A ROAD-MAP FOR MARINE RENEWABLE ENERGY RESEARCH IN THE UK

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Synopsis

The role of the UK Energy Research Centre Marine Energy Research Network in developing a route map for marine renewable energy research is described and put into the context of previous and current marine energy research at a national and EU level. A summary of the route mapping process is given based upon the Batelle approach. Justification is provided for route mapping in terms of encouraging cooperation and collaboration within the community to develop a coherent reseach, development and demonstration strategy, which will be used to inform policy makers and funding bodies. Some preliminary outputs from the network are presented in the paper to encourage discussion.

Introduction

The main purpose of developing a research road-map for any organisation or community is to outline an R, D & D strategy that best supports the commercial demands of an industry. Technology road-mapping is used by many different organisations, including industrial firms, collaborative groups based around a technology, and government agencies in their strategic planning processes. The major aim of route-maps developed by a government department is to ensure that support programmes focus on key areas. Route maps are developed in consultation with the main academic and industrial players in the community concerned. The documents should summarise the market, the present status of the technology, the benefits, and identify areas requiring further research. A time-line diagram is often included to show how the product or technology should be advancing and also indicate the critical stages in the development process. However, it should be stressed that it is not a Gantt Chart as used in project management. Road-maps are living documents and must be flexible in their application in order to promote and sustain a creative approach to the development of new technology.

Road-mapping has been used to map out developments in emerging technologies, for example hydrogen and fuel cells (1 & 2), nuclear fusion (3) or future technological advances in existing technologies, such as the Foresight Vehicle Technology Roadmap (4). The DTI published a Renewable Energy Technology Route Map in 2000/2001 (5), which included wave energy and tidal barrage schemes. A good example of cooperation within a community is the International Technology Roadmap for Semiconductors (ITRS), which is an assessment of semiconductor technology requirements, to ensure advancements in the performance of integrated circuits (6). It is a cooperative effort among global industry manufacturers and suppliers, government organisations, consortia and universities and was initiated in 2001. Since then the road map has been updated annually to reflect any changes that have taken place. The ITRS encourages discussion and debate throughout the community about the requirements for success, with the key factor to the success being consensus on industry drivers, requirements and technology timelines.

Wave energy has been supported by the UK Government at various times since the 1970s when wave energy first came to prominence in response to the oil crisis. Reviews of the UK Wave Energy Programme were published by the Energy Technology Support Unit (7-10). Thorpe's report and the Marine Foresight Panel report, both published in 1999, (10 & 11), led to the reinstatement of funding for marine renewable energy after a 10 year gap, to include both wave energy and tidal stream energy, but not tidal barrages.

Since the end of the '90s there has been signifcant growth in marine technology developers, with some successful prototype deployments in European waters, such as Wavedragon (12), Pelamis by Ocean Power Delivery (13), Archimedes Wave Swing by Teamworks Technologies (14), Seaflow by Marine Current Turbines (15) and Stingray by the Engineering Business (16). There are many other promising technologies at earlier stages of the development process. In order to assist and underpin this emerging marine renewable industry it is important to identify voids in the existing research framework, which could slow or arrest the development of marine technology, and to identify research expertise needed to fill these voids. This requires cooperation between researchers and technology developers to collate research priorities into a road-map or atlas describing the paths from start to finish. Road-mapping marine renewables has been done, but not presented in great detail or updated annually (5 & 17). The establishment of a network involving all members of the marine community is the best way to achieve such cooperation. Both the DTI (18) and the Scottish Executive (19) have recommended the establishment of a marine network to represent the community.

The vast energy resources in UK waters and government initiatives are partly responsible for the increase in industrial activity in the marine renewables sector. The UK government is promoting the role of renewables making the energy mix in the UK ever more complex. In his Energy Research Review Report to the Government, Professor Sir David King recommended the formation of a national research network to coordinate energy research, facillitate collaboration between UK industry and academia, and encourage UK participation in international projects. As a result the UK research councils (NERC, ESRC & EPSRC) formed the UK Energy Research Centre (UKERC), of which the UK Marine Research Network is a part of the theme entitled Future Sources of Energy (FSE).

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Existing Marine Renewables Reviews & Road-Maps

DTI Technology Road-map – Wave Energy

The DTI Technology Route Map, published in 2001 (5), was developed in conjuction with a review of wave energy technology undertaken by Ove-Arup (18). The document identifies the current status of the technology in the UK and worldwide. A number of R&D issues are highlighted in the document, but no detail is provided on the actual research required to tackle the challenges listed. The document stresses the need to provide a low risk and more economic path for the development of technology from model tank tests towards meaningful scale prototypes. From the Ove-Arup report it was concluded that there are no technical barrriers to the implementation of wave energy devices, and that there is an opportunity for technology transfer from the offshore industry. Marine renewable devices have to be developed within much tighter financial margins than offshore oil and gas infrastructure, and hence the cost of suitable offshore technology needs to be reduced if this transfer is to take place. A roadmap of activities with proposed target dates is tabulated in the document. This roadmap is generic in nature to take into account the differences between devices, and it is designed to assist the DTI in the management of its own R&D funding programme. Activities are divided according to whether the device is a well established concept currently being supported under the DTI programme or if it is a new concept. The tabulated road map is summarised in Tables 1 & 2. In terms of the established concepts some device concepts have fulfilled the target activities and more or less within the time-scale defined. It is not clear how many new concepts have met the targets, but this is very difficult because very little information on new devices being developed is available in the public domain, and it is a continuous process.

Although the roadmap in Tables I & II was derived for wave energy R, D & D a similar philosophy is applicable to tidal current energy systems, which has seen just as much industrial activity as wave energy in recent years. As with wave, some tidal energy projects have also completed the activities in Table 1 and others have progressed through Table 2 and are now being developed at full-scale

Table I Established concepts

Activity	*Target Date*
Reduce risk and uncertainty of key components.	End 2002
1/10th scale (or larger) prototype testing in real, meaningful sea environments	End 2002
Evaluate potential of concepts for further development	End 2003
Develop ½ or 1/3rd scale prototypes based on evaluation above and test in an offshore environment. Include Electrical aspects and evaluate the long term performance.	End 2004

Further develop projects on components where innovation is required.	End 2004
Report on performance of prototypes & prospects for commercial development.	End 2010

Table II New Concepts

Activity	*Target Date*
Complete initial feasibility studies and design evaluations.	2003
Further evaluation at 1/50 to 1/20 scale, with more detailed design engineering and cost studies.	2004
Take forward attractive concepts to typically 1/10th scale tests in a realistic sea environment.	2006

World Energy Council (WEC) Road-map

In 2001 the World Energy Council published a Survery of Energy Resources, which included wave energy and tidal barrages, but not tidal current energy. The section on wave energy, by Griffiths (17), provides an excellent summary of the resource, the status of the technology at the time, and recommendations for the way forward in terms of R&D and commercial exploitation. A road-map is presented to highlight the R&D needs for wave energy, reproduced in Figure 1.

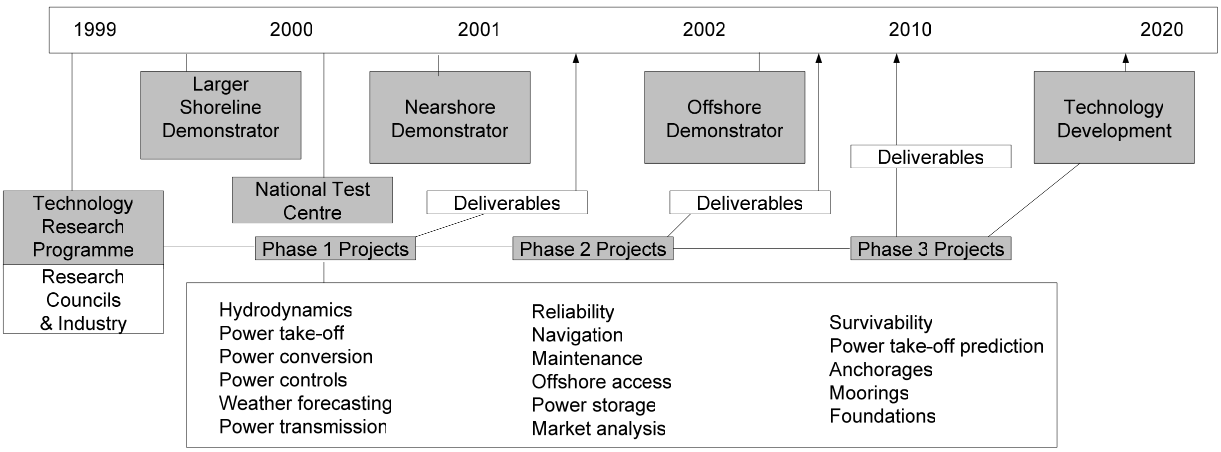

Fig 1 WEC R&D Road-map for Wave Energy, 2001.

Technology research programmes have been established – The EPSRC Supergen Marine Energy Consortium and the DTI R&D programme covers marine renewables. The former covers generic research and includes many of the topics listed in Figure 1. Funding from DTI and EU Frameworks has provided industrial funding for a large shoreline demonstrator and three offshore devices have been demonstrated at various degrees of operation. A National Test Centre has been established – the European Marine Energy Centre on Orkney provides offshore test facilities for wave devices, and a test site for tidal current devices is also being developed. As well as these offshore facilities the New and Renewable Energy Centre (NaREC) in NE England can test up to 1/10th Scale. In SW England an offshore wave hub is being proposed for testing arrays of devices. As with the DTI road-map the activities relating to prototype development have or are being implemented. In terms of the R&D priorities listed there was no detail on the research required into the technologies for each item. For example in Power Transmission, issues to be addressed may include HVDC or AC transmission, electrical interconnection of arrays, offshore electrical infrastructure, power quality and power conditioning.

IEA Report: Status & R&D Priorities, Wave and Marine Current Energy

In collaboration with the DTI the IEA Ocean Energy Systems Group published a report in 2003 on the research priorities for wave and tidal current energy converters. (21) The report includes a comprehensive review of existing technology, a review of global marine renewable activities and a detailed list of research priorities or tasks for both wave and marine current. The list of R&D priorities is divided into marine current and wave, with specific headings in wave related to the type of wave device:

Marine Current: Technology Information Centre, Resource Assessment, Operation & Maintenance, Biofouling, Impacts on Marine Life, Sealing, Weather and Wave Forecasting, Cavitation, Interaction with the Marine Environment, Turbulence, Installation foundations.

Wave Energy :

Overtopping devices: Overtopping Power Take Off Systems;

OWC: Design Standards, Market Development & Site selection;

Offshore: Control systems, floating device array configuration, mooring, electrical cabling, hydraulics.

Generic: Testing, proving, and certification methods and centres, fabrication, transport & installation, standards, monitoring systems, power smoothing and conditioning,

There are a number of topics which apply to both technologies even though they are only included within one category above. For example Weather and Wave Forecasting is important for wave as well as marine current; Resource Assessment still needs to be considered for wave; all the generic issues in wave are common to marine current. Until now the IEA report has provided the most detail in terms of research priorties, but it has not compiled them into a road-map with a time-line. A strategy for implementing the tasks was presented:

- *Task sharing* which relies on IEA members devoting specified resources and personnel to a common work programme.
- *Cost sharing* where members contribute to a common fund for conducting the work, which may be an experiment, an exchange of information or purchasing one piece of equipment.

UKERC Marine Energy Research Network

The UKERC Marine Research Network is one of five networks in the vertical theme Future Sources of Energy in UKERC. Biomass, PV, Fuel Cells and Carbon Sequestration make up the other four. New nuclear and fusion each occupy a watching brief at the Dalton Institute and at Culham respectively.

The general objectives of the FSE theme are as follows:

- To define and up-date the destinations and routes in the 2020 and 2050 sub-topic route plans;
- To increase the communication and coherence of research activity within each of the sub-topics;
- To increase the volume and effectiveness of spend in research in each of the sub-topics;
- To bring about greater stakeholder in-reach into the research agenda and outcomes;
- To engage more fully the beneficiaries of the research through wider dissemination and outreach.

These objectives have been expanded as follows specifically for the UK Marine Energy Research Network:

- To develop a research road map or plan to assist technology developers in the successful deployment and commercialisation of marine renewable technology up to 2020.
- To assess and fill the gaps in expertise required to implement the priorities identified in the road map.
- Establish focus groups within the network to implement the road map by applying for external funding.
- To consult with all academic, industrial, government and funding bodies in the development and implementation of the road map.

Research Road-Maps

The Batelle approach to developing emerging technology road-maps is described in detail by Placet and Clarke (22). There are 3 steps to developing an emerging technology road-map:

Step 1: Choosing the Destinations

In this step the long-term technical goals are set as those required to meet the commercial needs of the community. Most organisations set short term goals, because these fit in clearly with the firm's business objectives. However, in the case of the marine renewable industry, which is at the start of its evolution there must be a long term vision, as the science and technology contributing to the community is still very much at the R&D stage. The development of the marine renewable industry will be influenced by advances in technology, the market and policy developments. Hence in defining the long term technical goals, other contributory factors such as business goals and policy must be taken into account. The end product of Step 1 is the identification of those business goals, which require strategic technology development.

The process of deriving the technical goals can be considered in three different levels:

- ***Level 1*** defines the vision, which for this exercise would extend to 2020.
- ***Level 2*** defines the components of the business strategy required to meet this vision.
- ***Level 3*** defines the technical needs to meet the business strategy.

Step 2: Surveying the Potential Paths

The next step is to assess the alternative technological paths that could be followed to meet the critical business goals. This assessment should include current technical approaches and new approaches to reflect “out of the box” creative thinking. A hierarchy is defined to support the strategic business or policy goals. At the top of the hierarchy is the Productive Technology System, which is the integrated technology system that is the final output of a firm, in the form of a saleable product. In the case of marine renewable technologies it will be wave- or tidal-current energy devices generating electricity. At the other extreme of the hierarchy is the Technology Capabilities, which are needed to develop the critical technologies and make the system competitive. Connecting the two extremes of the hierarchy there are Technology Platforms and Component Technologies. Technology Platforms include IP, market, business and technical ‘know-how’, which when combined will provide a competitive advantage for the Productive Technology System. The Component Technologies includes technology units that support one or more Technology Platforms. In the case of marine renewable technologies a Productive Technology Stream would be the marine energy devices generating electricity that was being sold to market. Technology Platforms may include installation systems, power-take-off systems, mooring systems, grid connection systems, energy storage systems, novel material and structures for survivability. This is only part of a much longer list of acknowledged platforms. Component Technologies for say power-take-off systems could include, hydraulics, electrical generators, turbines. Finally aspects of Technology Capabilities address specific research areas required to advance the individual Component Technologies or introduce new technologies.

Connecting the outputs from the Productive Technology Stream into Strategic Technical Needs defined in Step 1 provides the link between the two steps. In surveying the potential paths the process has to move down the hierarchy from the top level, and at each level define the tasks required, which are then used in Step 3 to synthesise and interconnect them to form the route map.

Step 3: Mapping the Course

The final step is the setting of priorities and analysis of the implications of the road map for the community or the firm. Mapping, as the term implies, involves doing this visually so that all the alternatives can be explored and the perceived risks can be understood. This must involve determining the weaknesses and strengths of ongoing activities and assessing the expertise within the community to undertake specific activities. It may well be that the analysis shows that expertise from outside the community is required for some tasks. This step must also investigate potential for overlap and duplication.

UKERC Marine Road-Map – Current Status

A workshop was held on 14th April 2005 in Edinburgh at which 25 delegates attended representing the community - academic, consultants and technology developers. The objectives of the workshop were twofold: firstly to explain the philosophy behind UKERC and the Marine Research Network in particular, and secondly to begin the process of road-mapping, in particular Step 1. From the discussion a full list of research priorities was established, which complements the IEA priority list. The research priority list was grouped into topic headings forming distinct Technology Working Groups. Thematic and technology-specific experts will be invited onto these working groups to further refine the research tasks identified in each group. This will essentially fulfill steps 2 & 3 of the road-mapping process. A flavour of the preliminary outcomes from the Step 1 will be presented in this section, but it should be stressed that the information presented is still in draft form. Comments from the community are of course welcome at anytime and will be fed into the process.

Level 1: 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."

Level 2: Business Strategy

It is proposed that the business strategy required to fulfill the vision statement consists of the following ten actions:

1. Exploit the UK marine energy resource taking into account the environment and marine users.
2. Bring together academic and industrial partners to collaborate on the challenges facing the marine renewable industry and to train the next generation of engineers required to sustain the industry.
3. Build up manufacturing facilities.
4. Export high value engineering products and expertise.
5. Promote a market driven industry.

6. Provide world class test facilities in both wave and tidal current systems at all scales of development.
7. Establish standards and certification.
8. Work closely with the onshore grid operator to enable the economic exploitation of the marine resource.
9. The successful installation and operation of small wave and tidal current farms, to build up investor confidence.
10. Develop a supply chain to support technology developers.

Level 3: Technical Strategy

It is proposed that the following *Technology Working Groups* (TWG) are established for both wave and tidal current energy to formulate the technical strategy required to support the business strategy:

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

The research priorities in some groups will be very different for wave compared to tidal, but the content of TWG 5 will be common for both wave and tidal. Not all the TWGs will be considered in detail because horizontal themes elsewhere in UKERC cover aspects such as the Marine Environment (TWG 10) and Policy & Economics (TWG 13). The Marine Research Network will keep a watching brief on TWGs 10 & 13, whilst feeding information into other UKERC themes covering these in more detail. Outputs from many of the working groups will feed into the Standards working group.

As an example of priorities identified within the TWGs, Tables III & IV list the content for Test Facilities & Installation, O&M, with an indication of the time-scale required to complete the task and the applicability to wave or tidal.

Table III Technology Work Group: Test Facilities

Review & calibrate existing test tanks	Wave & Tidal	Short
Combined tidal current and wave tank for scale model tests.	Wave & Tidal	Medium
A deep wide channel required for medium scale testing.	Tidal	Short
Full scale offshore tidal current facility.	Tidal	Short
Offshore component test platform.	Wave & Tidal	Short/Medium
Bi-directional flow wind tunnel	Wave (OWC)	Short/Medium

Table IV Technology Work Group: Installation, O&M

Custom vessels required, for both installation and O&M.	Wave & Tidal	Short/Medium
Develop H&S standards for installation & O&M.	Wave & Tidal	Short
Maintain an O&M database, to include failures, incidents etc.	Wave & Tidal	Short/Medium
Develop standard risk assessment procedures.	Wave & Tidal	Short
Advanced lubricants	Wave & Tidal	Short
Training for O&M procedures	Wave & Tidal	Short/Medium
Adverse sea installation & maintenance	Wave & Tidal	Short/Medium
Performance & condition monitoring	Wave & Tidal	Short/Medium

In Tables 3 & 4 short term is defined as in the 3-5 year time-frame, medium term is 5-10 years and long term is 10-20 years. By identifying time-frames at this stage the research paths can be outlined for steps 2 & 3 of the road mapping process. It should be noted that a full-scale tidal test facility is being installed at EMEC, and so this priority will be complete within the target, but there may be other priorities associated with this task that will be ongoing after it has been completed such as environmental monitoring of marine life and the impact on the sea bed due to installation. Thus each priority can be refined into a number of sub-tasks, which will have their own associated time frames. For instance the Development of Custom Installation & O&M Vessels can be further divided into the following priorities:

- Design of tidal current or wave devices to suit more standard vessels.
- Investigate working in tidal currents > 1.5m/s.
- Installation vessels matched to heave.
- Fast installation vessel

It should also be noted that priorities listed in some TWGs will be strongly linked to others. For example priorities listed in Electrical Power Infrastructure & Technology related to offshore transmission systems and the laying of power cables feed into Installation and O&M. Analysis of the data collected in Step 1 is important in order to show the links between the TWGs and how they feed into the business strategy required for the vision statement. Some aspects of the business strategy will be of higher priority than others, and without identifying the links between the TWGs and the themes of the business strategy it is not possible to implement Steps 2 & 3 of the road-mapping process. Previous exercises in road-mapping or research prioritisation have not included such an analysis. The final outcome from Step 1 will provide funding bodies with an indication of the major business and science and engineering priorities for the marine renewable community to meet the vision statement. Funding can thereafter be considered for allocation to general technology working areas and made available at the appropriate point in the time-frame as determined in steps 2 & 3 of the road-mapping process.

Conclusion

This paper has introduced the objectives of the UKERC and in particular the Marine Research Network, which has the principal objective of developing a research route map for marine renewable energy. The process of route mapping has been summarised, and discussed in the context of marine renewables. Data from Step 1 (as defined by Batelle) of the marine road map has been described in detail leading to the definition of a vision statement, a business strategy and a list of technology working groups forming the technical strategy. Analysis will continue to show how the science and engineering strategy links into the business strategy, to advise funding bodies in the possible future allocation of funds. The authors welcome contributions from any and all members of the community in the compilation of the Marine Renewable Energy Road-map.

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