK to address these questions?
3. What challenges are we likely to face?
4. What do we need to do to ensure we are ready to address these research challenges (e.g. PhD training, data collection/curation, research Infrastructure, funding philosophy etc.)?

The outputs from each of these different groups were recorded onto flipcharts, after which the groups had to provide a five minute report back to other groups outlining their key messages.

Figure 3 Research Clusters 'Deep Dive' Session

8.3 Results

This exercise generated a large volume of data. The key themes that emerged from are presented here in the main text. The detailed outputs from each of the groups are documented in Annex A.

Areas for Future Research

- **Energy services** – what is energy for, exactly? Why do we need it and how do these needs change in different contexts?
- **Discrepancies between predictions/models and reality** – Research into what is responsible for these gaps and how such gaps might be minimized.
- **Focus on 'energy in the workplace'**, which has traditionally been ignored. Understanding how energy use here is both different and similar to in the home.
- **Energy decision making processes** – Particularly in relation to technology adoption and investment.
- **Factors responsible for influencing people's energy practices** - Differences in energy practices in different contexts (e.g. home vs. workplace, young vs. old, rural vs. urban). Also, how such practices change alongside relevant social/cultural trends.
- **Rebound Effect** – Nuances between macro and micro level rebound. Also, examination of whether it is 'a bad thing'
- **Differences in building stock** and implications for energy efficiency measures, householder's energy practices etc.
- **User-technology interface** – Exploring the complex relationship between people and energy technologies
- **Governance** – multi-level, community/local led, relationship between different governance models and different energy futures
- **Lock-In** – Explore under-studied lock-in effects such as the lock-in effects derived from energy policy and long-term infrastructure
- Opportunities to **scale-up deployment and utilisation of energy technologies** in the home and workplace
- **Equity** – who are the winners and losers of innovative energy technologies, policies, business models etc. How do we promote equality around in relation to use?
- **Skills and training** – Skills across a broad spectrum of professions. Focus on the factors responsible for enabling or constraining the development of necessary skills in UK.

Key Requirements to Undertake this Research

- **Promotion of inter-disciplinarily:**
  - Institutionalise 'energy' as a new cross-disciplinary discipline
  - Marrying technical and social insights e.g. building designers with a strong understanding of human energy consumption behaviours
- **Importance of data,** particularly data management and dissemination to help inform energy related decision making
- **Vocational training programmes** (e.g. technology installers, facilities managers), not just PhDs and MScs
- **Correspondence and collaboration** between a broad range of energy stakeholders
- **New tools to support building design** – Especially those that are sensitive to the uncertainties associated with energy system change
- **New metrics for energy use and services**
- Synthesis between **qualitative and quantitative methods,** especially in model building
- Greater engagement from energy community with **management, business and political science schools**
- **Action research,** potentially in relation to demand-side energy policy, technology development or community energy initiatives
- A role for **intermediary organisations** (e.g. ETI, TSB, Royal Institutes/Academies) to promote interdisciplinarity and research collaborations
- **Embracing uncertainty** in both model, technology and building design

9 Research Cluster 'Deep Dive 2': Cross-Cutting

9.1 Methodology

Participants were allocated to five groups, which included a mix of individuals representing the different communities identified in Section 88.2. The groups were asked to cover as many super-clusters as possible but were invited to prioritise:

Group 1: Energy budgets and allowances
Group 2: The Impact of changing social and demographic factors on energy demand
Group 3: Shaping of policy decisions
Group 4: Engagement with energy users
Group 5: The Role of innovative, high-level technologies[1]

As it was felt by some participants that technology had been somewhat neglected in previous discussions, Group 5 was formed entirely of those with engineering expertise and was invited to take a broad view of needs for technology research. For each cluster, groups were invited to address the following questions:

1. What are the key research questions relating to this area?
2. Whose job should it be / who is best placed to undertake this research?
3. How might the different organisations and research communities collaborate with one another in order to address these key research questions?
4. What capabilities / capacities do we need in place for the UK to address these questions?

[1] This group was invited to cover technology aspects more broadly in light of the fact that some workshop participants believed that not enough attention had been focused on technology. However, this group was constituted entirely of people with engineering/technology expertise

5. What do we need to do to ensure we are ready to address these research challenges (PhD training, data collection/curation, research Infrastructure, funding philosophy etc.)

The groups did not report back in plenary but there was a brief feedback session.

9.2 Results

9.2.1 Group 1 – Cluster 2: Energy Budgets and Allowances

What are the key research questions relating to this area?

- **Scale:** individual v home v life? Regional v national? 2050 v annual v weekly?
- **Technical feasibility:** cost/benefit; scope; IT tools and automation
- **Societal acceptability:** equity; entitlement; compulsory v voluntary
- Level of benefits in relation to other policies and measures

Whose job should it be / who is best placed to undertake this research?

- Research Councils should cover some aspects

How might the different organisations and research communities collaborate with one another in order to address these key research questions?

- Coherent framework at national and EU levels, e.g. through the establishment of a roadmap

What capabilities / capacities do we need in place for the UK to address these questions?

- Energy literacy
- Multidisciplinarity by analogy with life cycle assessment

What do we need to do to ensure we are ready to address these research challenges

- Interdisciplinary roadmap
- Education for energy literacy, e.g. school syllabus
- IT tools for carbon minimisation: meters; monitors; alarms, controls
- Accounting systems

9.2.2 Group 2 - Cluster 3: Impact of changing social and demographic factors on energy demand

What are the key research questions relating to this area?

- Tomorrow's old people v today's old people
- Identifying social trends and demographic shifts that are relevant
- Tight linkage over time of energy supply and consumption trends
- Programme of scenario research questions, (e.g. will people go on cruises if air travel gets expensive?)
- Impact of personal trading quotas
- History/future questions about practices and how they expand with energy supply
- Space heating will not be 70% of demand for ever - appliances change in uses etc.
- What if wheat yields continue to fall?
- International trends -convergence on western ideas of normal consumption
- Marginalization of Europe in world economy - what impacts on consumption?
- Demographic shifts -population, regional, migration, urban/rural, home ownership decline
- Crowding/density

- Sharing cars/homes as affordability declines

Whose job should it be / who is best placed to undertake this research?

- ESRC territory but also foresight scenarios
- Partnership with commercial data holders (e.g. Experian)
- Groups working on Europeanisation/internationalisation but not currently on energy (e.g. security bodies)
- Comparative studies, e.g. is Japan our future?
- The implications of how people are spending their time (time budgeting)

How might the different organisations and research communities collaborate with one another in order to address these key research questions?

- Strategic partnership between ESRC and market researchers/forecasters
- Established research teams are not asking these questions, so a brokerage job is needed for example between energy research and demographic research communities
- Links with Foresight, LWEC etc.

What capabilities/capacities do we need in place for the UK to address these questions?

- Data set availability – need access to rich data sets
- Need to know map out the relevant research landscape - who's doing what

What do we need to do to ensure we are ready to address these research challenges

- Exploratory strategy workshop
- Rapid evidence assessment
- Rapid ideas assessment
- Identify original and less obvious data sources.
- Exploit existing partnerships such as with Defra

9.2.3 Group 3 Cluster 4– The shaping of policy decisions

What are the key research questions relating to this area?

- Evidence based policy appraisal
- What is the current use of policy appraisal and how could it be improved?
- Research to broaden range of policy tools
- The relationship between policy goals, policy tools/mechanisms/instruments and policy actors (e.g. consultation with different actors)
- Testing the validity of entrenched, commonly used assumptions that inform policy-making
- Who actually informs policy? Which actors?
- What kinds of models are being used to inform policy? How should models be used to inform policy decisions? What are the implications of using models to inform policy? What are the alternatives?
- Best and worst opportunities for regulation
- How do we ensure that research on future energy systems and policies addresses the impacts on wellbeing and equity?
- Effects of efficiency measures on occupant well-being
- Methodology for multi-criteria evaluation of energy efficiency projects
- What metrics should be used to evaluate for different dimensions (e.g. social vs. economic)? Can you quantify everything and should you?

- How different priorities (e.g. social, policy, and economics) are traded off against one another/negotiated.
- How is academic research fed into policy making/process? How is this research selected by government? How does policy appraisal feed into policy making?

Whose job should it be / who is best placed to undertake this research?

- Academic role to examine the policy making process; governance structures and role of policy actors. Maybe best placed to cross-examine why certain policies were or were not successful, i.e. learning from history to inform the present
- Government departments have a big role in testing long-held assumptions. Also, to undertake policy evaluation. However, Government departments need to be brave because it might uncover poor policy making from the past
- Not trade associations and interest groups because they are biased. Avoid conflicts of interest
- Those that are living with policies are in the best position to evaluate then, along with those at the top of the chain who were involved in designing them. Researchers should engage with these people'

How might different organisations and research communities collaborate with one another in order to address these key research questions?

- Zero carbon hub – industry and government working together to develop policy. What is the cost of and effectiveness of intermediary organisations in developing policy?
- There aren't well routinized processes to undertake policy appraisal and incorporate the lessons learned from this into future policy
- Identify ways in which research can be structured to meet the current needs of policy making
- Lessons should be sufficiently broad that they transcend individual policies
- Secondments between academia and government
- Knowledge exchange networks to inform both parties

What capabilities/capacities do we need in place for the UK to address these questions?

- Building channels between academia and government (e.g. PhD placements, Parliamentary Office of Science and Technology Policy positions). Helps to develop legitimacy and relationships between academic and government individuals/actors
- Stumping up the cash
- Getting the right players in the room (i.e. the correct people from academia and government, as well as policy-users)
- Getting buy-in from government to be honest about their policy-making and successes/failures of policy

9.2.4 Group 4 – Clusters 9a: Novel technologies and how that creates engagement and 9b: Understanding how to communicate with and engage the public around energy use

What are the key research questions relating to this area?

High-level questions

- What are the key moments for possible intervention in different market segments?
- What channels can be used to access different market segments?
- How to access, engage, address, and motivate desired audiences?
- Receptivity changes through different media channels?

- Engage with people via energy services?
- Who is trusted on energy messages?
- If we were to consider energy as a public good/common good would we consider things differently?
- Can the public sector be a trendsetter?

Detailed questions

- Better information on energy use and how the impact of information endures. It's about more than just messaging:
    - Smart meters can reduce energy consumption by between 0 and 30% and the effects can last from a few weeks to about 6 months, but longer. How do we deal with that?
- How do you measure the effectiveness of interventions? Which methods work for quantification? What metrics do we need?
- What do people hear when we talk about energy use and efficiency? Technical terminology may not help but linked to energy services.
- Is there a national model for policy, does it have to be site specific, or is there a combination of the two? How do you move from generic to specific scale? Who has the capacity to engage? What are the key moments for effective interventions?
    - "Moments" is about life stages and individuals, e.g. how to get people to do something differently when they're moving into a new place, when they retire etc.
- How, where and when should we segment markets? Transcends socio-economic groups.
- Public engagement has not been thought through. It is not just a one-way process based on messaging. Message is a two-way process and messages can come from markets, suppliers, customers. For example, academics no longer talk about "knowledge transfer" but "knowledge exchange", "coproduction of knowledge". At all stages, operational/demand side as well.
- How can we most effectively use social network analysis?
- Need to address links to well-being and comfort.
- People have different understandings of the word "energy". This may limit how they can engage with it (e.g. they may think about electricity only, but not gas). Need to understand the relationship between 'the "framing of energy" and the messages people hear.

Whose job should it be / who is best placed to undertake this research?

- **ESRC:** framing, language, engagement, social network analysis. Identify gaps between the energy research community and other relevant research field. Synthesise and generate new research where necessary.
- **Government: Defra, DECC, DCLG:** Monitoring and evaluation. Designing things from the outset so that they can subsequently be evaluated. Commission the baseline beforehand.
- **Industry:** Help with data, e.g. from smart meters. But: challenges on: data privacy; legal challenges make sharing a hassle to share it. Assisting in the design of interventions. Marketing and influencing expertise.

How might different organisations and research communities collaborate with one another in order to address these key research questions?

- Coordination between government and energy companies

What capabilities/capacities do we need in place for the UK to address these questions?

- Developing a shared understanding
- Balancing expectations of funders, users and equity

- Data: sharing; access; baselines; creation and curation of datasets
- How does the energy sector access and use that data? How do we take forward new data in a way that enables it to be useful, and be so over a longer period of time?
- Capacity and capability, better theoretical understanding and better joining up of what we have in terms of both theoretical and practical experiences.
- Cross-pollination, e.g. taking research insights from psychology and take it into energy use. Understand how to take critical/theoretical social science and figure out how that can be applied.
- The Alliance for Useful Evidence will be funding "What Works Centres". There could be one on energy policy.

9.2.5 Group 5 – Cluster 13 Technology

Reflecting their particular remit, this group focused on research challenges and questions.

- Role of catalytic enabling technologies: ICT, monitoring, maintenance etc.
- Sensing of the environment, but defining comfort is very difficult although there are five physical parameters that can be measured. Checking for potential problems, e.g. humidity
- Making the human interface intuitive and natural. People often use thermostats like a volume control
- Smart controllers. The bulk of this is standard PID (proportional-integral-derivative controller), but you could move beyond that to predictive control, self-tuning control, auto optimisation control taking account of behaviour with occupancy detection, behaviour pattern recognition, programming personal preferences (e.g. the time people come home, spotting abnormal behaviour, security services
- New business models providing real time service provision. Getting the kit into the control loop
- ICT/comms: micro nets of communicating sensors; wireless LAN; 4G / fibre optic services there are unintended consequences
- Infrastructure: mapping of subterranean landscapes; rapid prototyping of building scale structures; heat networks; “contention management” to address the issue that a network link may not allow everyone to draw full power at the same time; optimising energy infrastructure
- Micro generation, distributed generation and local grids
- Smart local network control: the algorithms must get more complex along with the challenges
- Advanced insulation
- Integration of thermal storage into “variable mass” buildings
- Improving the aesthetic quality of retro-fit solutions
- Addressing the challenge of moisture absorbing surface with better insulated buildings
- DC distribution instead of 240V AC?
- Relatively speaking heat is a much bigger system integration problem than transport. use electricity for the majority of the time and gas at peak (heat) load.
- Energy conversion: fuel cells; vehicle to grid
- Summer cooling of houses and the provision of peak cooling
- Design of houses that are flexible enough for all seasons
- Air tightness; needed for high efficiency but most people like some air flow
- Modelling for design purposes, compliance and possibly online control. Can you do agent based modelling of `typical' users?
- Optimum utility supply. Modelling buildings and systems

9.3 Plenary Feedback

Comment: We have a broad range of technology topics but should we think more about Technology Readiness Levels (TRLs)? What is the role of the Technology Strategy Board ? Do research councils address more fundamental technology research? An alternative view was that innovation happens in

different ways and TRLs may not be the right way to approach in this sector. “Scale” for example is not really addressed by TRLs.

10 Reflections Exercise

10.1 Process

This exercise provided participants with the opportunity to build upon ideas they had formulated during the hotspots/clustering and deep-dive exercises. It also allowed them to highlight any broader issues they wanted to raise about the workshop or to make any more general contributions to the RCUK Energy Strategy Fellowship Prospectus. The purpose of this exercise was to ensure that the finer detail generated during the workshop was not lost and that it could be highlighted and further developed for the purposes of the Prospectus. The reflective review session was structured as follows:

Option One: ***Independent Reflection***

> A room was set aside for individuals to work on their own to record their thoughts and ideas to add to the research prospectus.

Option Two: ***Chat Room***

> A room was provided for participants who wanted to talk through their reactions to the themes and research ideas. A note taker was present to record the discussion .

Option Three: ***Reflect and Chat***

> In the main room a period of individual reflection was provided using a timer and then the participants were grouped into trios to discuss and share their individual reflections. The mixture of discussion and reflection enabled the participants to develop their ideas by ‘bouncing’ these off other members in their group.

Participants were encouraged to post any written output from this session into the reflections post box. Additionally a follow up email address was provided for those participants who had written their reflections electronically.

10.2 Output from Chatty Room

- **Communal Energy Services –** Explore the opportunities for communal energy service provision. What services are commonly needed or desired? How might these be provided communally?
- **Values Associated with Energy –** How and why do we value energy? How have these values changed over the years and why? Also, appreciating the relationship between the value and cost of energy. For example, . if I make the effort to cut and burn my own wood, am I more likely to burn it sparingly?
- **Embedded Inefficiency Costs –** To what extent is inefficiency reflected in the cost of products and services (e.g. hairdryers)
- **Slow Energy -** Discussion around the concept of ‘slow energy’, i.e. the antithesis of fast, on-demand energy. A form of energy that may take a longer time to source but may also be available for a longer period of time than most (e.g. slow-release heating from building materials) - ‘Making time for energy’
- **Neo-liberalism vs. Localism** – Are there inconsistencies between these two agendas? How might we reconcile these? Why is the localism agenda beginning to re-emerge?

- **Heat Networks vs. Autonomy –** Households in the UK are used to individual control over their heating needs and may reject the notion of communal heat supply as this provides them with less autonomy
- **Harnessing Community 'Disaster' Action –** Recognition that communities in the UK often mobilise quickly and effectively in the context of local or national disasters. How can we utilise into this latent potential to address the energy trilemma? - 'Energy and Solidarity'
- **Absence of Public Trust –** How has distrust of Energy Utilities amongst the public damaged the transition to a sustainable energy system? E.g. free energy efficiency measures often ignored as they are considered a 'scam'

Please note that after the workshop invitees were provided with a draft copy of the workshop report, which they were encouraged to provide feedback on. Any feedback provided by invitees is marked with an * to identify it as a post-workshop reflection.

10.3 Individual, Anonymised Responses

10.3.1 Future Research

- **Technological Innovation** - Basic technology research that could affect energy use dramatically (e.g. super thin insulation materials)
- **Energy Business Model Innovation** - Do we have the business models to make all this work? The current through-put based approach won't allow this to happen at scale?
    - Will the infrastructure business models/interdependencies call cover the role of innovative business models in sustainability transitions sufficiently?
- **How do we scale up energy efficiency?** – Important question if we accept that there is a large and economic potential for improving energy efficiency across all sectors e.g. scaling up demand for energy efficiency, supply of energy efficiency and flow of finance into energy efficiency involvement:
    - ***Demand*** – Need to understand the factors that enable or constrain decision makers to making decisions that improve energy efficiency, as well as understanding technical/economic opportunities across different sector and how management decisions get made
    - ***Supply*** – Number of capacity issues that need to be researched, e.g. skills gaps at all levels from trades people through to designers
    - ***Finance*** – Examination of the real financial performance of efficiency investments
- **Factors that will influence long-term energy demand** such as the effects of advanced materials and/or advanced manufacturing technologies
- **Deeper understanding of 'Energy Demand'** – Need to develop a more sophisticated understanding of energy demand
- **Nuances of consumption across different contexts** - Urban vs. non-urban, city vs. communities
- **Historical differences in energy demand** and the factors responsible for these
- **Relationship between energy supply and demand** - Have we considered the connection between demand (absolute and profile) on the supply systems (and how its operated)?
    - Blurring of supply and demand through on-site energy generation, electric cars etc.
- **Nexus between energy, food and water** – Where do these exist and how might these issues be addressed simultaneously?
- **Role of Intermediary Organisations** - Need to understand the role of middle agents in shaping and delivering (or inhibiting) society change. Intermediaries of many kinds frame and negotiate the implementation of change

- **Attractiveness/sex appeal of energy efficiency** – How do we make it more attractive? What are the cultural explanations for its relatively low-level of attractiveness compared to micro-generation?
- **Energy Perceived of Differently** – Why do we view energy differently to other goods and services?
- **Ethics of energy use** in a time of climate change, resource insecurity and widening inequalities
- ***Energy Vulnerability & Fuel Poverty** – Growing research agenda around questions of access, pathways to vulnerability, effectiveness of area-based interventions, and multi-scalar energy vulnerability. The framing of energy 'equity' or 'justice' predominantly used at the workshop is quite narrow.
- **Energy as a Common Resource** - There is a lot of research on the management of common resources (mainly natural) which might provide insight on alternative approaches
- **Co-evolution** needs to be more central to analyses of changes in energy practices and energy system change
- **Comparison with other countries** – Lesson learning drawing on case studies and datasets from overseas (e.g. cities and workplaces with intensive commitment to action, research and investment)
- ***Decentralised Energy Futures –** Development of more scenarios/futures that consider what a decentralised energy system might look like and the society it supports. In particular there are important knowledge gaps in terms of energy activity at a local level, particularly the range and ambition of local authority energy strategies, as well as opportunities for communities to become actively engaged with energy systems and their transformation. A need for some inter-disciplinary work structured around both actual and potential local approaches to energy, which do not start from the traditional supply-side/demand-side division
- **Implications of the economic crisis** (e.g. public spending cuts, reduced spending power of citizens etc.) on energy research and transition towards sustainable energy system
- **Timescale** – pace of change an important subject

10.3.2 Needs to Undertake Research

- **Refining the Knowledge Exchange Supply Chain -** There is a large gap in taking ideas from University to the real world: i.e. DECC, other government departments, industry, end users.
- **Development of tools and methodologies** to manage the complexity associated with energy use?
- **Language and terminology** - What can/should be done to provide coherence of language?
    - With the emergence of socio-technical project themes, there is a real need to ensure a mutual understanding of language and concepts between physical scientists, engineers and social scientists. This must encompass mutual respect for methodologies and expectations
- **Workshop road shows** to roll-out best collaborative practice, illustrated by case studies.
- **University campuses as living labs** – 'practice what you preach'
- **Management of Expectations** - Need to actively manage people's expectations about lifestyles for the future. These must be in life with what is achievable to ensure the public remains onside and engaged.

10.3.3 Broader Feedback and Reflections

- **Ideas were generally conservative**, with not enough questioning of the prevailing paradigm around energy (e.g. low-carbon, climate change mitigation etc.)

- **Lack of Focus on Certain Areas** - Discussion of fuel poverty, equity, social issues, climate change adaptation, embodied energy and uncertainty etc. seems to have been 'backgrounded'
- **Research Methodologies –** Little discussion around how these should be used
- **Coherence of Research Clusters** - Do the various research clusters fit together as a coherent whole? How will the research clusters be used?
- ***Difficult to Group & Boundary Research Topics** – A lack of super-clusters helped to demonstrate the very different ways participants interpreted/constructed the research issues in this domain. These different perspectives generally made it difficult to group similar research themes together and place a clearly defined boundary around them.
- **Synergies with Transport** - Urban scale energy efficiency analysis especially linked to transport energy
- **Home vs. Workplace** - Very little distinction made by group between Home and Workplace. Instead the many participants chose to focus on research themes that concerned both contexts. Perhaps these categories are not useful?
- **Non-domestic is not Homogenous –** Not necessarily homogeneity across all different non-domestic/commercial sub-sectors. Key literature already exists on energy demand and investment in specific market segments, e.g. retail, hospitality, university, hospital sub-sectors etc.
- **Spatial Scale** - Questions around whether or not the micro to macro scale was useful
- **Terminology** - Do we have the right definition of innovation?
- **Technology Readiness Levels (TRLs)** - Technology readiness is not appropriate and too narrow
- **Involve the wider community** in reviewing drafts of your report
- **Peer-Review Process** – What will be the peer review process for the Prospectus?
- **Catherine Mitchell's Research Fellowship** – How will the two fellowships work alongside one another?
- **Link with DECC's Work** - How does this link to EEDO's research planning exercise?
- **Research Framework vs. Research Themes** - Workshop created more ideas for projects than ideas about how to structure an RCUK strategy to generate such ideas
- **Flash Cards** – generated some interesting gems that should be explored further

11 Future Research Capabilities – Where are we now?

Working individually, people were asked to identify where they thought we are now in terms of research capabilities for tackling future research challenges relating to energy in the home and workplace. They were invited to score these on a scale of 0-10 (0 = no chance, 10 = well setup) and explain their score on a post-it note. Unlike the previous exercise that examined 'Research Capabilities: Where Are We Now?' (Section 5) the participants were not asked this time to divide between 'home' and 'workplace' this time as this division had become somewhat blurred as they had begun to examine opportunities for future research in this area.

The following graph shows the distribution of the 26 post-its. The average score was 5.0 +/- 1.7, indicating that there was a moderate degree of consensus that the UK is neither well nor poorly positioned to tackle future research challenges in this field. A striking outcome of this exercise is the polarisation of views about the UK's interdisciplinary research capabilities, with individual scores ranging from 1 to 8, a much broader range than for the previous exercise. Figure 4 summarises the results, while **Table** divides the results into three classes: low capability (0-3); medium capability (4-6); and high capability (7-10), and sets out the detailed results.

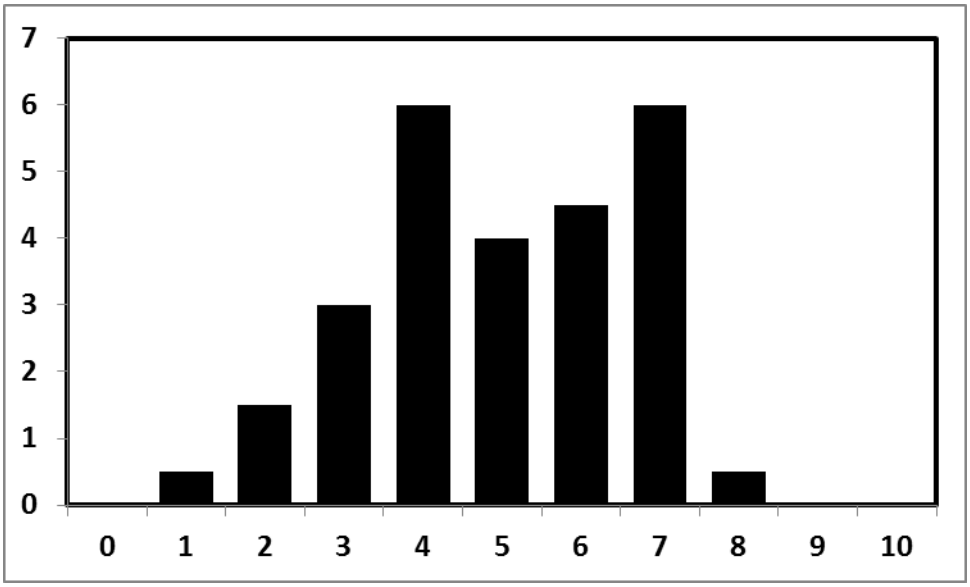

Figure 4 Distribution of perceived UK capability levels against future energy research challenges

Table 6 UK's perceived capability levels to address future energy research challenges

High capability levels			
7	**8**	**9**	**10**
Lots of capable people out there – there's an opportunity	N/A	N/A	N/A
Need collaboration between physical and social scientists Need public and private funding			
We have capability and importantly the awareness and desire to do the work What we lack is the capacity but I feel we are moving in the right direction on this			
Home – Lots of data, capability, knowledge, expertise, experience BUT some missing bits			
Problem is not capabilities but opportunities in the context of support, political will, funding, incentives etc.			
Have lots of data and ability to generate more, as well as good research capability			

Medium capability levels		
4	**5**	**6**
Workplace – Severe lack of key data. Good skills and recognition of problems	Home – retrofit domestic due to useful recent case-studies	**6.5** – Strong on ambition to achieve and skills but weaker on resources and facilities. Important that we get engineering and social science communities working together
Not only research challenges/knowledge sharing but how to feed research findings/outcomes into policy process.	Weaknesses – Integrative, complex research, particularly socio-technical and environment Strengths – Discrete, technology and building focused research	High-powered academic community Strength in energy economics and systems BUT Economic crisis, cuts, weakening of key organisations Access to datasets Need for multi-sector, interdisciplinary partnerships
Lack of knowledge for understanding demand for energy efficiency. Lack of data on non-domestic stock. Errors in building models	A great set of answerable questions but can we get a 'well-to-wheel' approach that sees how business/consumers will adapt and use new technology	Strong on methodologies but weak on data and applications
We know what some of the questions are but need more scoping and resourcing to start addressing Also, a greater skills mix	We will need to bring a wider range of research teams in to working on energy and we have no idea if they will be interested We also need to get much better at translating between disciplines, as well as between researchers and end users or research	Broad skills base but challenges require new approaches
Need to examine capabilities clusters and shared facilities		
The big challenge is to make completely different domains discuss matter with one another and understand each other		

Low capability levels			
0	**1**	**2**	**3**
N/A	Not very much data on 'workplace'. More complex than homes, however potentially easier to study as it is less invasive	Non-domestic retrofit – lack of data	Lack of resources and expertise to address breadth and scale of hotspots identified
			Seems unlikely that the research community will be able to flush out the largest issues to focus research on. This is evident from the divergent framing, which reveal a lack of underlying consensus. Also, consensus is probably not going to deliver what is required
			Weaknesses in science-policy interface (particularly social science) – challenging to both sides. Divisions between engineers and social scientists still difficult

12 Key Points: Start, Stop, Continue

Participants worked in groups of four to list the three issues that have emerged for each person during the workshop. They were asked how the Research Councils could assist in terms of things they could:

- Start doing/do more of
- Continue to do
- Stop doing/do less

The responses were recorded on flipcharts and each group reported back verbally on one issue they had identified. **Table** presents the outputs of this exercise.

There were far more suggestions for things that the Research Councils could start or do more of the recommendations for either continuing or scaling back. Surprisingly few recommendations relate to research content or focus. Most related to: research commissioning processes; interdisciplinarity/cross-Council collaboration; and impact/stakeholder engagement. There was also a small number of comments about PhD training.

Table 7 Participants' recommendations going forward for Energy Research Programme

Start doing/do more of	Continue to do	Stop doing/do less
Research Focus		
More funding of large scale longitudinal studies of interventions	Funding for technology-oriented research	Don't fund things others can do better, e.g. market research on late-stage technologies
Fund more social science, business and management research in the non-domestic sector	Using the strengths of academia: long-term thinking; tackling equity issues (some research projects could be market research–led)	Stop doing things ETI/TSB should could do better
More research on understanding human needs related to energy products and services		
Do more research on building models/performance gap		
Do more on the trust issue, e.g. trust/distrust of energy suppliers and government		
More work on behaviour in different segments (domestic and non-domestic)		
Maths and interdisciplinary research		
Research Process		
Longer larger grants	Theme and multi-centre calls	Less working solo – require collaboration
Improve quality of peer review process particularly for directed calls	Continue this process of engagement	Less silo/traditional thinking
More encouragement for innovative "responsive mode" bids		Reporting of project findings is deficient
More homogeneous approach to research governance		
Have old style Research Programmes		
Encourage private /public research collaboration		
Start small grant curve ball research		
Interdisciplinarity		
More equitable peer review for cross-council projects	Supporting the formation of coalitions between different research groups	Stop "pass the parcel" between Research Councils as many projects are "orphans". More integration across Councils
Greater mixed-discipline approach as no single discipline can deliver on this subject	Cross-Council projects	
Equip themselves for multi-disciplinary evaluation		
Support interdisciplinary research with dedicated funded opportunities to establish mutual understanding		

Impact		
Start more funded secondments across industry, academia and policymaking	Joint funding with industry	Don't always insist on stakeholder engagement – it can become a barrier to innovative/critical research
Mix academic and non-academic teams		
Strengthen research/policy interfaces		
Enable research projects as academic/non-academic collaboration		
Rethink "impact" in terms of relationships with policy		
Ensure more thinking about how activities by Research Councils feed into policy concerns		
More knowledge-sharing activities across different actors		
Do more to transfer learning from different disciplines into energy (e.g. social network analysis)		
Training		
Support more training for PhD researchers in: a) translating their results for users; b) understanding and respecting the contributions of other disciplines	Engineering doctorates – good for industry and students	Don't stop project students – DTCs aren't appropriate in all circumstances
	CASE studentships	

13 Organising Group Review and Outstanding Questions

The facilitators invited Matthew Hannon and Jim Skea to reflect on the workshop and respond to any questions participants had.

Matthew noted the breadth of the subject and the depth of some of the research questions identified. This was wonderfully illustrated by the question "what is energy for"? The group has identified many ideas including opportunities not just for the Research Councils, but also for universities to collaborate with like-minded bodies. In terms of the balance between home and workplace, once research ideas were grouped we lost sight of the home/workplace distinction. There was a concern that we had not focussed enough on technology, but many exciting ideas were generated on topics such as energy equity and alternative community-business models.

Jim commented that this had been a sophisticated set of participants, many of whom had a lot of experience of facilitated process. This could have resulted in a workshop that followed a very different path from the one that we had planned but, with a little re-framing, the process worked well. The concern that technology had been underplayed was redressed in the final session through the work of a technology-focused group. One question we didn't adequately address: many of the recommendations are not necessarily for the Research Councils but for other bodies. We may address this in follow-up questions when we distribute the draft report.

Question: There was an excellent set of clusters and themes. How will these be prioritised?

Jim noted that the Fellowship team had been careful to say that they were generating evidence for the Research Councils to go through their own processes. They make the final decisions though they would take our recommendations into account.

Question: How will you structure the output and identify where there are key dependencies.

Jim replied that this would be part of the "next steps" which would be as follows. We have a template for capturing the workshop output which we devised following the *Fossil Fuel and* CCS Workshop. We had hoped to synthesise a prospectus document in one step but we found that we needed an intermediate workshop report. We aim to send this out for comment in three weeks. We will include a question about the role of the Research Councils vis-a-vis other bodies at the same time. Following your responses, we will start putting the prospectus document together.

The next four workshops will be processed in the same way. In addition, we are likely to run one more concluding strategy workshops to tie things together in July and will consider preparing one more document which assesses cross-connections between different topics.

Annex A: Research Cluster 'Deep-Dive' – Detailed Outcomes

Group A: Home and Community Systems

Group A examine only Cluster 6, which referred to 'Governance: Community, Sectoral and Constitutional'.

Key research questions?

The key research questions in relation to this field fell into four main categories:

Factors in Local and Community Organisation

- Why the need for community energy projects? UK just at the beginning of the path (e.g. Ashton Hayes, Bath and West Community Energy, Thameswey Energy, Eco Islands)
- How do community groups come together? How do communities develop energy schemes and networks?
- Comparative and holistic analysis of other community energy systems to help UK learn from others regarding locally owned and managed energy networks:
- Impact of new social media on community-scale self-organisation and management of energy initiatives.
- Who are the 'wilful individuals' that things happen with regards to delivering locally based energy schemes, e.g. Dan Thompson who led the clean-up after the riots?

Barriers and Lock-In

- What are the barriers or opportunities for communities to develop local networks to support community energy initiatives? This may involve councils, investment companies, local businesses, Energy Utilities working together
- What would you need to change in terms of local governance to promote community energy initiatives?
- How might those local schemes link to larger energy companies, i.e. link the local to the national?
- Regulation and barriers to entry for community-scale energy entrepreneurs, e.g. How do you simplify the bureaucracy to enable entry into the energy at the micro-level?
- What policy conditions do you need to create to enable local level governance?
    - Impact of national-level government on local governance?
    - How do you nest local projects into national policy?
- Lock-in effects of current and future policy (i.e. energy policy, planning policy, local government policy etc.).
    - How do you design policy to avoid or minimise future lock-in?

Capacities, Skills and System Constraints at Local Government Level

- Integration of activities going beyond energy services (e.g. Monmouthshire Community Interest Company) at local level
- Skills and capacities in local government and community bodies:
    - Needs for effective management of local energy systems
    - Skills gaps and lack of capacities
- Electricity storage at community level: implications for construction sector (home and commercial), architecture communities and local planning system

What capabilities and capacities are required to address these questions?

- Inter-disciplinary 'whole-area' action research e.g. on development of a city-scale community energy system.
- Energy governance research groups: integrated energy and social systems expertise
- Development of energy governance skills and capacities for local governance
- Funding to examine impacts of decentralised generation on distribution/transmission networks

What challenges are we likely to face?

- Vested interests (e.g. industry)
- Politics at national, local and community levels
- Demand for such initiatives at the community level
- Technical barriers about working in the energy market (e.g. ICT)
- Investment need and availability of affordable finance
- Burn-out and over-reliance on 'wilful individuals'. How to ensure schemes live on and leave a legacy?
- Re-organisation, budget cuts and loss of capacity in major systems: local government, NHS, public agencies etc.
- Lack of sectoral energy data, e.g. lots on residential but little on commercial often to do with issues of IP

What do we need to do address these research challenges?

- Provide and enable access to existing data – e.g. via a service similar to UKERC Atlas that disseminates research and outputs based on organisations' user preferences
- Create baselines for sectors currently lacking data (e.g. offices, retail etc.)
- Green Investment Bank – Structure it so that it can provide support for research
- Energy Company Obligation – Ensure it is used cleverly at the community level and in conjunction with Green Deal
- Develop energy as a discipline like economics or engineering, at PhD level and beyond, i.e.

Group B: Smart Technology

This group examined Cluster 1 'User-Technology Interface'

Key research questions?

- How to get customers to appreciate and apply demand response technologies to manage peak demand, supply and pricing?
- Who in society and business will benefit (most) from new technology? Are there any losers?
    - How to mitigate against undesirable outcomes?
- How to get consumers engaged in energy system and their own energy demand?
    - How to create a better solution to their problem or needs?
    - How could we get access to people's homes to trial new technology?
- Explore the positive effects of rebound effects?
- How might we enable a wider uptake of new and existing energy technologies?
    - What regulatory structures and business models are required?
    - What do consumers want and need? How do these needs vary by different sectors, households, areas (e.g. rural vs. urban)?

What capabilities and capacities are required to address these questions?

- Innovation
- Engineering

- Skills
- Economic markets
- Multiple actors engaged in the process from production (e.g. engineers) through to utilisation (e.g. economists and psychologists)
- Psychology – Trust is a challenge. How might we gain access to test technologies with real people in real homes? Psychological theory may help us devise a strategy to do so, particularly by providing insight into why a variety of in energy consumptions practices exist

What challenges are we likely to face?

- Lots of funding and research but little sharing of the knowledge being generated. Therefore, development of some form of hub or centre of excellence to bring together expertise of learning via knowledge sharing, team building etc.
- Ordering the roll-out of different technological innovations for different times, e.g. smart meters after roll-out of smart grid
- Understanding what motivates people and what people value. Develop market mechanisms capable of satisfying these needs and desires

What do we need to do address these research challenges?

- Funding to establish a hub of research excellence
- Communicate and engage with relevant stakeholders
- Development of a roadmap for smart energy solutions outlining research priorities

Group C: What is Energy For?

This group examined clusters 7, 8, 14 and 15. As this group of clusters was so large they focused on a broad research question that encapsulated the different clusters; 'what is energy for?'

Key research questions?

- What is energy for?
    - What do people perceive energy to be for? How do they value it? What services do people derive from it?
    - How do the above change in relation to different demographic/social groups? What will people expect to be able to do? How has this/will this change over time?
- What is the demand elasticity of different energy services?
    - Peak demand vs. Peak practices: Once you start to try and understand why we have a peak, you can think about how to smooth it
- Preparedness to pay for different energy services and energy efficiency measures
- Equity:
    - When is it all right to borrow for energy access? (e.g. who benefits from Green Deal?)
    - How does access to finance affect what different groups use energy for?
    - What do people consider the fairest way to reduce energy demand? We never ask people?
    - Social implications of treating energy as a unit of exchange, as if it were a currency?
- Decisions:
    - What stages are there in the energy decision making process?
    - Who gets to make energy related decisions? How are different decision making groups linked up, (i.e. the ecology of energy decision making)?'

- What assumptions do decision-makers make about basic and other needs for energy services
- What decisions affect what energy is used for?
- How do businesses cost/value energy inputs?

What capabilities and capacities are required to address these questions?

- Need more courage in both academic and government policy to address the above questions
- Long-term historical research into 'how do uses of energy develop and change?'
  - Mapping trends in practices and forecasting based on historical understanding
- Broader measures to capture peak demand/peak practice:
  - kWh not terribly useful. We need new units, for light, for fun? "Is this 10 funs?"
  - Develop energy exchange rates, e.g. "About 1 convenience".
    - Different amount of light has different effect depending on time of day. What units do we use for that?
  - Examples include:
    - Societal synchronisation index (a measure of how synchronised – in terms of timing – different end use practices are)
    - Fossilization and Transformation Index of Society (a measure of which energy-using practices are emerging, and disappearing)
    - Chart-atlas of contemporary energy-intensive practices (to show who enacts such practices and where: capturing aspects of social distribution)
  - Reconcile energy performance metrics with financial performance metrics
- Shift towards the notion of energy services:
    - Thinking about how the world currently thinks of energy as a unit of exchange
    - How/what to move to for new indicators
- Linking the infrastructures people to this topic:
  - All the future plans for new nuclear, and all that, really fail to ask the question "what is energy for". Get them to stop treating energy as a currency and challenge their prevailing assumptions
- Change in Perception of Research Community:
  - People that ask "what is energy for" are perceived as hippies, not as smart Harvard suit-and-tie wearing people. Big problem.

What challenges are we likely to face?

- A lack of courage to engage in this area of research and develop the capabilities/capacities necessary to undertake it

What do we need to do address these research challenges?

- Transfer from corporate domain:
  - PhD students are not enough. Need to persuade corporate focused individuals to engage in this area
- Inter-disciplinary mixing:
  - Engage a broad range of organisations to consider these questions, (e.g. ETI, construction companies, financial institutions, tourist companies etc.)
  - Fund philosophers to work with economists to generate new questions and theoretical frameworks to underpin these
- Summer schools:
  - Most are academic but also need more business oriented summer schools that attract a broad range of people
- Introducing new standards and metrics:

    - What standards are required to promote education?
- New kind of economics:
    - Need radically unusual economists to think through the economics and valuation of end use practices/services rather than resources
    - Get economics off resource base and on to services – an 'Economics of Services'. There's actually a whole sociology of economics that looks into 'how stuff is valued', (e.g. in US)
- Need to constantly keep the question of 'what is energy for' in mind:
    - Energy is not 'one' thing – Need to move from a focus on energy (i.e. kWh) to the services it makes possible

Group D: Socio-Technical Systems

Focused on research cluster 5b '*Cradle 2 cradle – Energy efficiency optimisation for the future' and* 12 '*Investigating Alternative Futures*'. These clusters are distinct from one another and were consequently dealt with separately by the group as reflected in this section.

Cluster 5b: Cradle 2 Cradle – Life Cycle Analysis

Key research questions?

- Questions around embodied energy and carbon (e.g. energy technologies, homes etc.)
- Remote consumption/upstream emissions (e.g. telephony)
- Product life and lock-in effects - if devices last a long time they are likely to have a greater lock-in effect (e.g. road-bridges last for hundreds of years but is road-transport the future?)
- Decommissioning of infrastructure (e.g. gas networks) and buildings
    - When do you abandon the built environment? The same question facing technology such as old televisions.
- Recycling/recovery.
- Energy is embodied in other utilities, not just products (e.g. water)
- Energy is embodied in the product but also the process of using the product.
- Functional entities in the context of an uncertain future, with respect to both availability of resource and demand for particular functions:
    - How do we design for uncertainty? How can we future-proof?
    - Building artefacts in turn reduces the level of uncertainty e.g. path dependency, lock-in etc. 'If you build a road more people are likely to drive…'
- System efficiency – where are the boundaries?
    - Cost efficiency vs. resource efficiency vs. carbon efficiency
    - Where is efficiency the objective and when is it not?

What capabilities and capacities are required to address these questions?

- Skills and experts:
    - Energy analysts
    - Life-cycle analysis specialists – 'process bottom-up'
    - Consumption – based accounting – 'process top-down'
    - Cost accountants – a hybrid of the two
    - Designers to balance the need of the product with the trade-offs (e.g. resource use)
    - Political scientists – experts on governance and policy
- Tools to enable designers to design these products that draw upon LCA insights.

- Sociologists that can examine the types of functions we can derive from energy and how this might change with time.
- Integrative-system efficiency – combining insights from different efficiency metrics (e.g. energy, carbon, resource) into a coherent system.

What challenges are we likely to face?

- Productive inter-disciplinary engagement:
    - Understanding how different people operate, such as methodological approaches
    - Inter-disciplinary training
    - Require long-term, stable funding to achieve this i.e. a working relationship
- The term efficiency is subjective and the boundaries of efficiency differ between disciplines
- Uncertainty in how the future will 'play out'
- Equity – distribution of costs and benefits. There are issues about how we balance the focus of financial efficiency/gain with others (e.g. resource efficiency and environmental protection)
    - Need to balance between the various costs AND benefits generated throughout the life-time of the product
    - Need to make these benefits and costs clear/transparent in order to discuss how these are apportioned across the supply chain
        - Some costs are difficult to quantify. They may be hidden and/or contested

What do we need to do address these research challenges?

- Engagement between different disciplines – Long-term stable funding to develop inter-disciplinary working relationships
- Interdisciplinary training at Masters and PhD level to appreciate different theoretical and methodological positions
- New methods to enable inter-disciplinary interaction
- A mix of quantitative and qualitative methods to enable a stronger understanding of system efficiency
- What you want to achieve can become the boundary – As a default, policy might be taken as the system boundary to help address the complexity of developing efficient systems
- Ways to incorporate the notion of energy and environmental justice in LCA

Cluster 12: Investigating Alternative Future

Key research questions?

- Which futures does our current governance paradigm allow?
    - What are the different potential governance arrangements? (e.g. market rules, central government, decentralised governance/community)
    - How do different governance paradigms contribute to alternative futures?
    - How might a combination of these work and what kind of future would it lead to?
- Realising futures via governance arrangements. How do these work in practice?
- Development of 'place specific futures' in the context of national futures (e.g. city, region etc.)
- How different governance arrangements relate to different spatial/geographical scales:
    - Can we take a multi-level approach towards governance (e.g. cities, communities, regions etc.)?
- Integration of quantitative and qualitative developed futures (e.g. transition pathways).

- Developing 'visions of the future' that are robust against unforeseen events and unconventional wisdoms (e.g. what happens if energy prices don't go up, how does this affect governance arrangements and impact upon existing strategies)
- Adaptive governance as a means of a form of governance – can we change track if needed?

What capabilities and capacities are required to address these questions?

- Scenarios/pathways:
    - Narrative descriptions
    - Technical elaboration
    - Whole-systems appraisal (technical, environmental, economic, social dimensions)
    - Multi-scale modelling
- Disciplines:
    - Political scientists – theories of governance and big governance issues (e.g. constitution changes, leaving the EU etc.)
    - Institutional dynamics – e.g. response of incumbent energy utilities to alternative futures
- Horizon scanning – those things that might affect the energy system in the future (e.g. fracking). Focus on changes to dimensions such as user practices, economics, technology, resources
    - Imperative that the coevolution of these various dimensions is examined and understood

What challenges are we likely to face?

- Need sufficient legitimacy/status to engage with elite stakeholders e.g. government, industry, communities (e.g. reputation, 'believability' of future scenarios etc.)
- Difficult to manage stakeholders' own agenda and vested interests
- Need to break out of the disciplinary mould to ask and address cross-cutting questions BUT there are epistemic research communities and stakeholders
- Foresight and horizon scanning is very difficult. What methods should be used?
- Difficulty in combining qualitative and quantitative approaches in modelling
- Need to make the assumptions underpinning models more transparent and robust. Efforts should also be made to 'build in' and manage uncertainty
- Quality assurance of 'futures' methods and dealing with the possibility they are inadequate

What do we need to do address these research challenges?

- Inter-disciplinary communities of practice – experience building around this type of work to ensure people become more familiar with other disciplines, their methods and the value of their research
- Networking to engage with and understand key stakeholders:
    - Mechanisms to enable collaboration
    - Recognise what stakeholders need and what they can provide (e.g. information, time etc.)
    - Care to ensure reconciliation between the conflict between the needs of business and academic (research) – need to recognise tensions

Group E: Retrofit Implementation

This group examined clusters 5d '*Reconfiguring current technologies and processes (i.e. retrofitting)*' and 8b '*How to understand decision making about energy efficiency decisions*'

Cluster 5d - Reconfiguring current technologies and processes (i.e. retrofitting)

Key research questions

- Nature and condition of the whole building stock
- Segmentation of the stock, its owners and its occupiers to disaggregate different consumer segment's expectations/motivations (e.g. citizens vs. organisations):
    - Understanding interests, opportunities and barriers in each segment
- Focus on exploring commercial (especially diff org types), rented and industrial consumer segments as these have traditionally been neglected
- Developing financial instruments and other incentives for each of these segments to support uptake of retrofit e.g. whole building packages
- Skills, capacity development and institutional innovation
- Do assessment tools like SAP work?

What capabilities and capacities are required to address these questions?

- To have analogies for the non-domestic sector of the following:
    - House condition surveys
    - Case study/demonstration of retrofit
    - Craft skill analysis for Green Deal has been done
    - Standard Assessment Procedure (SAP)
    - TSB
    - Randomised control trial of what works round Green Deal in the domestic sector
    - Green Deal Pathfinders
- Better understanding of and data for non-domestic stock
    - Data for commercial properties analogous with domestic data from English House Condition Survey

What challenges are we likely to face?

- Understanding the performance gap (e.g. expected/modelled v actual) for all sectors
- Skills to implement retrofit is an issue
- Whole building approach is a challenge, i.e. design, installation and optimisation

What do we need to do address these research challenges?

- 'Whole house' testing facilities and regimes
- Data for the non-domestic building stock
- Register of real-world exemplars in all sectors
- Understanding of how we improve innovation in construction sector
- Understanding of management of interdisciplinarity process, e.g. at business schools. Turning solutions into practice
- Better understanding of industrial partners - partnerships between industry/academia
- Connectivity between intervention/delivery and research activity (e.g. DECC and DCLG with RCUK)

Cluster 8b - How to understand decision making about energy efficiency decisions

Key research questions?

Based around the who, what, where, when and how of decision making

- Who - Segmentation between owner-occupiers, organisations, clients, experts, system integrators etc. with a view towards disaggregating expectations/motivations
    - Understand their different interests, opportunities and barriers
    - Commercial is a particular gap, i.e. different organisational types
    - Also, gaps with building industry and rented sector
- Where - Segmentation between stock, focusing both on the nature and condition of the building stock
- What:
    - Whole building measures/packages rather than individual measures
    - Potentially supported by whole-building policies
- When:
    - Timing and policy windows e.g. all at once vs. incremental interventions
    - At what stage of the owner/occupier's life or tenure?
- How - Delivery of measures:
    - Business models to deliver measures
    - Necessary to decamp from home/office?
    - Integrating agency and capacity (clients and contractors)

What capabilities and capacities are required to address these questions?

- Systematic, critical review of literature surrounding decision making, experience and practice, as well as retrofit
- Skills requirements of system integrators and intermediaries
- Growing the market – client knowledge and interest
- Data - Case study evidence from domestic sector and more evidence in non-domestic sector because commercial
- Frameworks in place to manage planning issues associated with retrofit of heritage buildings

What challenges are we likely to face?

- Travel for work
- Changing demographics
- Changing high street
- Ageing and changes
- Less localised business

What do we need to do address these research challenges?

- See Cluster 5d

Group F: Outcome Controlled Building Design

This group examined clusters 1, 5c, 10, 13 (see Table 4), which were considered to fall under the theme '*Outcome Controlled Building Design*'.

Key research questions?

- Gap between models/expectations and reality, for example buildings which have the same kit can often have very different consumption:

    - 'Manufacturers make the kit and say this works well. It's good kit. Then it gets put in, mistakes in the installation or scale and you get problems'
    - How can we identify and quantify the factors responsible for this gap?
    - Can whole building models be developed that incorporate agent based, physical and behavioural modelling?
- Monitoring:
    - Can we develop diagnostic tools to monitor progress from building design to performance?
    - Can monitoring of building/system/occupant performance be achieved cost-effectively? If so can it help us identify factors responsible for discrepancies and potential solutions?
- Human-control interfaces - we need research into building control that takes into account how people use them:
    - Are there types of technology (e.g. controls) that are more 'people proof'? Might these techs/interfaces reflect natural behaviours and preferences
        - 'There are two approaches to design: either hide the interface completely and the technology takes over, or engage the consumer'
    - Understanding the sensitivity of buildings to occupant behaviour
    - Can socio-economic characteristics help understand energy performance? How can we better identify these groups' needs and meet them more effectively?
- Manufacturing techniques – Why is it you get very detailed quality control in some manufacturing, not in the building design?
    - Which new manufacturing techniques can be used for retrofit buildings/new build?
    - Offsite manufactured components and sub-systems to enable de-skilling of installations and pre-validated performance levels
- Tools for decision-making for architects, developers, people using buildings
    - How could we include human behaviour in the development of design tools and software
    - Tools for architects to assist multi-factor decision making processes
    - Can such models/tools be sensitive to the needs of different demographic groups?
- Convergence of internet and cloud based building services (i.e. energy, security, artificial intelligence)
- How do different human behaviours influence technological adoption?
- Advanced heat storage materials – programmable release of energy
- What is unique about the UK in terms of deployment and effectiveness of building controls?
- Can we better train installers? What skills do we need for building performance?

What capabilities and capacities are required to address these questions?

Four key skills were identified as necessary to address the above research questions.

Skill 1 – Model Builders

- Not enough modellers
- There is a discipline around synthesising capabilities across domains (the domains are Technology/Design/Behaviour)
- We need PhD projects that promote cross-disciplinary work
- We need models to be derived from real world measurements - Validation of models

Skill 2 - Architects and Building Services Engineers should develop behavioural understanding

- Need to understand more about people's energy consumption behaviour - People have very different ways of living in their home and engineers must be sensitive to these
- Should also happen in reverse, i.e. behavioural scientists should be sensitive to how technical factors influence energy consumption behaviours

Skill 3 – 'Up-skilling' of Facility Management and Rewarding Performance

- Don't confuse FM with building services engineers. Different job, which requires different skills

Skill 4 - Installation workforce

- Focus specifically on training here

What challenges are we likely to face?

- Lack of skills in certain areas, due to deficiencies in training frameworks
- Lack of individuals who can relate to other relevant disciplines (e.g. building control engineers) with a strong understanding of the factors influencing human energy consumption
- Poor understanding of why some building control systems fail to deliver, despite strong design

What do we need to do address these research challenges?

- Post-doctoral training:
    - PhD projects that incorporate cross-disciplinary research projects
    - Building control engineering MScs and PhDs, with a strong behavioural focus
    - Energy system modellers
- Role for Academies and Institutes - Get 'chartered institutes' (e.g. Royal Institute of British Architects, Royal Academy of Engineering) to engage with their fellows (or potential fellows) to focus more on developing cross-disciplinary expertise
- Training, not just research - Development of formal training frameworks (e.g. facilities managers). Focus on it as a profession. Also, make provision for training the trainers

Group G: Understanding Non-Domestic Drivers of Demand

This group examined clusters 8a '*Energy decision making and implications at different levels*' and 8b '*How to understand decision making about energy efficiency decisions*', under the super-cluster '*Energy Related Decision Making*'

Key research questions?

- **Actual decision-making:**
    - Is an energy efficiency investment a separate (and different) decision to other types of investment decisions?
    - What factors influence energy decision making in each sector, subsector, segment?, for instance in relation to energy efficiency investment
        - What are the enabling and constraining conditions for energy efficiency investment in each sector and sub-sector?
    - Where, when and how do people make decisions
        - How does this differ in terms of individuals' profession and role within their respective organisations?
        - How do such decisions link to other decisions about buildings?
- **Data:**
    - How can energy management systems improve/change understanding of energy use?
    - How can we improve the use of data to measure changes in energy use, for instance to verify the savings?

    - What information do companies collect on energy use at present and why?
        - What do these companies do with this data?
        - Can we pool data? Good work in the US in some cities on opening up such data.
- **Rebound:**
    - How do savings on energy costs in companies get recycled? Do these lead to productivity gain?
        - Do energy efficiency improvements actually drive economic growth?
    - What is the real impact of rebound in non-domestic sectors (i.e. buildings and industry)?
- **Scaling Up Supply and Demand:**
    - How do you get aggregation of large energy efficiency projects in a region or segment of industry?
    - How to grow the project development chain, such as local, political support?
    - How do we increase the capacity for integrative design in building owners and designers?

What capabilities and capacities are required to address these questions?

- **Actual Decision Making:**
    - Business research made relevant to questions around energy use
    - Focus on energy research in management schools
- **Data:**
    - Data management and sharing
        - Technology is there, e.g. data warehouses exist, but how to get people interested in it, and once they're interested, get them the skills?
- **Rebound:**
    - Macro and micro understanding of rebound effect
    - Developing an agreed framework for understand rebound effects
- **Scaling Up Supply and Demand:**
    - Developing new mixes of skills - technical and political skills in one (you're dealing with local politicians)
        - Specific skills required include consultancy and leadership
- **Energy action research** - going out there, seeing it in practice, not just being in ivory towers or government offices. Dealing with the messiness of real-life situations.

Annex B: Agenda

Tuesday 5th Feb	
10.15	Arrival and Registration
10.30	**Session One:** ***Introduction*** Introduction to the purpose and process of this Expert Workshop and the overall development plan to create an Energy Research and Training Prospectus
	Discussions and activities to share current thinking in this key area of the energy domain in order to generate different perspectives and ideas on the challenges we are facing
12.30	Lunch
13.30	**Session Two:** ***Exploring the Research Themes*** Discussions and activities to identify and develop potential research themes from different perspectives
	Session Three: ***Reflection and Summary*** Activities to reflect on the various different emerging research themes and their relationships
17.30	Close
19.00	Drinks Reception and Dinner
Wednesday 6th Feb	
9.00	**Session One:** ***Introduction to Day Two***
	Session Two: ***Deeper Analysis of the Emergent Research Themes*** Discussions and activities to explore emergent research themes more deeply, with the aim of identifying drivers and barriers to these different future research themes
12.15	Lunch
13.15	**Session Three:** ***Further Development of Research Themes*** Discussion and activities to further shape the prospectus
	Session Four: ***Summary and Next Steps*** Plenary session to summarise and discuss the key outputs of the workshop, as well as the next steps in the development of the prospectus
16.00	Event Finishes

Appendix C: Attendance List

Surname	Forename	Organisation
Batterbee	John	ETI
Bell	Christine	Centre for Facilitation
Chapman	Nigel	Centre for Facilitation
Christie	Ian	University of Surrey
Curwell	Stephen	University of Salford
Danskin	Hunter	DECC
Eames	Malcom	University of Cardiff
Edrich	William	Yorkshire Energy Services
Fawkes	Steven	Day One Energy Solutions and Bglobal
Grünewald	Philipp	The Fellowship Team
Gupta	Rajat	Oxford Brookes
Hammond	Geoff	University of Bath
Hannon	Matthew	The Fellowship Team
Hargreaves	Tom	University of East Anglia
Hawkey	Dave	University of Edinburgh
Holtum	David	EPSRC
Jagger	Nick	University of Leeds
Janda	Katy	Oxford University
Kammerer	Iris	The Fellowship Team
Karvonen	Andrew	University of Manchester
Lipson	Matthew	DECC (Wednesday only)
Loveday	Dennis	Loughborough University
Lowe	Robert	UCL
Meagher	Sarah	DECC
Mourshed	Monjur	Loughborough University
Owen	Paula	Independent
Owen	Liz	DECC (Tuesday only)
Oxley	Stephen	DECC
Ozkan	Nazmiye	University of Westminster
Pfenninger	Stefan	The Fellowship Team
Roelich	Katy	University of Leeds
Schweber	Libby	University of Reading
Shove	Elizabeth	Lancaster University
Skea	Jim	The Fellowship Team
Stephenson	Peter	ESRC
Vuillermoz	Aurelie	EDF
Wade	Joanne	Open University
Watson	Jeremy	Arup