Research Councils UK Energy Programme Strategy Fellowship

Summary of "light touch" workshop on

Wind, Wave and Tidal Energy

Working Document: Draft

October 2013

This is a report of a workshop held to support the development of the Research Councils UK Energy Research and Training Prospectus at Imperial College London on 25 September 2013

Dr Matthew Hannon
Prof Jim Skea
Centre for Environmental Policy
Imperial College London
14 Princes Gardens
London SW7 1NA

http://www3.imperial.ac.uk/rcukenergystrategy

Research Councils Energy Programme

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

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

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

Energy Strategy Fellowship

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

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

One of the main inputs to the Prospectus is a series of four high-level strategic workshops and six in-depth expert workshops which took place October 2012- July 2013. Three additional "light touch workshops", one of which is summarised here, were conducted between July and September 2013. Following peer-review, the first version of the Prospectus is being published in November 2013 and will then be reviewed and updated on an annual cycle during the lifetime of the Fellowship, which ends in 2017.

This document reports views expressed by individuals at the "light touch" workshop held in September 2013. Not all views expressed represent a consensus. Views expressed are noted by the Fellowship team but not all will necessarily be endorsed in the final version of the Energy Research and Training Prospectus.

Contents

List of Acronyms

CDT	Centre for Doctoral Training
CFD	Computational fluid dynamics
DECC	Department of Energy and Climate Change
EERA	European Energy Research Alliance
EMEC	European Marine Energy Centre
EPSRC	Engineering and Physical Sciences Research Council
ESRC	Economic and Social Research Council
ETI	Energy Technologies Institute
HVDC	High voltage direct current
IDCORE	Industrial Doctoral Centre for Offshore Renewable Energy
IET	Institution of Engineering and Technology
IP	Intellectual property
LCICG	Low Carbon Innovation Coordination Group
LWEC	Living With Environmental Change
MREKEP	Marine Renewable Energy Knowledge Exchange Programme
MW	Megawatt
NAREC	National Renewable Energy Centre
NAREL	National Analytical Radiation Environmental Laboratory
NERC	Natural Environment Research Council
O&M	Operation and maintenance
PV	photovoltaic
RCUK	Research Councils UK
R&D	Research and development
REF	Research Excellence Framework
RIIO	Revenue = Incentives + Innovation + Outputs
SMEs	Small To Medium Sized Enterprises
TRL	Technology Readiness Level
TSB	Technology Strategy Board
UKCMER	SuperGen UK Centre for Marine Energy Research
UKERC	UK Energy Research Centre
UKERC-EDC	UK Energy Research Centre Energy Data Centre
WWT	Wind, Wave and Tidal

1 Overview

This document summarises the outcomes of a workshop held on the 25th September 2013 in order to identify research and training needs relating to wind, wave and tidal (WWT) energy. The workshop was organised with input from Henry Jeffrey of the University of Edinburgh, Mel Austen of the Plymouth Marine Laboratory, and Bill Leithead and David Infield of Strathclyde University.

There were 20 participants at the workshop (excluding the Fellowship team), 14 of whom were academics and researchers falling within the communities supported by the Engineering and Physical Sciences Research Council (EPSRC) and the Natural Environment Research Council (NERC). The remaining participants came from Government, business and funding bodies (See Annex C).

This record of the meeting constitutes a working document intended to capture the outcomes of the workshop. It represents an intermediate step in the production of a full Energy Strategy Fellowship report, which will set out the prospectus for energy research and training needs relating to industrial energy. It has two purposes; a) to provide a resource which can be 'mined' in order to produce the prospectus document; and b) to provide an account of the workshop for archival purposes.

This document reports views expressed by individuals at the expert workshop held in September 2013. Not all views expressed represent a consensus. Views expressed are noted by the Fellowship team but not all will necessarily be endorsed in the final version of the Energy Research and Training Prospectus.

2 Introductory Session: The Energy Strategy Fellowship and the Workshop

2.1 Introduction

During the opening session the Strategy Fellowship team described the background to the workshop and introduced the day's activities. The presentation covered three topics: (1) the background to the Energy Strategy Fellowship; (2) the emerging conclusions from preceding "strategy" workshops; and (3) the conduct of the industrial energy workshop.

2.2 Background to the Fellowship

Jim Skea (Energy Strategy Fellow) made a presentation outlining the background and rationale for the RCUK Energy Strategy Fellowship and the activities being undertaken. He noted the role of the Prospectus in informing the future design of the RCUK's Energy Programme. The presentation covered the following points:

- The recommendations of the International Panel for the 2010 RCUK Review of Energy;
- The conclusions regarding the high quality of the science tempered by concerns about links to policy and follow-through to commercialisation;
- The vision for the Energy Research and Training Prospectus under development by the Fellowship Team;
- The programme of strategic and expert workshops and light-touch reviews being conducted; and
- The purpose of the expert workshops and the process which through the workshop outputs would be translated and synthesised for the prospectus document.

2.3 Emerging conclusions from strategy workshops

Aidan Rhodes summarised the outcomes of the preceding "strategy" workshops.

The first workshop, *Energy Strategies and Energy Research Needs,* had highlighted a gap between participants' *aspirations* for an ideal energy system in 2050 which met the UK's climate objectives and the system they *expected* to emerge. The deployment of technologies associated with the low-carbon agenda was anticipated to be lower than aspirations and the deployment of incumbent technologies correspondingly greater. The example of electricity generation technologies was presented, with unabated gas expected to play a larger role than would be desirable, while technologies such as offshore wind would play a lower role. Participants had also assessed the range of energy technologies in terms of their relevance to future UK energy, the UK's industrial capabilities relative to competitors and the UK's scientific capability. It had been believed that the UK had strong capabilities with respect to ocean energy (wave and tidal) in both the scientific and industrial spheres but that these technologies were only moderately relevant to UK energy futures. On the other hand, wind energy was seen to be highly relevant but industrial capabilities were seen to be moderate although scientific capabilities were high.

The second workshop, *The Role of Environmental Science, Social Science and Economics,* was less easy to summarise but participants had believed that the UK academic incentive system did not encourage interdisciplinary working. There was also a belief that energy research was currently focused too much on "kit" and did not pay enough attention to human behaviour.

The third strategy workshop, *The Research Councils and the Energy Innovation Landscape,* had used two case studies, *marine renewables* and *molecular PV,* to exemplify respectively "use-inspired" and "science-inspired" research areas. Participants noted the needs for: stronger mechanisms for feeding back findings from later stages in the innovation process to basic research projects; adaptable and flexible testing facilities; ensuring spin-out companies can understand and access their potential markets; and clear policy signals and market regulations. A particular observation was that, in the mid-2000s, EPSRC had moved towards applied research and development in the absence of the subsequent support that came from bodies such as the Energy Technologies Institute (ETI) and the Technology Strategy Board (TSB). EPSRC had later moved back towards the more basic end of the innovation chain. Aidan Rhodes suggested that the scope of Research Council activities should be considered during the day's activities.

2.4 Conduct of the workshop

Matthew Hannon introduced the plan for the day's activities. The purpose was to: listen to the opinions of participants; identify ideas for the research prospectus; and highlight priorities for future research. Broadly, the morning's activities would identify "hotspots" for future research, while in the afternoon the participants would do a "deep dive" to identify more specific research challenges associated with the hotspots as well as what needed to be in place for these challenges to be met.

3 The Research Landscape: where are we now

Working individually, people were asked to identify how well placed the UK currently is in terms of research capabilities in wind, wave and tidal energy so that we can meet the challenges of the future. They were invited to score these on a scale of 0-10 (0 = no chance, 10 = well set up) and explain their score on a post-it note. Figure 1 shows the distribution of the 40 post-it comments, which are detailed in Table 1, which have been grouped by wind specific (yellow), marine specific (blue) or a combination (green) given their characteristic differences.

Participants' scores were remarkably close to a normal distribution with an average score of 6.0 and a standard deviation of 2.5. This represents among the highest ratings given in in any of the workshops run in this series. Key themes emerging that emerged from the review included (1) a strong research community in terms of technology, environmental resource/impacts and socio-economic aspects; (2)

good investments in testing facilities; major challenges in terms of cost reduction; (3) the need for greater integration/co-operation between groups; (4) the need for better joining up between basic research and applied R&D; (5) a related concern that ESPRC work might become disconnected from more commercial activity; and (6) a perception of lower levels of support at the higher TRLs.

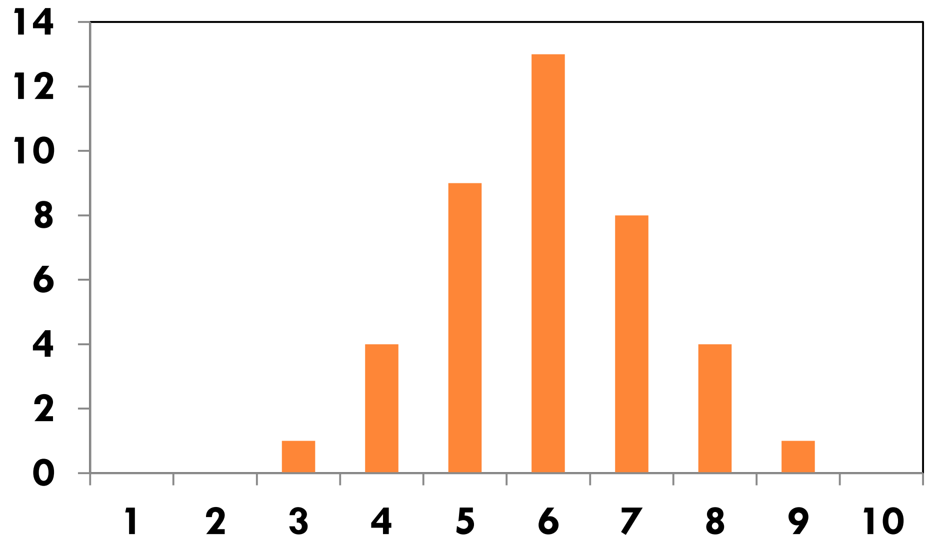

Figure 1: Distribution of perceived UK research capabilities in wind, wave and tidal energy

Table 1: UK's perceived capability levels to address existing energy research challenges

High capability levels		
8		**9**
For all technologies there is a high research capability in terms of environmental resource and impacts but this is highly limited by the scope of current funding and by the availability of relevant data. The attitudes of industry to data collection and access are also a barrier.		World-leading people and infrastructure for ***wave and tidal***.
Economics, policy and modelling (mostly relating to ***wind***) are good.		
For onshore ***wind***, we need better power conversion/conditioning and local storage. There is a lot of work carried out internationally.		
For ***wind*** in general, there is a strong technical base coupled with clear cost reduction challenges. However, making best use of expertise and facilities may require change.		
Medium capability levels		
5	**6**	**7**
For ***wind, wave and tidal***. Social science research capability, but limited by scope of funding applied to marine renewables, the number of interested academics and the need for 1st degree [raw] data.	R&D facilities are in place to meet future needs for testing devices for commercial action. There's a need for the wave, tidal and OSW industry to move towards cost-reduction. From an industry perspective, this is a priority going forwards	The research base and expertise are strong. Test facilities are available though there are challenges to their development and use (NAREC, Aberdeen, Hunterston, WAVEHub). More is needed.
For ***wind/tidal***, there is a danger that as EPSRC push back down the 'TRL' levels the projects they support could become irrelevant to industry. There needs to be more balance. A joint EPSRC/TSB call could address this issue	For ***offshore wind and tidal***, good basic work is taking place. O&M is the big problem in the context of weather conditions	Very strong engineering community. Links to strong work in other relevant sectors could be improved.
For ***wind***, there is limited, high quality capacity in some areas. This is below critical mass given the projected size of the industry by 2050.	For ***wind***, we have the policy; the research capability; and industry is looking to the UK to take the lead on offshore	For ***offshore wind***, ***wave and tidal***, early stage research benefits from more support (public funding) than do the later stages of the innovation chain.
For ***wind***, technical innovation and cost reduction.	***Wind*** is under resourced. We have world leading experts but not in all areas. Still playing catch up to some extent.	Positive features are the EPSRC hubs in marine and wind and the CDT in wind/marine. The negatives are that funding is technically focussed and there is a lack of social science activity.
For ***wind***, what is done is of a high quality internationally but is at a small scale compared to Europe and given the large number of challenges facing the sector. Progress is hampered by not having access to a test turbine. The research community, although growing, needs to be bigger.	Limited funding for ***wind*** and too few universities involved. Lack full scale testing facilities.	
For ***wind***, the capability of academic staff is modest. There needs to be more focus on technology relative to resource and integration focussed. Access to test facilities and data is limited.	For ***wind***, the challenge is to change from 'niche' player-on-shore to main market actor.	
For ***wind***, low critical mass given the projected size of the industry in 2050. Limited, high quality capacity in some areas.	For ***wind***, the strengths are electric control and offshore structures. The weaknesses are O&M, condition monitoring and continued access to full scale testing.	

Table 1 continued

Medium capability levels		
5	**6**	**7**
For ***wave***, the challenge is to move from proof of concept to large commercial players. The Research Councils being part of the LCICG means it can be better coordinated with the later TRLs.	For ***tidal***, pockets of excellence in some areas. Collaboration with industry improving but still hindered by IP issues. Improvements needed on cabling and connections.	For ***tidal***, academic capacity is very concentrated. There are problems with the demographics of the community. Good/improving test facilities. Limited data access. Generic research is favoured over specifics. There is too much environmental over-engineering.
For ***wave***, need more interdisciplinary understanding of interaction of tidal forces within the wave resource. There is expertise in each, but needs joining together.	For ***wave***, academic capacity is concentrated. Good and improving test facilities, but limited access to data. There is limited expertise at the array scale and there is more 'generic' research than specific. The demographics of the research community are a problem.	For ***tidal stream***, there are too few universities involved. Good test facilities.
For ***wave and tidal***, too much focus on the low TRLs. Need more collaboration with TSB etc. to ensure research does not become irrelevant to the emerging sector	For ***wave and tidal***, the strength is in modelling, and the scale of test facilities. The weaknesses are reliability, O&M, land management and materials.	For ***wave***, there are too few universities involved. Good test facilities.
	For ***wave and tidal***, We have the policy and we have the industry which the UK started.	***Wave and tidal*** are still at an early stage of development. Have good test facilities but the scale of research activity needs to be increased. The work being done is internationally leading.
	For ***tidal***, some key expertise is available but there are not yet the incentives in place to apply it to tidal systems. Facilities are being developed but there is a lack of interaction between key international groups.	
	For ***tidal***, theory is good, testing is average, drivetrain is poor.	

Low capability levels	
3.5	**4**
For ***wave***, key expertise is available but systems not yet considered at an industrial scale. Most potential research expertise is applied in other sectors.	For ***tidal***, the challenge is to move from proof of concept to commercial players
	On ***tidal barrage***, just need to get on with it! ***Tidal stream***, more basic research is needed on longevity
	For ***wave***, there is too much concentration on generic issues and too much duplication. Needs improved coordination and the filling of funding gaps.
	For ***wave***, the challenge is to upscale. The technology is less well developed than wind.

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

4.1 Introduction to the Exercise

This exercise was designed to identify a range of topics that participants believed should be the subject of future UK research in the wind, wave and tidal area.

4.2 Methodology

Overview

In order to identify future energy research opportunities, the participants were first invited to identify 'research hotspots', defined as:

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

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

How Were the Research Hotspots Generated?

During the first part of the process participants worked individually to generate initial ideas about potential hotspots. During the second part, participants formed pairs to discuss and record the hotspots on post-it-notes.

Once the pairs had discussed and recorded the hotspots they were asked to place these on a wall chart as shown in Figure 2. The purpose of the x-y axes was to act as a guide for participants to place their post-its with a view to clustering related hotspots. During this process, one additional column and one additional row were added at the suggestion of participants. The additional column covered hotspots that might be applicable across the entire innovation chain. The additional row covered cross-cutting hotspots that might be relevant to all technologies. Figure 3 contains a set of photographs showing the initial distribution of hotspots on the conceptual framework grid.

Onshore wind					
Offshore wind					
Tidal barrage					
Tidal stream					
Wave energy					
Ocean current power					
Ocean thermal power					
Cross-cutting					
	Research	Applied Research and Development	Demonstration	Pre-commercial Deployment	Across the innovation chain

Figure 2: Conceptual Framework for Research Challenges

Figure 3: Initial positioning of hotspots

Clustering Hot Spots

Working together as a group, participants reviewed the wall chart and brought together related hotspots into clusters. Individual members of the group first proposed clusters. With the consent of the group, hotspot post-its were then transferred to a separate wall-chart and grouped together.

After the first pass, participants then reviewed the proposed clusters. Using a system of green, red and yellow cards, participants could confirm their support for the clusters, veto them or provoke further discussion. This process led to some debate as to whether some clusters should be amalgamated or, alternatively sub-divided into further clusters. It was agreed that some hotspots (especially those relating to sensors) should be duplicated and placed in more than one cluster. The final arrangement had the consent of the entire group.

4.3 Results

The workshop participants identified the following clusters:

1. Design
2. Foundations and support structures
3. Asset management
4. Reliability
5. Understanding of wind and marine resources
6. Grid integration
7. Environment
8. Sensing
9. Economic, social and governance

The clustering exercise triggered debate around the following issues:

- *Design* should cover both devices and arrays.
- It was agreed that *Foundations and Support Structures* should be combined and that the coverage went beyond civil engineering.
- *Reliability* should cover both performance and survivability.
- Should condition monitoring be separated from the *Reliability* cluster? It was agreed that it should and be broadened to cover *Asset Management* which would also include installation and operation
- *Grid integration* should include storage. This should also cover the scheduling of conventional plant which was also an economic issue.
- There was a lengthy debate as to whether those hotspots relating to *Sensing* should be placed in different clusters depending on whether they related to *Asset Management*, *Reliability* or *Environmental Issues*. The final agreement was to duplicate these hotspots and cover them in specific discussions on sensors as well as in other clusters.
- The term *Governance* was added to the *Economic and Social* cluster.
- Although economists and social scientists were not well represented at the workshop, these perspectives were essential.

Table 2 shows the final agreed set of clusters along with the hotspots included in each. In addition, participants identified at this stage a number of cross-cutting issues that fell outside the working definition of hotspots. These are listed in Table 3. Key themes include the need for a focus on cost reduction, Cross-Council/interdisciplinary working and the potential for learning from other sectors.

Table 2: Research clusters and associated hotspots

Cluster Name(s)	Hotspots
Design	– Materials use and efficiency – life cycle cost, yield and environmental aspects (all technologies) – Whole system design methods, space to think – Test and demonstration sites for components and whole systems – Protocols and benchmarks for tank/wind tunnel CFD – Control and instrumentation – Array control strategies, energy faults – Anonymous data sharing from test facilities – Whole system array design and operation, e.g. wake effects, integrated control, multi-constraint planning tools, power output forecasting (all technologies) – Larger offshore wind turbines (>6MW) – Floating wind – Wind rotor design – Underlying technologies for very large wind turbines – Novel wind turbines (including floating) – Low speed turbine design for tidal ocean current – Low head and variable head turbines for tidal barrage – Novel power take -off for wave and tidal
Foundations and support structures	– Foundations and support structures – Floating foundations for water depth greater than 50m – Larger offshore wind turbines (>6 MW) – Cost effective foundations for tidal – Cost effective moorings for wave and tidal – Deep water moorings and foundations for wave and tidal
Asset management	– Understanding of weather windows, condition monitoring and optimisation of support infrastructure to manage O&M costs – Condition monitoring/asset management – Installation – Use facilities to share device-level data anonymously while protecting IP – Data for model validation – Use test facilities for data collection to facilitate cross-industry collaboration – Operation and maintenance logistics – Cost reduction through increased availability using intelligent condition monitoring and more advanced design for operating environment – Optimal operation and control of large offshore windfarms to manage O&M – Automated integrated sensing and monitoring for tidal – Control systems and instrumentation for wave – Installation and recovery modelling research for wave and tidal

Table 2 (continued)

Cluster Name(s)	Hotspots
Reliability	– Design – Improved mechanical load prediction – Improved performance and light-weighting of materials – System level risk and reliability assessment bridging component and system scales – Material for increased reliability – Energy storage to facilitate control – Simplified control systems as basis for new concepts – Development and validation of models to reduce dependence on field trials for components/systems and for cumulative changes to flows – Collect and share reliability data – Wave/current interactions – Reliability modelling for wave and tide – Explain unreliability of wave and tide and the economic implication
Understanding wind and marine resources	– Resource characterisation including improved sensors – Data for model validation – Offshore wind resource and atmospheric conditions – Turbulence modelling for tidal – Understanding of wave current turbulence and tidal arrays – Array modelling for wave and tide – Better understanding of wave and tide resource to enhance survivability and device efficiency
Grid integration	– Electrical connection of arrays and transmission to load centres – Multi-terminal HVDC technology – Smart marine grids – control, storage, device and fluid interaction (feedbacks) – Provision of power system support services: grid scale storage; demand side management; smart generators and interfaces; transmission system integration; on-device storage – Local grid system development (UK infrastructure not enough) – Integration of storage, cables, interconnection, HVDC – Offshore networks – Offshore connection to shore for distances > 100 km – Grid scale energy storage for offshore renewables – Energy storage – Markets/prediction/methods/rules for scheduling conventional plant alongside renewables – System performance modelling for wave and tidal
Environment	– Novel sensors – birds, marine mammals – Acoustic noise from wave and tidal machines – installation and operation – Technology for rapid assessment of impacts on ecosystem components – Impacts of single and cumulative developments on sea mammals and birds through whole life cycle of marine renewable developments and whole supply chains – empirical and modelling – Cumulative impacts of marine renewables on ecosystem structure, functioning and services at appropriate spatial and temporal scales including whole life cycle and supply chain – empirical and modelling – Linking of impacts on sea mammals and birds to wider ecosystem models for holistic ecosystem understanding – Interaction of marine renewable impacts (economic, social, environmental) with the impacts of other marine sectors, e.g. fisheries, transport, recreation – Water quality aspects [of wind farm development?] – Integrated environmental modelling for tidal energy

Table 2 (continued)

Sensing	– Better sensors for gathering marine data – Novel sensors – birds, marine mammals – Noise from wave and tidal machines – Integrated/automatic sensing and monitoring systems for tidal stream – Technology for rapid monitoring of impacts on ecosystem components (noise, disturbance etc.) – Develop facilities that would enable anonymous sharing of data – Use test centres for data collection and to facilitate collaboration across the industry – Collect and share data for model validation in all fields
Economic, social and governance	– Public perceptions and acceptance of renewables etc. – Public acceptability of marine renewables – Consumer impact of renewables (research, deployment, testing etc.) – Multi-constraint array planning tools – How best to engage with the general public – approaches to aligning public attitudes with need – Wind demonstration – Is the policy landscape supporting demonstration/ piloting/cost reduction at scale – Whole life-cycle assessment of social, economic and ecosystem costs and benefits at local and national scales – Communicating system knowledge (environmental, social, economic, engineering) to enable practical use by policymakers, regulators and developer – Evaluation of support policies

Table 3: Cross-cutting issues identified during the identification of hotspots

Priority is research that will help reduce the cost of energy (especially offshore wind)
Cost reduction!
For wind – do everything better
Reduce dependence on TRLs - focus discussion on state of 'product development'
Allocate projects
Research needed on whole systems implications
Cross-Council funding – environmental, social, economic, engineering, technological
Key areas of learning and best practice from other industries to offshore wind, wave and tide
Pockets of excellence in some areas
Collaboration with industry improving but still hindered by IP
Improvements needed on cabling and connectors

5 Identifying research challenges

5.1 Introduction to the Exercise

In this exercise, participants were asked to identify key research questions relating to the research clusters and super-clusters that had been identified in the morning session, as well as any potential challenges that might be encountered in undertaking this research and what might needed to be done in order to address these challenges.

5.2 Methodology

Participants formed three similar interest groups and each group selected whichever research clusters/super clusters they wanted to examine in greater detail. These are outlined in Table 4.

Table 4: Community groups and their selected clusters for Deep-Dive session

Group	Selected Clusters/Super-Clusters Description
A	Devices
	Foundations and support structures
B	Understanding of Wind & Marine Resources
	Grid Integration
C	Asset Management
	Reliability
D	Economic, social and governance
	Sensing
	Environment

To assist the deep-dive process, each team was provided with an activity sheet with a set of questions and suggestions as how each question could be approached. The questions were as follows:

1. *What are the main research challenges we need to address?*

2. In order to address these challenges, what do we need in place? Consider for example:
   - *What capabilities / capacities do we need in place?*
   - *Do our current ways of working need to change? If so, how and why?*
   - *Whose job should it be/who is best placed to do/fund this research?*
   - *What needs to happen in terms of coordination and alignment to maximise success?*
   - *What do we need to have in place to ensure we are ready to address these research challenges? (e.g. PhD training, data collection/curation, research Infrastructure, funding philosophy etc.)*

5.3 Results

Group A

'Devices'; and 'Foundations and support structures'

What are the main research challenges we need to address?

- **Developing validated, integrated design tools for reaction sub-systems (e.g. foundations and support structures) that account for dynamic loads.**
- **Modelling resources, both pre- and post-energy extraction,** to help inform the design of WWT technologies and arrays.
- Development of novel power take offs, drive trains and structural materials to allow **step-change innovations** to emerge at both the system (i.e. device-level) and sub-system (i.e. device component level (e.g. generator; gear box etc.) level.
- **Whole system array design and operation.**

Whose job should it be/who is best placed to do/fund this research?; What needs to happen in terms of coordination and alignment to maximise success?

- Need to **work more closely with European partners via collaborative networks** (e.g. EERA networks) to ensure that research is not being duplicated and to share complementary resources to provide 'added value' research. Additional incentives/resources should be made available to researchers nation-wide to engage at the European level. For example, funding to travel to European Energy Research Alliance meetings.

- Need to **incentivise industry to collaborate with universities** in this research area, particularly as industrial collaboration encourages industry to take ownership of new innovations and help to translate such 'blue sky ideas' into viable commercial propositions. Joint calls between Research Councils and other R&D support bodies (e.g. Catapult Centres, TSB, ETI) could help to formally link the academic and industry domains, as well as providing organisations from both sectors with a financial incentive to undertake research in this area. For example, NERC-TSB did this for a wind, wave and tidal research call.
    - Highlighted that the more 'cost sensitive' research challenges (i.e. a-c) would benefit most from industrial collaboration. In particular, industrial collaboration on sub-systems (i.e. device components) is particularly important given their design and performance expertise in this field. Cost focused, professional engineers are likely to play a key role.

What capabilities / capacities do we need in place?; Do our current ways of working need to change? If so, how and why?; What do we need to have in place to ensure we are ready to address these research challenges? (e.g. PhD training, data collection/curation, research Infrastructure, funding philosophy etc.)

- **Access to existing data** (e.g. flow loads, performance) from test sites, operating farms etc., as well as the **collection and dissemination of new data**, particularly from potential deployment sites. Some type of campaign might help top achieve these goals.
- Current sensors aren't sufficient to collect the higher quality data that is required and so the **development of new sensors is essential.**
- **Experienced researchers are essential**, which should be trained primarily via EngD and PhD degrees, as well as 'on-the-job' Research Assistant position. Post-graduate degrees could utilise industrial support, as has been the case in the wind sector.
- **Access to test facilities**, specifically test-beds and test-tanks (e.g. wave tanks; wind tunnels etc.) for the development of systems and sub-systems (e.g. test turbines to test novel drive-trains, materials, structures etc.
- Access to **high-performance computational facilities** for resource modelling, integrated design etc.

Group B

'Understanding of Wind & Marine Resources'

What are the main research challenges we need to address?

- At present we really only have a macro-level understanding of the WWT energy resources. We understand much less about the **conditions that impact the performance of individual devices**, i.e. what it experiences.
    - Macro level – what is the amount of resource available (subject to constraints)?
        - This will require in situ and remote sensing of conditions to gauge turbulence and wider fluid dynamics.
    - Meso level - Modelling array-array and device-device interaction.
    - Micro level – Modelling resource-device interaction, e.g. turbulence modelling.
- Broadly, **how will climate change influence WWT energy resources?** For example, the distribution of wind resource across the UK in 30 years' time.
- In relation to tidal energy, what is **the influence of different meteorological changes on tides** and how do these impact upon device/array performance?

- **Portfolio management of different resources** (e.g. wind, wave, tidal etc.) and associated challenges. For instance, how do these different resources interact with and affect one another?

What capabilities / capacities do we need in place?

- In **situ and remote sensing of conditions to generate high quality, widely available temporal, spatial & statistical resource data**. Resource modelling is then required to make sense of this data.
- **Improved capabilities in computational fluid dynamics and better integration with Metocean modelling capability.**
- **Better geoscience/engineering working.**
- Need **cross-disciplinary PhD training** e.g. CDTs. PhDs training at a national level was considered a strength, however the CDT model was questioned as the most suitable model. For instance, a critical mass of research is required to support a CDT and few universities are large enough to support one independently, thus giving rise to university CDT partnerships.

'Grid Integration'

What are the main research challenges we need to address?

- Up to now generation (e.g. Fossil Fuels) has acted as the network balancing tool, but that won't be the case with the proliferation of renewable energy technologies such as WWT. Key grid infrastructure challenges for WWT energy include:
    - **Resource characterisation of WWT energy** to understand potential inputs into system and where the grid will need to link to.
    - The practical challenge of **linking up WWT plants to the grid**, particularly offshore WWT.
    - **Manage intermittency of WWT energy to maintain electricity network balancing.** This will require a combination of demand side management, network planning and grid reinforcement.
- Exploring opportunities to use offshore connections not only as a link to domestic grid but also as **international electricity interconnectors**, for example with Europe.
- Examining **the role of storage in facilitating WWT energy** generation, distribution and supply in the context of the UK electricity networks.
- Identifying **key ancillary services for WWT energy and how these might be provided**. Ensure these are in synergy with the availability of weather windows that will allow for system intervention.
- Exploring suitable **market conditions to facilitate WWT grid connections; grid balancing; provision of ancillary services** etc.
- Identifying the **network topology (i.e. arrangement of network components) of onshore and offshore WWT network connections.**
- WWT energy grid integration raises some technical research challenges:
    - Improving the **power output of cables**, i.e. how much electricity can be squeezed down the wire?
    - **Improvements in DC circuit breakers.**
    - **Siting transformers offshore**, in extreme conditions.

What capabilities / capacities do we need in place?

- UK considered to have some very strong, world-leading R&D communities but that efforts need to be taken to **ensure that this strength is maintained and better integrated.**

- Interdiscplinarity is key - There are several research communities that could make a valuable contribution to WWT energy grid integration (e.g. engineering, geography, meteorology etc.) but at represent these do not interact sufficiently. **Greater communication and collaboration between the Research Councils** could help address this issue.
- Need to **guard against Research Councils over-managing the research agenda** because this may stifle the emergence of more innovative, leading-edge research challenges.
- Some funding mechanisms are too complex (e.g. Ofgem's RIIO) meaning that researchers are unsure how to engage with and secure funds from them. **Funding mechanisms should be set out and communicated appropriately.**
- **Research council funding too focussed to applied research**, which isn't a university's primary focus. For instance, difficult to understand where to source funding for grid integration modelling.

'Understanding of Wind & Marine Resources'; and 'Grid Integration'

The group approached the two research clusters as one when considering the following questions:

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

- **Industry needs to fund research/R&D** but in a way that is feasible for universities to engage with, particularly as universities have capabilities in terms of applied R&D that industry doesn't. Collaboration can be mutually beneficial but both industry and academia must explore what the other can offer in terms of skills, experience and expertise.
    - Schemes like Ofgem's Low Carbon Networks Fund (LCNF) could present an appropriate funding mechanism.
    - Difficult to quantify, particularly in terms of financial gain, what industry gains from this type of collaboration.
- Industry could play an important role in research but **doesn't typically have the right people (e.g. of an academic disposition) or the necessary time to tackle big questions.**
    - The Bell Labs model could address the former which focused on amassing huge intellectual resources.
    - The Google model could address the latter by providing staff with one day a week to tackle relevant challenges of their choice could work.
- Concern that **responsive mode funding rewards people that are good at writing research grants, rather than people who are good at doing research.** Particularly as the research money is paid on the strength of the proposal (as it is paid upfront), rather than the quality of the subsequent research. This might be addressed by research project quality assessment during and after the grant, which could have funding implications. Therefore, academics' track record used to assess proposals would not only contain a list of grants won but also the quality of the outputs of the research that these grants funded.
    - Beware of the 'Tom Cruise' effect: i.e. once you become famous, people assume you're good and give you more work. This is analogous with research funding. A 'self-fulfilling prophecy'.
    - Peer-review does to some extent hold researchers accountable for the quality of their research.
    - It was felt that the energy research communities could be better represented in responsive-mode calls.

What needs to happen in terms of coordination and alignment to maximise success?

- **Less funding given aside to support coordination and alignment** and more giving money to support good quality research
- **Supergens/Hubs could do with refining to facilitate international engagement**. For instance, current structure makes it difficult to network with international colleagues (e.g. Chinese and Indian colleagues). It is often very difficult to know how good the proposals are from these other countries.

Do our current ways of working need to change? If so, how and why?; What do we need to have in place to ensure we are ready to address these research challenges? (e.g. PhD training, data collection/curation, research Infrastructure, funding philosophy etc.)

- ESRC is accessible and searchable to anyone. This same model should be followed for WWT energy data so that researchers can access it, via a **central repository for data**. However, there are IP issues if data is shared between universities, even if projects have been funded by the same body (e.g. EPSRC).
- **Cross-disciplinary, regional summer school programs,** such as the UKERC summer school
- **Best practice** in terms of research should be shared across the community.
- Encouraging **more women into engineering** is a problem, possibly by changing the culture of research institutions.
- **National collaborative projects on major research challenges** can provide large scale, WWT energy resource data but this must then be disseminated/shared widely, in a similar vein to the Human Genome Project.

Group C

'Asset Management'

What are the main research challenges we need to address?

- **Data communications:** How can you get data of good enough quality from offshore sites (wind/marine) in enough time to manage them properly?
- **Signal processing and automatic data interpretation:** Currently need condition monitoring engineers to monitor the data to assess condition of assets. Need automated interpretation to lower costs and the necessary systems integration of this.
- **Operation and maintenance strategies:** Specifically micro-asset management (i.e. individual asset) and macro-asset management (i.e. whole windfarms). Micro is like looking at health of an individual, macro is ensuring the population survives. Specific questions include:
    - Can you analyse one machine as a benchmark, or derive weak performance through models or cluster models of groups of turbines?
    - Can we anticipate failures for components/groups of components? What data is required?
- **Verification of condition monitoring systems:** Quantification of condition monitoring performance and added value vs. cost.

'Reliability'

What are the main research challenges we need to address?

- **Verified device models:** Specifically resource to wire – everything between the wave/wind and generated, transmitted electricity. Need to improve mechanical load predictions via verified device models, which we don't have at scale presently.

- **Understanding operating loads for marine:** Need to understand the duty cycles for testing turbines under standard operation and extreme loads. A strong understanding operational load analysis is also especially important.
- **Economic analysis to achieve optimum reliability levels:** How reliable should offshore devices be? They won't be as reliable as onshore given the different technologies and O&M regimes. Need an economic analysis to derive optimum and desired reliability levels.
- **Developing accelerated life teasing procedures:** Not just techniques and procedures but also test facilities

'Asset Management'; and 'Reliability'

The group approached the two research clusters as one when considering the following questions:

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

- Suggestion that **Supergen Hubs focus too much on meetings and networking, and less on actual basic research.**
- **Funding should come from a combination of EPSRC, TSB and Catapults.**

What needs to happen in terms of coordination and alignment to maximise success?

- **Inadequate coordination of TSB, Carbon Trust, EPSRC etc.** Must consider whether current organisations (e.g. UKERC) are capable of addressing this issue. If not how might matters be addressed?
- **EU coordination has been facilitated by initiatives such as the European Wind Academy.** It would be useful to have a similar organisation for marine? Whilst organisations such as IET have supported marine energy via the provision of conferences and undergraduate support, much less has been done at the PhD level.
- Must **ensure that CDTs continue to engage in research that is aligned with the problems facing industry.**

What capabilities / capacities do we need in place?; Do our current ways of working need to change? If so, how and why?; What do we need to have in place to ensure we are ready to address these research challenges? (e.g. PhD training, data collection/curation, research Infrastructure, funding philosophy etc.)

- **Address the conception that offshore wind is a mature technology** because it isn't.
- Need **access to real, physical data.**
- **Mapping existing test facilities & finding the gaps where new ones will be needed.**
- **Access to full-scale devices for testing and to collect very detailed data.**
- **PhD training –** Make CDTs more of a 'hub', with other universities able to take on CDT students for specific projects. Establish funding mechanisms for other types of PhD studentships to complement CDTs, and increased funding opportunities.
- Establish a **national database for the collection and curation of reliability data.** For instance NAREC have a large-scale test facility but unlikely academics will see many of the interesting results due to commercial sensitivity of it.
- Increased funding for **access to large-scale test facilities** would be useful.
- **Need to link R&D funding to perceived and emerging national needs.** Questions around whether the amount of funding spent on research in this sector is commensurate with perceived short and long term risks to the UK economy?

- Given the future expectations in both wind and marine, **EPSRC should provide sufficient funds to provide increase the capacity and capability of the UK research base.** It will also help to raise the status of these technologies and provide more investor confidence.

Group D

'Sensing'

What are the main research challenges we need to address?

- **Spatial and temporal sensing of marine and wind resources** (e.g. wave and wind characterisation).
- **Sensing for environmental impacts in extreme environments.** For instance, noise impacts on birds, mammals, fish etc. of wind or marine energy at sea.

'Environment'

What are the main research challenges we need to address?

- **Understanding the cumulative environmental impacts** (e.g. physical, chemical, biological, behavioural etc.) of wind and marine energy technologies on ecosystem and ecosystem services
    - Specifically, the effects of devices on hydrodynamics and the implications for marine biology. For example, examining the impact of tidal turbine wakes on the environment, in terms of shear/strain/pressure effects on marine organisms.
    - Identify positive feedbacks, which may ultimately negative or positive outcomes for ecosystem services. Are there any win-wins?
- Over-emphasis on iconic species. There is a need to **understand the impacts on the whole ecosystem**, not just specific, 'priority' organisms.
- What are the **environmental implications of large scale deployment** of marine and wind energy technologies, compared to small-scale? Are these different?

'Economic, social and governance'

What are the main research challenges we need to address?

- **Impacts of marine and wind energy technology on the ecosystem services** that other sectors rely on (e.g. fishing, farming, shipping etc.). What are the positive and negative impacts in terms of cultural, societal and economic value? What are the trade-offs?
    - How do these implications change according to scale (e.g. national to local)?
- **Develop marine and wind energy planning tools** that:
    - account for trade-offs between different sectors and associated constraints;
    - incorporate Strategic Environmental Assessment/Impact Assessment protocol; and
    - are sensitive to the land-sea interface e.g. how discharge from rivers impact upon marine energy resources.
- What are the **trade-offs associated with the move to intermittent renewables** from less-intermittent conventional fuels? What is the market price of managing this intermittency?
- **Life cycle assessment marine and wind energy technologies,** not just operation or installation of technologies.
- **Public perceptions, acceptability and understanding of marine and wind energy.**
- **Does government support or hinder innovation in this sector** via market signals, land-use planning, energy pricing etc.

'Sensing'; 'Environment'; and 'Economic, social and governance'

The group approached the three research clusters as one when considering the following questions:

What capabilities / capacities do we need in place?; Do our current ways of working need to change? If so, how and why?; Whose job should it be/who is best placed to do/fund this research?; What needs to happen in terms of coordination and alignment to maximise success?; What do we need to have in place to ensure we are ready to address these research challenges? (e.g. PhD training, data collection/curation, research Infrastructure, funding philosophy etc.)

Research Funding Structures

- **Big integrated projects that stretch across disciplines** (e.g. social, environmental, engineering). Better coordination between research councils is needed to facilitate this (e.g. EPSRC & NERC). A higher level of integration and a stronger institutional memory across research councils should also help to avoid duplication of research.
- Concerns that whilst SUPERGEN 'hub and challenge' model works, it does **not provide the core partners with enough influence.**
- SUPERGEN outputs not currently communicated well. Need appropriate communication tools and transfer knowledge mechanisms to ensure that information is passed from experts to policy makers. **Funding should be made available within grants for impact activities.**

Data and Modelling

- **Development of new sensing technology** because current equipment is at or already beyond its limit in terms of resource characterisation and environmental impacts. For instance, very difficult to understand what marine life currently inhabits a particular ocean area due to the limitations of underwater visualisation and acoustic sensing equipment.
    - Current size of sensing technology market insufficient for improved sensing technologies to emerge quickly, therefore maybe a need for growth in this market, which could be supported by regulation.
- **Lots of high quality data** is needed to improve our understanding of resource characterisation and environmental impacts, as well as help validate current models. Data exists but often not shared across industry due to IP issues around data and performance (e.g. military data), as well as the practical challenge of collating and storing data from so many different parties. Also, it is often the case also that developers don't want data collected in close vicinity of its devices.
    - It is possible that a trusted intermediary or additional regulation could address some of these problems.
    - Data curation lessons could be learnt from UKERC's experiences.
- **Better stakeholder engagement** could help improve understanding of marine and wind resources by drawing upon their vast experience (e.g. fishermen and marine resources).
- **More robust qualitative and quantitative methodologies** to process and 'make sense' of sensor data. Lessons could be learnt from the social sciences.
- **Develop models for the right scale and validate these using data**. After, fine scale characterisation, smaller models can be embedded into larger models but supercomputers are needed. After heavy use and refining, models may then be restructured to enable them to be used a decision making tools by regulators.

Training

- **Avoid using PhDs as cheap Research Assistants.**

- Whilst the value of Continuing Professional Development (CPD) and PhD secondment schemes are quite obvious, these often don't work well or don't happen because **industry is short on time**. Solutions are needed to support these schemes.
- **Inter-disciplinary PhDs should be promoted.** UKERC is a good example of an interdisciplinary research and training program. Strathclyde's Industrial Doctoral Centre for Offshore Renewable Energy (IDCORE) was also highlighted as a best practice example of bringing inter-disciplinary PhD students together with industry, however some industry members were frustrated by the structure imposed by the CDT model to some extent.
- **Inter-disciplinary PhD students should be given more time to undertake their studies,** given the challenge of inter-disciplinary research.

6 Reflective writing

6.1 Process

The purpose of this exercise was to ensure that the finer detail generated during the workshop was not lost. It provided participants with the opportunity to build upon ideas they had formulated during the clustering and deep-dive exercises and allowed them to flag any broader issues they wanted to raise. Participants were provided with two options for the reflective review session:

Option One: *Independent Reflection*

Participants were invited to work on their own to record their thoughts and ideas in writing

Option Two: *Reflect and Chat*

Participants were invited to firstly reflect on their thoughts and ideas, before sharing them informally with other people in the room. This enabled participants to develop their ideas by 'bouncing' them off other members in their group. Again participants were asked to record the outputs of this session in writing

Participants were encouraged to post any written output from this session into a reflections post box or email their thoughts to the organisers.

6.2 Output

Research

- **Wave and tidal resource characterisation** was highlighted as an important research area. In particular, examining the interplay of both wave and tidal resources at both potential wave and tidal energy sites. For example, the importance of tidal vectors in terms of wave resources
- **Grid solutions to maximize utilisation of UK electricity generated from marine resources.** For example, using locally generated electricity to power local needs (e.g. transport) could be part of the solution

Workshop Process

- Important that the research clusters should not be treated in isolation and that any potential **linkages between the clusters are drawn out**
- Insufficient time spent on considering training needs, rather than research priorities. If this sector is too succeed, intellectual capital is as important as human resource, not more important.

- Workshop was very focused on EPSRC type research, i.e. **very engineering and industry focused**. Insufficient focus on the environmental, social and economic aspects of WWT energy, which has typically been the domain of NERC and ESRC. For instance, some aspects of non-engineering factors that influence WWT related energy system planning had been missed. This was in part due to an underrepresentation of environmental, social and economic researchers at the workshop. Importantly, representatives from these research areas had been invited to the workshop but were unable to attend for various reasons.
- It was felt that the workshop would have benefitted from the **input from materials engineers/scientists.**
- One participant felt that the workshop captured only a **small sample** of a much larger UK wind and marine research community.

Research Funding and Support

- Wave and tidal are a critical point of industry development with large OEMs entering the sector. It is essential that **research funders ensure they have industry engagement such as an EPSRC-TSB joint call** or there is a real danger that EPSRC research will be ignored by industry.
- Suggestion to **stop funding ETI**. It was felt that it consumers valuable resources but doesn't share the results of its work.
- Recommendation to establish a **national centre for wind research.**
- The **current level of funding for WWT research, especially wind, is far too low** considering the expectations for their overall contribution to the energy mix in the future (i.e. 2020, 2050).

Data

- **Access to data of all types** was a recurring theme; however the problem is that the entire renewable energy industry views data as IP that needs to be protected. There needs to be some high level activity to address this issue.
- Suggestion that academics eng**age with and understand the views of the marine industry** more broadly rather than just seeking data for research projects.

7 Key pointers for the Research Councils – start/stop/continue

Participants were asked to generate recommendations as to how the Research Councils could support research in this area relating to the following three categories:

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

One of the key themes to emerge was the call for joint research funding between academia and industry through coordinated calls between various funding bodies. Specifically, it was suggested that the Research Councils could establish a joint research programme with TSB. Additionally, a number of people emphasised the value of joint research councils funding calls, such as between EPSRC and NERC for example. It was felt that these arrangements would help the Research Councils to coordinate with each other, as well as other organisations (e.g. government funders of research to develop joined up research programmes. There was call for support, specifically funding, for UK researchers to collaborate with European partners and access European energy research funding (e.g. Horizon 2020). Finally, in terms of training, a strong theme to emerge was the call for a project based PhD studentships to return. This was not necessarily instead of CDTs but as another means of funding PhDs to complement the CDT model. Table 5 presents the outputs of this exercise.

Table 5: Suggested Actions for the Research Councils

Start doing/do more of	Continue to do	Stop doing/do less
Research Funding Structure & Management		
Enable joint funding of academic and industry through coordinated calls between various funding bodies, e.g. Joint Research Programme with TSB – cited by five participants	Funding Hubs	Review 'Hubs' - lot of work for very little gain? (x2)
Joint research council calls (x3)	Grand challenges and targeted calls	Reduce funding for responsive mode research
Research councils to coordinate with each other and government funders of research to develop joined up research programmes (x2)	Supergen consortia (for continuity), but expand mechanisms for new partners to get involved	Targeted Calls
Fund interdisciplinary research	Funding UKERC type programs	Consortia
Simplify calls for funding - learning more complex		Asking SMEs for Financial contributors in Joint calls with TSB etc.
Increase level of funding available		Reduce or stop LWEC and use the funding more effectively in large scale strategic and coordinated programmes
Responsive mode		Compartmentalisation of research into 'technical' vs. 'environmental'
Force supergen consortia to engage properly		'Cosy' non-competitive bids
Managing/coordinating grand challenge called to prevent duplication		Having 'one bid per institution' calls
Joint progress meeting between NERC, MREKEP and UKCMER		Considering wave & tidal energy together
Weight peer review scores on how well they fit with the funding call		Funding calls that support individuals only: focus on collaboration.
Large coordinated multidisciplinary programmes on specific topics		
Fund large scale interdisciplinary projects		
Annual grand challenge calls in each technology with specific topics each time		
A national research centre in Wind should be established		
Industrial Collaboration		
Try to engage more widely with research institutes (less cliquey) and industry		Calls only at low TRL with no industry engagement
Work with industry to develop industry valued programmes and those of relevance and value to the development of a marine energy industry in the UK		
Focus of Research Funding		
Have joint offshore WWT calls	Focus on devices	Funding nuclear fusion
Device-Device interaction projects	Continue to support Marine: it's a critical time for the sector	
Research and Test Facilities		
Facilitate access to best wind turbines		

NERC Vessel access for EPSRC projects		
Engage industry in multidisciplinary research		
Fund structured access to test facilities (e.g. wind turbine, NAREL test beds etc.)		
Data		
Coordinated central curation of data archiving		
National level data generation/collation projects to support research (e.g. renewable resource)		
Make use of test sites for: data gathering / facilitation / anonymisation of data / real-life experience and knowledge of issue across sectors		
Open source code/data models		
Encourage projects to make their data available (e.g. through UKREC-EDC), treat as a publication		
More funding available for data collection at representative sites. Not just reliance on using existing data		
PhD & Post-Doc Training		
Return of project studentships (x5)	Funding CDTs	DTCs
Continue to support CDT type large centres (size matters in industrial collaboration)	Fund EngD programmes	
National level training courses for PhD students (not CDTs)	Doctoral training grants	
	Funding UKERC summer schools	
International Collaboration		
Support UK researchers to engage with EERA (x2)		
Collaborate with EU more		
Facilitate access to EU funding projects		

8 Wrap-up and next steps

Jim Skea summed up the Fellowship team's impression of the workshop and described how a summary of the workshop would be produced as an intermediate step in the development of the *Wind, Wave and Tide* Prospectus Report. The Prospectus as a whole would be launched ta the Royal Society on 12 November 2013.

The main impressions were:

- After a challenging start to the day, the workshop had generated a valuable set of outputs comparable in quality to those obtained through the two-day residential workshops.
- Links with industry had emerged as a particularly strong theme during the workshop.
- The findings in terms of research process and funding arrangements (e.g. CDTs and project-based studentships) echoed findings from workshop covering other areas
- The boundary between basic/applied research supported by the Research Councils and bodies with a more applied R&D focus such as TSB and ETI had changed in recent year. In the mid-2000s

before, ETI and TSB were established the Research Councils had moved towards the applied end of the spectrum but had now moved back towards their core interests in basic/applied research.

- Wave energy support was currently the subject of a review by the Chief Scientific Adviser at BIS. This has been partly driven by the fact that the technology had not made nearly as much progress towards commercial demonstration as had been anticipated a few years ago. The Research Councils would need to keep their support in this are under review in line with the development of the wider energy innovation agenda.

Annex A: Agenda

10.00	Arrival, Registration and Coffee
10:30	**Introductions**
10.35	**Session One:** ***Introduction*** Introduction to the purpose and process of the workshop and the overall development plan for creating an Energy Research and Training Prospectus
10:50	**Session Two:** ***The Current Wind, Wave and Tidal Energy Research Landscape*** How well set up is the UK, in terms of research capabilities in Wind, Wave and Tidal energy, to meet the challenges of the future?
11:10	**Session Three:** ***Identification of Key Wind, Wave and Tidal Energy Research Challenges*** Identify the key emerging research challenges and cluster these into higher level research themes
12.45	Lunch
13.30	**Session Four: 'Deep-dive'** ***Analysis of Emerging Research Themes*** What are the associated research questions? Whose job is it to take these forward? What research infrastructure do we need (research/testing facilities, data collection/curation etc.)? What are the training needs?
15:15	Tea break
15:30	**Session Five:** ***Drawing it all together and Next Steps*** What have we missed? What should the Research Councils continue to do, do more/less of?
16.30	Close

Annex B: Attendance List

Forename	Surname	Organisation
Mel	Austen	Plymouth Marine Laboratory
Mike	Barnes	University of Manchester
Oankar	Birdi	Renewables UK
Carolyn	Campbell	BIS
Chris	Dent	Durham University
Geoff	Dutton	Rutherford Appleton Laboratory
Richard	Green	Imperial College London
Matthew	Hannon	Fellowship Team
Gareth	Harrison	University of Edinburgh
Mike	Hemsley	Fellowship Team
Simon	Hogg	Durham University
David	Infield	Strathclyde University
David	Ingram	University of Edinburgh
Farida	Isroliwala	DECC
Henry	Jeffrey	University of Edinburgh
Bill	Leithead	Strathclyde University
Ian	Masters	University of Swansea
Markus	Mueller	University of Edinburgh
Jennifer	Norris	EMEC
Lewis	Preece	EPSRC
Aidan	Rhodes	Fellowship Team
Jim	Skea	Fellowship Team
Kavita	Srinivasan	Committee on Climate Change
Tim	Stallard	University of Manchester