UKERC
UK Energy Research Centre

UKERC Interdisciplinary Review

Synthesis Report

Working Paper

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Executive Summary

The UK Energy Research Centre (UKERC) is funded under the Research Councils' Energy Programme (RCEP) to carry out 'whole-systems' interdisciplinary energy research, and to act as a central hub for University-based energy research in the UK. UKERC was created in 2004 under a 5-year award from three Research Councils: the Natural Environment Research Council (NERC), Engineering and Physical Sciences Research Council (EPSRC) and Economic and Social Research Council (ESRC). A Phase 2 programme of work was supported by the same three funding bodies between May 2009 and April 2014. A third phase of UKERC research will start in May 2014.

This report presents the results of a research project which undertook an analysis of UKERC's interdisciplinary energy research achievements: its strengths, weaknesses and lessons for the future. The review was carried out internally by staff from UKERC's Research Co-ordination and Meeting Place teams. The project included a review of the existing literature on interdisciplinary energy research, a facilitated group discussion convened at UKERC's Annual Assembly conference in July 2013 (n=15) , an online survey of the UKERC research community (conducted between July and September 2013) (n=90), and a number of semi-structured interviews with UKERC researchers, members of the wider energy research community and UKERC's non-academic stakeholders (conducted between September 2013 and January 2014) (n=18).

The analysis has highlighted many of the benefits and challenges of interdisciplinary research found in the wider research literature – and in energy and environmental domains in particular. Interdisciplinary research faces particular and persistent operational and strategic barriers, for both programme managers and individual researchers. Successful interdisciplinary research involves recognising these barriers, and explicitly and reflexively taking them into account in programme commissioning, design and management, and the findings reported here highlight a number of opportunities for improved interdisciplinary methods and practices for next phase UKERC.

At the same time, any individual research programme such as UKERC's has to work within the wider institutional framework and reward structures of academic research. The extent to which UKERC's interdisciplinary successes and limitations echo those of similar initiatives in the UK and elsewhere suggests that there are no easy routes to interdisciplinarity.

The project has highlighted a number of UKERC's interdisciplinary achievements, but also some weaknesses. There is clear recognition that UKERC has helped to build the

UK's interdisciplinary energy research capacity. Survey respondents overwhelmingly agreed that UKERC had helped develop an interdisciplinary community that will have an impact on future UK energy research and policy, and also, that their own involvement in UKERC had made them more likely to participate in interdisciplinary energy research in the future. A particular strength of UKERC research is its capacity to bring together different disciplines to address 'real-world' problems.

Although there was broad recognition of UKERC's impact in fostering space and capacity for 'problem-driven' energy research, it was seen as having been less pioneering, organisationally and methodologically, than some other initiatives, in terms of its interdisciplinary research methods or outputs. Survey respondents, interviewees and group discussants highlighted a tendency in UKERC toward more compartmentalised multidisciplinary research rather than more integrated interdisciplinarity research.

The most common interdisciplinary research experiences in Phase 2 UKERC have been single scholars or small groups of project-based researchers, rather than cross-theme and cross-centre projects. This is also reflected on an emphasis (shared with other similar initiatives) on committed individuals in UKERC's interdisciplinary achievements. This suggests the need for more explicit attention in UKERC on interdisciplinary structures and processes, and perhaps greater methodological ambition. There were suggestions in the survey, facilitated group discussion and semi-structured interviews that more ambitious forms of interdisciplinarity within UKERC were possible, and desirable – for example, by designing the research programme more explicitly around 'big research questions', with whole systems interdisciplinarity built-in from the start, rather than being introduced through mid-phase 'Flagship' projects.

These limitations need to be understood in the context of the particular challenges – internal and contextual ¬ that have faced Phase 2 UKERC in realising its interdisciplinary ambitions. Internally, there has been a difficult balance to be struck between cohesiveness and openness in running a 'Core and Flex' funding model. The designation of around half of UKERC's Phase 2 research funds to a 'flexible research fund' (allocated through a series of open and competitive research calls) allowed the involvement of a wide range of research disciplines – as was intended – but this also undermined the prospects more ambitious forms of interdisciplinary research which rely on sustained cross-disciplinary understanding and familiarity. As compared to Phase 1, for example, UKERC Phase 2's more diverse (and temporary) research community is reflected in a reduced emphasis on whole system, Centre-wide 'Flagship' projects.

Contextually, UKERC Phase 2 has coincided with a framework of academic evaluation and reward (the UK Research Excellence Framework, or REF) which has tended to privilege monodisciplinary, individual research achievement above collaborative, interdisciplinary research and research-policy exchange. Less directly, Phase 2 has also been shaped by the increased urgency and politicisation of UK energy policy.

A repeated message – for research funding bodies as well as programme managers – was that the extra time and effort needed for successful interdisciplinary research needs to be explicitly acknowledged and built-in to budgets and programme design, with, for example, dedicated time and effort on interdisciplinary exchange, and support for cross-disciplinary 'translators'. There are persistent barriers between disciplines – both immediate linguistic issues and deeper-level epistemological differences – and addressing these attending to the hard details of research structure, organisation and processes.

As well as 'internal' matters for UKERC, there are implications here for the wider UK energy research system. For example, in enabling the well-recognised barrier to interdisciplinary to be overcome, survey respondents and interviewees identified the need for stronger collaboration between the UK's disciplinary-based research councils, and also, for UKERC, its funders and advisors to more clearly define its role in a UK energy research landscape that has rapidly expanded in Phase 2's lifetime.

While most UKERC researchers have a keen interest developing collaborations across disciplines, they are also concerned about the extra challenges of interdisciplinary research: operationally, the difficulty of combining disciplinary identity with interdisciplinary achievement, and strategically, the persistent barriers to funding, publication and career progression. Academic institutions and incentives still tend to privilege disciplinary-based identity and outputs. Ultimately, UKERC's interdisciplinary achievements and limitations cannot be judged in isolation: there is a widely-shared perception – among both researchers and stakeholders – that UKERC Phase 2 has operated in a challenging wider context. For those involved in UKERC, the benefits of interdisciplinary research outweigh the challenges, and the additional effort involved is seen as worthwhile. Above all, an interdisciplinary perspective is seen by the vast majority of those involved with UKERC as researchers, advisors or users, as being essential to fulfilling the UK's ambitions for societally and policy relevant research.

1.Introduction

The UK Energy Research Centre (UKERC) is funded under the Research Councils' Energy Programme (RCEP) to carry out 'whole-systems' interdisciplinary energy research, and to act as a central hub for University-based energy research in the UK. UKERC was created in 2004 under a 5-year award from three Research Councils: the Natural Environment Research Council (NERC), Engineering and Physical Science Research Council (EPSRC) and Economic and Social Science Research Council (ESRC). A Phase 2 programme of work was commissioned in 2009, for a further five years. A third phase of UKERC research will commence in May 2014.

The research reported here is based on a project commissioned by UKERC's independent Research Committee to review UKERC's research programme in terms of its interdisciplinary research achievements, challenges and lessons learned. The project was carried out internally, by staff drawn from UKERC's Research Co-ordination and Meeting Place teams.

The project includes a review of the existing literature on interdisciplinary energy research, a facilitated group discussion convened at UKERC's Annual Assembly conference in July 2013 (n=15) , an online survey of the UKERC research community (conducted between July and September 2013) (n=90), and a number of semi-structured interviews with UKERC researchers, members of the wider energy research community and UKERC's non-academic stakeholders (conducted mostly in September and October 2013) (n=18).

Chapter 2 of this report presents the outcomes of the facilitated group discussion; Chapter 3 presents the survey results and Chapter 4 presents the results of the semi-structured interviews; Chapter 5 offers some conclusions and recommendations. The rest of this chapter provides an introduction to UKERC.

1.1 Introduction to UKERC

Phase I UKERC (2004-2009)

UKERC was created in the early 2000s, at a time when UK energy R&D was starting to recover from a very low base. Its genesis was the Chief Scientific Advisor's Energy Research Review Group (ERRG), which reported to the wider Cabinet Office PIU Energy Review in 2002. In calling for the creation of a national UK energy research centre, the ERRG emphasised the need for a multidisciplinary approach:

The research challenges are many and diverse. Nearly all cross the boundaries of physical science, engineering, environmental science, socio-economic and socio-

political sciences, and life sciences … A multidisciplinary approach is essential in this area as the socio-political and regulatory regime, environmental and health impacts and public acceptability must all be taken into account in the development of technological solutions to future energy supply (Energy Research Review Group, 2001).

UKERC was duly launched in 2004, tasked with running its own whole system research programme and networking wider UK energy research activities. However, rather than a single site national centre, as the ERRG had envisaged, UKERC was created as a distributed centre through a collaboration between eight universities/research institutes, with its HQ at Imperial College. It was also awarded a significantly smaller budget (c. £3m per year) than the £10m per year recommended by the ERRG; though often referred to as the 'flagship' centre of the Research Councils Energy Programme (RCEP), UKERC has in practice always been a very small fraction of overall RCEP spending (Figure 1).

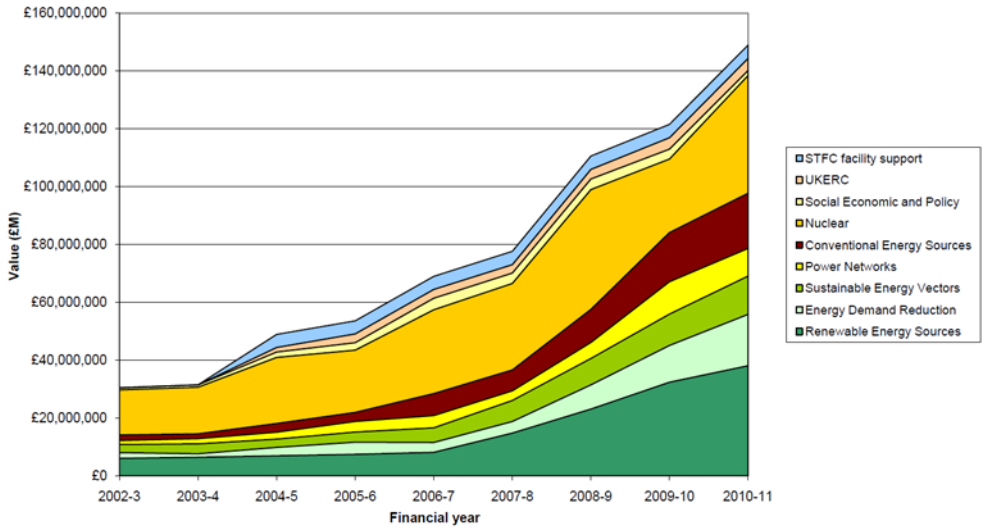

Figure 1: Research Councils' Energy Programme, Annual Expenditure by Research Theme (Source: Research Councils UK, 2010, Research Councils UK Review of Energy in the United Kingdom Research Councils UK, Swindon)

In its first phase (2004-09) UKERC's research programme was organised thematically, with three vertical, domain specific themes (each led by a different university): demand reduction, future sources of energy and infrastructure and supply; and three horizontal, cross-cutting themes: systems and modelling, environmental sustainability and energy and materials.

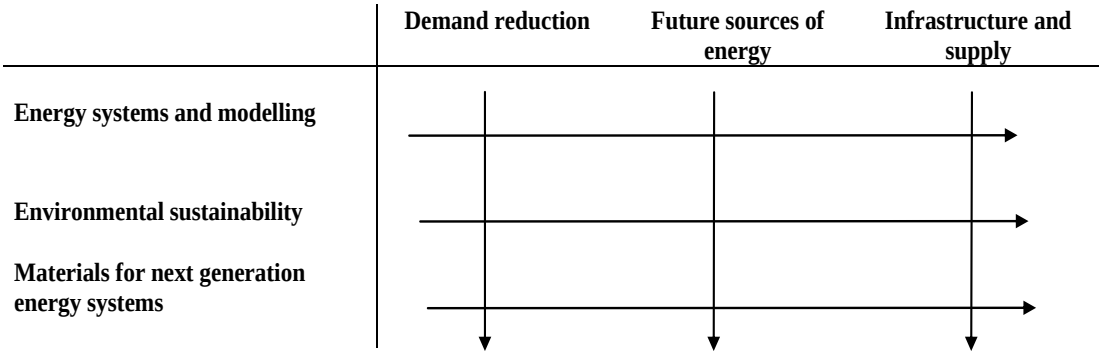

Figure 2: UKERC Phase I Thematic Research Programme Structure (2004-2006)

Mid-way through Phase I, a view developed among UKERC's senior researchers that the thematic structure was consolidating silos rather than promoting inter-disciplinarity. This prompted the creation of an 'integrating project' (known later as the Energy 2050 project) which was structured in a more networked, problem-driven way. The Energy 2050 project was designed a vehicle for interdisciplinarity in UKERC I, deliberately creating interdependencies between different themes and institutions.

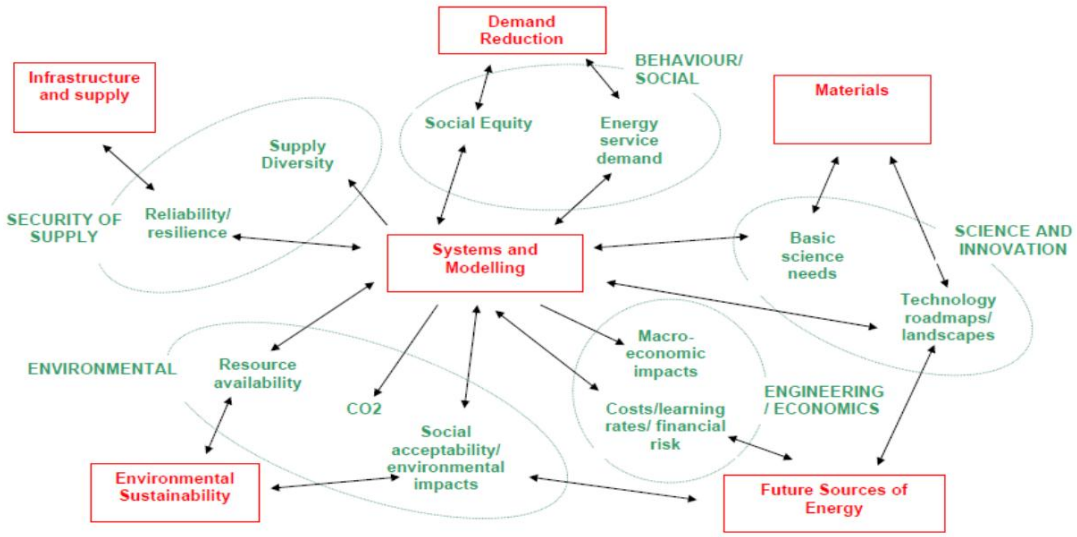

Figure 3: UKERC Phase I Networked Research Programme Structure (2007-09)

Phase II UKERC (2004-2009)

UKERC Phase II includes three main areas of activity: an interdisciplinary, whole-systems, problem based research programme; capacity-building activities through interdisciplinary PhD training, support for early stage career researchers and informal networking opportunities for UKERC members; a range of knowledge exchange activities aimed at reinforcing the cohesion of the wider UK energy research community.

The UKERC II funding model differed significantly from Phase I. While Phase I operated as a conventional consortium of a small number of 'core' partners across 5 research themes and funded over its entire 5-year duration (see Figure 4). Phase II issued half of its research funds through a series of competitive research calls.

UKERC's Phase II research programme has been structured into five themes: Energy Demand, Energy Supply, Energy Systems, Energy & Environment and Technology and Policy Assessment (TPA). Research in each theme is based around a key aspect of the energy system. The only exception is TPA, which reports on topical issues that are of direct relevance to the wider stakeholder community through a meta-analytic framework of existing research. The themes have been set up to be problem-based, not discipline based .

While the division in themes was mainly followed for managerial reasons, an effort has been made to support different levels of interdisciplinarity, i.e. across the research themes, at project level and at individual researcher level. Cross-theme collaboration is actively encouraged and a number of cross-cutting inter-theme projects have been undertaken. This includes the two Phase II flagship projects Energy Strategy Under Uncertainty and UK Energy in a Global Context, and a number of synthesising projects at the level of research themes.

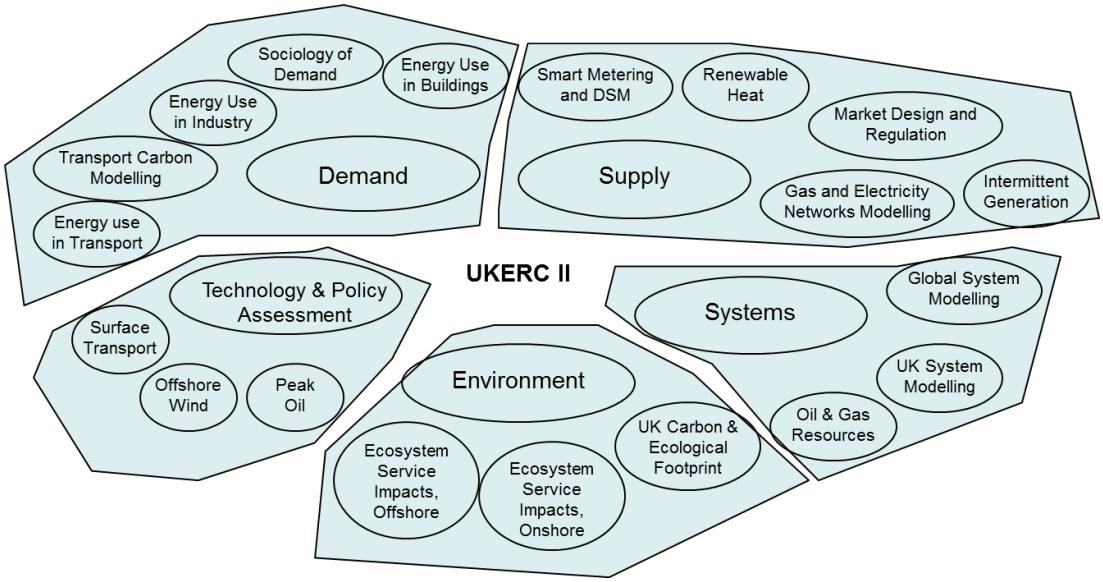

Figure 4: UKERC Phase II Networked Research Programme Structure (2007-09)

By 2012 this 'Core + Fund' model had transformed the make-up of UKERC, and UKERC II is characterised by much wider disciplinary participation than UKERC I, across the environmental sciences, engineering and physical sciences and social and economic sciences. (An explicit request from the Research Councils was that Phase II UKERC include bigger contributions from the social and environmental sciences).

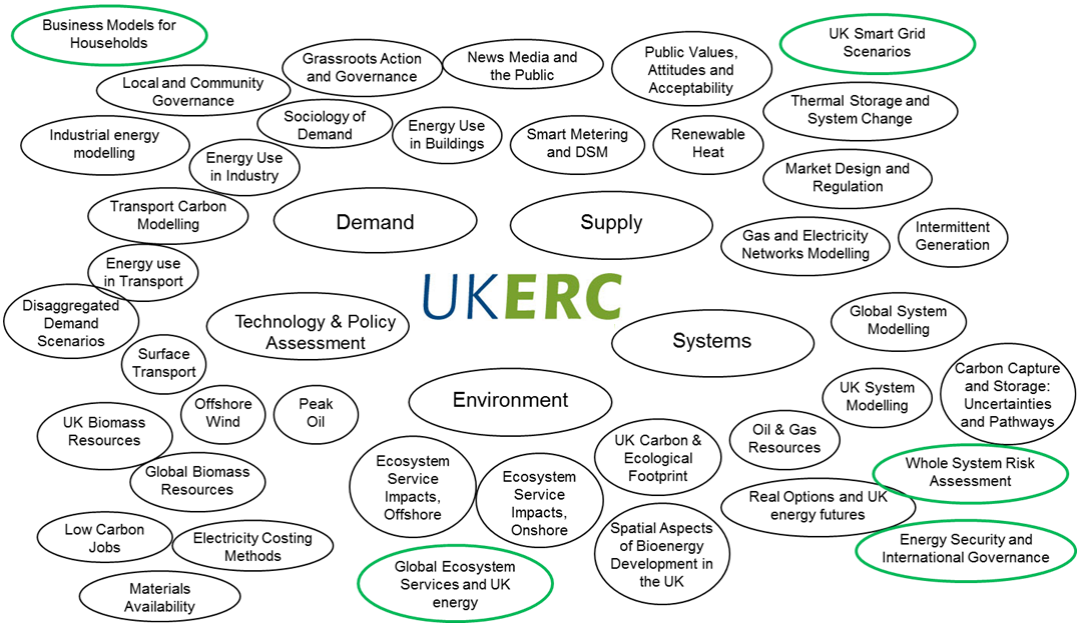

Figure 5: UKERC Phase II Core+Fund Research Programme (2012)

By 2012, UKERC II included 5 research themes, 16 Core projects (including 10 'tied' PhD studentships), 16 Research Fund projects, 6 'Technology and Policy Assessment' projects, 7 interdisciplinary studentships and over 150 investigators, researchers, students (around 50 FTE at peak). This meant that the UKERC II research funds (around £12m over 5 years, including non-research activities, were spread more widely and thinly than in Phase I.

UKERC II's Research Fund provided a source of flexibility and responsiveness in fast-changing times, introducing new skills and disciplines, and fulfilling the request to raise the profile of social and environmental disciplines. All the Research Fund calls for proposals emphasised the interdisciplinary dimensions of research and the links between specific research projects and the wider UKERC research programme.

As a result, UKERC II was characterised by much wider disciplinary participation than UKERC I, across the environmental sciences (biological sciences, ecology, environmental risk management) engineering and physical sciences (mechanical engineering, electrical engineering, buildings physics, systems engineering) and social and economic sciences (economics, political science, psychology, sociology, human geography, media studies, innovation studies and management science) (Table 1).

The Research Fund has presented greater challenges in terms of the coherence and integration of UKERC's research programme (and in anticipation of this challenge, UKERC II included a strengthened management and governance structure, with a dedicated three-person Research Co-ordination Team and an independent Research

Committee). Even so, the 'Core + Fund' funding model has involved a trade-off between flexibility and diversity, and integration and coherence. Even with the strategic direction offered by its Co-Directors, Research Co-ordination and Research Committee, the Fund has introduced a diverse set of projects and researchers, with new projects, researchers and disciplines introduced in each funding round.

Theme	Funding Model	No of Researchers	Main Disciplinary Backgrounds
Energy Demand	Core	13	Psychology, geography, physics, engineering, chemistry, transport management, marketing, business, political science, anthropology, sociology
	Flexible Fund	29	
Energy Supply	Core	10	Engineering, building services, chemistry, sociology, psychology, human geography, computer science, physics
	Flexible Fund	18	
Energy Systems	Core	10	Economics, mathematics, physics, engineering, geography, political science, geology, chemistry, chemical engineering, biology, energy planning
	Flexible Fund	26	
Energy & Environment	Core	19	Ecology, environmental law, biology, physics, geography, chemistry, oceanography, economics, geology, engineering, mathematics
	Flexible Fund	26	
Technology & Policy Assessment	Core	6	Economics, chemistry, engineering
	Flexible Fund	2	
Research Coordination	Core	4	Innovation Studies, engineering
Total of core programme		62	
Total of flexible fund		101	
Total		163	

Table 1: Core and Research Fund researcher allocation by theme

As well as the personnel and team-building challenges involved here, this has meant some conceptual and intellectual challenges. Inevitably, there are tensions as well as synergies between different disciplines, and the different values, approaches and

methods of different disciplines are not always easy to combine. For individual researchers, too there has been at times a trade-off between disciplinary and cross-disciplinary work. UKERC II has coincided with the UK's Research Excellence Framework (REF) which has tended to give priority to individual and disciplinary-based research outputs.

2. Facilitated Group Discussion

2.1 Introduction

Two members of UKERC's Research Co-ordination team (Mark Winskel and Ioanna Ketsopoulou) ran a facilitated a group discussion on interdisciplinary energy research during UKERC's Annual Assembly 2013. The meeting, on 10th July 2013 at the University of Warwick, was held under the Chatham House Rule, to encourage open and frank discussion. The discussion – which lasted around 90 minutes – was recorded and fully transcribed. This chapter is based on an edited transcript of the discussion. Particular insights, or particular recommendations for UKERC's future research design and modelling, have been emphasised by underlining.

The UKERC Annual Assembly – a 48-hour residential conference held over 3 days – has been a regular part of UKERC's annual calendar of Centre-wide meetings since 2004. The 2013 Assembly was attended by almost 100 academic researchers and support staff. The interdisciplinary group discussion was held in parallel with a number of other research meetings, which restricted the numbers of those able to attend. Nevertheless, the discussion attracted 15 participants, representing a diverse mix of: *research areas* (from across UKERC's engineering, environmental and social science research interests and funding bodies), *career stages* (from PhD students to senior researchers), and *job roles* (including researchers directly involved in the UKERC research programme, external researchers with other experiences of interdisciplinary energy research), and advisors and stakeholders from UKERC's Research Committee, Supervisory Board, and non-UKERC researchers).

At the start of the meeting each participant was invited to describe their own work experiences and disciplinary identities. This revealed a wide variety of disciplinary identities and career paths, including: innovation studies (originally physics and environmental technology); civil engineering; applied economics and modelling; economics and policy; social science and policy (originally music and environmental technology); chemistry and materials science; interdisciplinary industrial engineering (originally combustion engineering); energy technology, economics and policy (originally physics and economics); social science – energy and society (originally environmental sciences / physical geography / modelling); energy economics, energy systems modelling and integrated assessment / climate science (originally engineering and economics); social science, psychology and human geography (originally sociology); energy systems analysis and engineering (across all four main types) (originally physics); applied physics and computer programming (originally environmental sciences); technical and non-technical aspects of energy efficiency

and public engagement (originally engineering); social and physical sciences on renewables (originally physical sciences).

It is notable that a number of the participants were reluctant or struggled to describe themselves in disciplinary terms, or to associate themselves with disciplinary identities. As the descriptions given above suggest, many of those participating saw themselves as having multiple roles and disciplinary identities – often simultaneously – and as having careers which have spanned across disciplinary boundaries. As a self-selecting group interested in interdisciplinary research, this is perhaps unsurprising, but it highlights the complex and multiform character of interdisciplinary-oriented researchers.

Following the tour of the room the meeting chair, Mark Winskel (UKERC Research Co-ordinator), introduced UKERC's interdisciplinary review project and gave a short outline of the interdisciplinarity research elements of UKERC Phase I and Phase II. He also introduced the different forms of *interdisciplinarity* described in the wider literature, from relatively weak (*multi-disciplinarity*) to strong (*transdiciplinarity*) forms; each is associated with different research methods and design.

After the introductory presentation the group discussion was largely free-flowing, allowing participants to raise issues and respond to each other's remarks, but loosely guided along the following themes (developed in advance by Mark Winskel and Ioanna Ketsopoulou):

- ***Motivations and Barriers.*** *Does interdisciplinarity matter? Is working with other disciplines an important part of your research? What are the main drivers for interdisciplinary research? What are the main barriers?*
- ***Experiences and Recommendations.*** *How well do you think UKERC has worked as an interdisciplinary research centre? Which parts of UKERC has been more or less successful? How does UKERC compare to other interdisciplinary research programmes, in your experience? Do you have any suggestions for improved ways of interdisciplinary working?*
- ***Engagement.*** *Should non-academic stakeholders (policymakers, businesses, NGOs, civil society) play a more important role in UKERC research?*

Individual identities have not been revealed in the report that follows. The following codings are used – based on broad categories of job roles and career stage:

- EC1, EC2 etc. = Early Career Researchers (PhD Students and postdocs with less than c.5 years' experience)

- MC1, MC2 etc. = Mid-Career Researchers (researchers with at least several years of research experience)
- SR1, SR2, etc. = Senior Researchers (researchers with senior roles and decades of experience)
- SA 1, 2, etc. = Stakeholder advisor 1, 2 (senior figures from industry, policy etc. who have an advisory role within UKERC).
- MW = Mark Winskel (Chair, when asking questions)

2.2 Motivations and Barriers

We are a very biased sample, in that the fact that we are here, in UKERC and this group, means that we think that interdisciplinarity matters. Otherwise I would just sit in my home discipline and department, and have a much easier life [MC1].

I totally agree – inter-disciplinarity work is a pain – you put up with the pain because you have research questions that exercise us individually that you want to pursue, that require interdisciplinary working; they are often societal problems [MC2]

Interdisciplinarians tend to be problem-focused, not discipline-focused [SR1]

It's difficult, but not a pain – it's stimulating and enjoyable to try and understand the implications of one discipline's insights for another. If there's such a thing as weak or poor inter-disciplinary research, it can be due to underestimating the difficulties involved, and assuming it will happen automatically. The result can be a patching-together of work which isn't complementary or has any real cross-over or added-value. The difficulties need to be acknowledged and built-in to the planning stage [EC1]

It's useful to [distinguish] between the project you are involved with compared to the academic position you have. The UK provides a lot of freedom to do interdisciplinary research compared to other countries. [MC2]

The REF [Research Excellence Framework] is a fundamental barrier as it's discipline based. Career progression is often strictly defined by disciplines. There is funding for inter-disciplinary PhD studentships, but the students often have problems with career progression. You need … support from … your academic village / profession. The question for candidate lectureships is often 'what can you teach'? I've pretended to be a more conventional disciplinary-based academic, just to get in the lectureship door [MC2]

Inter-disciplinary research projects can be fun, but there are problems in terms of career progression. Senior academics who are successful interdisciplinarians, often

do inter-disciplinary research after they've reached the top-level within their discipline. We now have a lot more interdisciplinary PhDs, but the question is how will these people progress within established academic structures? [MC2]

Some people do extra disciplinary-based research on the side, to tick the boxes and get lectureships. Even with the new interdisciplinary funding streams, it's not really changed. [MC3]

Can you get back into being a disciplinarian once you've done interdisciplinary work? [SA2]

It depends how far you go – how much you have 'sinned' [MC1]

There's a lot of maintenance needed to be at the top of your research field, and that's very difficult for one person try to keep on top of multiple disciplines [MC4]

Inter-disciplinarity is not suited for everyone – some researchers try working out of their discipline and then go back [as] they find it very uncomfortable … many people are not confident to speak outside of their field [SR3]

For hard sciences, doing more applied work can be seen as a 'soft option'. Scientific journals tend to be very disciplinary based. The prestige journals in engineering, and the big institutions – think of the engineering institutions – tend to be very disciplinary based. Teaching departments at universities tend to be traditionally arranged – we're mostly not teaching in interdisciplinary energy institutes. [SR2]

That said, many universities are now setting up inter-disciplinary energy institutes, and often they are engineering or physical sciences-led. [My organisation] always tries to encourage the social sciences to be brought in. That's why UKERC is so valuable, because it ensures that the different disciplines are brought together [SA1]

From a research funding point of view, it's now good to be inter-disciplinary [but] there is a time-lag between funding and career assessment. Research funding has become interdisciplinary, but publishing and research assessment haven't [SR2]

At [my university] there are a range of social and technical scientists working on energy – the institutional boundary is based on the problem – that has to be 'energy' rather than wider environmental issues … [so] there are new kinds of boundaries and divides, but defined in terms of the topic focus of the research, rather than the contributing disciplines [MC6]

[My] university took a conscious decision to create inter-disciplinary hubs on energy, water, food and others; all are interdisciplinary, though some are more multi-disciplinary. The hubs are problem focused, but everyone is based in a home

disciplinary department – it doesn't threaten or dissolve the home departments. The interdisciplinary institutes are seen by our VC as relatively temporary organisations that may come and go: 'we'll still have a chemistry and history department in 100 years, but we may not have an energy institute' [MC5]

What's struck me most since joining academia is that this discussion wouldn't happen anywhere else. Inter-disciplinary team working happened all the time [in my previous job, in a policy institute] – I managed a team of 30 people made up of engineers, lawyers, economists, political scientists, geographers etc. I knew that the different people brought complementary skills, and if I'd had been asked I would have said this was interdisciplinary, but it wasn't an obsession. In academia you get asked 'what are you?' – your disciplinary identity matters. To me it's great when younger academics reply 'I don't know / I don't have one'. It's great that there are single people who span the disciplines on these issues. The civil service is based on generalists. [MC5]

But academia is based on expertise, so in a sense we are expected to be disciplinary [MC3]

And in industry you still end up working in silos – it's just that they are different silos [SA1]

Every organisation creates its silos for logical, management reasons. In a sense this is out of the control of UKERC, and we just have to live with it. We – and UKERC – can't change how our home institutions, or stakeholders, or funders, organise themselves. We have to work with the way they are [SR1].

UKERC aspires to do policy relevant research. While it is possible to do disciplinary-based policy-relevant research, policy-makers are often naturally trying to understand multiple dimensions of the problem, so if you can offer that, you're more likely to have a positive reception [MC5].

I find it unhelpful when academics introduce themselves to non-academic audiences by their discipline [MC4].

But doesn't the policymaker want need to be assured about where they get their advice from, their credentials? Presenting yourself as somebody who knows about everything won't be very convincing. Belonging to a particular discipline gives you credibility, that shouldn't be dropped entirely [SA2].

You still need a way to introduce yourself, credibly – that's not unique to academia [MC]

One reason why inter-d is important, and why coming to UKERC events is valuable for academics, is because it gives you an awareness about how your work is being received by others disciplines and by non-academics, and how you interpret work from other disciplines [MC3]

What about when there are disagreements between disciplines about what the 'right answer' is? … In UKERC we had some experience of this in phase 2, and it's hard to reconcile. The specific problem we had was that claims for the implications of the work were being made which were not seen by some as being well based – it meant we had to recognise the concerns of disciplinary-based expertise [MC4].

There will be differences between disciplines, for example between economists and sociologists. [SA2].

Language is often the problem. You have to convey ideas in an understandable language for other disciplines. While you share the same specialist language and terminology [within] your discipline, it's important to use more accessible terms when relating to other disciplines. This matters when putting together interdisciplinary proposals … the ability and preparedness to put things in terms intelligible to [different] communit[ies] ... Insisting on only using the precise terms used within a discipline is bound to be a barrier[MC5].

That seems to be an important point: if you're only working within your one discipline you are working with your disciplinary peers, whereas if you are problem-oriented … working across disciplines and audiences you need to use a different language [SA2].

Another condition / criterion for success is getting on with people, because you need to have more patience – because others will speak in a different dialect from you. Within a discipline, working with colleagues can happen more easily … to work in an inter-disciplinary team, there needs to be a willingness to put in that upfront investment, and go the extra mile. It's more important to get on with the people you work with. This takes time and is an extra investment [MC2].

That's absolutely the key point about interdisciplinary working. There's often an assumption that if you just put people in the same room then interdisciplinarity magically happens –it doesn't. For example, I'm engaged in an interdisciplinary project team, with a lawyer, a property specialist, a sociologist and engineers; it took us about six months of meetings, meeting once a month, just to pick apart each other's terminology, ways of thinking, technology, research method, what is deemed to be good or indifferent work, and the pace of work. It took ages to figure that out, but now, as a group, we've been working together, writing papers, putting in grant

applications for about three years, and I'm sure we'll stick together for quite some time to come, but we needed that overhead investment in spending time figuring out how each other thinks. That cannot be under-estimated. If future UKERC wants to address interdisciplinarity in a more formal way, spending some money to give people the time to figure each other out is worth its weight in gold [SR1].

We've defined inter-disciplinarity in terms of being problem-driven and bringing different disciplines together to work on a common problem, but if that problem isn't sufficiently well-defined, that can be a real barrier to interdisciplinary working. I've been involved in projects where the defined problem would appear to allow different disciplines to contribute, but in which the specific problems that the different disciplines are addressing are actually so far apart, that there is nothing that they can say to each other [EC1].

That's fine, if you want the different bits of the problem to be addressed by different disciplines – for social scientists to work on one bit, and engineers on another – but not if you intended a genuinely interdisciplinary project. To achieve that, you need to think about the problem definition and the way that different discipline … are going to meet in the middle of the problem, rather than be at two opposite ends [EC1].

What about the difference between more integrated and more decentralised versions of energy futures, based on either engineering models (integrated) or sociological (decentralised) versions of the futures – can, or should, they be made compatible? Should we try to reconcile them for policymakers – or is that just likely to mislead? Perhaps we should just be clear what different disciplines are saying about a problem, and what assumptions and evidence those differences are based on, rather than trying to force things together [MC4].

That isn't an interdisciplinary problem definition – that's people with different criteria and insights. I had in mind a technology-based project, where all the technologists were looking at long-term materials, technology and supply chain development, and the social scientists were looking at public acceptability issues. They were so far apart, they couldn't come together [EC1].

You sometimes get marriages of convenience, rather than collaboration on problem definition. I've been in industrial projects like that – the collaboration is motivated by an awareness that there's a funding opportunity. What you tend to end up with is a bag-of-bits rather than a creative interdisciplinary project. What defines proper interdisciplinary working is that they have integration through proper project management – that's crucial [SA1].

That's as much about good team and project management as interdisciplinarity [SR1].

It's also about valuing other disciplines. [MC3]

If you don't think other disciplines have anything to offer then that's going to be a problem. [MC5]

I've met colleagues who think interdisciplinarity is just a way to extend their discipline, rather than learning something from other disciplines. Researchers need to think that other disciplines will bring something additional [MC4].

It takes time and effort to work in an interdisciplinary way. It's about learning other languages, it only happens through personal contact … to understand the language of different disciplines. Limited project time can be a problem. That implies that a single project needs to have a minimum length. If you only have six months it's not going to work, because you need at least that time just to understand each other [SR2]

Sometimes the issue is that when designing a project you don't realise what skills you are lacking and what skills are needed. Future UKERC needs to think what disciplines are needed. For example in the UKERC Research Committee, we realised we need political science insights on gas futures, so we had to go out and acquire that expertise [SR2].

UKERC needs to think about where it is deficient: for example, on health impacts of energy, we have very little expertise; also, given that UKERC is predominantly EPSRC funded, there is little technical or engineering expertise. We need to consciously think about what disciplines we need to tackle the problems, and then 'marriage broke' to an extent – that would probably lead to better answers. [SR2].

There's probably a perception that UKERC has become more about the social and environmental sciences, at least among the engineering community – precisely those areas where we were perceived to be weak at the end of phase 1. [MC4]

The question was asked at the end of Phase 1 about whether UKERC needed to carry on doing social science, and I among other argued 'yes', but what's needed are social scientists who can communicate with engineers – learning the language and having the dialogue. I think that's what UKERC does, and I think there's a wider perception that that is what the energy sector needs. [SA1]

Interdisciplinary work is about people. Of course, I think fundamentally my own discipline is the best one. I'm not really interested in other disciplines, but I am interested in smart people from other disciplines. I find those people because they publish something interesting and well-informed in policy journals – and so I want to interact with them. I've had very different experiences – in a former department, I

met someone identifying themselves by an abstract sub-disciplinary term, and I knew I had nothing to learn from them. We're talking about labels and disciplines, but for me it's really about people. I don't have any textbooks from other disciplines on my shelf, but I have lots of business cards of people working on other disciplines. When I'm writing a proposal, I don't say 'I need an electrical engineer for that bit' I say, oh, that guy knows something about that, I'll ask him [MC1].

If the project is well defined, that really helps. The work we are now doing couldn't be addressed without all the different disciplines working together, but people need to be very clear on what they are expected to contribute, and what the final outcomes will be [SR4]

It's almost as though you need a six-month grant to work out what disciplines are needed, get the conversations going, what the problems are, and only then apply for a research grant, rather than just conventionally responding to a call.[MC3]

There are different models. In one model, if we are engaged in giving very practical answers to real world problems, the solutions aren't likely to be academic ones. In those circumstances it seems disciplines can combine together and they almost stop identifying themselves as being from a particular discipline. Then there is another model, in which the need is identified for particular disciplines, and disciplinary gaps are identified and filled – you get the lawyer or engineer to tell you something, and then he or she does that and goes away again. There are different models of working [SA2]

A lot of what appears to be interdisciplinary, in terms of the call and the proposal, is much more conventional, based on home disciplines. [MC5]

Q. Why is it that some disciplines have a really hard time working together? [MW]

One problem is that people identify and introduce themselves as belonging to sub-tribes within their discipline, rather than their broader disciplinary affiliation. People then break their departments into sub-departments … For some economists, being inter-disciplinary means as a labour economists working with environmental economists, whereas UKERC tends to talk about engineers working with economists. [MC1]

We can understand this as the distance between disciplines; and some disciplines being further away than others. The only way to reduce the distance is by learning the language, or finding someone else who can translate, or having a beer with them (which always helps). As an economist, I can learn the language of psychology to an extent, but unless I can find someone who is willing to narrow the distance, through

their willingness to engage or their personality, it doesn't work – that's why I'm always looking for people. [MC1]

That came through in the quiz last night, when there was specialist knowledge and symbols being used. That can lead to confusion. [MC5]

2.3 Experiences and Recommendations

UKERC was invited to work with a particular funding model for phase 2. That has presented some problems for interdisciplinary integration – for example the time needed to build up understanding hasn't been possible for some of the shorter research fund projects, beyond the small team of researchers directly involved [MC4].

It's important to note that UKERC is trying to do two things which I think are equally important. It's not only expected to be inter-disciplinary, but also whole-systems. When you look across the energy programme, there are very few other things like that. There are a lot of interdisciplinary things in more specific technology areas, but UKERC takes a whole-systems view, while recognising there are different system levels [MC5].

I used to work on another project that was not just focussing on energy: there was a population group, a land-use group and an energy group, and comparing that to UKERC, I find that in UKERC … it has to be defined as energy … or it's not feasible for UKERC. The other initiative was designed to be as flexible as necessary to deal with real world problems; to that extent, UKERC is unable to compete at that level of interdisciplinarity. A focus on 'energy only' can be a barrier. Some questions cannot be dealt with although they are important. Climate issues are an example.[MC6]

I think some of that may need to change, given where the political discourse is, and the imperatives on the funding bodies: e.g. the emphasis now on economic growth and recovery, and whether green energy is an inhibitor or enabler of growth … I think UKERC will have to expand into those areas, especially, the role of energy in the wider economy. [MC5]

There are some concerns about over-extension here – UKERC knows about energy systems, but not really water, food systems. Should it be seeking to cover those areas, given its limited resources, and also that the RCs address other parts of the nexus in different ways – e.g. the new Nexus network initiative by ESRC? [MC4]

It depends on how you see yourself. I see myself as an energy researcher, rather than a climate change researcher – that's partly because I was doing energy research before climate change became a powerful issue, and I see energy as much as being about security and affordability issues as climate. I find the distinction between energy and climate research a helpful one, but I realise others may not. [MC4]

What else works well? The inter-disciplinary studentship scheme – no one else would do that across the Councils; the summer school, which provides a fantastic experience; the Assembly and General Meetings, because they are large enough and have enough time to allow for interaction with different disciplines. Face-to-face meetings are good to bring people together, and without them it would be difficult to forge cross-disciplinary partnerships. [SR2]

Tyndall does have an Annual Assembly also, but having the [UKERC] General Meetings as well really does make a difference in helping to bring people together regularly [MC3].

From an inter-disciplinary studentship view, the community that UKERC offers has been very helpful, in terms of meeting other students and academics who are also doing interdisciplinary research. Your supervisors aren't necessarily doing inter-disciplinary research, so having that community and support – and the summer school – is really important. I know that students on NERC-ESRC joint awards haven't necessarily had that same network of support, and have found it more difficult. That's been a real positive. [EC2]

Q. Are there ways to improve the annual assembly and general meetings? [MW]

Having very quick presentations are good, because they force people to focus and think about language. The scale and size of UKERC is also good and not represented in similar initiatives; for example, the Supergen bioenergy initiative: that achieved technical interdisciplinarity, but not much social science involvement. It was much smaller than UKERC, and that made a difference. [SA1]

One thing missing in Phase 2, and that has been lost, is a strong dialogue between social science and engineering. The engineering aspects have become very narrow, within the supply theme. I thought about that when I was listening to the supply theme integration project presentation: they were looking at narrow issues, there were a hundred gaps! I think the demand theme has remained broader, with still a good technical spread. But overall it means the full interaction across the key areas isn't happening in UKERC. [SA1]

It's been noticeable that the projects that have really come through Research Fund review and commissioning well have been from the social and environmental sciences, rather than engineering. [MC4]

For engineering, the limited size of UKERC grants is a barrier. Engineers would rather spend valuable time preparing grants for larger awards. I'm split between departments, and my engineering colleagues wouldn't get out of bed for less than a couple of million. Social scientists are delighted when they can get a few 10k! For a

social scientist, 50-100k is a meaningful project; that won't allow enough lab time for an engineer. [MC5]

You have to be careful, you will start driving UKERC in the wrong direction, if the suggestion is that it should commission £2m grants to engineers. Engineers will work for 50k, alongside their other activities, as long as you point out the impact that interdisciplinary working with UKERC can have in their other areas of activity.[SA1]

That's not true – the engineers I work with have bigger fish to fry and they're simply not interested in £50k opportunities. [MC5]

The problem is that time is so tight, and bang-for-buck, writing a 50k proposal probably still takes about half the time as a 2m one, so [engineers] focus on the 2m opportunities [SR1]

… and you don't have the transaction costs of interdisciplinarity, as we've been talking about [MC5].

For example, the 500k UKERC award on smart grids is split between 5 institutions. That's not to say it can't be done, but it's not so surprising that it's been more difficult to engage engineers in phase 2. Some people will get involved, but may others will see that the costs outweigh the benefits [MC5].

One solution here may be for UKERC to be part-funders of larger EPSRC / Supergen awards, so it doesn't need to wholly-fund 2m awards [MC3].

The current UKERC structure into research themes – supply, demand, systems and environment – can constrain inter-disciplinarity. Are there different ways to structure future UKERC, to be more problem-centred and encourage inter-disciplinarity? [MC3]

We should also talk about what UKERC hasn't been good at. There is now a lot of Supergen Hubs in particular areas, but they tend to exist on their own, and when they're asked what UKERC is, they haven't a clue. Perhaps we should bring them into the UKERC Assembly, invite guest speakers, and so we can better appreciate the technical challenges in particular areas – electricity networks, solar PV, marine energy – so UKERC could engage with the experts in those areas. A slightly expanded form of the Assembly – up to around 150 people – could still work. We also need better links with the EPSRC Doctoral Training Centres – some of those are quite wide-ranging – they could provide a source of student expertise for UKERC, without UKERC having to pay for them. EPSRC and the Energy Programme have set up a lot of different networks and centres, but there's no glue to hole them together. [SR2]

The Doctoral Training Centres are also an example of where engineers will get involved in inter-disciplinary working for relatively little resource – as little as one studentship perhaps [SA1]

From the outside, speaking as someone who has only recently joined the UKERC family, those of us on the outside perceived UKERC as a 'closed-shop', and not good at engaging with those who weren't UKERC, whether it was Supergens, or the wider research community, and who perhaps had something to offer. [SR1]

That feeling was stronger in Phase 1, flexible funding has helped to open-up the Centre [MC5].

Yes, but the problem is that during Phase 2 the wider energy research community has expanded dramatically, so there is a much bigger set of people who work on energy issues but who aren't involved in UKERC but who might feel they have something to offer. Even though UKERC itself has expanded rapidly in Phase 2, and is now around 200 people, as a proportion of the whole energy community, it has decreased.[MC4]

One way around this would be to invite guest speakers to the Assembly, for example from the Energy Demand Centres or the Supergens, without them becoming formal members of UKERC [MC3]

I think we've been focussed on integrating the UKERC community, as we've brought in new people with each successive Research Fund round, and we've spent less time thinking about how we could also include the wider research community.[MC4]

What about internal communications within UKERC – as the Centre grows, that becomes more and more of a challenge, and I wonder what the perception about that is within UKERC? [MC5]

There are a lot of internal communications and reporting requirements, to the extent that they drive me slightly mad, but which on another level make you feel part of the community. [MC3]

2.4 Engagement and Interaction with non-academic stakeholders

There is a suggestion that academic research should be more involving of non-academic stakeholders (policy, businesses and others) from the beginning – to co-design and co-produce its research. Should UKERC do more of that? [MW]

UKERC must retain its identity as an academic institution. There's a danger that UKERC becomes too much like a consultancy. [SA2]

On policy interactions: I know a lot of people [in UKERC] do excellent policy-relevant research, but there's an issue about timescales. It can be difficult to turn around policy questions, as they emerge. I think there might be value in a longer term, continuous strategic engagement with the policy community, to join-up with them on what are the current and future priorities, what is on the back-burner, what will be a priority soon, etc. Would a long-term strategic engagement be beneficial, rather than a more responsive interaction? [EC2]

The short answer is no, in my view. TPA already do this by setting up specialist steering groups for each of their projects, on a project-by-project basis, but it wouldn't be appropriate for the whole of UKERC, inviting 'the stakeholders' to comment on everything we do, it wouldn't work.[SR2]

I feel the opposite. I've been sat here for a long time in UKERC as the 'industry person', and I'm very aware that colleagues in industry are not aware of your projects, even though much of it is very relevant and could benefit them. That communication hasn't worked as well as it could have done, during both Phase 1 and Phase 2. [SA1]

It's possible just to circulate lists of upcoming activities – DECC now issue lists of the things they are going to fund, UKERC could also let policymakers know what research UKERC its going to fund [MC3].

UKERC has an industry newsletter… [SR2]

That isn't the level of engagement I'm looking for. I'm not suggesting inviting industry into the Assembly – that wouldn't work – but for Phase 3 UKERC there needs to be a vehicle for engaging with industry more actively. Not as consultants, or as a threat to the quality of what's being done. [S1A]

I agree, but the question is *how* – even when we engage, we assume the knowledge is being passed through the organisation, such as DECC, we find it hasn't – it just stays with the person you've engaged with. [SR2]

Industry engagement needs to be devolved down to the project level. At the moment that's happening, but its rather patchy, and it could be encouraged more widely, so it becomes more of the norm – while still leaving the final decision on the exact form it should take with the PI. [MC5]

3. Online Survey

3.1 Introduction

Within the overall interdisciplinary review project, the online survey provided an opportunity for the involvement of the entire UKERC phase 2 research community, and many of UKERC's academic and non-academic stakeholders.

The survey was designed by UKERC's Research Co-ordination Team. It was informed by issues raised at a facilitated group discussion convened during UKERC's Annual Assembly 2013, and by follow-up exchanges with some UKERC researchers, Research Committee and Advisory Board members. The survey included 23 questions, presented on an online platform, and open to invited applicants over several weeks between June and September 2013. As well as specific questions, the survey was designed with many 'free text' boxes to allow less constrained input. A full list of the survey questions is provided in the Annex.

Invitations were sent to all members of UKERC's Phase 2 research programme, including Core and Research Fund researchers from across UKERC's five research themes, non-research HQ staff and UKERC's interdisciplinary PhD research students.[1] Invitations were also sent to members of UKERC's independent Research Committee. As the next Section describes, the respondents (n=90) included a broad mix of researchers by discipline, seniority and role in UKERC.

The survey was structured in three parts:

- The first part provided information on the profiles of respondents – their career stage, disciplinary background and role in UKERC; the findings are presented in Section 3.2 of this chapter.
- The second – and largest – part of the survey explored respondents experiences of interdisciplinary research in UKERC and elsewhere, across several areas: UKERC's overall performance compared to other centres; particular elements that have worked well or less well; the way in which different disciplines were represented and interacted; the wider impact of UKERC's interdisciplinary efforts; and the motivations and barriers for researchers' involvement in interdisciplinary research. The findings are presented in Section 3.3 of this chapter

[1] Details of UKERC's research and non-research activities are available at www.ukerc.ac.uk

- The third and final part of the survey invited respondents to offer recommendations to researchers, research managers and funding bodies, as well as any general observations or comments. The findings here are presented in Section 3.4 of this chapter.

3.2 Survey Respondents

Status and disciplinary backgrounds

The overall survey response rate was 44% (90/206) – suggesting a significant level of interest in interdisciplinary research among UKERC researchers. Survey respondents came from a range of academic positions by seniority (Figure 6).

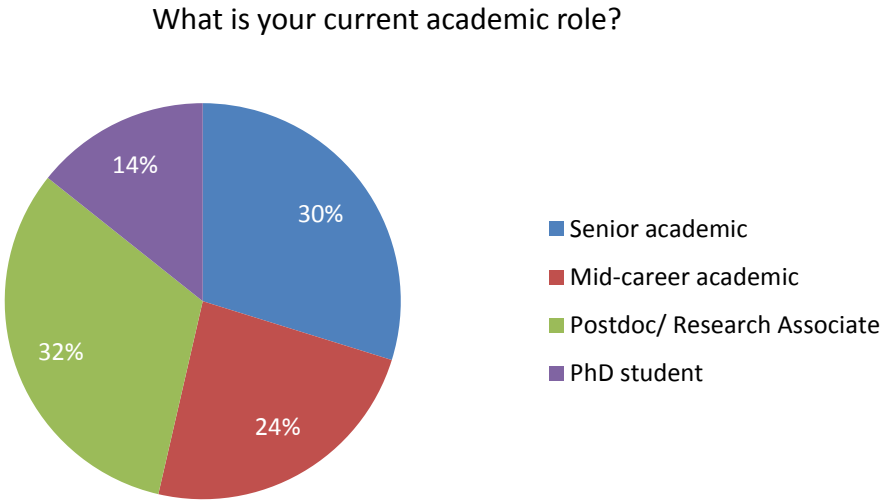

Figure 6: Survey respondents by career stage

Respondents were also drawn from a range of broad disciplinary identities (or 'macro-disciplines') spanning the Centre's cross-disciplinary remit and funding bodies, including social sciences; engineering and physical sciences; economics; and environmental and biological sciences (Figure 7).

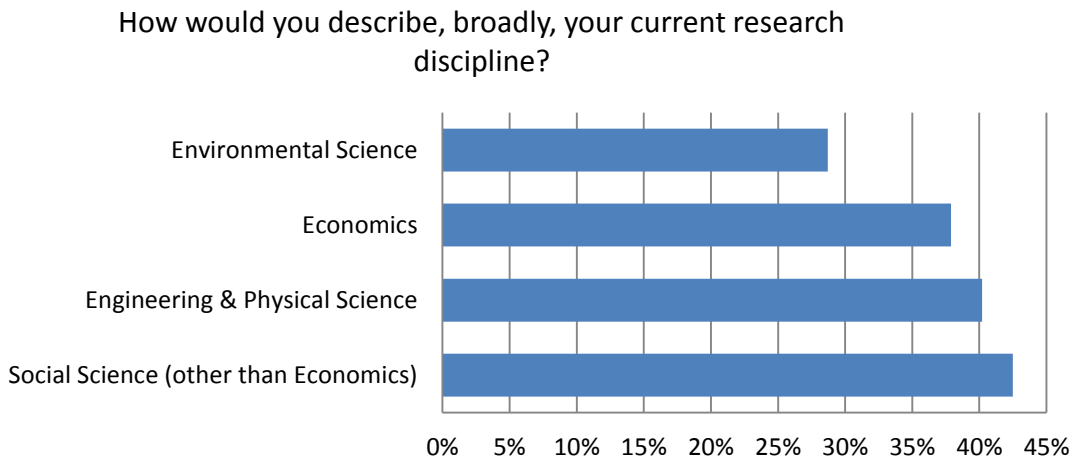

Figure 7: Respondents' self-declared disciplinary backgrounds

A small number of respondents – all senior or mid-career academics – identified themselves with multiple macro-disciplinary identities. A few respondents' comments highlighted the difficulty (or even irrelevance) of disciplinary identity, as their expertise has shifted over the course of their career.

> *'I don't think of being in a discipline any more'*
>
> *'engineering originally, but now a social scientist'*
>
> *'generalist, but most comfortable at the … boundaries'*

Beyond these macro-level disciplinary identities, a variety of more specific disciplinary identities were revealed in respondents' comments. Self-defined sub-disciplines mentioned here included some familiar and established academic disciplines, such as human geography, ecological economics, mechanical engineering and oceanography, but also some highly applied and quite specific identities that don't fit easily into established academic structures, including energy policy, energy demand reduction, energy modelling, ecosystem services, technology policy, risk and uncertainty modelling, and human-centred design.

Research roles in UKERC

A range of research roles in UKERC were represented in the survey, including researchers, co-investigators, principal investigators and interdisciplinary research students (Figure 8). A number of respondents declared more than one role and participate in a number of projects. Other participants included members of UKERC's Research Committee, Supervisory Board and Advisory Group.

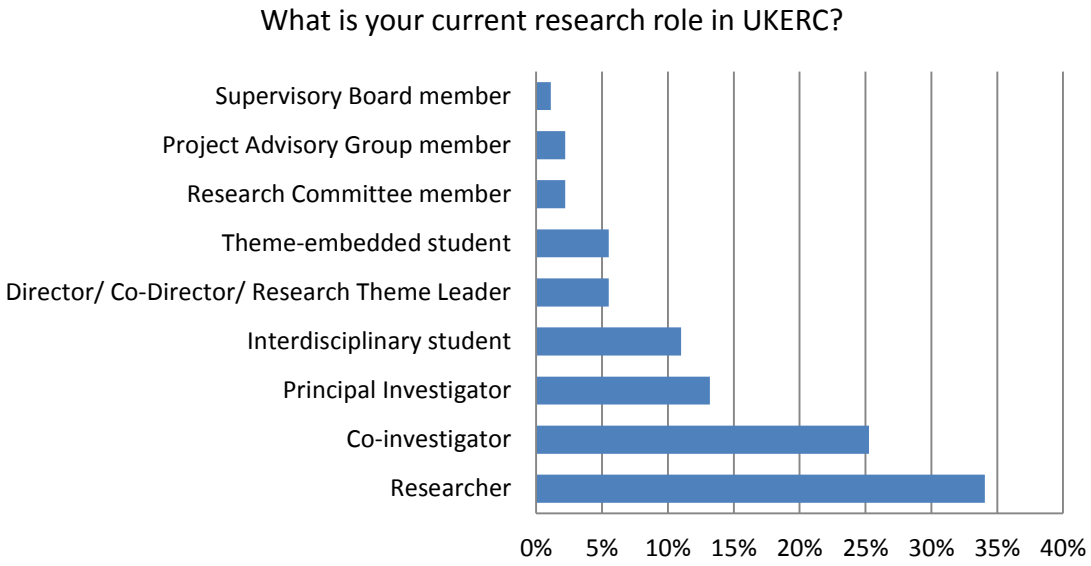

Figure 8: Respondents' Roles in UKERC

Although all levels of seniority are seen as having been engaged in interdisciplinary research, junior researchers – PhD students, postdocs and research assistants – are seen as having had particularly strong interdisciplinary engagement in UKERC (Figure 9). This raises the need for support for interdisciplinary career progression, especially given the extra challenges of interdisciplinary academic careers (discussed in Section 3.8 below).

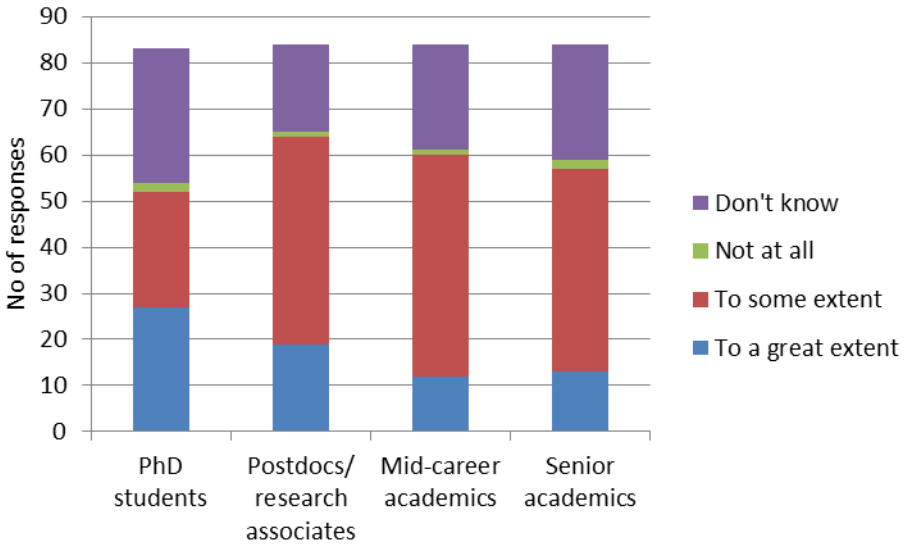

Figure 9: Perceived engagement in interdisciplinary research, based on career stage

UKERC's five Research Themes were all reasonably well represented at the survey (Figure 10), and the results broadly correlate with the size of the themes in terms of person years. However, less than a fifth of respondents (17%) were involved in either

of the two Phase 2 'Flagship' projects, which are designed to offer Centre-wide research insight.

UKERC's relatively limited efforts on Centre-wide research integration in Phase 2 reflects its changed funding model and programme design. While Phase 1 UKERC was supported by a pre-assigned five-year allocation of resources, around half the research funds for Phase 2 was allocated by a series of open and competitive research calls.

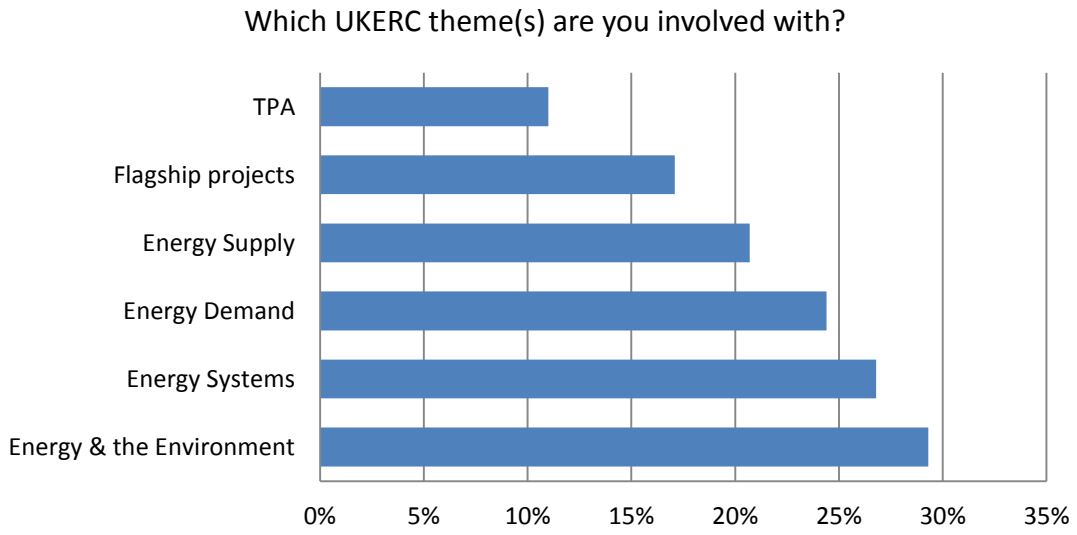

Figure 10: UKERC Research themes' representation

Just over half of the survey respondents identified themselves as being supported by Research Fund – rather than Core-funded – projects, confirming that the Research Fund has led to a significant remaking of the UKERC research community. (For many researchers, the 'Core/Flex' distinction is immaterial: around one-third of respondents stated that they didn't know whether they are Core or Research Fund funded). At the same time, a quarter of respondents participated in more than one theme, indicating a degree of cross-thematic interaction.

While this 'core+fund' model has injected flexibility and diversity to UKERC's research, it has also presented greater challenges in terms of research integration, and the Centre's Phase 2 research strategy has emphasised on theme-level synthesis as well as centre-wide Flagship projects. The Phase 2 experiences highlights the challenge of combining flexibility and openness with coherence and integration, and as the next sections (3.1. and 3.2) discuss, this also has possible implications for UKERC's ability to engage in more ambitious forms of interdisciplinary research.

3.3 Research content and structure

Interdisiplinary research experience

For most respondents (just under 2/3rds), their participation in UKERC is not their first experience of interdisciplinary research. When invited to compare UKERC to their other experience, around half indicated that UKERC's approach towards interdisciplinary research rated 'about the same', with just under a quarter stating UKERC had performed better (Figure 11).

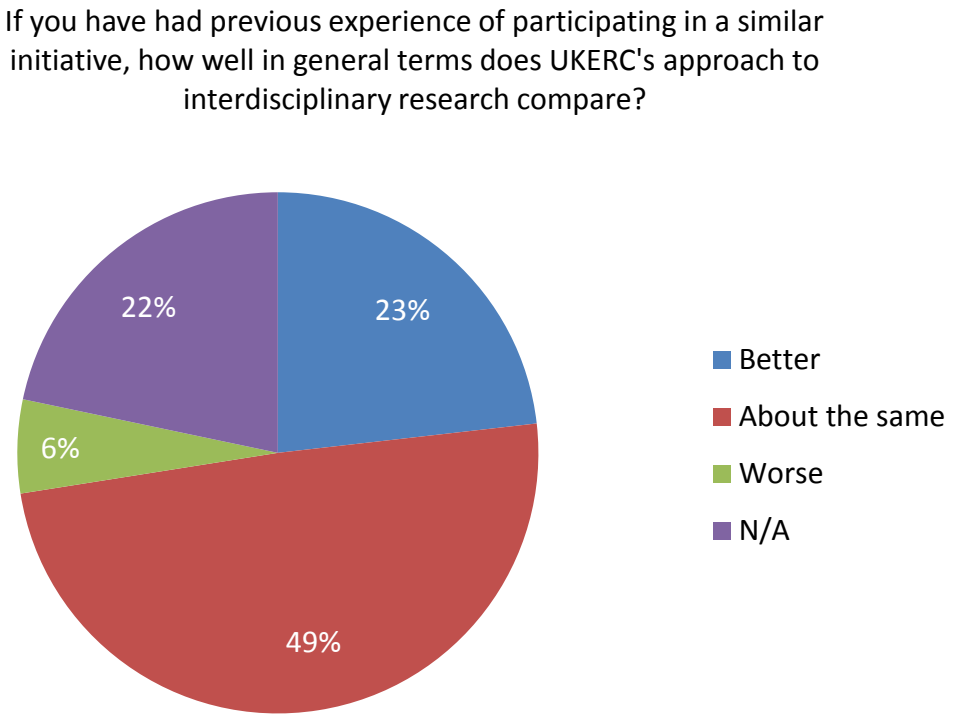

Figure 11: UKERC's interdisciplinary research rating, compared to previous experiences

Respondents' comments confirmed this pattern, with some researchers highlighting UKERC's achievements in interdisciplinary working:

> *'UKERC has been very successful in interdisciplinary research'*
>
> *'[my] previous 'interdisciplinary' activities were mostly in name only'*
>
> *'UKERC has better inter-theme interaction and integration'*

For others, UKERC's efforts had more limited or partial impact, and one respondent highlighted a more visible focus on interdisciplinarity in another initiative:

'UKERC is making greater efforts to help disciplines understand and value one another's contributions, but I'm not sure we've quite got there yet'

'UKERC is better than some and worse than others. Basically, I do not feel that it is explicitly encouraged or supported, but neither is it discouraged or shunned'

'[there are] some patches of very good collaboration and other patches where there seems to be less effective interdisciplinary working'

'I was involved in several RELU [Rural Economy and Land Use] projects - the emphasis on interdisciplinary working was more explicit there'

Other than in project commissioning and reporting – perhaps less visible parts of the research process for many researchers – UKERC has supported interdisciplinarity by mainly 'soft' measures, for example Centre-wide meetings and thematic workshops. For some respondents, this is reflected in a reliance on committed individuals for interdisciplinary achievement, rather than more 'top-down' directed activities.

'it encourages interdisciplinary bids, but [there is] less collaboration between groups beyond research projects'

'it is down to the individual's desire to embrace interdisciplinary working practices'

'there is primarily reliance on the attitudes of individual researchers'.

'UKERC has tried very hard to achieve [interdisciplinarity]. However this has not always worked out. Perhaps it doesn't need to … [it] is perhaps more a function of individuals than the centre itself'.

Research content and structure

There is broad acknowledgement that UKERC has supported interdisciplinary energy research. Over three-quarters of participants agreed or strongly agreed that the content and structure of the UKERC research programme supported interdisciplinary collaboration (Figure 12).

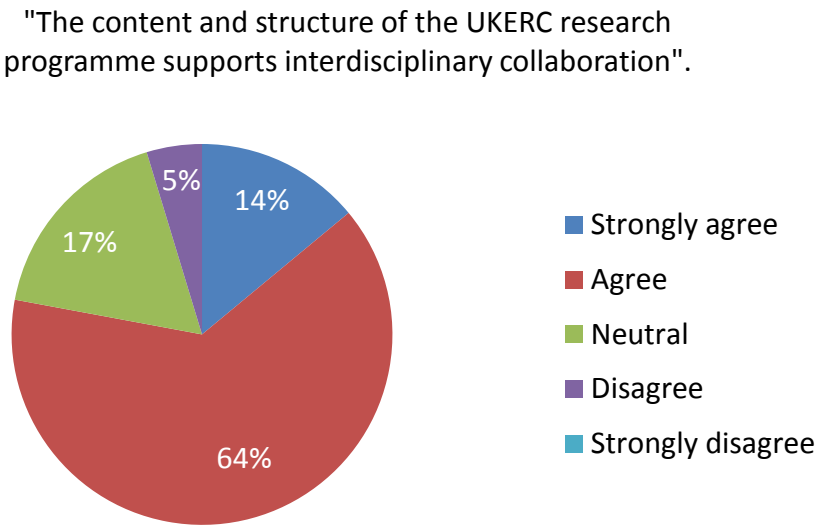

Figure 12: Assessment of UKERC's research programme

Respondents' comments paint a more mixed picture, and offer some insight on underlying tensions and barriers. A recurring theme here was that UKERC had tended to carry out *multidisciplinary* research (where different disciplines work alongside each other in parallel) rather than *interdisciplinary* (where there is an effort at disciplinary combination or integration).

> *'interdisciplinary research is often discussed, but it is difficult to think of specific examples of successful application, as opposed to multidisciplinary research, which … is more prevalent',*
>
> *'the content and structure allows people in different disciplines to communicate occasionally, but fundamentally to continue to work separately'*
>
> *' each of the groups may still be 'in their discipline' yet their collaboration at the very least encourages interdisciplinary between them (or is that multi-disciplinary?').*

Other comments suggested that the organisation of the Phase 2 research programme into five domain-based themes (*supply, demand, systems, energy and environment* and *technology and policy assessment*) had presented barriers to interdisciplinary working:

> *'Supply versus … demand is an immediate disadvantage'*
>
> *'[better] to organise the research around "Big Questions" as opposed to themes'*

Research-supporting activities

Respondents were asked to consider the role of UKERC's research-supporting functions and activities in enabling interdisciplinarity (Figure 13). The results suggest that the thematic workshops convened by UKERC's Meeting Place function and the regular calendar of Centre-wide meetings were seen as the most effective mechanisms – the Meeting Place was highly rated here by more than half of respondents.

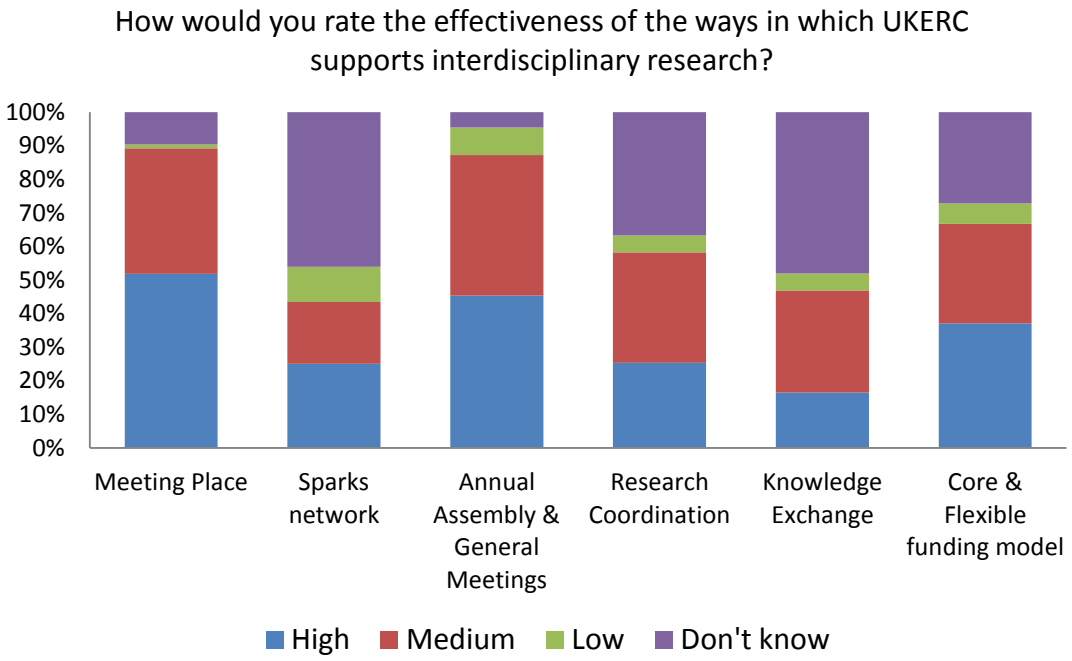

Figure 13: Effectiveness of interdisciplinary research support

A significant proportion of respondents felt unable to judge the effectiveness of UKERC's research supporting functions. This is perhaps understandable: many of the roles here are carried out 'behind the scenes': specifying calls for proposals, supporting annual monitoring and organising Centre meetings, serving the wider UK energy research community, or having more targeted remits, such as to early- stage researchers.

'flexibility supports collaboration – not 'content' or 'structure'. The exception to this is the Meeting Place, which is a structure that supports flexibility'

'[the interdisciplinary studentships] … develop true interdisciplinarity'

'theme meetings … have been very effective'

'the communication function for promoting UKERC reports has worked very well'

Sources of interdisciplinarity

Respondents were invited to assess where interdisciplinarity has been most prominent within the Centre's research programme (Figure 14). The results suggest that interdisciplinarity has been strongest in UKERC's smaller-scale activities: individual projects and researchers, and *within* rather than *between* research themes. By comparison, larger-scale and more outward-facing activities – such as cross-theme collaboration, and links with the wider research community and non-academic stakeholders – were seen as being less effective.

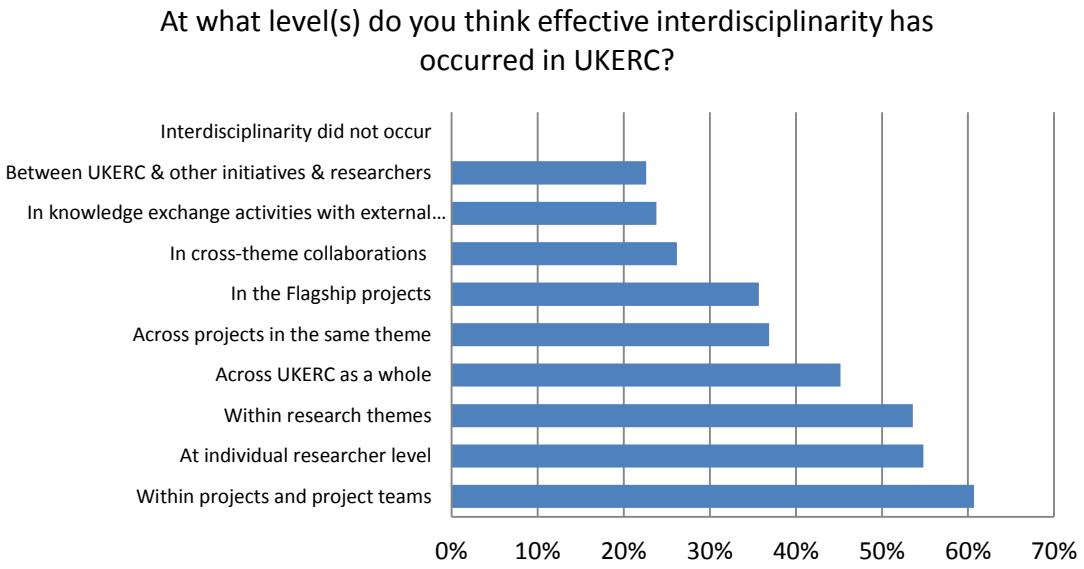

Figure 14: Different sources of interdisciplinarity in UKERC

Again, some caution is needed in interpreting this result: as a number of respondents themselves pointed out, researchers tend have more direct experience of project-level activity than higher-level initiatives. In addition, some higher-level efforts, such as theme synthesis projects, are recent additions to the Phase 2 research programme. Even so, the indication here is that the prevailing interdisciplinary experience in phase 2 UKERC has been among relatively small groups of researchers involved in studentships, projects and themes, rather than larger-scale initiatives across themes and the Centre as a whole.

There was some suggestion in respondents comments that this pattern relates to the structure of the Phase UKERC 2 programme, in terms of its orientation to *flexibility* rather than *integration* – a significant change from the less-open and diverse but more tightly integrated Phase 1 research programme – as manifest in the Phase 1 *Energy 2050* project. Among Phase 2 projects, a Research Fund interdisciplinary project on Carbon Capture and Storage (CCS) was mentioned as an example of successful engagement across the social and engineering sciences.

'it has occurred …less … between different projects and across the themes.'

'Energy 2050 was arguably the furthest down this route that UKERC has gone. As an interdisciplinary exercise it was far from perfect but it did force some useful interactions'

'in the CCS project … we had some good interaction between social scientists and … other backgrounds, although there was probably still some room for improvement'

As is discussed later (Section 4.1) interdisciplinary research often relies on cross-disciplinary relationship-building over time, and the suggested trade-off here between *programme flexibility* and *depth of interdisciplinary interaction* has some implications. As UKERC's Phase 2 experience suggests, an emphasis on flexibility and diversity may reduce the prospects for more ambitious forms of interdisciplinary research. Another respondent explicitly highlighted this trade-off – though in the context of a perceived orientation in UKERC toward cohesion rather than openness.

'there is a cohesiveness and strong sense of identity within UKERC. This is the positive flip side to it being seen as a bit of a closed shop by some not part of UKERC'

Disciplinary identity, representation and interaction

All of UKERC's 'macro' disciplinary communities – *environmental sciences, engineering and physical sciences, economics* and *social sciences* – were seen as being reasonably well represented among respondents. However, although social science (other than economics) was the biggest disciplinary community in self-declared identity (Figure 7), engineering and physical science was perceived as having the strongest representation in UKERC research (Figure 15). Although the differences between disciplinary identity (Figure 7) and representation (Figure 15) are small and shouldn't be overstated, they suggest a slight bias in UKERC research toward more 'techno-economic' disciplines.

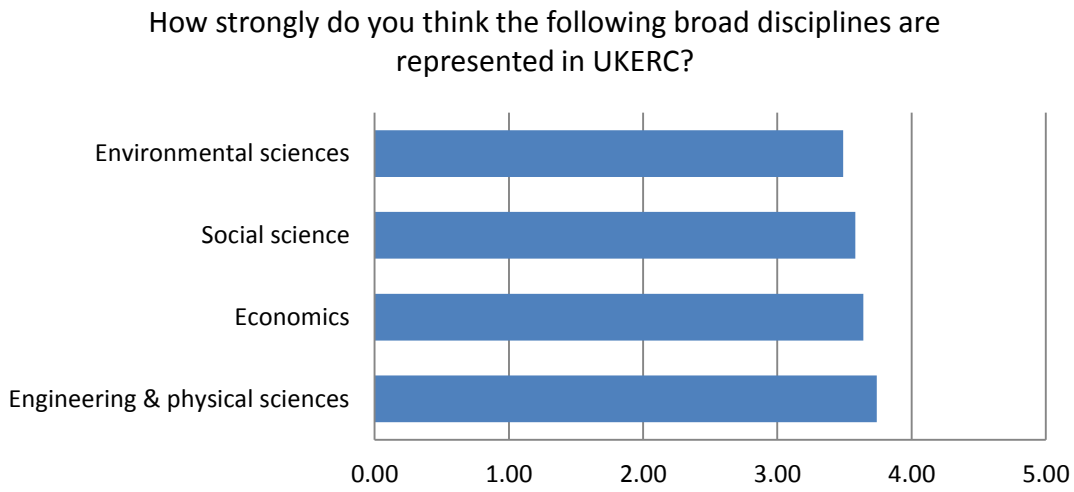

Figure 15: Strength of disciplinary representation in UKERC research

Respondents' comments allowed some further consideration of disciplinary identity and representation in UKERC – with references to the quality and standing of social science and engineering research. These comments highlight the challenges of reconciling interdisciplinary achievement with strong disciplinary identity, and reveal the nuanced and interpretive nature of disciplinary identity and representation.

> '*[interdisciplinarity] is strong … but … dominated by technical/ engineering expertise'*.
>
> '*social science … has … recently become more strongly represented*'.
>
> *'although many people and projects involve aspects of social science …. most people have a hard science or engineering background'.*
>
> *'although there are lots of 'engineers' within UKERC, I think their research is often at a higher systems level … than being involved in … the application of technologies.'*

In terms of the strength of cross-disciplinary interaction, the strongest links were seen as being between *economics* and *engineering* , then between *economics* and *environmental science*, and *social sciences* with *environmental sciences* (Figure 16). One respondent highlighted the role of the 'global' flagship projects in strengthening the connection between *environmental science* and *social science.* Levels of interaction were seen as being lowest between *social sciences* and *economics* and *environmental sciences* with *engineering*.

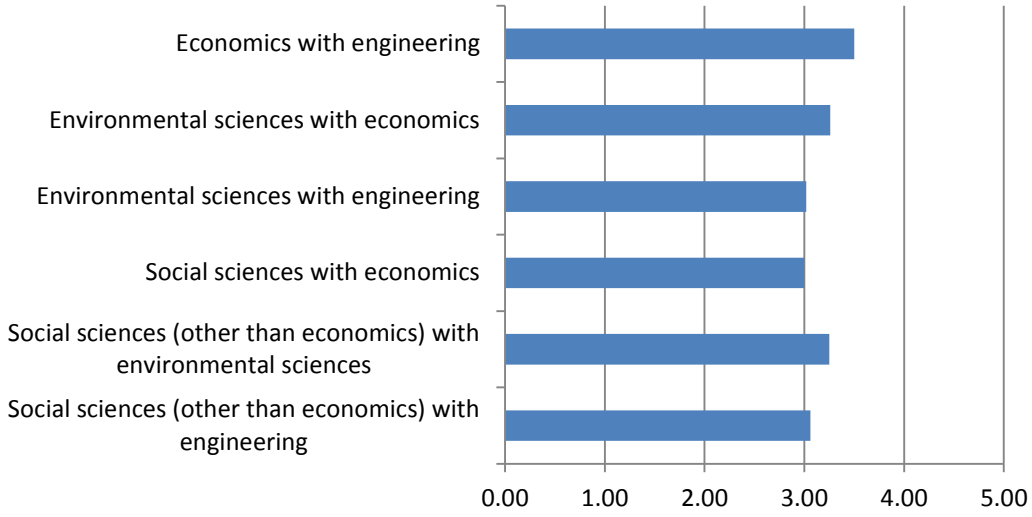

Figure 16: Perceived strength of interaction between disciplines

Research impact and dissemination

Survey participants were asked to assess the main academic and non-academic impacts of UKERC's interdisciplinary energy research. The greatest perceived strengths of UKERC research was its orientation to 'real-world' problems and bringing together different disciplines; it is seen to have made less impact at developing new research approaches and methods (Figure 17).

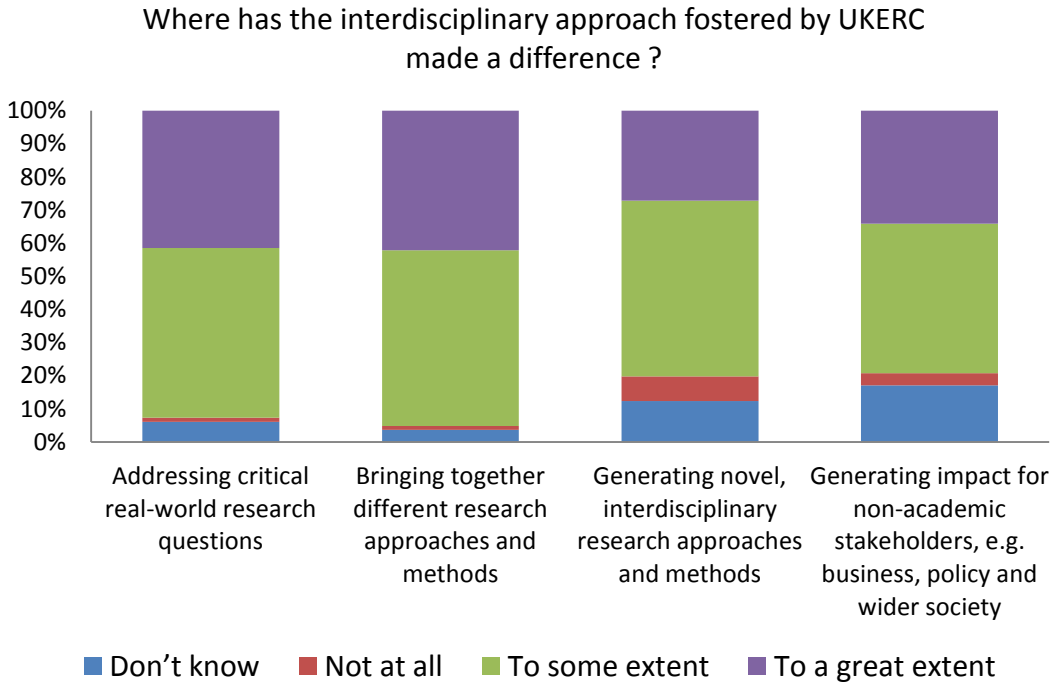

Figure 17: Effect of UKERC's interdisciplinary approach

The results also suggest that UKERC has had an impact on many of its researchers' publishing strategies, with just under half of respondents having found novel publication channels as a result of their involvement in UKERC research (Figure 18).

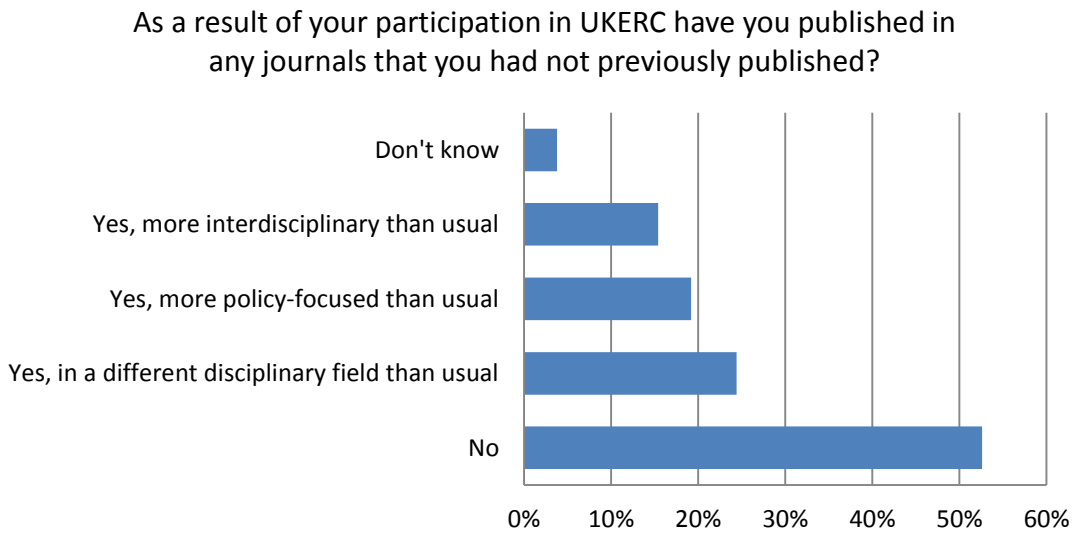

Figure 18: Impact on publication strategy

This is encouraging, given the well-documented challenges of publishing interdisciplinary research in the highest-rated academic journals; indeed, one respondent pointed to the higher anticipated impact from interdisciplinary work.

> *'[we] have targeted social science journals that I would not normally publish in.'*
>
> *'[we] anticipate getting higher impact publications than without interdisciplinary collaborations'.*

Capacity Building

There is strong evidence that UKERC is helping to build the UK's interdisciplinary energy research base. Almost 90% of respondents *agreed* or *strongly agreed* that UKERC has helped develop an interdisciplinary research community (Figure 19), and almost three-quarters *agreed* or *strongly agreed* that their UKERC involvement had made them more likely to participate in interdisciplinary energy research in the future (Figure 20).

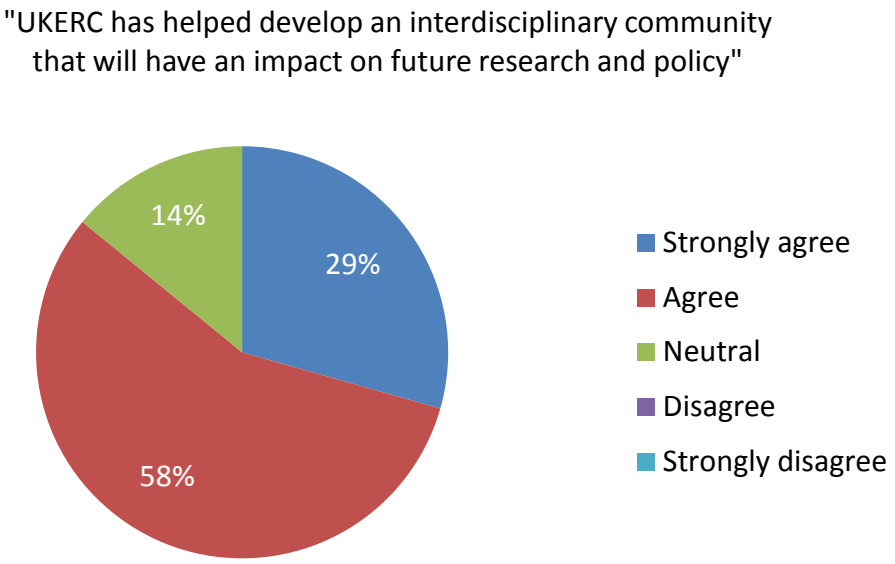

Figure 19: UKERC's impact on future research and policy

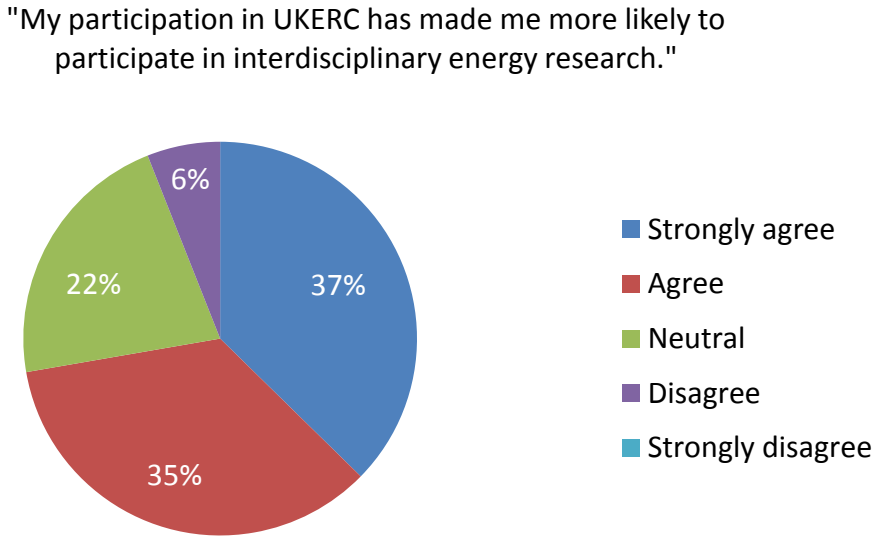

Figure 20: Future participation in interdisciplinary energy research

Motivations and barriers

Perhaps unsurprisingly, given the extra challenges involved, the strongest reported reasons for involvement in interdisciplinary research are personal and inquisitive: developing new collaborations across disciplines and following a personal interest in novel research questions and methods. More outward or formal incentives – improved publication or research funding opportunities, or changed career ambitions – are less significant (Figure 21).

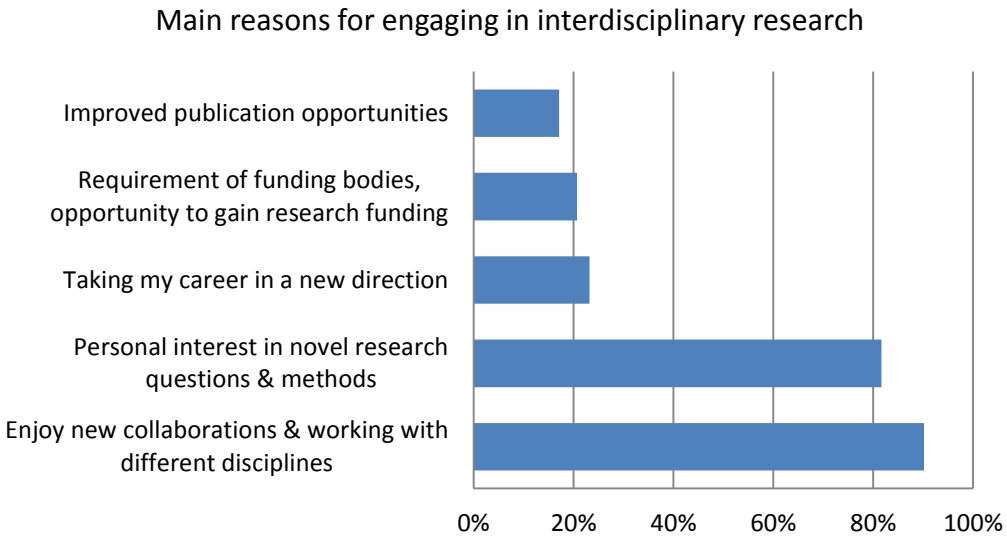

Figure 21: Motivations for interdisciplinary research

'single discipline approaches are (not) effective for looking at the questions I hope to help answer'

'[interdisciplinarity] is essential if we are to address the problems relating to energy'.

'addressing real world issues which cannot be resolved by one discipline alone'

Alongside this strong personal interest, however, is considerable concern about the added challenges and practical difficulties of interdisciplinary research, especially the greater demands of interdisciplinary research design and its diluting effect on disciplinary identity, in a still highly disciplinary-oriented institutional environment (Figure 22).

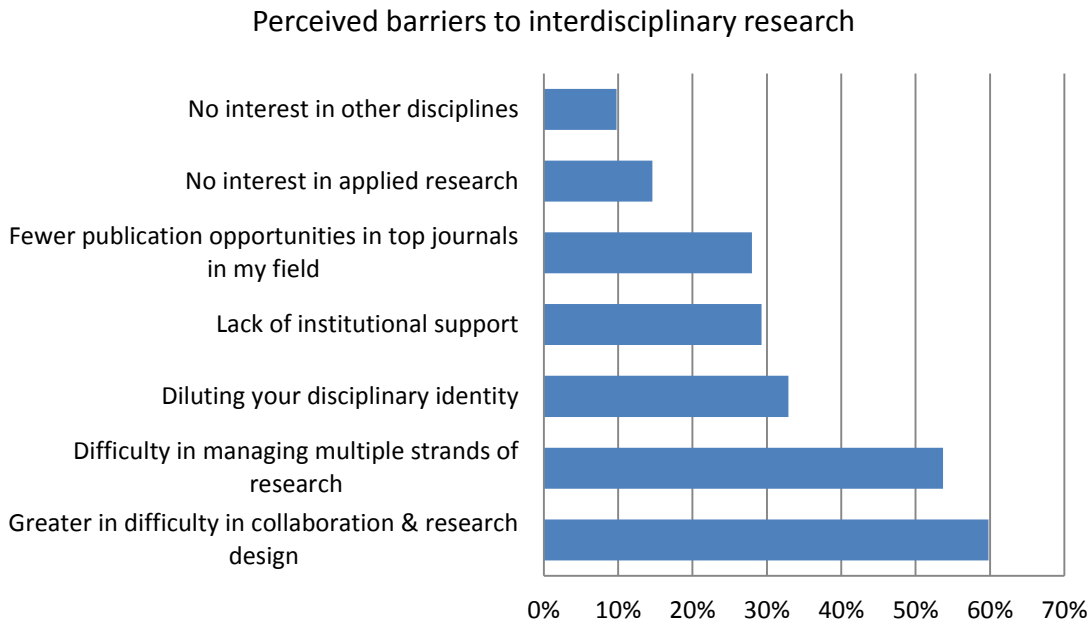

Figure 22: Barriers to engaging in interdisciplinary research

Respondents' comments highlighted the multiple perceived disadvantages to academic career progression – publishing, funding and promotion – presented by interdisciplinary research:

' publishing and funding are still more difficult for interdisciplinary work'

'there is still very limited (funder) support … outside a very techno-economic, innovation and technology transfer type model'

'funding can be more difficult due to lack of ownership of interdisciplinary area'

'being interdisciplinary can have negative effects on publication rankings and career prospects'

'most academic appointments are still focused on single disciplines'

' [it's] easier to progress as an academic if you can give yourself a strong disciplinary home'

Some respondents highlighted the UK's Research Excellence Framework (REF) as a particular barrier to interdisciplinary research during Phase 2 UKERC:

'REF is a major barrier'

'[there is no] REF category for energy research. Policy-related papers are 'no-go' in an engineering panel'

'REF is a disincentive to potential partners … since they will have to justify 'mixed' papers to a discipline specific submission panel'

Alongside this, others suggested that, in the right circumstances the barriers to interdisciplinarity can be reduced or overcome:

'I've been lucky in that I've always worked in interdisciplinary environments - so the barriers have been less important for me'

'the opportunity is there if you want to take it'

3.4 Recommendations

In the final part of the survey, respondents were given an opportunity to offer suggestions for researchers, research programme leaders and funding bodies involved in promoting and developing interdisciplinary energy research, and to pass on any final observations or comments.

A recurring theme in respondents' recommendations was that successful interdisciplinary research requires additional time, effort and resources as compared to disciplinary-based research. A number of respondents highlighted the value they have derived from UKERC-enabled interpersonal interaction and networking, and the need to provide for this in research programme design and funding:

'*being able to have access to such a wide range of energy researchers, with a variety of disciplinary backgrounds but sympathetic to interdisciplinary approaches, has been immensely helpful to me as an early career researcher*'.

'*For interdisciplinary PhD students, it's particularly important to develop a good network of other students and academics in both (or several) fields of your research… having regular contact with students in my second discipline really helped to refine some of the research questions. These contacts were nearly as valuable as having a supervisor in that discipline*'

'*more networking events [are needed]… so new collaborations can be developed - perhaps save funding to help foster this'*

For a number of respondents, the need for explicit attention to cross-disciplinary relationship-building reflected the 'language barrier' between different disciplines; one respondent highlighted the problem of discipline-specific language at interdisciplinary events such as the UKERC Annual Assembly.

> *'arts and humanities speak a different language from the sciences… we need to take time to educate each other a bit in each other's disciplines so that we have inter-disciplinary individuals within each project'*
>
> *'people from different disciplines speak different languages. Getting over this language barrier is a key challenge and one that few researchers are willing to take on*'
>
> *'presentations at interdisciplinary events such as the Annual Assembly use a great deal of jargon and assumed knowledge … [they] can be difficult to follow and the key message is lost'*

Reflecting the barriers between disciplines, some respondents recommended building-in dedicated time for researchers to familiarise themselves with the contributions and methods of different disciplines – especially in the early stages, but also on a recurring basis.

> *'it takes a while to understand … other techniques … outside your field … [the] first few months are just understanding what you can do'*
>
> *'ensure enough resource is available to enable time for different disciplines to get to know each other and see the benefits of working collaboratively'*
>
> '*all long term research projects … [should] be subject to the PI's in each discipline attending a 3-5 day [meeting] … to get to know each other's methods and come to agreement on common … terminology and units of measurement … to set out the scope of the collaboration … and provide points of contact throughout'*
>
> *'specific funding [should be] allocated to create interaction between different disciplinary parts … e.g. away days … recurring meetings … talking in less formal settings is valuable'*

One respondent highlighted the particular need to support early-stage interdisciplinary research careers:

> *'my main concern is for the future prospects of UKERC PhD students … additional support would be welcome*'

Alongside built-in 'interaction time', a number of respondents suggested the need for research managers and funding bodies to recognise the value of cross-disciplinary co-ordinators or 'translators', who tend to have less traditional academic profiles.

> *'[we need] dedicated human resources for fostering and facilitating collaboration, and leadership programmes to encourage this type of role … to foster collaborative work between groups, themes and disciplines'*
>
> *'many researchers … remain disciplinary experts. The challenge is in developing 'coordinating individuals' who can develop and facilitate their collaboration'*
>
> *'for successful interdisciplinary collaboration, you need two types of people: … disciplinary experts who are willing to collaborate with aliens from another discipline … and … translators and facilitators (who may not be disciplinary experts themselves)'*

Other aspects of research programme design and funding that were highlighted included: striking a different balance between 'core' and 'flex' funding; the need to change UKERC's organisational structure to a 'problem-based' structure; and the need for greater interaction within themes.

> *'make more use of flexible funding to bring in the people, teams, disciplines you need – have less committed [core funding] … as this causes lock-in and stagnation'*
>
> *'be 'problem-focused' rather 'theme-focused'. It's the outcome that is important'*
>
> *'[we need] greater coordination at theme level to encourage students of … different areas within the same theme, to mix and share ideas, information'*

In terms of future interdisciplinary representation and collaboration, suggestions included improved representation of engineering, and engineering-social science collaboration. Respondents also highlighted the need for improved cross-Council collaboration, and for UKERC to better define its position in the UK's evolving energy research institutional landscape:

'greater interaction between engineering and social sciences/economics'

'*more engineering please'*

'*ESRC and EPSRC need to do more joint things or get better at interdisciplinary responses*'

'*UKERC needs to develop (perhaps novel) mechanisms for interfacing with the natural science and engineering-facing projects within the changing RCEP landscape, i.e. the BBSRC Sustainable Bioenergy Centre, the EPSRC EUED Centres, the Supergen Hubs, and various energy-related Doctoral training Centres*'

Respondents also highlighted the way in which data gaps presented a barrier to interdisciplinary research:

'*it should be mandatory that data and results from taxpayer funded research is … made available to all… to avoid re-inventing the wheel and to speed up … adoption of the results'*

'some … institutions and senior academics hoard and guard data as if it is their own, after it has been paid for by the public purse. This is a barrier to intra and inter disciplinary research'

Finally, despite the many barriers and recognised need for improvement, some respondents reiterated the value and rewards of interdisciplinary research:

'*interdisciplinary work is very difficult (it usually defaults to multidisciplinary research), but can bring really new insights … all parties need to be prepared to concede some ground, listen to others and share their knowledge; then it is possible to move forward.'*

'although it's a massive challenge to work in a truly interdisciplinary way, the final results are worthwhile'

4. Semi-structured Interviews

4.1 Introduction

The research reported here is part of a project commissioned by UKERC's independent Research Committee to review UKERC's research programme in terms of its interdisciplinary research achievements, challenges and lessons learned.

Whereas most of the participants in other fieldwork elements for this project – the facilitated discussion group and online survey – came from within the UKERC community, the majority of the interviews were with 'external': academic advisors, academics not involved with UKERC, and non-academic 'stakeholder' advisors. All the interviewees have had some experience of interdisciplinary research, and many have had extensive experience working across disciplines, and across academic, policy business and other stakeholder domains.

Interviewee role in UKERC	Interviewee research, work and disciplinary background	Interviewee code
Early career researcher	Environmental and social science	EC1
Early career researcher	Social science, engineering and policy	EC2
Mid-career researcher	Energy systems and modelling	MC2
Senior Researcher	Energy demand, social and technical	SR1
Senior Researcher	Social science, techno-economic and policy analysis	SR2
Senior Researcher	Engineering, whole energy systems analysis	SR3
Academic Advisor	Physics, energy and buildings	AA1
Academic Advisor	Energy economics, business and regulation	AA2
Academic Advisor	Biosciences, environmental science and policy	AA3
Academic Advisor	Environmental social science	AA4
Academic Advisor*	Social and environmental science	AA5
External Academic	Social science and environmental policy	EA1
External Academic	Energy policy and energy innovation	EA2
External Academic	Environmental science and knowledge transfer	EA3
Stakeholder Advisor	Industrial engineering and research exchange	SA1
Stakeholder Advisor	Energy and climate policy, research-policy links	SA2
Stakeholder Advisor	Environmental policy and regulation	SA3
Stakeholder Advisor	Physics / research funding and commissioning	SA4

Figure 1: UKERC Interdisciplinary Review Project Interviewees

* = written response

Seventeen semi-structured interviews were carried out, either in-person or by telephone (Figure 1). Interviewees were drawn from both UKERC's research programme and from the Centre's external advisors and stakeholders. Almost all of the interviews were conducted during September and October 2013, with one carried out in January 2014; in addition, one academic advisor to UKERC provided detailed written comments to the project team as a follow-up to the facilitated group discussion, and these comments are included here as an additional 'interview script'. Three interviewers carried out the interviews: Mark Winskel and Ioanna Ketsopoulou from UKERC's Research Co-ordination Team, and Tim Churchouse from UKERC's Meeting Place team.

Definitions and Framings

- Can you please describe your current role and responsibilities, and briefly, your past roles and experiences?
- What do you understand by the term 'interdisciplinary research'? What does it mean in the context of UKERC's remit for 'whole systems' energy research?
- Do you draw any distinction between multi-disciplinary, inter-disciplinary and trans-disciplinary research?

Metrics and Evaluation

- What do you think are useful measures or metrics for success in interdisciplinary research?

Motivations, Benefits and Barriers

- Can you say something about the reasons and motivations for your involvement in interdisciplinary energy research? How much of this interest stems from internal / individual motivation, or from external pressures and opportunities?
- What do you consider to be the benefits of interdisciplinary research on energy? What are the drawbacks, or obstacles?

Experiences and Examples

- Please describe one or more experiences you have had working across disciplines, either within or outside UKERC. Why did the collaboration begin? Which disciplines were involved?

- Were there any difficulties faced related to the interdisciplinary aspects of the work? If so, how were they addressed?
- Can you compare your experiences of working on interdisciplinary research within UKERC and outside, in terms of good and bad experiences? How do you explain any differences?

Lessons and Recommendations

Looking back at your experiences of interdisciplinary energy research, can you suggest some ways to improve UKERC's efforts, and their value for researchers, policymakers and others? Please discuss your lessons and recommendations in terms of:

- How different disciplines can work together
- Research leadership and management
- The organisation of a research programme, across themes, projects and problems
- Developing individual researcher's skills
- Integrating flagship projects that bring together a 'whole systems' perspective
- Funding structures and project commissioning
- The role of research-supporting activities
- The role of stakeholders and research users, such as policymakers, businesses and NGOs in co-designing and co-producing research; at what stages of the research should stakeholders be involved, and what are the best ways of involving them?

Box 1: Interview Guideline Questions

Interviews were conducted on a semi-structured basis, with reference to a set of guideline questions, sent to the interviewees in advance (Box 1). However, each interview was conducted so as to reflect the particular roles and responsibilities of each interviewee, and while reference was made to each the broad headings on the guideline question sheet, specific questions were adjusted or omitted according to the interviewee's experiences and interests. Interviews lasted between 45 and 90 minutes; all were recorded, and detailed notes were then made of the main points raised, based on a close listening to the full recording. The rest of this report summarises interviewee's observations and suggestions in the broad categories.

4.2 Definitions and Framings

What do you understand by the term 'interdisciplinary research'? Do you draw any distinction between multi-disciplinary, inter-disciplinary and trans-disciplinary research? What does interdisciplinarity mean in the context of UKERC's remit for 'whole systems' energy research?

Interviewees expressed a range of opinion on the value (or otherwise) of explicitly distinguishing between different forms, or definitions of interdisciplinarity. These differences cut-across academic-stakeholder divides, so that some stakeholders from research funding bodies and industry – as well as some academics – saw value in explicitly recognising the different types of interdisciplinary engagement:

Interdisciplinary research … requires more than one discipline to work together to answer the question … Multidisciplinary research regards different disciplines inputting information to answer a question, but not actually working together … the distinction does matter – it matters a lot. [SR1]

Multidisciplinarity is a failure … people pursuing their own tracks. There's a fine line between interdisciplinary and transdisciplinary research; the old boundaries have broken-down and should be abandoned. [AA3]

[In my organisation] we distinguish between multi-disciplinary and inter-disciplinary [research] – multi-disciplinary is less integrated, and is more institutionally separated. [SA4]

Multidisciplinary means different disciplines working in silos focusing on different parts of the problem … Interdisciplinary is more integrated and interactive … looking through each other's eyes. Transdisciplinary … goes beyond academic disciplines; for work to be relevant to policymakers, not only must it be interdisciplinary … [it must] also incorporate other perspectives. [EA1]

The discussion … [on] degrees of interdisciplinarity [is] really useful .. even within engineering, different disciplines need to work together … interdisciplinary working has its place, but we need specific skills also in place, because they will need to be called on. [SA1]

For other interviewees – both academic and non-academics – there was little value to be had from explicitly differentiating between different forms of interdisciplinarity:

These terms are not very important – different communities have different meanings for them. [EA2]

They are very subtle distinctions … I don't really get hung up about those differences. [AA4]

I'm interested in energy – in answers and solutions to problems in the energy arena – more than … in a particular discipline. [SR2]

[As] a UKERC stakeholder I do not see the distinctions between interdisciplinary, multidisciplinary and transdisciplinary as important. [SA3]

[Policymakers] don't get too hung up on disciplinary or unit boundaries – this is less of a problem than in academia … the main 'barrier' is between evidence-gathering and policy-making. [SA2]

A similar spread of views emerged on the value – or otherwise – of explicit attention to the term 'whole systems' interdisciplinary research; again, however, there was no clear-cut divide between academic and non-academic interviewees on this question.

For some interviewees, attending explicitly to the term was a useful way to discuss the character and complexity of socio-technical interactions, and the multiple perspectives associated with interdisciplinary framings. One academic interviewee felt this was not a meaningful or entirely well-suited term in the UKERC context.

Whole systems is about ensuring one does not simply look at one sector in isolation … to make sure [some] policy goals are not set at the expense of others … [for example] an approach that reduces GHG emissions in the UK … [by] outsourcing … or having severe social and economic impact. [SA3]

To properly understand the energy system … you need to understand economics, behaviour, policy, the relationship between policy and investment … 'whole-systems' means understanding the interconnectedness between all those aspects. [SR2]

I'm a firm believer in systems perspectives … [but] the problem is drawing the boundary – you need to think about 'systems of systems' to understand how interactions propagate. [AA3]

There is more to 'whole systems' than people normally mention … it involves all sorts of social phenomena as well as physical kit … interdisciplinarity goes beyond whole systems … [to ask] what counts as a system? … how it's divided-up is determined by how one looks at it. [EA1]

'Whole-systems' energy research doesn't mean that much – the term comes from environmental science, but energy is differently defined. [EA2]

4.3 Metrics and Evaluation

What do you think are useful measures or metrics for success in interdisciplinary research?

Interviewees views differed on the whether there were any particular difficulties in assessing and metricising interdisciplinary research. While one researcher suggested that there were no particular difficulties and others listed possible metrics, a number of others saw interdisciplinary evaluation and metricisation as problematic – and linked these difficulties with barriers to interdisciplinary research in academia; for some these were deep challenges:

Metrics for successful inter-disciplinary research are the same as with research in general. [MC1]

Proxy indicators of successful interdisciplinary research could include: number of papers with authors from multiple disciplines; impact and citations of these papers; type of journal … for example, if a paper with a genuine co-author from engineering is published in a top sociology journal; [the] number of first-time collaborations on academic papers; and evidence of follow-up interdisciplinary collaborations. [AA5]

[Evaluation can include] impact case studies, securing funding from a range of sources – including different Research Councils – and blended skill sets. [AA4]

We lack successful metrics for interdisciplinary research; REF [the UK's Research Excellence Framework] relies upon discipline-based panels that struggle to assess interdisciplinary papers. [SR2]

Metrics are difficult for interdisciplinarity – it tends to score less well than disciplinary work. Network analysis doesn't really work – it encourages spreading too thinly – networking should be a by-product rather than an end in itself … We need social science surveys to identify usefulness, rather than trying to metricise it. Transdisciplinarity is easier to measure because it's based on outside impact – for example, through REF case studies. [AA3]

Showing a variety of angles and interconnections between different disciplines is important –but it is difficult to normalise indicators, as there are many ways of achieving them. [SA3]

Measures and metrics … [are] unfortunately formed from the 'audit culture' … most are mindless … and more about looking good; they are not actually useful at assessing the quality of the work. [EA1]

4.4 Motivations and Benefits

Can you say something about the reasons and motivations for your involvement in interdisciplinary energy research? How much of this interest stems from internal / individual motivation, or from external pressures and opportunities? What do you consider to be the benefits of interdisciplinary research on energy?

A repeated theme in interviewees' discussion of the benefits of interdisciplinarity – and the motivation for their own interest – was its greater capacity to address the 'real world' problems facing energy policymakers and other decisionmakers beyond academia. Although some academic interviewees distinguished between internal and external motivations, for many, internal and contextual drivers were interwoven, with personal motivation linked to a desire to be involved in the development of fuller responses to complex social problems, and therefore lend wider meaning, relevance and impact to their academic research:

When addressing complex problems there is a risk of ignoring something important if you have only one disciplinary perspective. [AA2]

Insights from one disciplinary approach feed into another – you can develop a more holistic understanding. [EC2]

My motivation is the application of research and real world impact … [my] interest is 90% internal. [EA2]

[It's] primarily from my own motivations. The opportunities were there, but without personal interest I wouldn't have gone for them … [interdisciplinarity] covers more of the energy system, and so [it] can have higher impact and policy implications. [EC2]

Interdisciplinary research gives you the opportunity to look at the really big questions … the big questions cut across disciplinary boundaries – questions such as: is there likely to be lots of CCS in 20 years' time? It's not possible to answer that by engineers, economics, sociologists [alone] – you … need all of them. [SR1]

My involvement … has come from a combination of internal motivation and external opportunities … interdisciplinary projects that are problem-focused rather than focused on a particular discipline are very useful from the point of view of policymakers … it matters to the real world. [SR2]

Co-design and interdisciplinarity is the way we need address [the] big challenges … I started running-up against the limits of disciplinary boundaries about 15 years ago … [in terms of] how research translates into reality. I've always wanted to have impact beyond the academic world. [AA3]

Interdisciplinarity has very high relevance for energy research … it's about researchers with different skills working together on common problems … to develop common understandings and approaches, through joint publications, and involving industrial companies. [AA4]

The written comments submitted by one mid-career academic suggested the need to consider the differing motivations for interdisciplinary engagement for different disciplines, and for researchers at different career-stages:

Motivations … may differ according to disciplines … for example, modellers may find it easiest, engineers may accept it because their solutions are not adopted … social scientists … may accept it because of the grant funding opportunity … Motivations are also likely to differ according to career stage: I think it's most attractive for PhD students and post-docs … more difficult for early and mid-career academics and again easier for professors. [AA5]

One industrial stakeholder identified an instrumental value in interdisciplinarity, in terms of fuller high-level energy systems analysis than amenable to narrower, disciplinary-based framings:

We need insight across a range of disciplines … energy needs interdisciplinary institutions at the moment … [to] identify which choices we need to make … of course engineers feel they have the best solutions … the problem is that those [solutions] are probably wrong, because of the way the problem has been bounded … That's why we need interdisciplinary exchange and framing … to free the constraints and perspectives … [and] end up with something more like the future is likely to be. [SA1]

Two university-based interviewees identified more specific benefits from interdisciplinary research – firstly, conceptual development within mono-disciplines, and secondly and more materially, the opportunities to generate research income:

One of the benefits of inter-disciplinarity is … development within individual disciplines. [EA2]

Universities have been waking up to the opportunities for growth through interdisciplinary exchange [AA3].

4.5 Barriers and Drawbacks

What are the drawbacks or obstacles for interdisciplinary research on energy?

Some repeated concerns emerged from interviewees' discussion of the problems of interdisciplinary energy research. Again, recognition of the extra challenges of interdisciplinarity was evident in some interviewees from policy and funding stakeholders, as well as within academia.

One common concern was the greater operational challenges of interdisciplinary enquiry, especially, the additional time and effort needed compared to mono-disciplinary research.

To bring together very different disciplines, e.g. between physical and social scientists, our experience was this needed a lot of time to bring people together, across different languages and publishing places; it wasn't easy. [SA4]

Time – it can take a while. It feels like you are just brushing the surface and not actually getting into the detail … [it] can have a detrimental impact on one's career if you lose your discipline … there is a stigma of shallow knowledge. [EC1]

Time – the time it takes to get sufficient understanding of new perspectives in order to do it well … Trying to get others to understand … Different social scientists have different approaches to the same question, so there is high complexity even within narrow disciplines. [SR1]

Interdisciplinary research is hard, as systems are complex. Public policy needs clear messages and interdisciplinary research is difficult to convey. [SA3]

The big drawbacks are that it takes time to develop interdisciplinary and transdisciplinary understandings, and quite a big personal investment. [AA3]

A particular concern emerged for the challenges for individual scholars practicing interdisciplinary research – both short-term, operational challenges and longer term problems of career development and support:

At an individual researcher level … the drawback can be that you have nothing to compare it to and [you] can be unsure of the rigorousness of your research … Each of your supervisors is an expert in their field, but doesn't have a broader view. You have to find a way to turn your interdisciplinary background into an asset rather than an obstacle. [EC2]

Interdisciplinary researchers … [can] lose much of their sense of disciplinary identity; they are … we need more evidence on their career progression beyond the post-doc phase. [AA5]

[A] big problem is continuity of funds … where are all the [interdisciplinary] people we've trained up to go? [AA3]

Alongside these shared concerns, however, one academic suggested that there were no special operational barriers for interdisciplinary research:

The difficulties I faced in an inter-disciplinary project … were the same that can be faced in any project, around communication and publishing … they were not directly related to the interdisciplinary aspects of the project. [AA2]

Another repeatedly raised concern was the UK's academic institutional context, especially its academic evaluation system. Several academic interviewees raised the specific challenges of the UK Research Excellence Framework (REF), an evaluation exercise which has coincided with the running of UKERC Phase II:

Within UKERC there is pressure to be engaged in interdisciplinary research, but [in] academia as a whole the pressure is in the other direction … [UKERC is] different from much of academic life. [SR1]

There are tensions in academia. Despite the fact that the Research Councils put a lot of emphasis on interdisciplinarity, when your research is evaluated you have to go on a disciplinary-based REF panel. It's much more difficult to receive recognition by academic peers for interdisciplinary work, despite the fact that users and policy makers find it very helpful. The real world isn't disciplinary, so there is a problem with the way academia evaluates itself …

Interdisciplinarity makes evaluation by one's institution and REF more difficult. It would be much easier to be an economist, publish in economics journals and not worry the interaction between energy, economics … [and] engineering, or trying to understand the further reaches of behavioural economics. [SR2]

Academics who want to do well and have a good reputation must continue to publish in publications that reflect well on them and their field … [With] interdisciplinary research, you can lose rigour and decrease the quality of the research, and it does have some career risks … If a researcher needs to publish four key papers a year in respected publications because … [of] the demands of their REF or home department, then they will prioritise key disciplinary journals. If you are able to turn out ten-plus papers a year, then you can perhaps spread into different disciplines; the REF is a constraint to publishing interdisciplinary work. [AA4]

Academics … usually have to ensure that they publish in ranked journals as part of their assessment exercises. Interdisciplinary research is valued – but respectable journals are normally discipline-focused … interdisciplinary journals are seen to be ranked low. [EA1]

The top journals are all disciplinary-based or general science. [AA3]

The disincentives for academics to engage in interdisciplinary research were also recognised by two stakeholder interviewees:

Research assessment exercises are structured in a way that academics feel they must achieve successful peer reviews …. normally these do need to be structured by disciplines; policy relevance is sometimes still seen as an add-on. [SA3]

We have a problem with disciplinary reward systems, and where best to publish. Peer reviews of institutes tend to create problems for even the best research institutes. Open access [publishing] is a good way forwards. [SA4]

4.6 Barriers and Drawbacks

Can you compare your experiences of working on interdisciplinary research within UKERC and outside, in terms of good and bad experiences? How do you explain any differences?

Interviewees differed on their views of the relative standing of UKERC's interdisciplinary research efforts. Some interviewees offered a positive assessment of UKERC – especially in its ability to create and foster a protected place for good interdisciplinary interaction:

UKERC has been better than others at achieving interdisciplinary research, as people come in with the right attitude. [SR1]

UKERC is a much more positive place to work compared to other experiences … everybody involved … knows that it is an interdisciplinary endeavour, so they're up for doing interdisciplinary work. In comparison you can be involved with colleagues within your institution or other consortia and feel they have been forced to engage with people outside their core discipline … I have experience … where the different people involved don't really have a significant connection … UKERC does that brilliantly well. [SR2]

The UKERC research centre model has huge advantages – you have more levers to influence people to be inter-disciplinary – for example, through the flexible research fund … UKERC was one of [my] best experiences in inter-disciplinary research. [EA2]

Other comments on UKERC's performance, from both within and beyond those directly involved, were more critical, especially in terms of its specific interdisciplinary research processes and outputs:

There hasn't been enough interdisciplinary work across themes in Phase 2 [UKERC]; some [research themes] are more [discipline] focused than others: Supply to engineering; Environment to environmental sciences; Systems to economics; Demand to social science … some researchers tend to work on a question that they can answer [from] within their research theme. [SR1]

UKERC Phase 1 was quite integrated, but it was seen as an 'exclusive club'. Phase 2 tried to be more inclusive, but ended up with a not particularly well integrated programme – lots of flexible funding projects … ran off on their own. [SR2]

UKERC seems rather under-funded and its projects are quite small. You've seeded lots of interesting work, but it's unclear how that will continue … [the] projects are very short and there isn't a mechanism for continuity. [SA4]

The Energy 2050 project – a UKERC-wide 'whole system' integrating project conducted mostly in Phase 1 UKERC, was referenced by a number of interviewees. There were mixed opinions about the interdisciplinary strengths and weaknesses of the 2050 project, and while some interviewees saw the project in positive terms, others compared it unfavourably to a parallel whole systems project part funded by a UK research council, the Transition Pathways project, in terms of balanced disciplinary representation and attention to processes for interdisciplinary exchange:

The [Energy] 2050 book was a good example of … an interdisciplinary project. It did have a big question … and [it] bought together people from different themes with very different backgrounds to answer it … it [had] an economic modelling focus, but all projects had to be led by somebody from a different theme … it forced interaction between modellers and social scientists. [SR1]

Energy 2050 was arguably the furthest … that UKERC has gone. As an interdisciplinary exercise it was far from perfect but it did force some useful interactions. [SR2]

There were tensions in [the Energy 2050] project between people who synthesised … [and the] people who provided the data. [EA2]

The Energy 2050 project … ended up being very Markal-focused and there were some tensions … Transition Pathways was more consciously interdisciplinary … and more thought was placed on the actual process … Energy 2050 was more about the end-product with less thought about process. [EC1]

On the Transitions Pathways project … we brought different disciplines together across the disciplines, engineers and social scientists. It was fascinating to see the assumptions different disciplines brought to that Sandpit [being] challenged … Once you overcome those … novel contributions can be brought in, and the whole becomes much more than the sum of the parts; no one discipline can do that on its own … Transition Pathways is a good example of transdisciplinarity, working with broader stakeholders. [SA1]

Transitions Pathways … was originally put together from a Sandpit, and the experts involved were 50% engineers and 50% social and policy by background. [SR3]

Another comparative reference was made to the Rural Economy and Land Use programme [RELU] programme, supported by a number of UK research councils, government departments and others. For one interviewee, RELU was seen as a more successful in interdisciplinary programme than UKERC:

Crucially [RELU] had a pot of money under [its] control … [it] built-up a portfolio of projects to tackle a diversity of issues, and then made sure there were opportunities for cross-project exchange … in contrast with UKERC's approach … RELU was the best example I know of, in terms of building a community of practice. [AA3]

Another interviewee was closely involved with the development of RELU's interdisciplinary research strategy; this interviewee's experience is reported here at some length (Box 2).

We had a very reflexive approach to interdisciplinarity in RELU – we saw [it] as a research experiment … in how to bridge across disciplines and between academic and stakeholder communities… We put a lot of effort into relationship-building – through providing opportunities for promoting project results [and] developing policy and practice notes. We had some modest resource for inter-project activity – that was a lot of work, [but] most projects took the opportunities. We didn't 'performance manage' – we tried to create a community of engaged researchers. We never held a conventional academic conference – they were all cross-disciplinary and stakeholder based. Ultimately, there are very few carrots and sticks available – it's a coalition of the willing. [EA3]

We developed a number of interdisciplinary special issues in high-impact monodisciplinary journals … the proposition was to explore the prospects for interdisciplinarity, bringing social science into technical and scientific issues for the first time. This proved really successful, and helped to tie the research programme and projects together. We combined a strong disciplinary base with inter-disciplinary insight; this was quite novel. [EA3]

[Our] research strategy involved [us] with NERC-ESRC-BBSRC [multiple research councils]. Previous initiatives were seen as not very well integrated, and resources weren't pooled. The pooling of resources made a big difference – requiring all projects to combine perspectives from at least two research councils … [our] Advisory Council, made up of mostly non-academic public sector reps, identified the broad research themes … ESRC also appointed a social science advisor. [EA3]

We created four calls for proposals – [we] consulted with wider stakeholders but we left the researchers themselves to specify the detailed research content … we didn't specify the research disciplines and methods in any detail … we wanted to open up discussion with the research community. [EA3]

RELU [was] less explicitly 'whole system' oriented than UKERC. We avoided a single methodological or modelling approach, while still being holistic and integrated where appropriate … We tried opening-up systems models to different disciplines and stakeholders … we produced a special issue on expert modelling drawing on different projects. [EA3]

We tried to bring in different disciplinary mixes where there were established links, for example, between economics and environmental science; in other areas – for example, between social and biological sciences there were no established links, and here we tried to create opportunities for balanced engagement, rather than more asymmetric engagements … At the programme level, we tried to create a suite of projects, led by different disciplines. Each of the three [research] councils wanted projects that spoke to their respective communities, across different waves of funding. [EA3]

Box 2: The Interdisciplinary Research Strategy of the Rural Economy and Land Use [RELU] Programme

4.7 Lessons and Recommendations

Looking back at your experiences of interdisciplinary energy research, can you suggest some ways to improve UKERC's efforts, and their value for researchers, policymakers and others?

How different disciplines can work together: general guidelines for interdisciplinary research exchange

Several interviewees emphasised the need for attention to people as well as process – to select and support enthusiastic interdisciplinarians, and allowing them time and opportunity to develop into an interdisciplinary team:

It is important to find the right people, with the right attitude, above the right discipline … it's about working with people who have the passion and drive to work in interdisciplinary research. [SR1]

It does take a bit longer than disciplinary focused work … you do need that time for people to do it well … [You] need to make sure that everyone involved wants to do interdisciplinary research – sometimes people get involved as its seen as a good thing to do, but never fully contribute. [EC1]

For good interdisciplinarity research you need personal chemistry, respect for other disciplinary skills, and interesting problems. [AA2]

It takes time and interdisciplinary research should be given time … time to make mistakes is also important. [SR1]

The best collaborations come out of relationships of trust … this means giving enough upfront time for interaction to build up trust and respect. A danger with big collaborations is the number of people who are used to getting their way, and there's a lot of academic snobbery…

Each discipline has its own norms for success, and they can be quite different … Some disciplines are more inclined to [interdisciplinarity] than others … lack of respect [between disciplines] is crippling … for the worse kind of disciplinary monotheists, the rest of the world might as well not exist. [AA4]

There are several person and process criteria for successful interdisciplinary projects … person criteria include: motivation to solve societal problems, willingness to learn about other disciplines and expand intellectual horizons, being collaboratively-minded and having a small disciplinary ego; process criteria include: the time to get to know each-other, agreed problem definition, agreed overall approach with clarity about roles, [and] having parallel research strands with regular, interactive, stock-taking rather than a 'bolt-on' approach. [AA5]

One tension pointed to by a number of interviewees was the extent to which interdisciplinarity should (or could) be imposed on a top-down or centre-out basis, versus a more facilitative, bottom-up approach; a related issue here was the need to recognise and allow for disciplinary benefits from interdisciplinary working:

You need extra time for different disciplines to understand each other. Perceptions are also important – people need to be open-minded … how do researchers feel about their contributions? Are there visible contributions from each discipline? Individuals have to be open-minded … [and] know how to present the benefits of [their] work to other disciplines. [EC2]

The added value for each party needs to be clear, otherwise it will be forced … Inter-disciplinarity doesn't necessarily hold value in itself, it's only a tool that lets you better address the topics you want to … sometimes the starting points can be so different that there [isn't] any common ground – for example, social scientists and economists … it can't be imposed top-down. [MC1]

Projects can fail if inter-disciplinarity is expected to be bottom-up – it needs to be pre-defined … projects have to be designed to be inter-disciplinary from the start. [EA2]

Several interviewees offered descriptions of how different disciplinary communities tended to engage in interdisciplinary research, and the dynamics of interdisciplinary interaction across the social, physical and environmental sciences:

Engineers and economists tend to work well together, social scientists and economists not so much, because they look at different aspects of the problem … you need economists who can accept more qualitative work. [AA2]

Engineers and pure scientists are often driven to finding the 'right' answer – a point solution … That doesn't really work for many social scientists, who are concerned with subjectivity and framing. That's part of the conflict. In hard sciences, people are trained into certain ways of problem-framing … challenging that becomes a deep challenge to your fundamental approach … It also comes in the claim from some in the social sciences that perception is reality – subjectivity and objectivity. These are deep and potentially threatening or undermining matters. [AA3]

We found ecologists in our programme were able to work more straightforwardly with quantitative social science … It's more about how detailed and individual epistemologies map onto each other, rather than more general cross- disciplinary mapping. [EA3]

There is a complete failure to make use of the insights of social science … [in] the conduct of [interdisciplinary] research. [EA1]

We need shared problem-solving … bringing different languages and history … A lot of energy institutes that have been set up are engineering-led, and they may not have thought about how to involve social scientists, even within their own institute – the link between disciplinary and interdisciplinary capability isn't thought through. People tend to present themselves as a one-stop-shop, but don't have all the pieces and don't understand the links between disciplinary and interdisciplinary research. [SA1]

[We] tend to place more emphasis on social scientists than in the past – that's really needed now, as energy technologies have become more controversial – [but] we tend to work with more technically-oriented social science institutes … it's easier to get high-quality [research] for less money in social sciences than physical sciences. [SA4]

Research leadership and programme design

Following-on from the general guidelines outlined above, several interviewees made a number of more operational recommendations for interdisciplinary research leadership and high-level aspects of interdisciplinary research programme design:

Research leadership involves making time to build relationships and let things develop … you also need to know when to cut your losses or refocus … be aware whether and when people are talking to each other or not. [AA2]

Leadership here means being a charismatic champion, [and] persuading the funding councils and publishers to think in different ways. Academics resist being managed – they see themselves as being self-employed … [and] unless there is immediate success, people will often think the learning curve is too steep, and they'll walk away – there's a small window of opportunity. [AA3]

Think in a question-oriented way and reflect on why interdisciplinarity will be beneficial. It should be designed-in … and not treated as an add-on. [EC2]

When designing the research, you need to consider objectives against means. [EA2]

Theme leaders should keep in mind what they're trying to achieve, and not just try and use UKERC as an opportunity to do what they would have been doing anyway. [SR2]

You need to have opportunities for informal thinking and interaction … research themes should be problem-based and include people from different disciplines. [AA2]

Interdisciplinary leadership training is a key aspect …

All organisational models have their advantages and disadvantages. It's important to recognise those, and say how you are going to deal with them. [SA1]

At a further level of detail, some interviewees suggested the need to create – and resource –specific, dedicated structures for interdisciplinary working, over and above those that might be found in a more disciplinary-oriented programme:

Each theme needs a leader, however each theme should have a deputy who is from a different discipline from the theme leader. Meetings should be regular within themes … each theme leader should have their own way of developing training within the theme and then [UKERC should] perhaps run a small workshop across themes to share best practices. [SR3]

Communication and engagement is sometimes lacking and as seen as a bolt-on (sometimes only 5-15% of the research spend) … a much higher percentage, such as 33%, can give much better results – but some researchers would rather spend that money on the core research. [AA4]

Unless you explicitly allocate resource on [cross-project exchange] … you're on a multi-, not inter-disciplinary track You need [to specify] 75% of …allocated [researcher] time working on a project, then 25% of their time allocated for working with other projects. [AA3]

Some of the high-level advice on research design that emerged from stakeholder interviewees suggested that UKERC needed to be clearer about its identity and remit within the UK's wider academic and non-academic energy research environment – and pay explicit attention to the resources needed to successfully discharge its differing roles:

UKERC needs to be clearer about what its remit is – the extent to which it presents its own research, or is a gateway for the wider community (for example, what are the overlaps with EUED [end-use energy demand] centres? It's not really credible for UKERC to continue to claim to be the voice of the academic research community. [SA2]

UKERC needs to decide whether to focus and concentrate .. [on] a few institutions, or be very open. If it's being asked to be very open, it needs more funding. If it tries to do both, it risks jeopardising its research quality. [SA4]

Research Support Activities

A number of interviewees highlighted the contributions from of central co-ordinating, networking and exchange teams within an interdisciplinary research programme, including their reflections on UKERC's research supporting activities to date, and how they might be improved in the future:

Research coordination and knowledge exchange [teams] can help define the right questions. [EC2]

Research coordination … is central to UKERC, as they look at what are the big questions and … how we answer them … unfortunately research coordination [in UKERC Phase II] has had to spend a lot of time managing the Research Fund rather than interacting with the research programme …

[UKERC's] Meeting Place [interdisciplinary workshop management team] offers time and space for all parties to learn and understand other people's disciplines … the methods that the Meeting Place use are something that should be applied [more widely] within UKERC. [SR1]

The SPARKS [PhD student network] was a major positive experience of UKERC … meeting people from different backgrounds … was the best support network. [EC1]

The Meeting Place and Knowledge Exchange [teams] should be more … research-conscious and research-focused. [EA2]

Maybe it would be good to get specific input from people who specialise in interdisciplinary studies and how to make people work together across disciplines; it's difficult to make it happen in reality. [SR2]

Funding structures and project commissioning

A number of interviewees noted the advantages for interdisciplinary research programme design in having a proportion of funds reserved for responsive or follow-on research; some interviewees offered suggestions for the design and operation of a flexible research fund:

It's good to have flexibility through the Research Fund … part of the Research Fund can be reserved for addressing issues that come up unexpectedly, such as shale gas. [AA1]

Core and flexible funding is good as it gives you the chance to respond to things as they emerge. Flexible funding can keep core researchers on their toes [and] make sure they'll keep delivering, given the prospect of future funding. [AA2].

The Research Committee has helped in opening-up UKERC … flexible fund projects [have had] higher impact and been more focused. [EA2]

When putting together a call [for flexible fund research proposals], the specific skills that are needed should be more explicitly defined; this would help UKERC in terms of inclusivity. [AA1]

Over the course of a long programme priorities will change and you need flexibility … the research councils take so much time [and] there is scope for doing things more quickly. You need the insiders within a consortium to be able to allocate resource quite quickly and then bring in others if the expertise isn't there. [AA3]

UKERC might consider a 'stage-gate' [funding] process, so academics don't go off for two years to run a project … [full] funding follows only after there is some evidence of co-design and interdisciplinarity. [SA2]

Two interviewees noted a need for interdisciplinary programmes supported by multiple funding bodies to attend to the particular interests and needs of individual funders:

Cross-council funding shapes disciplinary involvement in different ways than single council funding. [EA3]

[Given] the politics of research councils, [its] better to have research themes where [each] council's contribution is easily recognised. [EA2]

Integrating projects and research synthesis

One aspect of programme design mentioned by a number of interviewees was for interdisciplinary research integration – and creating mechanisms for the articulation of a 'whole systems' perspective – from the beginning of a research programme.

It's a good idea to have lots of small projects on specific topics, but also the flagship projects on more general topics. [SA4]

Start with integrating aspirations from the beginning. [SR2]

[You] need to have a clear [integration] strategy early on. [SR1]

Two other interviews highlighted the value of a more dedicated, topic-level research-synthesising activity, such as has been performed by UKERC's Technology and Policy Assessment (TPA) team:

The things that make the field are the big-picture review papers or synthetic reviews. [AA3]

The TPA research synthesis model is particularly useful, and could be extended. [SA2]

Stakeholder and advisory relations; at what stages of research should stakeholders be involved, and what are the best ways of involving them?

There was some difference of view among interviewees regarding the extent to which interdisciplinary academic researchers should become more closely engaged with policy, business and other stakeholders. While some interviewees – both academic and non-academic – suggested the need for closer stakeholder involvement in interdisciplinary research, a number of others – especially academic interviewees – raised concerns.

These reservations included the practical difficulties of closer stakeholder working, given the different work cultures, and also, to the threat closer collaboration posed to academics' research independence:

UKERC needs to have multiple stakeholders, [with] continuous background involvement. [EA2]

There's a need to involve stakeholders more directly than in advisory groups. That would give more credibility to research – [that's] a problem in academia in general, not only UKERC – [you should] approach trade associations instead of individual companies. [AA1]

Policymakers have very different timescales and the connection with academics can be patchy. There should be on-going communication to overcome this. [EC2]

Policy-related research value isn't self-evident – it's a dance and [researchers] need to make sure that it has value to users. [EA1]

It's useful to have external stakeholders as advisors, but you have to be careful not to take it too far or you risk being treated as a consultancy … stakeholders want to answer questions that are directly relevant to their benefit … it can be difficult to have projects assigned to you by external stakeholders, [it's] better to maintain flexibility to determine your own project. [MC1]

Co-producing research means you could lose control of your research agenda. [AA4]

The main constraint is actually the time available you have with stakeholders and policymakers; they only have a short time so you have to cut out certain bits of information. [SR1]

Business users are always difficult to interact with because we [academics] don't work on their time scales and [they] want very specific benefits. [SR1]

A number of interviewees – both academic and non-academic – suggested that these tensions could be reconciled by allowing for significant stakeholder engagement in the early stages of research commissioning and design, but not in the later stages of research production:

Co-design is paramount – co-production less. [SA2]

Non-academic stakeholders should be involved early on to help define the scope of the research; there should be a regular, fixed-in form of contact, maybe through advisory panels as in the [UKERC] Public Attitudes project. [EC2]

I'm in favour of co-funding and co-design – it needs to be built in from the very beginning – but there are concerns about co-production, especially in more contested areas, and where there are cartel concerns. There are co-design methods which allow for identifying agreed research priorities. [AA3]

It's useful to know what's interesting for industrial partners, but you need to be careful to avoid biases. They should be involved at early stages of projects – involve them, but don't follow them. [AA2]

It's important to decide in advance who are the owners of the research outputs, what the roles are. We don't want too much impact of companies on public research. [SA4]

The interviewees included senior policy, industry and research funding stakeholders; their views on academic-stakeholder engagement, and their suggestions for improvement, are detailed below (Boxes 3 and 4); both suggest the need – and the opportunity – for improved stakeholder relations.

For [policymakers] in our engagement with researchers in academia, there are two key issues or problems: firstly, problem definition: especially, encouraging academics to see the problem from a policymaker's perspective rather than preaching to us – although learning is needed on both sides; and secondly, the timing of research and research results: policy works to relatively short timescales. [SA2]

There are often problems with the way academics seek to engage with policy: having a 'communications' or 'dissemination' mind-set, and not making contact at the right time. A step change is needed in the quality of research-policy exchange. [SA2]

Different government departments have different 'cultures of expertise': Treasury is economics-oriented, DEFRA is science-led, BIS is industry-led and DECC is somewhere in-between. There were probably low expectations about UKERC input into policy in 2008, at the commissioning of Phase II, given its links to BERR. [SA2]

DECC tends to use contract tendering to provide evidence. This is expensive, and doesn't always represent the full balance of evidence. There's a need for improved links with academics to help this … UKERC and DECC could co-host a knowledge broker – someone who could get inside the UKERC research programme, and also [understand] DECC needs. [SA2]

The translation of [research] language and outputs to policymakers is essential … a lot of research out there hasn't been able to provide useful answers … for example, I've received lots of information about bioenergy assessments that … just provide more questions than answers – this is of very little use to policymakers, although it may be interesting for academics; many academics are still reluctant to make their work policy relevant. [SA3]

I've been situated somewhere between academia and public policy most of my career … interdisciplinary project leaders need to involve policymakers much earlier, and higher-level policy makers and stakeholders … for example, the DECC [pathways] calculator had policymakers and end-users in mind from the outset … UKERC does a reasonably good job of dissemination … [but] the end-users of the research … should be targeted as a priority. [SA3]

Box 3: Policymakers' Perspectives on UKERC Stakeholder Relations

I think UKERC has a problem with its relationship with industry. UKERC has been very focussed on social sciences and the policymaking stakeholder. Social scientists tend to be more comfortable talking to policymakers than industrialists – that's seen as less of a compromise … I can't point to lots of examples where there is deep engagement [with industry], or just in terms of getting its outputs out there. When I challenge people in UKERC on that, I don't sense a great enthusiasm to getting their work out to a broad set of stakeholders … [UKERC needs to] create material that can be useful to busy people … engage with the key gatekeepers and give them something that enables them to promote your story. [SA1]

UKERC needs to understand who its stakeholders are, how it will reach them, and give people assigned roles. The academics in UKERC need to understand that – make sure people are promoting UKERC in their engagements and are prepared to wear their UKERC hats … industry engagement can't be wholly handed over to a knowledge exchange team – it needs to be embedded in the whole organisation, or it won't be prioritised. Have plans, have a strategy, have metrics. [SA1]

Academia is a cost-effective way of providing useful knowledge – especially institutions, academics and researchers who are hungry … There are some interesting institutional models, going beyond normal forms of co-operation between business and universities – for example, the TSB catapult centres [SA1].

Look for benefit from public researchers' interaction with businesses – for example, through their access to data for systems analysis … [or] modelling of smart energy systems – that's why you need to interact … we have close interaction between utilities and university-based modellers; I haven't seen that in the UKERC programme [SA4]

Box 4: Business and Research Funder Perspectives on UKERC Stakeholder Relations

Finally, one problematic issue addressed by two interviewees was the influence on academic research objectivity arising from deeper forms of research-stakeholder interaction, often referred to as 'transdisciplinary' research. While for one interviewee had encountered difficulties in transdisciplinary research (outside UKERC), for another, it was seen as allowing for more explicit, normative-based framings in contentious areas such as energy policy and research:

I've had some problems … collaborating with campaign groups, and the biases / normativity involved … that's a risk for interdisciplinary research – the clash between objectivity and subjectivity. [AA3]

[The] research councils … want to engage … in an objective process … [but] It isn't possible to be non-normative or value free … and research shouldn't pretend that there is such a thing … In UKERC there isn't much mention about controversy or power – it's more 'let's be neutral', and then disseminate to stakeholders … the etiquette is to pretend there is no such thing as power in research – [but] it is important to be open about power relations. [EA1]

5. Conclusions

The aims of this project were fourfold: firstly, to consider the general challenges and opportunities of interdisciplinary energy research; secondly, to explore the experiences and views of the UKERC research community in relation to interdisciplinarity; thirdly, to assess the particular strengths and weaknesses of UKERC's efforts to foster interdisciplinary energy research; and finally, to identify specific opportunities for the improved design and conduct of interdisciplinary research in future UKERC activities.

The project was well-received by many UKERC researchers and stakeholders, with the engagement of a significant proportion – around half – of the entire Phase 2 research programme, and representatives from UKERC's policy, business and other advisory stakeholder. Despite this broad level of interest, the results inevitably reflect the personal experiences and impressions of those who participated, in some cases based on limited experience and/or a partial knowledge of UKERC's activities.

Phase 2 UKERC has faced particular challenges in realising its interdisciplinary ambitions: a tension between cohesiveness and flexibility in managing its 'Core and Flex' funding model, which has led to UKERC having a more diverse but less stable research community, and the wider challenges of the increased urgency of energy research problems, and UK's institutional context for academic research.

Despite these challenges, UKERC researchers and stakeholder hold broadly positive views on UKERC's interdisciplinary efforts – while also indicating room for improvement. The clear majority of survey respondents agreed that UKERC had supported interdisciplinary collaboration through its content and structure. In addition to of its direct achievements, UKERC is recognised as having helped to build-up the interdisciplinary energy research community in the UK, with almost three-quarters of survey respondents indicating that their involvement in UKERC had increased the likelihood of their future participation in interdisciplinary energy research. Respondents also highlighted UKERC's 'real-world' orientation and policy relevance and impact.

Although there was broad recognition of UKERC's achievements in creating spaces for interdisciplinary research, it is seen by many as having been less pioneering, in terms of its methods, practices and organisational make-up, than some other initiatives, and some respondents highlighted a tendency in UKERC toward multidisciplinary rather than interdisciplinarity research. This suggests the need for more conscious attention and reflection on interdisciplinary processes and methods, and perhaps greater ambition in the future. Indeed, there were suggestions in the survey, facilitated group discussion and semi-structured interviews that more

ambitious forms of interdisciplinarity were possible, and desirable – for example, by designing the research programme more explicitly around 'big research questions', with interdisciplinarity built-in from the start, rather than being introduced through mid-phase 'Flagship' projects.

A repeated theme among group discussants and interviewees was that successful inter-disciplinary research relies on committed and motivated individuals, and under any programme structure, UKERC's interdisciplinary ambitions will continue to depend on these. At the same time, project participants also repeatedly emphasised the need for programme design and funding models to recognise the added challenges of interdisciplinary research, by offering dedicated time and resources for interdisciplinary exchange and translation. There are persistent barriers between disciplines – linguistic and also deeper epistemological barriers – and addressing these means allowing for them in the details of programme design and funding structures.

The results suggest considerable researcher and stakeholder enthusiasm for interdisciplinarity, but also recognition and concerns about its practical challenges and professional implications, including academic career progression (particularly for the junior researchers) in an institutional context which has tended to privilege disciplinary expertise and reinforce disciplinary boundaries. Ultimately, UKERC's interdisciplinary achievements and limitations cannot be judged in isolation: there is a widely-shared perception – among both researchers and stakeholders – that UKERC Phase 2 has operated in a challenging wider context for interdisciplinary research. Nevertheless, for many involved in UKERC, the benefits of interdisciplinary research outweigh the challenges, and the additional effort involved is seen as worthwhile. Above all, an interdisciplinary perspective is seen by the vast majority of the researchers and stakeholders who participated in this project as being essential to fulfilling UKERC's ambitions for whole-systems research, and addressing critical societal problems in the UK and beyond.

Annex: Survey Questions

Q1. We would like to know a bit more about you. Providing your details is optional and all responses will be anonymised in any reports and publications.

Answered: 82 Skipped: 8

Q2. What is your current academic role?

Answered: 84 Skipped: 6

Q3. How would you describe, broadly, your current research discipline?

Answered: 87 Skipped: 3

Q4. What is your current research role in UKERC?

Answered: 77 Skipped: 13

Q5. Which UKERC theme(s) are you involved with?

Answered: 82 Skipped: 8

Q6. Are you involved in Core or Research Fund projects?

Answered: 82 Skipped: 8

Q7. Did you have any experience of participating in an interdisciplinary centre or project before joining UKERC?

Answered: 87 Skipped: 3

Q8. If you answered 'yes' to the previous question, how well in general terms does UKERC's approach to interdisciplinary research compare?

Answered: 69 Skipped: 21

Q9. "The content and structure of the UKERC research programme supports interdisciplinary collaboration"

Answered: 86 Skipped: 4

Q10. Below is a list of ways in which UKERC supports interdiciplinary research. How do you rate the effectiveness of those that you've used?

Answered: 86 Skipped: 4

Q11. At what level(s) do you think effective interdisciplinarity has occurred in UKERC? Tick all that apply.

Answered: 84 Skipped: 6

Q12. How strongly do you think the following broad disciplines are represented in UKERC?

Answered: 84 Skipped: 6

Q13. How well have different disciplines interacted in UKERC?

Answered: 82 Skipped: 8