



UKERC Interdisciplinary Review: Research Report

Final Version, April 2015

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Acknowledgements

This research was undertaken within the UK Energy Research Centre, supported by the UK Research Councils under Natural Environment Research Council award NE/G007748/1. The authors wish to thank two reviewers for their comments on an earlier version of this report, and to the many people who contributed their views and experiences from across UKERC's research and stakeholding communities in the course of the research reported here. The views expressed are the authors' own, rather than those of their funders or employers.

Executive Summary

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 an initial 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 2009 and 2014. A third five-year phase of research, supported by EPSRC, NERC and ESRC, started in May 2014.

This report presents the results of a project which reviewed UKERC's interdisciplinary research capacities and achievements, in terms of strengths, weaknesses and scope for improvement. The review, which involved a large number of UKERC's researchers and stakeholders, was led by UKERC staff responsible for research co-ordination and workshop facilitation. The project was commissioned in-part to inform and support UKERC's Phase 3 research strategy during 2013 and 2014.

The project included a review of the literature on interdisciplinary energy research, a review of the experiences of other similar interdisciplinary energy and climate change research initiatives in the UK, a facilitated group discussion, an online survey, and a number of semi-structured interviews. As well as this report, ongoing analysis of the project findings is linking the UKERC interdisciplinary experience to other developments in energy and climate change publicly-funded research, and to wider, more conceptually-informed issues in the interdisciplinary studies research literature.

Project Findings

There is widespread recognition of UKERC's interdisciplinary achievements and strengths, but also some suggested weaknesses and opportunities for improved interdisciplinary working. The researchers and others consulted in the course of this project overwhelmingly agreed that UKERC had helped develop an interdisciplinary energy research community in the UK, and also, that their own involvement in UKERC had made them more likely to participate in interdisciplinary energy research in the future. A particular perceived strength of UKERC research is its capacity to bring together different disciplines to address 'real-world' problems.

Alongside this strong track record in capacity building for 'problem-driven' energy research, UKERC was seen as less pioneering in its interdisciplinary methods and

outputs than some other initiatives. Survey respondents, interviewees and discussion group participants highlighted a tendency in Phase 2 UKERC to more compartmentalised *multidisciplinary* research rather than more integrated *interdisciplinary* research across UKERC's research themes. This suggests the need for more explicit attention on interdisciplinary structures and processes, and there were suggestions that more ambitious forms of interdisciplinarity were possible and desirable – for example, by designing the research programme more explicitly around cross-cutting research questions, with an emphasis on centre-wide interdisciplinarity initiatives from the start, rather than being introduced in mid-phase 'Flagship' projects.

These limitations reflect some operational and contextual challenges that faced Phase 2 UKERC. Operationally, a difficult balance had to be struck between cohesiveness and openness: the designation of around half of UKERC's Phase 2 research funds to a 'flexible fund' (allocated through a series of open and competitive calls) enabled the involvement of a wide range of research institutions and disciplines, but a strong emphasis on openness and diversity arguably undermined the prospects for more ambitious forms of interdisciplinary research which rely on deeper levels of understanding, familiarity and trust. UKERC 2 also suffered from some discontinuity of strategic and operational personnel, which also impacted on interdisciplinary capacity. Alongside renewal and change, continuity is a key foundation of interdisciplinary achievement.

Contextually, Phase 2 coincided with a UK academic assessment exercise which tended to privilege monodisciplinary, individualistic research achievement. While most researchers involved in UKERC have a keen interest developing collaborations across disciplines, they are also aware of the difficulties of combining disciplinary identity with interdisciplinary achievement, in terms of funding, publishing and career progression. There is a need for further research on the development of interdisciplinary research careers. Less directly, Phase 2 was also shaped by an increased sense of crisis in UK energy policy, and more urgent and exigent tendencies can marginalise whole systems interdisciplinary research.

Another prominent theme in this project (and wider research) is the key role of research funding, commissioning and assessment in shaping and supporting interdisciplinary research capacity and achievements. The UKERC experience, like others before, suggests the need for improved collaboration and partnership between the UK's disciplinary-based Research Councils in pursuit of interdisciplinary research ambitions, and more joined-up and consistent processes for commissioning and assessing interdisciplinary research.

There is no single mode or method for interdisciplinary research, but rather many different experiences, approaches and techniques. Perhaps reflecting UKERC's historic orientation to applied physical sciences and economics, and also its 'whole systems' remit, the prevailing interdisciplinary rationale in UKERC (especially in Phase 1) has been on synthesis and integration. With greater disciplinary heterogeneity in UKERC in Phase 2 and Phase 3, and as part of a more reflexive approach, more consideration should be given to the multiple forms of interdisciplinarity in UKERC. This might, for example, involve recognising the limits of interdisciplinarity given disciplinary differences, or greater efforts at transdisciplinary research with stakeholders more fully involved in design.

Conclusion

In an uncertain political and economic outlook for energy research, a commitment to independent, holistic and interdisciplinary research becomes ever more salient. Yet there are powerful 'transaction costs' and barriers to interdisciplinary research, and the resonance of UKERC's experience with other similar research initiatives suggests that some rather well-reported challenges have yet to be adequately addressed.

Powerful barriers remain to interdisciplinary research, in terms of academic institutions and incentive mechanisms, and also more epistemological and ontological divides. Successful interdisciplinary research involves recognising these barriers, and explicitly taking them into account throughout the research cycle, including commissioning and assessment processes as well as a 'root-and-branch' research strategy. Ultimately, UKERC's interdisciplinary achievements and limitations cannot be judged in isolation. Improving UKERC's interdisciplinary capacities is a joint responsibility of all those involved.

Recommendations for Researchers, Funders and Assessors

Recognise the distinctive role and value of interdisciplinary, whole systems research

Interdisciplinarity is driven by the need for research to better reflect complex ‘real world’ problems, particularly in energy and environment areas, than is possible with mono-disciplinary research. Whole systems research involves understanding interrelationships in complex systems – attending to particular problems while also maintaining an evolving appreciation of the whole. This is a challenging mission.

Be explicit and reflexive, and draw on wider experiences and expertise

Devising, implementing and reviewing an interdisciplinary research strategy should be an explicit part of UKERC’s activities. To promote and support this, consideration should be given to seeking advice and support from specialists in interdisciplinary research management, or those with similar experiences of co-ordinating large interdisciplinary research programmes.

Allow for the extra time and effort involved

Successful interdisciplinary research requires additional time and effort. This needs to be factored-in to research programme design and funding, especially in the early stages, but also on a recurring basis. As well as disciplinary experts, there is an important role for interdisciplinary translators and facilitators.

Decide on interdisciplinary ambition

Interdisciplinarity can happen in many different ways, and there is no single best practice blueprint. UKERC should be more explicit about its interdisciplinary ambition, across *multidisciplinarity* (with self-contained disciplines with low levels of collaboration); *interdisciplinarity* (which seeks more integrated disciplinary perspectives and more holistic outcomes); and *transdisciplinarity* (with strong elements of co-design and/or co-production with non-academic stakeholders). There is a need to consider the different modes of interdisciplinary exchange beyond integration and synthesis. Different ambitions imply different research designs and resource requirements, and perceived failures in interdisciplinary initiatives may relate to unrealistic expectations. It is useful to agree on the broad nature and extent of interdisciplinary ambition early-on, while also allowing some flexibility given that research programmes develop and change over time.

Aim for balanced disciplinary representation

An effort to achieve disciplinary balance at different levels (especially, theme and programme-level) encourages interdisciplinarity, and helps guard against the emergence of dominant and marginalised disciplines.

Recognise the trade-off between inclusiveness and integration

A strong emphasis on openness and diversity in research programmes erodes capacity for more ambitious forms of interdisciplinarity which rely on familiarity and trust. This trade-off should be anticipated by both researchers and their funders.

Value strategic and organisational continuity

Although it has benefitted from three successive awards from RCUK, UKERC has also faced high multiple expectations, changing resource models and some organisational discontinuity. Such discontinuities can erode the development of interdisciplinary whole systems research capacity.

Clarify UKERC's remit

There is a need for clarity on UKERC's roles as both a research programme in its own right and a networking and representative body for the wider research community – and recognition of the resource implications involved, given the dramatic growth in the energy research community over UKERC's lifetime.

Strengthen collaboration with the wider energy research community

UKERC should seek to engage more systematically with the wider energy research community. For example, UKERC events could include more guest speakers from other major initiatives. There should also be greater efforts at co-funding research with other large programmes within the RC's Energy Programme

Recognise the interests of different funders

Given UKERC's funding is provided by multiple Research Councils (rather than a single interdisciplinary Council or single cross-Council commissioning body) UKERC's research strategy needs to recognise the distinctive interests of each individual Council and their respective research communities.

Regularly engage with stakeholders in research co-design, and consider more ambitious efforts at transdisciplinarity

UKERC should enable regular, substantial stakeholder and policy engagement in its research design and commissioning, and in interpreting research outcomes. However, there are some concerns among researchers about the more direct involvement of stakeholders in research production, and radical transdisciplinarity may be better seen as an experimental rather than a mainstream element of Phase 3.

Devise and use interdisciplinary evaluation metrics

Conventional research metrics, such as journal prestige or citation patterns are less appropriate for assessing interdisciplinary research. Other forms of assessment should also be used, such as impact case studies, interdisciplinary output counts, and evidence of follow-on funding.

Develop a systemic, 'root-and-branch' interdisciplinary research strategy

UKERC should develop a root-and-branch interdisciplinary research strategy across *researcher, project, theme, and programme* levels. Some suggested elements in this strategy are:

- At the *researcher level*, offer interdisciplinary publishing opportunities by negotiating interdisciplinary special issues of high-impact journals. Researchers also value UKERC-run events and networks which create a protected space for interdisciplinary exchange.
- At the *project level*, devise and commission projects which deliberately and explicitly combine together different methods and perspectives, with dedicated review processes for assessing the interdisciplinary credentials of proposals.
- At the *theme level*, each theme should have a theme leader and deputy from different disciplines. Meetings should be regular within themes, with occasional workshops across themes to share best practices. Theme achievements in interdisciplinarity should be regularly reviewed.
- At the *programme level*, foster interdisciplinary capacity through 'seed-corn' funding, and running workshops and conferences designed to promote interdisciplinary exchange. The overall interdisciplinary research strategy should be regularly reviewed.

Recognise the collective responsibility of funders, researchers and assessors

As well as a more explicit and reflexive strategic leadership by its senior researchers, strengthening UKERC's interdisciplinary ambitions and achievements require a stronger partnership of all those involved in the commissioning, management and assessment of its research.

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1. Introduction and Literature Review

1.1 UKERC Background

1.1.1 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 second phase programme of work was supported by the same three funding bodies between May 2009 and April 2014. A third five-year phase of research, again supported by EPSRC, NERC and ESRC, started in May 2014.

This report based on a project commissioned by Phase 2 UKERC's independent Research Committee to review UKERC's research programme in terms of its interdisciplinary research achievements and challenges, so as to draw out some lessons and recommendations for Phase 3 UKERC. The project was carried out by UKERC's central staff from its 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 mostly in September and October 2013 (n=18).

The rest of this chapter provides an introduction to UKERC, and a review of some of the wider research literature on interdisciplinary research, especially as related to energy and environmental problems. Chapter 2 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 based on UKERC's experience to date, and develops a set of recommendations for next phase UKERC and wider interdisciplinary energy research in the UK.

1.1.2 UKERC Phase 1 (2004-2009)

UKERC was created in the early 2000s, at a time when the UK’s public spending on energy research was starting to recover from a very low base. Its genesis was an Energy Research Review Group (ERRG), set up by the then Chief Scientific Advisor, Sir David King. The ERRG’s work fed into to a wider review conducted by the UK Cabinet Office – the first comprehensive review of UK energy policy since privatisation of the energy industries in the 1980s (PIU, 2002). The ERRG called for the creation of a national energy research centre for the UK, and emphasised the need for a multidisciplinary approach to energy research:

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. (ERRG, 2001)

The UK Energy Research Centre was duly launched in 2004, charged with two main tasks: running its own ‘whole system’ research programme, and networking and capacity-building for the UK’s wider 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 and research institutes, with its headquarters 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 been a very small (and diminishing) fraction of Councils’ spending on energy research (Figure 1).

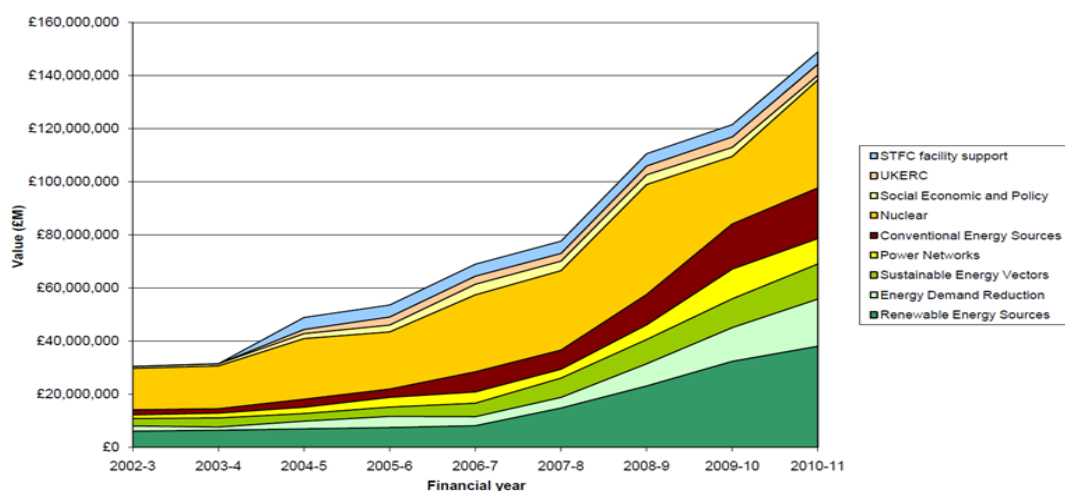


Figure 1: Research Councils’ Energy Programme, Annual Expenditure by Theme

(Source: Research Councils UK, 2010)

In its first phase (2004–09) UKERC’s research programme was organised around six themes: three ‘vertical’ themes covering particular parts of the energy system (demand reduction, future sources of energy and infrastructure and supply); and three cross-cutting ‘horizontal’ themes (energy systems and modelling, environmental sustainability and next generation energy materials) (Figure 2).

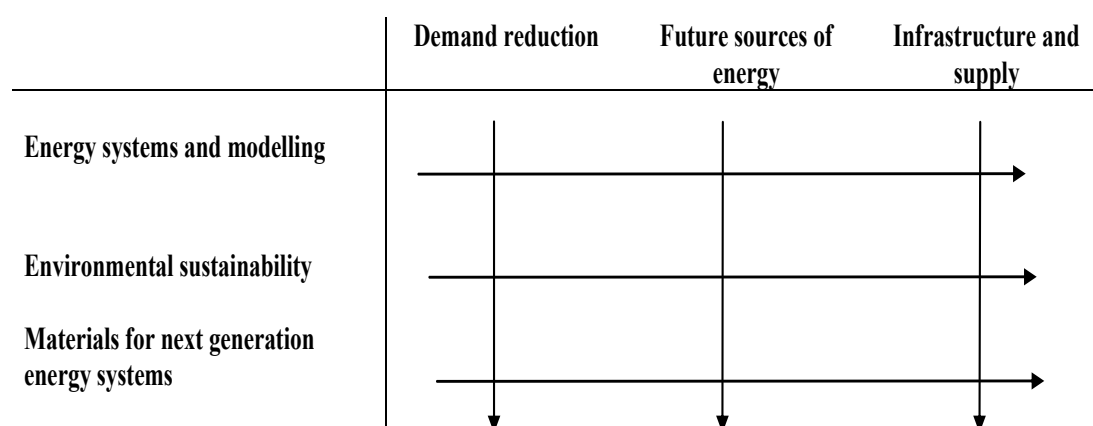


Figure 2: UKERC Phase I Thematic Research Programme Structure (2004-2006)

Mid-way through Phase I, a view developed among UKERC’s senior researchers that the thematic structure was tending to reinforce silos rather than promote interdisciplinarity (Skea, 2013). This prompted the creation of an ‘integrating project’ (known later as the *Energy 2050* project) which was organised in a more explicitly networked, problem-driven way (Figure 3). Energy 2050 was deliberately designed as a means of promoting interdisciplinarity, by creating interdependencies between different research themes, disciplines and institutions.

The Energy 2050 project involved changed ways of working for almost all Phase 1 UKERC researchers; it meant, for example, that from late 2007 to mid-2009, the agendas for all of UKERC’s regular series of General Meetings and Annual Assemblies were designed around Energy 2050 working groups. The major outputs from the project were a ‘synthesis report’ released at the end of Phase 1, and an edited book collection published 18 months into Phase 2 (Skea et al., 2011).

In retrospect, Energy 2050 had its successes and limitations in interdisciplinary terms (Skea, 2013; Winskel, 2013a). On the plus side, it greatly strengthened UKERC’s whole systems perspective, in its account of the UK energy system as complex socio-technical whole, and the role of research in reflecting the interdependencies involved. However, Energy 2050 became, in practice, modelling-centric, with its scenarios constructed essentially as a series of modelling inputs and outputs (Skea, 2013). Modelling can become a dominant research method at the

systems level, and there is a need for careful attention to the ways that disciplines engage with one another in whole systems projects.

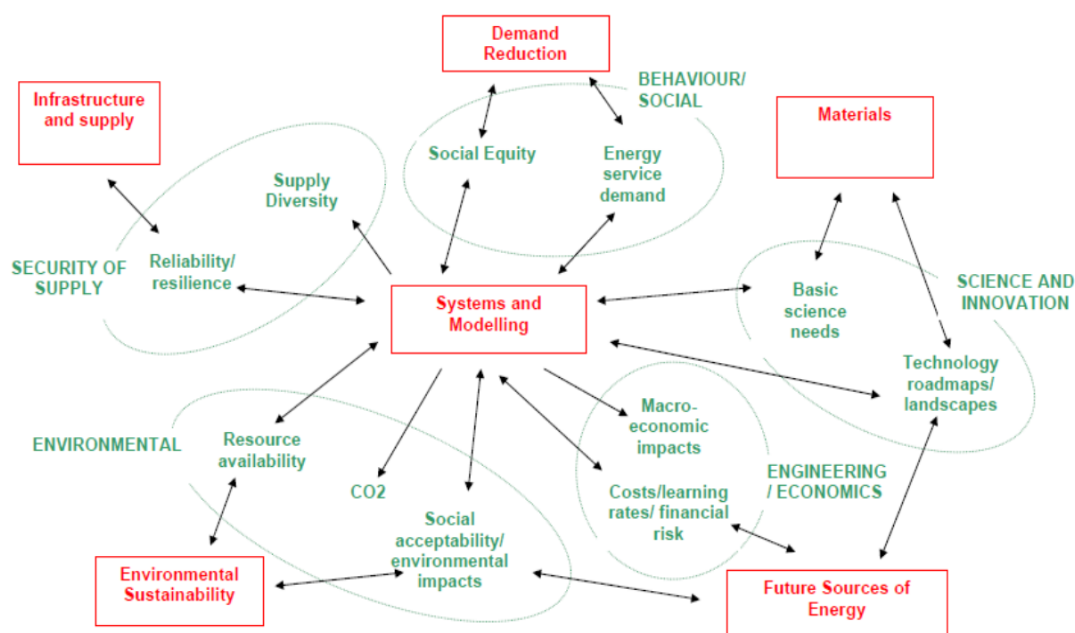


Figure 3: UKERC Phase I Energy 2050 Research Programme Structure (2007-09)

In addition, Energy 2050 articulated a partial and incomplete ‘whole system’ perspective, with a tendency to neglect more radical technologies and behaviours, such as smart grids and local energy systems, and giving little attention to some socio–environmental issues (consumption–based accounting, whole lifecycle impacts and public attitudes) and important ‘real–world’ (but difficult to model) enablers and barriers, such as investment risk, technology risk and homeowners’ decision–making (Winkel, 2013a). These limitations informed a refreshed research agenda for UKERC Phase II. The continuity of funding and personnel between phases was important here, in enabling a more considered analysis of the research outcomes of Energy 2050 than was possible at the end of Phase 1 (in the form of an edited book collection, published over 18 months after the publication of the Energy 2050 synthesis report), and also, developing a revised research strategy.

1.1.3 UKERC Phase 2 (2009-2014)

Towards the end of Phase 1, the Research Councils indicated their intention to fund a second 5–year phase of UKERC research. UKERC Phase 2 operated in a much changed domestic and international political and economic context to Phase I, with an overall policy emphasis on economic recovery, a rapidly changing energy policy context, and a weakened political consensus on climate change. Reflecting these changes, the overall Centre mission was redefined from ‘*what are the options for the energy system in 2050?*’ in Phase I, to ‘*how can we manage the transition, given a*

*deeply uncertain world which won't develop along smooth trajectories?'. Other notable changes in emphasis for Phase 2 (in-part made at the request of the Research Councils and stakeholders) were to be more *explicitly international* in outlook, and have greater emphasis on *medium term challenges* (in the 2020s and 2030s) than the long term 'end-point' of 2050 (UKERC, 2008).*

As is typical for large scale research centres in the UK, the UKERC recommissioning process involved a lengthy period of consultation between Research Council programme managers, senior UKERC researchers, and representatives from wider research, business and other stakeholder groups. A recurring tension during this process was the need to allow for both *continuity* and *renewal*. In issuing its 'Invitation to Tender' for Phase 2, the Natural Environmental Research Council (NERC) (the lead Research Council for Phases 1 and 2) stressed the need for continuity, given the increasing sense of urgency on energy policy and energy research:

An open competition [for Phase 2] would be counterproductive, given the high level of recent changes in the energy innovation landscape and the urgency of addressing the energy challenges presented by climate change and the need for secure energy supplies. A single proposal is therefore being invited. (NERC, 2008)

NERC also made clear that UKERC's broad remit was to remain largely unchanged – Phase 2 was expected to conduct 'a strongly visionary and integrating whole-systems work programme focused on inter-disciplinary research' (NERC, 2008), while also undertaking capacity-building activities, including interdisciplinary PhD training, support for early stage career researchers, networking opportunities for UKERC members, and a range of knowledge exchange activities for the wider energy research community.

The value of continuity in large-scale research initiatives was highlighted by an international review of UK energy research; funding plans for large centres, the review concluded, should be 'for no less than 10 years' (RCUK, 2010, p24). While there were high-level elements of continuity in UKERC recommissioning, important differences were imposed on Phase 2's funding and organisation. Although Research Council spending on energy was now expanding rapidly (Figure 1), UKERC Phase 2 was to be funded at approximately the same level as Phase 1 (c.£3.5m p.a.). NERC suggested that around 40% of this should be dedicated to networking and capacity building activities, leaving just over £2m p.a. for research.

Within the research programme, a major change (and further division of spending) was introduced by the Research Councils. While Phase I UKERC had operated as a conventional research consortium funded upfront for five years, around half of UKERC Phase 2 research funds were to be allocated 'flexibly', through a series of

open and competitive research calls. The stated aims of the flexible Research Fund were threefold: to bring a *wider range of researchers and disciplines* into UKERC; to ensure that the *best science* was used to deliver the research; and to allow the programme to *develop flexibly* in the light of new scientific insights or external developments (NERC, 2008).

The Research Councils also suggested some broad strategic priorities for the Research Fund, and next phase UKERC's overall research programme. In the course of recommissioning, some criticism had emerged from the wider research and stakeholder community regarding Phase 1's achievements in social and environmental science. This led to an additional request from NERC that the flexible Research Fund should enable the greater involvement of social and environmental research disciplines in Phase 2 (UKERC, 2009).

The Research Fund transformed UKERC's make-up. Between 2009 and 2011, 16 'Research Fund' projects were commissioned over four rounds of open calls. Each round involved inviting proposals on a number of specific research topics. Additionally, after 2011, UKERC's Research Directorate, Research Committee and Research Co-ordination Team redeployed some remaining UKERC funds to commission further projects in a series of invited 'closed' calls. These 'residual funds' projects (12 in all) were designed to make specific contributions to the maturing Phase 2 programme. Three distinctive types of project were commissioned using residual funds: firstly, follow-on projects by core theme partners (many of whom were only funded for the first three years of Phase 2 because of budget restrictions); secondly, synthesising projects to draw together activities across UKERC's Demand, Supply and Energy and Environment research themes; and thirdly, projects to contribute to two cross-Centre 'flagship' research projects undertaken in the later stages of Phase 2: *UK Energy in a Global Context* and *Energy Strategy under Uncertainty*.

Project commissioning, through either the Research Fund or residual funds, lasted throughout the five years of Phase 2, and led to a major expansion of UKERC's research portfolio. By early 2014, UKERC's Phase 2 research programme spanned 50 research projects: 16 Core projects, 16 Research Fund projects, 4 Research Theme synthesis projects and 8 projects commissioned to support the flagship projects. The research programme supported 10 PhD studentships embedded in research themes, and an additional 7 competitively awarded interdisciplinary studentships were funded through UKERC's capacity-building role. Over 150 project investigators, researchers and students were involved in Phase 2, equivalent to 50 full time staff at peak. Overall, UKERC's Phase 2 research funds were spread much more thinly than in Phase 1.

Phase 2 was also characterised by much wider disciplinary participation than Phase 1, across the environmental sciences, engineering and physical sciences, and social and economic sciences (Table 1). All of the Research Fund calls for proposals identified the interdisciplinary dimensions of the research being requested, indicated some likely contributing disciplines and the intended contribution of the research to UKERC’s whole systems research programme.

The Research Fund largely fulfilled its goals of providing a useful source of flexibility and responsiveness introducing new research disciplines (especially from social and environmental disciplines) (Skea, 2013). At the same time, it presented significant operational challenges. Managing the Fund (and residual funds), in terms of the scoping, specifying and commissioning of research calls, and the integration of new projects and researchers, proved to be a major task for UKERC’s research strategists and managers, including the Research Director, Research Co-ordination Team, Research Committee and Research Theme Leaders / Directors’ Committee.

Research Theme	Funding Type	No. of Researchers	Researchers’ 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, policy
	Flexible Fund	2	
Research Coordination	Core	4	Innovation studies, engineering
Total of core programme		62	
Total of flexible fund		101	
Total		163	

Table 1: Contributing Research Disciplines to UKERC’s Phase 2 Research Programme

Strategically, the 'Core + Fund' Centre model involved a recurring trade-off between *flexibility and diversity* on the one hand, and *integration and coherence* on the other. New projects, researchers and disciplines were introduced in each funding round, while, in the second half of Phase 2, many researchers left the programme after the end of their projects (the maximum length of Research Fund projects was 2 years), and funding constraints meant that many Core researchers were only funded for 3 years. The overall result was a larger, more diverse but less stable research community, restricting Phase 2's ability to engage in more ambitious forms of interdisciplinarity which tend to rely on strong 'relationships of trust' across disciplines.

For individual UKERC researchers, too, there was a trade-off between disciplinary and cross-disciplinary work; Phase 2 coincided with the UK's Research Excellence Framework (REF), which, like other such assessment exercises has tended to give priority to individual and disciplinary-based research outputs. (As other Chapters in this report document, the REF was a common concern for many UKERC researchers in Phase 2).

Finally, it should also be noted that Phase 2 UKERC experienced some discontinuities in strategic leadership and organisational capacities which also arguably restricted the Centre's momentum on research integration. UKERC's inaugural Research Director, Professor Jim Skea, left three years into Phase 2 in June 2012 (and worked in a part-time capacity after March 2012), to take-up a newly created position as UK Research Councils' Energy Strategy Fellow. His successor, Professor Jim Watson, assumed the role of Research Director in February 2013. The change of strategic leadership – and the several months of interregnum – inevitably had an impact on the overall development of Phase 2 research. In addition, there were discontinuities in several other HQ roles between 2009 and 2014, including UKERC's Knowledge Exchange Manager and Assistant, Research Co-ordination Assistant, Communications Manager and Assistant, and PA to the Centre Directors.

While other strategic positions in UKERC provided continuity, including the Executive Director, Research Committee Chair, Research Co-ordinator, and four of five Research Theme leaders, the turnover of staff in key management roles, combined with the temporary involvement of many researchers, weakened UKERC's capacity for interdisciplinary exchange. As reported elsewhere in this report, this meant, for example, a reduced emphasis on Centre-wide integrating activities (akin to Energy 2050) in the later stages of Phase 2.

1.2 Literature Review

1.2.1 Introduction

As the non-academic knows from everyday experience, life is an interdisciplinary business (Larkin, 1977, p.vii)

The world has problems, but universities have departments (Brewer, 1999, p.327)

There is now a substantial body of research addressing the drivers, challenges and experiences of interdisciplinary research. This literature is itself highly diverse: some of it is more conceptually oriented to the epistemological and ontological synergies and dissonances between disciplines, some of it based on empirical / case study investigations, including the reported experiences of researchers and research managers, and some of it is more instrumental and pragmatic, aimed at improving interdisciplinary methods and developing ‘best practice’ guidelines.

Only a short, selected account of this research field is possible within the confines of this report. In summarising this wider research, the focus here is on the more instrumental, pragmatic and empirical literature, especially the role of interdisciplinarity in energy and environmental research, and on the reported experiences of those working on similar research fields as UKERC. This has meant the more theoretically and conceptually oriented interdisciplinary studies literature is largely overlooked here, and indeed the overall analytical perspective in this report is broadly realist and positivist – the report is rather pragmatically concerned with the UKERC’s efforts to fulfil its remit for whole systems interdisciplinary research.

As one reviewer to an earlier version of this report observed, this approach leaves unanswered some of the more problematic but compelling aspects of interdisciplinary research. A more critical and interpretivist analysis would, for example, allow for a fuller and more nuanced consideration of the extent to which UKERC’s interdisciplinarity efforts were constrained by disciplinary-based epistemological differences (alongside other issues), the different ways that disciplinary relations developed other than simply through integration or synthesis, and to pose as an open-ended question the desirability and achievability of interdisciplinarity in different research contexts.

Although these issues don’t go wholly unconsidered in this report – some of the specific tensions and challenges of interdisciplinarity *are* raised by those UKERC researchers and stakeholders in empirical evidence presented in Chapters 2, 3 and 4 – it has not been possible, given time and resource constraints, to systematically address the deeper concerns of the interpretivist and constructivist literature on interdisciplinarity. Subsequent outputs based on the project findings will offer more

critical interpretations of the UKERC interdisciplinary experience. For fuller accounts of the interdisciplinary research literature, including more critical and interpretivist perspectives, see, for example: Barry et al. (2008); Frodeman et al. (2010); Lyall et al., (2011); and Phillipson et al. (2012).

Reflecting the complexity and breadth of the ‘interdisciplinary studies’ research field, there is a lexicon of different terms to describe the different ways disciplines might engage with one another. Distinctions are commonly drawn between:

multidisciplinarity (with still relatively self-contained disciplines and low levels of collaboration); *interdisciplinarity* (with more integrated disciplinary perspectives on a problem, and more holistic outcomes); and *transdisciplinarity* (with a strong element of co-design and co-production with non-academic stakeholders). Each is associated with different forms of research design.

Lyall (2013) differentiated between multi- and inter-disciplinary research in terms of levels of integration and orientation to either problem solving or disciplinary development (Figure 6). Clearly, different modes of interdisciplinarity imply different research designs. Lyall (2013) concluded that failure in interdisciplinary initiatives may be related to unrealistic expectations, a trivialised view of other disciplines’ roles or more pragmatic problems in fostering collaboration. Both Lyall et al. (2011) and Skea (2013) suggested that more ambitious forms of interdisciplinary whole systems research can be seen as being low quality and superficial, so that the highest achieving disciplinary-based researchers may not be attracted to it.

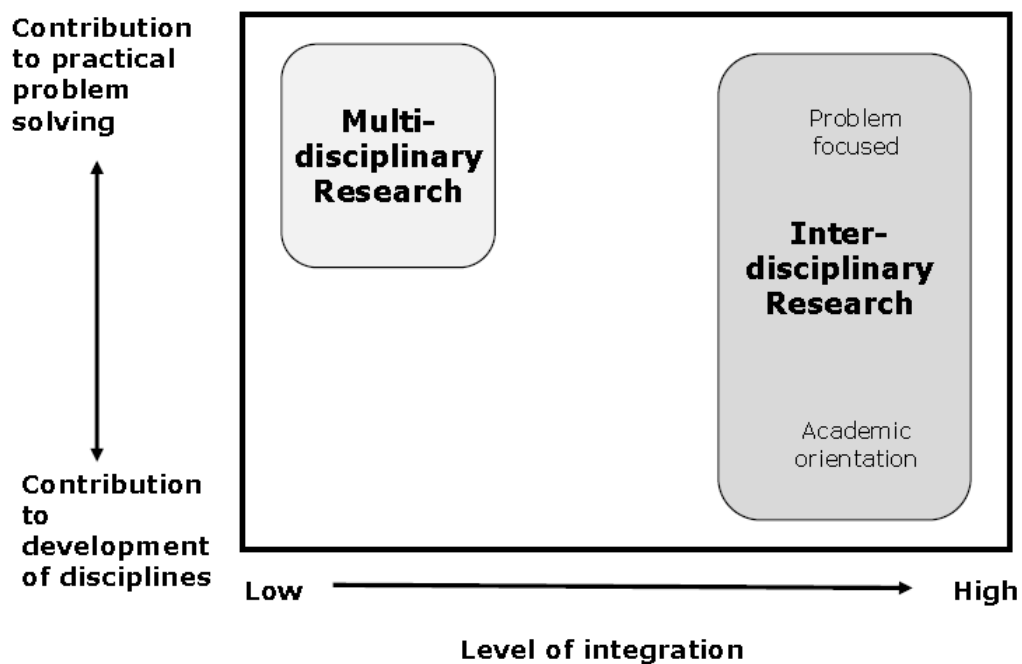


Figure 4 Multi- and Inter-Disciplinary Research (Lyall, 2013)

1.2.2 Conceptualising Interdisciplinarity

A number of researchers in energy and environment research areas have considered the desirability and merits of interdisciplinarity. Watkinson (2006) described the distinctive roles and styles of monodisciplinary and interdisciplinary research: disciplines are established domains of knowledge sharing a common set of theories, methodologies and tools; inter-disciplinary research, by contrast, is:

an organised programme of activity where the distinct theories, methods and tools in each discipline are shared and used in some combinatorial way to yield new insights ... that could not be gleaned from a post-hoc synthesis (ibid., p.9).

A repeated theme among advocates of interdisciplinarity is the need for research to better reflect 'real world' problems, particularly in energy and environment areas. Watkinson described this in terms of the need to 'understand the complexity and inter-dependency of the real world of nature and humanity ... [through] a 'whole-systems' approach ... involving the natural, physical and social sciences' (ibid., p9). Similarly for Hulme (2006a, p.16) interdisciplinarity was a 'response to the recognition that many environmental, social or technological policy-driven research challenges need to deal with the complexity and interdependency of the real world'.

For Lovett (2013) interdisciplinary perspectives were needed for energy and environmental problems because of their boundary-crossing nature and global scale. Lovett noted the special challenges of interdisciplinary projects: the need to develop a common *language* (especially in moving from multidisciplinary to interdisciplinary research); the need to recognise differences in *spatial scale*; and the need to agree common *units of analysis*. Collaboration that involves a mixing of *methods*, he added, was often more demanding than that involving different *disciplines*; for example, quantitative geographers and economists can work more easily together than qualitative and quantitative geographers.

Lowe (2013) traced the origins of disciplinary specialisation in academia, and the educational, academic and societal prompts for interdisciplinary collaboration. He outlined three possible advantages of interdisciplinarity: devising new problem framings, analysing technologies in their social and environmental contexts, and improving the accountability of decision-making. Social sciences tended to be used in three distinctive ways in interdisciplinary research: problem framing, soliciting public and stakeholder preferences, and analysing the governance of complex systems. Lowe suggested that social and environmental sciences – but not physical sciences – had a shared orientation to 'interventionist' research, with learning through *field interventions* rather than *controlled experiments*, and he noted that climate change had brought about a new impetus for interdisciplinary working.

Winskel (2013a) identified two drivers for interdisciplinary energy research: personal motivation and changing institutional context. An interdisciplinarity research orientation often reflected an individual researcher's disinclination to disciplinary abstraction; as Rip and Kemp (1996) noted, research problems 'cut across levels and categories so that no one ... discipline, oriented to its own methods and ideals of explanation, can capture the complexity' (Rip and Kemp, 1995). Institutionally, Winskel (op cit.) noted, the UK energy sector has undergone remarkable changes in a generation, from a world of concentrated and hierarchical corporate authority and expertise, to more distributed and contested expertise and authority – suggesting the need for an interdisciplinary perspective.

Brewer (1999, p327) described the limits of monodisciplinarity for environmental problems in terms of the creation of 'a fragmented knowledge base which informs problems only with great difficulty'. For Brewer, any single research method had blind spots that focused attention on selected aspects, while blocking it out for others. The mission of interdisciplinary research was 'to view problems with a variety of different approaches, and then assemble their partial insights into something approximating a composite whole' (ibid., p.330).

For Brewer, interdisciplinarity required 'problem-oriented inquiry', with problems designating theory and methods rather than (in discipline-based, curiosity-driven inquiry) the other way around. Being problem-driven meant directing attention on missing parts of an analysis, using multiple methods and stimulating the creation of unexpected policy alternatives. Interdisciplinarity also involved developing a 'contextual' perspective, i.e. explicitly considering the relationship between the parts and whole of a problem: directing analytical attention to particular problems while also maintaining a tentative, evolving appreciation of the whole. It also required a historical sensitising, with an appreciation of the past, present, and future.

Ultimately, Brewer (1999) argued, a problem orientation implied adopting a 'constructivist' view, with research problems seen as human or social constructs. Researchers define problems in such a way as to give prominence to their own expertise and preferred course of action, so 'real world' problems do not exist independently of their sociocultural, political, economic and psychological context. However, Brewer noted, while social constructivism is a well-established perspective in the social sciences (e.g. Schon, 1979; Pinch and Bijker, 1984), it remains largely unfamiliar in the physical sciences, and at times has been received with hostility (Ross, 1996).

For Barry et al. (2008) interdisciplinarity was inherently disruptive, in that it challenged rules governing the rigorous application of disciplinary methods and

concepts. Barry et al. also questioned the often tacit assumption that interdisciplinarity can be understood only in terms of the *synthesis* or integration of two or more disciplines, and suggested two other ‘modes’ interdisciplinary engagement: firstly, *subordination–service*, involving cross–disciplinary hierarchies and subordinate disciplines ‘filling knowledge gaps’ in more dominant ones – for example, the use of social science to provide social context or public understanding of engineering and physical science–led research; secondly, *agonistic–antagonistic*, with a more explicit attempt at critical, oppositional exchange between disciplines, possibly leading to radical transdisciplinarity and the abandoning of disciplinary conventions.

Barry et al. (2008) noted that while there is no core method for interdisciplinary research –but rather a multitude of approaches and techniques – the dominant mode in climate change research has been on system synthesis and integration. As later chapters of this report testify, UKERC’s interdisciplinary research efforts have indeed been driven, albeit rather implicitly, by an *integrative–synthesis* rationale. However, some of the actual interdisciplinary experiences of UKERC researchers can also be understood as *subordination–service* exchange –for example, within the *Energy 2050* project (see 1.1.2 above). Despite greater disciplinary heterogeneity in Phase 2 UKERC, an emphasis on *integrative–synthesis* interdisciplinary exchange has continued, though with rather less formal and concerted emphasis. Throughout, there appears to be less experience of agonistic–antagonistic relations, at least explicitly. Future research will consider UKERC’s interdisciplinary strategy and experiences in terms of the different modes of interdisciplinarity, and its associations with UKERC’s evolving disciplinary composition.

1.2.3 Experiences of Interdisciplinary Energy and Environmental Research

There is now a substantial accumulated evidence base on the experiences of interdisciplinary energy and environment research in the UK and internationally. This short review covers a small number of prominent UK initiatives which are broadly comparable to UKERC, either in terms of their substantive research concerns, or the scale or scope of their interdisciplinary ambitions and practices. In the context of the present report, the initiatives described below are particularly valuable in that each initiative has paid explicit and reflexive attention to its interdisciplinary experiences.

Tyndall Centre

The Tyndall Centre was a pioneer of interdisciplinary climate change research in the UK. Tyndall was created in 2000 as a national centre for strategic climate change research, funded by the UK Research Councils. Like UKERC, it was constituted as a distributed centre, composed of leading research groups in UK universities and

research institutes. Since 2011, Tyndall has operated as an academic research partnership, with no core funding from the Research Councils. A number of senior figures in the Tyndall Centre have published articles on their interdisciplinary experiences; together, they highlight the powerful barriers to interdisciplinary research in the UK.

Tyndall's former Director, Mike Hulme (2006a) described some of the persistent institutional and cultural barriers to the funding, execution and evaluation of interdisciplinary research. Hulme identified three interrelated problems in the UK's research culture: inappropriate procedures for reviewing interdisciplinary proposals, a failure to recognise the extra capacity-building costs of interdisciplinarity, and an instinctive preference for traditional performance measures to gauge output.

Overcoming these barriers, Hulme argued, required a single decision-making process, authorised and delegated by each of the contributing Research Councils, informed by a single set of recommendations from an expert review panel. Such panels should consist mostly of relevant interdisciplinary experts, rather than disciplinary experts drawn from different disciplines. A set of agreed goals and criteria should be established that all parties abide by throughout the decision-making process. Hulme called for an independent review and audit of the processes used by the Research Councils, to establish clearer accountability for funding decisions.

Another senior Tyndall Centre researcher, Kevin Anderson, offered a salutary account of the challenges of interdisciplinary research (Anderson, 2006). The realisation of Tyndall's interdisciplinary vision, Anderson stated, was hampered by the 'silo mentality' of academic disciplines, the numerous structural divisions within universities – and the strong sense of competition between them. Like UKERC Phase 2, Tyndall faced the challenges of geographical distributedness and competitive resource allocation. Some of the Centre partners, he suggested, viewed Tyndall simply as another funding stream. He was particularly critical of Research Council practice regarding interdisciplinary research:

the Research Councils [must] undergo a fundamental sea change in their appreciation of inter-disciplinary research ... the[ir] mindset and internal machinery ... is simply not appropriate... If such research is to flourish in the UK, it will be necessary either to establish an independent inter-disciplinary funding council or to have a proportion of the individual ... council budgets allotted to inter-disciplinary research, and distributed by an independent panel (Anderson 2006, p14).

Hulme (2006b) reviewed the Tyndall Centre experience as an 'experimental lab' in interdisciplinarity so as to draw lessons for researchers, funders and stakeholders.

For *researchers*, he argued, geographical proximity carried a valuable premium, and distributed centres inevitably face barriers. Hulme identified different measures of success for the Tyndall Centre *as a whole* and the *individuals* working within it. *Funding bodies* reviewing and decision-making processes remained ‘instinctively disciplinary’, or only ‘grudgingly multi-disciplinary’, leading to ambiguity and confusion on interdisciplinary funding aims and assessment. Finally, Hulme noted, developing transdisciplinary relationships between *stakeholders and researchers* is costly across all stages – it is easy to use the rhetoric of knowledge ‘co-production’, but very hard to deliver, especially when competing priorities abound.

Transition Pathways

Transition Pathways (TP) was a relatively small interdisciplinary research consortium set-up under an EPSRC and Eon public-private co-funding initiative for an initial three and a half years (2008–11); the same partners were recommissioned by the EPSRC in 2011 for a further 3.5 years, under the *Realising Transition Pathways* project. A distinctive aspect of the TP consortium has been its explicit attention to interdisciplinary research methods and research design – indeed, this has constituted an important part of TP’s research effort and outputs.

Hargreaves and Burgess (2009) reported findings from interviews with TP consortium members on interdisciplinarity. They found ‘an almost total divide’ on engineers and social scientists’ perceptions of what interdisciplinarity offered, what levels of interaction and integration it required, and the challenges that it posed (*ibid.*, p12). Social scientists were generally less optimistic about the prospects of interdisciplinarity achievement.

Although interdisciplinarity was often promoted in contemporary research, Hargreaves and Burgess stated, it is not always carefully thought-through. There are deep differences between disciplinary cultures – including on what constitutes a research problem, and initial enthusiasm may not be sufficient to overcome the challenges, ‘raising the possibility that some disciplinary differences may be insurmountable’ (*ibid.*, p14)

A follow-on assessment of the challenges of interdisciplinarity in the Transition Pathways consortium was offered by Longhurst and Chilvers (2012). Echoing Hargreaves and Burgess, Longhurst and Chilvers suggested that social scientists were more sceptical on the compatibility of different methods than engineers; for example, some social scientists harboured antipathy toward quantitative modelling – a key research method for many engineers and economists. Interdisciplinarity encourages reflexivity, they noted, but more powerful disciplines may be less willing, or have less reason, to engage in it.

Longhurst and Chilvers described how specific features of Transition Pathway's research design had enabled relationship-building between social and engineering sciences, and between qualitative and quantitative work. Concepts such as 'socio-technical transition pathways' and pathway 'branching points' had proven helpful integration mechanisms. Even so, Longhurst and Chilvers concluded, the project had operated mostly as a multidisciplinary consortium, with only 'glimpses' of interdisciplinarity: 'most partners contributions remained firmly within existing disciplinary paradigms' (ibid., p28). These limitations reflected a set of barriers: disciplinary language differences, deeper ontological and epistemological issues and problems of physical distance.

The contrasting understandings of, and levels of interest in, interdisciplinarity across disciplinary groupings has also been noted by others. Paul Rouse (a former senior Research Council officer on energy research) suggested that natural scientists tended to be more open to interdisciplinary research than social scientists (in Hannon et al., 2012). Rouse noted the fundamental differences between the 'laws and determinisms' of natural sciences and 'interpretive' social sciences. Lyall et al. (2013) also argued that social sciences faced particularly powerful barriers to interdisciplinarity, given their affiliation with specific research methods – methods which may be incompatible with one another.

Longhurst and Chilvers (2012) drew up a number of recommendations for interdisciplinary working. They highlighted the importance of *mutual respect*, and of recognising the role of interdisciplinary *translators* to facilitate dialogue – though this still left deeper ontological and epistemological barriers. They concluded that it was helpful to decide on the nature and extent of integration at the early stages, to manage expectations. A focus on mechanisms for *producing* and *integrating* knowledge flows was also important – to mitigate uncertainty and insecurity. Interdisciplinarity needs to be constantly managed and on occasions, forced. Given the time needed to develop common understandings in interdisciplinary research, Hargreaves and Burgess (2009) called for seed-corn funds to be used ahead of a full research programme.

Rural Economy and Land Use

The Rural Economy and Land Use (RELU) programme was a major interdisciplinary research programme funded by the ESRC, NERC and BBSRC (the Biotechnology and Biological Sciences Research Council) between 2004 and 2013. RELU included around 450 researchers and 40 disciplines – considerably larger than UKERC Phase 2 – although its disciplinary mix was weighted towards environmental and social sciences, and unlike UKERC it did not include engineering and physical sciences disciplines to a significant degree. Senior RELU researchers have published a number

of papers on interdisciplinary research methods and findings (e.g. Lowe and Phillipson, 2009; RELU, 2011; Lowe, Phillipson and Wilkinson, 2013).

Lowe (2013) described RELU's 'root and branch' approach to interdisciplinary working, across individual researcher, research project and programme levels. At the *researcher* level, a key focus was on academic publishing; here, RELU negotiated interdisciplinary special issues of high-impact disciplinary journals. At the *project* level, all RELU project teams were expected to combine together different staff, methods and perspectives, and there was an emphasis on innovative project design (RELU, 2011). At the *programme* level, RELU fostered interdisciplinarity through seed-corn funding, running workshops and conferences designed to promote shared perspectives, and offering interdisciplinary training and career guidance. RELU also developed a dedicated process for proposal assessment, with assessors selected for their experience and understanding of interdisciplinary research.

Quantifying and Understanding the Earth System (QUEST)

Quest was a large programme of interdisciplinary earth science research funded by NERC between 2006 and 2011, aimed at improved understanding and predictability of global environmental change. Although it had a rather different set of research concerns and disciplinary participation than UKERC and other energy system-oriented research programmes, QUEST shared an explicit concern for interdisciplinarity, most notably in a project commissioned towards the end of the programme on 'Capturing Lessons for Interdisciplinarity' (Lyll et al., 2011; Lyll and Fletcher, 2013). The *Capturing Lessons* project included a detailed review of the interdisciplinary research literature, and case studies of a number of other NERC-funded interdisciplinary research initiatives, including the Tyndall Centre and UKERC.

Lyll et al. (2011) argued that as interdisciplinary research has expanded under support from funding bodies, the dangers of its 'uncritical advocacy' have increased, especially given low levels of understanding of how best to manage and evaluate it. Given that much knowledge in this area remained tacit, Lyll et al. (2011) set out detailed guidance on management and planning, with an emphasis on the need for leadership reflection and adaptation. Lyll (2013) drew on the *Capturing Lessons* project to develop recommendations for best practice in terms of 'key success factors' (Figure 5).

The *Capturing Lessons* project found that peer review processes were repeatedly cited as a problem for interdisciplinary research, in terms of: the quality criteria used, the composition and management of review processes and the end-of-award evaluation processes. A number of recommendations to NERC and other Research Councils were developed, including: the setting-up an interdisciplinary reviewers' college, providing shared administrative resources for interdisciplinary investments,

creating an ‘Interdisciplinary Funders Forum’ and a researchers’ ‘Interdisciplinary Portal’ to co-ordinate and consolidate access to information; and running community-building events across different interdisciplinary programmes (Lyll, 2013).

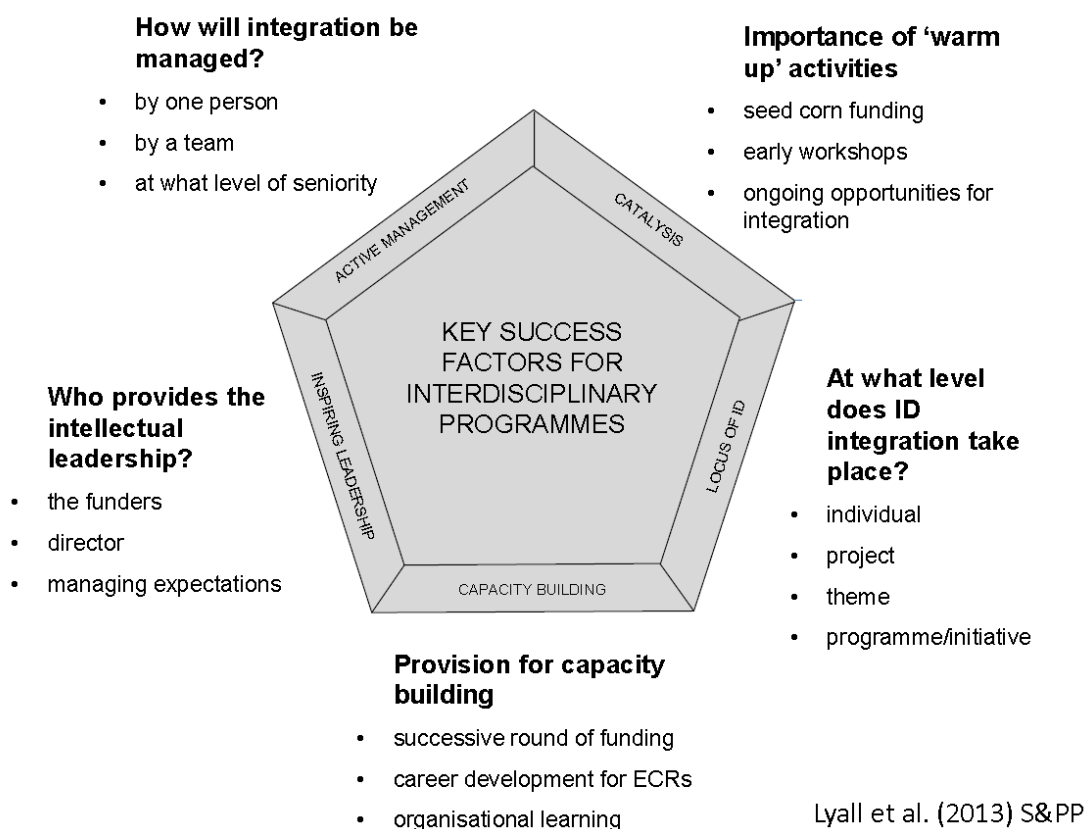


Figure 5 Key Success Factors for Interdisciplinary Research (Lyall et al., 2013)

Lyall (2013) also identified criteria for good interdisciplinary research proposals:

- indicate the *expected outcomes* from the combination of disciplines/approaches and the *likely benefits* for disciplines and stakeholders
- demonstrate a good understanding of the strengths and weaknesses of the disciplines involved, and justify the choice of disciplines based on the research questions
- acknowledge the challenges of interdisciplinarity, and devise an effective strategy for methodological integration and fostering interactions
- set out a flexible timetable, accepting that interdisciplinary research may need to develop and change (the need for flexibility was also highlighted by Anderson, 2006 and Hargreaves and Burgess, 2009)

Lyall (2013) went on to examine the role of review panels in interdisciplinary research in some detail; her recommendations here included:

- select panel members based on breadth of disciplinary understanding rather than narrow expertise
- have a critical mass (at least one-third) of panel members with successful interdisciplinary research track records
- provide guidance on evaluation, including clear criteria on valuing different disciplinary contributions, and procedures for dealing with disagreements
- set-out the responsibilities of the panel chair in ensuring that guidelines are implemented and not sidelined in favour of traditional disciplinary criteria

Lyall et al. (2013) concluded that as well as resource and management issues, the prospects for interdisciplinarity were greatly shaped by funding and commissioning processes (see also Lowe and Phillipson, 2009). Rather than a linear pass-through of responsibilities from funders and assessors to research centre managers, this implied the need for ongoing engagement between those responsible for the commissioning, doing and evaluation of interdisciplinary research.

1.3 Summary

The first part of this chapter offered a short institutional history of UKERC since its creation in 2004. By the end of Phase 3 in 2019, UKERC will have benefitted from 15 years continuous funding from three UK Research Councils, with a total public investment of around £50m. While this represents a sustained commitment to interdisciplinary and whole systems academic energy research in the UK, the UKERC institutional (and interdisciplinary) experience, has in practice been a rather unstable and challenging one, as the Centre has responded to high expectations, limited and distributed resources, changing organisational templates and a rapidly evolving research and policy context.

Within this, the tension between openness and coherence became a defining feature of Phase 2 UKERC's research strategy between 2009 and 2014. More recently, and despite calls among interdisciplinary research leaders for continuity and dedicated institutions for commissioning and assessing interdisciplinary proposals and achievements and, the Centre has experienced a protracted recommissioning process for Phase 3, across different assessment panels and evaluation criteria.

The chapter also reviewed the wider interdisciplinary studies literature. Perhaps reflecting UKERC's historic institutional base in applied natural and economic sciences, this review rather pragmatically focused on more realist and positivist strands of this literature – while also recognising the value of additional analysis of UKERC's interdisciplinary experience from a constructivist / interpretivist perspective. Indeed, despite the Centre's overarching tacit commitment to 'interdisciplinarity as integration', there are indications that other forms of exchange, especially

subordination–service, have been an important part of the UKERC interdisciplinary experience for some researchers and projects. Future work will explore this further.

Finally, the chapter also reviewed a number of UKERC's interdisciplinary peer initiatives – selected in–part because they have been more explicitly reflexive about their interdisciplinary achievements. The RELU programme, the Tyndall Centre and the Transition Pathways consortium have all seen their interdisciplinary experiences as a key part of their own research, and each has published reflexive accounts of this in the course of their interdisciplinary journeys. By comparison, UKERC's reflexive voice is only now emerging; the following chapters constitute the first extended hearing of this voice.

2. Facilitated Group Discussion

2.1 Introduction

In April 2013 UKERC's Meeting Place events facilitation team staged a 2-day residential workshop on interdisciplinarity in energy research. Though not formally part of the UKERC's interdisciplinary review project, the workshop provided a valuable opportunity for UKERC researchers to consider and share their interdisciplinary research experiences (Winskel, 2013b).

Following on from this, UKERC's Research Co-ordination team organised a group discussion on interdisciplinary energy research in UKERC during the Centre's Annual Assembly in July 2013. The meeting 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 suggestions for UKERC's future research strategy have been highlighted by italicising.

The UKERC Annual Assembly, a 48-hour residential conference, 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, energy policymakers, other stakeholders and UKERC support staff. The interdisciplinary group discussion was held in parallel with a number of other research meetings, limiting the numbers able to attend; even so, the discussion attracted 15 participants, spanning a diverse mix of *researcher disciplines* (from engineering, environmental and social sciences), *career stages* (from PhD students to senior researchers), and *roles and experiences* (including researchers directly involved in the UKERC research programme, external researchers and advisors and stakeholders from UKERC's Research Committee and Supervisory Board).

At the start of the meeting each participant was invited to describe their own work experiences and identities in disciplinary terms. This revealed a wide variety of 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;
- industrial engineering (originally combustion engineering);
- energy technology, economics and policy (originally physics and economics);

- energy and society (originally environmental sciences and modelling);
- energy economics, systems modelling and integrated assessment (originally engineering and economics);
- social science, psychology and human geography (originally sociology);
- energy systems analysis and engineering (originally physics);
- applied physics and computer programming (originally environmental sciences);
- energy efficiency and public engagement (originally engineering);
- social and physical sciences on renewable energy (originally physical sciences)

Notably, a number of participants were reluctant to (or struggled to) describe themselves in disciplinary terms, or to associate themselves with conventional disciplinary identities. As the descriptions given above suggest, many of those participating saw themselves as having multiple roles and disciplinary identities, with career paths which have spanned 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 researchers.

After a short introductory presentation on the aims and concerns of the UKERC interdisciplinary review project, the group discussion was largely free-flowing, allowing participants to raise issues and respond to each other's remarks, but loosely structured along the following themes:

- **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 have 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?
- **Stakeholder Engagement.** Should non-academic stakeholders (policymakers, businesses, NGOs, civil society) play a more important role in UKERC research?

Individual identities have been anonymised; the following coding is used, based broadly on job role 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)
- SA1, SA2, etc. = *Stakeholder Advisors* (senior figures from industry, policy etc. with an advisory or support role in UKERC).

2.2 Motivations and Barriers

We are a very biased sample, in that ... we think that interdisciplinarity matters – otherwise I would just sit in my home discipline and department and have a much easier life [MC1].

Inter-disciplinarity work is a pain – [we] put up with the pain because [we] have research questions that exercise us ... that require interdisciplinary working; they are often societal problems [MC2]

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

It's difficult– it's stimulating and enjoyable to try and understand the implications of one discipline's insights for another [EC1]

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]

Career Structures and Academic Institutions

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. You need ... support from ... your academic village.

... 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.

... 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.

... There is funding for *interdisciplinary PhD studentships*, but the students often have problems with career progression. We now have a lot more interdisciplinary PhDs, but the question is how will these people progress within established academic structures? [MC2]

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]

Many universities are now setting up interdisciplinary 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 interdisciplinary [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 multidisciplinary. 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 ... as relatively temporary organisations that may come and go [MC5]

Expertise and Identity

What's struck me most since joining academia is that ... 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 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. 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]

[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]

One reason why interdisciplinarity 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]

Disciplinary Divides and Research Design

What about when there are *disagreements between disciplines about what the 'right answer' is?* ... In UKERC we had some experience of this in ... and it's hard to reconcile ... it meant we had to recognise the concerns of disciplinary-based expertise [MC4]

Why is it that some disciplines have a really hard time working together? [MC4]

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 ... 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]

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 [MC5]

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 others will speak in a different dialect from you ... to work in an inter-disciplinary team, there needs to be a willingness to put in that *upfront investment, and go the extra mile* [MC2]

If there's such a thing as weak or poor interdisciplinary 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]

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, 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 ... 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]

It takes *time and effort to work in an interdisciplinary way ...* Learning other [disciplinary] languages ... only happens through *personal contact ...* Limited project time can be a problem ... *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]

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]

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].

We've defined interdisciplinarity 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 it can be a real barrier ...* I've been involved in projects where ... 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 ... you

need to think about ... the way that different disciplines ... meet in the middle of the problem, rather than be at opposite ends [EC1].

You sometimes get marriages of convenience, rather than collaboration on problem definition ... *what defines proper interdisciplinary working is that they have integration through proper project management* – that's crucial [SA1].

If the project is well defined, that really helps ... people need to be very clear on what they are expected to contribute, and what the final outcomes will be [SR4]

Gap-Filling or Bridge-Building?

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' ... 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]

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 ... 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]

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 ... 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 [SA2]

2.3 Experiences and Recommendations

UKERC's remit – beyond energy?

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 interdisciplinary, 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 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 ... in UKERC, it has to be defined as energy, or it's not feasible. The other initiative was designed to be as flexible as necessary to deal with real world problems ... *UKERC is unable to compete at that level of interdisciplinarity. A focus on 'energy only' can be a barrier* [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 Research Councils address other parts of the nexus in different ways – e.g. the new Nexus network initiative by ESRC? ... *I find the distinction between energy and climate research a helpful one, but I realise others may not* [MC4]

Scale, reach and balance

What else works well [in UKERC]? The interdisciplinary studentship scheme; 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]

From an interdisciplinary 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 ... 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 [EC2]

The scale and size of UKERC are 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 ... the demand theme has remained broader ... 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 ... For a social scientist, £50–100k is a meaningful project; that won't allow enough lab time for an engineer [MC5]

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]

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 many others will see that the costs outweigh the benefits [MC5]

Engaging with the wider research community

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 can constrain interdisciplinarity. Are there different ways to structure future UKERC, to be more *problem-centred* and encourage interdisciplinarity? [MC3]

There are 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 ... 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 hold them together* [SR2]

The Doctoral Training Centres are also an example of where *engineers will get involved in interdisciplinary 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]

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 ... 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]

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]

2.4 Engagement with non-academic stakeholders

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. ... rather than a more responsive interaction [EC2]

The short answer is no [not to engage more closely] in my view. TPA [UKERC's Technology and Policy Assessment research theme] 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]

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

I feel the opposite ... 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 ... *for Phase 3 UKERC there needs to be a vehicle for engaging with industry more actively*, not as consultants, or as a threat to quality [SA1]

It's possible just to circulate lists of upcoming activities ... UKERC could let policymakers know what research UKERC its going to fund [MC3]

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

3. Online Survey

3.1 Introduction

Within the overall interdisciplinary review project, the online survey offered an opportunity for the involvement of the entire UKERC Phase 2 research community, and a small number of UKERC's academic and non-academic stakeholders. The survey was focused in large part on exploring the views and experiences of interdisciplinarity among UKERC researchers, and as such it was less well suited to soliciting the views of UKERC's non-academic stakeholders. The other parts of the research fieldwork (group discussion and individual interviews) were used to explore stakeholder views.

The survey was designed by UKERC's Phase 2 Research Co-ordination team, drawing on issues raised at a facilitated group discussion convened during UKERC's Annual Assembly 2013 (see Chapter 2 above), and by follow-up conversations with some UKERC researchers, Research Committee members and Advisory Board members; a list of survey questions is provided in Annex 2. The survey comprised 22 questions on a 'SurveyMonkey' online platform, 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 for personal comments. A selection of these free text comments are included here in text boxes, beneath the relevant survey question.

Survey invitations were sent to all members of UKERC's Phase 2 research programme (as of July 2013) from across UKERC's five research themes, UKERC's interdisciplinary PhD research students, members of UKERC's independent Research Committee and HQ support staff – some 206 individuals in total; there were 90 respondents, across a broad mix of researchers by discipline, seniority and role in UKERC. The survey was structured in three parts:

- Part 1 requested information on the *profiles of respondents* – their career stage, disciplinary background and role in UKERC; findings are presented in Section 3.2.
- Part 2 explored *respondents' experiences of interdisciplinary research* in UKERC and elsewhere, including 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 impact of UKERC's interdisciplinary efforts; and the motivations and barriers for researchers' involvement in interdisciplinary research; findings are presented in Section 3.3.
- Part 3 invited respondents to offer *recommendations to researchers, research managers and funding bodies*, as well as any general observations or comments; findings are presented in Section 3.4.

3.2 Survey Respondents

3.2.1 Status and disciplinary backgrounds

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

What is your current academic role?

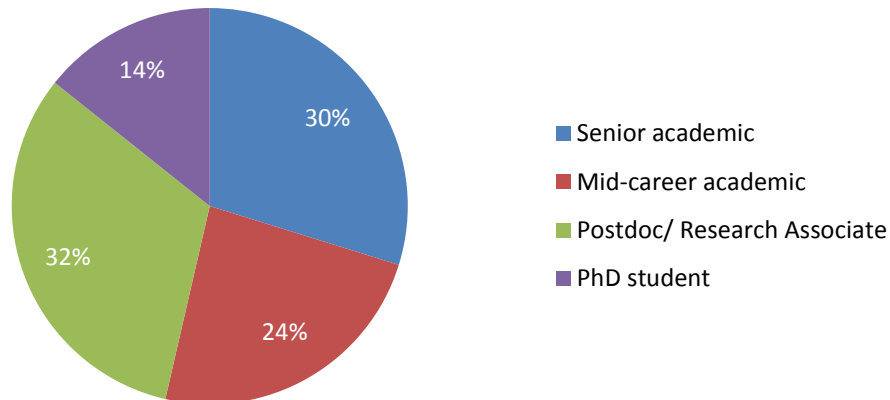


Figure 6: Academic respondents, by career stage

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

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

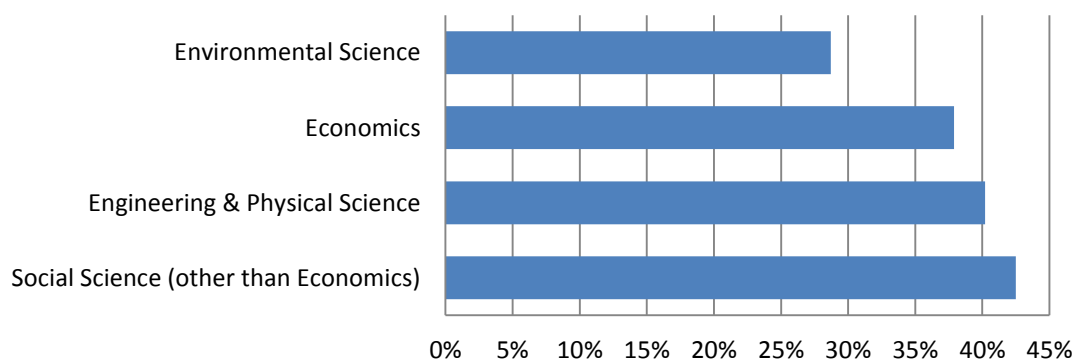


Figure 7: Respondents’ self-declared disciplinary backgrounds

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 fit less 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.

3.2.2 Research roles in UKERC

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

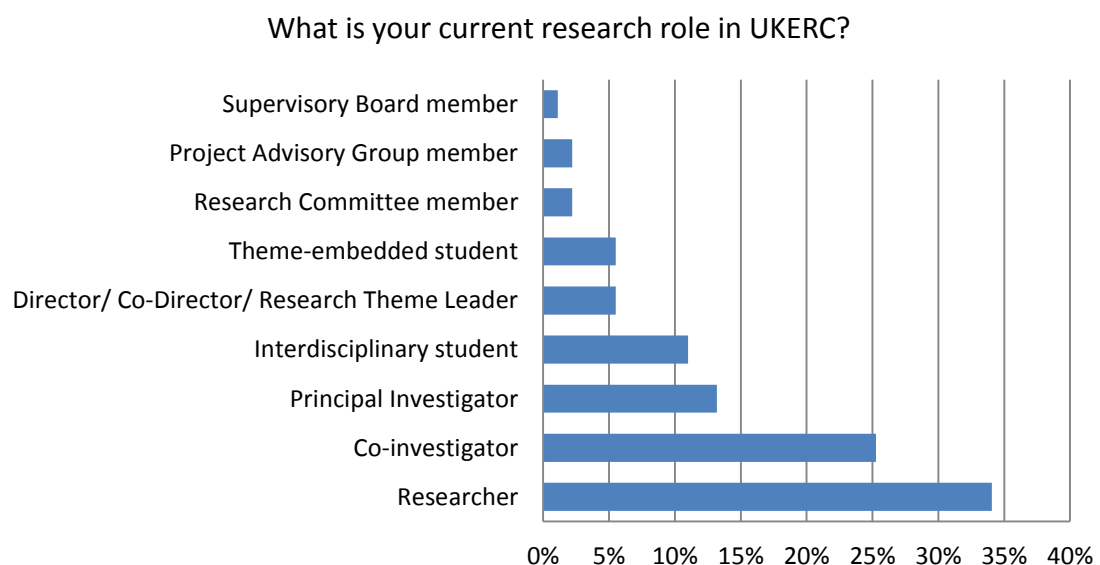


Figure 8: Respondents' Roles in UKERC

Although all levels of seniority are seen as having been engaged in interdisciplinary research, early career 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 Chapter 2 and in Section 3.8 below).

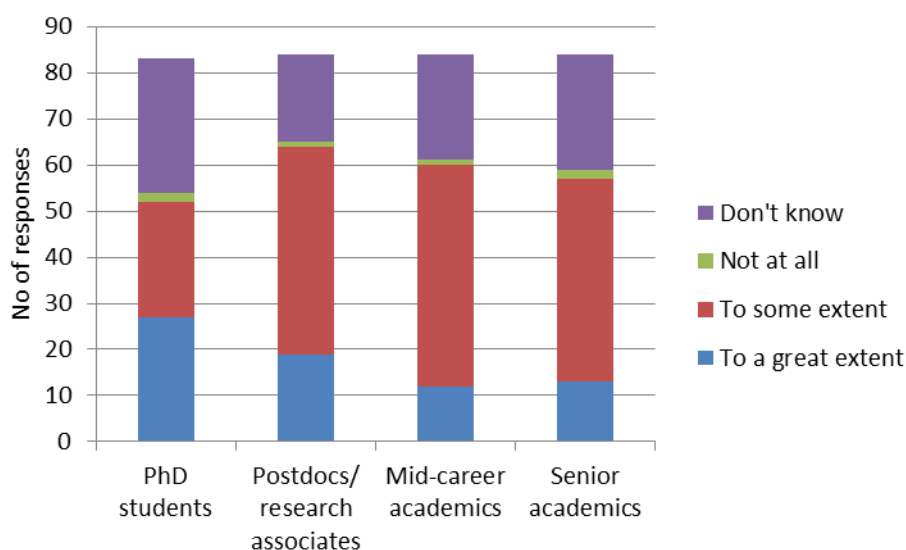


Figure 9: Perceived engagement in interdisciplinary research, based on career stage

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 were designed to develop Centre-wide research insights. As described in Chapter 1, UKERC’s relatively limited achievements in Centre-wide research integration in Phase 2 reflect its changed funding model and programme design.

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 significant level of cross-thematic interaction.

While the ‘Core+ Fund’ model 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 theme-level synthesis as well as centre-wide Flagship projects. A repeated theme of this project has been the challenge of combining flexibility and openness with coherence and integration, and as the next sections discuss, this has informed UKERC’s ability to engage in more ambitious forms of interdisciplinary research.

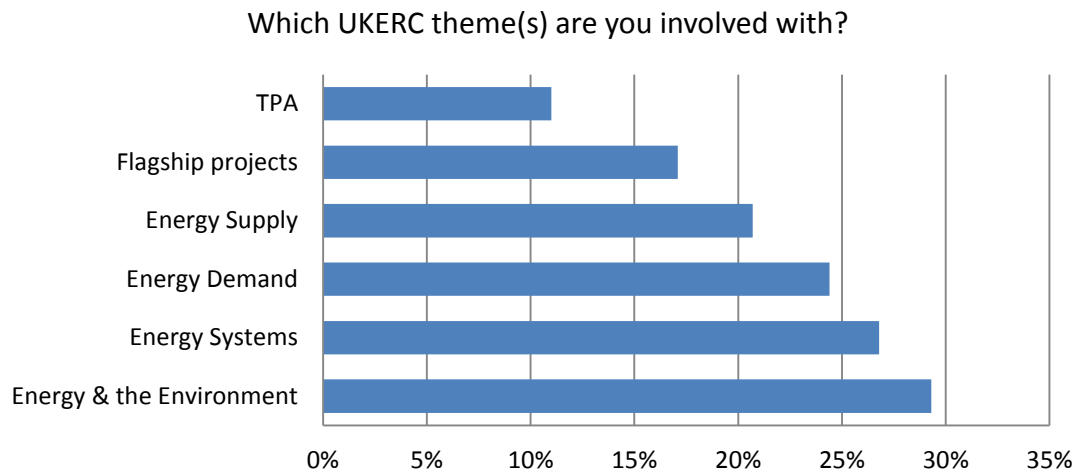


Figure 10: UKERC Research themes' representation

3.3 Research content and structure

3.3.1 Interdisciplinary research experience

For most respondents (just under 2/3rds), their participation in UKERC was 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).

If you have had previous experience of participating in a similar initiative, how well in general terms does UKERC's approach to interdisciplinary research compare?

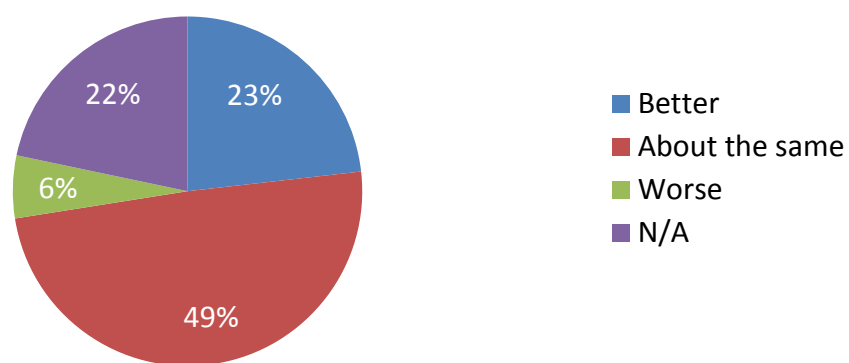


Figure 11: UKERC's interdisciplinary research, relative standing

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 progress reporting requirements – 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'.

3.3.2 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 had supported interdisciplinary collaboration (Figure 12).

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

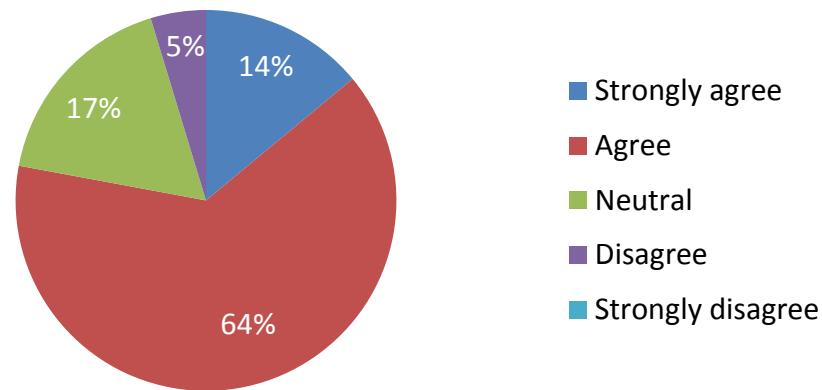


Figure 12: Assessment of UKERC's research programme

Respondents' comments painted 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'

3.3.3 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.

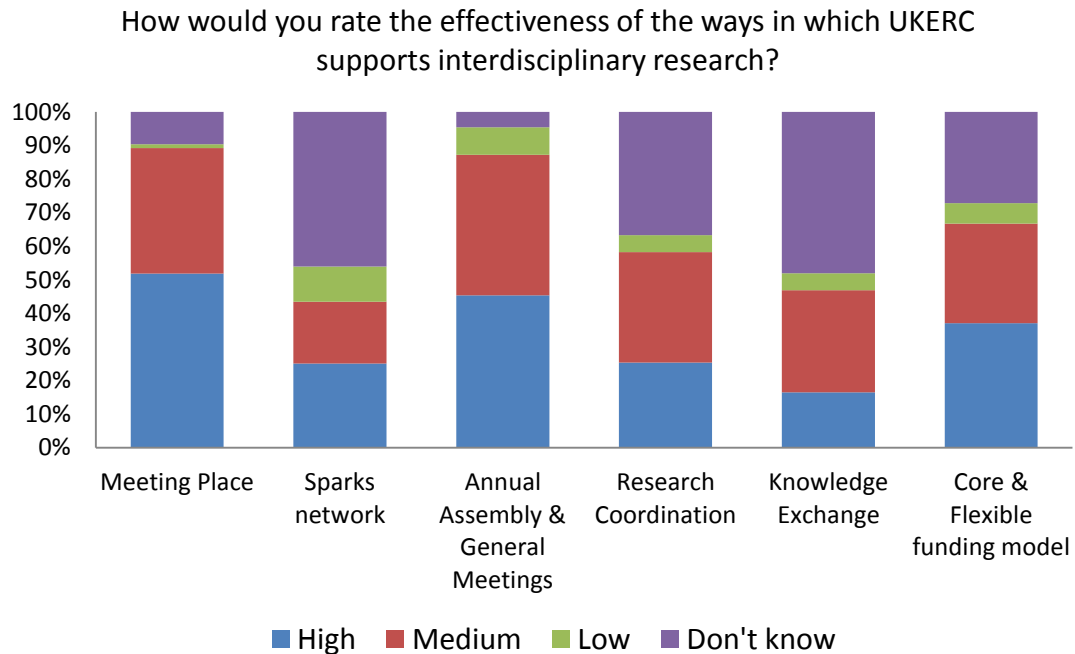


Figure 13: Effectiveness of interdisciplinary research support

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 operate ‘behind the scenes’: specifying calls for proposals, supporting annual monitoring, 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’

3.3.4 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.

At what level(s) do you think effective interdisciplinarity has occurred in UKERC?

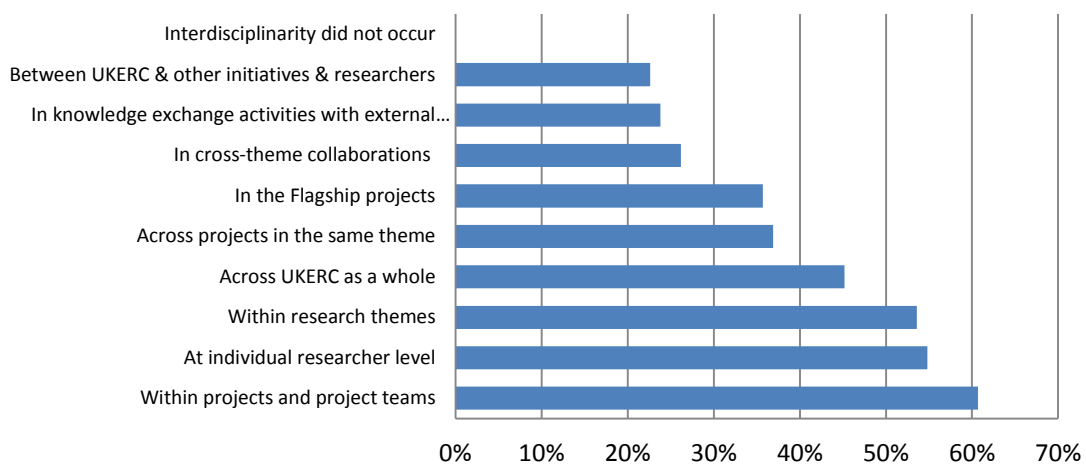


Figure 14: Different sources of interdisciplinarity in UKERC

Again, some caution is needed in interpreting this result: as a number of respondents themselves pointed out, researchers tend to have more direct experience of project-level activity than more aggregated initiatives. In addition, some aggregated efforts, such as theme synthesis projects, were recent additions to the Phase 2 research programme at the time of the survey in Q3 2013 (over 4 years into Phase 2’s 5 years programme). *Nevertheless, 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 (see Chapter 1). 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 elsewhere in this report (Sections 1.2 and 4.1) interdisciplinary research often relies on sustained cross-disciplinary relationship-building over time, suggesting a trade-off between *programme flexibility* and *depth of interdisciplinary interaction*. UKERC's Phase 2 experience suggests that 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 direction 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'

3.3.5 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* and *representation* are relatively small and shouldn't be overstated, they suggest a slight bias in UKERC research toward more techno-economic disciplines.

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

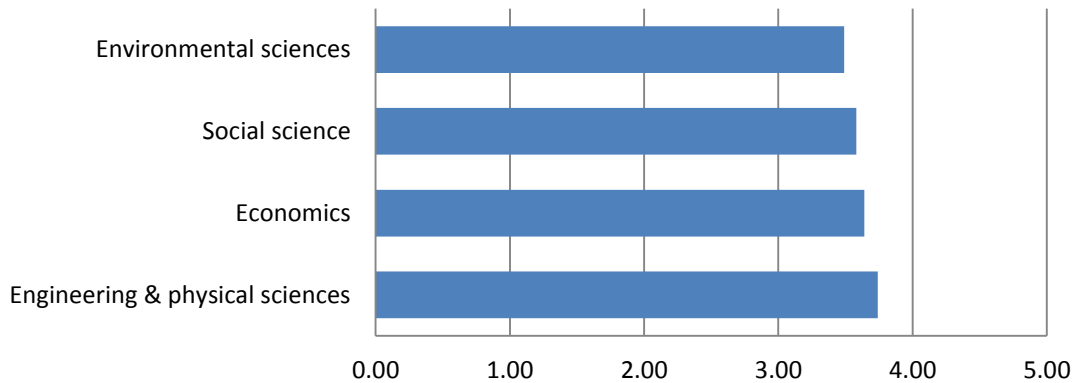


Figure 15: Strength of disciplinary representation in UKERC research

Respondents' comments allowed some further consideration of disciplinary identity and representation – with reference to the quality and standing of social science and engineering research. These comments highlight the challenges of reconciling interdisciplinary achievement with strong disciplinary identity, both for individual researchers and 'whole systems' research programmes.

'[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*. Again, the differences here are relatively small and fall within a small range.

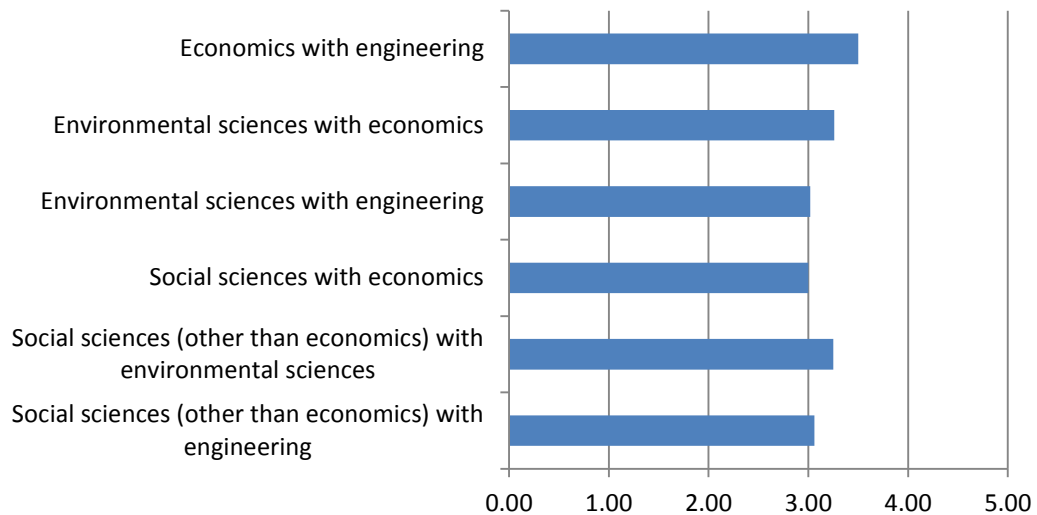


Figure 16: Perceived strength of interaction between disciplines

3.3.6 Research impact and dissemination

Survey participants were asked to assess the main academic and non-academic impacts of UKERC's research. The greatest perceived strengths of UKERC research were 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).

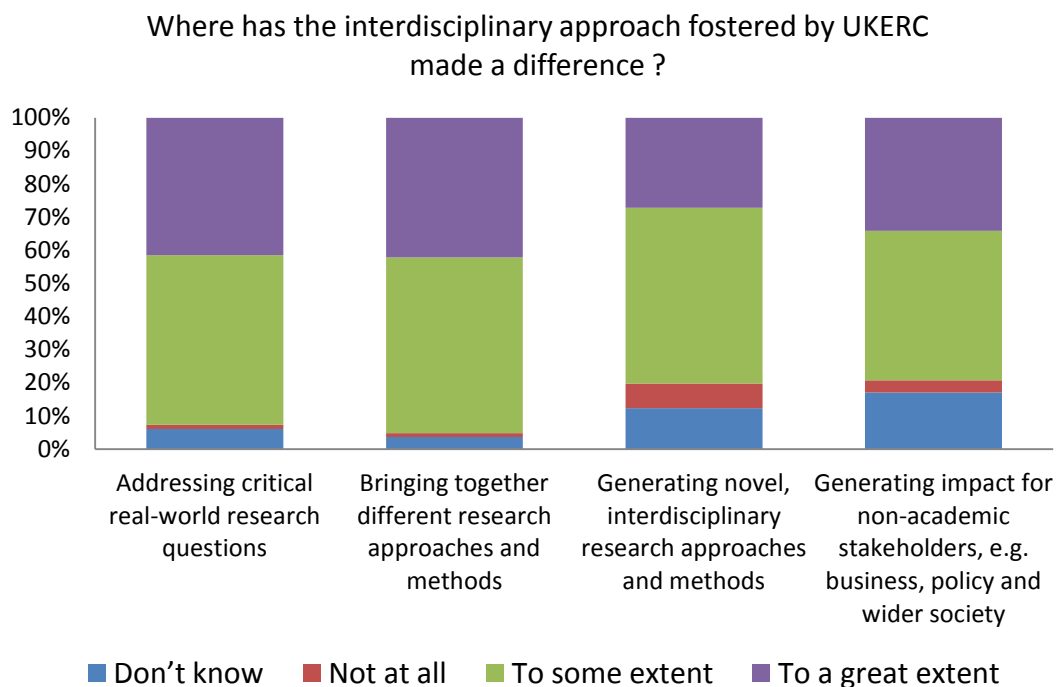


Figure 17: Effect of UKERC's interdisciplinary approach

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).

As a result of your participation in UKERC have you published in any journals that you had not previously published?

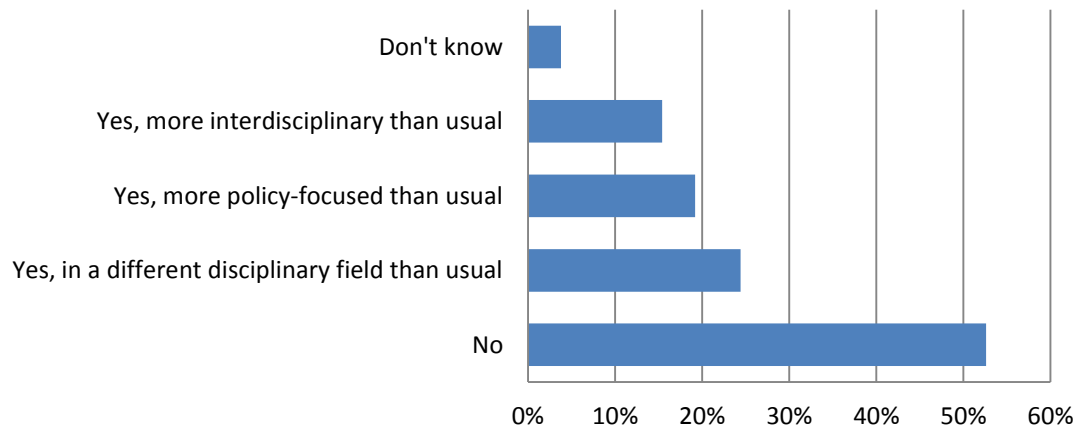


Figure 18: Impact on publication strategy

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'.

3.3.7 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).

"UKERC has helped develop an interdisciplinary community that will have an impact on future research and policy"

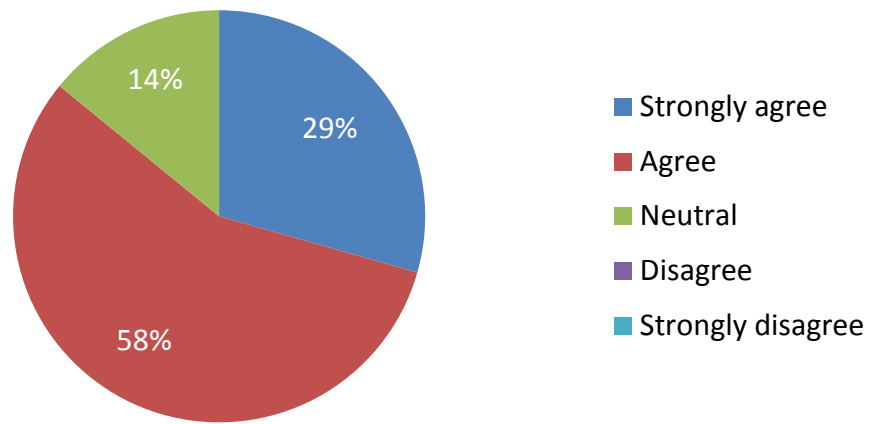


Figure 19: UKERC's impact on future research and policy

"My participation in UKERC has made me more likely to participate in interdisciplinary energy research."

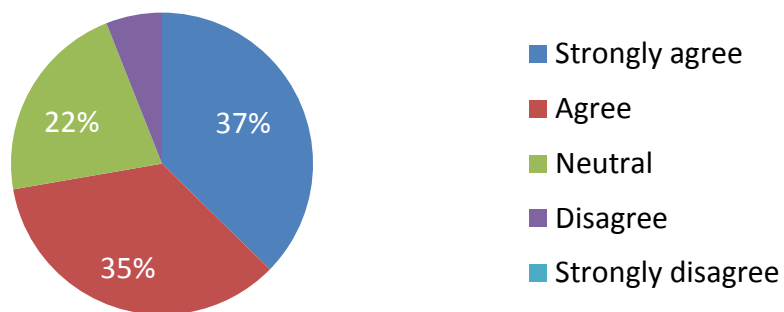


Figure 20: Future participation in interdisciplinary energy research

3.3.8 Motivations and barriers

Perhaps unsurprisingly, given the extra challenges involved, the strongest reported reasons for involvement in interdisciplinary research are personal and inquisitive: wishing to develop 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).

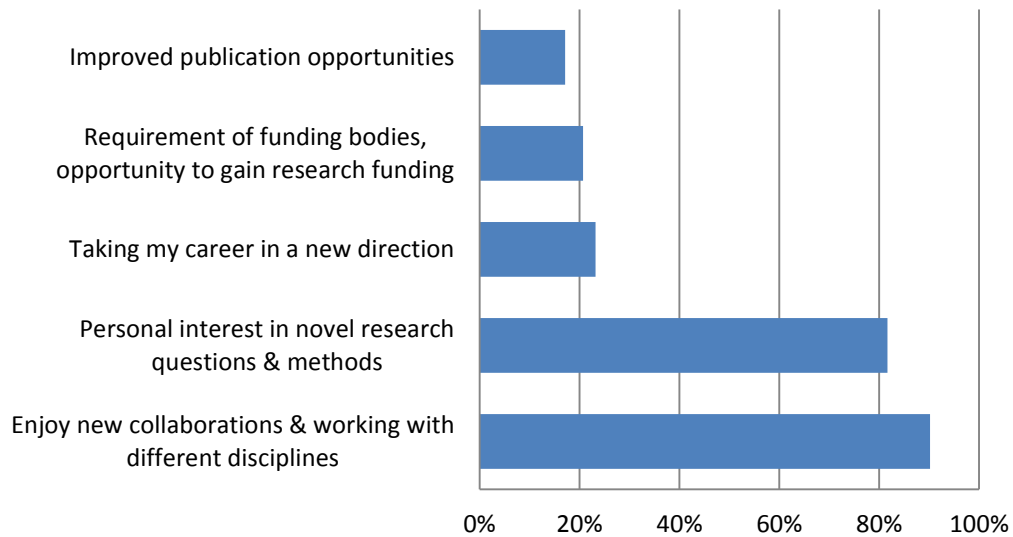


Figure 21: Motivations for interdisciplinary research

'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 an awareness of 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).

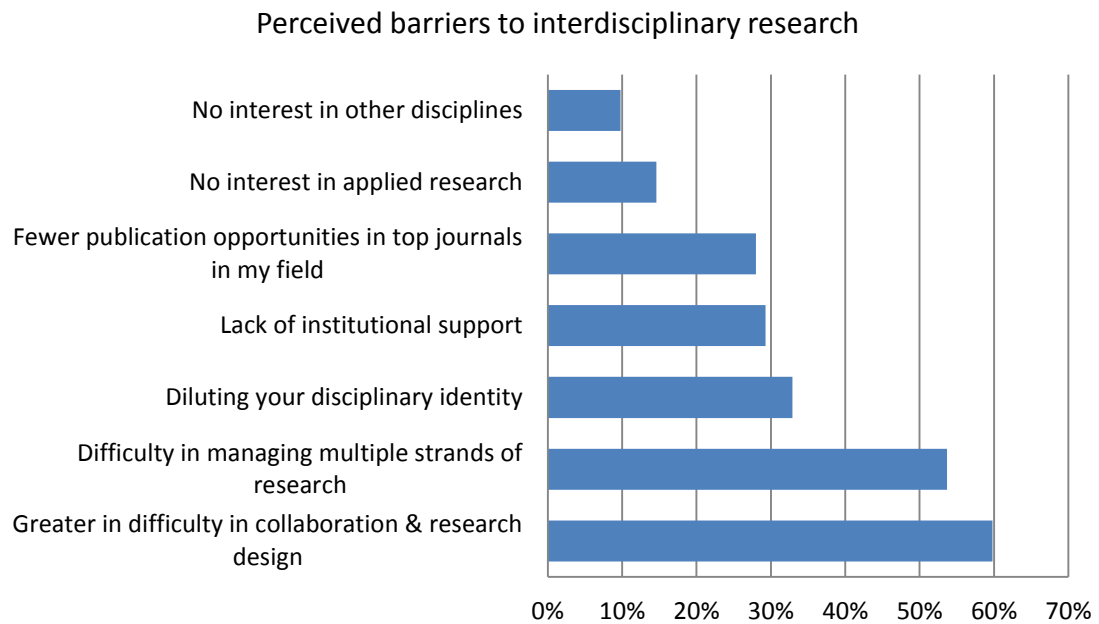


Figure 22: Barriers to engaging in interdisciplinary research

Respondents' comments highlighted the multiple perceived disadvantages to academic career progression – publishing, funding and promotion – associated with 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 also highlighted the UK's Research Excellence Framework (REF) as a particular barrier to interdisciplinary research during the lifetime of 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 less, or more easily 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 was 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 interdisciplinary 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 of research programmes, 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 in these free-form comments included: striking a different balance between ‘core’ and ‘flex’ funding; the need to change UKERC’s organisation 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 ... [from] different areas within the same theme to mix and share ideas’

In terms of future interdisciplinary representation and collaboration, suggestions included improved representation of engineering, and stronger engineering-social science links. Respondents also highlighted the need for improved cross-Research 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'

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

'UKERC needs to develop ... 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 ... Doctoral Training Centres'

Respondents also highlighted a need for better data sharing across the research community:

'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 '

'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 challenges to interdisciplinary research, some respondents reiterated its value and rewards:

'interdisciplinary work is very difficult – it usually defaults to multidisciplinary research – but it 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

Within the overall project, semi-structured interviews allowed for detailed and extended exploration of interdisciplinary experiences, challenges and recommendations. Seventeen semi-structured interviews were carried out, either in-person or by telephone; 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’ (Figure 1).

Whereas participants in other fieldwork elements for this project – the facilitated discussion group and online survey – came mainly from within the UKERC research community, the majority of the interviews were with ‘externals’: academic advisors, academics not involved with UKERC, and non-academic stakeholders. 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 23: Interdisciplinary Interviewees (* written response)

Interviews were conducted on a semi-structured basis, with reference to a set of guideline questions, sent to the interviewees in advance (Figure 24). 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.

Definitions and Framings

- 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 multidisciplinary, interdisciplinary and transdisciplinary 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 Suggestions

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?

Figure 24: Interview Guideline Questions

Almost all of the interviews were conducted during September and October 2013, with one carried out in January 2014; the interviewers were Mark Winskel and Ioanna Ketsopoulou from UKERC's Research Co-ordination team, and Tim Churchouse from UKERC's Meeting Place team. 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 chapter summarises interviewees' observations and suggestions in the broad categories.

4.2 Definitions and Framings

Interviewees expressed mixed 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:

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 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 multidisciplinary and interdisciplinary [research] – multidisciplinary is less integrated, and is more institutionally separated. [SA4]

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 [SA1]

Other interviewees – again both academic and non-academic – saw little or no 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 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 of explicit attention to the term 'whole systems' research; again, however, there was no clear-cut divide between academic and non-academic interviewees. For some interviewees, the term was a useful way to discuss the character and complexity of socio-technical interactions and the multiple perspectives associated with interdisciplinary framings.

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]

One academic interviewee felt this was not a meaningful or well-suited term in the UKERC context:

'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

Interviewees' views differed on the whether there were any particular difficulties in metricising and assessing 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 persistent barriers to interdisciplinary research in academia (see also the discussion in Section 1.2):

Metrics for successful interdisciplinary 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 ... and evidence of follow-up interdisciplinary collaborations. [AA5]

[Evaluation could 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 ... 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 ... they are not actually useful at assessing the quality of the work. [EA1]

4.4 Motivations and Benefits

A repeated theme in interviewees' discussion of the attraction and benefits of interdisciplinarity was its capacity to address the 'real world' problems facing policymakers and other decision-makers. Although some academic interviewees distinguished between internal and external motivations, for many internal and contextual drivers were interwoven, and linked to a desire to be involved in the development of fuller responses to complex social problems, lending wider meaning, relevance and impact to their academic research:

[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]

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 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 ... 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 specific academic benefits from interdisciplinary research – firstly, conceptual development within disciplines, and more materially, the opportunities to generate research income:

One of the benefits of interdisciplinarity 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

Some shared concerns emerged from interviewees' discussion of the problems of interdisciplinary energy research. Recognition of the extra challenges of interdisciplinarity was evident among some stakeholders, as well as within academia. One common concern was the greater operational challenges of interdisciplinary enquiry, especially, the additional time and effort involved.

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

Time – the time it takes to get sufficient understanding of new perspectives in order to do it well ... 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]

Particular concerns related to the both the quality and standing of interdisciplinary research, and also, longer term career development and support, especially for early career researchers:

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]

[With] interdisciplinary research, you can lose rigour and decrease the quality of the research, and it does have some career risks [AA4].

Interdisciplinary researchers ... [can] lose much of their sense of disciplinary identity ... 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]

Another repeated concern was the UK's academic institutional context, especially its 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. [SR2]

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. [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 ... they will prioritise key disciplinary journals ... the REF is a constraint to publishing interdisciplinary work. [AA4]

The disincentives for academics to engage in interdisciplinary research were also recognised by stakeholders:

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 Experiences and Examples

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

UKERC is a much more positive place to work compared to other experiences ... everybody involved ... knows that it is an interdisciplinary endeavour ... 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. [SR2]

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

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 interdisciplinary research. [EA2]

Other comments, from within and outside UKERC, were more critical of the Centre, in terms of its research processes and outputs; one advisor related this to under-resourcing:

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 (see Section 1.1), was referenced by a number of interviewees. There were mixed opinions about the interdisciplinary strengths and weaknesses of the project: while some saw it in positive terms, others compared it unfavourably to another whole systems project, *Transition Pathways* (see Section 1.2), in terms of achieving a balanced disciplinary representation, and attention to detailed processes for interdisciplinary exchange:

The [Energy] 2050 book was a good example of ... an interdisciplinary project. It did have a big question ... and [it] brought 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]

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]

The Transitions Pathways project ... brought different disciplines together across the disciplines, engineers and social scientists. It was fascinating to see the assumptions different disciplines brought ... [being] challenged ... Once you overcome those ... the whole becomes much more than the sum of the parts... 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]

Other comparisons were made to the Rural Economy and Land Use programme [RELU] programme, supported by a number of UK research councils, government departments and others (see Section 1.2). For one interviewee, RELU was 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; given its relevance for UKERC, this interviewee's experience is reported here at length.

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.

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 ... combin[ing] a strong disciplinary base with interdisciplinary insight.

The pooling of resources made a big difference – requiring all projects to combine perspectives from at least two Research Councils... each of the three Councils wanted projects that spoke to their respective communities, across different waves of funding ... ESRC also appointed a social science advisor.

[Our] Advisory Council, made up of mostly non-academic public sector reps, identified the broad research themes ... we left the researchers themselves to specify the detailed research content ... we didn't specify ... disciplines and methods in any detail ... we wanted to open up discussion with the research community.

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

4.7 Lessons and Suggestions

4.7.1 People and Processes

Several interviewees emphasised the need for attention to *people* as well as *process* –i.e. to select and support enthusiastic interdisciplinarians, and provide them with resources and time 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 ... make sure that everyone involved wants to do it [EC1]

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 ... Each discipline has its own norms for success, and they can be quite different ... 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; related issues here were the need to allow for disciplinary benefits from interdisciplinary working, and to recognise when interdisciplinarity may not be possible, or appropriate:

You need extra time for different disciplines to understand each other. Perceptions are also important ... 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 ... Interdisciplinarity 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 interdisciplinarity is expected to be bottom-up - it needs to be pre-defined ... projects have to be designed to be interdisciplinary from the start. [EA2]

Several interviewees offered descriptions of how different disciplinary communities tended to engage in interdisciplinary research, across the social, physical and environmental sciences; particular themes here were the changing role of the social sciences in energy research, and differences between *realist* and *interpretive* disciplines:

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 ... 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]

A lot of energy institutes... are engineering-led, and they may not have thought about how to involve social scientists ... 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]

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

4.7.2 Research leadership and programme design

Several interviewees made a number of more specific, operational recommendations for research leadership and high-level programme design, especially, the merits of having a 'problem-driven' structure.

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]

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]

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 ... do what they would have been doing anyway. [SR2]

You need to have opportunities for informal thinking and interaction ... 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 support specific, dedicated structures for interdisciplinary working:

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]

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]

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]

There was some call for greater clarity on UKERC's identity and remit within the UK's wider academic and non-academic energy research environment - with more explicit attention on 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 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]

4.7.3 Research Support Activities

A number of interviewees highlighted the contributions from co-ordinating, and networking personnel within an interdisciplinary research programme - both their activities to date in UKERC, and how they might be strengthened 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] have had to spend a lot of time managing the Research Fund, rather than interacting with the research programme [SR1]

[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]

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]

4.7.4 Funding and 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 went on to offer suggestions for the design and operation of a flexible research fund:

It's good to have flexibility through the Research Fund ... part of [it] ... 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 the need to attend to the particular influence and interests of individual funding bodies:

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]

4.7.5 Integrating and synthesising projects

One aspect of programme design mentioned by a number of interviewees was the need to create 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 topic-based synthesising activity, such as 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]

4.7.6 Stakeholder relations

There was some difference of view among interviewees on whether interdisciplinary academics should become more closely engaged with policy, business and other stakeholders. While some interviewees – both academic and non-academic – suggested the need for closer involvement, a number of academics raised concerns,

both on the practical difficulties involved, given different interests and timescales, and also, to the threat posed to academic independence:

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 – approach trade associations instead of individual companies. [AA1]

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

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]

Policymakers have very different timescales and the connection with academics can be patchy. There should be on-going communication to overcome this ... a regular, fixed-in form of contact ... through advisory panels as in the [UKERC] Public Attitudes project. [EC2]

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]

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]

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 less involvement in research production:

Non-academic stakeholders should be involved early on to help define the scope of the research [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]

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

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]

The interviewees included senior policy, industry and research funding figures; their views suggest the need for improved stakeholder relations in UKERC.

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 ... and secondly, the timing of 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 ... 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 [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 ... many academics are still reluctant to make their work policy relevant. [SA3]

Interdisciplinary project leaders need to involve policymakers much earlier, and higher-level policy makers and stakeholders ... UKERC does a reasonably good job of dissemination ... [but] the end-users of the research should be targeted as a priority. [SA3]

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] ... I don't sense a great enthusiasm [SA1]

UKERC needs to understand who its stakeholders are, how it will reach them, and give people assigned roles ... 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]

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

Finally, one problematic issue raised by two interviewees was deeper forms of research–stakeholder interaction, often referred to as 'transdisciplinary' research. While one interviewee had encountered difficulties here, for another, it was seen as a welcome opportunity for more explicitly normative research in contentious areas:

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. Summary, Conclusions and Recommendations

5.1 Introduction

Within its overall aim of assessing UKERC's interdisciplinary research experiences, this project had three related concerns: firstly, to review the wider interdisciplinary research literature and the experiences of similar interdisciplinary research initiatives in the UK; secondly, to explore the experiences and views of the UKERC research community in relation to interdisciplinarity and assess the relative strengths and weaknesses of UKERC's efforts to foster interdisciplinarity; and finally, to identify opportunities for the improved design and conduct of interdisciplinary research in future UKERC activities. This final chapter summarises findings on the first three aspects (5.1), and then develops a series of recommendations for UKERC's Phase 3 research strategy (5.2). As the recommendations spell out, there is no single 'best-practice blueprint' for interdisciplinary research, and not all the guidelines and recommendations set out are wholly consistent with each other – for example, calls for clarity of research ambition from the outset are at odds with calls for strategic flexibility as research unfolds. The recommendations are set out to provoke and support UKERC Phase 3 planning among researchers, advisors and funders.

5.2 Summary and Conclusions

Chapter 1 included a brief history of UKERC phases 1 and 2. From its outset, UKERC has had a distinctive dual remit, as a centre for interdisciplinary, 'whole systems' energy research and also a networking and representative body for the wider UK energy research community. These parallel research and networking roles commanded significant parts of the Centre's limited resources in its first two Phases. UKERC was created with a much smaller budget than originally suggested and its funding has not grown in-step with the wider Research Councils' Energy Programme. As a result, the Centre has been expected to co-ordinate and represent a dramatically expanded research community on a fixed or diminishing budget.

UKERC research has experienced two distinctive phases. For the first five years the Centre operated as a conventional consortium with a defined budget for its members. As the wider energy research community began to grow, a perception developed of UKERC as an 'insiders club', and in its second phase, from 2009, half the Centre's research budget was awarded by open competition. This flexible Research Fund strongly shaped UKERC Phase 2's disciplinary make-up and interdisciplinary achievements, and by the end of the phase UKERC comprised a much broader and more diverse research community – but also a less integrated one. The tension between openness and coherence was a defining feature of Phase 2 UKERC.

The transition between phases 1 and 2 had strong elements of continuity, so that many of the research challenges and blind-spots that emerged in Phase 1 were taken forwards in Phase 2, especially in specifying Research Fund calls for proposals. However, UKERC Phase 2 subsequently experienced some strategic discontinuity, notably with the departure, mid-Phase, of its inaugural Research Director. This inevitably impacted on the Centre's interdisciplinary achievements in Phase 2, particularly in integrative whole systems research. More recently the Centre has experienced a lengthy and complex recommissioning process for Phase 3, despite calls in the interdisciplinary research literature for continuity and consistency in fostering interdisciplinary capacity.

As the short review of the wider interdisciplinary studies literature in Chapter 1 noted, there is no single mode or method for interdisciplinary research, but rather a multitude of experiences, approaches and techniques. Reflecting UKERC's orientation to positivist physical sciences and economics, and also its 'whole systems' remit, the prevailing interdisciplinary rationale in UKERC, especially in Phase 1, has been on research integration. Rather tacitly, UKERC's research strategy has conflated the pursuit of interdisciplinarity and the development of a systemic perspective with integration and synthesis of its research programme. One suggestion emerging from the evidence generated for this project (and in reviewer comments on a draft version of this report) is that more explicit recognition of epistemological tensions between 'positivist' and 'interpretive' disciplines, and of the other forms of interdisciplinary exchange than systems integration – should become more prominent in UKERC.

Given the disciplinary heterogeneity in UKERC in Phase 2 (and continuing in Phase 3), and as part of a more reflexive approach, consideration should be given to the multiple forms that interdisciplinarity happens (or should happen) in UKERC. For example, reduced political, stakeholder and academic consensus on UK energy policy (and energy system definition and imperatives), may require more explicit recognition of normative tension in energy research. There is also an opportunity for more radical efforts at transdisciplinary research, with the fuller participation of policymakers and other stakeholders in UKERC research – although consultations for this project have revealed researchers' concerns here for academic independence.

The review of the wider experiences of interdisciplinarity in the UK highlighted many of the challenges that have been encountered by UKERC. This is perhaps unsurprising – other initiatives such as the Tyndall Centre, Transition Pathways and RELU have operated contemporaneously with UKERC, within the same broad political, economic and institutional context. Nevertheless, the fact that similar barriers and difficulties are reported across different centres suggests a lack of learning and feedback among funding bodies, commissioning panels, assessors and senior

researchers. Despite its significant growth over recent years, the overall sense is that interdisciplinary research ‘remains difficult to fund, difficult to do and to evaluate’ (Hulme, 2006a, p16).

Nevertheless, each interdisciplinary research programme has a particular make-up and set of experiences, with, for example, RELU having been able to cultivate a relatively close relationship with its funders and stakeholders, and to have gone further than others in devising and implementing a ‘root and branch’ strategy for interdisciplinary research. This shows the scope for individual initiatives to respond to common challenges in different ways, and for UKERC Phase 3, suggests the prospect of improved design and practice. For example, a number of UKERC’s peers have explicitly reflected on their interdisciplinary achievements, with analysis of their interdisciplinary experiences embedded in their evolving research strategies. By comparison, UKERC’s reflexive analytical voice has only recently emerged. The need for more structured and reflexive strategic analysis is an important high-level lesson.

Perhaps because of its historic lack of analytical reflection, UKERC’s interdisciplinary review project was welcomed by many within the Centre, with the involvement of almost half of the entire Phase 2 research programme, and many policy, business and other stakeholders. The researcher and stakeholder views and experiences reported in Chapters 2, 3 and 4 show considerable recognition of the Centre’s interdisciplinary achievements. UKERC is widely seen as an important protected space for interdisciplinary energy research, and as having made a significant contribution to interdisciplinary research capacity in the UK. There is also widespread recognition of UKERC’s ‘real-world’ orientation and policy relevance.

At the same time, there are widespread concerns in the research community about the practical challenges and professional dangers of interdisciplinarity, including career progression (particularly for early career researchers) in an academic reward system which still tends to privilege disciplinary-based expertise and outputs. The consultations also revealed that UKERC is seen as having been less pioneering, in its methods and practices than some other initiatives, and some respondents highlighted a tendency toward *multidisciplinary* rather than *interdisciplinarity* research. This suggests the need for more conscious attention on interdisciplinary strategy, processes and structures. More ambitious forms of interdisciplinarity are possible – for example, 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.

Under any programme structure, however, interdisciplinary research will rely on committed individuals, and consultees repeatedly noted the need for research

programme funding and design to recognise and respond to the added challenges of interdisciplinary research – for example, by offering dedicated time and resources for interdisciplinary exchange and translation. The persistent barriers between disciplines cannot be tackled without attending to the hard details of resource allocation and research design.

Ultimately, UKERC's interdisciplinary achievements and limitations cannot be judged in isolation – any single initiative operates in a wider setting of institutional barriers and rewards. As well as a more determined and explicit focus on its strategic processes and structures, improving the prospects for interdisciplinarity in UKERC and other similar initiatives depends on building and maintaining strong relationships between all those involved – researchers, funders, assessors, policymakers and other stakeholders. Despite the many challenges involved, UKERC's founding principles for independent, holistic and interdisciplinary research are valued by the vast majority of its researchers and stakeholders. Indeed, in an urgent but politically contested and economically uncertain context, these principles become ever more salient.

5.3 Recommendations for Researchers, Funders and Assessors

Recognise the distinctive role and value of interdisciplinary, whole systems research

Interdisciplinarity is driven by the need for research to better reflect complex 'real world' problems, particularly in energy and environment areas, than is possible with mono-disciplinary research. Whole systems research involves understanding interrelationships in complex systems – attending to particular problems while also maintaining an evolving appreciation of the whole. This is a challenging mission.

Be explicit and reflexive, and draw on wider experiences and expertise

Devising, implementing and reviewing an interdisciplinary research strategy should be an explicit part of UKERC's activities. To promote and support this, consideration should be given to seeking advice and support from specialists in interdisciplinary research management, or those with similar experiences of co-ordinating large interdisciplinary research programmes.

Allow for the extra time and effort involved

Successful interdisciplinary research requires additional time and effort. This needs to be factored-in to research programme design and funding, especially in the early stages, but also on a recurring basis. As well as disciplinary experts, there is an important role for interdisciplinary translators and facilitators.

Decide on interdisciplinary ambition

Interdisciplinarity can happen in many different ways, and there is no single best practice blueprint. UKERC should be more explicit about its interdisciplinary ambition, across *multidisciplinarity* (with self-contained disciplines with low levels of collaboration); *interdisciplinarity* (which seeks more integrated disciplinary perspectives and more holistic outcomes); and *transdisciplinarity* (with strong elements of co-design and/or co-production with non-academic stakeholders). There is a need to consider the different modes of interdisciplinary exchange beyond integration and synthesis. Different ambitions imply different research designs and resource requirements, and perceived failures in interdisciplinary initiatives may relate to unrealistic expectations. It is useful to agree on the broad nature and extent of interdisciplinary ambition early-on, while also allowing some flexibility given that research programmes develop and change over time.

Aim for balanced disciplinary representation

An effort to achieve disciplinary balance at different levels (especially, theme and programme-level) encourages interdisciplinarity, and helps guard against the emergence of dominant and marginalised disciplines.

Recognise the trade-off between inclusiveness and integration

A strong emphasis on openness and diversity in research programmes erodes capacity for more ambitious forms of interdisciplinarity which rely on familiarity and trust. This trade-off should be anticipated by both researchers and their funders.

Value strategic and organisational continuity

Although it has benefitted from three successive awards from RCUK, UKERC has also faced high multiple expectations, changing resource models and some organisational discontinuity. Such discontinuities can erode the development of interdisciplinary whole systems research capacity.

Clarify UKERC's remit

There is a need for clarity on UKERC's roles as both a research programme in its own right and a networking and representative body for the wider research community – and recognition of the resource implications involved, given the dramatic growth in the energy research community over UKERC's lifetime.

Strengthen collaboration with the wider energy research community

UKERC should seek to engage more systematically with the wider energy research community. For example, UKERC events could include more guest speakers from other major initiatives. There should also be greater efforts at co-funding research with other large programmes within the RC's Energy Programme.

Recognise the interests of different funders

Given UKERC's funding is provided by multiple Research Councils (rather than a single interdisciplinary Council or single cross-Council commissioning body) UKERC's research strategy needs to recognise the distinctive interests of each individual Council and their respective research communities.

Regularly engage with stakeholders in research co-design, and consider more ambitious efforts at transdisciplinarity

UKERC should enable regular, substantial stakeholder and policy engagement in its research design and commissioning, and in interpreting research outcomes. However, there are some concerns among researchers about the more direct involvement of stakeholders in research production, and radical transdisciplinarity may be better seen as an experimental rather than a mainstream element of Phase 3.

Devise and use interdisciplinary evaluation

Conventional research metrics, such as journal prestige or citation patterns are less appropriate for assessing interdisciplinary research. Other forms of assessment should also be used, such as impact case studies, interdisciplinary output counts, and evidence of follow-on funding.

Develop a systemic, 'root-and-branch' interdisciplinary research strategy

UKERC should develop a root-and-branch interdisciplinary research strategy at *researcher, project, theme, and programme* levels; suggested elements in this are:

- At the *researcher level*, offer interdisciplinary publishing opportunities by negotiating interdisciplinary special issues of high-impact journals. Researchers also value UKERC-run events and networks which create a protected space for interdisciplinary exchange.
- At the *project level*, devise and commission projects which deliberately and explicitly combine together different methods and perspectives, with dedicated review processes for assessing the interdisciplinary credentials of proposals.
- At the *theme level*, each theme should have a theme leader and deputy from different disciplines. Meetings should be regular within themes, with occasional workshops across themes to share best practices. Theme achievements in interdisciplinarity should be regularly reviewed.
- At the *programme level*, foster interdisciplinary capacity through 'seed-corn' funding, and running workshops and conferences designed to promote interdisciplinary exchange. The overall interdisciplinary research strategy should be regularly reviewed.

Recognise the collective responsibility of funders, researchers and assessors

As well as a more explicit and reflexive strategic leadership by its senior researchers, strengthening UKERC's interdisciplinary ambitions and achievements require a stronger partnership of all those involved in the commissioning, management and assessment of its research.

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Annex 1: Interdisciplinary Review Project Specification Note

Doing interdisciplinary energy research: experiences and lessons from the UK Energy Research Centre (February 2013)

Background, Rationale

The UK Energy Research Centre (UKERC) is the ‘flagship’ programme of the UK Research Councils Energy Programme (RCEP), and a cornerstone of the RCEP’s efforts on cross-disciplinary ‘whole systems’ energy research. The UKERC Phase II Research Programme (2009 to 2014) offers a rich case for assessing the opportunities and challenges of interdisciplinary energy research. Among UK energy research centres, UKERC has been at the forefront of ‘core + flex’ funding – a funding model that is now being more widely adopted. Interest in a review of interdisciplinarity in UKERC has been indicated by its Research Committee, Advisory Board and Supervisory Board. Such a study should offer timely lessons for the future of interdisciplinary energy studies in the UK.

Research Aim, Questions and Design

The overall **aim** of this study is to analyse the UKERC II research programme *as a case study in interdisciplinary energy research, in terms of strengths, weaknesses, challenges and lessons learned*. The research will engage with the emerging academic literature on the management of interdisciplinary research in energy-environmental studies.¹ It will also consider UKERC experiences in the wider public research context and of comparable initiatives (e.g. the NERC-led Rural Economy and Land Use (RELU) programme). More specific research **questions** include:

- Where has interdisciplinarity occurred in the UKERC II research programme (i.e. within or across the research themes, research projects, individual researchers); where has it been less manifest?
- What forms of cross-disciplinarity activity have been evident (e.g. multi-, inter-, trans-)?
- Have some particular disciplines, centres or individuals shown greater propensity to cross-disciplinary engagement than others, and if so, why?
- Have particular research organisation models (such as research institutes, teaching departments or research council centres) shown differing commitments to interdisciplinary working?
- How have UKERC’s other functions beyond its research programme (such as the Meeting Place events) helped to promote and support interdisciplinary research (either within or beyond the UKERC)?
- Have the suggested benefits of interdisciplinarity been demonstrated, in terms of particular research results or wider impacts?
- What lessons can be drawn from the UKERC II research experience, for UKERC itself and for wider publicly funded research in the UK on energy and beyond?

¹ Lowe, P. and J. Phillipson (2009) ‘Barriers to Research Collaboration Across Disciplines: Scientific Paradigms and Institutional Practices’ *Environment and Planning A*, 41: 1171-1184

In terms of research **methods**, the conceptual element will include a selected review of the relevant research literature. Following on from this, the empirical parts of the project will include an online survey of UKERC researchers and stakeholders, with selected in-depth semi-structured interviews. A group exercise and consultation will be conducted at the UKERC Assembly in July. The project write-up will synthesise empirical and conceptual strands, and offer recommendations for research managers and funders. The project will also be informed by a parallel workshop series on interdisciplinarity being hosted by UKERC's Sparks PhD network and the Meeting Place (Watson and Winskel are on the steering group of this event).

Budget, Management, Impact

The project will be led by UKERC's Research Co-ordination Team over a 6 months period (April to September 2013). Winskel and Ketsopoulou will each contribute 1-day/week during this period. Watson will provide a small amount of his time for project supervision and advice. Additional dedicated researcher time (3 months FTE) will also be required to assist with empirical work and literature reviewing. This will be costed at c. £30k (at 80% FEC), including a small travel allowance.

The project will produce two UKERC Working Papers (one on the literature review [July 2013] and one on empirical findings [Sept 2013]) and one Research Report [Nov 2013]. Project findings will also be highlighted in the Final Report on UKERC phase II to be launched in April 2014. Interim findings will also be disseminated for response to UKERC associated bodies (Research Committee, Advisory Board and Supervisory Board). The results will also be written up for journal paper publication.

Annex2: Online Survey Questions

Note: only the headline question is given below. Survey participants were presented with a list of options for most of the questions, in 'multiple choice' format.

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 interdisciplinary 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

Q14. How well have different types of UKERC researchers engaged in interdisciplinary research?

Answered: 84 Skipped: 6

Q.15 Where has the interdisciplinary approach fostered by UKERC made a difference?

Answered: 83 Skipped: 7

Q.16 As a result of your participation in UKERC have you published in any journals that you had not previously published?

Answered: 78 Skipped: 12

Q.17 My participation in UKERC has made me more likely to participate in interdisciplinary energy research.

Answered: 83 Skipped: 7

Q18. What are your main reasons for engaging in interdisciplinary research?

Answered 82 Skipped: 8

Q.19. What are the main barriers to engaging in interdisciplinary research?

Answered 82 Skipped: 8

Q.20 UKERC has helped develop an interdisciplinary community that will have an impact on future research and policy

Answered 85 Skipped: 5

Q.21. Please suggest any lessons for future researchers, programme leaders/ managers and funders.

Answered: 27 Skipped: 63

Q.22. Do you have any other comments or suggestions?

Answered: 16 Skipped: 74

Q.22. Please let us know if you would be willing to be interviewed as part of this work

Answered: 83 Skipped: 7