UKERC ENERGY RESEARCH ROADMAP SYNTHESIS : OCEAN ENERGY

March 2014

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1. Overview

This document reviews and highlights the most important information presented in eight marine energy roadmaps, including:

- U.S. Marine and Hydrokinetic Renewable Energy Roadmap-Ocean Renewable Energy Coalition
- Charting the Course: Canada's Marine Renewable Energy Technology Roadmap- Marine Renewables Canada
- Ocean Energy Roadmap-Sustainable Energy Authority of Ireland
- ORECCA European Offshore Renewable Energy Roadmap- Ocean Renewable Energy Conversion Platform Coordination Action
- An International Vision for Ocean Energy-Ocean Energy Systems
- Industry Vision Paper - European Ocean Energy
- EERA and ERA-NET Joint Workshop on Wave and Tidal Energy Within the European Union -European Energy Research Alliance
- Strategic Technology Agenda-Strategic Initiative for Ocean Energy

This document provides the latest thinking on marine energy roadmaps. Several industries, national and global marine energy roadmaps have been published, and are continuously undergoing updating to keep aligned with the progress of the industry.

The roadmaps within this document do not only cover the technology, as was the main focus of earlier versions, but examine the whole industry on a national or global scale. This will be seen within the U.S., Canada and Ireland, Ocean Renewable Energy Conversion Platform Coordination Action and European Ocean Energy roadmaps. Alternatively, the EERA document focuses on the current research needs of the industry. Furthermore, the SI-Ocean document aims to address, and make recommendations to overcome technological barriers previously identified.

Despite differences in the scope and methodology of the roadmaps, several themes common themes resonate throughout. These include the need for better resource characterisation, technology development innovation, examination of environmental effects, increase in test infrastructure and facilities. Additionally, there is a large focused placed on areas for collaborative and cross-boundary research. Finally, a major concept seen throughout all of the roadmaps is the focus of achieving a reduction in the levelised cost of energy in order to become more competitive with other traditional and renewable energy sources, as well as creating standardisation for technology and policies for the industry, in the aim of accelerating development and deployment.

The roadmaps reviewed in this document provide a high-level understanding of where the marine energy industry is at present, and the challenges that need to be overcome in order to achieve a successful industry. Whilst each country may have their own initiatives, the examination of these roadmaps identifies the key research areas that can lead to collaboration and acceleration within the industry.

2. U.S. MARINE AND HYDROKINETIC RENEWABLE ENERGY ROADMAP

Ocean Renewable Energy Coalition

http://www.oceanrenewable.com/wp-content/uploads/2011/05/MHK-Roadmap-Final-November-2011.pdf

The US identified the need to establish a marine energy roadmap to accelerate development and deployment. Thus, a series of stakeholder meetings were held between 2009 and 2010, with input from technical experts, developers, utilities, university researcher and many more, in an effort to establish the needs of the industry. From that, the US Marine and Hydrokinetic Renewable Energy Roadmap was established. The result is an overview of the US marine and hydrokinetic (MHK) industry at present, challenges to overcome and a route to achieving targets through a roadmap and action plan.

Taking from lessons learned in the wind industry, the US estimates installation of over 15GW by 2030, with a creation of up to 36,000 jobs across the US. In order to achieve this goal, there is acknowledgment that there is a considerable amount of synergies with existing industries working in the marine environment, including offshore wind and oil and gas.

Within the report, the US marine energy industry has identified eight key areas of which need continued research and development, in order to achieve the 2030 commercialisation and installation targets. These areas are:

- Technical research and development
- Policy
- Siting and permitting
- Environmental research
- Market development
- Economic and financial issues
- Grid integration
- Education and workforce training

The roadmap continues, outlining forward movement to achieve the targets including identifying research areas, the need for standardised protocols and coordination between permitting agencies, stakeholder groups and industry and a need for the development of national test infrastructure to support testing and deployment activities. In addition, the need for public policy reform for MHK commercialisation, in particular permitting, is addressed as a barrier and the need for improvement.

A three phase commercialisation pathway from demonstration projects to large, commercial, utility scale arrays, as well as the priorities and strategies for achieving each phase receive a large focus within the report. The three phases include:

- Phase 1 includes technology demonstration and pilot projects from 100kW to 5 MW. This phase focuses on performing fundamental research and gathering data, in order to identify gaps, develop protocols, in addition to identifying a funding mechanism for knowledge and data sharing.
- Phase 2 consists of pilot projects (5 MW) transitioning to small commercial arrays (50 MW). Priority areas of research within this phase include streamlining decision making processes, including reducing permitting costs, and refining protocols.
- Phase 3 focuses on small arrays (50 MW) with a transition to large, utility-scale arrays (100 MW). Research priorities include cost reduction and transition to utility scale projects, in addition to fundamental and applied research on MHK technologies.

The report concludes by stating the need of consistent funding, including an increased mixture of market pull and technology push mechanisms, better collaboration between permitting agencies, researchers, industry developers, and state and federal agencies.

3. CHARTING THE COURSE: CANADA'S MARINE RENEWABLE ENERGY TECHNOLOGY ROADMAP

Marine Renewables Canada

http://www.marinerenewables.ca/wp-content/uploads/2012/09/MRE_Roadmap_e.pdf

In 2010, researchers, technology developers, utilities, independent power producers, service providers and government representatives collaborated in a series of workshops, resulting in the production of Canada's Marine Renewable Energy Technology Roadmap. The roadmap identifies the needs of the Canadian industry, as well as provides actions necessary to achieve targets and goals.

The roadmap outlines the targets set by the industry which include a generating capacity of 75 MW by 2016, 250 MW by 2020 and 2000 MW by 2030. These targets all come with the added benefit of a projected $2 billion in annual economic value. In addition, Canada aims to be the leading developer of water-to-wire river-current systems by 2020, whilst setting standards for defining operating procedures and best practices for the industry. Canada aims to provide value-added goods or services to 30% of all global marine energy project by 2020 and 50% by 2030.

Canada's aims to achieve targets by using a multi-faceted approach which pushes to create shared infrastructure initiatives by increasing collaboration accelerate technology development and innovation in protocols, research, supply chain and financial mechanisms. As part of this approach, four target areas have been identified:

- Development targets and technological opportunities
- Technical mean s of achieving faster cost reductions and advancing operational approaches
- Critical technical issues that either create advantages for Canada or put its progress at risk
- Strategic priorities to focus research, design and development

Actions to achieve these targets are outlined within the roadmap as pathways and enables. There have been 6 key pathways (actions the feed into one another, leading to achievement of the defined goals) in the roadmap. These are:

- Leverage Canada's shared infrastructure
- Define the needs of utilities and how the marine energy industry can provide solutions
- Ensure Canada's advantage in river-current technologies
- Developing critical technology components
- Leveraging synergies from other sectors
- Developing and setting project design guidelines

These pathways are linked with five enablers (activities and tactics that create the foundation for progress), which help focus and aid movement of the six pathways. The enablers include:

- Develop technology incubators
- Accelerate innovation
- Enhance cross-sector technology and skills
- Enhance engineering procurement and construction capabilities
- Develop Canada's market position

The document concludes by stating that whilst there has been a significant increase in support for marine energy, momentum must continue, and investment in the industry key to its success. At this point, the industry needs to move forward with the assumption that public policy will evolve with alongside development and innovation. Finally, the roadmap states that the ultimate goal is to maximise the economic benefit of leadership of the marine renewable energy sector to Canada.

4. **OCEAN ENERGY ROADMAP**
Sustainable Energy Authority of Ireland
http://www.seai.ie/Renewables/Ocean_Energy_Roadmap.pdf

The Ocean Energy Roadmap for Ireland examines two scenarios that look at the resource potential and CO2 abatement opportunities. The document has an outlook of 2050, presenting baseline and ambitious growth scenarios based on economic and technical assumptions. The main purpose of the roadmap is to stimulate debate and communication for the 2050 outlook.

The roadmap, which is based on programme experience, analysis and modelling and commissioned studies, identifies the potential of 29 GW of installed capacity by 2050. This could also account for the employment of 70,000 people, with an economic benefit of €12 billion seen by 2030 and €120 billion seen by 2050.

In addition to the economic and technical benefits, the roadmap touches on other opportunities such as CO_2 abatement, national energy security and the opportunity to export electricity. By continuing to support the growth of the ocean energy industry, Ireland could contribute to the reduction of up to 94MtCO_2 by 2050.

Much of the roadmap is focused on the outlook of the next 10 years. In order to achieve these targets, the roadmap acknowledges the need for continued support in terms of industry infrastructure and national test sites. Further, the roadmap touches on the need to continue grid modelling, upgrading and interconnection that support device deployment. Building upon, a key finding within the report suggests that to ensure maximum returns for the Irish economy and ocean energy sector, the development of infrastructure should be a main focus.

Other areas of focus for the next 10 years include continued support for research and development, technology innovation, smart ocean and smart bay concepts. Along with technology and economic focused initiatives, the roadmap also pinpoints the need for evolvement of policies and expertise within the industry. The Irish ocean energy industry will put a focus on developing expertise in supportive policies, as well as manufacturing, deployment, O&M and specialist support services. It is intended that in the future, the Irish ocean energy industry will export both electricity and expertise to other countries.

The document concludes by making several baseline and ambitious growth comparisons including that of primary energy equivalency, employment and CO_2 abatement projections.

5. ORECCA EUROPEAN OFFSHORE RENEWABLE ENERGY ROADMAP Offshore Renewable Energy Conversion Platform Coordination Action

http://www.orecca.eu/c/document_library/get_file?uuid=1e696618-9425-4265-aaff-b15d72100862&groupId=10129

The ORECCA roadmap examines synergies, opportunities and barriers between the offshore wind, wave and tidal energy sectors. The main goals of the roadmap are to identify the synergies and use them to overcome barriers and accelerate deployment, in a cost-effective and environmentally sustainable manner. This is done by examining 5 key areas within the roadmap:

- Resource
- Finance
- Technology
- Infrastructure
- Environment, Regulation and Legislation

The roadmap continues, examining each of the key areas. First, resource is examined and the roadmap reports the 'hotspot' areas for offshore wind, wave and tidal and the potential for combined resource use. The roadmap identifies the Western facing Atlantic coasts of Scotland, UK, Ireland, Spain and Portugal as one hotspot, and the Northern North Sea of the coast of Scotland and Norway as the other. There is a suggestion that co-locating wind and wave resources should be a focus since there is a constraint in the depth of water between tidal and wind resources.

The roadmap highlights the importance of the resource water depths and distance from shore noting that approximately 80% of the combine resource in Europe is in water depths of greater than 60m, and approximately 50% of the resource is further than 100km from shore. Therefore, there is a need to develop technologies that will withstand deployments in deeper waters and further offshore.

Table 1 Breakdown of the resource in the three areas by distance from shore and water depth.

	Distance from Shore	Water Depth
	% of combined resource further than 100km from shore	**%of combined resource in water depths of greater than 60m**
North and Baltic Sea Area	40%	70%
Atlantic Ocean Area	60%	97%
Mediterranean & Black Sea Area	30%	94%

Next, the roadmap examines the financial support measures in place for offshore renewable energy. An analysis of production based incentives (PBI) was conducted for 12 countries. At the time of the analysis, only 7 had a PBI in place for ocean energy, which is a significant reason for the high cost of energy. The roadmap continues to provide recommendations of how to assist with decreasing the cost of ocean energy. These recommendations include developing a careful balance between market pull and technology push support measures and to target deployment, with an aim to facilitate investment within the sector.

The roadmap then identifies several challenges and opportunities concerning technology within the sector. Within this section, synergies and commonalities between tidal, wave and offshore wind are identified, in addition to priority research areas. Recommendations are provided within the roadmap, centred on the need for the creation of policies for design consensus and a focused effort to attack priority areas of research, which are also presented in the roadmap.

The roadmap identifies ports and offshore supply chain, vessel and grid as the priority infrastructure necessary for the commercialisation of offshore renewable energy. This section examines location of infrastructure to align with the hotspots identified in the Resource section. In addition, there is a significant focus on the vessels necessary for installation of components and devices, and the synergies between offshore wind, wave and tidal. Finally, the roadmap highlights the need for both a European level grid connection and a state level grid connection.

Finally, the challenges and opportunities of regulation, legislation and environmental impact of offshore ocean energy is examined. Licensing and consenting of projects varies across European countries. There is a great need to harmonise the licensing process across Europe, and for individual countries to have a more streamlined process. The roadmap also sets out priority areas for which environmental impact research should be focused, which includes cumulative effects, EMF effect of subsea cables and sedimentation and habitat chance near devices, among others.

By breaking up the roadmap into key areas, the reader is able to see how each key area provides feedback into other areas. This provides a comprehensive overview of the synergies between the offshore wind, wave and tidal energy sectors.

6. AN INTERNATIONAL VISION FOR OCEAN ENERGY

Ocean Energy Systems

http://www.ocean-energy-systems.org/about_oes/oes_vision_brochure/

This vision paper examines the trajectory of the ocean energy sector from a global viewpoint. The document starts by presenting the global ocean energy capacity (337 GW by 2050), as well as the global number of jobs created (1.2million by 2050), and finally the carbon savings (1.0 billion tonnes).

The roadmap continues to present the world energy supply and demand projections, touching on the fact that non-OECD countries account for the majority of the world's electricity demand. This is due to the growth of economic activity, population and urbanisation and industrial production. World electricity consumption is projected to double from 2008-2035, and paired with the recognition of anthropogenic effects on climate change, more attention will be put on the use of renewable energy resources.

The paper then addresses 6 different ocean energy resources:

- Ocean waves and swells
- Tidal range
- Tidal currents
- Ocean currents
- Ocean thermal energy
- Salinity gradients

Each section covers the how energy is harnessed from the different resources, as well as the potential power from each resource.

Moving forward, the document examines the different types of technologies available for harnessing resources. The first technologies presented are wave energy converters, placing emphasis on the fact that there is still little consensus among device technology. Next, tidal current devices are shown, exhibiting some consensus with three major types of technologies. Finally, tidal range, ocean current, OTEC and salinity gradient technologies are presented.

The document continues by looking at learning and cost reduction potential, placing emphasis on learning by doing and by research in order to accelerate innovation. In addition, the need for a balance of technology push and market pull mechanisms is highlighted.

The next two sections of the paper examine the synergies between ocean energy and other sectors, and different markets in which ocean energy technologies could be integrated. The paper looks at the synergies between the varying types of ocean energy, as well as those between ocean energy and other sectors. Three key markets are identified for ocean energy technologies:

- Grid connected electricity
- Off-grid power for remote communities
- Ocean energy for other uses-cooling, heating and desalination for drinking water

Continuing, the next section addresses the key challenges that must be overcome to maximise the industry's potential. These include:

- Development of international guidelines and standards, and policies specifically associated to ocean energy.
- Development of supply chain and infrastructure
- Balance of market pull and technology push financial mechanisms
- Continued research of environmental effects
- Marine special planning

The paper concludes by delivering OES's 5-year strategic plan, with the mission of becoming an 'Authoritative Voice for Ocean Energy.'

7. INDUSTRY VISION PAPER

European Ocean Energy

http://www.oceanenergy-europe.eu/images/Publications/European_Ocean_Energy-Industry_Vision_Paper_2013.pdf

The Vision document examines the barriers and opportunities of the ocean energy sector from a high-level European perspective. It identifies the need to decarbonise the electricity supply in order to meet a 20% carbon reduction by 2020 goal. In order to maintain the progress that has been made in recent years, the industry challenges must be addressed at a European level.

The Vision document suggests that Europe currently leads the ocean energy industry although other countries are closing-in on Europe's advantage, due to an increase in funding for pre-commercial device testing. This includes providing support to the international industry, to ensure Europe can establish a domestic supply chain, which can eventually be exported on the global market.

Next, the document highlights the importance of ocean energy and the encouragement of the Parliament and Council to support the industry. Included in this is the idea that ocean energy should be placed higher on the EU research agenda. In addition, by utilising Europe's ocean energy resource, it is suggested that there could be a reduction in risk, job creation, clean power production and infrastructure rejuvenation.

Further into the document three main types of risk are presented, as well as a model for risk management. The risks assessed in the document are:

- Technology Advancement
- Project Development Pipeline: Policy and Infrastructure
- Market Mechanisms and Finance: Combined Financing Target >€1bn

The risk management model includes the following initiatives that have already helped the UK become the leader in marine energy:

- Market Pull: Attractive revenue incentives
- Market Push: Focused and sustained grant support
- Policy Intent and Regulatory Framework
- World class technology testing facilities
- Project pipeline and site availability

The document continues by providing a more in-depth assessment of the three risk areas. The main takeaway from the 'Technology Advancement' area is the focus on creating technology with reliable performance that can withstand the harsh marine environment, with an equal focus on cost reduction. The 'Project Development Pipeline' programme focuses on the idea that the development of a pipeline is essential to ensure installation targets are met. Finally, the 'Market Mechanisms and Finance' programme examines the need for long-term financial support and a balance of market push and pull support schemes.

The document then presents an overview of the Danish wind industry development's 'lessons learned' for the marine energy industry. In addition, the document mentions the Member States' Position Paper and the application for EC support under the European Research Area Network (ERA-Net) for coordination of activities and funding.

The Vision document concludes by providing key recommendations for the areas of working in partnerships and the three key risk areas. In addition, the Vision document then provides a comparison of the marine energy industry to the Airbus project, identifying similarities between the industries. Finally, an overview of the SI Ocean project is provided which focuses on collaboration of research and development in order to accelerate deployments of wave and tidal technologies.

8. EERA AND ERA-NET JOINT WORKSHOP ON WAVE AND TIDAL ENERGY WITHIN THE EUROPEAN UNION

European Energy Research Alliance

http://www.eera-set.eu/index.php?index=29

A workshop took place in January 2014 to identify the most important future research needs of the wave and tidal energy sectors, identify potential new solutions to existing challenges, highlighting priorities for future research innovation and to provide input for future funding calls for ocean energy research topics.

The document provides an overview of the workshop, which consisted of participants from government, industry and academic research centres. The report is intended to:

- Provide an account of the workshop for archival purposes; and
- Provide a resource rich with information that can be referenced in research work.

The document progresses by examining how participants of the workshop view the current EU wave and tidal energy research capabilities on a scale of 1-10. The average score of the results was 7.0 from which a variety of themes emerged as discussions continued.

The next section focuses on the identification of research 'hotspots', along with other themes for European wave and tidal energy research. The hotspots were identified as belonging under one of three broad themes:

- Basic underpinning research
- Applied research and development
- Arrays/early demonstration

The document then presents the eight research clusters that were a result of continued discussions:

- Technology- development for devices and components
- Technology-reliability
- Resource and geophysical conditions for device and array development
- Environmental impact of device and array development
- Technology- development for balance of plant and system
- Array and farm grid integration
- Market and economics
- Installation and operations

The document then presents the results of a task of identifying key research challenges of each cluster by answering 6 questions:

- What are the main research challenges we need to address for our research to be first class in terms of both excellence and impact?
- What capabilities and capacities do we need in place to undertake this research?
- Do our current ways of working need to change? If so, how and why?
- Whose job should it be, or who is best placed to do/fund this research?
- What needs to happen in terms of coordination and alignment to maximise success in this research area?
- What do we need to have in place to ensure we are ready to address these research challenges?

Overall, it was decided that Joint Calls member states will be key to enabling knowledge transfer and finding solutions to the identified challenges.

9. STRATEGIC TECHNOLOGY AGENDA

Strategic Initiative for Ocean Energy

http://www.si-ocean.eu/en/

The Strategic Technology Agenda was drafted by the SI-Ocean consortium as means to help accelerate the current and future technological development of the ocean energy sector. The document aims to present recommendations to address technological barriers identified within the SI-Ocean project.

The document begins by presenting the current state of the technology, and current levelised cost of energy. The document recognises that ocean energy is still in a nascent state and in order to get to a point in which ocean energy supplies a substantial amount of energy to the grid, array or farm installations are necessary.

Tidal is presented to reach commercialisation before wave technologies, which can be seen by the number of tidal technologies undergoing full-scale demonstration. Additionally, tidal technologies have a greater level of convergence than wave technologies. Wave technologies require additional R&D, innovation and testing.

The document also points out that the development status of the technologies is reflective of the high levelised cost of energy (LCOE) compared to traditional and other renewable energy sources. Early tidal array costs currently vary between 24 and 47 cents/kWh, whilst wave arrays range between 34 and 63 cents/kWh. In order to become cost competitive with other technologies, 5 and 10GW of tidal and wave installed capacity would be required, respectively.

The report continues highlighting mechanisms that could help reduce LCOE. These include:

- Performance improvement
- Up-scaling
- Experience
- Innovation

The report goes on to identify high level challenges of the sector including:

- Enabling technology
- Risk management
- Technology fragmentation and design consensus
- Grid access, connectivity and infrastructure
- Economic perspective
- Establishing equitable environmental mitigation measures

Further, some recommendations of how to overcome these challenges are presents. These are:

- Reduce the cost of the technology through innovation and learning by doing;
- Address technology fragmentation at subcomponent level to increase supply chain appetite for investment;
- Address lack of co-operation by identifying collaboration opportunities;
- Identify the best strategies that will allow safe and efficient deployment of arrays.

The next section addresses two main common themes that are necessary to address in order to overcome the sector challenges: **technology development** and **deployment and risk reduction**. The discussion continues to identify the need for further substantial investment into the industry, and a balance of financial mechanisms. The report also notes the difficulty of satisfying investor confidence and the insufficient confidence in the current technology.

The remainder of the report further addresses the two main themes, starting with technology development. This section starts by identifying the challenges and barriers hindering the development of both wave and tidal technologies:

- Reliability, Operability & Survivability of devices and sub-components;
- Lack of design tools;
- Manufacture & supply chain;
- Knowledge exchanges.

These are followed by achievable objectives in the aim of addressing these challenges. The objectives for this theme are:

- Prove and advance technology towards development of small scale arrays;
- Improve the reliability of WECs, TECs and components through the use of proven offshore components and systems;
- Increase component, sub-component and sub-system reliability and performance levels to help technologies meet and exceed availability targets;
- Continue the development of emerging designs and components through continuous innovation;
- Implement long-term cost reduction pathways alongside high levels of reliability and survivability;
- Enhance control and monitoring systems for single devices and develop array tools;
- Continued technology push programmes to finance the development of systems and sub-systems through to commercial readiness.

The document then identifies mechanisms for which and be used to address these objectives. Finally, recommendations for the theme are presented, including:

- Establishment of new RDI&D programmes aimed at reliability, availability and survivability of WECs and TECs;
- Establishing mechanisms that support innovation to ensure long-term cost reduction;
- Increasing investor confidence through validation of performance and reliability of devices in real sea conditions;
- Development of emerging designs an investigate optimisation and innovation of sub-systems components, to identify cost-reduction pathways through engagement with the supply chain;
- Creation of standards and guidelines for evaluating and testing devices;
- Continued co-operation at European scale.

The next section identifies the challenges and barriers of the second theme of deployment and risk reduction:

- Low rates of deployment;
- High risk associated with movement from single device deployment to array installations;
- Installation, O&M and retrieval operations;
- Infrastructure.

Again, these are followed by objectives in the aim of addressing the challenges. These include:

- Encourage the development of WECs and TECs to operate autonomously and in array configuration;
- Demonstrate operability, reliability and survivability of pilot farms in real sea conditions;

- Develop new replicable and standardised procedure for installation;
- Unlock optimised manufacturing processes;
- Investigate grid integration feasibility and develop infrastructure;
- Ensure conditions for deployment in lower resource harsh environments;
- Identify and ensure efficiency and effective long-term cost reduction pathways.

The section is completed by identifying the mechanisms and recommendation for achieving the objectives. The recommendations include:

- Demonstration of wave and tidal technologies in real sea conditions, specifically focusing on gaining access to test and demonstration facilities;
- Development of standardised cross-sector operational procedures for installation, maintenance and retrieval of devices;
- Unlocking economies of scale;
- Establishment of guidelines and standards for grid integration and connection, whilst facilitating access in the short term.

The document concludes by offering final recommendations for the sector. It is recommended that mechanisms are focused on addressing the needs of the short-to-medium term, moving the sector towards large-scale array deployments. Furthermore, it is recommended that to ensure progression of both wave and tidal technologies, technological priorities are aligned with the Vision of the EU-Horizon 2020 funding programme which is focused on:

- Demonstration of advanced technologies including existing prototypes, leading to full-scale testing and pilot array deployment
- Progression of technologies at TRL 3-5 and development of novel and innovative technologies (TRL 1-3), components, materials and further existing concepts.

Finally, the document recommends differentiating the wave and tidal energy sectors, as tidal is closer to commercialisation than wave. Therefore, technology-specific agendas, framework policies and market deployment strategies should be put in place. Also the document recommends differentiation of the sectors, it is not to be forgotten that cross-sector cooperation will benefit both sectors, and in order to achieve the necessary funding, the level of commitment and coordinated RDI&D will need to go beyond the current levels.