UKERC ENERGY RESEARCH ATLAS: INTERDISCIPLINARY WHOLE SYSTEMS RESEARCH

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1. Overview

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Characterisation of the field

The concept of *whole energy systems* refers to research that considers all dimensions of energy systems change. It applies insights from different academic disciplines and types of expertise to understand this change. The concept has been especially associated with UK energy research and development. The UK's network of academics, the UK Energy Research Centre (UKERC), was assigned to develop a whole systems approach by the national science funding organisation Research Councils UK, today's UK Research and Innovation (UKRI). The UKERC's focus on whole systems has corresponded with a wide definition of the energy system as *"the set of technologies, physical infrastructure, institutions, policies, and practices located in, and associated with the UK which enable energy services to be delivered to UK consumers"* (UKERC, 2009).

This landscape document describes major UK research initiatives that have contributed knowledge to interdisciplinary whole systems perspectives. It concentrates on projects that have the following characteristics, recognised by a recent review of interdisciplinary whole systems energy research**:**

1. *Intellectual diversity*: Different academic disciplines draw upon diverse data, methods, and forms of proof. Engaging with these diverse knowledge bases is a key aim for interdisciplinary whole systems initiatives.
2. *Integrative knowledge production*: Interdisciplinary whole systems initiatives aim at integrating academics from different disciplines to develop common research designs and research outputs.
3. *Transdisciplinary knowledge production*: The knowledge production in whole systems initiatives engages non-academic stakeholders, such as industries, policy makers, wider publics, citizens, or technology 'end users'. The non-academic stakeholders are viewed as active collaborators in whole systems research projects and as co-designers of research designs and research outputs.

The landscape collects research initiatives that integrate experts from key academic disciplines (especially between engineering and physics, social sciences and economics, and environmental sciences), which produce research outputs jointly by the members of these different disciplines, and which build partnerships between universities, industries, policy makers, and various other non-academic stakeholders. The scope will be on the research group or higher level and therefore individual fellowships have not been included. The UKERC Research Landscape on Socio-Economic Issues and the UKERC Research Landscape on Energy Systems Modelling will contain several initiatives that were not selected to this document, though there also are a number of overlaps between these three landscape documents.

This UKERC Research Landscape was previously published in 2009, then named as *Interdisciplinary Research Centres.* In this updated document, the primary aim has been changed substantively drawing from discussions with senior experts in the UKERC. Ten years ago, the number of new energy centres and networks that cut across standard departmental and faculty structures was already increasing. Today, the activity around interdisciplinary energy centres and networks in the UK has grown so much that its description would no longer meaningfully fit into a single review. With this in view, the document concentrates on major funding streams to interdisciplinary whole systems research in Section 3. It also outlines some of the UK participation in energy-related EU programmes in Section 8, which lists selected EU interdisciplinary and whole systems research projects with UK participants.

2. Capabilities Assessment

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Not applicable.

3. Basic and applied strategic research

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This section describes major UK funding streams for interdisciplinary whole systems research. As outlined above, it will focus on initiatives and projects whose research combines knowledge bases from various academic disciplines, integrates representatives of different disciplines in knowledge production, and engages non-academic stakeholders as co-producers of research designs and outputs.

The primary scope will be on the research funding awarded by the UK's Engineering and Physical Sciences Research Council (EPSRC). The EPSRC structures its support to two key themes: *Capability*, which means long-term disciplinary and multidisciplinary research; and *Challenge*, which is aimed at addressing global, economic, and societal challenges. Energy is one of the seven Challenge themes. In the current EPSRC portfolio of grants to energy, *Whole Energy Systems* constitutes the third-largest area, following nuclear fission and end use energy demand (energy efficiency). Overall, one tenth of the current EPSRC energy research funding has been granted to whole energy systems research. The table below describes the major recent grants in this area. In addition to the EPSRC Research Portfolio, a substantial part of this material was collected from the UKERC Energy Data Centre focusing on major projects that address the environmental, social and economic impacts of energy from a whole systems perspective.

Table 3.1: Research Funding

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
Decarbonising Transport through Electrification, a Whole System Approach (DTE), Cardiff University	EPSRC	The multidisciplinary network for Decarbonizing Transport through Electrification (DTE) will bring together research expertise to address the challenges of interactions between energy networks, future electric vehicle charging infrastructure (including roadside wireless charging, the shift to autonomous vehicles), electric and hybrid aircraft and electrification of the rail network. The DTE network will bring together industry, academia and the public sector to identify the challenges limiting current implementation of an electrified, integrated transport system across the automotive, aerospace and rail sectors. The network will develop and sustain an interdisciplinary team to solve these challenges, leveraging external funding from both public and private sectors, aiming to be become self sustainable in future and growing to establish an International Conference. The network will be inclusive, with a focus EDI and mechanisms to support colleagues such as early career researchers. The DTE network will address low-carbon transport modes (road, rail and airborne) alongside associated electricity infrastructures to support existing and deliver future mobility needs, treating these as an integrated system embedded within the electricity energy vector with the goal of decarbonising the transport sector. It will explore drivers for change within the transport system including technology innovation, individual mobility needs and economic requirements for change alongside environmental and social concerns for sustainability and consider the role, social acceptance	£915,858	2019-2022	£305,286

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		and impact of policies and regulations to result in emissions reduction. The network has three key "Work Streams" focusing on: (i) vehicular technologies; (ii) charging infrastructure; (iii) energy systems. These will be underpinned by cross-cutting themes around large scale data analysis and human factors. The network also has a dedicated Work Stream on people-based activities to enable us to widen our dissemination and impact across other communities. The outcome of the DTE network is expected to transform current practices and research in the decarbonization of transport (considering a number of different perspectives).			
Integrated Operation and Planning for Smart Electric Distribution Networks (OPEN), Cardiff University	EPSRC	The UK has a commitment to reduce its greenhouse gas emissions by at least 80% by 2050 relative to 1990 levels. DECC's 2050 Pathway Analysis shows the various ways through which we can achieve this target. All feature a high penetration level of renewable generation and a very substantial uptake of electrification of heat and transport, particularly from 2030 onwards. This will place unprecedented demand and distributed generation on electricity supply infrastructure, particularly the distribution systems due to their size. If a business as usual model is to apply, then the costs of de-carbonisation will be very high. Being equally confronted by the pressure of global climate change and sustainable development, the Chinese government has declared that by 2020 the carbon emission per-unit GDP will reduce to 40-45% of that in 2008. However China also needs to meet a 10% annual demand increase which has been on-going for the past 20 years, and this rate of growth is expected to continue for at least another 10 years. Therefore reinforcement of current distribution networks in an economic and sustainable	£1,002,351	2013-2016	£334,117

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		way while meeting customers' rising expectation of supply quality and reliability is one of the basic requirements of Smart Grid development in China. It is a matter of urgency to investigate how to develop and adapt the current distribution network using Smart Grid interventions in order to facilitate timely connection of low carbon and sustainable technologies in a cost-effective manner. This is a global challenge faced by UK, China and many other countries. Our consortium brings together leading researchers from the UK and China to jointly investigate the integrated operation and planning for smart distribution networks to address two key research challenges: (1) Conventional network operational and planning approaches do not address the emerging opportunities offered by increased measurement and control and do not deal with the inevitable uncertainties of smart distribution networks. (2) A general understanding of how national or regional electricity distribution infrastructure should be developed and operated using Smart Grid interventions is required urgently by those making policy within Distribution companies and in Government/Regulators. Such an understanding cannot be gained from running conventional power system analysis tools and then manually assessing the results. New techniques and approaches will be investigated to address these important questions			

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		(1) Distribution state estimation and probabilistic predictive control approaches will be used to determine the location and control policies of smart grid interventions including Soft Open Points and electronic embedded hybrid on-load tap changers. (2) Novel dynamic pricing techniques will be proposed to resolve conflicts between energy markets and network operation and find synergies where these exist. (3) A very fast network assessment tool and a rolling planning tool that will bridge the gap between planning and operation will be developed. (4) New visualisation and reporting techniques will be developed to give network planners, operators as well policy makers clear insights as to how Smart Grid interventions can be used most effectively. Complementary, cross-country expertise will allow us to undertake the challenging research with substantially reduced cost, time and effort. The research will build upon the long-time well established collaborations between partner institutions of the two countries. Our ambition is to provide a strategic direction for the future of smart electricity distribution networks in the 2030-2050 time frame and deliver methodologies and technologies of alternative network operation and planning strategies in order to facilitate a cost effective evolution to a low carbon future.			
Aggregators as diGital Intermediaries in Local Electricity markets	EPSRC	There has been a huge investment in micro generation from both customers and small scale providers, particularly in residential PV. Individual participation of	£719,499	2018-2020 (follow-on funding)	£359,750

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(AGILE), Cranfield University		these assets (offers to buy/sell/store energy) by micro/domestic scale agents in local, distributed electricity markets is currently a significant business and technological challenge in the UK's large-scale energy systems. A solution to enable energy trading between small scale generators and consumers that provides a compelling business case for storage and further penetration of embedded renewables is essential. New aggregators, that is, new market players who are highly adaptable in terms of dynamically organising Distributed Energy Resources (DERs), are emerging to provide a retail service to distributed groups of customers who could not manage to act in the energy market on their own. These aggregators would deal with requirements of the wider energy system by utilising diverse and multiple low carbon and renewable technologies for generation and storage to provide local/micro-grid solutions. However, there are significant barriers to the emergence of such entities which can be overcome by adoption of contemporary digital technologies. AGILE sets out an integrated digital solution which can deliver suitable mechanisms to allow aggregators to offer the wider energy market bundled DER services of particular duration and value. To allow this, the preferences and descriptions of DERs, which form smart, micro contracts, will be articulated using an agent based model. Bids and offers will be enabled through integration with Distributed Ledger Technologies (DLTs) which will provide a trustworthy			

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		implementation of the scheme through a distributed database trusted by all agents. AGILE will examine the synergies between several permissioned, public, and hybrid DLTs as there are key questions about which type of ledger and related services is best for this elastic aggregator approach. An optimisation model will recommend particular configurations of DERs satisfying several portfolio optimisation strategies (financial, environmental and social welfare). The validation of preferred configurations of DERs is an essential step to ensure the feasibility of DER incorporation and a digitised, stylised IEEE network will be integrated into the digital solution to achieve this. Validation using a range of realistic network topologies will be performed to evaluate the effect on aggregator business models.			
Bioenergy value chains: Whole systems analysis and optimisation, Imperial College London	EPSRC	Most energy system studies of the UK indicate a strong role for bioenergy in the coming decades, especially if the UK is to meet its climate change mitigation ambitions. However, there is a need to understand how bioenergy systems can be implement without negative sustainability-related impacts. There is therefore a need for multi-scale systems analyses to support the understanding of these inter-related issues and to support decision-making around land use, interactions with food production and acceleration of bioenergy technologies, while ensuring that a range of sustainability measures are quantified and that minimum standards can be guaranteed.	£1,560,086	2013-2018	£346,686

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		This project will build on bioenergy system models (Imperial College, RRes, Soton) partners) and combine it with other models, including the UK-TIMES model (UCL), ecosystem and resource models (Soton, Manchester) and international trade models (UCL). This toolkit will be used to identify robust and promising options for the UK, including land use, resources and technologies. This overall modelling framework would be able to determine which value chains can best contribute to a technologically efficient, low cost and low carbon UK energy system. Configuring the model to avoid the use of side constraints to limit the amount of land available for bioenergy and bio-based materials/chemicals will lead to a better understanding of how biomass production can be intercalated into existing UK energy and agricultural infrastructures. This framework will be used to explore the bioenergy value chains and technology developments most relevant to the UK under different scenarios (e.g. high/low food security, high/low biomass imports etc.). The coupling to wider UK energy models as well as global resource models/data will ensure coherence in the overall systems and scenarios developed and to ensure clarity in the role of bioenergy in the wider UK energy system. Resource and technology models and information on future improvements as well as requirements for adoption and diffusion will be incorporated into the model. Sample value chains developed will also be assessed for their wider ecosystem impacts within the UK, particularly in terms			

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		of the change in expected key ecosystem services overall arising from changes in land use against a reference scenario. The implications of technological improvements in system critical technologies such as 2G biofuels, bio-SNG gas and the provision of renewable heat will also be considered. The linking of value chain and system models will help to examine the opportunities and indirect impacts of increased biomass use for energy and chemicals and critically evaluate mitigation strategies for GHG emissions and resource depletion, and will feed into a wider policy analysis activity that will examine the dynamics of changing system infrastructure at intermediate time periods between now and 2050. The key outcomes will include: - Understanding the potential and risks of different biomass technologies, and the interfaces between competing requirements for land use - Understanding cost reductions, lifecycle environmental profiles and system implications of bioenergy and biorenewables - Identifying and modelling the impact of greater system integration -integrated energy, food, by-product systems, and cascading use of biomass - Understanding what it would take to achieve a significant (e.g. 10%) contribution from biomass in the UK - and identify the pre-requisites/critical path for			

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		mobilisation (resources, policies, institutions and timescales). - Developing scenarios describing what policies, infrastructure, institutions etc. would be needed and where - Lifecycle, techno- and socio-economic and environmental/ecosystem, evaluation of the value chains associated with a material level of bioenergy in the UK			
Integrated Development of Low-Carbon Energy Systems (IDLES): A Whole-System Paradigm for Creating a National Strategy, Imperial College London	EPSRC	The long-term evolution of energy systems is set by the investment decisions of very many actors such as up-stream resource companies, power plant operators, network infrastructure providers, vehicle owners, transport system operators and building developers and occupiers. But these decisions are deliberately shaped by markets and incentives that have been designed by local and national governments to achieve policy objectives on energy, air-quality, economic growth and so on. It is clear then that government and businesses need detailed and dependable evidence of what can be achieved, what format of energy system we should aim for, what new technologies need to be encouraged, and how energy systems can form part of an industrial strategy to new goods and services. It is widely accepted that a whole-system view of energy is needed, covering not only multiple energy sectors (gas, heat, electricity and transport fuel) but also the behaviour of individuals and organisations within the energy consuming sectors such as transport and the built environment. This means that modelling energy production, delivery and use in a future integrated	£7,047,665	2018-2023	£1,409,533

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		system is highly complex and analytically challenging. To provide evidence to government and business on what an optimised future system may look like, one has to rise to these modelling challenges. For electricity systems alone, there are established models that can optimise for security, cost and emissions given some assumptions (and sensitivities) and these have been used to provide policy and business strategy evidence. However, such models do not exist for the complex interactions of integrated systems and not at the level of fine detailed needed to expose particularly difficult operating conditions. Our vision is to tackle the very challenging modelling required for integrated energy systems by combining multi-physics optimising techno-economic models with machine learning of human behaviour and operational models emerging multi-carrier network and conversion technologies. The direction we wish to take is clear but there are many detailed challenges along the way for which highly innovative solutions will be needed to overcome the hurdles encountered. The programme grant structure enables us to assemble an exceptional team of experts across many disciplines. There are new and exciting opportunities, for instance, to apply machine learning to identify in a quantitative way models of consumer behaviour and responsiveness to incentives that can help explore demand-side flexibility within an integrated energy system. We have engaged four major partners from complementary sectors of the energy system that will support the programme with significant funding			

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		(approximately 35% additional funding) and more importantly engage with us and each other to share insights, challenges, data and case studies. EDF Energy provide the perspective on an energy retail business and access to smart meter trail data. Shell provide insights into the future fuels to be used in transport and building services. National Grid (System Operator) give the perspective of the use of flexibility and new service propositions for efficient system operations. ABB are a provider of data acquisition and control systems and provide industrial perspective of decentralisation of control. ABB have committed to providing substantial equipment and resource to build a verification and demonstration facility for decentralised control. We are also engaging examples of the new entrants, often smaller companies with potentially disruptive technologies and business models, who will engage and share some of their insights.			
National Centre for Energy Systems Integration (CESI), Newcastle University	EPSRC	Energy systems are vitally important to the future of UK industry and society. However, the energy trilemma presents many complex interconnected challenges. Current integrated energy systems modelling and simulation techniques suffer from a series of shortcomings that undermine their ability to develop and inform improved policy and planning decisions, therefore preventing the UK realising huge potential benefits. The current approach is characterised by high level static models which produce answers or predictions that are highly subject to a set of critical simplifying assumptions and therefore cannot be relied upon with a high degree of confidence. They are unable to provide sufficiently accurate or detailed, integrated representations of the physics, engineering, social,	£5,359,128	2016-2021	£1,071,825

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		spatial temporal or stochastic aspects of real energy systems. They also struggle to generate robust long term plans in the face of uncertainties in commercial and technological developments and the effects of climate change, behavioural dynamics and technological interdependencies. The aim of the Centre for Energy Systems Integration (CESI) is to address this weakness and reduce the risks associated with securing and delivering a fully integrated future energy system for the UK. This will be achieved through the development of a radically different, holistic modelling, simulation and optimisation methodology which makes use of existing high level tools from academic, industry and government networks and couples them with detailed models validated using full scale multi vector demonstration systems. CESI will carry out uncertainty quantification to identify the robust messages which the models are providing about the real world, and to identify where effort on improving models should be focused in order to maximise learning about the real world. This approach, and the associated models and data, will be made available to the energy community and will provide a rigorous underpinning for current integrated energy systems research, so that future energy system planning and policy formulation can be carried out with a greater degree of confidence than is currently possible. CESI is a unique partnership of five research intensive universities and underpinning strategic partner Siemens (contribution value of £7.1m to the centre) The Universities of Newcastle, Durham, Edinburgh, Heriot-			

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		Watt and Sussex have a combined RCUK energy portfolio worth over £100m. The centre will have a physical base as Newcastle University which will release space for the centre in the new £60m Urban Sciences Building. This building will contain world-class facilities from which to lead international research into digitally enabled urban sustainability and will also be physically connected to a full scale instrumented multi vector energy system. The building will feature an Urban Observatory, which will collect a diverse set of data from across the city, and a 3D Decision Theatre which will enable real-time data to be analysed, explored and the enable the testing of hypotheses. The main aim of CESI's work is to develop a modular 'plug-n-play' environment in which components of the energy system can be co-simulated and optimised in detail. With no technology considered in isolation, considering sectors as an interlinked whole, the interactions and rebound effects across technologies and users can be examined. The methodology proposed is a system architect concept underpinned by a twin track approach of detailed multi-vector, integrated simulation and optimisation at various scales incorporating uncertainty, coupled with large scale demonstration and experimental facilities in order to test, validate and evaluate solutions and scenarios. A System Architect takes a fully integrated, balanced, long term, transparent approach to energy system planning unfettered by silos and short term thinking.			

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Supergen Energy Networks Hub, Newcastle University	EPSRC	Energy networks are vitally important enablers for the UK energy sector and therefore UK industry and society. The energy trilemma (energy security, environmental impact and social cost) presents many complex interconnected challenges which reach beyond the UK and have huge relevance internationally. These challenges vary considerably from region to region, and change as a result of technology and society changes. Therefore, the planning, design and operation of energy networks needs to be revisited and optimised. Current energy networks research does not fully embrace a whole systems approach and is therefore not developing a deep enough understanding of the interconnected and interdependent nature of energy network infrastructure. The Supergen Energy Networks Hub will provide leadership, a core research programme and mechanisms/funding for the energy networks community to grow and come together to develop this deeper understanding and explore opportunities to shape energy networks which are fit for the future. The research component of the Hub's activities comprises an interconnected and complementary series of work packages. The work packages are: WP1: Understanding, Shaping and Challenging; WP2: Energy Network Infrastructure; WP3: ICT and Data; WP4: Policy and Society; WP5: Markets and Regulation; WP6: Risk and Uncertainty. WP1 incorporates a co-evolutionary approach and brings the other work packages together in a structured way. WP2 is the backbone of the research, dealing with the physical infrastructure in a multi vector manner from the outset.	£5,100,772	2018-2022	£1,275,193

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		WP3 to WP6 deal with aspects of energy networks that cut across, and are equally valid, for all vectors and have the ability to integrate and modernise network infrastructures. All work packages will consider both planning and design as well as operational aspects. Experimental work and demonstrators will be essential to progress in energy networks research and the Hub will bring these facilities to bear through WP1. The Hub will engage with the energy networks communities throughout the research programme, to ensure that the work is informed by best practice and that the findings are widely visible and understood. The main objectives of the communication and engagement activities will be to ensure the energy networks academic community are connected and coherent, and that their work has a high profile and deep level of understanding in the relevant Industrial, Governmental and Societal communities both nationally and internationally. This will maximise the chances of high impact outcomes in the energy networks space as well as promoting energy networks as an exciting and dynamic area to carry out research, thus attracting the brightest minds to get involved. Communication and engagement activities will be a constant feature of the Hub and will be particularly energetic during the first twelve months in order to rapidly establish a brand, and an open and supportive culture within the relevant communities. Engagement activities will as far as possible be carried out in conjunction with other key organisations in the energy			

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		space, to maximise the value of the engagement activities. The Hub aims to become a beacon for equality, diversity and inclusion. Our mission is to enhance equality of opportunity and create a positive, flourishing, safe and inclusive environment for everyone associated with the Hub, from staff, students, Advisory Board members and general Hub representation (at conferences, workshops and reviews). We recognise the need and the challenges to support early career researchers, and improve the balance of protected characteristics across the entire Hub community, such as race or ethnicity, gender reassignment, disability, sex, sexual orientation, age, religion or belief, pregnancy or maternity status, marital status or socio-economic background.			
International Centre for Infrastructure Futures (ICIF), University College London	EPSRC	Compared to many parts of the world, the UK has under-invested in its infrastructure in recent decades. It now faces many challenges in upgrading its infrastructure so that it is appropriate for the social, economic and environmental challenges it will face in the remainder of the 21st century. A key challenge involves taking into account the ways in which infrastructure systems in one sector increasingly rely on other infrastructure systems in other sectors in order to operate. These interdependencies mean failures in one system can cause follow-on failures in other systems. For example, failures in the water system might knock out electricity supplies, which disrupt communications, and therefore transportation, which prevent engineers getting to the original problem in the water infrastructure. These problems now generate major economic and social costs. Unfortunately they are	£3,444,605	2013-2017	£898,592

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		difficult to manage because the UK infrastructure system has historically been built, and is currently operated and managed, around individual infrastructure sectors. Because many privatised utilities have focused on operating infrastructure assets, they have limited experience in producing new ones or of understanding these interdependencies. Many of the old national R&D laboratories have been shut down and there is a lack of capability in the UK to procure and deliver the modern infrastructure the UK requires. On the one hand, this makes innovation risky. On the other hand, it creates significant commercial opportunities for firms that can improve their understanding of infrastructure interdependencies and speed up how they develop and test their new business models. This learning is difficult because infrastructure innovation is undertaken in complex networks of firms, rather than in an individual firm, and typically has to address a wide range of stakeholders, regulators, customers, users and suppliers. Currently, the UK lacks a shared learning environment where these different actors can come together and explore the strengths and weaknesses of different options. This makes innovation more difficult and costly, as firms are forced to 'learn by doing' and find it difficult to anticipate technical, economic, legal and societal constraints on their activity before they embark on costly development projects. The Centre will create a shared, facilitated learning environment in which social scientists, engineers, industrialists, policy makers and other stakeholders can			

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		research and learn together to understand how better to exploit the technical and market opportunities that emerge from the increased interdependence of infrastructure systems. The Centre will focus on the development and implementation of innovative business models and aims to support UK firms wishing to exploit them in international markets. The Centre will undertake a wide range of research activities on infrastructure interdependencies with users, which will allow problems to be discovered and addressed earlier and at lower cost. Because infrastructure innovations alter the social distribution of risks and rewards, the public needs to be involved in decision making to ensure business models and forms of regulation are socially robust. As a consequence, the Centre has a major focus on using its research to catalyse a broader national debate about the future of the UK's infrastructure, and how it might contribute towards a more sustainable, economically vibrant, and fair society. Beneficiaries from the Centre's activities include existing utility businesses, entrepreneurs wishing to enter the infrastructure sector, regulators, government and, perhaps most importantly, our communities who will benefit from more efficient and less vulnerable infrastructure based services.			
Operationalising Socio-Technical Energy Transitions (O-STET), University College London	EPSRC	The implementation phase of the energy system transition has shown that ambitious decarbonisation strategies must not only encompass radical techno-economic change but also incorporate societal and political dimensions as well. Socio-Technical Energy Transitions (STET) represents the cutting-edge of truly interdisciplinary academic research - incorporating a	£510,111	2018-2020 (follow-on funding)	£255,055

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		marriage of qualitative and quantitative elements in the multi-level perspective, co-evolutionary theories, the application of complexity science, and the use of adaptive policy pathways. However despite the vibrancy of academic research, the impact of STET research on policy and industrial decision-making to date has been negligible. O-STET is focused on operationalising and applying this highly novel interdisciplinary approach. O-STET will have four main concrete deliverables via two contrasting approaches: A. STET modelling 1a An open-source modelling framework with agent specific decision-making, and positive/negative feedbacks between political and societal drivers. 2a A stripped down decision maker tool for iterative stakeholder engagement. B. STET scenarios 1b Logically consistent, uncertainty-exploring scenarios, to frame both qualitative dialogues and existing energy models. 2b In-depth perspectives on branching points and critical components. The team combines the UK's leading energy systems modelling group (at UCL) with the UK's leading			

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		innovation and transitions group at the University of Sussex. The PI is highly experienced at leading major whole systems projects with deep interaction with key stakeholders. In this he is closely supported by the Co-Is at Sussex and UCL, all of whom have a demonstrable success in collaboration, management and output delivery on past EPSRC projects. Responding directly to the requirements of this EPSRC Call, the O-STET project is structurally embedded with the Energy Systems Catapult, acting as an external "Analytical Laboratory" to the ESC. O-STET will first provide a theoretical and research framing of the ESC's portfolio of energy models and wider project-based assets. Second, bilateral interaction with the ESC will enable novel STET modelling and scenario tools to be iteratively developed and operationalised. Third, to maximise the applicability of the outputs of these new perspectives we will produce a stripped down STET decision-maker tool with a clear graphical user interface (GUI), as well as in-depth perspectives on branching points and critical components for key elements of STET scenarios (for example, new business models). The O-STET project team and the ESC will then combine as a "Platform" to disseminate STET insights to the full policy and industry energy community, anchored through a set of 6 stakeholder and technical workshops. O-STET will have a major online presence where we will curate and disseminate the open source resources produced under the project; including full models, modular components for hybridisation with other models, model documentation, datasets, socio-technical			

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		modelling protocols, scenario templates, data, and policy briefs.			
Realising Energy Storage Technologies in Low-carbon Energy Systems (RESTLESS), University College London	EPSRC	This project aims to understand how novel energy storage technologies might best be integrated into an evolving, lower-carbon UK energy system in the future. It will identify technical, environmental, public acceptability, economic and policy issues, and will propose solutions to overcome barriers to deployment. As electricity is increasingly generated by highly-variable renewables and relatively inflexible nuclear power stations, alternatives to the use of highly-flexible fossil-fuelled generation as a means of balancing the electricity system will become increasingly valuable. Numerous technologies for storing electricity are under development to meet this demand, and as the cost of storage is reduced through innovation, it is possible that they could have an important role in a low-carbon energy system. The Energy Storage Supergen Hub is producing a UK roadmap for energy storage that will be the starting point for this project. The value of grid-scale storage to the electricity system has been assessed for some scenarios. For extreme cases comprising only renewable and nuclear generation, the value is potentially substantial. However, the value of energy storage to the UK depends on the costs and benefits relative to sharing electricity imbalances through greater European interconnection, demand-side electricity response, and wider energy system storage, and the optimal approaches to integrating energy storage at different levels across the whole energy system are not well	£1,402,239	2015-2019	£350,560

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		understood. This project will take a broader approach than existing projects by considering energy system scenarios in which storage options are more integrated across the whole energy system, using a series of soft-linked energy and electricity system models. Demand-side response and increased interconnection will be considered as counterfactual technologies that reduces the need for storage. Three broad hypotheses will be investigated in this project: (i) that a whole energy system approach to ES is necessary to fully understand how different technologies might contribute as innovation reduces costs and as the UK energy system evolves; (ii) that a range of technological, economic and social factors affect the value of ES, so should all be considered in energy system scenarios; and, (iii) that the economic value of the difference between good and bad policy decisions relating to the role of energy storage in the transition to low-carbon generation is in the order of £bns. A broader, multidisciplinary approach, which extends beyond the techno-economic methodologies that are adopted by most studies, will be used to fully assess the value of energy storage. This project will therefore also examine public acceptability issues for the first time, compare the environmental impacts of storage technologies using life-cycle analyses, and examine important economic issues surrounding market design to realise the value of storage services provided by consumers. All of these analyses will be underpinned by the development of technology-neutral metrics for ES			

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		technologies to inform the project modelling work and the wider scientific community. These multidisciplinary considerations will be combined in a series of integrated future scenarios for energy storage to identify no-regrets technologies. The project will conclude by examining the implications of these scenarios for UK Government policy, energy regulation and research priorities. The analyses will be technical only to the point of identifying the requirements for energy storage, with absolutely no bias towards or against any classes of storage technology.			
UK Energy Research Centre (UKERC) Phase 3, University College London	EPSRC	This initiative set out a five-year programme of activities for phase 3 of the UK Energy Research Centre (UKERC). UKERC's main objective was to conduct and synthesise independent research on energy systems that is academically excellent and relevant to policy, business and other stakeholders. UKERC's research programme was complemented by engagement and knowledge exchange activities, some of which were performed on behalf of (or in conjunction with) the wider UK energy research community. Phase 3 built on UKERC's strong track record of research and engagement. UKERC's research and other activities were substantially re-oriented in phase 3. The first two phases of UKERC focused on understanding what a decarbonised UK energy system will look like in 2050 and how the transition towards this system could be achieved. The third phase recognised the increasingly contested and uncertain nature of energy system change. It explored the UK energy transition in an uncertain world, and the synergies and trade-offs between the key drivers for this transition. Whilst the need to achieve deep	£13,531,962	2014-2019	£2,537,243

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		emissions reductions remained a driver for UKERC's research, phase 3 analysed a wider range of potential energy system transitions in the UK. These included future energy pathways that do not achieve such deep reductions in emissions. The phase 3 research programme comprised six interdisciplinary themes, each of which was guided by a problem-focused research question. These themes focused on the development and analysis of future pathways for the UK energy system; the implications of these pathways for resources and vectors; the implications for energy systems at local, national and international scales; the interactions between the energy system and the wider economy; the implications for decision making by individuals and organisations; and the review and synthesis of evidence on contentious energy topics. UKERC phase 3 included a core research programme and a flexible Research Fund. The fund increased the breadth and depth of UKERC's research programme, provided resources to strengthen UKERC's links with other important research centres, and ensured that UKERC was more inclusive. The UKERC research programme was expanded by a number of separately commissioned Research Challenges, the first of which focused on valuing natural capital in low carbon pathways. The research programme continued to be complemented by the Energy Data Centre (including the Projects catalogue and the data catalogue), and core non-			

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		research functions. These included three knowledge exchange networks for policy, business and academic communities, a substantial communications function, international engagement activities including EERA, continuation of the UKERC summer school on a trial fee-paying basis, and a network for early career researchers.			
UK Energy Research Centre (UKERC) Phase 4, University College London	EPSRC	This initiative set out a five-year programme of activities for phase 4 of the UK Energy Research Centre (UKERC). The UKERC phase 4 research programme will focus on new challenges and opportunities for implementing the energy transition, and will be concerned with the following key questions: • How will global, national and local developments influence the shape and pace of the UK's transition towards a low carbon energy system? • What are the potential economic, political, social and environmental costs and benefits of energy system change, and how can they be distributed equitably? • Which actors could take the lead in implementing the next stage of the UK's energy transition, and what are the implications for policy and governance? The research programme will use a whole systems approach to answer these questions. This includes: research that encompasses energy demand, networks and supply; research that is interdisciplinary, drawing on engineering, social and natural sciences; and research that goes beyond 'traditional' energy system boundaries, and builds bridges with other research communities. It will employ diverse methods, and address the questions within seven research themes.	£18,000,000	2019-2024	£3,600,000

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		Five main themes ("UK Energy in a global context", "Local and Regional Energy systems", "Energy, environment and landscape", "Energy infrastructure transitions, and "energy for mobility") will be complemented by two cross-cutting themes on energy systems for heat and industrial decarbonisation to ensure that these important challenges receive sufficient attention. There will also be four national capabilities: Technology and Policy Assessment (TPA), Energy Modelling Hub, Public Engagement Observatory, and Energy Data Centre. The first two capabilities will be managed together as 'Evidence for Decision Making'. The research programme will be significantly expanded through flexible research fund calls and co-funding, with new projects being incorporated within the most relevant themes. Integration across the research programme and capabilities will be essential to the success of phase 4. This will involve careful management and co-ordination, including specific activities to promote interdisciplinary working, and the strategic use of resources to promote research integration. The first integrating project will focus on interactions between energy systems and the economy. UKERC has run a flexible research fund during the last two phases (2 and 3). The fund has been used to expand UKERC's research programme and scope and to build collaborations with other research communities.			

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		During phase 3, the fund supported 11 new research projects, activities to scope new research agendas and the integration of UKERC research. We met our indicative phase 3 target of bringing in 40-50 additional researchers (the actual figure was 57). In phase 4, the flexible research fund will have a budget of £3.6m (at 80% FEC) and will build on experience in phases 2 and 3. We have reviewed the objectives of the fund, which will be: • To provide flexibility for the UKERC research programme in the light of new scientific insights or developments in policies, technologies or industries; • To bring a wider range of researchers and disciplines into UKERC's research programme, including researchers from outside the 'traditional' energy community; • To scope and develop new research agendas in partnership with funders, the research community and other stakeholders; and • To promote integration in the UKERC research programme, and to fill gaps where needed. In Phase 4 the flexible fund will support three types of activities, with a primary emphasis on commissioning new research: major research projects, scoping activities, and integrating projects. The research programme will continue to be complemented by the Energy Data Centre (including the Projects catalogue and the data catalogue), and core non-research functions.			

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
Whole Systems Energy Modelling Consortium (wholeSEM), University College London	EPSRC	Energy models provide essential quantitative insights into the 21st Century challenges of decarbonisation, energy security and cost-effectiveness. Models provide the integrating language that assists energy policy makers to make improved decisions under conditions of pervasive uncertainty. Whole systems energy modelling also has a central role in helping industrial and wider stakeholders assess future energy technologies and infrastructures, and the potential role of societal and behavioural change. Despite this fundamental underpinning role, the UK has not had a national strategic energy modelling activity. Models have been developed on a fragmented, reactive and ad-hoc basis, with a critical shortfall in the continuity of funding to develop new models, retain human capacity, and link modelling frameworks in innovative ways to answer new research questions. The whole systems energy modelling (wholeSEM www.wholesem.ac.uk) consortium was explicitly designed to enable the UK to make an internationally leading research impact in this critical area, and hence to provide cutting-edge transparent quantitative analysis to underpin public and private energy systems decision making. Following a rigorous selection process, the wholeSEM consortium encapsulated leading and interdisciplinary UK capacity in quantitative whole systems energy research. The key aims of the interdisciplinary wholeSEM consortium were:	£4,607,765	2013-2018	£1,023,947

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		1. Undertake internationally cutting edge research on prioritised energy system topics; 2. Integrate whole energy systems modelling approaches across disciplinary boundaries; 3. Build bilateral engagement mechanisms with the wider UK energy systems community in academia, government and industry. The wholeSEM consortium prioritised on key modelling areas of high relevance to interdisciplinary energy systems. Internationally leading research focused on: 1. How does energy demand co-evolve with changes in practice, supply, and policy? 2. How will the endogenous, uncertain, and path dependent process of technological change impact future energy systems? 3. How can the energy supply-demand system be optimised over multiple energy vectors and infrastructures? 4. What are the major future physical and economic interactions and stresses between the energy system and the broader environment? The consortium, employed extensive integration mechanisms to link and apply interdisciplinary models to key energy policy problems. This took place across the conceptualisation and development of innovative			

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		modelling approaches, model construction, and through an integrated set of use-cases. A key element of the wholeSEM was substantive bilateral engagement with stakeholders in academia, government and industry. Multi-layered integration mechanisms included: - A high-profile advisory board, with key policy/industry representation plus wider academic experts; - An innovative fellowship programme to enable bi-directional UK academic, policy and industrial and international experts to work with wholeSEM research teams; - A range of workshops including four internationally high profile annual UK energy modelling conferences, technical workshops focused on key modelling issues, and non-technical stakeholder workshops on model conceptualisation, development and use-cases; - Detailed and transparent documentation for all of the consortium's new energy models; - Model access, based on collaborative agreements with an expert model user group. This will ensure best-use of models, accountability and two-way flows of information from/to model developers, users and critics; - Collation and curation of energy modelling data sources (building off and working with the UKERC Energy Data Centre);			

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		- Provision of training in modelling techniques and software platforms, to train and develop the next generation of energy systems modellers, including interactions with centres for doctoral training (CDTs); - Interactive web-based information dissemination			
Peer-to-Peer Energy Trading and Sharing - 3M (Multi-times, Multi-scales, Multi-qualities), University of Bath	EPSRC	The future electrical grid will have unprecedented complexity and uncertainty. The cost of low carbon technologies (such as PV, electric vehicles, battery storage and heat pumps) is rapidly decreasing and they are increasingly being connected to the edge of the grid. Millions of businesses and homes, which were traditionally passive energy consumers, will become energy prosumers that can store, convert and/or generate energy enabling them to be an active actor. Each actor will make independent decisions to pursue their own 'selfish' or 'altruistic' goals (supporting schools and increasing reputation). These emerging traits make conventional centralised control, dispatch and scheduling tools no longer fit for purpose. The rise of prosumers, where energy buyers and sellers become increasingly blurred, is far beyond the capability of the current market and system operation framework [Hardy, Ofgem 2015]. The vision of this programme is to address this complex problem by providing strategic direction towards a horizontal energy supply, demonstrate its technical and commercial feasibilities and potential benefits to prosumers, communities and the grid in both Korea and the UK. The key aim of this consortium is to manage large rapid influx of DERs (e.g. in the Southwest of UK) through	£980,362	2016-2020	£280,103

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		increase horizontal energy collaboration/transaction management, thus substantially reduce the integration challenge to the vertical supply system. Managing millions of independent actors, each with a differing value proposition and each having changing levels of variability and uncertainty, is extremely challenging, as minor optimization errors at the individual level can build into major failures and inefficiencies at the regional and system level. Thus, the strategic research question we are addressing is, "How to align the technical and market arrangements with diverse social requirements, such that 'selfish and independent' goals pursued by millions of customers are aligned with the interests of the communities and the system?" We will undertake fundamental research into the principles of collaborative consumption/sharing economy and advanced understanding of prosumer energy to deliver a prototype peer-to-peer energy trading/sharing (P2P-ETS) platform. This will lead to a unique scalable market place for mass prosumers to buy/sell/share energy themselves. The goal is to provide an access to mass consumers with markets that encourage low carbon shock to be absorbed locally and substantially reduce the grid balancing and upgrading costs. We will combine leading UK/Korean strengths in smart grids, technologies, whole-system analyses, power system economics, and big data/machine learning to accelerate the understanding, design, development and deployment of P2P-ETS in the UK, Korea and beyond.			

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
Managing Air for Green Inner Cities, University of Cambridge	EPSRC	The challenge articulated in this project is: how to develop cities with no air pollution and no heat-island effect by 2050? It is difficult to predict with precision the future of cities, but there will be significant adaptations and changes by 2050, due to advances in technology, changing populations, social expectations and climate change. A roadmap is needed to ensure that decisions taken as the city evolves lead towards a sustainable future. Approximately half of the energy use, carbon dioxide emissions and exposure to air pollution in cities is due to either buildings or transportation, and this total energy use is increasing. Air pollution is projected to be the leading global cause of mortality by 2050. Therefore the question posed here in terms of air quality and temperature rise is important in its own right. However, these quantities together also provide, perhaps uniquely, specific measurable physical properties that cover an entire city and provide a metric for assessing the sustainability of system-wide decisions. Traditional approaches to urban environmental control rely on energy-consuming and carbon/toxics-producing heating, ventilation and air conditioning (HVAC) systems. These traditional approaches produce an unsustainable cycle of increasing energy use with associated emissions of carbon dioxide and pollutants leading to rising temperatures implying, in turn, greater use of HVAC. Breaking this vicious cycle requires a completely different engineered solution, one that couples with natural systems and does not depend solely on mechanical systems. This project will develop	£4,173,134	2015-2020	£834,627

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		a facility consisting of an integrated suite of models and an associated management and decision support system that together allow the city design and its operation to manage the air so that it becomes its own HVAC system, with clean, cool air providing low-energy solutions for health and comfort. This will be achieved by using natural ventilation in buildings to reduce demand for energy and ensuring air pollutants are diluted below levels that cause adverse health effects, coupled with increased albedo to reduce the heat island effect plus green (parks) and blue (water) spaces to provide both cooling and filtration of pollutants. We have brought together a trans-disciplinary research team to construct this facility. It will be comprised of three components: (i) a fully resolved air quality model that interacts with sensor data and provides detailed calculations of the air flow, pollutant and temperature distributions in complex city geometries and is fully coupled to naturally ventilated buildings, and green and blue spaces; (ii) reduced order models that allow rapid calculations for real time analysis and emergency response; and (iii) a cost-benefit model to assess the economic, social and environmental viability of options and decision. The scientific air quality component is a fully-resolved computational model that couples external and internal flows in naturally ventilated buildings at the building, block and borough scales. It will be supported and validated by field measurements at selected sites and by wind tunnel and salt-bath laboratory studies. The reduced order models will be developed from the			

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		computational model and from laboratory process studies, and will be capable of producing gross features such as mean pollutant concentrations and temperatures. They will be used to provide capabilities for scoping studies, and real-time and emergency response. The cost-benefit model will provide the link between the scientific and engineering models and implementation advice. It will include modules for the built environment, public spaces and transportation, and provide estimates of the life-cycle costs and benefits of the various scenarios at the individual building, city block and borough scales. Eventually, it is envisaged that this will also include social and health effects.			
Water Energy Food (WEFWEBs), University of Glasgow	EPSRC	The water, energy and food systems (the WEF) of the planet are under strain, sometimes described as the "perfect storm". They are all intrinsically linked and inter-dependent (the nexus), and humanity needs to plot a course to ensure sustainability and in an ideal world, equity of access to resources. The WEFWEBs project will examine the data and evidence for the water, energy and food systems and their interactions and dependencies within the local, regional and national environment. We need to maintain a balance between the three sometimes opposing directions that our primary systems are moving in to ensure that we safeguard our ecosystems, while still being able to live sustainably, in a world where demands are increasing. To study these systems and their dependencies and interactions, we need to bring together a multitude of different disciplines from the physical, environmental computational and mathematical sciences, with economics, social science,	£1,395,661	2015-2018	£465,220

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		psychology and policy. Each of the three systems needs to be studied through the data that exists concerning their flows, resources and impacts, but also through individual and civic understanding of the systems. We will collect, synthesise and assimilate existing data, and models with new data that will be collected using new sensing technology and social media. We will examine each of the multiple dimensions of the nexus in three place based studies where we can explore and examine the outputs from data analysis, process and network models, and social perceptions. This project delivers multiple dynamic WEF nexus maps with spatial level spanning the dimensions of the problem, reflecting current status and changes, and the interactions in the primary systems in space and time. There is currently no critically systemic, participatory, multi-stakeholder mapping of the entire multi-scale WEF nexus for the UK and this project offers innovation in terms of the multi-disciplinarity and variety of methods including systemic intervention, data analytics and crowd sourcing techniques to mapping the WEF nexus. Ultimately, WEFWEBs will provide a better understanding to citizens and policy makers alike of the effects of choices and decisions to be made.			
An integrated network to decarbonise transport (Decarbon8), University of Leeds	EPSRC	The latest report from the Intergovernmental Panel on Climate Change in 2018 highlighted the need for urgent, transformative change, on an unprecedented scale, if global warming is to be restricted to 1.5C. The challenge of reaching an 80% reduction in emissions by 2050 represents a huge technological, engineering, policy and	£1,013,725	2019-2022	£337,908

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		societal challenge for the next 30 years. This is a huge challenge for the transport sector, which accounts for over a quarter of UK domestic greenhouse gas emissions and has a flat emissions profile over recent years. The DecarboN8 project will develop a new network of researchers, working closely with industry and government, capable of designing solutions which can be deployed rapidly and at scale. It will develop answers to questions such as: 1) How can different places be rapidly switched to electromobility for personal travel? How do decisions on the private fleet interact with the quite different decarbonisation strategies for heavy vehicles? This requires integrating understanding of the changing carbon impacts of these options with knowledge on how energy systems work and are regulated with the operational realities of transport systems and their regulatory environment; and 2) What is the right balance between infrastructure expansion, intelligent system management and demand management? Will the embodied carbon emissions of major new infrastructure offset gains from improved flows and could these be delivered in other ways through technology? If so, how quickly could this happen, what are the societal implications and how will this impact on the resilience of our systems? The answer to these questions is unlikely to the same everywhere in the UK but little attention is paid to			

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		where the answers might be different and why. Coupled with boundaries between local government areas, transport network providers (road and rail in particular) and service operators there is potential for a lack of joined up approaches and stranded investments in ineffective technologies. The DecarboN8 network is led by the eight most research intensive Universities across the North of England (Durham, Lancaster, Leeds, Liverpool, Manchester, Newcastle, Sheffield and York) who will work with local, regional and national stakeholders to create an integrated test and research environment across the North in which national and international researchers can study the decarbonisation challenge at these different scales. The DecarboN8 network is organised across four integrated research themes (carbon pathways, social acceptance and societal readiness, future transport fuels and fuelling, digitisation, demand and infrastructure). These themes form the structure for a series of twelve research workshops which will bring new research interests together to better understand the specific challenges of the transport sector and then to work together on integrating solutions. The approach will incorporate throughout an emphasis on working with real world problems in 'places' to develop knowledge which is situated in a range of contexts. £400k of research funding will be available for the development of new collaborations, particularly for early career researchers. We will distribute this in a fair, open and transparent manner to promote excellent research.			

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		The network will help develop a more integrated environment for the development, testing and rapid deployment of solutions through activities including identifying and classifying data sources, holding innovation translation events, policy discussion forums and major events to highlight the opportunities and innovations. The research will involve industry and government stakeholders and citizens throughout to ensure the research outcomes meet the ambitions of the network of accelerating the rapid decarbonisation of transport.			
Creating Resilient Sustainable Microgrids through Hybrid Renewable Energy Systems, University of Leeds	EPSRC	Universal access to affordable modern clean energy is goal 7 of the UN Sustainable Development Goals (SDGs). The SDGs state that "Energy is central to nearly every major challenge and opportunity the world faces today. Be it for jobs, security, climate change, food production or increasing incomes, access to energy for all is essential." In sub-Saharan Africa, more than 625 million people have no access to modern energy services. Most African countries - 42 in all - are net energy importers and fossil-fuel-fired plants account for 81% of total electricity generation, which is mostly in South Africa. Most large infrastructure projects are public investments financed by national budgets. The estimated cost of bringing Africa's energy infrastructure to modern standard is 93 billion USD/ year. There is a huge gap between energy supply and demand in Africa, and other developing countries, that successive efforts have failed to bridge. The envisioned holistic hybrid MGs will lead to a prototype model for the creation of sustainable and resilient distribution networks for off-grid locations. This approach has the potential to enable electrification of millions of households. Both Tanzania	£1,259,750	2018-2021	£419,916

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		and Uganda are low income 'least developed' countries with a high level of rural poverty and very limited grid connectivity. The Republic of Congo is classed as a lower middle income country due to its mineral wealth, but has low grid connectivity away from cities and its research sector suffers from under-investment in research capacity building This project focuses on energy distribution in off-grid communities with a population of around 4000 inhabitants, a size that has been recommended by our African project partners as being the practical optimum for implementation. The research has an integrated approach to ensure that the design of the system is maintainable, has good longevity with low cost, meets diverse community energy needs and is resilient to natural hazards. The overall goal is to enable the development of sustainable and resilient energy distribution grids in rural communities of the low- and middle-income countries (LMICs) Tanzania, Uganda and Republic of the Congo, where currently at most 10% of the rural population has access to electricity. We will achieve this by designing a scalable low-cost MG infrastructure based on a novel planning methodology that incorporates real-time operational strategies and sustainable generation flexibility at the system design stage to reduce the investment requirements and increase sustainability. The MG paradigm will ensure that the research outcomes are also applicable to communities with sporadic grid connections. Building on the existing partnership platform created by the PI's five year £1.2M Royal Society renewable energy capacity building project, the present grant will enable us to			

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		realise and experimentally validate a unique, integrated, design platform that incorporates electrical network requirements with hybrid renewable energy generation sources as well as socio-economic and local community-driven considerations. This holistic approach is driven by the understanding that the creation of a truly sustainable, reliable, and locally maintainable energy distribution infrastructure needs to be focused on actual needs and local realities, beyond a purely electrical perspective. This will provide innovative distribution system configurations targeted at supporting the scalable and self-sustainable electrification of rural communities in our three partner countries. An advisory panel drawn from partners of our EPSRC Pump Priming for Global Challenge Research project will ensure that the results are also applicable to LMICs globally.			
GCRF: DAMS 2.0: Design and assessment of resilient and sustainable interventions in water-energy-food-environment Mega-Systems, University of Manchester	ESRC	The world is moving into an unprecedented era of dam-building with more than 3700 large dams currently planned or under construction, much of which are in DAC list countries. These projects have the potential to contribute significantly to the economic and social changes that underpin global Sustainable Development Goals (SDGs). However, past experiences show that poorly designed and planned dam projects conversely may have large negative impacts on the poor, and exacerbate political instability and environmental degradation. This project seeks to create the knowledge base, capacity and capability for a 'Dams 2.0' future, in which dams built in DAC list countries are selected, designed and operated to support resilient and sustainable national, regional and global development in a 2.0 degC world. This will be achieved by understanding and assessing dams as interdependent	£8,162,096	2017-2021	£1,920,493

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		human-nexus (water-energy-food-environment) system interventions and enabling stakeholders to negotiate economic, social, political and ecological impacts despite future uncertainty. Our project will address this ambitious goal through unique cross- and inter-disciplinary research and capacity development partnerships between three sets of key actors. First, our project will stimulate collaboration between several UK centres of research excellence in development, water-energy engineering, economics, food security, climate change, finance and ecology (the universities of Manchester (UM), Cambridge, University College London (UCL), Surrey, Newcastle and Southampton, the International Institute for Environment and Development (IIED), and the International Water Management Institute (IWMI). Second, we will consolidate links with a carefully selected network of researchers and policy-makers in 4 countries/regions (The Centre for Science and Industrial (CSIR) - Water in Ghana, Technological University of Yangon in Myanmar, Jordanian Institute of Science and Technology in the Middle East region, Institute of Economic Growth in Delhi, India). Thirdly, we will seek to work collaboratively with some of the world's most influential development organisations such as The World Bank (WB), International Union for the Conservation of Nature (IUCN), the International Finance Corporation (IFC), The Nature Conservancy (TNC), the International Hydropower Association (IHA), and the Climate Bond Initiative (CBI).			

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		Dams 2.0 is led by a team with a proven track record in successfully managing large consortium grants across multiple countries and disciplines that focus on applied development and policy impact challenges. Our work will provide tailored guidance and build capacity for water-energy-food systems management in each of our case studies regions. In addition, our project will create a framework and accompanying software toolkit for dam system design and training worldwide. This online software will link several open access water, energy, food, and ecological simulation models to state-of-the-art decision-making under uncertainty approaches. This software will be made accessible via an associated suite of online training materials (games & modules we plan to develop with IWMI and the World Bank) for use by dam selection/design/operation teams globally in a range of settings.			
Multi-energY storage-Social, TechnO-economic, Regulatory and Environmental assessment under uncertainty (MY-STORE), University of Manchester	EPSRC	The UK has a commitment to reduce its greenhouse gas emissions by at least 80% by 2050 relative to 1990 levels. While the potential role of energy storage to support integration of RES and help meet these challenging targets is well recognised, development of suitable frameworks that could facilitate energy storage rollout is still lacking. This is due to multiple factors that can be reflected in relevant Research Challenges that this project aims to address. These include: - An adequate understanding of commercial, regulatory, and institutional settings that can facilitate storage deployment; - Gaining insights into the true value streams that individual storage devices and coordinated portfolios of	£1,268,165	2016-2019	£362,332

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		different technologies can generate for different parties across different markets; - Modelling interactions and maximising synergies among different energy vectors, and in particular heat and gas besides electricity, in order to unlock the flexibility of multi-energy forms of storage; - Developing suitable techno-economic models that can cater for the relevant operational and investment uncertainties that affect storage operators and owners and properly consider network and market constraints; - Understanding of wider impacts and social responses of different storage technologies, including public perceptions and environmental impacts. Our Vision is to develop a comprehensive framework, supported by innovative techno-economic modelling techniques capable to deal with different types of operational and planning uncertainties as well as network constraints, aimed at fostering sustainable business cases for different types of energy storage. Our analyses will assess how individual energy storage devices or aggregated portfolios of devices connected to different network levels can provide multiple simultaneous steady-state, dynamic services and power quality services and assess the relevant impact and value arising from these services for different market parties. We will consider explicitly multi-energy forms of storage, and in particular different types of electrical energy storage and thermal energy storage technologies, as well as innovative technologies such as			

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		power-to-gas. Our models will be tested in various technical, commercial and regulatory environments and taking into account socio-economic and environmental aspects, including public perceptions to different technologies. The MY-STORE project will strategically supplement the current research and bring a new perspective by providing much broader context, understanding and responses to the wide-scale deployment of energy storage. Our Ambition is to be the first in the world to provide such a comprehensive framework that can inform policy debates and the business community on the value and role of any storage technology in the transition towards more sustainable energy networks. Notwithstanding the generality of the framework put forward, the studies will focus on the UK situation, with time horizons from short to medium term (around 2035) and then opening up to 2050 and beyond. In fact, part of our ambitious plan is to bring out the value and role of energy storage and demonstrate how it could be possible to build business cases already in the shorter term and even for technologies that are commercially available today (e.g., thermal energy storage and different types of batteries), and then to facilitate development of appropriate regulatory and market environments for wider scale storage deployment (and possibly based on new technologies) to deal with the challenges of developing a truly low-carbon energy system. Our research will put the UK at the international forefront in this important field and provide a secure			

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		platform for future developments, also based on close collaboration with our industrial partners which represent a variety of established and emerging multi-energy storage technologies that are being already deployed or trialled in the UK.			
Supergen Bioenergy Hub, University of Manchester	EPSRC	Biomass is plant or woody material that during its growth has absorbed CO2 from the atmosphere through photosynthesis . When the biomass is used to produce bioenergy it re-releases to atmosphere the same amount of CO2 as was sequestered during growth. Therefore, as long as biomass growth is close in time period to release there is no net addition to the long term atmospheric CO2 concentration. However, some aspects of processing and using the biomass may generate additional greenhouse gas emissions that need to be accounted for and, given that the UK is trying to decrease all carbon emissions it is important that we make efficient use of our biomass resource by maximizing the production and use of truly sustainable resource and developing efficient pre-treatment and conversion technologies. It is also important that we make the best use of the sustainable biomass resource and fully understand the wider impact and costs of implementation. This project brings together leading UK bioenergy research groups to develop sustainable bioenergy systems that support the UK's transition to an affordable, resilient, low-carbon energy future. We will synthesize previous work on land and feedstock availability to assess the realistic potential resource for UK bioenergy and examine new crops that could support UK farming by delivering ecosystem benefits as well as	£5,200,084	2018-2022	£1,300,021

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		biomass resource. We will test the performance of different feedstocks in high efficiency conversion options and develop new techniques which will improve resource efficiency in bioenergy systems, especially at small scale. We will evaluate the impact of using biomass for heat, electricity, transport fuels or chemicals to provide independent, authoritative information to guide decision making by industrialists and policy makers. We will assess the potential for bioenergy to contribute a proportion of the UK's future sustainable energy mix, taking into account the environmental, economic and social impacts of the processes. We will work with industrialists and policy makers to ensure that our work is relevant to their needs and reflects achievable implementation standards. We will share our findings in our research work widely with the industry and policy communities and make it accessible to societal stakeholders on our website, via special publications, in the conventional and on social media and with tailored events for public engagement.			
Techno-Economic framework for Resilient and Sustainable Electrification (TERSE), University of Manchester	EPSRC	Rural electrification is fundamental for the social and economic development and well-being of developing countries, as it supports the development of vital critical infrastructures (e.g. communication and transportation) and it provides energy to critical services to peoples' quality of everyday life, such as home appliances, health and water supply. The lack or limited and highly unreliable access to electricity still remains one of the key challenges that rural and remote communities face in these countries. In order though for the electrification to go beyond lightning, it is critical to develop energy networks that are sustainable, cost-effective, and	£1,024,786	2018-2021	£341,595

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		scalable, as well as resilient, particularly in areas that are frequently exposed to natural hazards, such as floods, monsoons, etc. In this context, the ambition of this project is to develop a novel holistic techno-economic framework for supporting and enabling the decision, policy and regulatory making towards the design of transformative energy networks in developing countries. This holistic framework will be supported by the development of an options portfolio for sustainable electrification, including a mixture of infrastructure solutions (e.g. building new or upgrading existing infrastructure) and emerging low-carbon distributed energy resources that will focus on the development of sustainable microgrids (both grid-connected and off-grid). Further, integrated system simulation models will be developed to analyse the vulnerability and quantify the risk and resilience profile of these energy solutions to natural hazards and extreme weather. This is highly timely given the latest evidence of the impact of such events worldwide and also highly critical if the rural communities are to withstand and quickly recover from such catastrophic events. Following these analyses, stochastic optimization planning techniques will be developed to support the optimal design of these energy networks, considering transformative energy technologies, to maximize the impact on the well-being of local communities. Building on this last point, the research team has developed a well-structured user-engagement strategy, bridging to wider socio-economic aspects of			

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		communities facing electrification challenges. The aims of this strategy are to get an in-depth understanding of the electricity needs of rural communities in the partner countries (China and Malaysia), enable their active role in the project and provide briefing and training sessions on the use of the new energy technologies to be applied in these communities. The UK and overseas research teams will jointly work with the local industrial partners to facilitate this active involvement of remote villages, communities and their local authorities. This project will aim to complement and further strengthen the current electrification plans of the partner countries, i.e. Malaysia and China. The research team will work closely with Sarawak Energy and other authorities in Malaysia to review and improve its Rural Power Supply Scheme that was formulated in 2015, as well as evaluate and improve the design, operability and maintenance planning of existing microgrids in Zhoushan islands, China, which also serve as excellent testbeds for validating the simulation models developed by the project. Within this context, this project will also aim to develop recommendations for changes and improvements in standards, regulatory and policy-making frameworks. We will aim to make the key findings and recommendations of this work of generic applicability and validity to accommodate its international development importance. This would also be of UK national importance, where building sustainable energy networks for reducing its carbon footprint, while being resilient to extreme weather (e.g., the storms of 1987, 2007 and 2015 which resulted in			

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		major power outages) is key for safeguarding the social and economic well-being of the country.			
Multi-scale Infrastructure Systems Analytics (MISTRAL), University of Oxford	EPSRC	National infrastructure provides essential services to a modern economy: energy, transport, digital communications, water supply, flood protection, and waste water / solid waste collection, treatment and disposal. The OECD estimates that globally US$53 trillion of infrastructure investment will be needed by 2030. The UK's National Infrastructure Plan set out over £460 billion of investment in the next decade, but is not yet known what effect that investment will have on the quality and reliability of national infrastructure services, the size of the economy, the resilience of society or its impacts upon the environment. Such a gap in knowledge exists because of the sheer complexity of infrastructure networks and their interactions with people and the environment. That means that there is too much guesswork, and too many untested assumptions in the planning, appraisal and design of infrastructure, from European energy networks to local drainage systems. Our vision is for infrastructure decisions to be guided by systems analysis. When this vision is realised, decision makers will have access to, and visualisation of, information that tells them how all infrastructure systems are performing. They will have models that help to pinpoint vulnerabilities and quantify the risks of failure. They will be able to perform 'what-if' analysis of proposed investments and explore the effects of future uncertainties, such as population growth, new technologies and climate change.	£5,374,638	2016-2020	£1,194,364

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		The UK Infrastructure Transitions Research Consortium (ITRC) is a consortium of seven UK universities, led by the University of Oxford, which has developed unique capability in infrastructure systems analysis, modelling and decision making. Thanks to an EPSRC Programme Grant (2011-2015) the ITRC has developed and demonstrated the world's first family of national infrastructure system models (NISMOD) for analysis and long-term planning of interdependent infrastructure systems. The research is already being used by utility companies, engineering consultants, the Institution of Civil Engineers and many parts of the UK government, to analyse risks and inform billions of pounds worth of better infrastructure decisions. Infrastructure UK is now using NISMOD to analyse the National Infrastructure Plan. The aim of MISTRAL is to develop and demonstrate a highly integrated analytics capability to inform strategic infrastructure decision making across scales, from local to global. MISTRAL will thereby radically extend infrastructure systems analysis capability: - Downscale: from ITRC's pioneering representation of national networks to the UK's 25.7 million households and 5.2 million businesses, representing the infrastructure services they demand and the multi-scale networks through which these services are delivered. - Upscale: from the national perspective to incorporate global interconnections via telecommunications, transport and energy networks.			

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		- Across-scale: to other national settings outside the UK, where infrastructure needs are greatest and where systems analysis represents a huge business opportunity for UK engineering firms. These research challenges urgently need to be tackled because infrastructure systems are interconnected across scales and prolific technological innovation is now occurring that will exploit, or may threaten, that interconnectedness. MISTRAL will push the frontiers of system research in order to quantify these opportunities and risks, providing the evidence needed to plan, invest in and design modern, sustainable and resilient infrastructure services. Five years ago, proposing theory, methodology and network models that stretched from the household to the globe, and from the UK to different national contexts would not have been credible. Now the opportunity for multi-scale modelling is coming into sight, and ITRC, perhaps uniquely, has the capacity and ambition to take on that challenge in the MISTRAL programme.			
Water Energy Food: Vaccinating the Nexus, University of Southampton	EPSRC	The demand for water, energy, and food (WEF) is increasing with a growing population and a larger proportion of people living high hydrocarbon dependent lifestyles. This is placing unprecedented pressure on global WEF resources, a situation that will be exacerbated with a shifting climate. To meet this demand and to ensure long-term WEF security there is a need for integrated, efficient, and sustainable resources management across the sectors. This is essential to enhance and maintain quality of life, and requires the overall system to adapt over appropriate timescales.	£1,581,410	2015-2019	£403,764

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		Analogous to the human immune system, resilience can be enhanced by learning from shocks to the WEF nexus that lead to recovery and adaptation through improving the systems long-term memory. Through shocks to the system (vaccination in this analogy), society is provided the opportunity to improve resilience and sustainable management of the WEF sectors. In this context, shocks are represented by: 1) historic events, 2) controlled experimental manipulation, and 3) defined inputs to models. This project will identify the interconnections between Water Energy and Food (WEF) through the development of an integrated framework and will reveal the vulnerabilities in the system and the diverse connections between the three facets of the nexus. The project consists of three work packages (WPs) that cover a diverse array of scenarios for both aquatic and terrestrial systems integrated with a social science and economic modelling. In WP1 the response of aquatic food organisms to the shock of delivering the water and energy infrastructure plan will be investigated, culminating in the development of planning decision support tools based on integrated hydrodynamic and agent based models. WP2 will take an experimental, field based, and modelling approach to investigate the response of agriculture (focusing on soils and crops) to flooding under alternative climate change scenarios and based on historic data. The social aspects of shifting agricultural regimes, e.g. greater use of bioenergy crops in areas liable to flooding, will be investigated and quantified. WP3 will provide the social and economic modelling that will gather and analyse data obtained from the case studies and provide feedback to improve the models. Further, WP3 will investigate potential			

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		barriers to dissemination and uptake of the results within institutions and by end users that may benefit with the view to develop approaches that ameliorate for this. This work package is also dedicated to ensuring delivery of impact which will be enabled through close collaboration with several non-academic partners including industry. Delivery of the project will be managed by a team with diverse interdisciplinary expertise (including engineers, ecologists, agriculturalists, mathematicians, and social scientists) from the Universities of Southampton, Bath, London, Nottingham, Aberystwyth University, Loughborough University, University College London, HR Wallingford, and supported by the Science and Technology Facilities Council. The team has a proven track record in project management, and strong links to industrial partners and other end users. The project will benefit industry, regulators, government, academia and the general public. The findings will be disseminated to: the academic community through publication of high impact research articles; the public through engagement via national and local media and internet and social networking platforms, and a structured Outreach programme involving schools and local science exhibitions; government through political outreach; and key stakeholders via relevant publications and participation in steering group workshops. The outputs will enable regulators to improve guidelines and to streamline the decision making processes for the benefit of industry and the nation as a whole.			
Analytical Middleware for Informed Distribution Networks	EPSRC	The programme of research that constitutes AMIDiNe will devise analytics that link point measurement to whole system to address the increasingly problematic	£703,091	2019-2021	£351,546

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
(AMIDiNe), University of Strathclyde		management of electrical load on distribution networks as the UK transitions to a low carbon energy system. Traditionally, distribution networks had no observability and power flowed from large generation plant to be consumed by customers in this 'last mile'. Now, and even more so in future, those customers are generators themselves and the large generators that once supplied them have been supplanted by intermittent renewables. This scenario has left the GB energy system in position where it is servicing smaller demands at a regional or national level but faces abrupt changes in the face of weather and group changes in load behaviour, therefore it needs to be more informed on the behaviour of distribution networks. The UK government's initiative to roll out Smart Meters across the UK by 2020 has the potential to illuminate the true nature of electricity demand at the distribution and below levels which could be used to inform network operation and planning. Increasing availability of Smart Meter data through the Data Communications Company has the potential to address this but only when placed within the context of analytical and physical models of the wider power system - unlike many recent 'Big Data' applications of machine learning, power systems applications encounter lower coverage of exemplars, feature well understood system relations but poorly understood behaviour in the face of uncertainty in established power system models. AMIDiNe sets out its analytics objectives in 3 interrelated areas, those of understanding how to incorporate analytics into existing network modelling strategies, how go from individual to group demand behavioural anticipation and the inverse problem: how			

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		to understand the constituent elements of demand aggregated to a common measurement point. Current research broadly involving Smart Metering focuses on speculative developments of future energy delivery networks and energy management strategies. Whether the objective is to provide customer analytics or automate domestic load control, the primary issue lies with understanding then acting on these data streams. Challenges that are presented by customer meter advance data include forecasting and prediction of consumption, classification or segmentation by customer behaviour group, disambiguating deferrable from non-deferrable loads and identifying changes in end use behaviour. Moving from a distribution network with enhanced visibility to augmenting an already 'smart' transmission system will need understanding of how lower resolution and possibly incomplete representations of the distribution network(s) can inform more efficient operation and planning for the transmission network in terms of control and generation capacity within the context of their existing models. Improving various distribution network functions such as distribution system state estimation, condition monitoring and service restoration is envisaged to utilise analytics to extrapolate from the current frequency of data, building on successful machine learning techniques already used in other domains. Strategic investment decisions for network infrastructure components can be made on the back of this improved information availability. These decisions could be deferred or brought forward in			

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		accordance with perceived threats to resilience posed by overloaded legacy plant in rural communities or in highly urbanised environments; similarly, operational challenges presented by renewable penetrations could be re-assessed according to their actual behaviour and its relation to network voltage and emergent protection configuration constraints.			
Energy Revolution Research Consortium (EnergyREV), University of Strathclyde	EPSRC	The Committee on Climate Change's most recent assessment of the UK's progress towards meeting its carbon budgets shows that UK emissions are 41% below 1990 levels. The UK Government's Industrial Strategy white paper states that this has been achieved while the economy has grown by two thirds. In our journey to meeting a reduction of at least 80% compared to 1990 levels, the Committee states that we must reduce emissions by at least 3% a year. They also say that despite the above progress we are not currently on track to meet the 2023-27 carbon budget. Clearly, significant further effort and innovation is required to meet our statutory obligations in this area. In line with this, the Government's Industrial Strategy identifies Clean Growth as a grand challenge stating "We will develop smart systems for cheap and clean energy across power, heating and transport ... We will launch a new Industrial Strategy 'Prospering from the energy revolution' programme to develop world-leading local smart energy systems that deliver cheaper and cleaner energy across power, heating and transport". The Industrial Strategy also points out that Innovation in clean growth is critical for low cost, low carbon infrastructure systems, and for realising the industrial opportunities needed to deliver economic benefits. In	£7,966,340	2018-2022	£2,389,902

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		response to this the Industrial Strategy Challenge Fund (ISCF) has launched the Prospering from the Energy Revolution (PFER) programme. It is focused on delivering (by 2022) investable and scalable local business models which use integrated approaches to deliver cleaner, cheaper, energy services for more prosperous and resilient communities. The resulting smart local energy systems should also benefit the national energy system as a whole. It also targets a ten times larger future-investment in local integrated energy systems versus business as usual in the 2020s while creating real world proving grounds to accelerate new products and services to full commercialisation. A major element of the activities is building UK leadership in integrated energy provision. To support the PFER programme, UKRI launched a call to establish the Energy Revolution Research Consortium (EnergyREV) to support this journey. A workshop was held in Birmingham to form and shape the consortium and to initiate the development of this project. The resulting EnergyREV consortium is diverse and highly multidisciplinary, incorporating 88% of the researchers who were selected for the workshop. EnergyREV will work with the Energy Systems Catapult to enable and inform demonstrators and demonstrator design projects (funded by the PFER programme) through their lifetime; undertaking analysis and evaluation, building and driving best practice and, leading knowledge exchange through national and international engagement with policy, academic and industrial communities. Further to this, EnergyREV has			

Funding Stream	Funding Agency	Description	Committed funds	Period	Representative Annual Spend
		shaped and defined a strategic programme of applied interdisciplinary research which aims to achieve significant outputs in the areas of whole energy systems and smart local energy systems. This will inform future energy investment by companies and Government. It will coordinate and integrate existing UK world-class knowledge, research teams and facilities, and through this provide advice, research and innovation support to help ensure the success of the PFER programme.			

4. Applied research
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Not applicable.

5. Development and Demonstration Funding
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Not applicable.

6. Research Facilities and Other Assets
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Not applicable.

7. Networks
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Not applicable.

8. UK Participation in EU Framework Programmes
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The European Energy Research Alliance (EERA) is a combination of public research institutions and universities in Europe that are pursuing low-carbon energy research. The EERA's Joint Programmes are clusters of partners that develop priorities for research areas in Europe, to shape the EU's research agenda and research priorities nationally. EERA hosts a Joint Programme on the Economic, Environmental and Social Impacts of Energy Policies and Technologies (JP e3s) that has been active since 2014. The JP e3s has focused on the complex interactions between socio-technical elements of low-carbon transitions including public acceptance, consumer behaviour, markets, and technologies. It is divided into five sub programmes:

- Public perception and engagement (coordinated by the Norwegian University of Science and Technology)
- Market design for energy transition (coordinated by SINTEF, Norway)
- Life Cycle Approach for evaluating the sustainability performance of energy technologies (coordinated by CIEMAT, Spain)
- Energy models for a system assessment of European low-carbon energy futures: markets, environmental and economic impacts (coordinated by ENEA, Italy)
- Sustainable low-carbon platform (coordinated by VTT, Finland)

The UKERC is a full participant of the EERA JP e3s and members of EERA also include several UK research organisations and universities.
European research funding to the UK has been awarded through the EU Framework Programmes. There have been several projects that develop interdisciplinary, multidisciplinary, and whole systems perspectives to energy with UK participants funded through the Framework Programmes. The table below lists some of these projects, focusing on those that have bridged between different academic disciplines (such as engineering and social sciences and humanities), integrated different types of knowledge about energy (such as computer models and governance), and engaged non-academic stakeholders (such as industries and policy makers) in the projects. The concept of interdisciplinary whole systems research is embedded in the UK's research policy and history and cannot be used entirely in the same manner across different European projects. Therefore, the list below is not meant to be exhaustive but to offer a selection of UK participation in major interdisciplinary research done from general socio-technical systems perspectives within the EU.

Table 8.1: EU Framework Programmes

Project	Objectives	Action Line	Type of Action	UK Participants	Coordinator and Partners	Total Funding	EU Funding	Duration	Annual spending
Energy Social sciences & Humanities Innovation Forum Targeting the SET-Plan (Energy-SHIFTS)	Energy-SHIFTS "Energy Social sciences & Humanities Innovation Forum Targeting the SET-Plan" will contribute to a European Energy Union that places societal needs centrally, by further developing Europe's leadership in using and applying energy-related Social Sciences and Humanities (energy-SSH). Our consortium brings together 4 leading interdisciplinary research institutes with 3 highly respected policy, industry and communications organisations from across the energy-SSH field,	H2020-EU.3.3. - SOCIETAL CHALLENGES - Secure, clean and efficient energy	Coordination and support action	Anglia Ruskin University	Anglia Ruskin University 6 participants	€1,014,560	€1,014,560	2019-2021	€507,280

Project	Objectives	Action Line	Type of Action	UK Participants	Coordinator and Partners	Total Funding	EU Funding	Duration	Annual spending
	to create an innovative and inclusive Forum. Our partners have significant energy-SSH H2020 project experience, direct working links with the EU's Strategic Energy Technology Plan (SET-Plan) communities, extensive networks in the energy domain, and represent excellent coverage across SSH disciplines and across Europe. These will enable us to maximise the impact of our Forum delivery within an intensive 2-year project. Energy-SHIFTS activities will target over 10,000 stakeholders and begin with scoping activities including: accessible guides to SSH in EU policy; workshops on SSH priority themes; online policy worker and researcher databases. We will build on this scoping work to implement: 4 Working Groups across SET-Plan themes; a Policy Fellowship scheme; an Early-Stage Researcher programme; masterclasses for policy, NGO, STEM, and media audiences; 4 online citizen debates; and a pan-European conference. Our consortium will bring their								

Project	Objectives	Action Line	Type of Action	UK Participants	Coordinator and Partners	Total Funding	EU Funding	Duration	Annual spending
	considerable expertise in research-policy dialogue to these activities. Our core activities will both provide immediate insights for the short-term directions of EU energy policy as well as foundations for longer-term mechanisms that will enable evidence-based energy-SSH insights to reach the 'policy front line'. As a central body bringing SSH communities together, we will work to directly inform future FP9 and SET-Plan priorities. Energy-SHIFTS will significantly enhance the policy impact of energy-SSH, and accelerate shifts to low-carbon energy systems.								
Social Sciences and Humanities for Advancing Policy in European Energy (SHAPE-ENERGY)	SHAPE-ENERGY "Social Sciences and Humanities for Advancing Policy in European Energy" will develop Europe's expertise in using and applying energy-SSH to accelerate the delivery of Europe's Energy Union Strategy. Our consortium brings together 7 leading academic partners and 6 highly respected policy, industry and communications practitioners from across the Energy, Social	H2020-EU.3.3.6. - Robust decision making and public engagement	Coordination and support action	Anglia Ruskin University	Anglia Ruskin University 12 participants	€1,996,573.75	€1,996,573.75	2017-2019	€998,287

Project	Objectives	Action Line	Type of Action	UK Participants	Coordinator and Partners	Total Funding	EU Funding	Duration	Annual spending
	Sciences and Humanities (energy-SSH) research field, to create an innovative and inclusive Platform. Our partners are involved in numerous European energy projects, have extensive, relevant networks in the energy domain, and represent exceptional coverage across SSH disciplines across Europe. These enable us to maximise the impact of our Platform delivery within an intensive 2-year project. SHAPE-ENERGY brings together those who 'demand' energy-SSH research and those who 'supply' that research to collaborate in 'shaping' Europe's energy future. A key deliverable will be a "2020-2030 research and innovation agenda" to underpin post-Horizon 2020 energy-focused work programmes. It will highlight how energy-SSH can be better embedded into energy policymaking, innovation and research in the next decade. Our SHAPE-ENERGY Platform activities will involve >12,114								

Project	Objectives	Action Line	Type of Action	UK Participants	Coordinator and Partners	Total Funding	EU Funding	Duration	Annual spending
	stakeholders and begin with scoping activities including: an academic workshop, call for evidence, interviews with business leaders and NGOs, online citizen debates and multi-level policy meetings. We will build on our scoping to then deliver: 18 multi-stakeholder workshops in cities across Europe, an Early Stage Researcher programme, Horizon 2020 sandpits, interdisciplinary think pieces, a research design challenge, and a pan-European conference. Our expert consortium will bring their considerable expertise to overcome difficulties in promoting interdisciplinary and cross-sector working, and reach out to new parts of Europe to create an inclusive, dynamic and open Platform. SHAPE-ENERGY will drive forward Europe's low carbon energy future.								
Guiding European Policy toward a low-carbon	The transition to a low carbon economy needs to achieve multiple aims: competitiveness, protection of the environment, creation of quality jobs, and social	H2020-EU.3.3.6. - Robust decision	Research and Innovation action	Anglia Ruskin University	Agencia Estatal Consejo Superior de Investigacione	€3,735,308.75	€3,735,308.75	2016-2019	€933,827.18

Project	Objectives	Action Line	Type of Action	UK Participants	Coordinator and Partners	Total Funding	EU Funding	Duration	Annual spending
economy. Modelling Energy system Development under Environmental And Socioeconomic constraints (MEDEAS)	welfare. Thus policy-makers and other key stakeholders require tools that need to focus beyond the energy sector by including these other domains of economy, society and the environment. Currently, most available tools lack integration of these important areas despite being tightly connected to the energy sector. Moreover, current energy modelling tools often lack documentation, transparency and have been developed for a specialized insider audience, which makes validation and comparison of results as well as independent review impossible. Our project aims to solve the current needs of integration and transparency by developing a leading-edge policy modelling tool based on WoLiM, TIMES and LEAP models and incorporating Input-Output Analysis, that allows for accounting of environmental, social and economic impacts. The modular design of the tool will take into account the necessary flexibility to deal with different levels and interests of	making and public engagement			s Científicas, Spain 11 participants				

Project	Objectives	Action Line	Type of Action	UK Participants	Coordinator and Partners	Total Funding	EU Funding	Duration	Annual spending
	stakeholders at great sectorial and spatial detail. Finally, transparency will be achieved through an open access freeware distribution of the model based on the open access programming language (Python), providing a detailed user manual, addressed to a wider non-specialist audience, and including free internet courses and learning materials.								
Social innovation Modelling Approaches to Realizing Transition to Energy Efficiency and Sustainability (SMARTEES)	Understanding citizen acceptance of the Energy Union, responsiveness to socioeconomic incentives for increased ownership, and prosumerism requires a multidisciplinary understanding of social systems and inclusiveness and robustness of policymaking depends on having empirically and theoretically grounded methodological tools to assess and adapt policy strategies. SMARTEES addresses this need by an iterative process: (1) integration of theories and methodologies of social innovation and agent-based socio-economic simulation in a	H2020-EU.3.3.6. - Robust decision making and public engagement	Research and Innovation action	The James Hutton Institute, Aberdeen City Council	Norwegian University of Science and Technology, Norway 10 participants	€3,988,038.25	€3,988,038.25	2018-2021	€1,329,346.08

Project	Objectives	Action Line	Type of Action	UK Participants	Coordinator and Partners	Total Funding	EU Funding	Duration	Annual spending
	comprehensive, flexible framework; (2) unprecedented data collection and integration in five trans-European case clusters in the domains of consumer-driven regenerative energy production, energy efficiency in buildings, low-carbon regional transport and consumer empowerment; (3) dynamic, multilevel agent-based models of successful innovation transfer; which ultimately lead to (4) a policy sandbox which allows a realistic prospective analysis of existing and future policy and market incentive scenarios. Each case cluster addresses a particular social innovation and consists of two reference cases and 4-5 followers. This enables SMARTEES to study the upscaling and replicability in different contexts. The policy sandbox is developed in a co-constructive process with users on the case level and in policymakers workshops on the European level. By doing this, SMARTEES contributes to robust and adaptive future policymaking,								

Project	Objectives	Action Line	Type of Action	UK Participants	Coordinator and Partners	Total Funding	EU Funding	Duration	Annual spending
	understanding of barriers and sources of resistance, the effects of the Energy Union on vulnerable consumer groups, genders and cultures. Furthermore, SMARTEES substantially drives advancement of social innovation and social simulation research by dynamic modelling of supply chains, companies, social groups, cities and neighbourhoods. In addition to making all modelling code and findings publically available, SMARTEES also ensures long term impact of the project by developing a commercialized version of the policy sandbox tool.								
European Network for Research, Good Practice and Innovation for Sustainable Energy (ENERGISE)	Considerable challenges remain today regarding Europe's transition towards a decarbonised energy system that meets the economic and social needs of its citizens. Rebound effects, that is, a full or partial cancelling-out of efficiency gains over time through increased overall energy use, highlight the centrality of consumption in multi-scalar decarbonisation efforts, urgently requiring attention from scientists and policy makers. Calls also	H2020-EU.3.3.6. - Robust decision making and public engagement	Research and Innovation action	Kingston University	National University of Ireland Galway 10 participants	€3,720,453.75	€3,720,453.75	2016-2019	€1,240,151.25

Project	Objectives	Action Line	Type of Action	UK Participants	Coordinator and Partners	Total Funding	EU Funding	Duration	Annual spending
	abound for innovative, research-led programmes to enhance the social acceptability of energy transition initiatives and technologies. Understanding how culture-specific views and practices and energy policy and governance both shape and reflect individual and collective energy choices is of paramount importance for the success of the Energy Union. ENERGISE responds directly to these challenges by engaging in frontier energy consumption scholarship. Recognising the persistence of diverse energy cultures, both within and between countries, ENERGISE offers an ambitious social science programme to enhance understanding of changes in energy consumption practices across 30 European countries. Moving beyond state-of-the-art research, ENERGISE theoretically frames and empirically investigates socio-economic, cultural, political and gender aspects of the energy transition.								

Project	Objectives	Action Line	Type of Action	UK Participants	Coordinator and Partners	Total Funding	EU Funding	Duration	Annual spending
	It also examines how routines and ruptures (re)shape household energy consumption practices. Adopting a cutting-edge Living Labs approach, designed specifically to facilitate cross-cultural comparisons, ENERGISE fuses tools for changing individual- and community-level energy consumption with a novel method for energy sustainability assessment. ENERGISE will open new research horizons and greatly enhance Europe's capacity for high-impact, gender-sensitive consumption research. It also offers timely support for public- and private-sector decision-makers who grapple with the design and implementation of measures to effectively reduce household energy consumption.								
Energy System Transition Through Stakeholder Activation, Education and Skills	ENTRUST provides mapping of Europe's energy system (key actors & their intersections, technologies, markets, policies, innovations) and an in-depth understanding of how human behaviour around energy is shaped by both technological systems and socio-demographic	H2020-EU.3.3.6. - Robust decision making and public	Research and Innovation action	Liverpool John Moores University, Integrated Environmental	University College Cork, Ireland 7 participants	€3,476,394.59	€3,476,394.59	2015-2018	€1,245,102.91

Project	Objectives	Action Line	Type of Action	UK Participants	Coordinator and Partners	Total Funding	EU Funding	Duration	Annual spending
Development (ENTRUST)	factors (esp. gender, age and socio-economic status). New understandings of energy-related practices and an intersectional approach to the socio-demographic factors in energy use will be deployed to enhance stakeholder engagement in Europe's energy transition. The role of gender will be illuminated by intersectional analyses of energy-related behaviour & attitudes towards energy technologies, which will assess how multiple identities and social positions, combine to shape practices. These analyses will be integrated within a transitions management framework which takes account of the complex meshing of human values and identities with technological systems. The third key paradigm informing the research is the concept of energy citizenship, with a key goal of ENTRUST being to enable individuals overcome barriers of gender, age and socio-economic status to become active	engagement		Solutions Ltd					

Project	Objectives	Action Line	Type of Action	UK Participants	Coordinator and Partners	Total Funding	EU Funding	Duration	Annual spending
	participants in their own energy transitions. Central to the project will be an in-depth engagement with 5 very different communities across the continent, who will be invited to be co-designers of their own energy transition. The consortium brings a diverse array of expertise to bear in assisting and reflexively monitoring these communities as they work to transform their energy behaviours, generating innovative transition pathways and business models capable of being replicated elsewhere in Europe. Deliverables will include a policy tool-kit incorporating contemporary best practice in promoting energy transitions at a Europe-wide level; a suite of innovative transition pathways and community engagement tools designed to stimulate dialogue and break down barriers to behaviour change and the adoption new technologies at a community level.								

Project	Objectives	Action Line	Type of Action	UK Participants	Coordinator and Partners	Total Funding	EU Funding	Duration	Annual spending
Enabling the Energy Union through understanding the drivers of individual and collective energy choices in Europe (ENABLE.EU)	The Energy Union Framework Strategy laid out on 25 February 2015 has embraced a citizens-oriented energy transition based on a low-carbon transformation of the energy system. The success of the energy transition pillar in the Energy Union will hinge upon the social acceptability of the necessary reforms and on the public engagement in conceptualizing, planning, and implementing low carbon energy transitions. The ENABLE.EU project will aim to define the key determinants of individual and collective energy choices in three key consumption areas - transportation, heating & cooling, and electricity – and in the shift to prosumption (users-led initiatives of decentralised energy production and trade). The project will also investigate the interrelations between individual and collective energy choices and their impact on regulatory, technological and investment decisions. The analysis will be based on national household and business surveys in 11 countries,	H2020-EU.3.3.6. - Robust decision making and public engagement	Research and Innovation action	London School of Economics and Political Science, Cambridge Econometrics Ltd	Istituto di Studi per l'Integrazione dei Sistemi, Italy 11 participants	€3,337,416.25	€3,337,416.25	2016-2019	€1,112,472.08

Project	Objectives	Action Line	Type of Action	UK Participants	Coordinator and Partners	Total Funding	EU Funding	Duration	Annual spending
	as well as research-area-based comparative case studies. ENABLE.EU aims to also strengthen the knowledge base for energy transition patterns by analysing existing public participation mechanisms, energy cultures, social mobilisation, scientists' engagement with citizens. Gender issues and concerns regarding energy vulnerability and affluence will be given particular attention. The project will also develop participatory-driven scenarios for the development of energy choices until 2050 by including the findings from the comparative sociological research in the E3ME model created by Cambridge Econometrics and used extensively by DG Energy. The findings from the modelling exercise will feed into the formulation of strategic and policy recommendations for overcoming the gaps in the social acceptability of the energy transition and the Energy Union plan. Results will be disseminated to relevant national and EU-level								

Project	Objectives	Action Line	Type of Action	UK Participants	Coordinator and Partners	Total Funding	EU Funding	Duration	Annual spending
	actors as well as to the general public.								
COP21: Results and Implications for Pathways and Policies for Low Emissions European Societies (COP21 RIPPLES)	The COP21 outcome represents an important new strategic context for EU climate policy. Analysing the implications of this new context requires an interdisciplinary approach, combining analysis of the evolution of the international climate regime as well as of NDCs and their socio-economic implications. Such analysis is also urgent, given the timelines imposed by the Paris Agreement for a "facilitative dialogue" in 2018 with a view to creating the conditions for the revision of NDC in 2020. In order to address the context described above, this project has four objectives : 1) Assess the adequacy of the NDCs submitted at COP21 in light of the global temperature target of limiting warming to 2°C/1.5°C. Through the analysis of GHG scenarios and energy system scenarios , the project will pay particular attention to the concrete system changes induced by NDCs, and compare them with	H2020-EU.3.5.1. - Fighting and adapting to climate change	Research and Innovation action	University College London, University of Cambridge, University of East Anglia, University of Oxford, Climate Strategies	Fondation Institut de Recherche pour le Développement Durable et les Relations Internationales, France 17 participants	€2,986,923.75	€2,986,923.75	2016-2019	€995,641

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	the changes required to meet the global temperature limit. The project will also analyse scenarios limiting warming to 1.5°C, and the impact of NDCs on other sectors, in particular land-use. 2) Assess the implications of NDCs and deeper mitigation pathways on other European socio-economic objectives. By integrating GHG and energy system scenarios into a range of different macro-economic, global energy system models and other quantified methodologies, the project will investigate implications for European socio-economic objectives related to innovation and technology deployment; trade and competiveness; investment, financial flows and economic growth ("green growth"); and global energy markets and energy security. 3. Assess the adequacy of the outcomes of COP21, and the implications and opportunities emerging from ongoing UNFCCC negotiations. The project will undertake a social sciences-based (in particular international law								

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	and international relations) assessment of the outcome of COP21. 4) Policy recommendations for EU climate policy and climate diplomacy.								
Energy Systems in Transition (ENSYSTRA)	To facilitate the necessary energy transition, there is an urgent need for highly trained professionals with the scientific knowledge and professional skills to analyse, understand and design relevant (new) energy systems and governance in different sectors and administration. The project Energy Systems in Transition (ENSYSTRA) aims to train 15 ESRs in this field. The objectives of ENSYSTRA are 1) to develop state-of-the-art science of energy systems transition, scenario analysis and energy modelling tools with emphasis on interdisciplinary model collaboration, 2) to provide ESRs with interdisciplinary, inter-sectoral and applied perspectives on the energy transition, 3) to provide new skills and competences for interdisciplinary analysis, 3) to establish collaboration between key	H2020-EU.1.3.1. - Fostering new skills by means of excellent initial training of researchers	European Training Networks	The University of Edinburgh, Community Energy Scotland Ltd, Offshore Renewable Energy Catapult Ltd, Scottish Government, Scottish Power Energy Networks Holdings Ltd	Rijksuniversiteit Groningen, Netherlands 5 participants 23 partners	€4,067,521.56	€4,067,521.56	2017-2021	€1,016,880

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	universities and their networks, 4) to create and increase linkages between different academic disciplines, applied research, industry and the public sector, 5) develop links and synergies between relevant scientific arenas, and 6) to contribute to accessible energy science based on open source work environments. By focussing on a prominent ‘‘living lab’’ of the energy transition, the North Sea region, the project will bring together a strong network and analytical capacity to understand energy system & scenario modeling; new energy technologies & infrastructures; actor behavior & interactions; and policy & market design, linking the regional to the international scale. Through a carefully designed training programme, ESRs are trained in both scientific and transferable skills with ample opportunity to collaborate between different projects and partners. The total effort will result in major progress in the field of energy system analysis								

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	and transition modelling. By the combined use and improvement of a range of modelling tools and methods, the project will deliver integral insights in energy transition pathways, policy implications and options for the North Sea region.								
Checking Assumptions aND promoting responsibility In smart Development projects (CANDID)	This project will study aspects of the 'smart' agenda in which practitioners from the Social and Human Sciences (SSH) offer unique and valuable insights of relevance to innovators and researchers in the ICT - LEIT areas. Centred on topics concerning of users, design, digital rights and critical infrastructures, CANDID will engage SSH and ICT - LEIT researchers in 'extended peer communications' aiming at Responsible Innovation. CANDID has three main objectives: 1) To facilitate a dialogue aiming at Responsible Research and Innovation between SSH researchers and researchers,	H2020-EU.2.1.1. - INDUSTRIAL LEADERSHIP - Leadership in enabling and industrial technologies - Information and Communication Technologies (ICT)	Research and Innovation action	The University of Edinburgh, University of Surrey 4 participants	Universitet i Bergen, Norway	€566,290	€566,290	2017	€566,290

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	engineers and innovators in the ICT – LEIT domains. This dialogue, intended as a multi-directional check on assumptions: on predominant ICT – LEIT imaginaries and innovation agendas; and on the presuppositions operative in SSH communities who interact in one way or another with ICT – LEIT communities, collaborate or work alongside them. The project is introducing a network of extended peer reviewers, from civil society, public initiatives, users and various forms of relevant knowledge and experience, to comment on and guide the process of checking (thereby providing a third perspective from which to check assumptions). 2) To describe and critically assess visions of 'smart', within the ICT – LEIT programmes in Horizon 2020, and in public								

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	discourse more generally, for thematic & discursive analyses. This is primarily an analytic task, to enable a deeper assessment of 'smart' in terms of tangible practices (see Objective 3). 3) To describe and produce, in the form of distinct Modules, insights on crucial topics on Science and Society intersections, as they play out within and in relation to visions of 'smart'. These Modules are: Module 1 – User and Design Configurations Module 2 – Risks, Rights and Engineering Module 3 – Sensing Infrastructures These Modules are intended to clarify and elaborate the complexity in 'smart' adaptation, and the inconclusiveness in								

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	design, engineering and user encounters.								
PROSumers for the Energy Union: mainstreaming active participation of citizens in the energy transition (PROSEU)	PROSEU aims to enable the mainstreaming of the prosumer phenomenon into the European Energy Union. Prosumers are active energy users who both consume and produce renewable energy (RE). The growth of prosumerism all over Europe challenges current energy market structures and institutions. PROSEU research will look into new business models, market regulations, infrastructural integration, technology scenarios and energy policies. PROSEU's interdisciplinary and transdisciplinary team will closely work together with RE Prosumer Initiatives (15 Living Labs), policymakers and other stakeholders from eight countries, following a quasi-experimental approach to learn how prosumer communities, start-ups and businesses are dealing with their own challenges, and to determine what incentive structures will enable the mainstreaming of RE Prosumerism, while safeguarding	H2020-EU.3.3.6. - Robust decision making and public engagement	Research and Innovation action	University of Leeds, ClientEarth	FCiências.ID - Associação para a Investigação e Desenvolvimento de Ciências, Portugal 10 participants	€3,124,073.75	€3,124,073.75	2018-2021	€1,041,357.92

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	citizen participation, inclusiveness and transparency. Moving beyond a case by case and fragmented body of research on prosumers, PROSEU will build an integrated knowledge framework for a socio-political, socioeconomic, business and financial, technological, socio-technical and sociocultural understanding of RE prosumerism and coalesce in a comprehensive identification and assessment of incentive structures to enable the process of mainstreaming RE prosumers in the context of the energy transition.								
New Clean Energy Communities in a Changing European Energy System (NEWCOMERS)	The European energy market is rapidly changing under the influence of three megatrends that currently drive the transformation of energy sectors worldwide: decarbonization, decentralization and digitalization. These megatrends have stimulated several technical and social innovations in the energy sector, which offer alternatives to the traditional business model of large centralized energy utilities and have the potential to further the goals of the Energy Union.	H2020-EU.3.3.6. - Robust decision making and public engagement	Research and Innovation action	University of Oxford	Stichting VU, Netherlands 7 participants	€2,984,668.75	€2,984,668.75	2019-2022	€994,889.58

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	One such example of social innovation in the energy sector are new forms of local energy communities that generate, store and use energy in a collaborative way and hence allow consumers to get involved in the production and storage of energy ("prosumage") at the local level. New clean energy communities in a changing European energy system (NEWCOMERS) are often democratic and participatory in nature and at the same time characterized by unconventional alliances of actors, the use of innovative and smart technologies and new forms of value creation for their members and society. The NEWCOMERS project aims to investigate which regulatory, institutional and social conditions, at the national and local level, are favorable for the emergence and operation of new clean energy communities. Furthermore, NEWCOMERS will explore how these new clean energy communities meet their members' (i.e. citizens' and consumers') needs better than more								

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	traditional energy services business models and whether they have the potential to increase the affordability of energy, their members' energy literacy and efficiency in the use of energy, as well as their members' and society's support for the clean energy transition. The ultimate goal of the NEWCOMERS project is to identify the types of clean energy communities that perform best along a variety of dimensions, such as resilience, citizen engagement, security, efficiency and affordability, while being based on sustainable business models that have the potential to be scaled-up.								
History of Nuclear Energy and Society (HoNESt)	HoNESt (History of Nuclear Energy and Society) involves an interdisciplinary team with many experienced researchers and 24 high profile research institutions. HoNESt's goal is to conduct a three-year interdisciplinary analysis of the experience of nuclear developments and its relationship to contemporary	H2020-Euratom-1.8. - Ensure availability and use of research infrastructures of pan_eur	Research and Innovation action	University of Central Lancashire, University of Leeds, University of York, The Board of Trustees	Universitat Pompeu Fabra, Spain 25 participants	€3,052,269	€3,052,269	2015-2019	€872,076.85

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	society with the aim of improving the understanding of the dynamics over the last 60 years. HoNESt's results will assist the current debate on future energy sources and the transition to affordable, secure, and clean energy production. Civil society's interaction with nuclear developments changes over time, and it is locally, nationally and transnationally specific. HoNESt will embrace the complexity of political, technological and economic challenges; safety; risk perception and communication, public engagement, media framing, social movements, etc. Research on these interactions has thus far been mostly fragmented. We will develop a pioneering integrated interdisciplinary approach, which is conceptually informed by Large Technological Systems (LTS) and Integrated Socio-technical System (IST), based on a close and innovative	opean relevance H2020-Euratom-1.2. - Contribute to the development of solutions for the management of ultimate nuclear waste H2020-Euratom-1.4. - Foster radiation protection H2020-Euratom-1.3. -		of the Science Museum, Rowe Eugene John – Gene Rowe Evaluations					

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	collaboration of historians and social scientists in this field. HoNESt will first collect extensive historical data from over 20 countries. These data will be jointly analyzed by historians and social scientists, through the lens of an innovative integrated approach, in order to improve our understanding of the mechanisms underlying decision making and associated citizen engagement with nuclear power. Through an innovative application of backcasting techniques, HoNESt will bring novel content to the debate on nuclear sustainable engagement futures. Looking backwards to the present, HoNESt will strategize and plan how these suitable engagement futures could be achieved. HoNESt will engage key stakeholders from industry, policy makers and civil society in a structured dialogue to insert the results into the public debate on nuclear energy.	Support the development and sustainability of nuclear competences at Union level H2020-Euratom-1.1. - Support safe operation of nuclear systems							

9. International Initiatives

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Not applicable.