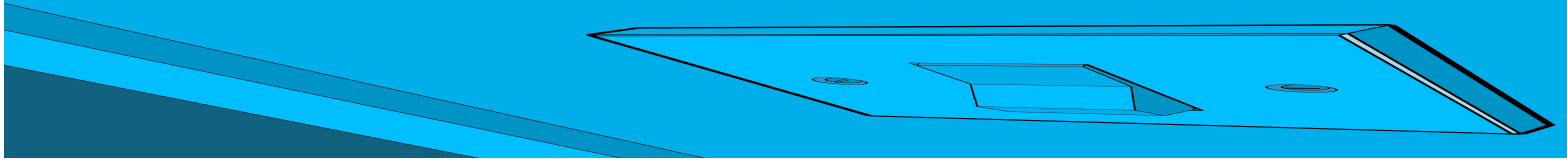


UKERC

A FRAMEWORK FOR AN INTERNATIONAL MARINE RENEWABLE ENERGY ROAD-MAP

Workshop Report, 23rd-24th January 2007

Reportage & editing by
Dr Markus Mueller, University of Edinburgh
Helen Bailey, University of Edinburgh
Jane Palmer, UK Energy Research Centre Meeting Place
Henry Jeffrey, University of Edinburgh

Event organised and sponsored by:

UKERC The meeting place

THE UNIVERSITY OF EDINBURGH

UK Energy Research Centre

Executive Summary

There is currently no detailed technology research road map for marine renewable energy in existence, although there are several bodies currently doing work in this area, including UKERC, CA-OE and the IEA Ocean Energy Group. In order to avoid duplication of effort and ensure a more coherent and co-ordinated approach, the principle objective of this workshop was to establish a strategy for a common international road-map for marine renewable energy, that reflects the needs of the community as a whole, but also includes regional/national requirements.

The aim of the workshop was to bring together key members of the marine renewable energy community, including academics, industry, policy-makers and funders, to discuss the current status of road-maps in this sector and identify the opportunities for bringing the existing work together into a single road-map to the benefit of the overall sector. A programme and attendee list, along with copies of the presentations given at the workshop are available on the Meeting Place website (http://www.ukerc.ac.uk/content/view/376/673).

DAY 1

1 Review of existing work marine road-mapping and prioritisation of R&D.

Presentations were made by UKERC, European Coordinated Action on Ocean Energy, IEA Ocean Energy Group, BWEA Marine Group, Ocean Renewable Energy Group Canada and the EPSRC Supergen Marine Consortium. Subsequent discussion points fell into 7 themes: EU Funding, Internationalising the Roadmap, Duplication of Research, Roadmap methodology, Scenario up to 2020, Gaps in Expertise , Research Priorities.

2 Identifying Gaps and Barriers.

The delegates were divided into four groups and asked to discuss the current body of road-mapping work within the context of the presentations given during the afternoon. The discussion was intended to be high level, not a detailed discussion of the research priorities, with a focus on three key questions:

- What do you consider to be the main objectives or goals of a marine energy road-map?
- What other aspects of the marine sector need to be added to the current body of work?
- Is there any existing work outside of the known landscape that can fill the gaps?

3. Discussion Summary

Discussion points from DAY 1 activities are summarised below. More detail can be found on pages 2 to 7 of the main report.

- The roadmap should not be a paper document, but a living document which is easily accessible to all stakeholders, including academics, technology developers, project developers, policy makers, government, investors and environmentalists.
- The UKERC road-map as presented is too academic focussed and needs to include the following clients: technology developers, project developers, policy makers and investors.
- Training and capacity building will be major challenges, and these need to be highlighted in the roadmap.
- The road-map has to be outward facing and based upon evidence gathered from the community.
- There needs to be strong links between other road-map or similar activities within IEA Ocean Energy Group and the CA-OE for example.
- IEA will provide guidance and will help collect and distribute information but will not be pro-active in developing the road-map – this is a strong network and will provide credibility to the road-map and process

- The technology road-map should be common across all countries, but road-maps on policy and environment will need to be country-specific, based on the technology road-map.
- Realistic and achievable targets need to be set as the final destination.
- The focus on marine renewables R&D in the UKERC roadmap and landscape analysis has resulted in not identifying knowledge transfer opportunities from other industrial sectors such as shipbuilding, wind energy and offshore oil and gas.
- It's important to interpret the targets given – ie the targets presented imply that a set amount of new devices need to be made per week – 5MW per week from 2013/2015. This needs to be discussed as the target must be realistic.
- Someone needs to take the lead and show where we are so far and then add value to the current attempts of roadmaps.
- Communication channels – we must ensure that all sectors of the industry are talking to one another, so that we know who is doing what and when.

DAY 2

1. Key Issues for Marine Renewable Energy.

Participants were invited to identify what they felt were the key issues to be addressed, and fell into the following 9 themes. More detail on each of these themes can be found in Section 2.1 in the main report.

- Links/collaboration, Roadmap issues, Funding, Communications, Materials & Components, Device issues, Data, Markets, Regulation

2. Vision Statement, Business Strategy and Technical Strategy for an International Roadmap

The Batelle approach has been adopted in the formulation of a roadmap for marine renewable energy. It involves defining a Vision Statement supported by a Business Strategy, which in turn is supported by a Technical Strategy. These have been defined for the UKERC roadmap draft based on output from 3 workshops held in 2005. The community was consulted on this approach through a questionnaire at the European Ocean Energy Conference in Bremerhaven in November 2006. The vision, business strategy and technical strategy are defined below and results from the questionnaire can be found on the UKERC website (http://www.ukerc.ac.uk/content/view/376/673).

Proposed Vision Statement:

Marine renewable energy should make a significant contribution to electricity generation in 2020 at a unit cost competitive with other forms of generation in the energy mix

Proposed Business Strategy:

1. Exploit the UK marine energy resource taking into account the environment and marine users.
2. Encourage collaboration between academia and industry.
3. Train the next generation of engineers required to sustain the industry.
4. Build up manufacturing facilities.
5. Export high value products – design expertise.
6. Promote a market driven industry.
7. Provide world class test facilities in both wave and tidal current systems at all scales of development.
8. Establish standards and certification.
9. Work closely with the onshore grid operator to enable the economic exploitation of the marine resource.
10. Installation and operation of small wave and tidal current farms.
11. Develop a supply chain to support technology developers.

Proposed Technical Strategy:

1. Test Facilities
2. Resource Modelling & Measurement

3. Device Modelling and Design
4. Electrical Power Infrastructure and Technology
5. Power Take Off & Control
6. Moorings and Sea Bed Foundations
7. Installation and O&M
8. Engineering Design/Survivability
9. Life Cycle/Manufacturing
10. Environmental and Marine Users
11. Standards & Certification.
12. Policy & Economics

Discussion Summary
The salient points are summarised in the bullet points below:

- The vision statement should be sharp and focused and optimistic, with an end date of 2020.
- It is important to be clear who the vision statement is aimed at and who we are trying to influence – targets should reflect the intended audience.
- Costs in 2020 are completely unknown for all energy industries but if it has made a significant contribution by 2020, then it will have to be cost competitive by definition
- Cost competitiveness does not necessarily have to be about electricity generation. Desalination is a much bigger market than electricity.
- The business strategy should reflect the fact that we are trying to build an industry and the output of that industry is a commercially viable product.
- Areas that need to be included in the business strategy are: market drivers, support industries (supply chain to technology developers), influence of policy makers, the needs of technology developers, project developers and investors (not just R&D) and the product lifecycle.
- The topics should be grouped into bigger strategic objectives and ordered in a logical way, in sequential steps say, so that prioritisation is possible.
- 'Standards and certification' are double speak for how to meet market specifications as the product doesn't have a client. Engineering for long term performance is part of meeting client's needs – timescale is important when calculating standards.
- Need to know how the technical strategy links with economics.
- System modelling should be included in the technical strategy. The current list simply looks at the separate parts.
- Standards and certification are necessary for getting finance and insurance. Insurance is reduced as standards are accepted.
- Harmonisation of standards will enable marine energy to be a global market and avoid the difficulties in the wind industry, where different countries have different standards.
- Standards should not act as a bottle neck, preventing development. A test device shouldn't have to comply to the standards of a full scale device
- There was a debate as to whether guidelines were preferable to standards.

3. Scenario – what are the destinations to 2020?

Markus Mueller outlined the proposed UKERC scenario for marine renewable energy which illustrates a final destination of 1-2GW of installed capacity at 2020, with the key milestones along the way. The scenario is presented in Section 3 in the main report.

The participants were divided into four groups and were first asked to spend five minutes individually identifying the three main challenges facing the marine renewable energy sector before sharing these within their groups, Each group was also provided with a copy of the UKERC scenario and asked to consider the following questions:

- What are the most appropriate milestones to achieve enroute and what is the most appropriate final destination for the marine energy industry?
- What is the correct timing of the milestones?

- What would be the regional differences?
- Is it possible to have one scenario covering the global marine community?

Each group was provided with a copy of the UKERC scenario to discuss and to mark up any proposed changes. In the feedback sessions the groups presented these modifications and summarised their discussions. A detailed list can be found in sections 3.1 and 3.2 of the marine report.

Discussion Summary
The salient points are summarised in the bullet points below:

- Scenario as presented is too technology focussed, hence the requirement for including additional milestones and outcomes relating to finance, policy and training etc.
- There appears to be general agreement with the technology based tasks.
- The scenario needs to include the needs of the financial community, project developers, manufacturing, and the supply chain, in order to meet the final 2020 target.
- The scenario could consist of a number of layers: R&D layer (as presented), infrastructure layer addressing manufacturing, policy/regulatory layer, & an environmental layer. Some of the layers could be generic or country specific.
- The final target in the scenario could reflect installed capacity, financial objectives and also markets other than electricity generation, such as desalination.

4. What are the research timelines to meet the scenario?
Each item in the Technical Strategy is considered as a Technology Working Group, and within each of these there are a number of research priorities, which were defined at a workshop introducing the UKERC Marine Energy Research Network held on 14th April 2005 at the University of Edinburgh. The research priorities in each Technology Working Group have been prioritised and developed into timelines. The output of these Technology Working Groups should then satisfy the requirements of the milestones enroute to the final destination defined in the scenario.

The delegates were divided into four groups as for the previous session and were provided with three timelines to discuss and address the following questions:

- What other activities should be included in the Technology Working Group
- Is the timing appropriate?
- Who is already doing this work?
- What is the best mechanism to identify who would be most appropriate to do this work?

Specific comments on each of the Technology Working Groups is provided in section 4.1 in the main report.

Discussion Summary
The salient points of the discussion are outlined below:

- A number of additional activities need to be included in the technology working groups.
- It is still not clear who the main providers are or should be for the activities in the technology working groups.
- There was an overwhelming feeling that standards should be replaced by BEST PRACTICE.
- Access to real world data for validating models is very important and requires collaboration between Unis and Developers, without compromising IP. A strategy needs to be formulated to enable this to take place, with buy in from developers.
- We need to understand why developers are not using University tanks for scale testing.
- Based upon the number of points raised, Engineering Design is probably the major issue facing developers.

- It was also proposed that there is an important Technology Working Group missing: *System Modelling and Performance*.

5. Recommendations/Actions

Since the roadmap is a living document it is more appropriate to make a list of recommendations or actions rather than a conclusion. The following is a list of recommendations and actions based upon the detailed discussions outlined in the main report. The intention is to use this list to develop an international marine roadmap based upon existing activities within the community, with UKERC taking the lead.

- Extend the landscape analysis to include other industrial sectors to investigate the potential for knowledge transfer to fill gaps in expertise.
- Assess the manufacturing and supply chain infrastructure required to meet the targets, and include in the roadmap.
- Expand the client base of the roadmap to include the needs of all stakeholders.
- Adopt a flexible and transparent roadmap framework so it can be applied to any country.
- Make the roadmap accessible to an audience reflecting the wide range if stakeholders.
- Make the roadmap web-based for ease of access and maintenance.
- Include the following additional strands in the roadmap: training and capability, infrastructure, finance.
- The relationship between all marine networks needs to be formalised.
- Modify the business strategy to reflect the fact that the output of that industry is a commercially viable product.
- Expand the business strategy to include: market drivers, support industries (supply chain to technology developers), influence of policy makers, the needs of technology developers, project developers and investors (not just R&D) and the product lifecycle.
- Group topics within the Business Strategy and prioritise them.
- Replace *Standards* with *Best Practice*.
- Include System modelling in the technical strategy.
- Modify the scenario so that it includes the needs of other stakeholders such as financial community, project developers, manufacturing, and the supply chain.
- Expand the scenario into of a number of layers: R&D layer (as presented), infrastructure layer addressing manufacturing, policy/regulatory layer, & an environmental layer. Some of the layers could be generic or country specific.
- Asses the final target in the scenario so that it reflects installed capacity, financial objectives and also markets other than electricity generation, such as desalination.
- Collate all the additional activities identified at the workshop into the technology work group timelines.
- Develop a framework to enable developers to share real physical data with academics without compromising developers IP rights.
- Add *System Modelling and Performance* to the Technical Strategy and hence the list of working groups. Hence identify the research priorities within this new group.
- Analyse the interactions between the Technical and Business Strategy.

Workshop Background

This report provides a summary of the presentations and discussions that took place over the two days, along with a list of the key recommendations resulting from these discussions. It should be noted that the authors accept that the report is not an exhaustive summary, but the authors feel that it provides an overview of the pertinent discussions. The transcript of the report has been built from flip charts and so its meaning may not be clear to people who did not attend the meeting. Please contact the report authors for clarification if necessary.

There is currently no detailed technology research road map for marine renewable energy in existence, although there are several bodies currently doing work in this area, including UKERC, CA-OE and the IEA Ocean Energy Group. In order to avoid duplication of effort and ensure a more coherent and co-ordinated approach, the principle objective of this workshop was to establish a strategy for a common international road-map for marine renewable energy, that reflects the needs of the community as a whole, but also includes regional/national requirements.

The aim of the workshop was to bring together key members of the marine renewable energy community, including academics, industry, policy-makers and funders, to discuss the current status of road-maps in this sector and identify the opportunities for bringing the existing work together into a single road-map to the benefit of the overall sector.

The workshop took place over two days and involved a mix of presentation sessions and facilitated sessions. The first day was focused on reviewing the road-mapping work already in existence, drawing on experience across a range of organisations. The second day was more heavily focused on discussing the over-arching framework for a common road-map and involved mainly self-managed small group work. A programme and attendee list, along with copies of the presentations given at the workshop are available on the Meeting Place website (http://www.ukerc.ac.uk/content/view/376/673).

About the Organisers and Sponsors

The subject of this workshop was proposed by Markus Mueller of University of Edinburgh, Marine Renewable Energy topic leader within UKERC's Future Sources of Energy theme, as part of the marine renewable energy road-mapping activity being undertaken by UKERC. A number of working papers on the UKERC's marine road-mapping activity can be found on the UKERC website (http://www.ukerc.ac.uk/content/view/254/452)The workshop was coordinated and sponsored by the UKERC Meeting Place.

The UK Energy Research Centre's mission is to be the UK's pre-eminent centre of research, and source of authoritative information and leadership, on sustainable energy systems. UKERC undertakes world-class research addressing whole-systems aspects of energy supply and use, while developing and maintaining the means to enable cohesive UK research in energy. A key supporting function of UKERC is the Meeting Place, based in Oxford, which aims to bring together members of the UK energy community and overseas experts from different disciplines, to learn, identify problems, develop solutions and further the energy debate.

Core Organising Team

Markus Mueller, University of Edinburgh Markus.Mueller@ed.ac.uk
Sarah Keay-Bright, UKERC Meeting Place sarah.keay-bright@ouce.ox.ac.uk
Jane Palmer, UKERC Meeting Place jane.palmer@ouce.ox.ac.uk
Henry Jeffrey, University of Edinburgh henry.jeffrey@ed.ac.uk

Day 1

1.1 Introduction

Markus Mueller, University of Edinburgh & Jane Palmer, UKERC Meeting Place

Markus Mueller welcomed the participants and outlined the purpose of the meeting whilst Jane Palmer discussed the agenda for the two days of the workshop and the format of the sessions, being a mix of presentation sessions and facilitated sessions involving small group work.

The intended outcomes of the workshop were presented as being:

- Discuss the final destination and milestones.
- Discuss the road-map methodology.
- Identify gaps in existing reviews and road-maps.
- Discuss a method for linking existing roadmaps.
- Identify what needs to be done to make the roadmap international and how national differences are incorporated.
- Identify actions to take the roadmap to the next stage after this workshop.
- Produce a workshop report

A number of issues were raised by participants in the general discussion:

- Suggested that 'international roadmap' is a very bold term, given that not all countries with marine renewable potential were present at the meeting.
- Those most active countries were represented, but it is accepted that a number of other countries with significant activity (or potential activity) were not present e.g. Australia, New Zealand, South Africa, USA, China, Japan. Some were contacted but were unable to attend.
- By engaging with the IEA Ocean Energy Group it is anticipated that other countries will be included in the wider consultation process following this meeting.
- The UKERC work on road-mapping has been presented in countries with a growing interest in marine renewable e.g. China and South Africa.

1.2 UKERC Marine Road-map

Markus Mueller, University of Edinburgh

1.2.1 Presentation: Setting the Scene & UKERC Marine Energy Road Map

Markus Mueller started by setting the scene for the workshop by presenting the case for an international marine technology road-map.

Markus went onto present the current work undertaken by UKERC on the marine road-map, outlining the general approach and methodology adopted by UKERC and the current status of the work. A possible scenario up to 2020 of 1-2GW installed in UK waters was presented along with the landscape study and accompanying analysis to identify gaps in expertise within the community.

1.2.2 Discussion from the Presentation

Theme 1: EU funding of device demonstration

- Presentation showed no EU funding directed towards demonstrators.
- However, it was reported from the floor that six devices at various scales have been funded at demonstration level and three at research level from the EU.

Theme 2: Internationalising the roadmap

- This workshop should be seen as a starting point leading to the production of something tangible, with a mechanism for including other contributions.
- The workshop is working from past documents, standards and guidelines, which are produced internationally. Hence there is a need to keep engaging the

international community, but there is also a need to take the lead, so that investment can be placed where it will be most effective for the marine sector.
- It was agreed that the roadmap should be a working document.
- There were a number of questions about how different countries and strategies could be incorporated into a single road-map and mechanisms for including those countries not present at the workshop.
- The road map should be global, initially with a focus on those countries with the greatest marine resource but flexible so that other countries can be included – a strategy is required for this.
- Flexibility is also required to cope with different government policy in different countries, i.e. the UK has problems with grid integration, but Portugal for example will not have the same issues. All countries have a need to have a different combination of economics and energy mix. These differences should be incorporated into one document, but we as a community have to identify them, which is where the consultation process comes in.
- The UKERC road-map work (in marine as well as other technology areas) has been presented in China, which has shown an interest but they don't have an equivalent road mapping process at present. In some areas they view the work as advanced and want to get involved. The road-map therefore has to have a mechanism for enabling such involvement.
- The demand for a road-map is the same in any country, and in fact previous road-maps have been referred to by numerous countries. We need to generate a tool that anyone can use and most importantly we need to focus on how the outputs are going to be used.

Theme 3: Duplication of Research
- It was stated that one of the reasons for having a road-map was to ensure research was not duplicated, but the duplication of research is important since different views and methods produce slightly different results and outcomes.
- The real danger is not actually knowing of previous research: it is important to review and be aware of previous research, but must also allow for diversity. This needs to be done in a dynamic way due to changes in development, policy and finance.

Theme 4: Road-map methodology
- It appears that the roadmap outputs are focused on the technology developers as a client but we should not forget the ocean power industry developers. They have different questions to the technology developers and they make the investments.
- Commercial project developers have different needs to technology developers and the road-map should reflect this.
- Currently the road-map is very much focused on research, which may mean it does not get the buy in from industry. It needs to be seen as relevant for industry too.
- Investors need to understand that the research is important to identify the most appropriate technology.
- The road-map must meet the needs of both developers and industry. Hence it should pick up problems for example in commercialisation and policy integration. The methodology is, therefore, important and not just in terms of addressing the needs of different parts of the sector, but also other countries.
- There may be more than one approach depending on were we are on the learning curve.
- As presented, the UKERC roadmap is focussed on research, but it is accepted that it should include the needs of the industry: both technology and project developers. The main section of the community consulted so far has been academic, which is clearly reflected in the focus of the road-map, but the industry is now being engaged through one-to-one interviews as part of the Supergen Marine Project. In addition the investment community should also be consulted and their needs fed into the roadmap.

Theme 5: Scenario up to 2020.

- The 2020 target provides a basis on which to identify the number of new devices that need to be made per week in order to achieve the target set, but this is very much at odds with the lack of supply chain support in the marine renewable sector.
- When the required volume of manufacture to achieve the target is added into the roadmap, the consequent time line for investors may not actually be realistic.

Theme 6: Gaps in Expertise

- From the landscape analysis, materials and moorings were considered to be potential major gaps in expertise. Moorings require more funding.
- However it was stated that research is driven by funding, and so relevant research has been/is being done but in different applications. For example the ship industry has a lot of expertise in materials for coatings and bearings.
- The Marine Science & Technology Department at the University of Newcastle has expertise in the materials and Aberdeen University has expertise in moorings.
- The focus on marine renewables R&D in the UKERC roadmap has resulted in not identifying knowledge transfer opportunities from other industrial sectors such as shipbuilding, wind energy and offshore oil and gas.

Theme 7: Research Priorities

- The list of research priorities should be seen as a challenge statement.
- Lots of hydrodynamic interactions have already been done by the oil industry and others, which need to be taken into account in drawing up the road-map and landscape.
- More research is required in some of the areas, but this will require more than just EPSRC funding.

1.3 Current Marine Roadmaps and Reviews

1.3.1 SUPERGEN Marine

Henry Jeffrey, University of Edinburgh

"Supergen Marine, Workpackage 3, Engineering Guidance", Henry Jeffrey, University of Edinburgh

Henry Jeffrey presented the work of WP3 in Supergen Marine. Engineering guidance involves the establishment of robust guidance procedures for the design, development and evaluation of marine energy converters and improved testing protocols. This is achieved by integrating the experience and skills of all consortium partners and others in the research community. The main outcomes from this WP is to determine, what is and what is not known with the community; what is know outside the community that could be of benefit; what we need to know; and what the opportunities are. Initially information has been gathered from 22 interviews within the Supergen consortium, but has now been extended to developers, policy makers and other academics. Questions addressed in the interviews include: gaps in knowledge, technology direction, political influence, commercial sector influence, and thoughts on the science arena. From interviews held, examples of current gaps include: physical validation data; environmental effects of wave energy; and understanding of the wave and tidal resource. Other outputs from the interviews have been grouped into future technology directions and externalities. Conclusions from the analysis will be fed into the UKERC roadmap. The interview process and data analysis is ongoing. For further information please contact Henry Jeffrey (Henry.Jeffrey@ed.ac.uk).

1.3.2 EU Coordinated Action on Ocean Energy

"Coordinated Action on Ocean Energy: Ocean Energy Roadmap", Cameron Johnstone, University of Strathclyde

Cameron Johnstone discussed the development of the European Ocean Energy road-map, explaining the reasoning and timing behind the process. In the EU roadmap the plan is to develop a member state by member state database of development status, barriers and support mechanisms. This will be linked with national roadmaps to establish common attributes, and to link in with national programmes in the following areas: Technology development and demonstration; project risk minimisation; project finance; policy formation; and commercial acceptance. There are three stages in the CA-OE road-map: Stage 1 is a member state status review, which is complete; Stage 2 is to form linkages with national roadmaps, which is ongoing; and Stage 3 is to test the robustness of the roadmap for different member states, which is also ongoing.
Click on the title see the full presentation.

1.3.3 IEA Ocean Energy Group

"IEA Ocean Energy Group, Strategy & Planning, 2007-2011", Katrina Polaski, IEA OES/Sustainable Energy Ireland

Katrina Polaski presented the work of IEA Ocean Energy Group in its first phase and their strategy for 2007-2011. In its first phase three annexes have been established: Review, Exchange and Dissemination of Information; Development of recommended practices for testing and evaluating ocean energy systems; and grid integration issues. Further information on these reports can be found on their website. The strategy up to 2011 includes encouraging networks of researchers and developers; providing objective authoritative information to developers and stakeholders; supporting collaboration to address the gaps and barriers; promoting policies and procedures consistent with sustainability; promoting the harmonisation of standards and procedures. The actions required to achieve this strategy are expanded in the presentation. Click on title to go the presentation.

1.3.4 British Wind Energy Association

"The Path to Power", Michael Hay, BWEA

Michael Hay summarised the BWEA's development of a commercialisation road-map funded by the npower Juice fund. The project was driven by the BWEA Marine Group in collaboration with Bond Pearce, ABP Mer, Econnect and Climate Change Capital. The main aspects covered were: strategy, finance, planning & permitting, and grid access. Time-lines for each aspect were presented with recommendations to meet the final 2020 targets. Click on title to go the presentation.

1.3.5 Canadian Ocean Renewable Energy Group

"Creating the Path for OE in Canada", Chris Campbell, OREG

Chris Campbell provided a brief introduction to the Ocean Renewable Energy Group in Canada – it was formed in 2004, and in 2006 had attracted 60 members. The group has represented its members at national and international events. It publishes a newsletter with 300 readers. In addition to members it has over 900 contacts. Canada itself is very energy rich, with most electricity coming from hydro, but there is a 40GW wave and tidal potential in 3 oceans. The group has been active in raising the profile of ocean energy in Canada, and influencing policy. Click on title to go the presentation

1.4 What are the gaps and barriers?

Small group work

The delegates were divided into four groups and asked to discuss the current body of road-mapping work within the context of the presentations given during the afternoon. The discussion was intended to be high level, not a detailed discussion of the research priorities, with a focus on three key questions:

1. What do you consider to be the main objectives or goals of a marine energy road-map?
2. What other aspects of the marine sector need to be added to the current body of work?
3. Is there any existing work outside of the known landscape that can fill the gaps?

1.4.1. What do you consider to be the main objectives or goals of a marine energy road-map?

Main goal:

Must define and enable a realisable route to credible levels of deployment in a believable timescale in an efficient way.

A road-map must support the goals by providing the following:

- A strategic vision
- Identification of the barriers to meeting that target
- Identification of the areas for funding to meet the target
- Influence on government policy and funding strategy
- Co-ordination/guidance on fundamental and applied R&D effort
- Full logical connection of research strands including development, research, environment, political, etc
- Standardised terminology and data
- An understanding of who the client is – systems approach to market
- A realistic appreciation and standardised documentation of the necessary resources including the following:
  - physical wave and tidal - > infrastructural
  - investment
  - policy
  - economic (funding)
  - supply chain
  - man power
  - end users
  - consents process
- Explicit statement of where we are as a sector in a deployment curve
- Data, data, data – access to physical data
- Targeting of step change opportunities that can bring marine renewables down the learning curve

Main objectives include:

- Road-map must provide credible and realistic targets
- It should manage expectations
- It needs to be accessible in engaging others
- It needs to be adoptable by new government initiatives and bodies

1.4.2. What other aspects of the marine sector need to be added to the current body of work?

- Infrastructure projections to 2013 (support skills base, manufacturing capacity etc) i.e. what infrastructure needs to be in place by, say 2013, to meet a 2020 target?
- Involve ALL with marine experience – the solution is out there
- Common themes or challenges that technology developers face, which could be solved by generic research
- Clarify type of map and boundaries – does it combine R&D with industry, geographical boundaries (not just nations)? But where in the energy chain infrastructure do we stop?
- Communication channels – we must ensure that all sectors of the industry are talking to one another, so that we know who is doing what and when

- Database of all expertise in the offshore sector
- Supply chain
- Policy (legislation/regulatory)
- Environmental interaction
- Social aspects/public engagement
- National requirements

1.4.3. Is there any existing work outside of the known landscape that can fill the gaps?

- HSE Database
- AEAT Reports
- Oil and gas resource materials
- Materials research elsewhere
- Naval architects/ship building
- Wind
- Oceanographic
- Oil and gas
- Admiralty House
- Constraints
- Aerospace
- Ship building
- Fisheries
- University networking – better co-ordination
- Standards and certification (insurers)
- Power industry
- Nano-materials
- Knowledge transfer (in general)

Day 2

2.1 Open space input – key issues for marine renewable energy

Participants were invited to identify what they felt were the key issues and questions they wanted to address in the workshop and to put their suggestions onto post-it notes. These were then grouped into the following themes:

Links/collaboration
- How will SUPERGEN interact with industry?
- Ensuring coherence across community
- Industry support and feedback
- Supply chain, skills base

Roadmap issues
- Investigate activities required to move down the learning curve
- Learning rates
- Identify roadblocks
- Define destination(s) -<dept./100MW target

Funding
- Finance
- Nature of funding mechanisms
- Venture Capital equity

Communications
- Guidelines to developers: how to, where, funding, point of contact.
- Process and protocol, for example HMRC test protocols.
- Who is the target audience?

Materials & Components
- Short term energy storage (inter-tidal peaks)
- Flexible power cables
- Moorings
- Oil seals
- Components: 11kV wet mateable connectors, 33kV, access systems
- Materials should be part of the supply chain

Device issues
- Maintenance
- Access
- Safety
- Survivability
- Number of arrays
- Grid access

Data
- Site data availability
- Resource understanding fundamentals

Markets
- World market, market growth, market share
- How will wave and tidal compete against offshore wind, which is cheaper, has known risks and is available now?

Regulation
- Commercial codes certification
- Regulations guidelines and insuranc

2.2 Vision, business and technical strategy for an international road-map

Markus Mueller presented a vision, business and technical strategy for an international road-map, as tested in a questionnaire circulated at the Bremerhaven Conference, for discussion by the group. (http://www.ukerc.ac.uk/content/view/376/673)

2.2.1 Vision statement

The proposed vision statement was:
Marine renewable energy should make a significant contribution to electricity generation in 2020 at a unit cost competitive with other forms of generation in the energy mix

The key points from the discussion were:
- The vision statement should be sharp and focused and optimistic, with an end date of 2020.
- It is important to be clear who the vision statement is aimed at and who we are trying to influence – targets should reflect the intended audience.
- If the roadmap is aimed at the industry, then we need to include a reference to industrial growth by 2020 – e.g. a 5 GW industry by 2020.
- If the roadmap is to be international, there needs to be an agreed terminology – marine energy or ocean energy. In Europe marine energy implies wave and tidal current, but this is not the case in the US.
- There was a debate about whether cost competitiveness should be included – marine cannot compete with fossil fuel prices but it could be compared to other renewable energy sources such as wind, although any figure included in the vision statement is likely to be too small to make a difference to the sector anyway
- Costs in 2020 are completely unknown for all energy industries but if it has made a significant contribution by 2020, then it will have to be cost competitive by definition
- Cost competitiveness does not necessarily have to be about electricity generation. Desalination is a much bigger market than electricity.

2.2.2 Business Strategy

The proposed business strategy was:
1. Exploit the UK marine energy resource taking into account the environment and marine users.
2. Encourage collaboration between academia and industry.
3. Train the next generation of engineers required to sustain the industry.
4. Build up manufacturing facilities.
5. Export high value products – design expertise.
6. Promote a market driven industry.
7. Provide world class test facilities in both wave and tidal current systems at all scales of development.
8. Establish standards and certification.
9. Work closely with the onshore grid operator to enable the economic exploitation of the marine resource.
10. Installation and operation of small wave and tidal current farms.
11. Develop a supply chain to support technology developers.

The key points from the discussion were:
- Need to be clear who the client for the strategy is.
- The business strategy should reflect the fact that we are trying to build an industry and the output of that industry is a commercially viable product.

- Need to engage with policy makers to assist in making the industry work to the point where subsidies are no longer required.
- Identification of the correct funding and support mechanisms is very important.
- Areas that need to be included in the strategy are: market drivers, support industries (supply chain to technology developers), influence of policy makers, the needs of technology developers, project developers and investors (not just R&D) and the product lifecycle.
- The topics should be grouped into bigger strategic objectives and ordered in a logical way, in sequential steps say, so that prioritisation is possible.
- Test facilities: there is a European Commission programme to link facilities in Europe – no point in spending resources to fill gaps when the answers are available somewhere else.

2.2.3 Technical Strategy

A list of 12 technology working groups was proposed, covering the key aspects for marine renewable energy:

1. Test Facilities
2. Resource Modelling & Measurement
3. Device Modelling and Design
4. Electrical Power Infrastructure and Technology
5. Power Take Off & Control
6. Moorings and Sea Bed Foundations
7. Installation and O&M
8. Engineering Design/Survivability
9. Life Cycle/Manufacturing
10. Environmental and Marine Users
11. Standards & Certification.
12. Policy & Economics

Discussion

There was substantial discussion around the technology group 'Standards and Certification', summarise as follows:

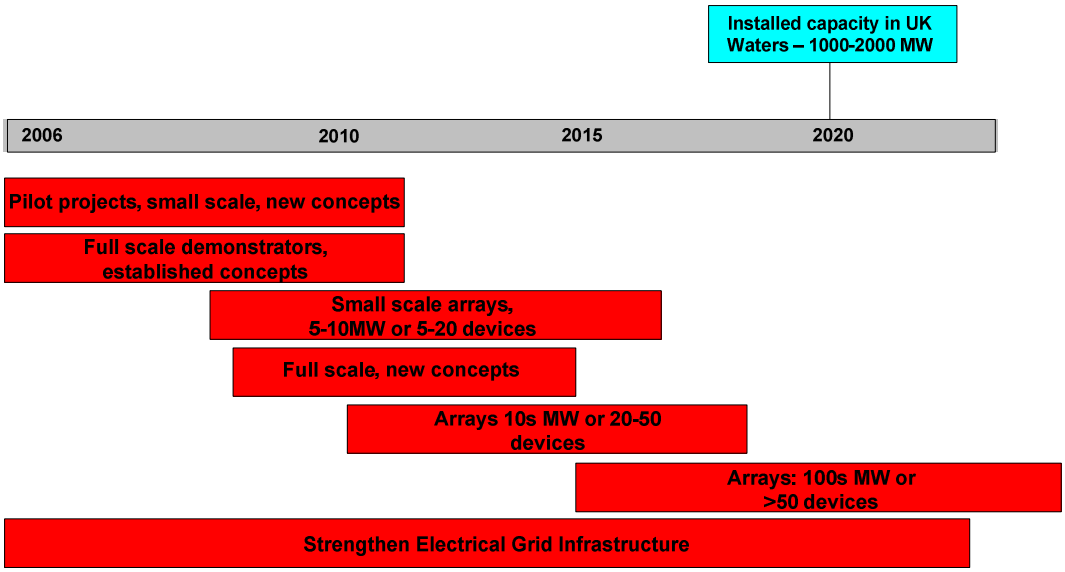
- 'Standards and certification' are double speak for how to meet market specifications as the product doesn't have a client. Engineering for long term performance is part of meeting client's needs – timescale is important when calculating standards.
- Standards and certification are necessary for getting finance and insurance. Insurance is reduced as standards are accepted.
- Product standards will be accepted when there are enough products available.
- Harmonisation of standards will enable marine energy to be a global market and avoid the difficulties in the wind industry, where different countries have different standards.
- However, standards should not act as a bottle neck, preventing development. A test device shouldn't have to comply to the standards of a full scale device
- There was a debate as to whether guidelines were preferable to standards.
- Certification is more difficult – need to implement current ones where appropriate.

Other general comments made included:

- Durability is not the same as lifecycle analysis or survivability. It is the expected lifetime that can then be compared to working life
- Need to know how the technical strategy links with economics.
- System modelling should be included in the technical strategy. The current list simply looks at the separate parts.

2.3 Scenario – what are the destinations to 2020?
Small group work

Markus Mueller outlined the proposed UKERC scenario for marine renewable energy which illustrates a final destination of 1-2GW of installed capacity at 2020, with the key milestones along the way.



Proposed Scenario for Marine Renewable Energy up to 2020

The scenario is divided into two sections split by the date-line from 2006 to 2020. The major tasks are positioned below the date-line, and the milestones are positioned above it.

The participants were divided into four groups (different to the groups on the previous day) and were first asked to spend five minutes individually identifying the three main challenges facing the marine renewable energy sector before sharing these within their groups, Each group was also provided with a copy of the UKERC scenario and asked to consider the following questions:

- What are the most appropriate milestones to achieve enroute and what is the most appropriate final destination for the marine energy industry?
- What is the correct timing of the milestones?
- What would be the regional differences?
- Is it possible to have one scenario covering the global marine community?

Each group was provided with a copy of the UKERC scenario to discuss and to mark up any proposed changes. In the feedback sessions the groups presented these modifications and summarised their discussions.

Specific comments on the Scenario document are summarised in Section 3.1.

These specific comments led to more general comments from the floor, which have been grouped into common themes and summarised in Section 3.2

2.3.1 Specific Responses to the Scenario.
2020 Target : Installed Capacity in UK waters of 1000-2000MW

- Target should be global.
- Final target needs to be big.
- Quote one figure, say 1500MW.
- The 2020 target could be related to first project finance.

- Final target should not just include electricity, there is a large desalination market.
- Final target could be linked to IRR, such that at 2020 IRR < 10%.
- Link the target to the number of design types: say at least 2 or 3 full scale design types in both wave and tidal current energy.

Additional Milestones

- One group proposed linking milestones to IRR and the involvement of investors or major energy companies as follows:
- 2006 – Current IRR = 30%, with multiple VCs involved in investment
- 2007 – Long term policy announcement required
- 2008 – 2-10 co-investors investors invest in technology
- 2012 – Major Energy company finances first 10MW array on their own.
- 2015 – IRR =15%
- 2020 – 1st project finance and IRR < 10%

Additional Tasks

- 2007 – Commitment to establishing high volume manufacturing
- 2008 – Complete all necessary array R&D
- 2008-2012 – Establish manufacturing facilities so that high volume manufacturing is underway in 2012.
- 2006 – 2020 – Technology cost reduction should be a continuous exercise.

The following points were thought to be country specific in their implementation, but need to be included in a generic scenario document.

- 2007-2010 – Finance & Support schemes for early and later technologies made available.
- 2010 – 2020 – Tariff/Pricing Policy needs to be in place to enable the technology tasks.
- 2006 – 2020 – Effective knowledge transfer, training and capacity building programmes should be continuous.
- It was felt that the electrical grid infrastructure issue is principally a UK problem, and to internationalise the roadmap, this task should include Site Availability, planning, consents etc.

Task Budgets

One group estimated costs and output in MW for the tasks in the scenario as follows:

- pre 2006 - £50m, 0MW installed
- Pilot Projects - £50m, 5MW
- Full scale demos, established concepts - £50m, 10MW
- Small scale arrays - £160m, 40MW
- Full scale new concepts - £50m, 10MW
- Arrays, 10s of MW etc - £500m, deliver 500MW
- Testing Infrastructure - £40m (additional task from 2006 – 2015)

2.3.2 General Comments

- Scenario is generally reasonably accurate
- Change of shape in sector is required by 2015
- Need a big company to come in to make it work (US wind industry is big because GE entered market) and a big input of personnel – other than Wavetrain (EU funded Marie Curie Research Training Network) there isn't the mechanism to get new people into this sector at present
- Need to clarify if the focus of the scenario is on technology developers or product developers
- Global target would be better for 2020 – needs solid pricing policy
- There should be three timelines in the scenario: installation timeline behind which are the R&D and policy timelines.
- Significant difference between countries in terms of policy

- Important step change in moving from small arrays to big arrays – need to identify some winners to facilitate this
- Need to identify £/MW installed – expecting growth to go up as cost goes down
- Need to think about facilities, choosing technology and refining needs

Other comments in the discussion session have been grouped according to themes:

Theme 1: Approach
- Mindset: marine -> power or power -> marine?
- Transparency and sharing of lessons learned to avoid time or financially costly failure
- Effective knowledge transfer
- Ensuring and maintaining coherence of action between technology (needs?), supply chain and skills base
- International collaboration
- Involvement of large industry players: who will the key players be? When will they come in? eg Shell, E.ON etc

Theme 2: Credibility
- Is marine going to be a credible part of the energy mix?
- Demonstrating credibility to ensure continued support all the way down the deployment curve
- Credible machines operating at sea for extended time feeding power to grid
- Expectation and risk management

Theme 3: Technology & design
- Focusing technical development on market performance requirements
- Design for durability & to requirements of end user
- Design consensus
- Technology evolution rates/scaling
- Technology development – sectoral
- Marine aspects from design through to operation

Theme 4: Infrastructure
- Grid connection availability
- Suitable sites
- Deployment and support infrastructure

Theme 5: Financial
- Cost & cost reduction
- Funding availability and timing
- Funding of early stage prototypes and small arrays
- Building confidence of financiers – public and private
- Uncertainty about revenue (ROCs) when deciding for arrays

Theme 6: Markets
- True picture of the market
- Commercial interest leading to lack of feedback and information sharing in the community
- Mobilising the value chain to deliver on ocean energy industry
- Supply chain

Theme 7: Regulation
- Development of standards, requirements, consents etc in different locations at different pace lading to lack of harmonisation
- Setting long term policy to give confidence to investors and supply chain manufacturers

Theme 8: Manufacturing & Production

- If we start from the end point (2020) and work backwards, we can establish the rate of production required – if start with 4 devices per week, would have to increase to 12 per week at a later stage to meet demand.
- To produce a large volume by 2020, need to have built first factory by 2012
- Manufacturing facilities require a 5 year lead time to produce a device per week, which means we have to start now to be producing by 2012
- Under a worst case scenario, new devices require a 4 year lead time with an additional 4-6 year lead time for an array – this will take too long. Therefore need to consider using existing devices that would be ready for arrays next year if want to meet target date.
- However, manufacturing process could be quicker than this – with wind, they go from nothing to the first turbines produced in a new factory at full capacity within 6 months.
- If demand is there, learning is quick, particularly if marine renewables can get to the stage where factories can just be replicated (as with wind), although there are still planning permission issues

2.3.3 Conclusion

Based on the discussion summarised in Sections 2.3.1 and 2.3.2 the following points can be concluded:

- Scenario as presented is too technology focussed, hence the requirement for including additional milestones and outcomes relating to finance, policy and training etc.
- There appears to be general agreement with the technology based tasks.
- The scenario needs to include the needs of the financial community, project developers, manufacturing, and the supply chain, in order to meet the final 2020 target.
- The scenario could consist of a number of layers: R&D layer (as presented), infrastructure layer addressing manufacturing, policy/regulatory layer, & an environmental layer. Some of the layers could be generic or country specific.
- The final target in the scenario could reflect installed capacity, financial objectives and also markets other than electricity generation, such as desalination.

2.4. What are the research timelines to meet the scenario?

Small group work

Time-lines for each Technology Working Group have been produced by Markus Mueller, based on the following structure: outputs are listed above a date line with the R&D activities to meet those outputs defined underneath the date line. Each activity is a general descriptor for a number of research priorities that were defined through a workshop introducing the UKERC Marine Energy Research Network held on 14th April 2005 at the University of Edinburgh. The output of these Technology Working Groups should then satisfy the requirements of the milestones enroute to the final destination defined in the scenario.

The delegates remained in the same four groups as for the previous session and were provided with three timelines to discuss (so all twelve timelines were covered between the groups) as a reference point for the following questions:

- What other activities should be included in the Technology Working Group
- Is the timing appropriate?
- Who is already doing this work?
- What is the best mechanism to identify who would be most appropriate to do this work?

Specific comments on each of the Technology Working Groups is provided in section 4.1, followed by a summary/conclusion on the comments.

2.4.1 Feedback on Research timelines

Power Take Off

- Additional aspects to include:
  - Gearboxes: tidal
  - Turbines: OWC, pulse or wells
  - Hydraulics: hose pump technology but not the associated turbine
  - Smoothing from arrays: does it occur or not?
- People involved:
  - Controls: academics and developers
  - Hydraulics: academics, developers and other organisations that currently work with hydraulics
- Energy storage is a problem common to all renewables – use existing knowledge

Moorings

- Common groups were fatigue, survivability, and reliability: what was fit for purpose?
- Unlike oil/gas industry, marine renewables doesn't want device to be stationary
- Potentially useful research from shipping, fish farming, navigational moorings and Admiral House
- Additional aspects to include: software design tools for non-stationary systems (more complex inputs compared to stationary systems
- Safety issues – can't afford a failure or fatality

Electrical Infrastructure

- Includes connection to the grid, undersea cables, knowledge transfer
- Use existing information from universities and off shore wind
- Avoid wet connectors at high voltage!
- People involved:
  - Cable laying: industry
  - Connecting arrays: developers
  - Mapping grid connections: academics
  - Direct drive, power controls: developers with input from academics
  - Potential for Knowledge Transfer from wind energy
  - Utilities
- Additional aspects to include:
  - Superconductors for linear generators
  - Umbilical cable from the subsea cable to the device (to cope with flexing if standard cables not appropriate)

O & M

- Who should do the work?
- No R&D, should be industry led.
- Additional aspects to include: decommissioning – will affect how devices are installed
- H&S standards for O&M are already available – industry needs to understand their applicability.

Engineering Design

- Additional aspects to include:
  - Reliability and failure mode analysis
  - Sub sea electricity arrays
  - Low erosion materials – composites and ceramics
  - understand sea structural forces better
  - predict durability to fatigue in marine environment
  - seals
  - selection for purpose – new materials
  - composites, ceramics

- design for manufacture
- subsea electrical array
- reliability, fma

- Survivability – applied to all relevant components. This is a consequence of the large stresses and forces on the device. Need to predict durability to succeed in a marine environment
- Assembly in water should be leading the manufacture
- Economics of scale from market
- Decommissioning – clear need to support reliability work for the assembly of a database of sub-components costs, reliabilities and failure rates – this should be publicly available
- The costs of the wave tanks and sea trails are much more than the cost of software development
- Need raw data to do validity, but companies will not share data
- Providers of Materials Research: Imperial, Southampton, Strathclyde, AMEC, NCC, Skanska, Arups, Cranfield, Ship industry)

Environmental

- Add Community Interaction to the title
- Consider at socio-economic – especially the benefits
- Navigation issues – lots of experience of buoys, but these are located where people want to go and not in dynamic water where we want to be
- Make it easy for permits to come through
- Cover all possibilities so that when issues occur we have the answers ready
- The *SEA* should be considered as the driver for this technology working group.
- This group is really the focus of the environmental theme in UKERC.

Best Practice (not standards!)

- Suggestion to drop the word 'standards' – use 'best practice' instead
- Additional aspects to include:
  - Materials and coatings
  - Moorings
  - Site assessment
- Developers motivated by making profit – need to demonstrate cost competitiveness
- Need to get big companies involved as soon as possible so they can contribute
- Need design consensus to reduce the number of concepts
- Need to identify areas where it is possible to put hundreds of machines
- Capacity figure should be set as an international target rather than a UK target

Resource modelling

- Additional aspects to include:
  - Device interaction with resource for both wave and tidal
- Providers
  - Universities, Admiralty House

Device Model

- Additional aspects to include:
  - Real world data
  - Off the shelf software: how difficult would it be to develop a generic code?
- Use of commercial codes – do developers not develop their own bespoke codes ?

Test

- More sea scale testing required (particularly for tide) – large leap from a 1/10th tank scale to the sea.
- Why are small developers not making use of existing facilities at universities? Possibly due to cost or not understanding their value

- Providers
  - Unis with tanks
  - NaREC, EMEC, Wallingford, HMRC,
  - Wavehub – funding announced.

Policy & Economics

- Include finance in the title.
- Additional aspects to include:
  - Governance – consenting/social licences/permits
  - Carbon pricing – market drivers

2.4.2 Conclusion on comments

Based on the discussion the following points can be concluded:

- A number of additional activities need to be included in the technology working groups.
- It is still not clear who the main providers are or should be for the activities in the technology working groups.
- There was an overwhelming feeling that standards should be replaced by BEST PRACTICE.
- Access to real world data for validating models is very important and requires collaboration between Unis and Developers, without compromising IP. A strategy needs to be formulated to enable this to take place, with buy in from developers.
- We need to understand why developers are not using University tanks for scale testing.
- Based upon the number of points raised, Engineering Design is probably the major issue facing developers.
- It was also proposed that there is an important Technology Working Group missing: *System Modelling and Performance*.

2.5 Next steps

A presentation summarising the main discussion points was made at the workshop and can be found at (http://www.ukerc.ac.uk/content/view/376/673 INSERT LINK).

This presentation has been distilled into the following points:

- The current road-map is too academic focussed and needs to include the following clients: technology developers, project developers, policy makers and investors.
- The road-map could therefore consist of a number of layers, with each layer for a different client and linkages between them all.
- It was proposed that the focus would be on a Technology R&D map for academics, technology developers and project developers, but with the needs of policy makers and investors in mind.
- The road-map has to be outward facing and based upon evidence gathered from the community.
- Someone needs to take the lead and show where we are so far and then add value to the current attempts of roadmaps.
- Something has to be done with the roadmap – it shouldn't just become a document but a working plan.
- The write-up from this meeting will be a first iteration to provoke people to set targets and provoke a reaction from other countries, with University of Edinburgh taking the lead.
- There needs to be strong links between other road-map or similar activities within IEA Ocean Energy Group and the CA-OE for example.
- IEA will provide guidance and will help collect and distribute information but will not be pro-active in developing the road-map – this is a strong network and will provide credibility to the road-map and process

- Training and capacity building will be major challenges, and these need to be highlighted in the roadmap.
- The technology road-map should be common across all countries, but road-maps on policy and environment will need to be country-specific, based on the technology road-map
- It is important to stress that whatever framework is adopted it must be transparent so that other countries can be incorporated.

3. Workshop Conclusion

Overall there was general agreement for the need for an international marine renewables technology road-map to serve the academic and industrial communities, but it needs to be flexible so that the interests of other stakeholders (policy makers, economists, environmentalists etc) and other countries can easily be included. The road-map should be a living document updated on a regular basis and owned by the marine renewable energy community. Hence, consultation and consensus with the community are necessary in the preparation and any future changes to the road-map. In order to internationalise the road-map there will be further consultations to ensure that all interests are covered and dissemination is widespread. The UKERC has resource to complete the current version of the road-map including the outputs from this workshop. UKERC will take the lead in the internationalisation of the road-map and proposals to use the UKERC Meeting Place will be submitted to bring the community together to work on and maintain the international marine technology road-map in the future.

Report Note

This report provides a summary of the presentations and discussions that took place over the two days, along with a list of the key recommendations resulting from these discussions. It should be noted that the authors accept that the report is not an exhaustive summary, but the authors feel that it provides an overview of the pertinent discussions. The transcript of the report has been built from flip charts and so its meaning may not be clear to people who did not attend the meeting. Please contact the UKERC for clarification if necessary.