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# Marine Energy Technology Roadmap

October 2010

## 1. Introduction & Purpose

The Energy Technologies Institute (ETI) is a public private partnership between six of the largest global industrial organisations – BP, Caterpillar, EDF Energy, E.ON, Rolls-Royce and Shell – and the UK Government. It makes targeted investments in large scale engineering projects designed to make a strategic difference to the economy focussing on the whole energy system across the spectrum of heat, power, transport and crucially the infrastructure that links them.

The ETI identifies a mix of potential energy sources and the cost implications and timings associated with implementing them to produce affordable, sustainable and secure energy sources that will help the UK meet its legally binding 2050 carbon reduction targets. As well as marine, the ETI currently has projects in offshore wind, transport, carbon capture and storage, energy storage and distribution, distributed energy, buildings and bio-energy.

Technology roadmaps are tools developed and utilised to manage the complex research and development process and overall industry development of a technology or industry sector in order to achieve a long term vision, target and/or goal.

This document is intended to identify the key technology and deployment issues faced by the marine energy sector in the UK, to provide initial prioritisation of these issues, and timelines for their delivery. The ultimate aim is to establish a commercially viable marine energy sector in the UK, supported by an extensive supply chain, thereby building skills and capacity at all levels.

This document is broadly a development and expansion of the findings and recommendations of the *UKERC Marine (Wave and Tidal Current) Renewable Energy Technology Roadmap*[1] produced in 2008, with a specific focus on how this relates to the ETI. An early version of this work and preliminary prioritisation rankings were critiqued by marine energy sector stakeholders at a European Commission SETIS workshop on Ocean Energy in January 2009. The high-level outputs were also been discussed during the development of DECC Marine Action Plan's Technology Roadmap theme.

In the above context, this Marine Energy Technology Roadmap, jointly developed by the Energy Technologies Institute (ETI) and the UK Energy Research Centre (UKERC), has two specific purposes:

- To serve as an update to the UKERC Marine Energy Technology Roadmap which was originally released in 2008
- To detail the marine energy technology development and demonstration activities identified by the ETI as its priorities for future project intervention

## 2. Deployment Strategy & Technology Development Targets

It is clear that the future energy system within the UK will require the deployment of significant quantities of low-carbon power generation plant if the UK government is to meet its legally binding 2050 carbon reduction targets under the Climate Change Act. It is also likely that a balanced portfolio of low-carbon technologies will be required to deliver the capacity and security of supply required out to 2050 and beyond.

[1] http://ukerc.rl.ac.uk/Roadmaps/Marine/Tech_roadmap_summary%20HJMWMM.pdf

Techno-economic modelling performed recently by the ETI has provided a preliminary assessment of the likely improvements in performance and cost reduction that will have to be delivered by the marine energy sector over time to deliver commercially-viable marine energy projects, and deployment rates that are likely to make a significant contribution to the UK's future electricity generation mix[2].

This information is shown pictorially in Appendix 1. The assumption made is that following early array deployment up to 2020 there is a subsequent rapid build-out of new projects, peaking around 2030. Following that time there is assumed to be a gradual reduction in the rate of new projects as resource availability diminishes. However, from around 2035 onwards it is assumed that a degree of asset replacement takes place as the early farms reach the end of their technical life.

## 3. Technology Development and Demonstration Priorities

This section summarises the technology development and demonstration options and ETI priorities that could contribute to the delivery of the required performance and cost improvements shown in Appendix 1.

The analysis performed by the ETI / UKERC was a two-stage process considering:

a) Identifying those technology development activities critical to the delivery of a commercial marine energy sector in the UK (i.e. what needs to happen to accelerate the commercialisation of the marine energy industry in the UK?)

b) Prioritising these activities from the perspective of the ETI taking into account its purpose, the skills & capabilities of the ETI Membership, and its operating model (i.e. which of these activities should the ETI prioritise for intervention?)

The development activities identified under (a) above have been categorised into five key themes to analyse which ones require the highest priority in a given area. These themes are based on a review of the UKERC Marine Energy Roadmap's Technology Working Areas (TWAs).

The 12 UKERC TWAs were synthesised and summarised into the following five key themes for the ETI / UKERC Roadmap:

- Device and system demonstrators
- Sub-components
- Guidelines and standards
- Tool development
- Infrastructure and enablers

Within each theme a number of specific required activities have been identified as shown in Appendix 2. These represent key issues and/or needs along the technology development chain for marine renewables.

To deliver the prioritisation of (b) above, the activities identified within each of these themes were then ranked in terms of the needs of the UK marine energy sector generically and their alignment with the objectives and purpose of the ETI. Further details of the assessment approach are detailed in section 4. The results of this prioritisation are reproduced in Appendices 3A and 3B.

[2] These deployment rates are of the order of 10 GW by 2030 and 20 GW by 2050, and are derived in the context of the need to deliver a future energy system in the UK that provides affordability, energy security and sustainability

## 4. Activity Prioritisation Approach

A key part of developing the ETI / UKERC Roadmap was to identify the activities needed to deliver industry commercialisation in the marine sector, and then use the alignment of these activities with the ETI purpose to identify the key activities where the ETI could focus its project intervention support.

Each activity summarised in Appendix 2 was ranked using ten simple assessment criteria. Seven of these correspond to an assessment of industry need, the remaining three being more relevant to the ETI purpose and objectives. For each criterion, the activity was given a score of 1-3, typically corresponding to low-medium-high. These criteria and the resulting scores were also weighted to represent the relative importance of each criterion to the prioritisation assessment. Table 1 shows the assessment criteria and weightings used in the analysis.

### Table 1: Assessment Criteria, Scores and Weightings

| Assessment criterion | Description | 1 | 2 | 3 | Importance (1-10) |
|---|---|---|---|---|---|
| Sector urgency | Is rapid development an urgent priority for the Marine energy sector? | LOW | MEDIUM | HIGH | 10 |
| Unique to the Marine energy sector or generic technology | Is the technology unique to the marine energy sector or generic across a number of sectors? | - | GENERIC | UNIQUE | 6 |
| Cost reduction potential - impact on CAPEX | What is the CAPEX cost reduction potential? | LOW | MEDIUM | HIGH | 7 |
| Existing funding level | To what degree is development funding already existing and being utilised? | HIGH | MEDIUM | LOW | 3 |
| Impact on technical risk and survivability | How much would development funding contribute to overall system risk reduction and survivability? | LOW | MEDIUM | HIGH | 10 |
| Level of adaption required | How readily adaptable is existing technology to the Marine energy sector? | HIGH | MEDIUM | LOW | 3 |
| Cost reduction potential – impact on OPEX | What is the OPEX cost reduction potential? | LOW | MEDIUM | HIGH | 7 |
| ETI Additionality | To what degree can ETI skills & capabilities add value to the development? | LOW | MEDIUM | HIGH | 10 |
| Impact of ETI investment | How much impact would ETI investment have on the development? | LOW | MEDIUM | HIGH | 6 |
| Fit with ETI objectives | How closely aligned is the technology/system with ETI objectives? | LOW | MEDIUM | HIGH | 8 |



Using the above approach, the following two normalised measures for each activity were derived from the scores:

a) UK Marine energy sector industry need (0-100)

b) Alignment with the purpose and objectives of ETI (0-100)

These were then plotted on a graph of the type shown in Figure 1 to determine the relative priority of each activity. The priority categories are summarised in Table 2.

**Figure 1: Priority Level Classifications**

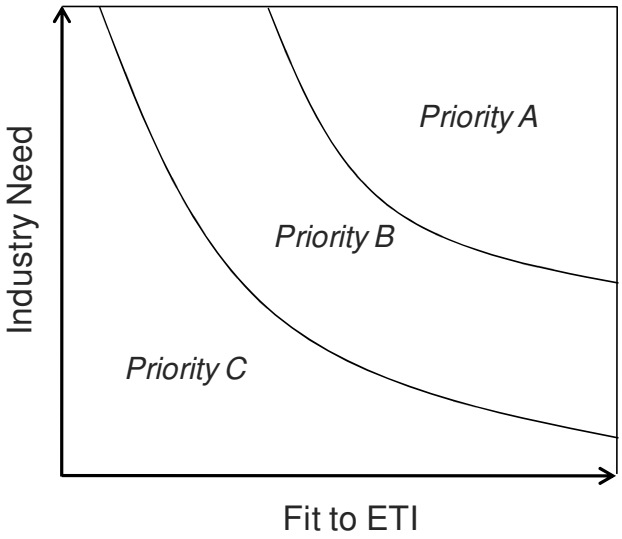



**Table 2: ETI Priority Categories**

| | |
|---|---|
| Priority A | Activities that have a high industry need and are also closely aligned with ETI purpose and additionality |
| Priority B | Activities that score highly on industry need but are not closely aligned with ETI purpose and additionality, or vice versa.<br>Priority B activities also include those that have a medium score for both industry need and ETI purpose and additionality |
| Priority C | Activities that generally score poorly on both industry need and ETI purpose and additionality.<br>Priority C activities also include some activities that score highly on industry need but are clearly not within the ETI's remit. |

It is important to note that just because an activity is classified as Category C this doesn't necessarily mean it is not an important industry issue. It is more likely to reflect a lack of alignment with ETI purpose.

## 5. Roadmap and Activity Implementation Timelines

In addition to identifying the key industry activities, and their relative prioritisation, it is important to understand the timelines against which these activities should be implemented to achieve marine energy sector commercialisation.

A preliminary assessment of the required timelines for the activities identified during this analysis has therefore been performed by the ETI and UKERC and is presented in Appendix 4. This includes an indication (through colour coding) of the relative ETI priorities associated with those activities.

## 6. Implications for Future ETI Activities

It is anticipated that the analysis presented in this document will be used by the ETI to help define future project interventions in the marine energy sector.

In general these interventions are likely to focus on the delivery of the Priority A activities identified in Appendix 3B, but major ETI projects may also incorporate Priority B and Priority C activities as part of a holistic / whole system demonstration approach where this delivers value for money.

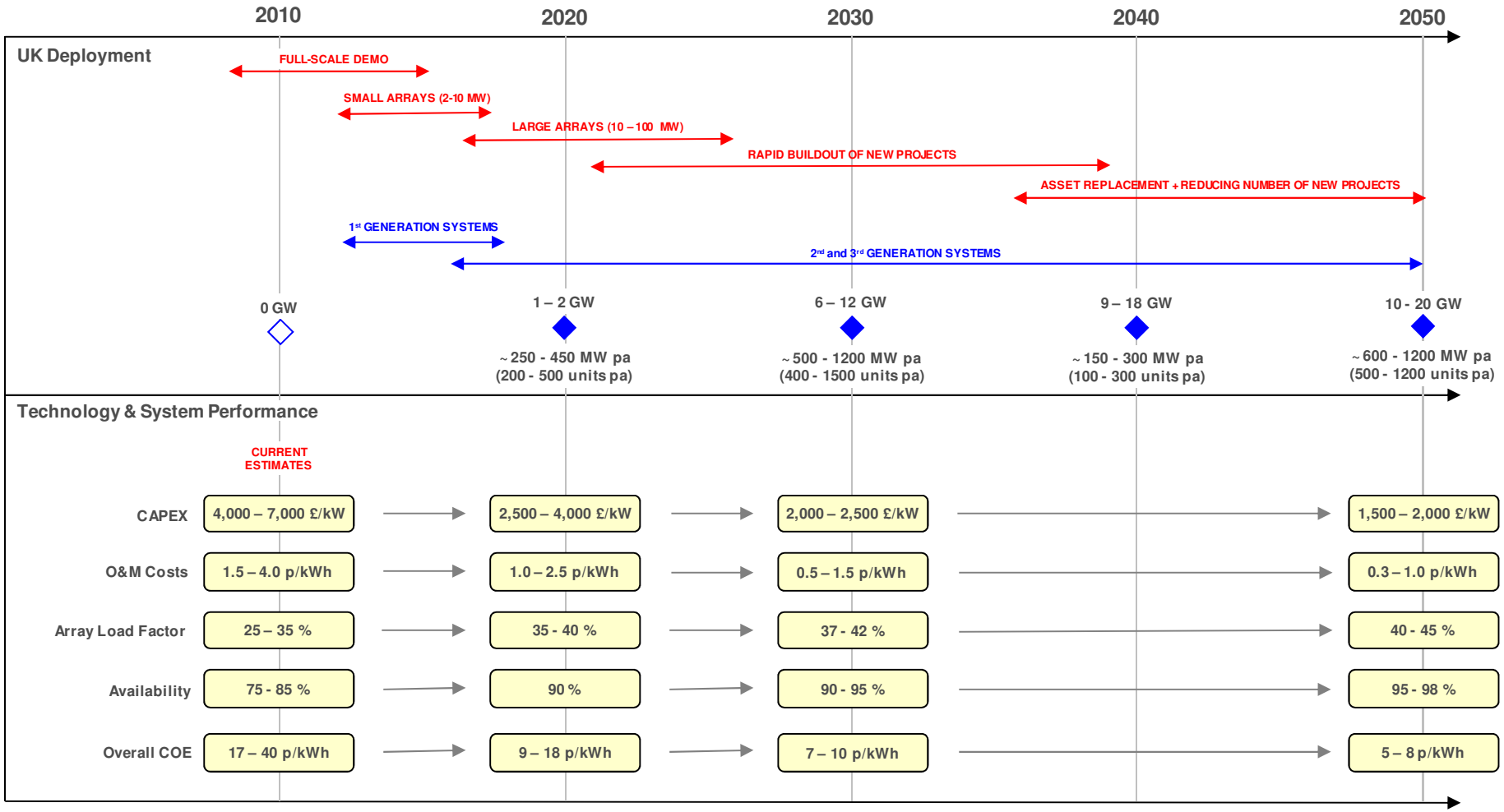
It should be noted that the prioritisation analysis presented in this document has been performed from the perspective of the ETI and its specific role and position within the energy funding landscape. Other UK funding organisations (such as the Carbon Trust, the Technology Strategy Board, etc) are likely to have differing priorities given their specific remits.

## 7. Acknowledgements

The ETI would like to thank UK Energy Research Centre, in particular Henry Jeffrey at Edinburgh University, for their major contribution to the prioritisation and Roadmapping activities summarised in this document.

The contributions of the Department of Energy and Climate Change's Marine Action Plan Technology Roadmapping Working Group and the European Strategic Energy Technology Plan (SET-PLAN) activities are also acknowledged.

## Appendix 1 – UK Marine Energy Deployment Strategy and Technology Development Targets



## Appendix 2 – Development Activities and Themes

| Device and System Demonstrators | Sub-components | Guidelines & Standards | Tool Development | Infrastructure & Enablers |
|---|---|---|---|---|
| Performance data collection | Control systems | Design guidelines and standards | Design optimisation tools | Skills and training (capacity building) |
| Installation methods | Power electronics | Manufacture, assembly & test standards | Device modelling tools | Supply chain development |
| Recovery methods | Generators (conventional) | Health & Safety guidelines | Array design and modelling tools | Development of open-sea testing facilities |
| Low-cost O&M techniques | Energy extraction technology (e.g. blades, interaction surface) | Certification rules | Resource analysis tools | Offshore grid system design and demonstration |
| 1st Generation device and array sea trials | Energy conversion system (e.g. PTO) | Development testing guidelines and standards | Techno-economic analysis tools | Array electrical system |
| 2nd Generation device development | Device structure | Performance guidelines and technical specifications | Failure mode and condition monitoring techniques | Onshore grid system development |
| 2nd Generation device and array sea trials | Foundations and mooring systems | Resource assessment guidelines and standards | Reliability modelling tools | Sub-sea electrical system equipment |
| | New device & component development (step-change) | Environmental guidelines and standards | Environmental Impact Assessment tools | Site consenting / leasing |
| | Offshore umbilical / wet HV connectors | | Site assessment tools | Knowledge transfer networks |
| | | | | Strategic environmental assessment |
| | | | | Component reliability data sharing |
| | | | | Harmonisation of model-scale testing facilities |
| | | | | Array interaction analysis |
| | | | | Continued long-term market support |

## Appendix 3A – Activity Prioritisation by Theme

| Device and System Demonstrators | Sub-components | Guidelines & Standards | Tool Development | Infrastructure & Enablers |
|---|---|---|---|---|
| Performance data collection | Control systems | Design guidelines and standards | Design optimisation tools | Skills and training (capacity building) |
| Installation methods | Power electronics | Manufacture, assembly & test standards | Device modelling tools | Supply chain development |
| Recovery methods | Generators (conventional) | Health & Safety guidelines | Array design and modelling tools | Development of open-sea testing facilities |
| Low-cost O&M techniques | Energy extraction technology (e.g. blades, interaction surface) | Certification rules | Resource analysis tools | Offshore grid system design and demonstration |
| 1st Generation device and array sea trials | Energy conversion system (e.g. PTO) | Development testing guidelines and standards | Techno-economic analysis tools | Array electrical system |
| 2nd Generation device development | Device structure | Performance guidelines and technical specifications | Failure mode and condition monitoring techniques | Onshore grid system development |
| 2nd Generation device and array sea trials | Foundations and mooring systems | Resource assessment guidelines and standards | Reliability modelling tools | Sub-sea electrical system equipment |
| | New device & component development (step-change) | Environmental guidelines and standards | Environmental Impact Assessment tools | Site consenting / leasing |
| | Offshore umbilical / wet HV connectors | | Site assessment tools | Knowledge transfer networks |
| | | | | Strategic environmental assessment |
| | | | | Component reliability data sharing |
| | | | | Harmonisation of model-scale testing facilities |
| | | | | Array interaction analysis |
| | | | | Continued long-term market support |

ETI **PRIORITY A ACTIVITY** **ETI PRIORITY B ACTIVITY** **ETI PRIORITY C ACTIVITY**

## Appendix 3B – ETI Activity Prioritisation by Priority Category

| PRIORITY A ACTIVITIES | PRIORITY B ACTIVITIES | PRIORITY C ACTIVITIES |
|---|---|---|
| Installation methods | Component reliability data sharing | Knowledge transfer networks |
| 1st Generation device and array sea trials | Offshore grid system design and demonstration | Harmonisation of model-scale testing facilities |
| Recovery methods | 2nd Generation device and array sea trials | Control systems |
| Reliability modelling tools | Development testing, guidance and standards | Site assessment tools |
| Resource analysis tools | Supply chain development | Environmental guidelines and standards |
| 2nd Generation device development | Techno-economic analysis tools | Certification rules |
| Foundations and mooring systems | Failure mode and condition monitoring techniques | Strategic environmental assessment |
| Array design and modelling tools | Sub-sea electrical system equipment | Array electrical system |
| Energy conversion system (e.g. PTO) | Energy extraction technology (e.g. Blades, interaction surface) | Site consenting / leasing |
| Design optimisation tools | Device structure | Continued long-term market support |
| Array interaction analysis | Manufacture, assembly and test standards | Skills and training (capacity building) |
| Low-cost O&M techniques | Resource assessment guidelines and standards | Environmental Impact Assessment tools |
| Performance data collection | Onshore grid system development | Health & Safety guidelines |
| New device and component development (step change) | Design guidelines and standards | Power electronics |
| Offshore umbilical / wet HV connectors | Development of open-sea testing facilities | Generators (conventional) |
| Device modelling tools | | |
| Performance guidelines & technical specifications | | |

## Appendix 4 – Roadmap & Activity Implementation Timelines