Research Councils UK Energy Programme Strategy Fellowship

Energy Strategy Fellowship Report 4:

Summary of Workshop on

The Research Councils and the Energy Innovation Landscape

March 2013

Energy
For a Low Carbon Future

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Research Councils Energy Programme

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

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

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

Energy Strategy Fellowship

The RCUK Energy Strategy Fellowship was established by EPSRC on behalf of Research Councils UK in April 2012 in response to the international Review Panel's recommendation that a fully integrated "roadmap" for UK research targets should be completed and maintained. The position is held by Jim Skea, Professor of Sustainable Energy in the Centre for Environmental Policy at Imperial College London. The main initial task is to synthesise an Energy Research and Training 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 forward activities alongside Government, RD&D funding bodies, the private sector and other stakeholders. The tool will highlight links along the innovation chain from basic science through to commercialisation. The tool will be flexible and adaptable and will take explicit account of uncertainties so that it can remain robust against emerging evidence about research achievements and policy priorities.

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

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

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Executive Summary

This report describes the outcomes of the workshop *The Research Councils and the Energy Innovation Landscape* held at Imperial College London on 20 February 2013. The workshop was the third in a series of three "strategic" workshops held under the auspices of the RCUK Energy Strategy Fellowship. The key aim of the Fellowship is to develop an *Energy Research and Training Prospectus* which will help the Research Councils to plan their portfolio of research and training in the energy field.

1. The opening session introduced the workshop and the wider process within which it fitted. The workshop would draw a distinction between research topics where priorities were "use-inspired" through pilot studies, demonstrations and early deployment, and those that were more about the exploitation of basic science. Key messages from the previous strategic workshops were then highlighted. In considering "desirable" versus "likely" UK energy futures, people's expectations had fallen well short of their aspirations. In terms of the case study technologies for the present workshop, the UK had been seen to be strong industrially and scientifically in marine renewables, but their relevance to UK energy futures was seen to be relatively low. The UK was seen to be scientifically strong on PV but weaker industrially with a middling relevance to energy futures.
2. The second session featured presentations from organisations operating at different stages along the energy innovation chain. Paul Durrant (DECC) first described the overall pattern of public low carbon innovation support in the UK, focusing on the role of the Low Carbon Innovation Coordination Group. Jason Green and Nigel Birch from the Engineering and Physical Sciences Research Council (EPSRC) then presented the work of the EPSRC Energy Programme and the Physical Sciences theme respectively, drawing attention to linkages and cooperative activities. Rob Saunders describe the more applied R&D role of the Technology Strategy Board (TSB) which aims to accelerate economic growth by stimulating and supporting business-led innovation
3. A "World Café" style breakout session addressed two technology case studies, one on marine renewables as an example of "use-inspired" research and the other on molecular PV as an example of an area more driven more by basic science. Table groups addressed four questions relating to: a) the transfer of basic physical science research into energy applications; b) the commercialisation and demonstration of energy technologies; c) interfaces and handovers between different innovation bodies and schemes; and d) the role of R&D infrastructure and testing sites.
4. The discussions yielded a wide range of insights. In spite of a healthy number of university 'spin out' companies for both marine renewables and molecular PV, there is a lack of mechanisms to support transfer of research beyond universities. The commercialisation of technologies should not be forced prematurely, e.g. prior to demonstration. It is important to understand what investors want and how to satisfy their needs. There is a mismatch in terms of the timescales between different bodies operating at different stages in the innovation chain. There is a need for infrastructure to demonstrate energy technologies and prove their potential commercial value.
5. The second breakout session focused on pathways towards deployment and how arrangements could be improved. Three groups focused on marine energy and three on molecular PV. Each group developed a stylised "roadmap" for the deployment of their case study technology. In relation to more ***basic research***, the groups concluded that there need to be stronger mechanisms for feeding back findings from later in the innovation process to the basic research stage. Greater national co-ordination and interdisciplinary research was needed to combat disciplinary 'siloing'. In relation to ***applied research and development***, the groups noted that understanding potential markets is important. Spin-out companies could be helped out more in this respect. There is a 'gap' in capabilities and the need for better, more flexible testing facilities. A system of Fraunhofer-style centres could help at the ***demonstration stage*** though TSB's Catapult centres partly fill that gap. Finally, for ***pre-commercial deployment***, clear policy signals are important. UKTI and other export organisations can help to promote a global market for UK technologies.

Acronyms

BBSRC	Biotechnology and Biological Sciences Research Council
BIS	Department of Business, Innovation and Skills
BSBEC	BBSRC Sustainable Bioenergy Centre
CCS	Carbon Capture and Storage
DECC	Department of Energy and Climate Change
DEFRA	Department for Environment, Food and Rural Affairs
EERA	European Energy Research Alliance
EMEC	European Marine Energy Centre
EMR	Electricity Market Reform
EPSRC	Engineering and Physical Sciences Research Council
ERA-NET	EU European Research Network Co-ordination activities
ERP	Energy Research Partnership
ESRC	Economic and Social Research Council
ETI	Energy Technologies Institute
EU SEII	Sociéte Européenne des Ingénieurs et des Industriels (European Society for Engineers and Industrialists
FiT	Feed-in-Tariff
FP7	Framework Programme 7 (EU Research and Technology Development Programme)
GIB	Green Investment Bank
IEA	International Energy Agency
IoM^3	Institute of Materials, Minerals and Mining
IoP	Institute of Physics
IP	Intellectual Property
KIC	EU Knowledge and Innovation Community
KTP	Knowledge Transfer Partnership
LCICG	Low Carbon Innovation Co-ordination Group
MRDF	Marine Renewable Deployment Fund
NER 300	New Entrant Reserve. Scheme to set aside 300m allowances under the EU Emissions Trading Scheme to support innovative renewable and CCS projects
NERC	Natural Environment Research Council
OEM	Original Equipment Manufacturer
PV	Photovoltaic
R&D	Research and Development
RCUK	Research Councils UK
REF	Research Excellence Framework
ROC	Renewables Obligation Certificate
RSC	Royal Society of Chemistry
SDI	Sustainable Development International
SME	Small to Medium Sized Enterprise
STFC	Science and Technology Facilities Council
TIC	Technology Innovation Centre
TINAs	Technology Innovation Needs Assessments
TRL	Technology Readiness Level
TSB	Technology Strategy Board
UKTI	UK Trade and Investment
VC	Venture Capital

1. Introduction

This report describes the discussions and outputs of the workshop *The Research Councils and the Energy Innovation Landscape* held at Imperial College London on 20 February 2013. The workshop was the third in a series of three "strategic" workshops held under the auspices of the RCUK Energy Strategy Fellowship established earlier in 2012. The key aim of the Fellowship is to develop an *Energy Research and Training Prospectus* which will help the Research Councils to plan their portfolio of research and training in the energy field.

2. Opening plenary

Jim Skea, RCUK Energy Strategy Fellow, opened the workshop by presenting an overview of the workshop and the wider process within which it fitted. He noted the recommendation of the International Panel which had reviewed the RCUK Energy Programme in 2010 that "a fully integrated "roadmap" for UK research targets should be completed and maintained to allow all to know and understand what is considered essential to meet society's needs". One of the primary functions of the RCUK Energy Strategy Fellowship was to establish this roadmap, which would take into account both skills and training needs. Following extensive consultations, the "roadmap" had been renamed a "prospectus". Key considerations were to take account of: energy security, affordability and economic opportunity as well as climate change; uncertainty about energy futures; and the interface between the Research Councils and other actors in the innovation chain. The prospectus is being delivered through a series of three "strategic" level workshops of which this was the third, and six expert workshops taking a deep-dive into more specific energy research. Two of these, on *Fossil Fuels and CCS* and *Energy in the Home and Workplace*, had been held in January and February 2013 respectively.

Jim then highlighted the conceptual underpinning of the current workshop, making a distinction between research topics where priorities were "use-inspired" through pilot studies, demonstration and early deployment, and those that were more about discovery and the exploitation of basic science. The workshop case studies on marine renewables and molecular PV were intended to exemplify these styles of research. Finally, Jim ran through the structure of the workshop highlighting what the Fellowship team sought to get out of each session.

Aidan Rhodes, Research Fellow within the Strategy Fellowship team, then highlighted key messages from the two previous strategic workshops. One of the messages from Workshop 1, *Energy Strategies and Energy Research Needs*, was that projections of world energy demand out to 2040 varied considerably. Exxon, for example, foresaw a world dominated much more by oil and gas than in the International Energy Agency's (IEA's) "2 degrees" scenario. There was considerably less biomass, other renewables and nuclear power. However, there was no technology in the IEA 2DS scenario that was not also present in the Exxon projections. Low-carbon technologies tended to be deployed more slowly and to a lesser extent. The Exxon forecast had some broad similarities with the IEA "4 degrees" scenario but had less coal and renewables.

A second message was that, when participants in the first workshop were invited to indicate what they thought of as "desirable" versus "likely" UK energy futures, expectations fell well short of aspirations. Taking the power sector as an example, the expected deployment of many low-carbon technologies fell short of aspirations with many participants expecting a considerable residual role for unabated gas in 2050.

Aidan also reported on how the workshop had assessed various areas of energy research in terms of relevance to UK energy futures, UK industrial capabilities and UK scientific capabilities. The most relevant areas were seen to be CCS, final demand in residential and commercial buildings and transport, energy systems analysis (which implicitly covers social and economic research) and oil and gas. The UK was seen to be strong both scientifically and industrially in the latter area. In terms of the case study technologies for the present workshop, the UK was seen to be strong industrially and scientifically in marine renewables, but their relevance to UK energy futures was seen to be relatively low. The UK was also seen to be scientifically strong on PV but weaker industrially with a middling relevance to energy futures. Aidan also highlighted a number of "nuggets" from the second strategy workshop on *The Role of Environmental Science, Social Science and Economics*. Higher level messages had been harder to extract from this workshop.

3. Views from the Innovation Chain

3.1. Introduction

The second session of the workshop featured four presentations providing an overview of key issues within the UK energy innovation chain. These covered: an overview of the landscape (Paul Durrant, Department of Energy and Climate Change (DECC)); links between basic "capability" and more applied "challenge" research in the Research Council sphere (Jason Green, Head of Engineering and Physical Sciences Research Council's (ESPRC) Energy Programme and Nigel Birch, Head of EPSRC's Physical Sciences theme); and the handover from the Research Councils to more applied research and development (Rob Saunders, Technology Strategy Board (TSB)).

3.2. Low Carbon Innovation – Coordinating UK HMG-backed Support, Paul Durrant, DECC

Paul Durrant structured his presentation round the following themes:

- The case for low-carbon innovation support, namely that the UK would not meet its climate change targets with current technologies at current costs.
- An overview of what many observers saw as an overly complex innovation landscape. Paul accepted that the overall approach could be improved, notably by making it easier for innovators to navigate the funding landscape, but that different bodies have different objectives.
- The Department for Business, Innovation and Skills (BIS) and DECC were the key sources of funding, operating through the Research Councils, TSB, the Energy Technologies Institute (ETI) and, to a lessening extent, the Carbon Trust.
- The Low Carbon Innovation Co-ordination Group (LCICG) had been established to maximise the impact of UK public sector funding for low carbon technologies. This comprises core and associate members.
- Paul noted LCICG's work on the Technology Innovation Needs Assessments (TINAs), which aim to create a robust knowledge base to guide government investment decisions. Nine TINAs, including marine renewables, have been published.

In questions, Paul was asked about industry engagement. He mentioned the Energy Research Partnership (ERP) as an important sounding board. The TINA process also increases engagement with industries. In retrospect, he explained that there could have been more of that.

3.3. Research Councils UK Energy Programme: For a Low Carbon Energy Future, Jason Green, EPSRC

Jason Green provided an overview of the Research Councils UK Energy Programme addressing the following topics.

- The Mission is to position the UK to meet its energy and environmental targets and policy goals through high quality research and postgraduate training. It was launched in 2002 and will invest £540m in 2011-15.
- The key objectives are to:
  - expand UK research capacity;
  - support a full spectrum of energy research relevant to the UK's energy objectives;
  - work in partnership with key stakeholders;
  - increase international visibility and collaboration.
- The current research portfolio is worth over £800m and the key priorities for 2010-14 are:
  - reducing energy consumption and demand;
  - speculative research aimed at understanding future energy options;
  - accelerated deployment of alternative energy technologies;
  - ensuring physical, economic, social and natural sciences research and basic research challenges are addressed, working jointly with TSB, ETI and others;
  - building capacity, e.g. through career advancement and leadership fellows;
  - building on major existing links with China and other priority countries
- Overall, EPSRC's strategic goals are to shape capability, deliver impacts and develop leaders. Challenge programmes such as the Energy Programme build on research capabilities, such as those in the physical sciences.
- Future planning depends on understanding the shape of the current portfolio and judging the relative scale of different investments in terms of quality, importance and capacity. The broad choice is to grow, maintain or reduce an area of research. Jason then summarised the EPSRC's current intentions within the Energy Programme.
- Finally, Jason outlined the EPSRC's overall financial plans out to 2015, divided between research, training and fellowships.

Jason was asked about the relationship between the Energy Programme which is cross-council, and EPSRC's work. For example, EPSRC and the Natural Environment Research Council (NERC) might have different views on the appropriate emphasis on fossil fuels given rising interest in unconventional sources. A NERC representative agreed that NERC might map it somewhat differently. From a geologist's perspective, the appropriate subject might be ocean basins. The same science addresses where you can store carbon, where you can store nuclear waste and where you can undertake fracking. There was agreement that it was important to look at the interactions between EPSRC and NERC and identify mutual benefits. The NERC representative also emphasised the importance of environmental science. Offshore developments could wipe out fisheries but, for example, if impacts are taken into account you could create fisheries nurseries with a positive effect instead of a negative one.

3.4. Challenge and Capability, Nigel Birch, EPSRC

Nigel Birch's presentation focused on ESPRC's Physical Sciences theme. There were four foci for the theme:

- ***Leaders***: developing inspirational scientific leadership while balancing creativity with capability and focusing the training portfolio so that it is aligned with strategic needs.

- ***Shaping***: Linking effectively to other capability and challenge themes and building on other external funding sources.
- ***Impact***: Making impact a 'smarter' rather than a serendipitous process. Also, enhancing capability at the Cross-Council interface
- ***Infrastructure***: Developing a national strategy and implementing an approach that supports rather than hinders science

The strategy for the theme was to:

- Focus on ground-breaking physical sciences research;
- Shape and integrate the portfolio to meet societal and economic challenges that rely on fundamental science for solutions;
- Maintain the flow of people to sustain capability at all career changes;
- Identify and help develop current and future research leaders

Nigel highlighted the *Materials for Energy Applications* call which had recognised the fundamental importance of materials research to meeting energy challenges and had been developed in association with the Energy Programme.

In questions, it was noted that NERC ran a responsive mode and that they worked across themes. Furthermore, BSBEC (BBSRC's Sustainable Bioenergy Centre) worked across the various research councils. It was also noted that material sciences, along with the biosciences and computational sciences, constituted three critical areas of basic science relevant to energy identified by the International Energy Agency. The work of the Science and Technology Facilities Council (STFC) was also noted. STFC is a fundamental science Research Council but also provides infrastructure for experiments relevant to energy science.

3.5. TSB Energy Activity and the Research Base, Rob Saunders, TSB

Rob Saunders noted that TSB is the UK's innovation agency, funded by BIS to accelerate economic growth by stimulating and supporting business-led innovation. TSB aims to: accelerate the journey from concept to commercialisation; invest in thematic priority areas; connect the innovation landscape; and turn government action into business opportunity. TSB invests £25m pa in energy but many other programmes are energy-relevant, e.g. built environment, transport and biosciences.

In practice TSB listens to business, figures out what's stopping innovation from happening and intervenes, picks out links and patterns from a mass of complexity and uncertainty, and joins people up, both business-to-business and business-to-research. A range of mechanisms are used to achieve this, such as "catapults", collaborative R&D and innovation vouchers. Some of these are designed to help make best use of working with the research base. Rob then provided some examples of these.

A new Energy Strategy had recently been published. It was explained that the energy system needs to undergo a radical transformation in order to address the energy trilemma (environment, security, affordability) and TSB believes this change provides an opportunity for UK business. In this context, TSB's role is to translate that opportunity and stimulate innovation that maximises economic benefit. The Strategy rests on three pillars:

- Developing affordable and secure sources of energy supply that also reduce GHG emissions;
- Integrating future demand and energy supply into a flexible, secure and resilient energy system;
- Reducing GHG emissions at point of use

In questions, Rob was asked whether TSB's work with the research base took place in parallel with the research councils. Did they engage the same people? Rob noted that TSB's core job was to fund applied late-stage research. It was about bringing technology to market. However, he explained that they also do some earlier stage research, for example through co-funded programmes with NERC and EPSRC.

4. Breakout Session 1: World Café

4.1 Introduction

The first breakout session was structured as a 'world café' where the attendees were split into four different discussion groups, two of which focused on molecular solar PV as a case study and the other two on marine energy. Experts on either marine energy or molecular PV sat on tables considering the relevant case study. Non-experts with a broader knowledge of the energy funding and innovation landscape in the UK self-selected their tables.

Each group was presented with four key questions, structured to guide their discussion across the whole innovation journey these two different technologies have undergone in the UK. These were as follows:

- Successes and challenges in transferring basic physical science research into energy applications?
- Successes and challenges in commercialising and demonstrating energy technologies?
- Successes and challenges in the interface and handover between innovation bodies and schemes?
- The role of R&D infrastructure and testing sites in the innovation journey?

The session lasted for 45 minutes in all. Mid-way through, half of the participants moved to another table in order to yield fresh insights. However, two experts on the relevant case study subject (i.e. either molecular PV or marine energy) remained at the same table.

Each group was assigned a notetaker responsible for capturing the groups' discussion. The groups were also asked to record key outputs on a flipchart. The cross-cutting conclusions are listed in the following section. A summary of the outputs of each group then follows.

4.2 Summary of Outputs

Transfer of basic physical science research into energy applications

- There are a healthy number of 'spin out' companies from universities for both marine and molecular PV
- There is a lack of organisations and mechanisms to support transfer of research beyond universities.
- It is difficult to secure seed funding for business development (e.g. from Venture Capital). Potential solutions include GIB and/or arms-length university support initiatives (e.g. Imperial Innovations)
- *Shifting sands* – application/impact of research may be undermined by changes to broader energy landscape.
- Cross-sector innovations are important as these can be utilised to support other sector-specific technological innovations (e.g. hydraulic pumps and wave energy technologies).
- It is important to strike a balance between technology/process specific research designed to generate IP and broader 'know-how', capable of supporting the uptake and transfer of IP.
- There is a tension between designing SUPERGENs to promote flexibility (i.e. SUPERGEN hubs) or to avoid overlap in research portfolio (i.e. traditional Supergen consortia).

Commercialising and demonstrating energy technologies

- TSB plays a key role in promoting transfer of research but there are opportunities to enhance its role and broaden its remit into commercialisation and demonstration.
- Complementary relationships between industries to support the uptake of innovative energy technologies (e.g. solar PV and construction industries) are important.
- Markets are generally structured to support dominant technologies (e.g. conventional PV), via things like technology standards. Vested interests are inclined to preserve the market 'as is'.
- Mergers and acquisitions are a double-edged sword. These are needed to bring scale to the industry but may redirect skills/expertise base outside the UK if led by international companies.
- Poor perceptions of a technology's potential importance by Government and other key stakeholders can damage its prospects
- It is a mistake to force commercialisation of technologies prior to necessary pre-cursory stages, e.g. demonstration.
- There is a potential to develop networks of start-up companies to promote lesson sharing around good practice for the demonstration and commercialisation of applied R&D.
- It is important to understand what investors want and how to satisfy their needs in order to secure investment.
- We need to be sensitive to the uniqueness of specific technologies e.g. marine renewables. There is no 'one size fits all' innovation process for all technologies.

Successes and challenges in the interface and handover between innovation bodies and schemes

- There is a mismatch in terms of the timescales between different bodies operating at different stages in the innovation chain.
- There are different ways of working/incentive systems across bodies operating at different stages in the innovation chain.

Role of R&D infrastructure and testing sites in the innovation journey

- Data and data infrastructure are important prerequisites of R&D at all stages.
- There is a need for infrastructure to demonstrate energy technologies and prove their potential commercial value.

4.3 Café Dialogue Group 1 – Molecular PV

Successes and challenges in transferring basic physical science research into energy applications

The group agreed that the UK possessed a very strong research base, built on the basis of a wealth of research council funding. This base presented the UK with significant potential to transfer the research into innovative energy applications. However, one of the challenges highlighted by the group was the difficulty of identifying future applications for innovative energy research being generated at TRLs 1-2. RCUK funding is not necessarily contingent on the identification of future applications. For example, there are no clear applications or commercial uses for grapheme, yet a considerable amount of research resource has been put into this area both at the UK and EU levels. Nevertheless, the ease with which this research may be transferred to the applied R & D stage (i.e. TRLs 3-4) and beyond (TRLs 5+) tends in general to be reliant on these applications being identified during the earlier research stages.

Successes and challenges in commercialising and demonstrating energy technologies

Whilst the UK had undertaken higher quality research than many other countries in the PV field, it had failed to demonstrate and commercialise this research as successfully as some other countries, notably Germany. Barriers included the lack of a strategic approach in the UK to identify potential applications of the research being generated by universities. There was no single body responsible for identifying how solar PV research might be utilised and subsequently applied. Taking such a strategic approach could enable the UK to identify commercial applications for an area in which it has substantial research capability, particularly if there is no major international competitor.

A related concern was that the UK lacked the necessary mechanisms to facilitate the transfer/dissemination of PV research to suitable organisations in order to realise these applications in a commercial sense. This point was illustrated by the case of the Carbon Trust's PV Accelerator competition. Whilst this scheme was a success, it hadn't been followed through: 'There are a lot of drivers and coordination to get to the point where it's almost market-ready but then suddenly everything stops'. In summary, the group felt that there was a major gap between academic research and its subsequent development, demonstration and commercialisation by small to medium sized enterprises (SMEs). This could be addressed by establishing a strategic body responsible for identifying potential applications for solar PV research and coordinating its application via a range of facilitative mechanisms.

A lack of early-stage capital investment was also identified as an important barrier to demonstration and commercialisation of molecular PV research. Whilst the group accepted that some companies (e.g. Solarpress), have managed to attract venture capital funding with an agreed commercialization stage normally of 3-4 years, securing the necessary capital investment to support demonstration and commercialisation is actually very difficult. Consequently, many solar PV SMEs in recent years have decided that the smartest way forward is to develop a non-capital intensive company. Instead of building their own factories as many companies did 5-10 years ago, they have developed partnerships with manufacturers, who assume responsibility for the manufacture of their PV technology. Doing so keeps the running costs down and reduces risks to the company, as well as their need for capital. The company G24i which has been developing dye-sensitive solar cells illustrates the risk of going it alone. It received significant investment from the US but they burned too much money too quickly and it took them too long to develop the technology.

The group suggested that Green Investment Bank (GIB) could help to address barriers by providing capital investment to molecular PV companies. However, one participant believed that the GIB would take its lead from other investment banks. If existing commercial banks are unwilling to support solar PV projects, for example because they perceive there to be an unsustainable trend in PV growth, then the GIB could react in a similar manner and limit its investment in PV. A potential solution was to learn lessons from Germany by fostering interest from large private sector companies and establishing public-private partnerships. In addition, the group didn't believe that the UK government truly believed that solar PV would play a key role in its energy future. This had implications for the regulatory framework for the energy sector as well as the attitudes towards PV of other key stakeholders. However, the group acknowledged that the UK government is beginning to see more of a role for solar PV.

Finally, the group raised concerns about the way in which the UK market had evolved to accommodate the commercialisation of conventional solar PV technology (i.e. crystalline Silicon based solar PV panels, situated on domestic roofs). This presented challenges for newer PV technologies (e.g. molecular PV): 'We risk losing potentially revolutionary applications of PV because we only focus on that one thing'. PV standards in the UK are structured to suit conventional solar PV technology because it is the dominant technology. Consequently, existing performance measures don't take into account shading and angles of PV technology or their embedded energy even though newer technologies tend to perform better against these performance measurements. Because existing PV standards are not sensitive to these measurements they tend to favour incumbent, traditional PV technologies at the expense of newer PV techs. 'Investors look at only the [energy] efficiency number'.

Successes and challenges in the interface and handover between innovation bodies and schemes

The group focused on the efforts of TSB in relation to the solar industry. The group were generally positive about its role in facilitating the transfer of research through the innovation chain. For instance, one attendee commented on the experiences of Solarpress, indicating that they had benefitted from TSB's assistance by being able access innovative R&D from universities and collaborate with other companies. They explained that the company is now 4 years old, employing approximately 12 people and is currently making great progress in developing their products in the lab. However, despite the valuable work TSB has undertaken, some concerns were raised.

The first concern was that many solar companies/research institutes had experienced difficulty in securing TSB funding and support. This was largely due to the complexity and resource intensity of the application process, which placed significant demands on these organisations. Whilst the group accepted that a rigorous application process was necessary, a number of organisations without the necessary resources and experience to prepare a funding bid for a collaborative R & D programme had been excluded. Consequently, a more supportive and inclusive process might be more effective.

The second concern related to the costs associated with collaboration between SMEs and academics, particularly the time demands and investment costs. Finally, the group was concerned that TSB could not provide the necessary funding to support companies' activities during the latter TRL stages, particularly commercialisation. However, it was particularly difficult to identify partners to collaborate with at this stage given the lack of capital available and the lack of appetite for risk during the financial downturn.

4.4 Café Dialogue Group 2 – Molecular PV

Successes and challenges in transferring basic physical science research into energy applications

The group was clear that transferring molecular PV research from universities to the private sector was difficult. The space immediately beyond academia was effectively a 'no-man's land'. In part, this was because there weren't sufficient opportunities for academics and their institutes to engage with applied R&D, which could help to facilitate the handover of the research to private sector organisations. For example, TSB could make 'proof of concept' grants available to not only business but also to academics. This would help to foster partnerships between academia and business that could be critical in transferring molecular PV research from TRLs 1-2 to TRLs 3-4 as actors operating in these spaces plans their R & D activities in conjunction with one another.

Another key barrier was the lack of seed funding to establish 'spin out' SMEs. In order to secure seed funding businesses often 'have to pitch to hundreds of potential investors'. One member of the group observed that 'getting money from Venture Capitalists takes about ten times more effort than getting Research Council funding'. Seed funding tended to be more focused on business development rather than technological development and was typically designed to ensure that the business was structured correctly to operate effectively in the market. Funding initiatives such as that provided by Imperial Innovations could present an effective solution for the provision of the necessary seed funding for business development. However, one benefit of sourcing funding directly from private-sector bodies (e.g. venture capitalists), rather than other funding bodies/schemes, was that private sector organisations are generally focused on getting the research to market. As such they will provide the help necessary to ensure that the research is developed has a specific application.

Finally, the group explored the idea of a network of 'spin out' SMEs, engaging in applied molecular PV R&D. Despite the fact that these companies were inherently in competition with one another, it was argued that there was a case for bringing them together. For example, they could form an interest group to secure and mobilise resources for the molecular PV sector. Forming such a network could help them to develop synergies building on their research interests. The group was interested in establishing whether there were examples of such PV networks in other countries or in other energy sub-sectors in the UK. NPL has established a series of Industrial Advisory Boards (IAGs), which could provide a starting platform in establishing how competing companies could work together toward a common interest.

Successes and challenges in commercialising and demonstrating energy technologies

Mergers and acquisitions led by foreign companies was identified as one potentially important factor influencing the demonstration and commercialisation of molecular PV technologies in the UK. The group cited the example of the firm CIGS Solar being acquired by a large Chinese firm. Mergers and acquisitions could help support demonstration and commercialisation through international commercial partnerships that would lead to additional skills, experience and capital being diverted towards the UK PV market. However, the downside was that the acquisition of UK molecular PV firms could mean that skills, experience and capital is transferred abroad, undermining the UK R&D base. For example, an organic PV manufacturer in Switzerland had received a lot of money from a Chinese organisation to entice it to move to China rather than to stay in Switzerland.

Like the other PV group, this group believed that current PV standards and efficiency measures do not take into account the better performance of molecular PV under cloudy skies or at different angles. Consequently, the performance of some advanced PV technologies is not acknowledged under current PV standards and metrics. Changing these would go some way towards supporting the demonstration and commercialisation of molecular PV technologies, as private sector companies would more easily recognise their strengths.

Importantly, many incumbent PV companies, who have made their money in the development and retail of conventional PV technologies, have a vested interest in ensuring that conventional PV remains the market leader. Consequently, they are likely to be wary of the disruptive potential of molecular PV and may act in hostile manner towards companies engaging in the development and sale of this innovative technology. Molecular PV companies will not only have to vie for dominance with companies in other sub-sectors (e.g. wind, gas) but also with companies in their own sub-sector.

The group underlined the importance of related industrial sectors in the demonstration and commercialisation of PV technologies. The cladding and construction industry is important to the PV sector, as organisations in this sector are responsible for integrating PV technology into the built environment. Without them, the technology could not be applied. The relationship was two way: the PV sector would benefit from the development of a range of different panel aesthetics (e.g. colour, size) that would provide architects and developers with more options in terms of building design and construction. There is also an important relationship between PV technology and glazing companies.

Finally, the group identified two barriers hindering the drive for the demonstration and commercialisation of molecular PV technologies. The first was the current low cost of silicon which has kept the cost of conventional PV technologies down, thus making them more affordable. This has reduced the incentive to support molecular PV technologies, which offer a potentially cheaper alternative. The second barrier was the perception amongst Government and other key stakeholders that PV does not realistically represent a major contributor to the future electricity generation mix in the UK. However, the group believed that this perception was slowly changing, thus providing investors with greater confidence in the UK PV market. It was noted that this was in part due to TSB's role to identify what the UK's role is in the context of the international PV market. There was a concern that new technologies could suffer from a perceptual bias against them due to the government's use of models based on standard PV efficiency measurements. There is currently an effort from several European institutions to produce measurements that incorporate the future potential of new PV technologies.

4.5 Café Dialogue Group 3 – Marine Energy

Successes and challenges in transferring basic physical science research into energy applications

Successes

The group considered the UK to have been particularly effective at transferring marine energy research from universities to SME 'spin-outs'. For instance, Pelamis Wave was identified as a good example of a company that owes its existence to the flow of expertise from universities. The firm has traditionally employed a large number of former MSc and PhD students largely because their skill sets are relevant to the development and deployment of Pelamis's technology.

Another success identified by the group was the flow of R&D from different research areas into the marine energy sector. The example of Pelamis Wave was used again to illustrate how innovations from other sectors, such as hydraulic pumps, have played a critical role in developing wave energy technology and more broadly, how important generic R&D can be in the development of specific energy technologies.

Challenges

One of the key challenges facing the transfer of marine energy research into application was the mismatch between the timescales that academia and industry work to. A typical research programme lasts three to five years, while industrial R&D operates on a much shorter timescale, typically months. This makes the transfer of research into application difficult, as industry often requires the research outputs before they are available for dissemination: 'if the academic doesn't give me the answer I need in a matter of months I'm not interested'. One potential solution was the application of integrating business planning alongside academic research planning to ensure that academic research was more sensitive to the users and thus the applications of their research.

A related barrier was that individuals used to operating to the longer time-scales associated with academia may struggle to make the transition into industry. There are also tensions between industry and academia due to the different incentive systems that operate. Academics are incentivised to publish in high-quality research journals through the Research Excellence Framework (REF), which informs universities' promotions policies. By way of contrast, industry needs to undertake R&D with the potential to generate significant sums of revenue for the company in the short to medium term.

Due to these different needs and incentives, companies engaging in applied R&D may choose to focus their efforts on generating their own Intellectual Property (IP) rather than building on that generated by universities because they are able to tailor programmes to meet their specific needs.

The group also discussed the conflict between undertaking research to generate IP and that which generates 'know how'. The group understood the former to be research that can be directly applied to inform the innovative design and development of technology. The latter referred to broader, less technology oriented research that is capable of playing a key role in supporting and facilitating the demonstration and commercialisation of innovative technologies, such as research into the design of effective government support mechanisms or the conditions under which users adopt innovative technologies. Whilst both forms of research were seen as important, the UK appears to have focused predominantly on undertaking research to generate 'know how' rather than IP. Consequently, this has limited the how much academic energy research has been transferred into applied energy R&D in recent years. However, the emphasis on 'know how' had played an important role in providing policy makers and industrialists with the confidence that the marine energy sector was worth backing, leading to broader initiatives like BIS's Marine Renewables Deployment Fund (MRDF).

A broader concern, not just related to research transfer, was whether academic research in marine energy should be structured around the traditional SUPERGEN consortia or the newer SUPERGEN hubs.

The former involves a large core grant that brings together a consortium of research institutes to undertake a specific research programme. The latter involves a smaller core research grant that brings together a community of research institutes to engage on a specific research area. Subsequent calls for proposals relate to research challenges that are identified by the community. While traditional SUPERGEN consortia have been successful in delivering high-quality, inter-disciplinary research, they lack the flexibility of the hubs which can shift their focus throughout their lifetime. However, in doing so, the hubs have the potential to duplicate research via open calls, a risk that is avoided under consortia arrangement. This problem could be addressed if reviewers of the funding bids were made fully aware of other bids and similar research projects being undertaken elsewhere.

Successes and challenges in commercialising and demonstrating energy technologies

Successes

The general consensus amongst the group was that a number of successful SME marine energy companies had emerged from universities as 'spin outs', indicating that the UK had been relatively successful in demonstrating marine energy technologies.

Much was made by the group of the transition from an SME, to an Original Equipment Manufacturer (OEM). Broadly, the group recognised SMEs in this sector as small, niche-level companies, which are closely involved in the development, manufacture and selling-on of marine energy technologies. The group saw these companies as 'one stage on from the mad Professor', typifying an embryonic industry. In contract, OEMs resell other companies' product under their own name and branding, offering their own warranty, support and licencing services for the product. The group explained that OEMs constituted much larger, wealthier companies, which were capable of 'scaling-up' marine energy technologies for commercialisation. The group generally regarded the transfer of innovative marine energy technologies from SMEs to OEMs via mergers and acquisitions as a necessary precursor to the large-scale commercialisation of these technologies.

Whilst some university inspired marine energy technology innovations had been adopted directly by OEMs without first being commercialised/demonstrated via SMEs, the majority had first been adopted by SMEs and later incorporated within larger OEMs via a process of mergers and acquisitions. For example, Siemens acquired Marine Current Turbines in early 2012. The group explained that because 'nowhere in the world is an industrial leader in marine energy at present' that large OEMs were happy to focus their attentions on the UK. Additionally, they highlighted the important role UK government support for marine energy had played in facilitating the transition from SMEs to larger multi-national marine companies. In particular, they underlined how the increase in the number of ROCs available for marine energy generation from 3 to 5 had attracted a number of larger companies to the UK marine energy sector. However, the group expressed concern around what Electricity Market Reform (EMR) might mean for the marine energy sector.

Challenges

One of the challenges facing the commercialisation and demonstration of marine energy technologies was the pressure on industry to commercialise technologies to generate revenue, before being 'market-ready'. The Archimedes Waveswing, developed by AWS Ocean Energy, was a good example of a technology, considered to have significant commercial potential, which had been required to 'run before it could walk'.

This pressure was generated in part by the companies themselves who wanted to realise the profit-making potential as quickly as possible, but also in part by investors (e.g. venture capitalists) responsible for financing the R&D stage. The Marine Renewables Deployment Fund (MRDF) had required developers of eligible technologies to demonstrate their market readiness. This meant that companies had engaged investors with a view to commercialising the technology before they had made the efforts necessary to make the technology market ready.

Another challenge was that the marine energy sector and the broader UK energy landscape are liable to change during the lifetime of academic research and applied R&D projects. Consequently, research outputs generated by universities and companies may lose their attraction to organisations involved in demonstration and commercialisation. Once a research project is underway, it is 'difficult to turn the ship around' even if this might be desirable from the point of view of end-users.

One means of addressing this challenge might be for research institutes to spend more time anticipating how the energy landscape might change during the length of the project. Another approach would be to ensure that research outputs had multiple applications. The example of materials science was cited. Outputs in this field normally have multiple applications and are more likely to be relevant to the needs of end-users than outputs which have a very narrow field of application.

Successes and challenges in the interface and handover between innovation bodies and schemes

The group did not spend much time discussing this question but did manage to highlight how the different ways various bodies work can make collaboration challenging at times. The group illustrated this with the example of how an academic used to undertaking research funded by EPSRC would most likely have to operate differently in terms of timescale and outputs when being supported by TSB or ETI. In addition, different innovation bodies across the R&D chain tend to operate using different innovation metrics. This can make collaboration difficult because different bodies measure outputs and ultimately their level of success in different ways.

The role of R&D infrastructure and testing sites in the innovation journey

The group ran out of time before they were able to discuss this question in any great detail. However they did note the important role that centres of excellence such as the SUPERGEN UK Centre for Marine Energy Research and the European Marine Energy Centre (EMEC) had played in facilitating the transfer of marine energy technology research and the commercialisation and demonstration of marine energy technologies. However, the slow progress at Wavehub in South West England, which remains unused since completion in 2010, was noted. Design may lead to different levels of effectiveness for different centres of excellence. This provides an opportunity to learn lessons from different approaches.

4.6 Café Dialogue Group 4 – Marine Energy

Successes and challenges in transferring basic physical science research into energy applications

The group was of the view that the UK had been very successful in the development of 'spin out' marine energy SMEs. This was attributed in part to the concerted effort of most universities to move beyond the publication of papers in academic journals towards activities that generated impact on the wider energy sector. This was also partly attributable to Government support for marine energy RD&D, for instance by making capital available. The group attributed the Government's support for the transfer of marine energy research from universities to other bodies along the innovation chain to a desire to ensure that capabilities are retained for the UK's economic benefit. This had not been the case with wind energy.

Successes and challenges in commercialising and demonstrating energy technologies

The group noted that more funding than ever is currently available to support demonstration of marine energy technologies. Demonstration has also been supported to an extent by investor surveys (e.g. KPMG's Energy Survey). These have helped bodies engaging in applied marine energy R&D and beyond to understand how they might raise the necessary capital from investors to support their activities. However, investors are often less familiar with marine energy than, for example PV, which can make them sceptical about investing: 'Silicon is understood by Silicon Valley, wave is not'.

The group paid attention to the characteristic differences between wave and tidal energy and how these have to some extent enjoyed different innovation journeys so far in the UK. For instance, unlike in the UK tidal energy sector, there is no clear technological lead for any single wave technology. Consequently, the wave sector may require additional scoping work to ascertain which technologies would best fit the UK's needs. Drawing on these differences they explained that it was important to acknowledge the differences between these marine energy technologies when developing strategies for their commercialisation and demonstration. However, despite the important characteristic differences between these two sub-sectors, the group explained that wave and tidal energy technologies may have benefitted from being discussed 'as one' because they are subject to a number of similar barriers. Consequently, these sub-sectors have been able to draw lessons from one another, such as key barriers and associated solutions to the development of commercial marine energy 'farms'. The ability to lesson share in this manner is likely to have supported the development of the marine energy sector as a whole.

There are various challenges facing deployment and commercialisation of marine energy, some of which are specific to the sector:

- Large scale deployment of marine energy means that infrastructure needs to be built and assembled locally rather than manufactured remotely and distributed globally.
- Unlike technologies such as PV, there is a limited number of suitable sites for demonstration and commercialisation in the UK.
- The scale and cost of marine energy demonstration and deployment means that investors are required to take some degree of ownership of the technology. This constitutes an added risk when comparing marine to smaller-scale technologies and can put off investors.
- Marine energy is particularly sensitive to environmental barriers (e.g. disturbance of coastal ecosystems). There are currently no clear methods for assessing these.
- The challenge is not just scaling up a single marine energy generation unit but also deploying large numbers as an array, making deployment and commercialisation more complex.
- "Patentability" is relatively low in marine energy, particularly compared to PV.

The role of R&D infrastructure and testing sites in the innovation journey

The group noted how important UK testing infrastructure, a legacy of the UK's maritime history, had been in the demonstration and deployment of marine technologies. The value of specific facilities were identified, such as EMEC in the Orkney Isles. The group also stressed the importance of collecting, storing and disseminating data relating to the innovation journey for marine energy. Because marine energy is a 'user inspired' technological innovation, constant feedback and learning via testing is needed throughout technology development. Testing has often been undertaken with the support of ETI and, while data has been generated, it has not been widely disseminated because of its commercial sensitivity and the terms of non-disclosure agreements. This raises two key questions: 1) what data do innovation bodies require to support the development of the marine energy sector; and 2) how can this data be disseminated in a responsible manner?

The group believed that benchmarking data is required to compare both the performance of different forms of marine energy technology and the performance of the same technology at different sites. This enables developers to 'understand where they are in terms of development'. Baseline and current environmental data from testing was another important body of information. This would enable marine energy developers to understand the environmental impacts of marine energy generation. The infrastructure for environmental data has been well-developed at Wave Hub but not at EMEC. It was noted that the Crown Estate is making efforts to improve environmental data infrastructure in the UK.

The group then explored how bodies of data relating to marine energy might be made more available, while protecting the interests of organisations holding IP. One recommendation was that data could be suitably anonymised to ensure that the no individual company can be linked with the performance marine energy technologies and sites. It was acknowledged that this might be difficult in practice due to the small number of technologies and sites in the UK. The second recommendation was that data could be fed back into the marine energy SUPERGEN, which could use it in confidence to guide its future work and/or feed into their analyses. Even if a protocol could be developed for data dissemination, a data infrastructure would also be needed to make easily available in a suitable form. The group believed that organisations such as the ETI and the Crown Estate were most suited to this task.

5. Breakout Session 2: Towards Deployment - Technology Roadmaps

5.1 Introduction and Methodology

The second Breakout Session focused on pathways towards deployment. Attendees were split into six groups, three focussing on marine energy and three on molecular PV. Each group was given the task of producing an illustrative “roadmap” for an idealised innovation process for their area, ‘user-inspired’ In the case of marine renewables and ‘research-inspired’ in the case of molecular PV. The roadmap was intended to show the journey from basic research to pre-commercial demonstration and deployment, showcasing the innovation bodies, schemes, incentives, physical infrastructure and test-beds that might be needed along the way.

The roadmaps were produced on sheets of A0 paper, using the template shown below as a guide. Participants were invited to use this framework if they desired, but they could also formulate and use their own framework if the one provided would not fit their needs. A rapporteur from each group presented their roadmap in a plenary session.

	Research		**Applied Research and Development**			**Demonstration**		**Pre-commercial Deployment**	
	TRL 1	TRL 2	TRL 3	TRL 4	TRL 5	TRL 6	TRL 7	TRL 8	TRL 9
Innovation Bodies and Funders									
Specific Schemes/ Grants/ Incentives									
Infrastructure and Test-bed Resources									

Table 1 Example framework for the road-mapping exercise

The following section presents key cross-cutting points arising from the exercise. Sections 5.3 and 5.4 present the specific results for molecular PV and marine renewables respectively. Section 5.5 summarises the final plenary session.

5.2 Key Points

5.2.1 Research

- There needs to be stronger mechanisms for feeding back findings from later in the innovation process to the basic research stage.
- International collaboration is very important at this stage.
- The private sector is not very active at this stage – tax incentives to support basic research and research 'clustering' would be welcomed.
- Greater national co-ordination and interdisciplinary research was stated as important to combat 'siloing' in research disciplines.
- Professional bodies have an important role to play at this stage.

5.2.2 Applied Research and Development

- 'Champions' are viewed as important to promote sectors to policymakers and bodies.
- There is seen to be a 'gap' in capabilities– a need for better, more flexible infrastructure and testing facilities.
- Understanding potential markets is very important. Spin-outs could use more help in this area.
- There is a need for better-funded Technology Innovation Centres (TICs), as well as more structured public programmes to entice private investors.

5.2.3 Demonstration

- This sector is dominated by private and late-stage public funding. Easier access to public funding could prevent technologies and companies from failing at this stage.
- Tax breaks for funders and a reduction in the administrative load could help to increase the flow of money and decrease burdens on spin-out companies.
- Marine technology especially has trouble attracting venture capital funding – larger corporations could play more of a role here.
- A system of Fraunhofer-style centres is important here – TSB's Catapult centres go some way towards filling this gap, but not all the way.

5.2.4 Pre-commercial Deployment

- Clear signals from government, such as the Renewables Obligation, feed-in tariffs and other policy signals, are very important at this stage to attract and ensure private support.
- Socio-economic acceptance of technologies is important for innovative technology to enjoy wide-scale uptake communities will have to want and accept the product.
- UKTI and other export organisations are important here in promoting a global market for the technology.

5.3 Results: Molecular PV

Table 2: Roadmap #1 for Molecular PV

	Research	Applied Research and Development	Demonstration	Pre-commercial Deployment
Funders	International Collaboration	Industry Led (TSB)	Venture Capital	
	RCUK	Sociéte Européenne des Ingénieurs et des Industriels (SEII)		
	No silos - responsive mode in materials modelling	ERANet for PV	Demonstration funding for new manufacturing technology	Communities
	Horizons 2020	Challenge-led Research and Innovation activities		Corporates investing in start-ups
	Early Sandpits			Ofgem/DECC
Schemes/Incentives	Underpinning Science Funding	There's a capability gap here!	Innovation/research/policy translators	Government incentive schemes
	Mission-driven funding with a PV priority			Good regulation
				Support for adoption of new technology
Infrastructure	Tax Incentives	Marketing		Flexible Manufacturing Capability
	Clustering of industry around science/infrastructure campuses	Flexible Teaming to Address Market Need	Policy	
	Test Facilities		Corporates investing in start-ups	
			Risk Portfolio analysis	
			Business Development	

Table 3: Roadmap #2 for Molecular PV

	Research	Applied Research and Development	Demonstration	Pre-commercial Deployment
Funders	RCUK	Venture Capitalists		Large Capex Investment from Manufacturer
	Utilities	Larger Industry	Strategic Investment from Industry	Strategic Funds
	International Collaboration	TSB	Manufacturers	Government (deployment)
	EU Funding			
Schemes/Incentives	Lift Restrictions on Industrial R&D Spend	Knowledge Transfer Partnerships	Standards and Certification	Social Context of Deployment
	Informal Industrial Collaborations	Seed Funding		Clear deployment support (e.g. FiT)
	CASE Students			
Infrastructure	Equipment funds for university lab.	Research Skills	Identifying the correct industrial partner with the right infrastructure	
	Training/Skills (PhDs)	Pre-Pilot Incubator Lab		Manufacturing Facilities
		Training/Skills (apprenticeships)		Industrial Policy (not a picking winners policy)

Table 4: Roadmap #3 for Molecular PV

	Research	Applied Research and Development	Demonstration	Pre-commercial Deployment
Funders	European Research Council	Carbon Trust	VC funding *	
	EPSRC	Climate KIC (Knowledge and Innovation Community)	Lift Restrictions on State Support	Government Support for Demo Projects *
	Feedback to Research Councils *	TSB	More TSB funding *	
	EU money for basic research *	Knowledge Transfer Partnerships/Schemes	Easier Access to TSB funding *	
		FP7/Horizon 2020 (EU)	Regional Development Agencies	
Schemes/Incentives	National Solar PV Research co-ordination *	Better Technology Innovation Centres	DECC Energy Entrepreneurs Programme	Mechanism to reduce Corporate Financial Risk *
	Corporate funding for research	Incubator Schemes *	DECC Incubation Support	Government Procurement *
		Understanding of Markets *	R&D Tax Rebates	
		Corporate Analysis of Research Initiatives *	Energy Policy on PV *	
		Business Awareness Training for Spinouts *	Revenue Streams *	
Infrastructure	Royal Society	Incubator Labs	Fraunhofer-like Centres *	State Aid Rules *
	Royal Society of Chemistry, Institute of Physics, Institute of Materials	Knowledge Exchange *	Access to Capital Initiatives	
	Outreach			

* Denotes a desired characteristic of the UK energy innovation system but one that is not currently present

5.4 Results: Marine Energy

Marine	Research	Applied Research and Development	Demonstration	Pre-commercial Deployment
Funders	RCUK	ETI		UKTI/SDI
	EERA	TSB	Devolved admins	Large Industrials
	Independent Assessors	DECC	Standards and Certification	
		EU FP7		
		Venture Capitalists		
Schemes/Incentives	Supergen	Sector Champions	Environmental and Social Impacts Assessment	ROCs
	Tech transfer from other sectors	Array Demonstrator Fund	Marine Renewables Deployment Fund	NER-300 (ETS New Entrant Reserve)
		NERC response, Flowtec etc		EMR
		Offshore Renewable Catapult		Technology transfer/development for cost reduction
		Technology Marinisation Fund		Saltire Prize (Scotland's marine renewables challenge)
Infrastructure	Flow Wave Testing Tank	EMEC Nursery	Wavehub	Common Installation Platforms
	Computer Aided Design	Design and build Centre of Excellence		Stable Policy
	Rapid small scale 3D printing	Exchanging of data and funding applications between funders		
	(Riso lab) Wave and Tidal tech benchmarks			
	Large Computer Clusters			

5.5 Cross-cutting conclusions

5.5.1 Research

International collaboration featured heavily on all groups' roadmaps, with EU funding, provided through FP7, the forthcoming Horizon 2020 and the European Research Council all receiving mentions. One area the group thought deserved greater attention was EU funding for basic research questions. It was perceived that EU funds were focused more on later-stage research and applications. Corporations may support basic research due to perceived downstream benefits, but most money at this stage comes from public bodies. There was a desire to see the private sector more active at this early stage. Venture capital and private equity could play an important role. Tax incentives and infrastructure investment could encourage more clustering of industry around science campuses.

There was considered to be too much 'siloing' of research at the lower TRLs with less collaboration between groups and disciplines than would be ideal. Greater national co-ordination was suggested by a couple of groups, with greater mission- or challenge-driven funding being provided. A system of more formal industrial collaborations, possibly in conjunction with greater use of CASE doctoral studentships, was suggested. Greater focus on incentives for interdisciplinary collaboration at the basic research stage could lead towards application as different disciplines need to feed into the development of specific products. Technology transfer from other sectors was especially important in marine energy.

Professional bodies, such as the Royal Society, the Institute of Physics, the Institute of Materials and the Royal Society of Chemistry, can help by connecting scientists, influencing policy and advancing interdisciplinary knowledge. Outreach programmes to educate general audiences about the potential and importance of early-stage research are also important. For marine renewables, large scale testing tanks, as well as computational design and modelling facilities, were viewed as important.

While the Research Councils may provide 'blue-sky' thinking, feedback mechanisms from later stages in the innovation journey are needed to influence and shape new basic research efforts during the earlier stages. Market signals, in the form of policy incentives and market and regulatory structures, are similarly important in that they provide incentives to develop and improve specific technologies.

5.5.2 Applied Research and Development

At this stage, basic Research Council funded research begins to be handed over to the TSB and other applied-stage innovation bodies. All groups mentioned the TSB, and several mentioned the knowledge transfer partnerships (KTP) programs designed to share knowledge and experience between the academic and industrial worlds. EU projects are more important at this stage, with ERANet for PV, the Solar EU Industrial Initiative and continuing FP7/Horizon 2020 programmes offering support. Marine energy is covered by the TSB's Offshore Renewables Catapult, the ETI and several TSB and DECC funding programmes. Sector champions were also viewed as very important in this area, to explain and promote the potential of the sector to outside interests and organisations.

All groups thought there was a significant gap in capabilities in this area, with a lack of well-designed schemes and incentives to move applied R&D forward. Flexible, accredited test facilities to support development are needed, perhaps complemented by a pre-pilot manufacturing lab for academics to test small demonstrators and proofs of concept. Technology and Innovation Centres (TICs) need to be better funded and focused, and there should be more incubator schemes, as well as business awareness training for spinout companies. Understanding potential markets for the technology at this stage is extremely important. One group advocated the creation of a central think-tank exploring how technologies could be implemented and who the customers would be. It is especially important to attract venture capital and corporate funding at this stage in order to avoid the so-called 'valley of death' around early demonstration. Centres of Excellence were also viewed as important.

5.5.3 Demonstration

Private funding becomes extremely important as technologies move to the demonstration stage. Participants identified the need for strategic investment from large industry players as well as funding from manufacturers, venture capitalists and private equity and finance. The Regional Development Agencies (RDAs) used to be major public sector players in this field, and DECC schemes such as the Energy Entrepreneurs Programme, Marine Renewables Deployment Fund and Incubation Support help to provide extra support. The abolition of the RDAs leaves a significant gap with only Scottish Enterprise now fulfilling this role. Extra and easier access to TSB funding could help support companies and technologies during this notoriously difficult stage. The burden of administration and management processes could be usefully minimised for smaller start-ups. The extension of tax breaks for corporate finance and venture capital directed at demonstration would increase the flow of private financing. However, it was noted that the marine renewables sector may not be suitable for venture capital finance due to the large upfront fixed costs and slow rates of return. Larger corporate support may be more important for this sector. Other potential sources of funding, such as Ofgem and the Green Investment Bank, could play a role in the future.

An extra indirect incentive could be the adoption of a clearer, more focused government policy on PV. A system of Fraunhofer-style labs, while expensive, could provide a strong path to the commercialisation of technologies. The Catapult centres announced by the TSB go some way towards fulfilling this goal, but not entirely. Public schemes could help start-ups to identify the correct industrial partners along with the right infrastructure and market access.

5.5.4 Pre-Commercial Deployment

At this stage, a large chunk of funding is provided by corporates, strategic finance funds and large investors. The quality and strength of regulation and policy support for deployment is very important at this stage, as it helps to attract private finance. If signals from government are not clear and consistent, private funders may not invest. Mechanisms such as the Renewables Obligation and feed-in-tariffs are essential. The EMR reforms currently going through Parliament as the Energy Bill are important for the large-scale adoption of all low-carbon technologies, including marine renewables

The social context and potential barriers to public acceptance need to be understood at this stage in the process. Communities need to want and accept a technology for it to achieve wide-scale uptake.

The main infrastructure need at this point is for large flexible manufacturing facilities. Common installation platforms are also very important for marine technologies.. UKTI has an important role to play in promoting the technology overseas to create markets and foster international collaboration.

5.6 Plenary Session

Jim Skea outlined what he considered to be the key messages from the road-mapping process.

1) There are significant differences between the PV and marine sectors. PV can be assembled and shipped from a science park. Marine devices are huge, require large-scale facilities for construction and cannot easily be shipped around.

2) A consistent message is that it is important to have a long-term vision to go along with a research programme. This vision could be signalled by market policies, for example FITs or ROCs.

3) Communication between what's done in the research base and what's done at the deployment level needs to be two-way. With the increase in overall spend on energy RD&D, EPSRC has moved back towards more basic science, while TSB and others have moved into the deployment space. We need to know what has made a difference in practice and feed that back into basic research.

4) There are fundamental environmental science needs relating to renewables deployment. We need to understand both the environmental resources upon which enable energy technologies and the environmental impacts. Social science and community acceptance is also important.

5) The role of the private sector has not been consistent. Since 2008, venture capital interest has waned and it has become more difficult to attract private investment. PV attracts funding more easily than marine reflecting the scale issue which distinguishes the two technologies. Ideally private funders would get involved at the earlier TRLs, for example through participation in research consortia. Start-ups and SMEs inevitably find it hard to engage at the early TRL stage due to their shorter-term concerns.

Final comments from participants addressed connections between Research Council funded research and later stages in the innovation chain and international connections.

There is challenging to encourage links between Research Councils-funded research and later stages in the innovation chain because the Research Excellence Framework (REF) focuses on academic journal paper publication and does not value innovation chain linkages highly. It was pointed out that REF is the responsibility of the Higher Education Funding Councils and is outside the RCUK remit.

Internationally, it was noted that the US and Japan appear to have more balanced public/private partnerships with incentives in place. The Fellowship team was invited to address this issue at future events. Collaboration at the EU and wider international levels had emerged as key issue several times at the workshop. The Fellowship team was also invited to give this more consideration. It was noted that the role of international innovation systems and the extent to which they impact the UK system are at the heart of the Fellowship research programme which follow the production of the research and training prospectus in Autumn 2013.

Annex A: Workshop Programme

10:00	**Coffee and registration**	
10:30	**Opening Plenary Session** Overview of the workshop and the wider process Messages from the process so far	 Jim Skea, Strategy Fellowship Aidan Rhodes, Strategy Fellowship
10:50	**Views from the Innovation Chain** Low Carbon Innovation Coordination Group Research Councils Energy Programme EPSRC Physical Sciences theme Technology Strategy Board	 Paul Durrant, DECC Jason Green, EPSRC Nigel Birch, EPSRC Rob Saunders, TSB
11:30	Discussion	
11:45	**Introducing the case studies** Marine renewables Molecular PV	 Henry Jeffrey, Edinburgh Jenny Nelson, Imperial
12:15	**World cafe: unpicking the innovation journey**	
13:00	**Lunch**	
13:45	**Break-out groups - Towards deployment: technology roadmaps** *Outcome:* Detailed 'roadmaps', showcasing a journey from basic research to commercially deployed product, one 'user-inspired' and the other 'research-inspired'.	
15:00	**Tea**	
15:15	**Report-back and Discussion** Groups present their 'roadmap' of the innovation journey. This is followed by a structured discussion on each roadmap.	
16:15	**Led discussion** Standing back: what are the wider lessons?	
16:30	**Close**	

Annex B: List of Attendees

First name	Surname	Organisation
Duncan	Eggar	BBSRC
Paul	Durrant	DECC
Kate	Payne	DECC
Henry	Jeffrey	Edinburgh University
Matthew	Hannon	Energy Strategy Fellowship
Aidan	Rhodes	Energy Strategy Fellowship
Skea	Jim	Energy Strategy Fellowship
Jason	Green	EPSRC
Jonathan	Radcliffe	ERP
Jim	Skea	Fellowship
Chiara	Candelise	Imperial College London
James	Durrant	Imperial College London
Philipp	Gruenewald	Imperial College London
Jenny	Nelson	Imperial College London
Stefan	Pfenniger	Imperial College London
Stuart	Irvine	IoM3
Tim	Stallard	Manchester University
Scott	Couch	Marine Current Turbines
Chris	Franklin	NERC
Sally	Reid	NERC
Fernando	Castro	NPL
Stefan	Bojanowski	Ofgem
Henry	Snaith	Oxford
Dierdre	Black	RSC
David	Butler	Scottish Enterprise
Rob	Saunders	TSB
Nicola	Combe	UKERC
Mike	Weston	UKERC

Annex C: List of Energy Strategy Fellowship Reports

Report 1: *Summary of Stakeholder Views and Way Forward*, September 2012

Report 2: *Energy Strategy and Energy Research Needs*, November 2012

Report 3: *The Role of Environmental Science, Social Science and Economics*, December 2012

Report 4: The Research Councils and the Energy Innovation Landscape, March 2013