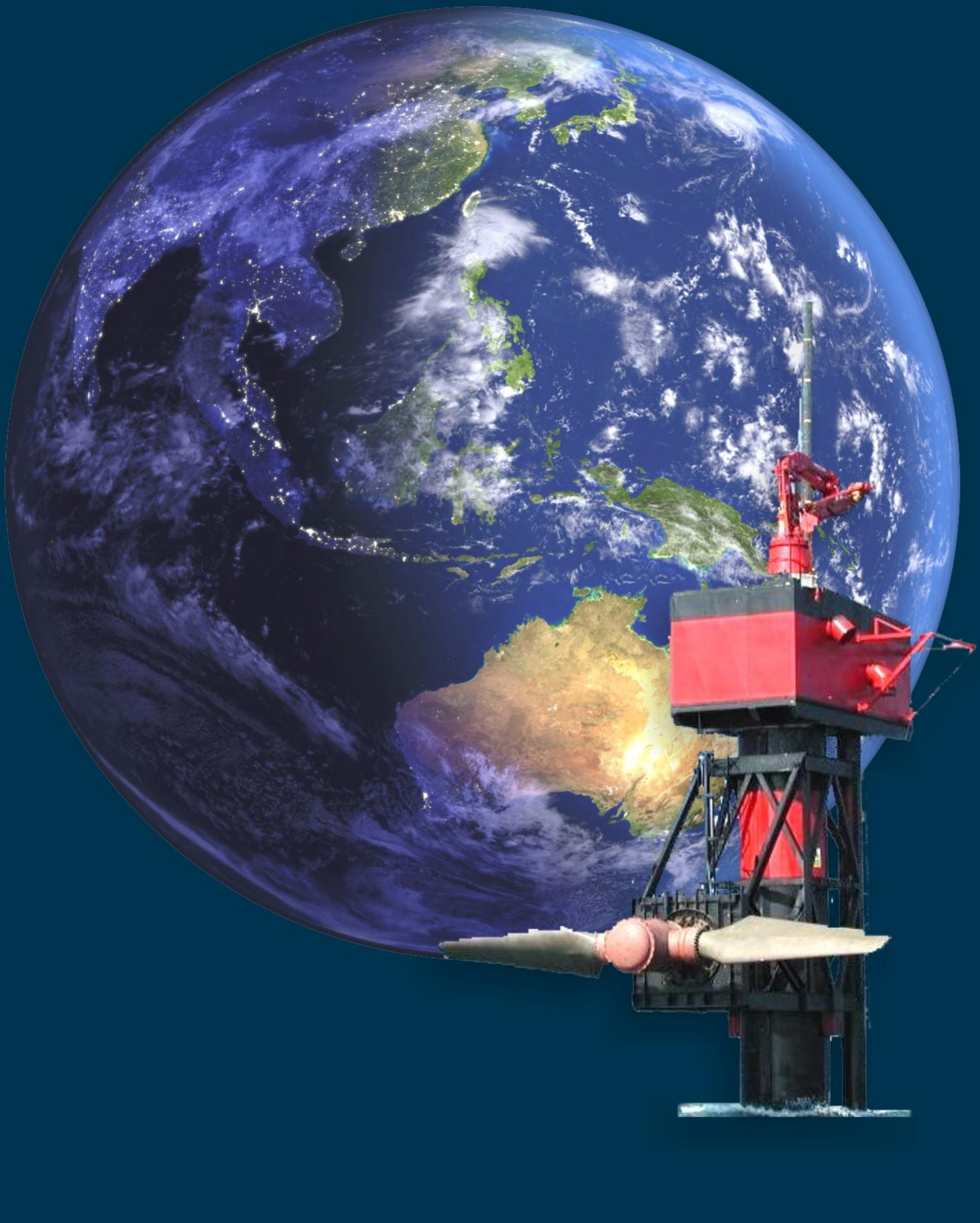
Technology Action Plan

MARINE ENERGY



MAJOR ECONOMIES FORUM
ON ENERGY AND CLIMATE

DECEMBER 2009

Technology Action Plan: Marine Energy

Report to the Major Economies Forum on Energy and Climate

Prepared by France
in consultation with MEF Partners

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PREFACE

The Leaders of the 17 partners[1] of the Major Economies Forum on Energy and Climate (MEF) agreed on 9 July 2009 that moving to a low-carbon economy provides an opportunity to promote continued economic growth and sustainable development as part of a vigorous response to the danger posed by climate change. They identified an urgent need for development and deployment of transformational clean energy technologies, and established the Global Partnership to drive such low-carbon, climate friendly technologies.

Plans were created to stimulate efforts among interested countries to advance actions on technologies including advanced vehicles; bioenergy; carbon capture, use, and storage; buildings sector energy efficiency; industrial sector energy efficiency; high-efficiency, low-emissions coal; marine energy; smart grids; solar energy; and wind energy. These plans include a menu of opportunities for individual and collective action that may be undertaken voluntarily by interested countries, in accordance with national circumstances. Further actions may be identified in support of these plans in the future.

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[1] Australia, Brazil, Canada, China, the European Union, France, Germany, India, Indonesia, Italy, Japan, Korea, Mexico, Russia, South Africa, the United Kingdom, and the United States

OVERVIEW

The world's oceans absorb and produce vast amounts of energy that are virtually untapped by current technology—including offshore wind, tidal streams, wave energy, biomass, thermal conversion, and more. Marine power is a clean, renewable energy source that holds great promise for helping to reduce the greenhouse gases emitted during power generation. But the development and deployment of technologies to harness this power hinges on the development of successful cross-country partnership efforts, climate change policies, and technology advancements.

To help government and industry better understand how to accelerate the development and deployment of sustainable marine energy technologies, this report provides an overview of technologies currently being researched to harness marine energy and their exploitation potentials. It also discusses current barriers to successful development, and best practices from several countries that are surmounting those barriers. Finally, the report offers three priority recommendations to speed the development and deployment of marine energy technologies.

HIGHLIGHTS OF THE MARINE ENERGY TECHNOLOGY ACTION PLAN

1. GHG Emissions and Mitigation Potential

- **Oceans absorb and expend great amounts of energy in many forms.** Oceans absorb from the sun a quantity of energy 1,000 times greater than the global energy demand each year.
- **Technology maturity varies greatly.** Several technologies—such as offshore wind, tidal turbines, etc.—have reached the deployment or development stage, while others are still in test stands or pilots.

2. Development and Deployment: Barriers and Best Practice Policies

- **Barriers** to the development and deployment of marine energy technologies include technology immaturity and costs, lack of technical expertise and cooperation, policy needs, environmental sustainability, and other impacts/issues.
- **Best practice policies** encouraging the development and deployment of marine energy technologies include cooperative development of technology roadmaps and action plans, impacts and environmental studies, and joint research projects.

3. Actions to Accelerate Development and Deployment

- **Supporting innovation:**
  - Develop proven technology that enables operators to provide investors with a guarantee of risk control.
  - Provide R&D funding for all marine energy technologies based on strategic research agendas, and identify potential areas for joint cooperation between countries.
- **Accelerating deployment:**
  - Identify maritime zones for large power generation to allow operators to encourage industry to develop technologies.

  - Reduce the administrative barriers to improving the deployment of marine technologies.
  - Set ambitious, concerted marine energy targets (country-specific or international) to provide long-term investment security.
- **Facilitating information sharing:**
  - Strengthen cooperation networks among marine energy research centers and other important stakeholders.
  - Raise public awareness of marine technologies by using a broad mix of instruments.
  - Build up marine energy expertise in governments and keep decision makers informed.

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1. MARINE ENERGY: GHG EMISSIONS PRODUCTION AND MITIGATION POTENTIAL

Marine power is a clean, renewable energy source that holds great promise for helping to reduce the greenhouse gases (GHGs) emitted during power generation. The power sector's heavy reliance on fossil fuels and rapid projected growth through 2030 raise grave concerns over the impact of the sector's emissions on climate and the environment. The extent to which marine power can help to mitigate these harmful emissions will be determined by the degree to which these emerging energy technologies can effectively displace the use of coal and other fossil fuels in the power sector over the next two decades and beyond.

GHG Emissions Production from Marine Energy

Marine energy technologies are considered clean because they generate a small fraction of the carbon dioxide (CO_2) and other greenhouse gases (GHGs) emitted by conventional power plants. However, the initial manufacture, delivery, and construction of marine energy technologies may produce some CO_2 emissions. In some regions, new infrastructure may be required to deliver the power from coastal areas to demand centers, generating additional CO_2 emissions—primarily during the construction phase.

Mitigation Potential for Marine Energy

The world's oceans receive thermal energy from the sun and respond to the gravitational forces of the sun and the moon. These energy inputs lead to the generation of powerful currents, winds, waves, and tides—vast amounts of energy that are virtually untapped by current technology. The energies transformed by oceans are 1,000 times greater than global energy demand. Technology advancements could enable the world to harness a subset of this clean and accessible worldwide energy source and reduce GHG emissions to the extent that marine energy replaces conventional fossil-based energy sources.

Technological, industrial, administrative, and environmental constraints will prevent countries from harnessing the full potential of energy produced by each marine source. Leveraging these energy sources will require close cooperation with other users of the sea and shores. What is socially, economically and environmentally appropriate to use may be lower than the technically exploitable potential. Seven potential marine energy sources are identified below.

Offshore Wind Power[2]

In offshore wind installations, turbines harness energy from the wind and send it back to shore through undersea cables. A 2009 European Environment Agency study set the technically exploitable potential in Europe at about 30,000 terawatt-hours (TWh)

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[2] Offshore wind power is covered in detail in the MEF Global Partnership's *Technology Action Plan: Wind Energy*.

per year. Though still at the research and demonstration level, floating wind turbines that are moored to the seabed by cables offer one intriguing technology possibility. Because they are placed far from the coast, these floating turbines have reduced visual impact, present fewer constraints in terms of depth limitations, and could provide access to much greater wind resources. The world's first full-scale floating turbine pilot, Hywind (2.3 megawatts [MW]), was officially inaugurated in the North Sea off the coast of Norway in September 2009.

Ocean Thermal Energy Conversion

Ocean thermal energy conversion (OTEC) uses a temperature difference of at least 20°C between deep water (upper limit of 6°C) and the surface (lower limit of 26°C) to generate electricity—as well as fresh water, cooling for air conditioning purposes, and derivatives for aquaculture. Though limited to intertropical areas, where waters have at least a 20°C temperature gradient, thermal conversion theoretically could generate about 80,000 TWh per year. Significant work is ongoing in the United States, India, Japan, and France.

Without more advanced energy storage technologies, this presumed resource could only provide power locally—specifically in the Pacific intertropical zone, which currently consumes limited amounts of electricity. Hydrogen storage might relieve this constraint in the future. In the interim, thermal conversion could be used in temperate zones to extract heat from warm water near the surface for use in heat pumps for heating and cooling applications.

Tidal Turbines

As an intermittent yet predictable resource, the kinetic energy from tidal currents could provide a semi-base load of electricity. The total resource identified by eight member and observer countries to the IEA Ocean Energy System Implementing Agreement adds up to 235 TWh. This figure does not include major parts of the world with relevant resources such as South America, Africa, Russia, Australia and New-Zealand. In addition, major ocean currents (e.g., Gulf Stream, Kuroshio) could be significant sources of current energy.

Tidal Barrages

The World Energy Council estimates the global potential for conventional single-basin sites[3] is 380 TWh per year for a 160 GW capacity. The Rance site's 240 MW capacity, inaugurated in 1966, makes it the largest tidal barrage worldwide. Renewed interest in tidal power can now be seen worldwide: in Korea, the Sihwa power plant (260 MW) is under construction and studies are under way on the Garolim project (500 MW); in the United Kingdom, studies have been re-launched for the River Severn plant (8.6 GW), based on the innovative concepts of tidal lagoons and multiple-basin plants. Canada and Russia recently published very ambitious targets for the installation of tidal barrages.

Wave Power (Ocean Wave Energy)

Ocean wave energy production could meet about 10% of annual global demand for electricity[4]—a technically exploitable potential of 1,400 TWh per year, according to

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[3] Estuaries with a tidal range greater than 5 meters.

[4] Annual world demand for electricity is 16,000 TWh/year. See IEA, *World Energy Outlook 2009*.

the World Energy Council. In metropolitan France, the technically exploitable potential is estimated at 40 TWh per year, about 10% of the theoretical resource (i.e., 400 TWh per year), which could generate some 10–15 GW, mainly along the Atlantic seafront. Strong potential is seen in France's overseas departments and local authorities (DOM-COM), such as Réunion Island, Polynesia, and New Caledonia, as well as Martinique and Guadeloupe. Demonstration projects for wave power have also been deployed in the United Kingdom, Ireland, and Denmark.

Marine Biomass[5]

Between 200,000 and 1,000,000 species of algae exist worldwide, demonstrating an exceptionally adaptable biodiversity that hints they are proportionally rich in new molecules and lipids. Compared to terrestrial oilseed plants, micro-algae[6] have numerous characteristics favoring fatty acid production, a significant advantage in producing fuels. Macro-algae[7] also have fuel production potential; they can be used for the production of biological biogas (methane) and, based on the sugar content, for the production of biofuels via a biological sugar conversion route.

Marine algae can produce a biomass yield 10 times higher than terrestrial crops, without the competing demands that farmland currently faces. Production could range from 20,000–60,000 liters of oil per hectare per year, compared with the best yield for terrestrial crops—6,000 liters of palm oil. Advances in this field require marine surface identification and cost reduction.

Osmotic Power (Salinity Gradient)

Because of the osmotic pressure difference between salt water and fresh water, when a river flows into the sea, it releases a large amount of energy as the fresh water dilutes the salt water. Scientists are testing two ways of recovering this energy: the first (in Norway) is based on osmosis, and the second (in the Netherlands) is based on reverse electrodialysis.

This technology is currently only available at a laboratory scale. Globally, a total of 730 GW could be achievable from rivers with flows of more than 500 m^3 per second. The sustainable potential, taking into account ecological guardrails and shipping-sector requirements, is estimated to be around 50% of the technical potential, or 2,000 TWh per year.

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[5] Marine biomass is covered in detail in the MEF Global Partnership's *Technology Action Plan: Bioenergy*.

[6] Micro-algae could be produced on land in factories (closed circuit, including oil extraction) or in open ponds.

[7] Macro-algae can be harvested from the sea or grown in ponds on land.

Total Potential

Taking into account all predominantly coastal marine areas that are currently regarded as technologically accessible, the total global energy potential for off-shore wind, waves, currents, and osmosis combined is approximately 9,000 TWh per year, with wind power offering by far the highest potential and quickest implementation. However, several factors reduce the likelihood that this potential will be fully achieved. For instance, the potential for concurrent use of several marine technologies in a single coastal area needs to be examined in more detail, because certain wave energy systems may be difficult to combine with wind farms. In addition, deployment of multiple marine energy systems in high-density installations could lead to significant habitat changes (e.g., because of noise emissions, increased shipping traffic, or other causes, such as underwater cables), which may result in such concurrent use being regarded as unsustainable (WBGU 2006).

Technology Maturity Varies

The technologies to harness the seven marine energy sources above exist at different stages of maturity. Large-scale business contracts exist for offshore wind turbines, for example, and some projects have already reached the demonstration stage. However, many other wave, wind, and heat technologies are only in test stands or pilots at this time. Funding for demonstration projects will be required to advance these technologies, and the support provided should be specific to each technology's specific stage of development. In addition, detailed studies have been published with analysis of the technological status and prospects of the different technologies.

It should be noted that several marine energy sources have the potential to do more than just produce electricity, enhancing their value. For example, marine energy technologies can also be used for desalination. Table 1 presents some of the potential uses for each marine energy source.

TABLE 1. MARINE RENEWABLE ENERGY SOURCES AND POTENTIAL USES

Marine Energy Source	Potential Uses		
	Electricity	Heat or Cooling	Fuels
Wind	X		
Movements (wave, current, tidal)	X		
Thermal	X	X	
Biomass	X	X	X (liquids)
Osmotic pressure	X		

2. DEVELOPMENT AND DEPLOYMENT: BARRIERS AND BEST PRACTICE POLICIES

To begin realizing the significant energy production and emissions reduction potential of marine energy, the sector must overcome a variety of imposing barriers. While a few countries are working together to advance research, development, and demonstration (RD&D) of marine energy, stakeholders must continue to evaluate and actively address these barriers through judicious design and application of supportive practices and policies.

Barriers to Development and Deployment

The main barriers to expansion of marine energy are the relatively young stage of development of the technologies and the severe marine environment in which they must operate. These issues raise a host of related challenges in the form of costs and investment issues, technology hurdles, infrastructure support, rudimentary international cooperation, and impact uncertainties issues.

Technology Immaturity and Costs

Marine energy technologies are not currently cost-competitive due to their early stage along the research and development continuum. Significant research is needed to improve their feasibility, efficiency, cost-effectiveness, reliability, and durability, particularly in harsh ocean environments. Uncertainties regarding the cost, time frame, and ultimate degree of success for many research pathways raise investment risk—indicating a need for substantial risk sharing by the public sector.

Costs for initial facility construction and maintenance must also be taken into account. Lacking a proven model for marine energy support operations, marine energy facilities currently draw on the offshore infrastructure used by the oil industry (e.g., ships, platform equipment, etc.), which carries a high price tag. Innovative construction, maintenance, and operations monitoring technologies are needed to lower these costs and improve cost-competitiveness.

Infrastructure Investment

Given existing grid infrastructures in industrialized countries, integrating large amounts of marine energy is a complex issue. Key issues need to be addressed regarding grid connections and the carrying capacity of existing transmission networks.

The operator of renewable installation normally pays the costs of grid connection, which can be extremely high. Connecting a marine energy installation located 100 km from shore to an existing electricity network can represent up to one third of the total cost for the installation. Once connected, the additional power must then be absorbed by the grid. Appropriate power management technologies and power electronic devices will need to be incorporated into coordinated control schemes to ensure smooth integration.

Increasing transmission and distribution capacity is a prerequisite to integrating increasing shares of renewable energy into the grid. Moreover, much of the existing transmission infrastructure in OECD countries is more than 40 years old and needs to be upgraded regardless of renewable energy deployment (IEA 2009). Upgrading transmission networks should make use of new cable technologies that increase grid flexibility.

Lack of Technical Expertise and Cooperation

A skilled workforce will be needed to effectively tackle the specific technological and engineering challenges of marine energy installations. The expert marine energy community will need to play an active role in guiding development of education and training programs that emphasize the appropriate disciplines to prepare this future work force.

To accelerate the technology learning curve, the marine energy community needs to train a new generation of scientists and attract expertise, such as for offshore wind power, to encourage knowledge sharing. The lack of specialized marine energy engineering expertise could result in cost and material inefficiencies, such as the over-sizing of equipment. Public authorities and the marine research communities can work to foster mutual understanding among all stakeholders in a project in order to pool skills in this technology.

Policy Needs

Accelerating the development and deployment of marine energy technologies to address climate goals will require strong and sustained support from policy makers around the globe. As with other technologies, policies are needed to provide capital investment incentives, establish standards and dedicated reference testing centers, expedite the permitting process, build the needed engineering capacity, provide a framework to foster knowledge and technology transfer, lower the technology risk, and attract investors.

Government funding and support will be essential to install the first generation of marine energy facilities. Performance and operating data acquired from these initial installations will help to attract investors for additional installations that will then assist in further refining the technology and building capacity. Full-fledged development and operating costs are beyond the reach of small and medium enterprises. Some large industries are already involved, but there is a need for long-term strategic development and deployment planning to secure industrial investments.

The process for obtaining the necessary permits and approvals for marine energy projects could be costly at the beginning (up to €1 million) and time consuming (up to two years), often because of overly broad administrative structures and their lack of familiarity with the technologies. Policies that provide standards, testing facilities, expedited permitting, and public education campaigns can help reduce these hurdles. To foster development of a wide variety[8] of ocean or hybrid technologies, countries will need to provide policy support for both mature and less mature technologies. This calls for a balanced approach.

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[8] Variety means both the coexistence of different technologies utilizing the same resource—such as floating wind turbines complementing conventional offshore turbines—and technologies using different resources.

International cooperation can expedite the building of a shared knowledge framework that can lay the foundation for meaningful progress. Such a framework might facilitate identification of ocean energy resources on a global scale or sharing of results from initial technology trials. In fact, such cooperation would make it possible for operators to develop a strategy for industrial development on a large scale. Partnerships could facilitate dialogue with the coastal populations most affected by marine energy projects.

Environmental Sustainability and Other Impacts/Issues

As marine energy technologies are deployed, effective coastal management will be critical to regulate potential conflicts over the use of coastal space. International collaboration on a comprehensive environmental adaptive management framework could enable marine energy technologies to co-exist in harmony with other maritime activities and the environment. A strong system for protecting the environment, studying impacts, and establishing a dialog with coastal communities could ultimately build public acceptance and support as well as expedite the siting and permitting process. Impact studies and environmental monitoring are expensive and currently form a significant part of the risk that project developers face when embarking on a development or demonstration project.

Current Best Practice Policies

Several countries have begun marine energy technology impact studies and projects, offering others valuable insight into the results and success of partnership efforts. A number of action plan and roadmapping activities are in progress around the world.

Leading Country Examples

European Union

The European Energy Program for Recovery, adopted in July 2009, foresees a financial envelope of €565 million for 2009 and 2010 dedicated to offshore wind projects. In particular, this initiative aims to improve the grid integration of offshore wind energy (two projects with 2.5 GW combined capacity), as well as fund new turbines, structures and components, optimize manufacturing capacities, and create an European offshore wind energy testing center (three projects with 2 GW combined capacity).

Denmark

Denmark has pioneered the field of monitoring the impacts related to marine energy installations. The country’s Horns Rev and Nysted offshore wind farms both integrated an environmental monitoring program (Dong Energy 2004; Dong Energy 2005), the outcomes of which were delivered in November 2006 at a conference in Helsingor (Dong Energy et al. 2006). Both farms also performed impact assessments, and non-technical summaries can be found on their respective websites.

The environmental monitoring program began in 1999 with an €11 million budget financed by Danish consumers through public service contributions. The program explored, for example, geophysical aspects, benthic communities, fish, marine mammals, birds, and socio-economic effects. A public-private partnership, the Danish Environmental Group, coordinated the program, and its results were assessed by the International Advisory Panel of Experts on Marine Ecology (IAPEME).

France

In France, various activities are underway to facilitate the emergence of marine renewable energies, while ensuring that knowledge about their impacts is shared. In October 2008, the French Ministry of Ecology, Energy, Sustainable Development and the Sea (MEEDDM), the French Environment and Energy Management Agency (ADEME), French regions, the French Research Institute for Exploitation of the Sea (IFREMER), and multiple industrial companies launched an effort to construct a joint roadmap for the development of marine renewable energies using a shared and open approach (IPANEMA initiative). In addition, the "Energies Bleues" program launched in April 2009 announced plans to build 6,000 MW of marine energy by 2020. In September 2009, France also announced a request for proposals for marine technologies demonstration projects. The results are expected to be published at the end of 2009 or early 2010.

Germany

Germany is a world leader in renewable energy and has already set up feed in-tariffs. Expanding into marine energy in May of 2009, Germany reserved an area of 100 square kilometers for exclusive use by operators of marine energy facilities and pledged to finance connections to the land-based grid. In September of the same year, Germany announced that 40 offshore wind farms, representing 12 GW (capable of powering 12 million homes) would be constructed in that reserved area. Germany is also developing technological research platforms specifically for wind power.

In terms of employment, each megawatt of installed wind power is likely to generate five jobs throughout the value chain (design, production, installation, operation and maintenance). France's target of 6,000 MW of marine energy could create a total of 30,000 manufacturing jobs. In comparison, German industry received €6 billion in orders in 2007, helping to create more than 100,000 jobs (BWE 2007).

Portugal

Portugal is developing a comprehensive national strategy for industrial deployment of wave power. The strategy involves detailed assessments of potential sites and impacts.

United Kingdom

The United Kingdom is strongly interested in wave, tidal stream, and tidal range technologies. It has a number of initiatives underway to support the development of these technologies.[9]

The United Kingdom has set up COWRIE (Collaborative Offshore Wind Research into the Environment), an organization devoted to researching and improving knowledge about the environmental impacts of offshore wind power. COWRIE was created by the Crown Estate in 2001, following the announcement of the first round of wind farm development (COWRIE 2009). Funds deposited by the 18 project developers were used to set up the organization and carry out a series of environmental studies (looking at both positive and negative impacts).

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[9] The United Kingdom is currently in the process of preparing a national Action Plan for Marine Energy Technologies. This work is planned to report in March 2010.

A COWRIE steering committee made up of marine environmental experts and specialists from relevant bodies (e.g., government departments, the British Wind Energy Association (BWEA), the Royal Society for the Protection of Birds (RSPB), developers of Round 1 projects, etc.) determines the types of research to be carried out. The body is separate from government R&D programs, and the participation by developers has been a critical factor in its success. This Round 1 system, which entailed one-off payment of an option fee by the successful project developer applicants, was used again for the Round 2 projects in 2003.

COWRIE aims to ensure that its results are widely disseminated. The studies conducted have improved knowledge of potential environmental issues and led to the publication of best-practice guidance documents that assist the industry in minimizing impacts. The studies focus on five priority research themes: birdlife and benthos, electromagnetic fields, seabird survey methodology, remote monitoring techniques, and underwater noise and vibration. Along with COWRIE, the United Kingdom’s Department for Environment, Food, and Rural Affairs (DEFRA) and Department for Industry (DTI) also finance research projects on offshore wind and the environment. The Centre for Environment, Fisheries, and Aquaculture Science (CEFAS), for example, is heading three projects to assess wave system modifications, develop guidelines for monitoring sediment transport, and research the socio-economic impacts of offshore development on the fisheries industry (CEFAS 2009).

In 2006, the United Kingdom initiated a strategy for dedicating selected sites to the production of marine energy. A public-private partnership was formed to connect these sites to the land grid, and the government granted feed-in tariffs. In 2009, the government committed ₤72 million to advance the commercial viability of large-scale technologies. In the near future, the United Kingdom is also expected to announce the result of a competitive solicitation for equipping nine offshore wind farms to generate 10 GW. A separate solicitation covers connecting those nine parks to the land grid at an estimated cost of ₤12 billion. A quarter of the developed marine energy technologies in the world today are in the United Kingdom.

United States

In May 2009, President Obama announced a new program in the U.S. Department of the Interior to support energy from ocean currents. The program authorizes leasing of federal waters for marine energy projects and is expected to open the door for major investment. A U.S. strategy for oceans is also under development.

Pooling of Skills and Cooperation

Optimizing the generation of marine energy will require cooperation among governments, industry, the research community, and other marine interests and stakeholders. Such cooperation will help to avoid conflicts among the different users in dedicated areas. Productivity and maintenance costs can even be improved by placing complementary marine activities in proximity (whether energy technologies or other activities, such as aquaculture). Finding and exploiting synergies among activities (e.g., joint studies, pooled maintenance costs or equipment) could increase their economic viability.

Current International Marine Energy Initiatives

Multilateral frameworks

- International Energy Agency Ocean Energy Systems (IEA-OES) implementing agreement—currently developing a global road map for marine energy[10]
- International Renewable Energy Agency (IRENA)

Regional and local frameworks

- Support large-scale demonstration projects.
- Joint Declaration on Cooperation in the Field of Research on Offshore Wind Energy Deployment, under the Strategic Energy Technology Plan (SET Plan; Denmark, Germany, and Sweden are participating)
- The Scottish Marine Energy Group (FREDS — the Forum for Renewable Energy Development in Scotland)
- The British Wind Energy Association (BWEA)
- The European Union Ocean Energy Association (EU-OEA)

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[10] The IEA-OES 2008 annual report, which is downloadable from their website (http://www.iea-oceans.org/publications.asp?id=1), provides a good overview of current activities across the world.

3. ACTIONS TO ACCELERATE DEVELOPMENT AND DEPLOYMENT

This plan has outlined the broad potential for reducing GHG emissions through the use of marine energy technologies. Effective marine energy technologies and their implementation are not based on "one size fits all" solutions. Specific country and regional factors will determine the appropriate set of technologies, applications, and solutions for each geographic area and country that wishes to implement effective marine energy policy. Nonetheless, all countries seeking to catalyze progress on marine energy technologies should consider similar categories of action. Countries can also work together to expedite their programs and develop standards that enable the wider dissemination of these technologies.

To achieve transformational gains in marine energy globally, MEF countries have developed a menu of opportunities to develop and deploy sustainable marine energy technologies. Many of these actions rely on, or can be effectively leveraged through, coordinated action among countries, including support for existing international forums on marine energy technologies or renewable energy in general. This chapter discusses both opportunities for individual country action as well as opportunities for cooperative action among MEF countries.

Menu of Opportunities for Individual and Collective Action

Chapter 2 illustrates some of the barriers and current activities that suggest specific individual and collective country actions that can help to reduce barriers and realize the full potential of sustainable marine energy technologies. Key categories of action for consideration include the following:

- Supporting innovation:
  - Develop new technologies.
  - Demonstrate new technologies.
- Accelerating deployment:
  - Establish voluntary industry standards and otherwise reduce investment risk.
  - Build deployment capacity.
  - Improve relative economics between advanced clean energy technologies and conventional technologies to encourage market-based adoption.
  - Establish and strengthen regulation.
- Facilitating information sharing:
  - Share best practices and knowledge.
  - Enhance public awareness.

The following section outlines a menu of actions within each category, generally listed in increasing order of ambition. Interested countries should consider the actions in each category to identify those that may be appropriate to their unique circumstances.

Supporting Innovation

- Develop proven technology that enables operators to provide investors with a guarantee of risk control.
- Provide R&D funding for all marine energy technologies based on strategic research agendas, and identify potential areas for joint cooperation between countries.
- Support large-scale demonstration projects.
- Facilitate transnational coordination of strategic research agendas to reduce duplication of effort by offering joined research programs for international collaboration.
- Provide for transnational access to full-scale open sea test sites, which is critical to many developers in the absence of reliable field data from full scale devices.
- Support a cross-sectoral approach for R&D programs that combines knowledge and experience from areas such as ocean energy, offshore wind, oil and gas, and other offshore engineering sectors. Enabling this know how transfer involves developing a better understanding of the costs to adapt components and methods to the marine environment, and identifying opportunities for collaboration with other industries and supply chain partners.
- Establish an international network of test facilities to avoid competition between infrastructures and to increase efficiency through complementary specialization.

Accelerating Deployment

- Identify maritime zones for large power generation to allow operators to encourage industry to develop technologies.
- Plan and anticipate investments for the grid at sea—recognizing in advance the need to share access to the grid among marine energy projects when possible to reduce the number of cables needed and thus, reduce costs along with environmental impacts.
- Designate areas for marine energy deployment early on to avoid space-use conflicts.
- Facilitate the system integration of marine electricity generation by extending the grid, increasing interconnection capacity, and improving storage and inverter technology.
- Reduce administrative barriers to improve the deployment of marine technologies.
- Establish simple and quick permitting procedures.
- Collaborate with private investors and banks to improve financing of marine technology.
- Set ambitious, concerted marine energy targets (country-specific or international) to provide long-term investment security.
- Establish a feed-in tariff that guarantees sufficient resources to operators, in order to create and develop a market.
- Streamline regulatory and licensing processes.

- Coordinate an offshore electricity network strategy that integrates offshore wind, ocean energy, and other energy sources and demand structures.
- Develop translational and regional infrastructure programs covering ports, vessels, and other supply chain requirements for the large-scale deployment of marine energy technologies.
- Provide financial incentives and risk mitigation to early stage investors.
- Design and implement support schemes to set up a new marine energy industry, including education and mobilization of human resources.

Facilitating Information Sharing

- Strengthen cooperation networks among marine energy research centers and other important stakeholders.
- Raise public awareness of marine technologies by using a broad mix of instruments.
- Build up marine energy expertise in governments and keep decision makers informed.
- Strengthen collaboration and mutual exchange between developed and developing countries, and enhance technology cooperation among developing countries.
- Support joint development of strategic environmental impact assessments and exchange of data from environmental studies and monitoring campaigns to identify the relevant environmental impacts of marine energy technologies and suitable mitigation measures.
- Support international activities on harmonization and standardization of technical requirements in cooperation with, e.g., IEC (International Electrotechnical Commission).
- Promote the harmonization of methodologies and terminologies.
- Reduce knowledge barriers that exist between international stakeholders through establishment of information gateways providing trusted information.
- Establish international exchange and training programs (following the model of existing European programs such as Marie Curie)
- Organize international networking events such as industry forums, conferences, policy seminars, etc.

Actions by Individual Countries

To accelerate development and deployment of marine energy technologies, countries should consider adopting some of the actions in each of the categories outlined above as appropriate to their goals and unique national circumstances.

More generally, MEF countries may wish to start by developing a national marine energy roadmap (or updating an existing roadmap) that identifies and appropriately sequences high-impact actions from each category as appropriate to their unique circumstances. These roadmaps may include resource assessments, targets and timelines, and would define the key stages for how marine energy technologies RD&D, associated market changes, and enabling legislation should be implemented in order to meet those targets. Moreover, they might be integrated with roadmaps for other technologies that would enable broader uptake of marine energy, e.g., smart grid, wind, bioenergy.

Periodically, countries should assess progress against their own action plan and correct their course as desired. At the very least, they may want to ensure that they are establishing policies or taking other enabling actions on the schedule envisioned in their road map. Similarly, they may establish a matrix of demonstration projects categorized by solution type in order to ensure they are addressing the full range of promising wind energy technology.

These individual actions could then feed into coordinated or cooperative international initiatives, to the extent appropriate or desired, in accordance with national circumstances.

Coordinated or Cooperative Actions

Beyond the individual efforts described above, countries should consider the vital role of international coordination and cooperation for the deployment of marine energy technologies. Many individual countries share the common goals of reducing GHG emissions or improving their use of energy, which should facilitate the creation of a cross-country, cross-region common vision and roadmap to accelerate marine energy technology development and deployment.

The Global Partnership can play an active role in overcoming common barriers faced by all countries to accelerate the development and deployment of marine energy technologies. Global Partnership initiatives would not replace ongoing work, e.g., by IRENA, but rather enhance cooperation globally. For instance, MEF countries could consider starting an initiative to identify whether they could join forces for marine energy demonstration projects.

MEF countries may also wish to consider collectively addressing the clear need for identification of global marine energy resources using harmonized methods. To foster needed consensus on how to quantify the potential for electricity generation and other applications, MEF countries could consider supporting enhanced international collaboration among researchers, data providers, and project developers.

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