UKERC Marine (Wave and Tidal Current) Renewable Energy Technology Roadmap

Summary Report

UK Energy Research Centre
University of Edinburgh

Contact Details:
Dr. Markus Mueller: Email: Markus.Mueller@ed.ac.uk
Henry Jeffrey: Email: Henry.Jeffrey@ed.ac.uk
School of Engineering & Electronics
University of Edinburgh
The King’s Buildings
Edinburgh
EH9 3JL

Executive Summary

This document is a technology roadmap: it provides a guide for mobilising the wave and tidal energy community in the UK down a deployment pathway towards a target of achieving 2GW installed capacity by 2020.

The roadmap is aimed at providing a focused and coherent approach to technology development in the marine sector, whilst taking into account the needs of other stakeholders. The successful implementation of the technology roadmap depends upon a number of complex interactions between commercial, political and technical aspects.

Although this roadmap is technically focused it also considers policy, environmental and commercialisation aspects of the marine energy sector, in order to display and put in context these wider influences.

The roadmap is aimed at ***technology developers, project developers, policy makers, government bodies, investors (public and private), the supply chain, consultants, and academics, in order to aid coherent progression of the sector.***

Although the roadmap has been written with the UK community in mind, it is expected that its core technical aspects will be applicable internationally, if modifications for a particular country's policy, regulation and infrastructure context are taken into consideration.

It should be stressed that the roadmap is a living document: it will evolve and be maintained over time according to technology advances, changes in policy, an understanding of the environment, and the changing overall landscape of the sector.

The roadmap has been arrived at as a result of consultation with the community at 4 workshops held since April 2005, as well as over 40 one-to-one interviews. Overall a Battelle methodology has been used in the construction of the roadmap, with a Delphi method used in the one-to-one interviews. This roadmap document builds upon a number of UKERC documents and the UKERC marine

landscape document, all of which are to be found on the UKERC website, www.ukerc.ac.uk. Finally although the UKERC hosts this roadmap, its ownership lies with marine sector itself, who have fed into it during the consultation process.

1. Document structure and Roadmap methodology

This document builds upon information raised during a series of expert consultations. Although it is not the purpose of this roadmap to provide a definitive statement on the ultimate route forward for this nascent sector, this document will show how certain deployment scenarios can be applied in the marine energy sector. It also details the requirements and timescales involved in achieving them.

The roadmap consultation process included 4 community workshops held between April 2005 and February 2007 and over 40 one to one stakeholder interviews (a more detailed timeline is provided in Appendix 2):

April 2005

- A review of existing marine energy technology reviews or roadmaps, and what are the major R&D challenges?
- Twenty five delegates attended the workshop held at the University of Edinburgh.

August/September 2005

- In collaboration with EMEC, workshops on Environmental (20 delegates) and Tidal Measurement Techniques (15 delegates) were held at the University of Edinburgh.

January 2007

- A workshop was held at the UKERC Meeting Place in Oxford entitled: "A Framework for an International Marine Renewable Energy Roadmap". 23 delegates attended from around the world.
- An initial version of the roadmap was presented to an international audience, and the feedback was used to in the compilation of the roadmap presented in this document.

Presentations and/or reports from all the workshops can be found on the UKERC website.

A Battelle methodology was used in the construction of the roadmap, with a Delphi method used in the one to one interviews.

The Battelle approach is underpinned by 4 main criteria for consideration in forming a roadmap:

1. **Vision Statement**: The Vision statement defines the major target for 2020, which will be achieved through the various stages of the Deployment Strategy.
2. **Deployment Strategy**: The deployment strategy defines a scenario for deployment of marine devices up to 2020, with the final deployment target defined in the vision statement.
3. **Commercial Strategy:** The commercial strategy defines the mechanisms and infrastructure required to achieve the various stages in the deployment strategy.
4. **Technical Strategy:** The technical strategy provides underpinning technical requirements and breakthroughs to facilitate the achievement of the commercial and deployment strategies.

During the consultation process the following vision statement was agreed upon as a suitable and challenging target for the sector:

<u>Vision Statement.</u>

The UKERC Marine Renewable Technology Roadmap aims to assist the UK marine and renewable energy community with the following[1]:

- **To exploit energy from waves and tidal currents in an environmentally and socially responsible way, aiming for an installed capacity of 2GW by 2020 in UK waters.**
- **To stimulate policy and funding instruments to overcome barriers to deployment.**
- **To establish a commercially viable industry supported by an extensive supply chain and thereby build skills capacity at all levels.**
- **To become competitive with other energy sources by 2020.**

The remainder of this document will provide the detail of the roadmap with chapter 2 detailing the deployment strategy, chapter 3 detailing the associated commercial strategy. Chapter 4 is main section of the document where the underpinning technical requirements and timelines are detailed and qualified for the roadmap. Finally, chapters 5 and 6 summarise the challenges and conclude the overall findings.

[1] In order to provide guidance to forming the vision statement it is worth comparing the respective current positions of the marine energy industry with the wind industry. It is estimated that marine renewables is 15-20 years behind wind, so that the target of 2GW installed capacity by 2020 reflects the development in wind in the UK.

The target is also in line with estimates in the Carbon Trust Marine Energy Challenge, which proposes 2-5GW of both wave and tidal current energy across Europe installed by 2020.

2. Deployment Strategy

The deployment strategy displayed in Figure 1 describes a scenario (or pathway) in graphical form, showing how 2GW of installed capacity could be installed by 2020. The interconnections and dependencies between the deployment strategy and the commercial and technical strategies are highlighted later in the document.

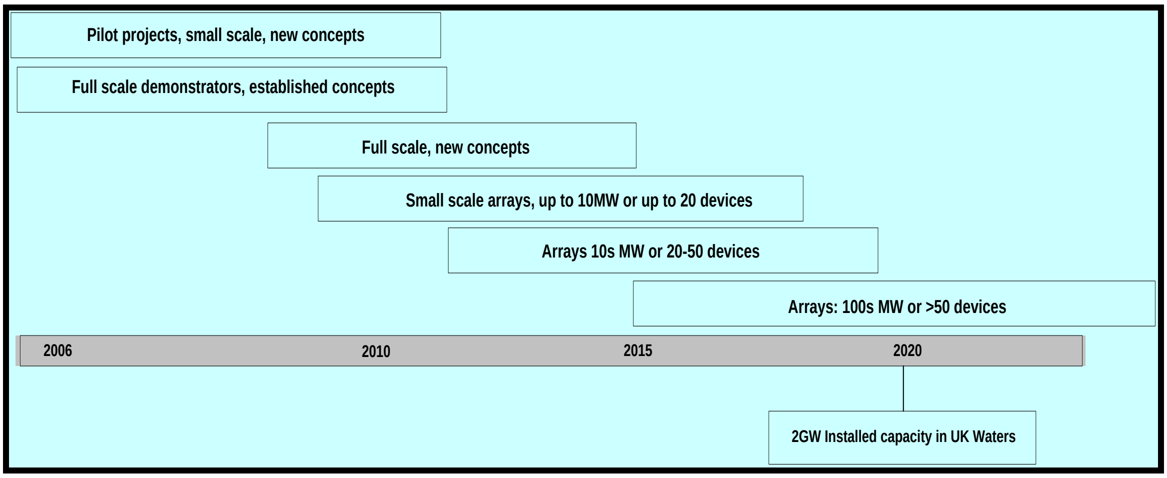

Figure 1: Deployment Scenario up to 2020[2]

The deployment strategy describes a scenario (or pathway) in graphical form, showing how 2GW of installed capacity could be installed by 2020. This goal will only be achieved through device deployment, and principally the deployment of significant device arrays. In order to ensure effective learning, deployment must be a progressive process, which is reflected in the scenario. It must be emphasised at this point, that this deployment strategy is based upon favourable and continuous economic and political climates being in place for marine energy throughout the deployment period, as well as the addressing of the technical challenges highlighted within this report.

Figure 1A displays the current funding policy landscape in the UK to facilitate and support the deployment of devices. To add context to this, Figure 1B displays a timeline of the current deployment situation.

[2] The scenario as presented is in line with the growth shown in the Path to Power deployment scenario (BWEA), leading to gradual growth of up to 200-300MW by 2012-2015 with rapid growth thereafter to 2020.

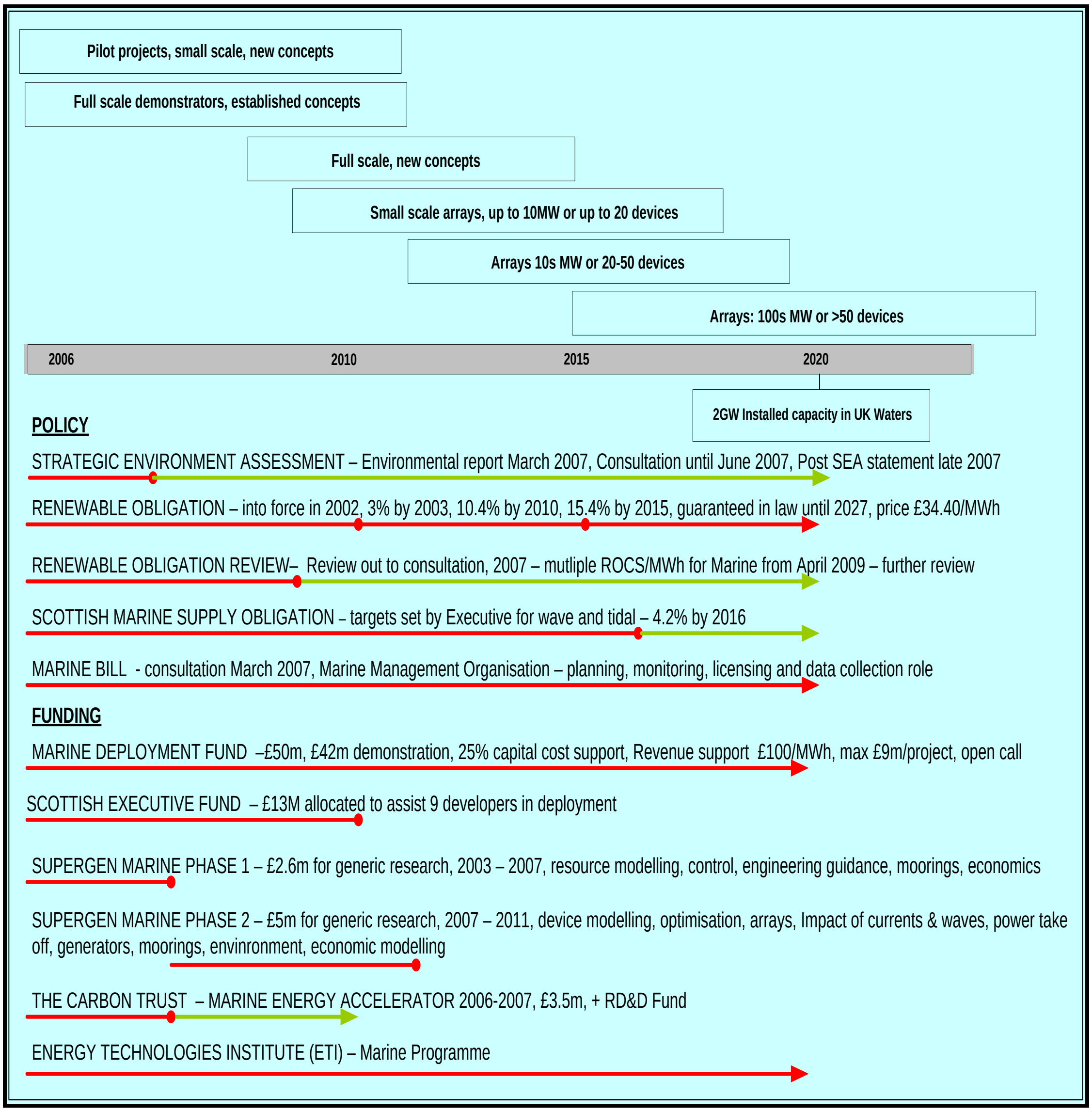

Figure1A: Current policy and funding landscape in the UK

In figure 1A and all the remaining deployment figures, the red line indicates a primary activity, milestones are indicated by a red dot, and the green line indicates a review period (within which mechanisms are developed and adjusted as necessary).

Clearly, the status (primary or review) of each of these themes and their relationship with the deployment strategy will be under regular review, depending upon changes in the technology or policy.

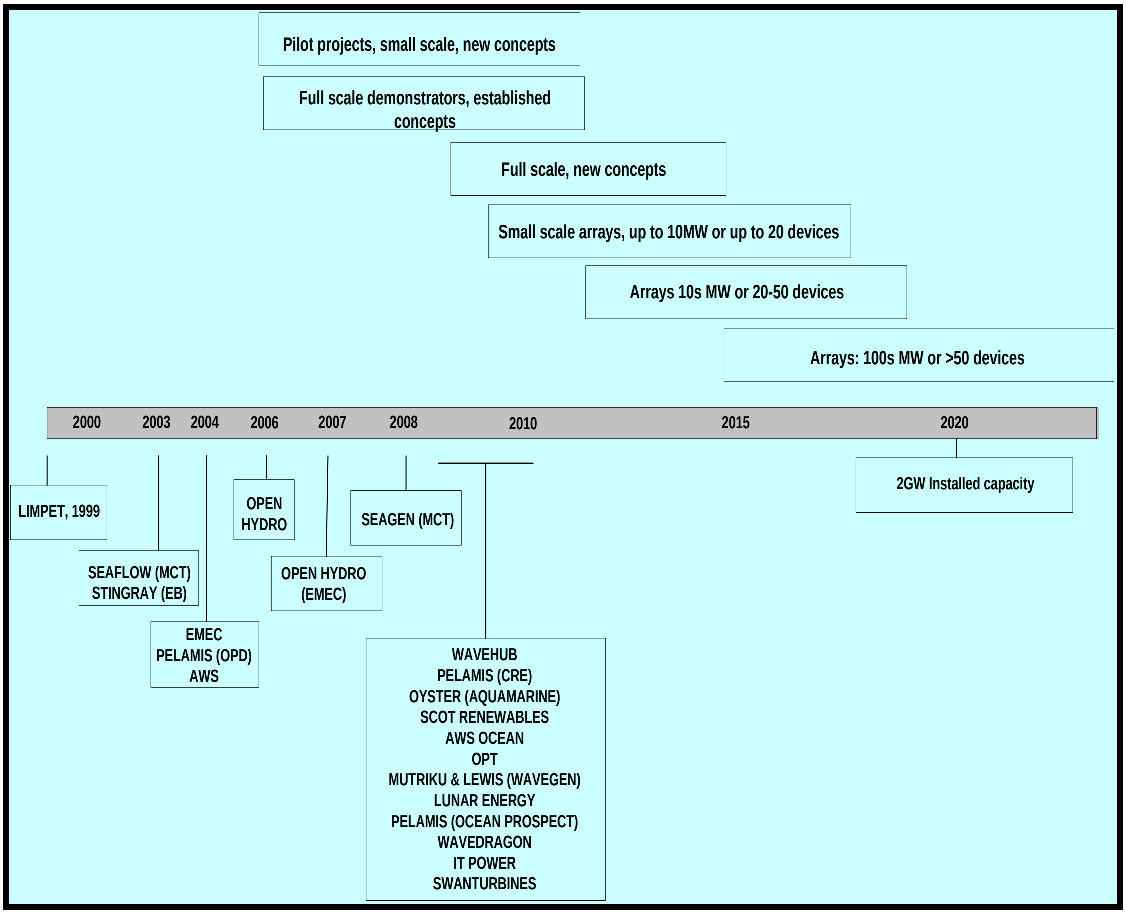

Figure1B: Present deployment landscape

It is anticipated that new devices will continue to be developed at small scales, while more established devices, being demonstrated in the sea, become adapted and improved. By around 2015 there will be industry consensus around families of wave and tidal energy devices.

As with any scenario, there are associated assumptions, which cover all aspects of the sector, including infrastructure, policy, economics and technical issues. For this roadmap, it has been assumed that:

1. An attractive market is in place for wave and tidal energy.
2. Manufacturing infrastructure is in place to meet low volume manufacture for small arrays ramping up to high volume manufacture by around 2015.
3. Resource, electrical grid and environmental assessments at all the most promising sites are completed before 2015.
4. Planning legislation is in place to enable all sites to be exploited to meet the 2020 target.

5. Individual device developers have stabilised their designs, and reached design consensus on their respective technologies allowing high volume manufacture and deployments by 2015.
6. Policies are in place to ensure a smooth transition from low volume to high volume deployment.
7. Manpower skills and capacity are available to service the rapid expansion required beyond 2015.
8. Electrical regulatory and infrastructure aspects are in place to enable large volume deployments of arrays.
9. Cost effective installation and O&M strategies have been established before 2015.

3. Commercial Strategy

Figure 2 shows the relationship between the commercial and deployment strategies. The main headings of the commercial strategy are in upper case, followed by a brief description of the main issues.

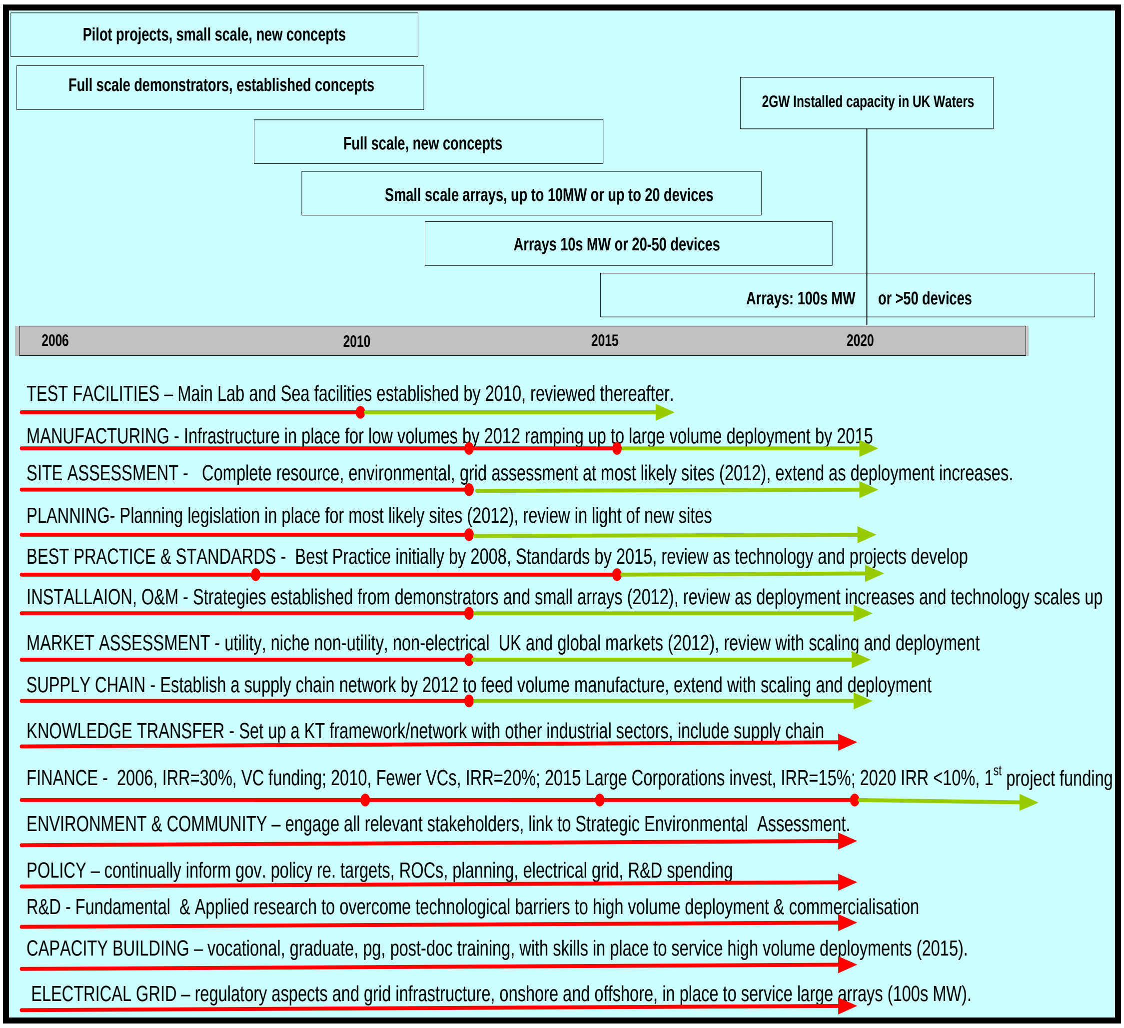

Figure 2: Time dependency between the Commercial Strategy and the Deployment Strategy

The commercial strategy (displayed in Figure 2) required to fulfil the deployment strategy consists of 10 main themes (some have sub-themes, leading to 15 items in Figure 2) covering all aspects of the RDD&D chain for an emerging technology such as marine renewables. An expansion of the 10 main and sub-themes can be found in Appendix 1.

4. Technical Strategy

Although dependent on both the deployment and commercial strategies, the underpinning technical strategy is the focus of this roadmap. The technical strategy has been divided into 12 themes referred to as Technology Working Areas (TWAs), which represent the technology development chain in marine renewable devices:

a) Resource Modelling & Measurement
b) Device modelling
c) Experimental Testing
d) Moorings & Sea Bed Attachments
e) Electrical Infrastructure
f) Power Take Off and Control
g) Engineering Design
h) Lifecycle & Manufacturing
i) Installation, O&M
j) Environmental
k) Standards
l) System Simulation

The following section will display the overall timeline for the Technical Strategy in relation to the Deployment Strategy, and also detailed qualified timelines for each of the TWAs.

Deployment Strategy and the Technical Strategy.

Figure 3 shows the overall relationship between the technical strategy and the deployment strategy, with the TWAs in upper case, followed by a brief description of the main technical issues.

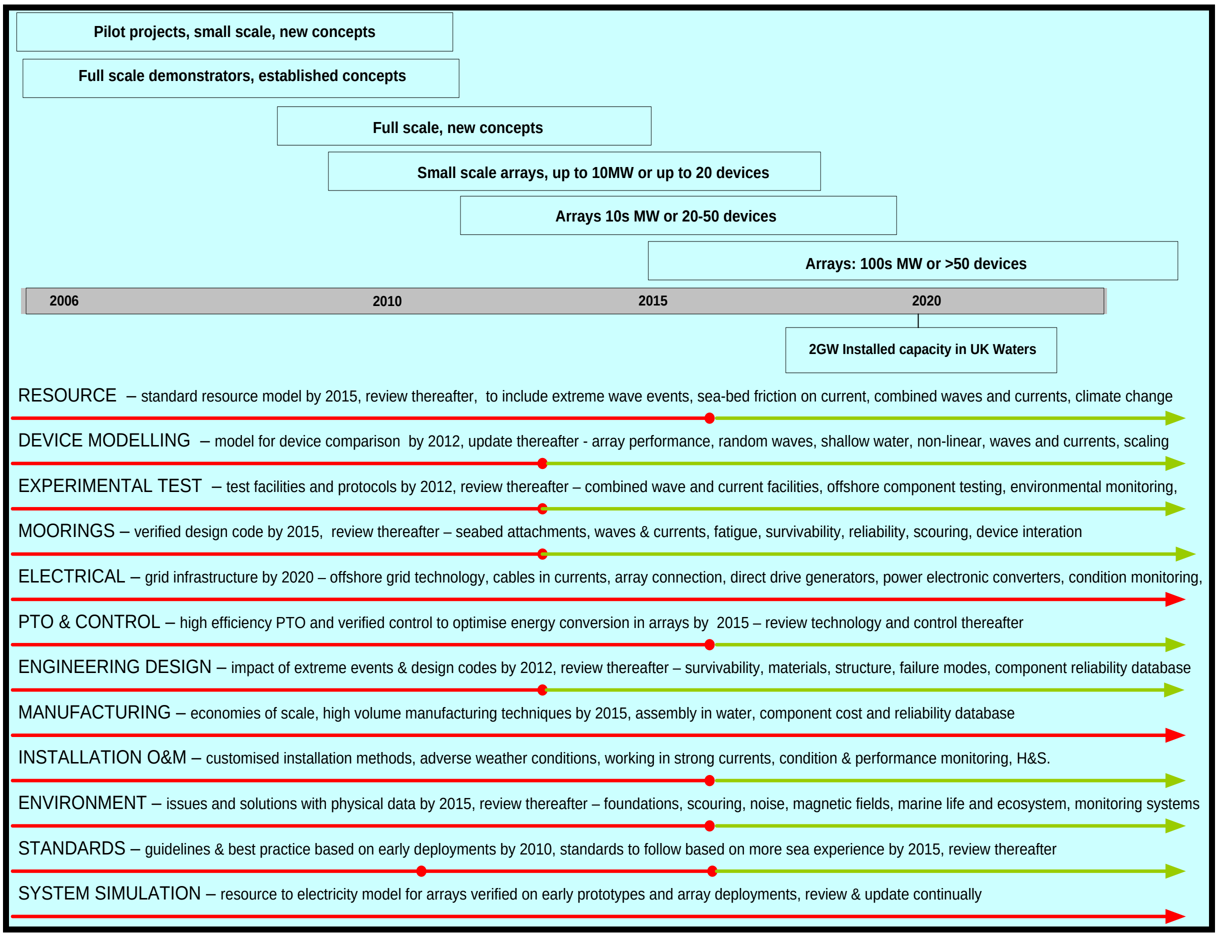

Figure 3: Time dependency between the Technical Strategy and the Deployment Strategy

The following figures (3A to 3K) display the qualified detailed timelines for each of these TWAs.

Technical Strategy: Resource Modelling & Measurement Timeline

Rationale:

- Resource modelling underpins both technical and economic development of devices.
- Knowledge of extreme events will impact the engineering design of a device and its ability to survive, which in turn has economic implications.
- A better knowledge of the near shore wave resource will inform the design of devices and the economic exploitation of such sites.
- The size of the wave resource is reasonably well understood, but the impact of climate change on the resource will affect design and economics.
- The tidal current resource is probably less well understood, in particular the impact of seabed friction and the environmental impact on sediment flow.
- Knowledge of the combined impact of waves and currents on devices is very limited.
- Modelling needs to be verified at model, intermediate and full scale to provide confidence in the use of these models, and is thus closely linked to Experimental Testing.
- These issues need to be better understood by 2015 so that there are no technical barriers to large volume deployment.

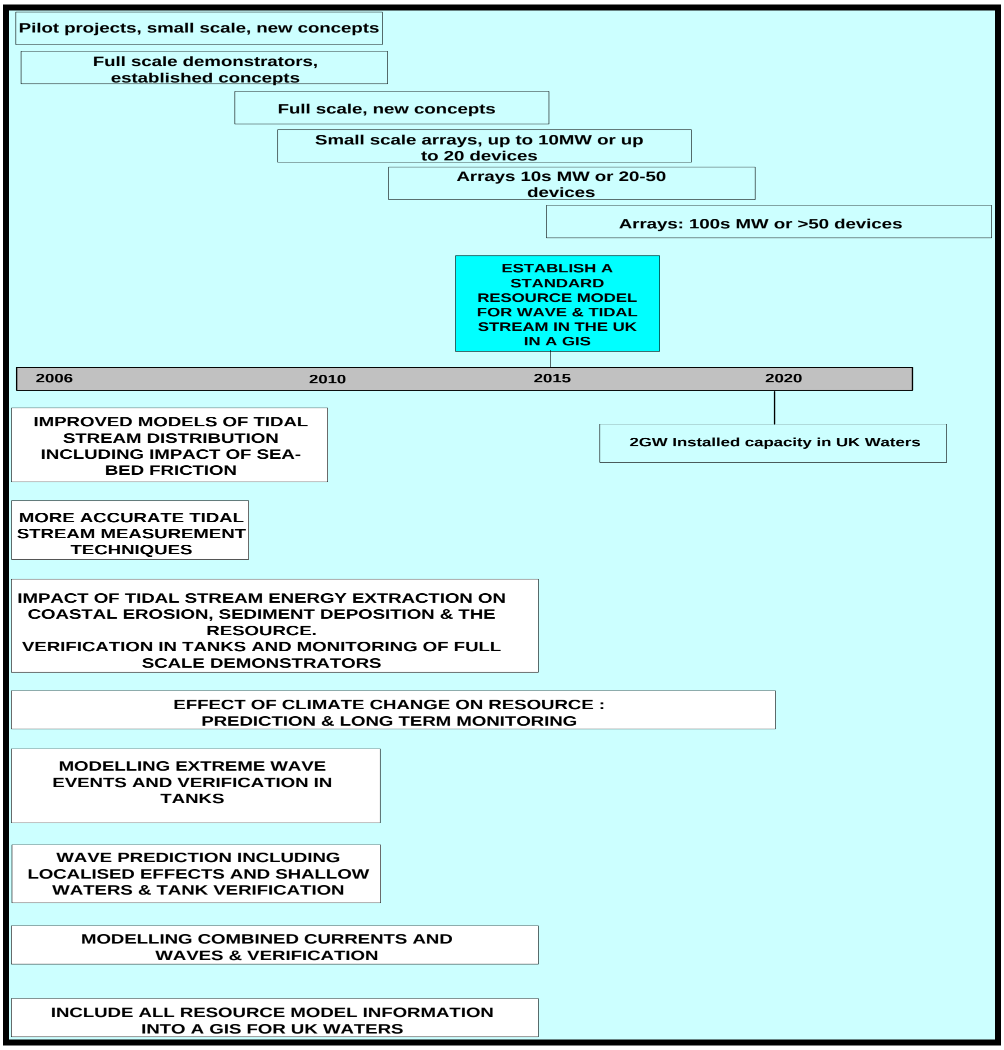

Figure 3A: Resource Modelling & Measurement Timeline

Technical Strategy: Device Modelling Timeline

Rationale:

- Traditionally the development process involves a number of stages in wave tanks at different scales, and a considerable time is needed before reaching a scale suitable for sea trials.
- This development time could be reduced by combining tank tests with more accurate device models that can be used with confidence.
- Modelling of devices in arrays is vital for large volume deployment of devices in arrays from 2015 onwards.
- Physical data from smaller arrays deployed from 2007 to 2012 should be used to verify array modelling work.
- There are close links with resource modelling, experimental testing, moorings, electrical infrastructure, PTO & control and system modelling.

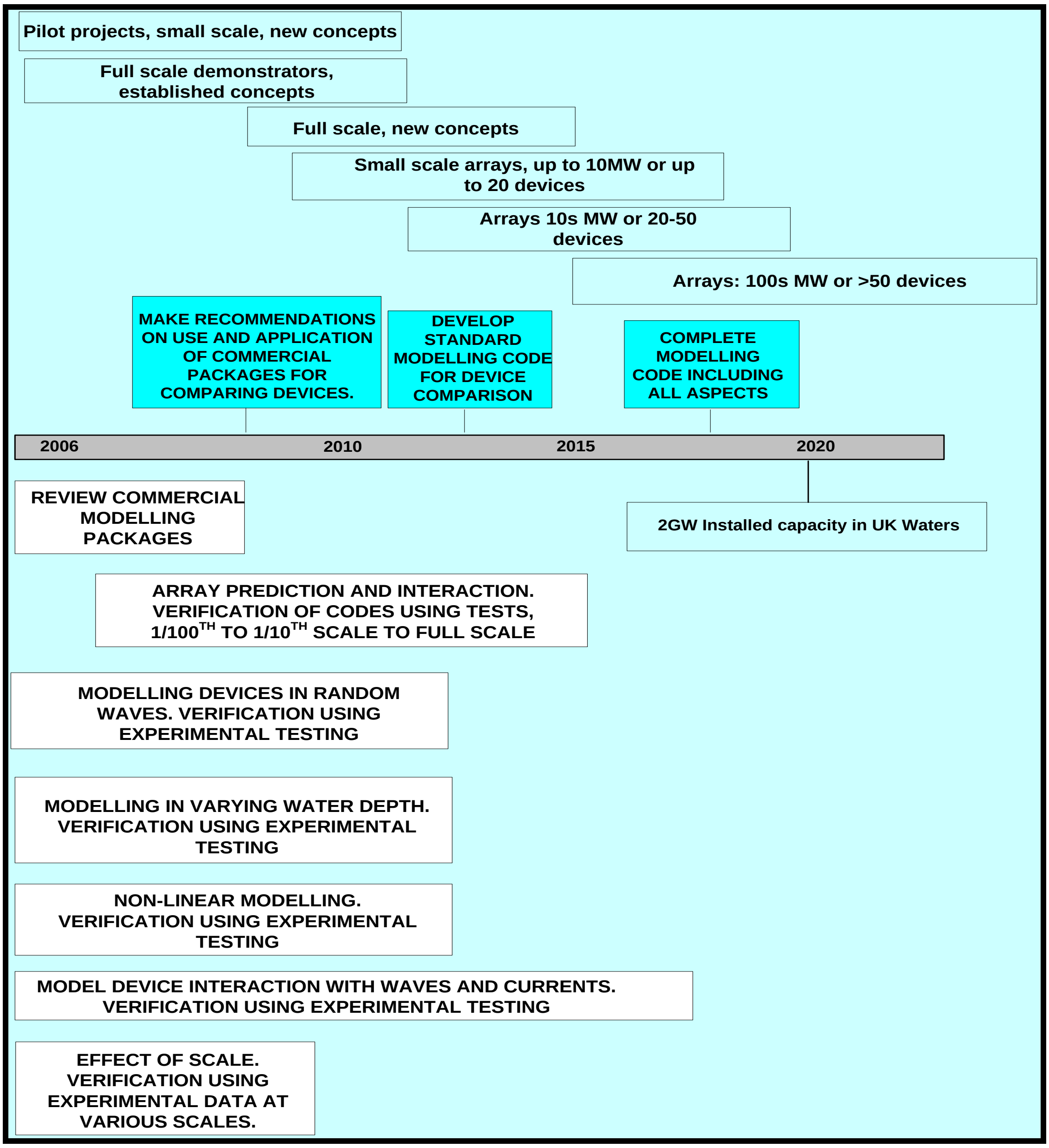

Figure 3B: Device Modelling Timeline

Technical Strategy: Experimental Testing Timeline

Rationale:

- Access to scale test tanks provides an economic method of assessing new concepts, which, when combined with accurate device models, has the potential to reduce the number of development stages.
- Tank test facilities provide a controlled and repeatable environment for device development.
- Sea test sites are already available at EMEC, and Wavehub is due to come online in August 2008.
- Test facilities are important for the verification of resource and device models.
- There is a gap in controllable and repeatable wet test facilities for tidal current systems.
- Towing tanks, when used for tidal energy tests do not adequately represent the interaction of a stationary energy extraction device in moving water.
- There is currently no facility for investigating the combination of current and waves.
- Component testing will contribute to a better understanding of reliability, but must be performed under realistic conditions.
- Testing standards and guidelines are required to ensure consistency between test facilities.
- Alongside resource and device modelling, experimental testing is integral to the engineering design and deployment of devices at all levels, from new concepts to large arrays.

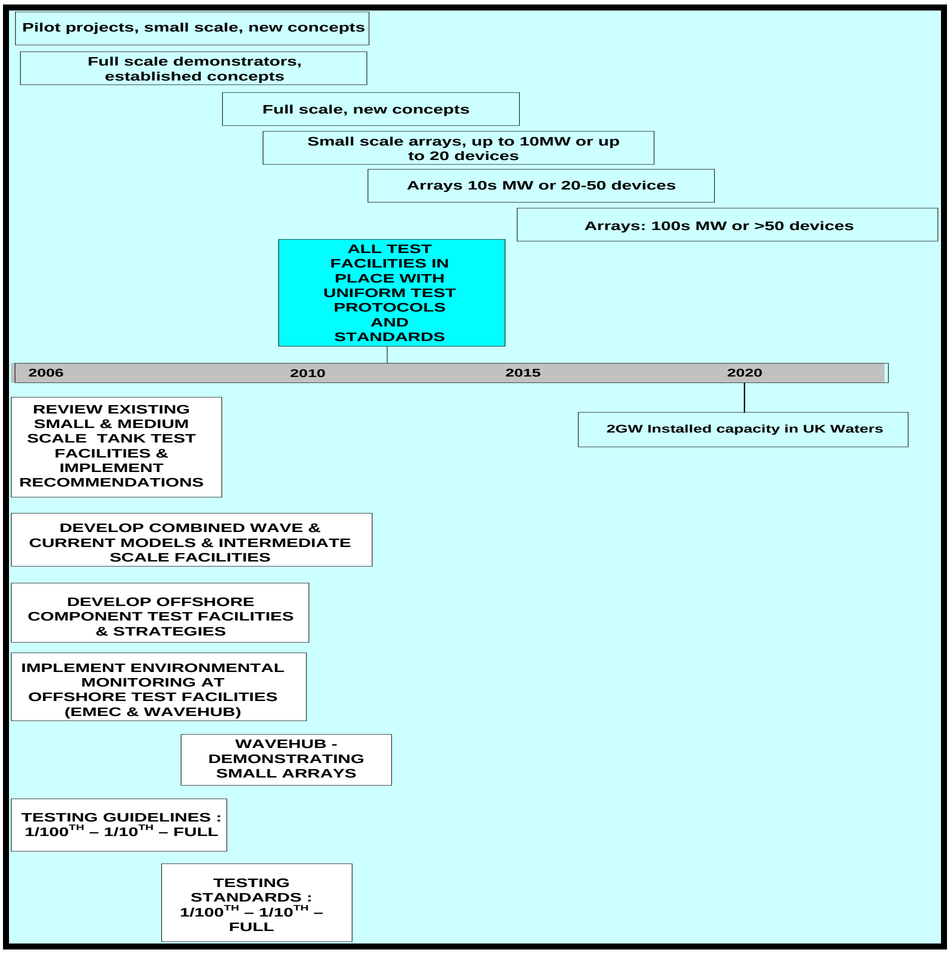

Figure 3C: Experimental Timeline

Technical Strategy: Moorings and Seabed Attachments Timeline

Rationale:

- Moorings and seabed attachments are integral to the successful deployment, operation and recovery of wave and tidal current devices.
- There would be significant benefit to the sector from the development of technologies that removed the need for large vessels and barges from the installation procedure.
- Knowledge gained from deployments between 2008 and 2012 must be used to finalise design tools for large volume deployment from 2015.
- Testing should take place in both scale test facilities and at sea, EMEC and Wavehub. Physical data from deployments at sea should be fed back to help validate design tools.
- This requires close interaction with resource, device modelling, experimental testing, engineering design, environment, and installation O&M.

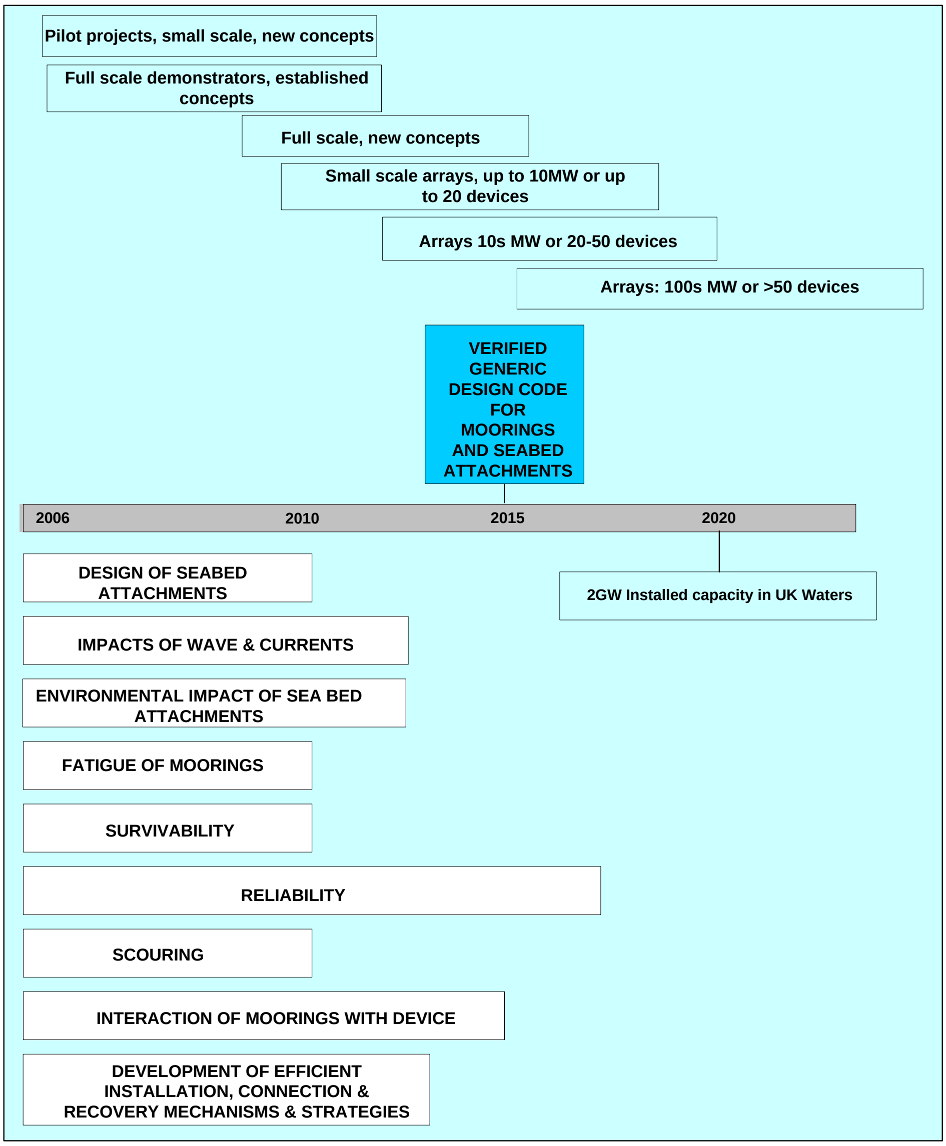

Figure 3D: Moorings & Seabed Attachments Timeline

Technical Strategy: Electrical Infrastructure Timeline

Rationale:

- In the UK, upgrading of the electrical grid infrastructure is critical to meeting the 2020 target.
- Upgrading is likely to be both onshore and offshore – the two have to be combined in such a way to minimise potential delays brought on by planning and environmental issues. A strategy needs to be in place by 2010.
- Electrical connection of devices, cable laying, and connection within and between arrays link in with installation and O&M.

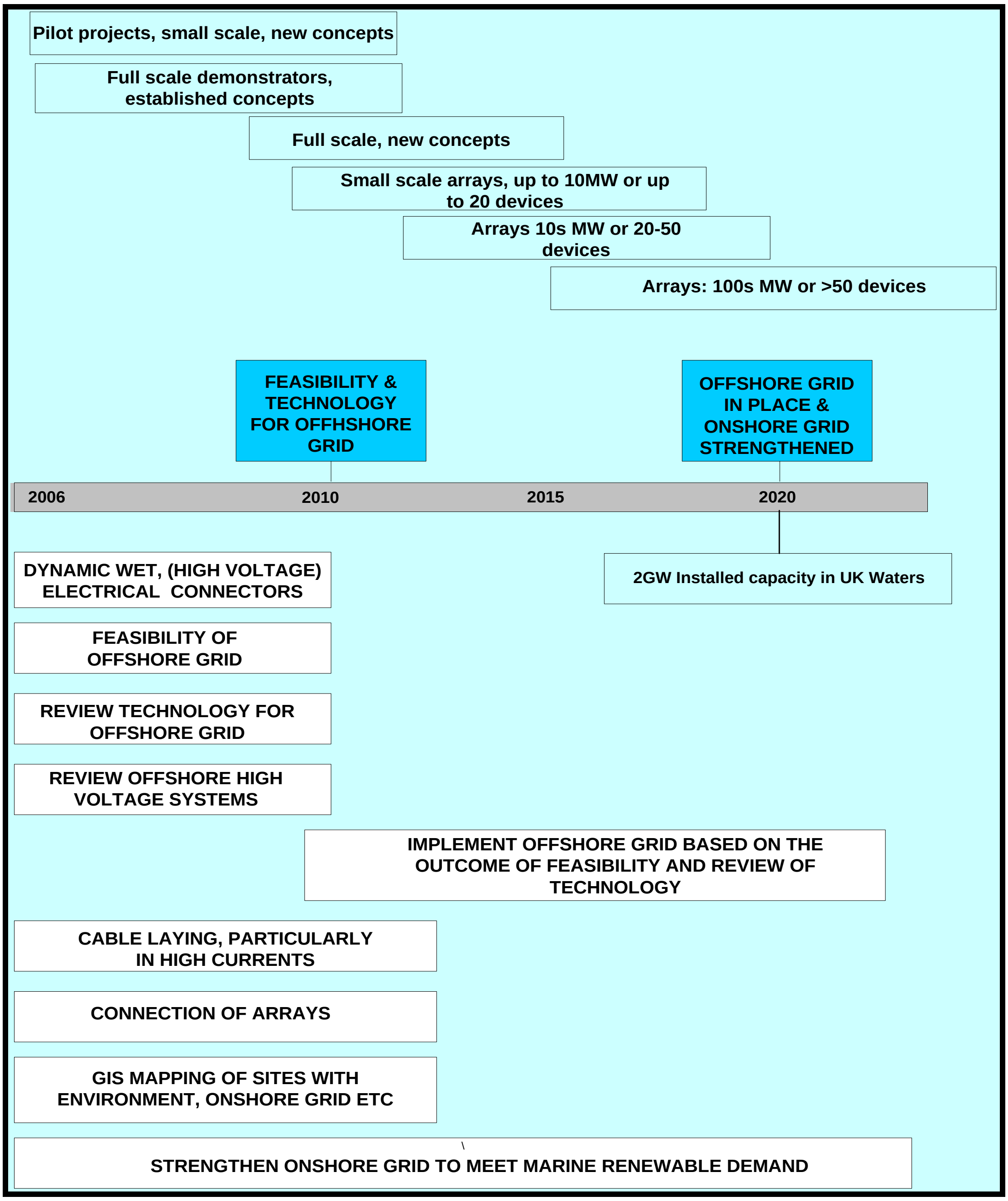

Figure 3E: Electrical Infrastructure Timeline

Technical Strategy: Power Take Off and Control Systems Timeline

Rationale:

- Conversion of the mechanical energy into electrical energy using direct drive provides a potentially more robust and efficient solution, compared to hydraulics or gearboxes driving a conventional rotary generator, but deployments are required to demonstrate the potential advantages, if direct drive is to make a significant contribution to large volume deployment from 2015 onwards.
- Power electronic converters are required to interface to the electrical grid, but once again, deployments are required to gain more knowledge of performance and reliability.
- Condition monitoring systems will play a role in O&M of devices, and should be intelligent, such that the PTO can be controlled to modify performance, ensuring continued operation even during a fault condition.
- Physical data collected from small scale deployments should be used to modify designs for large volume array deployments
- High part-load efficiency and effective control systems in power take off mechanisms such as hydraulics or air-turbines affect the technical performance and the economics of the system.
- Control strategies between devices in arrays need to be developed and tested in small array deployments for implementation in large arrays beyond 2015.
- Energy storage systems and alternative energy vectors are long term issues, but need to be investigated for non-electricity markets and further developments beyond 2020.
- There will be close links with resource and device modelling, electrical infrastructure, experimental testing, moorings, engineering design, markets and economics.

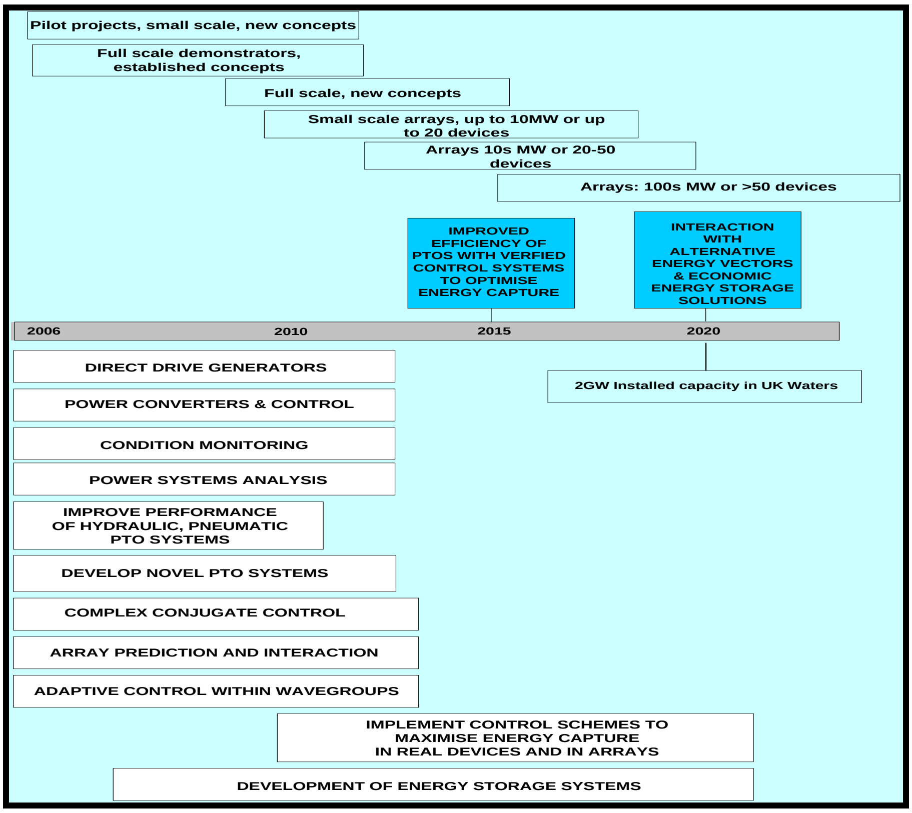

Figure 3F: Power Take Off & Control Systems Timeline

Technical Strategy: Engineering Design Timeline

Rationale:

- Engineering design is critical to successful large volume manufacture and deployment.
- Survivability is arguably the most important aspect of the development of any new device. This will benefit from advances in new structural materials, a better understanding of failure modes and component reliability, and the ability to forecast extreme events.
- There are close links with resource modelling (in terms of extreme events), device modelling, moorings, electrical infrastructure, PTO and control, manufacturing and environment.
- Standard design codes should be developed so that they can be applied to any new concept to assist efficient and effective development.

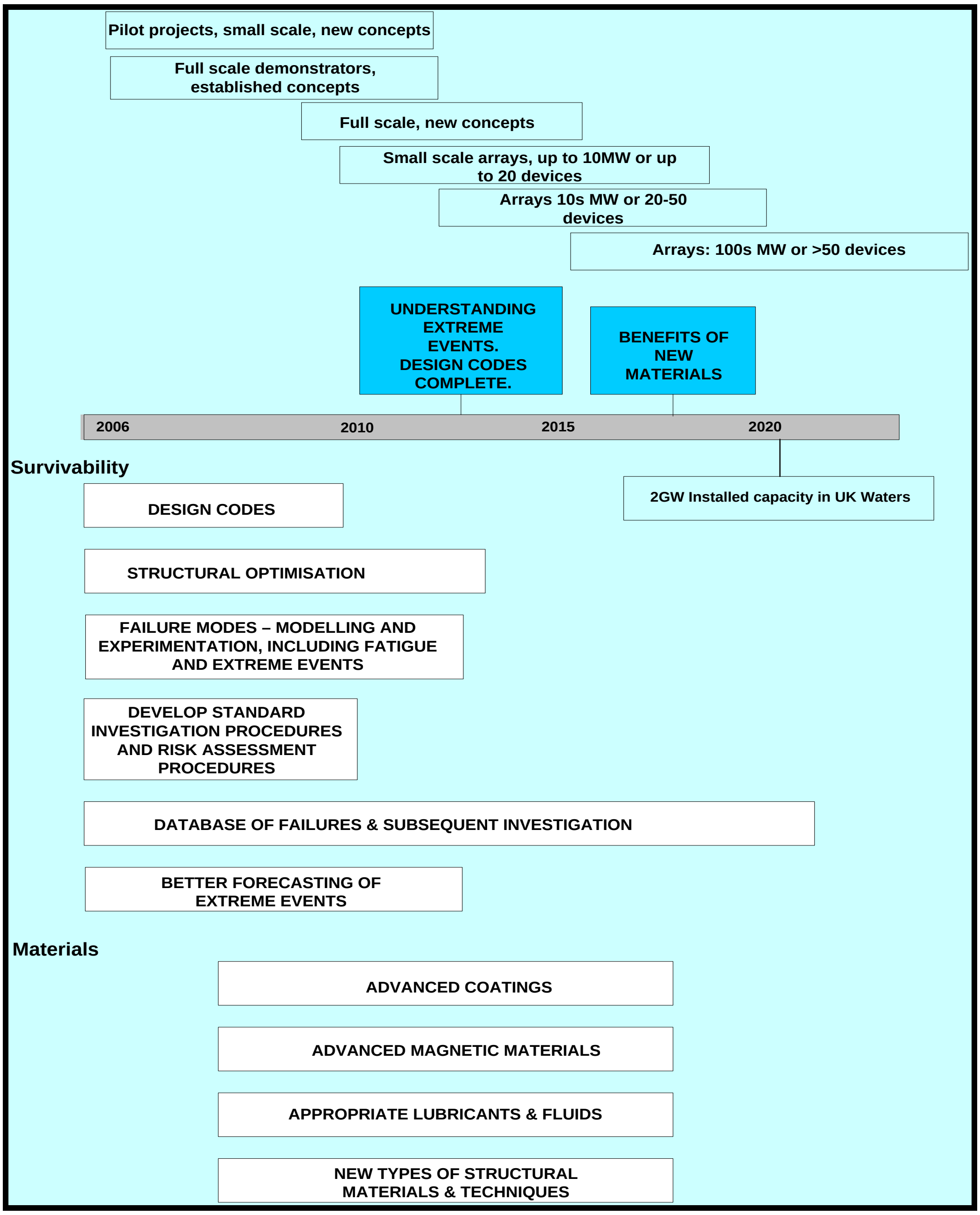

Figure 3G: Engineering Design Timeline

Technical Strategy: Lifecycle & Manufacturing Timeline

Rationale:

- Manufacturing infrastructure is one of the key aspects to meeting the 2020 target, and it should be in place by 2012 for high volume deployment from 2015 onwards.
- High volume manufacture will require device designs to have matured and a degree of consensus reached
- Scaling and the economics need to be assessed to determine the optimum production unit, which should be finalised for high volume deployment.
- During testing of small to medium arrays, device/array performance should be appraised, so that more confidence is gained for operation and costing for larger arrays.
- A generic component database including reliability and cost data will be a useful tool for developers.
- Manufacturing depends upon the engineering design of a device, it will influence the installation and operation of a device, and clearly cost effective manufacture will be vital for economic operation.

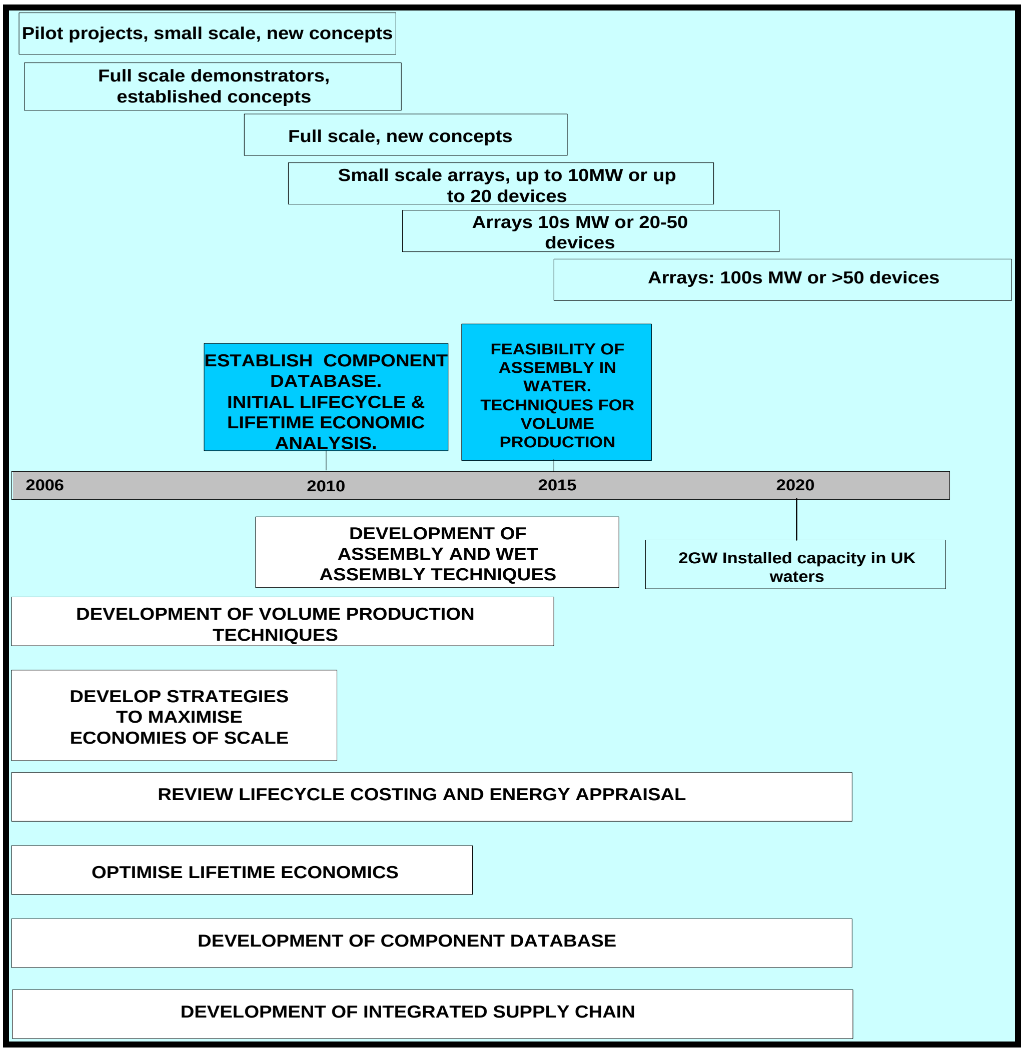

Figure 3H: Lifecycle and Manufacturing Timeline

Technical Strategy: Installation and O&M Timeline

Rationale:

- In order to achieve high volume deployments the community needs to have dedicated installation vessels or novel deployment methods so that they do not compete with other sectors of the offshore industry.
- Deployment of the small to medium sized arrays will provide experience of installation methods and O&M procedures, in various weather conditions.
- In both aspects, health and safety (H&S) procedures need to be established before even small scale deployments.
- Installation methods should be part of an integrated design procedure, forming part of design optimisation.
- Throughout the deployment phases, physical data detailing performance and reliability should be collected for verifying modelling and design tools.
- Intelligent condition monitoring methods need to be demonstrated to assist O&M.

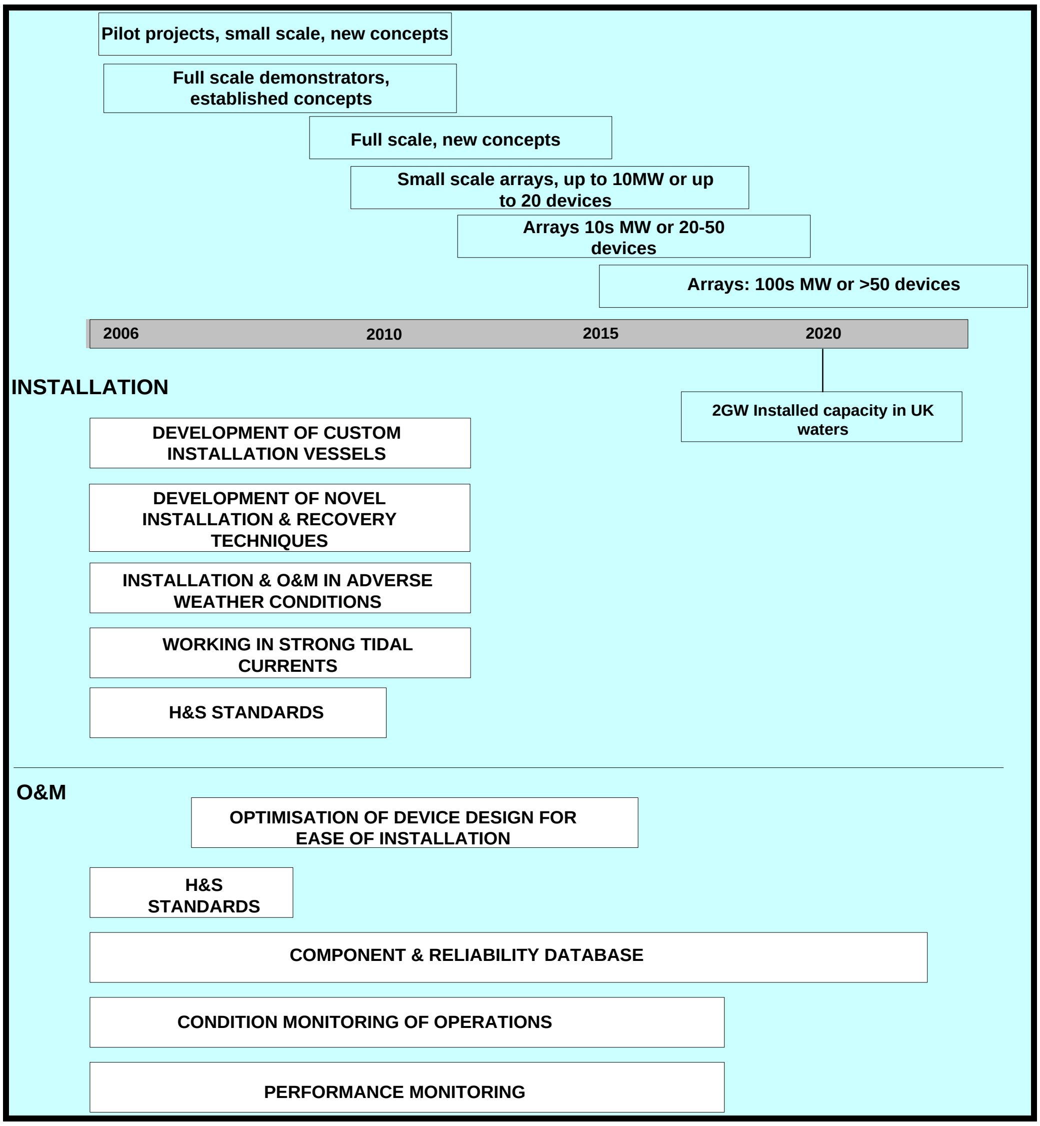

Figure 31: Installation, O&M Timeline

Technical Strategy: Environmental Timeline

Rationale:

- The impact of devices (installation, operation and decommissioning phases) on the environment needs to be monitored throughout the deployment of small to medium arrays.
- “The environment” includes not only marine life, but also the marine geography, e.g. the sea-bed and the coastline.
- Physical data collected during the monitoring process will be used to verify environmental modelling, assess the impact of new devices ,and assist in the planning process for large volume deployments from 2015.
- Environmental monitoring and post-processing of the results is important to solve potential environmental barriers to deployment. This will require close collaboration between the marine environment and marine energy communities.

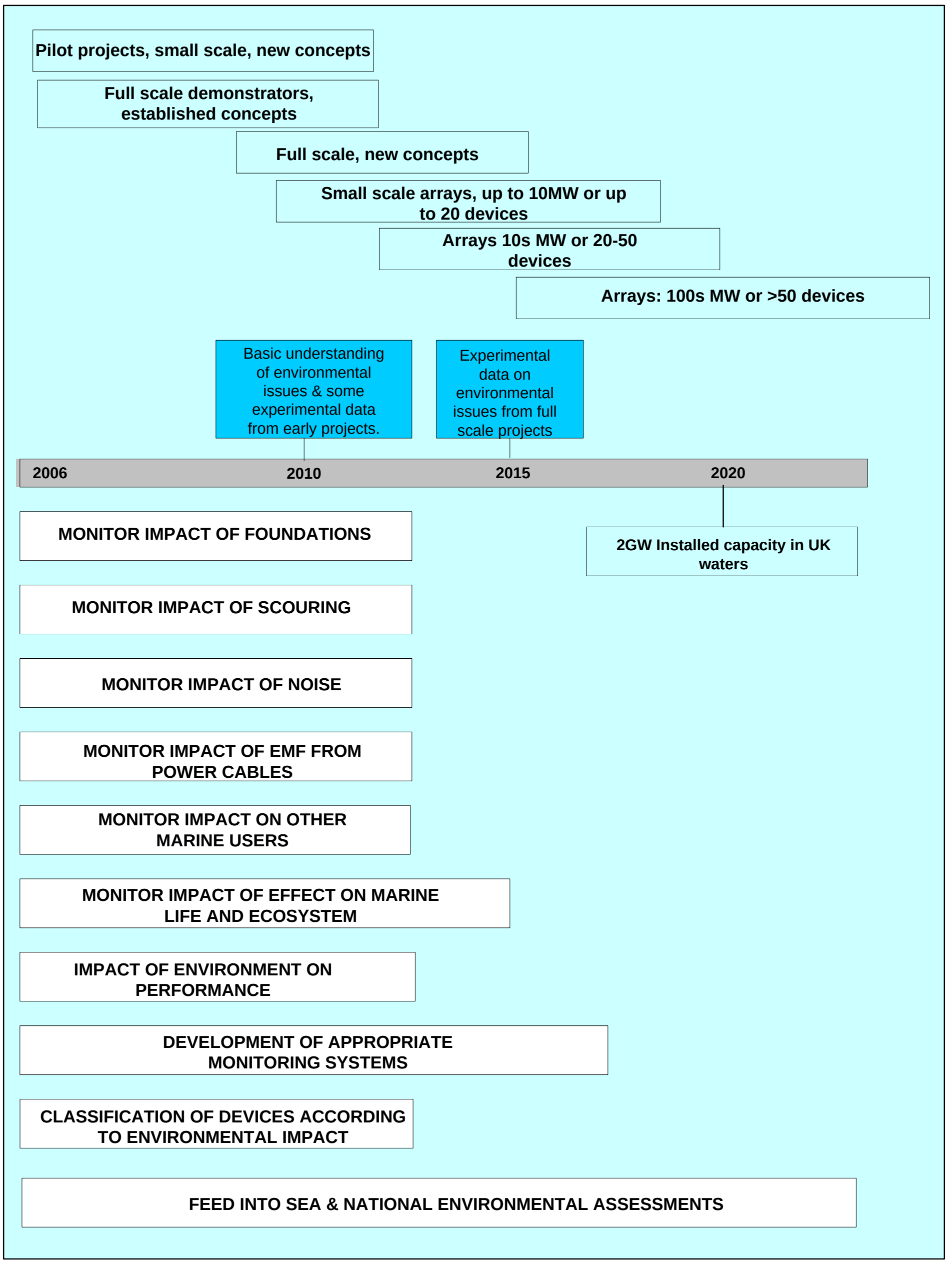

Figure 3J: Environmental Timeline

Technical Strategy: Standards Timeline

Rationale:

- Guidelines and best practice should be established before full standards are developed
- Results from all deployments – single prototypes to arrays – should be used to establish guidelines. Continued deployment will enable these guidelines to be verified, leading to the establishment of standards.
- Standards should be reviewed at regular intervals to take into account advances in technology and new knowledge of the environment.
- Establishing standards gives device and project developers, policy makers and potential investors more confidence in the capabilities of the technology.

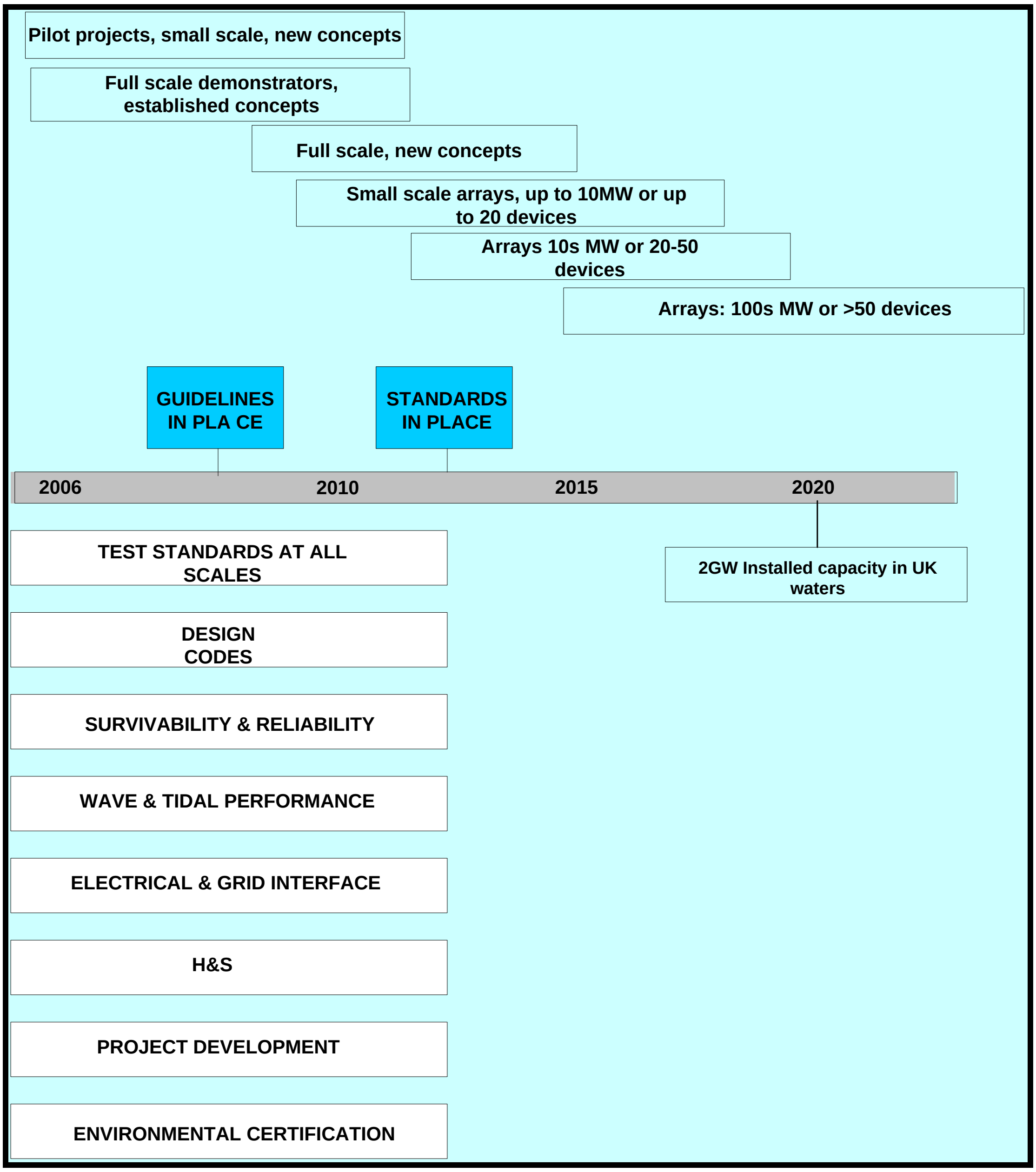

Figure 3K: Standards Timeline

5. Challenges and Summary

This section highlights the key challenges to be overcome in order to achieve the proposed deployment strategy, which have been categorised and summarised in Table 1, below:

Challenge	Priority / Required advances
Predictability Ability to understand resource–device interaction, such that it delivers predicted design performance.	Improved resource analysis and weather forecasting; improved hydrodynamic and primary power conversion modelling; improved understanding of floating and founded wave and tidal current device array effects; improved modelling of combined waves and currents.
Manufacturability Ability to develop a concept that can be manufactured within a prescribed cost, using existing or new technology.	Understand peak forces and consequences of increasing scale from 1/100th to full size; address turbulence and cavitation effects.
Installability Ability to install at site in marine and environmental conditions, using existing or new facilities.	Establish fabrication, transport and installation infrastructure; develop cost-effective foundations, moorings, anchoraging and connection methods. Develop electrical connectors, submarine cabling networks, improve network integration.
Operability Ability to control, operate and maintain devices for the necessary service periods determined by weather access.	Improve and develop offshore access, operation and maintenance techniques and strategies.
Survivability Ability to survive predicted and surprise extremes in wind, wave and tidal current conditions, in any combination.	Improved statistical analysis and short term prediction of extremes; design for cost-effective survival; establish standards, testing, proving and certification methods, and operate to them. Developed using feedback from operational data.
Reliability Ability to continue to operate reliably over its predicted lifetime, when maintained as planned.	Improved coating, sealing, monitoring, and reliability in marine environment; establish component reliability statistical database.
Affordability Ability to achieve a lifetime cost that ensures market access and return on investment in the prevailing economic climate.	Develop equitable means of lifetime costing and performance appraisal; understand cost–survival–performance relationships.

Table 1: Main Challenges to Deployment

6. Conclusion

- This document presents a marine renewable energy technology roadmap applicable to both wave and tidal current energy. It is based on evidence gathered from workshops and interviews with the main stakeholders in the marine energy community.
- A deployment scenario has been proposed supported by a commercial strategy and a technical strategy.
- Timeline diagrams of both the commercial and technical strategies have been overlayed onto the deployment scenario, to indicate the necessary cross links required to achieve the goal of 2GW installed capacity by 2020, as outlined in the vision statement.
- The major challenges facing the marine energy technology relate directly to the deployment scenario: *predictability, manufacturability, installability, operability, survivability, reliability and affordability.*
- Each of these challenges is addressed in more detail in the commercial and technical strategies, in which activities have been prioritised to meet the deployment scenario.
- The challenges identified relate very much to the technology, but industrial infrastructure is a major challenge facing the sector; this includes electrical, manufacturing, supply chain and human resources.
- Policy has an important role to play in the meeting the 2020 vision in the vision statement; it is vital that the technology roadmap and other research which details the technical challenges involved in marine energy are used to inform policy development. Policy and technology innovation are interdependent.
- The timelines in the document represent a list of prioritised recommendations and actions developed in consultation with the marine community, and therefore provide guidelines for funding bodies in terms of allocation of research funding.
- Finally, it should be remembered that the roadmap is a living document and will be updated on a regular basis to reflect changes in policy, technology and wider context.

Appendix: 1

The commercial strategy (displayed in Figure 2) required to fulfil the deployment strategy consists of 15 themes covering all aspects of the innovation chain for an emerging technology such as marine renewables. An expansion of these sub themes is presented below.

1. **Research & Development**
   - R&D includes fundamental and applied research to meet generic and more specific challenges associated with the technology.
   - The R&D priorities have been identified, and form the basis of the Technical Strategy, which is presented in Section 4.
   - Output from the UKERC Marine Renewable Landscape feeds into this theme in terms of identifying the gaps in expertise and technical barriers to be overcome, so that investment and resource can be focussed in the most appropriate places.
   - IP generation is the main commercialisation output from this theme.
   - R&D is a continuous theme throughout the deployment scenario to 2020 and beyond.
2. **Capacity Building**
   - The sector requires personnel from all backgrounds covering a range of qualifications who have the right skills to meet the vision and 2020 goal.
   - It is important to emphasise that vocational skills are just as important as degree qualifications.
   - Academia, further education colleges and industry need to work together here to ensure that students are working to fill gaps in expertise and developing the right skills in other areas.
   - Industry can assist this by helping to sponsor students and degree programmes.
   - Wavetrain, an EU-funded Marie Curie network, is a good example of an initiative that needs to be continually supported build up skills, encourage international mobility and collaboration.
   - Linking into the supply chain and the potential for knowledge transfer from other industries has a role to play in capacity building.

3. Infrastructure

This theme applies to the physical aspects of the sector and is broken down into 6 sub-groups:

a. Test Facilities

- Wet test facilities are available at all scales from 1/100th model scale to sea trials of near full scale prototypes.
- Model scale facilities tend to be found in academic institutions.
- NaREC offer 1/10th scale wave test facilities and a medium scale tidal test facility.
- EMEC offer both wave and tidal current full scale sea test facilities.
- Wavehub will provide wave test facilities for small arrays.
- It is currently not possible to test at model scale or intermediate scale in both waves and currents – this is a priority in the technical strategy.
- As well as wet test facilities, electro-mechanical test facilities will assist in the development of power take-off and control systems.
- A component testing facility is of benefit, in terms of enabling technology developers to choose the most appropriate and reliable components.
- All test facilities are closely linked to codes, standards and certification.

b. Manufacturing

- The required infrastructure needs to be in place to meet UK and global demand.
- To meet a target of 2GW by 2020 then by 2012, the sector needs to be able to build 1 unit per week, ramping up to an average of around 4 per week by 2015 to meet the deployment requirements.
- High volume manufacture requires design consensus of devices within individual classes of technologies.

c. Electrical Grid

- The sector needs to work with energy utilities to ensure the grid infrastructure is in place for the best sites that will be exploited first to meet the 2020 target.
- The sector needs to work with government, the regulator and planners to ensure that all potential barriers to development of the necessary grid infrastructure are overcome before large scale deployment in 2015.
- This theme should also consider both onshore and offshore grid issues.

d. **Installation & Deployment**

- Infrastructure is required to facilitate large volume deployments, so that the sector does not have to compete with other offshore sectors, principally the oil & gas sector.

e. **Operation & Maintenance**

- O&M is closely linked to the infrastructure required for deployment.
- O&M procedures will be specific to particular devices.
- A failure database covering all aspects of the technology will be of benefit to developers, and enable the supply chain to improve component reliability.

f. **Supply chain**

- The role of the supply chain needs to go beyond acting as a basic component supplier, to one of collaborating with developers to ensure that components are designed to be fit for purpose.
- Establish a supply chain network in order to transfer knowledge and experience between developers and suppliers to accelerate development.
- A supply chain landscape analysis will provide the sector with knowledge of cluster locations, and potential weaknesses/gaps in the chain.

4. **Environment & Community**

a. **Site & Resource Assessment**

- Survey seabed conditions, grid infrastructure, shipping lanes and leisure usage to assess the best sites to be first exploited.
- Provide standardised resource data for most promising sites.
- Include this information in a GIS database.
- Expand on the DTI wave and tidal current database (reference?).

b. **Environmental Impact**

- Exploitation of the marine resource requires a full understanding of the potential impact on marine life throughout the food chain.
- The SEA should be extended to the whole of the British Isles (i.e. including the Irish Republic).

c. **Community Outreach**

- The sector will work with all communities who may be affected by a high volume deployment of marine renewable energy devices.

- This will include marine leisure users, fishing industry, communities affected by electrical grid infrastructure expansions, and communities affected by the development of industrial infrastructure.

5. Planning

- The sector needs to work with UK government, the Crown Estate and planners (both at sea and on land) to develop a standard planning procedure for all sites in UK waters.
- The marine sector needs to learn from the experiences of the wind industry in both onshore and offshore developments.

6. Standards

- Best practice guidelines will be developed standards will then evolve from the best practice guidelines once large volume deployment is underway in 2015.
- EMEC are involved in the development of marine standards, and are preparing other documentation in cooperation with the marine community.

7. Market

- Small niche electricity markets, such as island generation, need to be assessed as a way of increasing early deployment.
- Markets other than electricity need to be assessed (such as desalination) thereby increasing early deployment.
- The sector needs to analyse the routes to market, and hence identify potential barriers, which may require technical or policy based solutions.

8. Policy

- The sector will benefit from working with policy groups to advise government bodies on the recommendations of the roadmap, and how they can be used to inform targets, planning, grid infrastructure and R&D funding.

9. Finance

- The sector needs to work closely with funding bodies (private and public) and investors to provide continuous and the most appropriate funding mechanisms at relevant points on the innovation chain.
- Successful small and medium scale deployments will strengthen investor confidence for high volume deployment from around 2015.

10. Knowledge Transfer

- Many of the solutions required to overcome technical and non-technical barriers will be obtained from other industrial sectors.
- Paths need to be established to ensure effective and timely movement of knowledge into the marine sector from other sectors, in both industrial and academic arenas.
- Knowledge transfer is closely linked with the supply chain.

Appendix: 2

UKERC Marine Technology Roadmap Timeline

In line with the key principles, the technology roadmap has been developed as a result of extensive consultation. The main stages in the roadmap timeline are summarised below.

January 2005

- The UK Energy Research Centre (UKERC) was established in January 2005 to coordinate energy research in the UK in response to a report by the UK's Chief Scientific Officer, Professor Sir David King.
- Marine Renewable Energy (wave and tidal current) is part of the Future Sources of Energy Theme, which also includes carbon storage, biofuels, PV, fuel cells and watching briefs on nuclear fission & fusion.
- Technology road-mapping is a major activity in each technology theme.

April 2005

- Work on the UKERC Marine Technology Roadmap commenced in April 2005, with a workshop to review existing marine energy technology reviews or roadmaps, and to identify the major R&D challenges.
- Twenty-five delegates attended the workshop held at the University of Edinburgh.
- Presentations made and a workshop report can be found on the UKERC website.

August/September 2005

- Roadmap project presented at the 6th European Wave and Tidal Energy Conference in Glasgow: "Developing a research route map for marine renewable energy technology in the UK".
- In collaboration with EMEC, workshops on Environmental and Tidal Measurement Techniques were held at the University of Edinburgh.

March 2006

- Update on roadmap project presented at the Marine Renewable Energy Conference as part of the IMAREST World Maritime Technology Conference in London: "A road-map for marine renewable energy research in the UK". Paper in Appendix ...The paper was chosen for publication in the IMAREST Journal ….

July 2006

- The roadmap was informed technology forecasting as undertaken by the Office of Science & Innovation (UK government), leading to the following publication: "Enabling Science and Technology for Marine Renewable Energy".

September 2006

- A collaboration with Supergen Marine was initiated to include interview data gathered by Henry Jeffrey from interviews with academics, technology developers, consultants and policy makers.

November 2006

- Update on roadmap project presented at the European Ocean Energy Conference in Bremerhaven, Germany: “An Analysis of the Research Landscape and Priorities for Marine Renewable Energy”.
- Questionnaire was handed out at the Bremerhaven conference to gain feedback on the proposed vision, business strategy and the technical strategy. Twenty-five replies were received.

January 2007

- A workshop was held at the UKERC Meeting Place in Oxford entitled: “A Framework for an International Marine Renewable Energy Roadmap”. 23 delegates attended from around the world.
- Presentations and the workshop report can be found on the UKERC website.
- An initial version of the roadmap was presented to an international audience, and the feedback was used to in the compilation of the roadmap presented in this document.
- First edition of the UKERC Marine Renewable R&D Landscape published and sent out for peer review.

September 2007

- Roadmap is presented to the 7th European Wave and Tidal Energy Conference in Portugal: “The UKERC Marine Renewable Energy Technology Roadmap”.
- UKERC Marine Renewable R&D Landscape updated based on results from peer review – available on UKERC website

December 2007

- First complete draft of the technology roadmap published on the UKERC website.

March 2008

- Final draft of UKERC Marine Renewable Energy Technology Roadmap published and distributed for consultation.